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Mechanical Design Guidelines

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1.0 PURPOSE AND SCOPE

1.1 General

1.1.1 Purpose

1. The purpose of this document is to provide the Entity's Mechanical Design Guidelines to be followed by the A/E as mandatory, minimally acceptable requirements for the following systems:
   a. Fire Protection
   b. Plumbing
   c. Heating, Ventilation, and Air Conditioning (including Hydronic Cooling as well as Fire and Life Safety System)
   d. Fuel Gas
2. These Mechanical Guidelines cover building types that fall into the following categories:
   a. Public/Government
   b. Commercial
   c. Residential
   d. Industrial
   e. Specialty Applications

1.1.2 Scope

1. The A/E will develop specific design criteria for planning, design, construction, sustainment, restoration, and/or modernization of buildings and structures following these Mechanical Design Guidelines. Project conditions may dictate the need to exceed the minimum requirements stated within these guidelines.
2. The provisions of these Mechanical Design Guidelines are not intended to prohibit the use of alternative systems, methods, or devices not specifically described; however, the use of alternative systems, methods, or devices can be used only after receiving approval from the Entity.
3. If a conflict is discovered between these Guidelines and other project documents, the conflict shall be brought to the attention of the Entity, who will provide resolution or direction.

1.1.3 Introduction

1. These Mechanical Design Guidelines:
   a. Establish the uniform design criteria and standards for mechanical systems and equipment to enable quality and cost-effective buildings and facilities that meet the needs and expectations of the end users.
   b. Provide explicit design criteria that will be used by the Entity to evaluate if all mechanical design criteria goals and requirements have been met.
2. The following objectives shall be reflected in the mechanical designs:
   a. The Entity is committed to excellence in the design and development of its sites and buildings. This requires an integrated approach by all disciplines to achieve the highest quality while providing cost effective mechanical systems.
   b. Flexibility and adaptability is required to accommodate renovations and future expansion without replacement of central building equipment or components.
   c. The essential principles of sustainable design shall address: energy conservation, material selection, water use reduction, environmental air quality, operations, and maintenance.

3. Material, equipment, products, and appurtenances, when available, shall be provided from an In-Kingdom Manufacturer. Procurement of material, equipment, products, and appurtenances manufactured Out-of-Kingdom shall be approved by the Entity.

2.0 FIRE PROTECTION

2.1 General

2.1.1 Authority Having Jurisdiction

1. The Entity is the final Authority Having Jurisdiction (AHJ) unless otherwise stated in project documents.
2. For Industrial facilities, the Fire Protection and Safety Systems design shall comply with the High Commission of Industrial Security Directives (HCIS).

2.1.2 Coordination and Integration

1. The design of a fire protection system requires coordination and integration with other discipline designs, such as, but not limited to, the fire alarm design for alarms related to tamper and flow switches, the plumbing design for drains from various elements of the fire suppression system, the electrical design for power to the fire pump and automatic transfer switch, and all physical disciplines for space to install piping and equipment.
2. Fire Protection system design shall be completed in full accordance with the respective health and safety requirements established by the Kingdom of Saudi Arabia and the Entity.

2.1.3 Abbreviations

1. Abbreviations in general are included in Volume 6, Chapter 2- Definitions and References (EPM-KE0-GL-000011)
2. Abbreviations specific to this section appear below:

Abbreviations	Description
A/E	Architect/Engineer
AHJ	Authority Having Jurisdiction
HCIS	High Commission of Industrial Security
HVAC	Heating, Ventilation, and Air Conditioning
NFPA	National Fire Protection Association
FM	Factory Mutual
IBC	International Building Code
IFC	International Fire Code
OS&Y	Outside Steam and Yoke
SBC	Saudi Building Code
SPDT	Single-Pole/Double-Throw
UL	Underwriters Laboratories, Inc.

2.1.4 Definitions

1. Definitions in general are included in Volume 6, Chapter 2- Definitions and References (EPM-KE0-GL-000011)
2. Definitions specific to this section appear below:

Definitions	Description
Atmosphere	The same as outdoors.
Concealed Exterior	Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures.
Concealed Interior	Concealed from view and protected from physical contact by building occupants.
Conditioned	Spaces directly provided with heating and cooling.

Definitions	Description
Exposed Exterior	Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions.
Exposed Interior	Exposed to view indoors (not concealed).
Finished Space	Space other than mechanical rooms, electrical rooms, furred spaces, pipe chases, unheated spaces immediately below the roof, space above ceilings, unexcavated spaces, crawl spaces, tunnels, and interstitial spaces.
Furnish	Supply and deliver to the project site, ready for unloading, unpacking, assembly, installation, and similar subsequent requirements.
Install	Operations at the project site, including unloading, unpacking, assembly, erection, placing, anchoring, applying, working to dimension, finishing, curing, protecting, cleaning, and similar requirements.
Indoors	Located inside the exterior walls and roof of the building.
Outdoors	Located outside the exterior walls and roof of the building.
Provide	Furnish and install complete and ready for intended use.
Unconditioned	Spaces without heating or cooling including ceiling plenums.

2.1.5 Codes, Standards, and References

1. The following documents establish the minimum requirements for the design of fire protection systems and equipment:
   a. Factory Mutual
   b. IEEE-979 – Guide for Substation Fire Protection
   c. International Building Code
   d. International Fire Code
   e. NFPA 1 - Fire Code
   f. NFPA 10 - Standard for Portable Fire Extinguishers
   g. NFPA 13 - Standard for Installation of Sprinkler Systems
   h. NFPA 13D - Standard for Installation of Sprinkler Systems for One and Two Family Dwellings and Manufactured Homes
   i. NFPA 13R - Sprinkler Systems in Residential Occupancies up to and including Four Stories in Height
   j. NFPA 14 - Standard for the Installation of Standpipe and Hose Systems
   k. NFPA 20 - Standard for the Installation of Stationary Pumps
   l. NFPA 22 - Standard for Water Tanks for Water Tanks for Private Fire Protection
   m. NFPA 96 – Standard for Ventilation Control and Fire Protection of Commercial Cooking Operation
   n. NFPA 2001 – Standard of Clean Agent Fire Extinguishing System
   o. SBC 801 - Fire Protection
   p. Underwriters Laboratories, Inc.
2. Refer to Volume 6, Chapter 5 – Codes, Standards, and References (EPM-KE0-GL-000014) for a list of additional codes, standards, and references.
3. In the event of a conflict between the codes or standards and this document, the SBC shall govern.

2.1.6 Approvals

1. The Entity shall review and approve all design reports, plans, drawings, and specifications as outline in Volume 6, Chapter 6 - Project Submission Standards and Requirements (EPM-KE0-GL-000015).

2. Fire Protection Designer for industrial facilities shall be a HCIS approved specialist. All design related to Fire Protection and Safety Systems, inclusive of material selection shall be approved by HCIS.

2.2 Commissioning

2.2.1 Testing and Commissioning Requirements

1. Refer to Volume 10, Chapter 2 – Project Testing and Commissioning Guideline (EPM-KT0-GL-000003) for testing and commissioning requirements.

2.3 Fire Protection Specialties

2.3.1 Valves

2.3.1.1 Supervisory Valves

1. Provide supervisory valves at the inlet and outlet of all items of equipment that may require maintenance and/or testing to avoid the need to drain the upstream and downstream piping when maintenance or testing is performed. Items of equipment requiring upstream and downstream supervisory valves include, but are not limited to, fire pumps, alarm check valves, backflow preventers, and pressure regulating valves.
2. All valves shall have a minimum pressure rating of 16 bar. In the event fire pump operation or building height results in pressures exceeding 16 bar, the valve pressure rating shall be 25 bar.
3. All supervisory valves shall have a supervisory switch to indicate if the valve is in fully open or fully closed position. Supervisory switches shall be tamper resistant type for class A, 4 wire supervisory connection for interconnection to the building fire alarm system.
4. Valves that are 65 mm and smaller shall be UL-listed/FM-approved OS&Y gate valves with separate tamper-resistant supervisory switches for interconnection with the building fire alarm system.
5. Valves that are larger than 65 mm shall be UL-listed/FM-approved butterfly valves with integral, tamper-resistant supervisory switches.
6. OS&Y gate valves that are UL-listed/FM-approved are permitted for use upstream of the fire pumps. OS&Y gate valves shall have resilient seats. Supervisory switch shall be installed in the OS&Y gate valve to monitor open position.
7. Refer to the project specification for fire water valves.

2.3.1.2 Pressure Regulating Valves

1. For small portions of the system or where system pressure exceeds the pressure rating of the sprinklers, provide a pressure regulating valve in the branch line or cross main feeding those components. Provide a pressure regulating valve complete with a pressure gauge upstream and downstream of the regulating valve along with a pressure relief valve that has its discharge line piped to a floor drain or mop sink.
2. For large sections of the fire protection system that exceed the pressure rating of the components, provide a pilot-operated, pressure regulating valve. The valve body shall be epoxy-coated. Provide a pressure regulating valve complete with a pressure gauge upstream and downstream of the regulating valve along with a pressure relief valve that has its discharge line piped to a floor drain or mop sink.
3. Refer to the project specification for fire water valves.

2.3.1.3 Post-Indicator Valves

1. Post-indicator valves shall be provided on the fire water service entrance to the building. The valve shall be a post-mounted, non-rising stem gate valve that extends to bury depth of the pipe

and shall be provided with a supervisory switch. The post-indicator valve shall be provided at a minimum of 12 m from the building. Supervisory switches shall be wired to the building alarm system.

2. Refer to the project specification for fire water valves.

2.3.1.4 Check Valves

1. General purpose check valves shall be provided in the fire protection system where flow direction is regulated. Valves shall be UL-Listed/FM-Approved, swing check valves.
    a. Typical locations requiring check valves include, but are not limited to:
        (1) piping between the fire department connection and the sprinkler supply piping
        (2) downstream from a fire pump
    b. Riser check valves shall be provided at the base of all fire protection system risers. Riser check valves shall be UL-Listed/FM-Approved, swing check valves.
2. Refer to the project specification for fire water valves.

2.3.2 Backflow Preventers

1. A backflow preventer shall be provided in the branch line that supplies water service to the fire protection system (in cases where the line branches off of a potable water line or otherwise required by the Entity or the applicable Code). The backflow preventer shall be a detector, double-check valve style with a stainless steel body and low pressure loss characteristics. The backflow preventer shall be insulated with fiberglass or rubber cellular insulation to prevent condensation.
2. Refer to the project specification for fire water piping specialties.

2.3.3 Fire Department Connection

1. A fire department connection shall be provided for each building to facilitate the fire department connecting to the building fire suppression system. The AHJ shall dictate the type and style of fire department connection.
2. The fire department connection shall be located on the street side of the building where the fire department will respond to the building in the event of a fire. The fire department connection shall be easily visible and accessible. The location of the connection shall be a minimum of 12 m from the building, preferably in the same general location as the post-indicator valve.
3. The inlet of the fire department connection shall be 500 mm above grade.
4. The fire department connection shall have an escutcheon plate labeled “STANDPIPE AND AUTO SPKR” with Arabic equivalent approved by the Entity.
5. The fire department connection shall be surrounded by carbon steel pipe bollards that are 1000 mm high to prevent it from being damaged by vehicles.
6. The fire department connection shall be a post-mounted, Siamese-type connection and shall be 65 mm x 65 mm x 100 mm. The inlet shall be furnished with a self-closing clapper valve and shall have threads suitable for coupling to fire department hoses.
7. A UL-Listed check valve and a 20 mm ball drip valve shall be provided where the piping to the fire department connection joins the sprinkler supply piping system. The drip valve outlet shall be piped to floor drain or to the exterior or the building.
8. Refer to the project specification for fire water piping specialties.

2.3.4 Roof Manifolds

1. A roof manifold shall be provided where required by NFPA 14, the SBC, or the AHJ for addressing a fire from the roof level.
2. The roof manifold shall be a two-way hydrant, 100 mm x 65 mm x 65 mm with caps and chains. The manifold shall be supplied with a plate lettered "WALL HYDRANT." Threads shall be compatible for coupling to fire department hoses.
3. The roof manifold shall be a UL-Listed/FM-Approved automatic ball drip type. The drain line shall be extended to, and terminate in, a floor drain or at a roof splash block.
4. Refer to the project specification for fire water piping specialties.

2.3.5 Floor Control Assembly

1. A floor control assembly shall be provided at each sprinkler branch connection to a standpipe or sprinkler riser.
2. The floor control assembly shall be comprised of a UL/FM supervisory butterfly valve, flow switch, flow switch tester, pressure gauge, along with a test and drain assembly to provide for testing and drainage of the sprinkler system. The floor control assembly shall have mechanical groove or welded assembly and the test/drain manifold shall have threaded connections with orifice equal to the size of one (1) sprinkler orifice. The outlet of the test and drain assembly shall be piped to a drain riser.
3. Refer to the project specification for fire water piping specialties.

2.3.6 Flow Switch Tester

1. The flow switch tester shall be provided to test the flow switch without the need to spill any test water to a drain. The unit shall consist of a water flow switch, pump, isolation ball valves, check valve, and fittings. The unit shall be rated for a working pressure of 12 bar at 50°C.
2. Manifold piping shall be Schedule 40 pipe. The pump shall be fitted with 230-volt motor and be controlled with a local key switch, which is also to be rated for 230 volts. The key switch shall be furnished with a back box capable of surface- or recessed-mounting. The unit shall be UL-Listed/FM-Approved. One flow switch tester manifold shall be provided for each floor level of the building or facility.
3. Refer to the project specification for fire water piping specialties.

2.4 Sprinklers

2.4.1 Sprinkler System Design

1. Provide sprinkler systems for buildings where required by the SBC, IBC, or NFPA. The SBC shall be the primary reference for sprinkler system design. The IBC and NFPA shall be referenced for subjects and issues not addressed in the SBC.
2. Types of fire sprinkler system design are discussed further in Subsection 2.4.2
3. The entire sprinkler system shall be hydraulically designed based on the results of the new water supply flow test conducted by the A/E or the local water authority. The A/E shall make arrangements with the local water authority for the flow test and shall witness the test. A minimum of 0.7 bar cushion shall be provided between the water supply curve and the system design point.
    a. Hydraulic sprinkler design software shall meet the requirements established by NFPA.
4. Hydraulic calculations shall be approved by the Entity and the AHJ prior to submitting the final design documents.
5. Fire water flow design criteria shall be based on the requirements established in the SBC.
6. Water velocities in pipes shall not exceed 6 m/s.
7. Special Occupancies

a. The SBC addresses the design of fire protection for special occupancies in dedicated Chapters relating specifically to each occupancy type. Design fire protection for special occupancies in strict accordance with the SBC.

(1) Design fire protection for paint shops and other finishing operations in strict accordance with the SBC.

(2) Design fire protection for storage of flammable liquids and chemicals in strict accordance with the SBC.

8. Refer to the project specifications for the fire sprinkler system.

2.4.2 Sprinkler Types

2.4.2.1 Standard-Response Sprinklers

1. Exposed (Upright or Pendant) Sprinklers

a. Exposed sprinklers shall only be used in applications where there are no ceilings.

b. Exposed sprinklers shall be large, glass bulb-operated, automatic sprinklers with chrome finish. The temperature rating shall be 68°C at 12 bar unless the application dictates the need for a higher temperature or pressure rating.

c. Provide wire sprinkler guards on sprinklers that could be subject to mechanical damage.

d. Provide an escutcheon to match the adjacent finishes for semi-recessed applications.

2. Concealed Sprinklers

a. Concealed sprinklers shall be used in all applications with ceilings.

b. Concealed sprinklers shall be solder link-operated, automatic sprinklers rated for 74°C and 12 bar unless the application dictates the need for a higher temperature or pressure rating

c. The cover plate color shall match the ceiling color.

3. Horizontal Sidewall Sprinklers

a. Horizontal sidewall sprinklers shall only be used in light hazard applications where they will eliminate the need for ceiling-mounted or exposed, overhead sprinklers entirely and either reduce the total number of sprinklers required or eliminate aesthetic issues of ceiling-mounted or exposed, overhead sprinklers.

b. Horizontal sidewall sprinklers shall be glass bulb-operated, automatic sprinklers rated for 68°C at 12 bar unless the application dictates a higher temperature or pressure rating.

4. Dry-Type Sprinklers (for areas subject to freezing and that require minimum area coverage)

a. Dry Pendant Sprinklers

(1) Dry pendent sprinklers shall be chrome-plated, large, glass bulb-operated sprinklers rated for 68°C at 12 bar.

(2) Sprinklers that have water lines going from a warm space into a cold space shall be installed with a manufactured sprinkler boot or appropriate caulking and insulation.

b. Dry Concealed Sprinklers

(1) Dry concealed sprinkler shall be large, glass bulb-operated sprinklers rated for 68°C at 12 bar.

(2) The cover plate color shall match ceiling color and be rated for 57°C.

(3) Sprinklers that have water lines going from a warm space into a cold space shall be installed with a manufactured sprinkler boot or appropriate calking and insulation.

c. Dry Horizontal Sidewall Sprinklers

(1) Dry, horizontal, sidewall sprinklers shall be chrome-plated, large, glass bulb-operated sprinklers rated for 68°C at 12 bar.

(2) Provide the sprinklers with factory-made, adjustable, chrome-plated escutcheons.

(3) All dry-type sprinklers that have water lines going from a warm space into a cold space shall be installed with a manufactured sprinkler boot or appropriate calking and insulation.

2.4.2.2 Quick Response Sprinklers

1. Quick-Response Sprinklers may be used in place of standard-response sprinklers where permitted by the referenced Codes and Standards as long as they are approved by the AHJ.
2. Exposed (Upright or Pendant) Quick-Response Sprinklers
   a. Exposed, quick-response sprinklers shall be chrome-plated, glass bulb-operated, automatic sprinklers rated for 68°C at 12 bar.
3. Concealed Quick-Response Sprinklers
   a. Concealed, quick-response sprinklers shall be solder link-operated, automatic sprinklers rated for 74°C at 12 bar. The cover plate color shall be selected by the Architect and be rated at 57°C.
4. Horizontal Sidewall Quick-Response Sprinklers
   a. Horizontal, sidewall, quick-response sprinklers shall be chrome-plated, solder link-operated sprinklers rated for 68°C at 12 bar.
5. Semi-Recessed Quick-Response Sprinklers
   a. Semi-recessed, quick-response sprinklers shall be chrome-plated, glass bulb-operated sprinklers rated for 68°C at 12 bar.
6. Sealed/Concealed Quick-Response Sprinklers
   a. Sealed/concealed, quick-response sprinklers for areas where the room is maintained by mechanical ventilation at a higher pressure than the surrounding spaces shall be fusible, solder-link, recessed sprinklers with a gasketed, cover plate rated for 74˚C at 12 bar.

2.4.2.3 Early Suppression Fast-Response Sprinklers

1. Early suppression, fast-response sprinklers are quick-responding, high-volume units that provide protection for high-piled storage occupancies. They suppress a fire by discharging a high volume of water directly onto the fire to reduce the heat release rate. They deliver large droplets of water at a high velocity to knock down the fire plume.
2. Early suppression, fast-response sprinklers deliver water at an output rate of 6.3 lps, which could be as much as four times the delivery rate of a standard sprinkler.
3. Early suppression, fast-response sprinkler heads are available in pendant or upright configurations.
4. Properly designed, early suppression, fast-response sprinkler systems can be installed at the ceiling and can eliminate the need for in-rack sprinklers in warehouse spaces.
5. Early suppression, fast-response sprinklers shall be rated for either 74°C or 101°C.
6. Early suppression, fast-response sprinklers are recommended to be used in large storage areas with high storage racks.

2.5 Materials

2.5.1 Pipe and Fittings

1. Design of all fire protection systems shall be based on the material requirements set forth in the appropriate NFPA Standards.
2. Material requirements for sprinkler systems shall be as set forth in NFPA 13.
3. Material requirements for standpipe systems shall be as set forth in NFPA 14.
4. Material requirements for dry chemical extinguishing systems shall be as set forth in NFPA 17.
5. Refer to the appropriate project specifications for the applicable fire protection equipment.

2.6 Fire Protection Standpipes

2.6.1 Fire Protection Standpipe Design

1. Fire protection standpipes shall be designed in strict accordance with the SBC, the IBC, and NFPA 14. The SBC shall be the primary reference for sprinkler system design. The IBC and NFPA 14 shall be referenced for subjects and issues not addressed in the SBC.
2. Standpipe classifications shall be in accordance with NFPA 14.
3. Provide a standpipe of the proper classification for the given construction in accordance with the SBC.
4. Provide fire hose valves and cabinets in accordance with the SBC and NFPA 14.
5. Refer to the project specification for fire protection standpipes.

2.7 Fire Pumps

2.7.1 Design

1. Design fire pumps in strict accordance with the SBC and NFPA 20. The SBC shall be the primary reference for fire pump design. NFPA 20 shall be referenced for subjects and issues not addressed in the SBC.
2. Where the building has an emergency generator that has been sized with adequate capacity to support an electric motor-driven fire pump, the fire pumps should be electric motor-driven units. Otherwise the fire pumps shall be diesel engine-driven units.
   a. Fuel storage, piping, and delivery for diesel engine-driven, fire pumps shall be designed in strict accordance with NFPA 20 and shall be approved by the Entity and the AHJ.
3. The pump room shall be ventilated in accordance with NFPA 20. For an electric motor-driven, fire pumps, provisions shall be made to prevent the room temperature from exceeding the maximum temperature rating of the motors or any controls in the room. For diesel fire pump, ventilation shall exceed the combustion air requirements of the engine. Fire pump room shall be separated from other mechanical equipment rooms.
   a. Ventilation from outdoors shall be drawn through sand trap louvers. (Refer to Subsection 4.4.1.1.)
4. Fire pump assembly shall be complete with circulation relief valve, pump casing automatic air vents, anti-vortex plate, liquid-filed pressure gauges, flowmeters for performance testing, and sensing line conforming to the requirements of NFPA 20. Pressure relief line and waste cone shall only be required if the pump shut-off head will exceed the system pressure requirements.
5. The fire water tank, suction line, and the selection of the pump shall be designed in a way to ensure that NPSH of the installation is equal or higher to the pump required NPSH to avoid cavitation at 150% of the rated flow.
6. Test manifold shall be return to tank or return to suction incase that the fire tank is not required in the design. Straight pipe lengths requirements based on flowmeter type shall be complied by the A/E.
7. Straight pipe lengths required by the pump in the suction line shall be complied. Reducer in the suction shall be eccentric type and shall be installed flat-on-top. Suction pressure gauge shall be compound type, liquid-filed gauge.
8. A jockey pump shall be provided and shall meet the requirements of NFPA 20. The minimum flow requirement for the jockey pump shall be based on allowable leakage in 10 minutes or 1 gpm whichever is larger, in compliance to NFPA 20.
9. Refer to the project specification for fire protection pumps.

2.8 Fire Protection Systems

2.8.1 Automatic Wet Systems

1. Provide wet-pipe sprinkler systems for buildings where required by the SBC, the IBC, or NFPA. The SBC shall be the primary reference for wet-pipe sprinkler system design. The IBC and NFPA shall be referenced for subjects and issues not addressed in the SBC.
2. Provide automatic wet sprinkler system or pre-action system for electrical rooms containing oil cooled type transformers as required by NFPA, IBC, and IEEE-979.
3. Sprinkler systems for all spaces shall be wet systems unless the release of water would cause irreparable harm to high-value equipment housed in the space (such as a data processing center) or the area is subject to freezing temperatures. In these instances, a pre-action or dry-type system shall be considered. The Entity shall be consulted and its approval obtained where designs include pre-action or dry-type sprinkler systems.
4. Refer to the appropriate project specifications for the applicable fire protection equipment.

2.8.2 Dry Systems

1. Provide dry-pipe sprinkler systems for buildings where required by the SBC, the IBC, or NFPA. The SBC shall be the primary reference for dry-pipe sprinkler system design. The IBC and NFPA shall be referenced for subjects and issues not addressed in the SBC.
2. Dry-pipe systems shall be used in areas subject to freezing. In a dry-pipe system, the piping is charged with compressed air or nitrogen, and the pressure holds a remote valve, known as a “dry-pipe valve,” in the closed position to prevent the piping from being charged with water. The following requirements apply to dry-pipe systems:
   a. Dry-pipe systems shall utilize regular, closed sprinkler heads.
   b. The dry-pipe valve shall be located in a secure, heated space.
   c. Provide a means of pressure maintenance in the piping system.
   d. Provide monitoring to indicate a reduction of air or nitrogen pressure in the piping system.
   e. The time limits for charging all dry-type sprinkler systems and maximum water velocities in piping shall be in accordance with NFPA.
   f. Water filling the piping system too rapidly may cause significant vibration, which in turn, can cause poorly anchored pipe to fail. Assure that piping is properly supported and anchored.
3. Design guidelines are provided in Subsection 2.4.2.1 part 4 for dry-sprinkler selection.
4. Refer to the appropriate project specifications for the applicable fire protection equipment.

2.8.3 Pre-Action Systems

1. Provide pre-action sprinkler systems for buildings where required by the SBC, the IBC, or NFPA. The SBC shall be the primary reference for pre-action sprinkler system design. The IBC and NFPA shall be referenced for subjects and issues not addressed in the SBC.
2. Pre-action control panel shall be integrated with the building Fire Alarm System.
3. Pre-action systems shall not be used where release of water over energized equipment may cause irreparable or costly damage. The following requirements apply to pre-action systems:
   a. Pre-action systems shall have dual, cross-zoned detection and shall be charged through an electrically-released, pre-action valve.
   b. Pre-action systems shall utilize regular, closed, sprinkler heads.
   c. Provide an alarm after the first zone of detection is activated. Provide an abort switch and a 60-second, count-down timer for aborting the filling of the system with water for up to one minute after a second zone of detection is activated.

d. The pre-action valve must be located in a secure space where it can be maintained. Provide an adequate drain in the space. A floor sink with a 75 mm drain pipe is preferred.

e. Provide a means of pressure maintenance in the piping system.

f. Provide monitoring to indicate a reduction of air or nitrogen pressure in the piping system.

g. The time limits for charging a pre-action system and the maximum water velocities in piping shall be in accordance with NFPA 13.

h. Water filling the piping too rapidly may cause significant vibration, which in turn, can cause poorly anchored pipe to fail. Assure that piping is properly supported and anchored.

4. Refer to the appropriate project specifications for the applicable fire protection equipment.

2.8.4 Clean Agent Fire Extinguishing Systems

1. Clean agent, fire extinguishing systems shall be used in lieu of pre-action sprinkler systems where release of water over energized equipment may cause irreparable or costly damage. Obtain the approval from the Entity and the AHJ prior to designing or specifying clean agent systems.
2. Clean agent systems shall be designed in strict accordance with NFPA 2001.
3. Agent release shall be initiated through a system of dual, cross-zoned, smoke detectors.
4. The system shall be designed based upon the “total flooding” principal.
5. Provide an alarm after the first zone of detection is activated. Provide an abort switch and a 60-second, count-down timer for aborting the release of the clean agent for up to one minute after a second zone of detection is activated.
6. Coordinate the location of the clean agent canisters with the Architect and the Structural Engineer, addressing the size and weight of the canisters.
7. Assure that all canisters and piping are properly supported and anchored. Significant forces result in the piping system when the agent is released.
8. Provide the proper volume of agent (which is to include an acceptable safety factor) that will result in an adequate concentration to extinguish the fire.
9. Confirm with the Architect that the volume (i.e., room or area) where the agent will be utilized will be properly sealed to allow the agent to maintain an adequate concentration for sufficient time to extinguish the fire.
10. Room served by clean agents shall be integrity tested as per the requirement of NFPA 2001.
11. Identify on the construction documents the path and means to exhaust the volume when the fire is extinguished.
12. Clean agent control panel shall be integrated with the building Fire Alarm System.
13. Halocarbon clean agents such as FM-200 and NOVEC shall not be used for rooms with oil filled electrical equipment.
14. Refer to the project specification for cleaning and disinfecting fire protection equipment.

2.8.5 Fire Protection Systems for Kitchen Hoods

1. Fire protection systems for kitchen hoods shall be designed in strict accordance with NFPA 96.
2. Coordinate the system requirements with the kitchen equipment designer.
3. Assure that grease filters comply with UL 1046.
4. Assure proper provisions have been made in the design to shut off fuel to the cooking appliance upon activation of the fire extinguishing system. Shut-off devices shall be manually reset.
5. Coordinate the requirements for the operation of the ventilation system upon activation of the extinguishing system with the HVAC designer. Some extinguishing systems require the

ventilation system to continue to operate, while others require the ventilation system to be de-energized upon activation of the extinguishing system.

6. Kitchen hoods fire protection system shall be integrated with the building Fire Alarm System.
7. Refer to the project specification for the commercial cooking range fire protection system.

3.0 PLUMBING

3.1 General

3.1.1 Authority Having Jurisdiction

1. The Entity is the final Authority Having Jurisdiction (AHJ) unless otherwise stated in project documents.

3.1.2 Coordination and Integration

1. The design of plumbing system requires coordination and integration with other discipline designs, such as, but not limited to, the architectural design, structural design, HVAC design, electrical design, and other physical discipline designs.
2. Plumbing work shall be completed in full accordance with the respective health and safety requirements established by the Kingdom of Saudi Arabia and the Entity.

3.1.3 Abbreviations

1. Abbreviations in general are included in Volume 6, Chapter 2 – Definitions and References (EPM-KE0-GL-000011).
2. Abbreviations specific to this section appear below:

Abbreviations	Description
AAMI	Association of Advancement of Medical Instrumentation
AHJ	Authority Having Jurisdiction
AGA	American Gas Association
ANSI	American National Standards Institute
ASPE	American Society of Plumbing Engineers
ASSE	American Society of Sanitary Engineers
ASTM	ASTM International
AWWA	American Water Works Association
AWS	American Welding Society
CAP	College of American Pathologists
CISPI	Cast Iron Soils and Pipe Institute
CLSI	Clinical and Laboratory Standard Institute
DFU	Drainage Fixture Unit
IAPMO	International Association of Plumbing and Mechanical Officials
IBC	International Building Code
IPC	International Plumbing Code
LEED	Leadership in Energy and Environmental Design
MSS	Manufacturer Standardization Society
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NSF	National Standards Foundation
OSHA	Occupational Safety and Health Administrations
PPFA	Plastic Pipe and Fitting Association

Abbreviations	Description
PDI	Plumbing and Drainage Institute
SASO	Saudi Arabian Standards Organization
SBC	Saudi Building Code
SEMI	Semi-conductor Equipment and Materials International
UL	Underwriters Laboratories, Inc.
US EPA	United States Environmental Protection Agency
USP	United States Pharmacopeia
WSFU	Water Supply Fixture Unit

3.1.4 Definitions

1. Definitions in general are included in Chapter 2 of Volume 6.
2. Definitions specific to this section appear below:

Definitions	Description
Atmosphere	The same as outdoors.
Concealed Exterior	Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures.
Concealed Interior	Concealed from view and protected from physical contact by building occupants.
Conditioned	Spaces directly provided with heating and cooling.
Exposed Exterior	Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions.
Exposed Interior	Exposed to view indoors (not concealed).
Finished Space	Space other than mechanical rooms, electrical rooms, furred spaces, pipe chases, unheated spaces immediately below the roof, space above ceilings, unexcavated spaces, crawl spaces, tunnels, and interstitial spaces.
Furnish	Supply and deliver to the project site, ready for unloading, unpacking, assembly, installation, and similar subsequent requirements.
Install	Operations at the project site, including unloading, unpacking, assembly, erection, placing, anchoring, applying, working to dimension, finishing, curing, protecting, cleaning, and similar requirements.
Indoors	Located inside the exterior walls and roof of the building.
Outdoors	Located outside the exterior walls and roof of the building.
Provide	Furnish and install complete and ready for intended use.
Unconditioned	Spaces without heating or cooling including ceiling plenums.

3.1.5 Codes, Standards, and References

1. There are numerous model Plumbing Codes, and some areas may have adopted portions of various Plumbing Codes as part of their design and installation requirements. The actual Plumbing Code requirements for a project shall be reviewed with the Entity.
2. The latest version of the following codes establish the minimum requirement for the design of plumbing systems and equipment:
   a. Saudi Building Code
   b. International Building Code
   c. International Plumbing Code
   d. International Fuel Gas Code
3. The following is a list of standards that also apply to the design of plumbing systems and equipment:
   a. American Gas Association
   b. American National Standards Institute
   c. American Society of Plumbing Engineers

d. American Society of Sanitary Engineers
e. American Water Works Association
f. American Welding Society
g. ASTM International
h. Cast Iron Soils Pipe Institute
i. International Association of Plumbing and Mechanical Officials
j. Manufacturer Standardization Society
k. National Standards Foundation
l. National Electrical Manufacturers Association
m. National Fire Protection Association
n. National Standards Foundation
o. Occupational Safety and Health Administrations
p. Plastic Pipe and Fitting Association
q. Plumbing and Drainage Institute
r. Saudi Arabian Standards Organization
s. Underwriters Laboratories, Inc.

4. Refer to Volume 6, Chapter 5 – Codes, Standards, and References (EPM-KE0-GL-000014) for a list of additional codes, standards, and references.
5. In the event of a conflict between the codes or standards and this document, the more stringent requirement shall govern.
6. The information provided in this section shall be used to augment sizing methods, sizing procedures, and design methods in the list of documents above, but should not be used as the primary basis of the plumbing design.

3.1.6 Approvals

1. The Entity shall review and approve all design reports, plans, drawings, and specifications as outlined in Volume 6, Chapter 6 - Project Submission Standards and Requirements (EPM-KE0-GL-000015)..

3.2 Commissioning

3.2.1 Testing and Commissioning Requirements

1. Refer to Volume 10, Chapter 2 – Project Testing and Commissioning Guideline (EPM-KT0-GL-000003) for testing and commissioning requirements.

3.3 Sustainability Design for Plumbing Systems

3.3.1 General

1. Refer to Volume 15, Chapter 1 – Sustainability (EPM-KU0-GL-000001) for sustainability requirements.
2. The Entity is committed to energy-efficient designs within the limits of budget constraints and within the bounds of good practice and conforming to the Energy Conservation Codes.
3. Buildings shall use water efficient plumbing fixtures, solar water heaters, components, and appurtenances to reduce:
   a. Operating Costs
   b. Water Consumption

c. Sewage Discharge
d. Energy Usage

3.3.2 Strategies for Increasing Water Efficiency

1. Building Sewage Conveyance
    a. Use of water-conserving fixtures
    b. Use of captured rain water
    c. Use of recycled gray water
2. Do not design or specify
    a. Equipment or components that utilize potable water for cooling
    b. Water-cooled ice machines

3.4 Piping Systems

3.4.1 Materials

1. Materials shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.
2. Materials shall be selected with consideration given for the environmental conditions as well as the ease of shipment, installation, and maintenance.
3. Materials shall be rated for the applicable system design temperature, pressure, and fluid content requirements.
4. Materials shall meet the requirements of the contract documents.
5. Because of the high ground water aggressiveness, all pipes placed below grade shall have external protection by using epoxy coating or tape wrap.

3.4.2 Installation

1. Pipe shall be installed within shafts, chases, ceiling cavities, or in other accessible locations.
2. No piping shall be embedded in walls or floors except as allowed by the statement above.

3.4.3 Domestic Hot Water and Cold Water Piping

1. Building hot water piping, cold water piping, and fittings shall conform to NSF 61 and one of the standards listed in the Saudi Building Code Sanitary Requirements (SBC 701).
2. Refer to the project specification for plumbing piping.
3. Potable water supply shall be determined as potable hot water and cold water by the Entity.
4. For LEED and non-LEED projects pursuing credit for potable water reduction, water line for flushing of plumbing fixtures shall be separated from the potable water line used in showers, basins, and typical application; and shall be termed as “processed gray water line”.
5. Structures equipped with plumbing fixtures utilized for human occupancy or habitation shall be provided with a potable supply of hot and/or cold water in the volume (i.e., flow rate capacity) and pressure required for operation.
6. Where the water pressure is not sufficient to supply the minimum pressure and flow rate required for proper operation of plumbing fixtures and components, the potable water supply shall be supplemented with a building water storage tank connected to a hydro-pneumatic pressure booster pumping system. For power efficiency point of view and lower life cycle cost, high rise building application shall utilize multiple break tanks and series pumping (combined domestic water transfer and pressure boosting).

7. Piping design shall include provisions for expansion and contraction in the piping systems to prevent undue stress or strain on piping, building anchor points, and connections to equipment.
8. Because of the variable conditions encountered in hydraulic design, it is impractical to provide detailed requirements and rules for sizing water system piping. The water distribution systems shall be designed and pipe sizes selected based upon peak demand for each facility.
9. To avoid problems with regards to legionella, domestic cold water shall be stored below 25°C. Hot water shall be stored between 60°C to 65°C (allowable fluctuation in storage tank during usage especially for storage type heating and semi-instantaneous heating) and shall be distributed above 50°C.
10. Design criteria for hot water and cold water piping
    a. Determine the minimum static pressure available from the supply source.
        (1) It is essential that enough pressure is available to overcome all system pressure drop caused by friction and building height.
        (2) The water systems shall be designed based on the lowest pressure available to ensure proper operation of plumbing fixtures; Saudi Building Code Sanitary Requirements (SBC 701), Section for Water Distribution System Design Criteria Required Capacity at Fixture Supply Pipe Outlet Table.
    b. Determine the plumbing fixture demand (for non-simultaneous demand)
        (1) When determining peak demand, Water Supply Fixture Units (WSFU) associated with each fixture type shall be used; Refer to the International Plumbing Code, Appendix E - Load Values Assigned to Fixtures Table.
        (2) The WSFU is a numerical factor that measures the load producing effect of a single plumbing fixture.
        (3) The WSFU shall then be converted into liters per minute flow rate for determining pipe sizes; Refer to the International Plumbing Code, Appendix E – Tables for Estimating Demand.
    c. Determine the plumbing fixture demand (for simultaneous demand, e.g. mosque, schools, gyms, etc.)
        (1) For simultaneous demand, plumbing fixture flow requirement are added numerically.
        (2) Diversity factor is based on designer’s judgement from experience.
        (3) For compound application where simultaneous demand application is mixed with non-simultaneous demand, cumulative demand flowrate (simultaneous demand) is converted to WSFU and added to the system WSFU to obtain the flowrate for sizing mains piping (main branch, risers, main lines).
    d. Determine pipe sizes
        (1) Based on system pressure requirements and loses
        (2) The equivalent liters per minute from cumulative WSFU for main branch, risers, and other mains.
        (3) Uniform friction loss not exceeding 400 Pascal per meter.
        (4) Water flow velocities not exceeding 2.5 m per second.
11. Hot water recirculation system shall be design based on the following criteria;
    a. Required recirculation rate shall be based on 0.063 ltrs. per second per 20 WSFU.
    b. Main recirculation line shall be routed in such a way that all hot water branch shall not exceed 5 meters to the fixture connection. Provide branch recirculation and temperature valve (for auto-balancing base on return temperature) or auto balancing valve (base on recirculation flowrate) if the distance exceed 5 meters. Branch recirculation shall be as close as possible to the served fixture.
    c. All index shall have temperature valve set to 60°C or auto balancing valve set at calculated recirculating flowrate.

d. Recirculation pump head shall be calculated based on recirculation flow requirements (based on cumulative WSFU of the whole circuit converted to flow) proportionate to the WSFU of every hot water supply main branch circuit, from the recirculation pump leading to the index branch and back via the recirculation line. Pressure drop for each and every node from and back to the recirculation pump shall be calculated.

e. Provide hot water circulators satisfying the calculated recirculation flow and pressure drop.

3.4.4 Sanitary Waste and Vent Piping

1. Building sanitary piping and fittings shall conform to one of the standards listed in the Saudi Building Code Sanitary Requirements (SBC 701), Section for Sanitary Drainage Systems.
2. Building vent piping and fittings shall conform to one of the standards listed in the Saudi Building Code Sanitary Requirements (SBC 701), Section for Sanitary Drainage Venting Systems.
3. Refer to the projects specification for Plumbing Piping.
4. Structures equipped with plumbing fixtures utilized for human occupancy or habitation shall be connected to the public sewer or an Entity approved disposal system.
5. Horizontal drainage piping shall be designed with uniform alignment at uniform slopes. The minimum velocity of flow to achieve scouring action is 0.60 m per second.
6. Waste water discharging into the sanitary drainage system shall have a temperature of 60° C or less. When higher temperatures exist, an approved cooling method shall be provided or a separate drainage line shall be provided using heat resistant or thermal piping.
7. Building sanitary that cannot discharge by gravity shall discharge into a tightly covered and vented sewage ejector from which the effluent shall be lifted and discharged into the gravity sanitary system by automatic pumping equipment and components.
8. Connections and changes in direction shall be designed with drainage fittings. The fittings shall not have interior ledges, shoulders, or reductions capable of retarding or obstructing flow.
9. Cleanouts:
   a. Shall be indicated at every change of horizontal direction greater than 45 degrees. Where more than one change of direction occurs in a run of piping, only one cleanout is required for each 12 m of developed length of sanitary pipe.
   b. Shall be provided at the base of each drainage stack or riser.
   c. Shall be provided at the junction of the building drain and building sewer. The cleanout shall be located on either the inside or outside of the building wall.
   d. Refer to the projects specification for Plumbing Piping Specialties
10. Sanitary drainage systems within a building shall be completely independent of the storm drainage system.
11. For LEED and non-LEED projects pursuing credit for water use reduction, provide separate waste and soil piping in drainage system. Waste water can undergo secondary water treatment for irrigation or plumbing fixtures re-use (gray water).
12. Design criteria for sanitary piping
   a. Determine the plumbing fixture demand
      (1) When determining peak drainage demand, Drainage Fixture Units (DFU) associated with each fixture type shall be used. The DFU is a numerical factor that measures the load producing effect of a single plumbing fixture; Refer to the International Plumbing Code, Chapter 7 - Drainage Fixture Units for Fixtures and Groups Table.
      (2) Values for continuous and semi-continuous flow into the drainage system shall be computed on the basis that 0.06 liters per second is equivalent to two DFU.
   b. Determine pipe sizes

(1) Each pipe branch and main shall be determined based the number of DFU's connected; Refer to International Plumbing Code, Chapter 7 - Building Drains and Sewers Table and Horizontal Fixture Branches and Stacks Table.

(2) Horizontal stack offsets shall be sized as required for building drains.

(3) Vertical stack offsets shall be sized for straight stacks.

13. Design criteria for vent piping

    c. The diameter of individual vents, branch vents, circuit vents, and relief vents shall be at least one half the required diameter of the drain served.

    d. Vent pipes shall not be less than 30 mm in diameter.

    e. Vent exceeding 12 m in developed length shall be increased by one nominal pipe size for the entire developed length of the vent pipe.

3.4.5 Storm and Secondary (Emergency) Storm Drainage Piping

1. Building storm and secondary (emergency) storm piping and fittings shall conform to one of the standards listed in the Saudi Building Code Sanitary Requirements (SBC 701), Section for Storm Drainage Systems.
2. Refer to the projects specification for Plumbing Piping.
3. Roofs, paved areas, yards, courts, and courtyards shall be drain into the public storm system or an approved place of disposal.
4. Horizontal drainage piping shall be designed with uniform alignment at uniform slopes. The minimum velocity of flow to achieve scouring action is 0.60 m per second.
5. Building storm drains that cannot discharge by gravity shall discharge into a tightly covered and vented sump from which effluent shall be lifted and discharged into the gravity drainage system by automatic pumping equipment.
6. Building secondary (emergency) storm discharge shall have a point of discharge above grade in a location that would typically be observed by building occupants or maintenance personnel.
7. Connections and changes in direction shall be designed with drainage fittings. The fittings shall not have interior ledges, shoulders, or reductions capable of retarding or obstructing flow.
8. Cleanouts
    a. Shall be indicated at every horizontal change of direction greater than 45 degrees. Where more than one change of direction occurs in a run of piping, only one cleanout is required for each 12 m of developed length of sanitary pipe.
    b. Shall be provided at the base of each drainage stack or riser.
    c. Shall be provided at the junction of the building drain and building sewer. The cleanout shall be located on either the inside or outside of the building wall.
    d. Refer to the project specification for plumbing piping specialties.
9. Storm drainage and secondary (emergency) storm systems within a building shall be completely independent from each other and the sanitary drainage system.
10. Design criteria for storm piping
    a. The size of vertical storm stacks, horizontal storm mains, and branches shall be based on 100-year hourly rainfall rate or other rainfall rates determined by approved local weather data. The most stringent criteria shall be used as the basis of design; Refer to the Saudi Building Code Sanitary Requirements (SBC 701), Section 6 – Size of Vertical Conductors and Leaders Table and Size of Horizontal Storm Drainage Piping Table.
    b. Determine the maximum projected square meter drain area for each drain.
    c. One half of the area of any vertical wall that diverts storm water into the storm drainage system shall be included into the calculation.
11. Design criteria for secondary (emergency) storm piping

a. The size of the secondary (emergency) storm shall be sized in accordance with the requirements of the storm drainage system.

3.4.6 Compressed Air Piping

1. No mandated code requirements have been developed specifically for compressed air systems, however the Compressed Gas Association, The National Fire Protection Association Standards and ASPE Plumbing Engineering Design Handbook, Volume 3 – Special Plumbing Systems, Chapter 9 - Compressed Air Systems shall be used for the basis of design.
2. Refer to the projects specification for General Service Compressed Air Systems.
3. The compressed air system shall be controlled, regulated, and sized to ensure that an adequate volume of air, at a pressure and purity to satisfy user requirements, is delivered during peak demand.
4. The entire compressed air system, including but not limited to air dryer, pre-filters, after filters, controls shall be mounted on a single heavy-duty structural steel support frame.
5. Design criteria for compressed air piping
    a. Identify each process, work station, or piece of equipment requiring compressed air.
    b. Determine the volume of air and pressure required for each location.
    c. Determine the condition requirements for each location, such as the allowable moisture content, particulate size, and oil content.
    d. Determine how much time the individual tool or process will be in actual use for a one minute period of time (duty cycle).
        (1) To determine the duty cycle, the user should be consulted, they are the only authority capable of providing the length of time an individual tool is in use
    e. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).
        (1) It may be difficult to accurately determine the simultaneous use factor so sufficient receiver capacity or larger compressor capacity must be provided to allow for variances in use.
    f. Determine the extent of allowable leakage
        (1) Leakage is a function of the number of connections to the system and the quality of the pipe assembly.
        (2) Many smaller tools and operations will generally have a greater leakage than a few larger ones.
        (3) Leakage rates
            (a) A well-maintained system may have a leakage rate of approximately 2 to 5 percent.
            (b) A typical system may have a leakage rate of approximately 10 percent.
            (c) A poorly maintained system may have a leakage rate of approximately 25 percent.
    g. Determine an allowance for future expansion.
    h. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).
    i. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).
    j. Select the air compressor type, conditioning equipment, equipment location, and air inlet, making sure that cubic meters / minute, liters / minute, or liters / second is consistently used for both the system and compressor capacity rating.

6. Pipe sizing shall be determined based on the more stringent of the following:
    a. Maximum of 7 kPa pressure drop per 30 m
    b. Maximum friction loss to the furthest outlet of 35 kPa
7. A properly sized, constantly working air compressor usually requires less maintenance than a compressor that runs intermittently.

3.4.7 Natural Gas Piping

1. Building natural gas piping and fittings shall conform to one of the standards listed in the International Fuel Gas Code, Chapter 4 - Gas Piping Installation.
2. Refer to the projects specification for Plumbing Piping.
3. The system shall be designed to provide a supply of gas sufficient to meet the maximum demand at no less than the minimum supply pressure associated with each piece of equipment or component.
4. The two most commonly used gases are natural gas and liquefied petroleum gas.
5. Design criteria for gas piping
    a. Determine the minimum gas pressure available.
    b. Identify each process, work station or piece of equipment requiring a gas source.
    c. Determine the volume of gas required for each location.
        (1) Total connected load based on cubic meter per hour of every device requiring gas in the building.
    d. Determine the pressure range for each location.
        (1) The available pressure after the meter could be quite low and requires that the friction loss through the piping system be kept low.
    e. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).
        (1) It may be difficult to accurately determine a simultaneous use factor.
        (2) Include Plumbing and HVAC equipment demand.
    f. Determine an allowance for future expansion.
    g. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).
    h. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).
    i. Select the meter, regulator, equipment, equipment location, and components, based on the equivalent length and total cubic meters / hour demand.
    j. Indoor service pressure shall not exceed 20 psig as per NFPA 54.
    k. Polyethylene piping shall not be used indoors but is allowed to be used for buried and outdoor piping with maximum service pressure of 30 psig as per NFPA 54.
    l. The main gas solenoid valve or the gas controller shall be integrated with the building Fire Detection and Alarm System.
6. Design criteria for liquefied petroleum gas piping
    a. The design criteria for liquefied petroleum gas is similar to natural gas and natural gas sizing charts however a conversion factor of 0.63 must be applied to reduce the indicated flow rate.

3.4.8 Vacuum Piping

1. No mandated code requirements have been developed specifically for vacuum systems however ASPE Plumbing Engineering Design Handbook, Volume 2 – Plumbing Systems, Chapter 10 – Vacuum Systems shall be used for the basis of design.
2. The vacuum system shall be controlled, regulated, and sized to ensure that an adequate vacuum is provided during peak demand.
3. The entire vacuum system shall be mounted on a single heavy-duty structural steel support frame.
4. Design criteria for vacuum piping
   a. Identify each process, work station or piece of equipment requiring vacuum.
   b. Determine the vacuum required for each location.
      (1) Total connected load based on cubic meter per minute of every device requiring vacuum in the building.
   c. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).
      (1) It is difficult to accurately determine a simultaneous use factor so sufficient receiver capacity must be provided to allow for variances in use.
   d. Determine an allowance for future expansion.
   e. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).
   f. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).
   g. Select the meter, regulator, equipment, equipment location, and components, based on the equivalent length and total cubic meters per hour demand.
5. Cleanouts shall be strategically located throughout the piping system to allow for the removal of debris.
6. A properly sized, constantly working vacuum pump usually requires less maintenance than a compressor that runs intermittently.
7. Minimum pipe sizes; Exact pipe sizes shall be determined based on project requirement:
   a. 10 mm for a single connection or short piece of pipe
   b. 20 mm for multiple connections on branch piping
   c. 25 mm for main piping

3.4.9 Irrigation System

1. No mandated code requirements have been developed specifically for irrigation systems, however ASPE Plumbing Engineering Design Handbook, Volume 3 – Special Plumbing Systems, Chapter 4 – Irrigation Systems shall be used for the basis of design.
2. When designing Irrigation System, the A/E shall consider the following;
   a. Site Plan – shall clearly indicate building lines for sprinkler head type selection to avoid overspray. Shrub and hedges diameter and height must be indicated to determine sprinkler head type that will suite.
   b. Type of Planting – different variety of planting requires more frequent watering than others. Sprinkler types and trickle heads/drippers selection depends in types of planting. Operating pressure requirements varies for different types of sprinkler and drippers, therefore zoning consideration will be very important.

c. Type of soil – soil type determines the watering flowrate and watering frequency to the soil to penetrate the root zone.

d. System location – determine evaporation rates base on climatic condition. Sloping terrain requires pressure regulation and effective drainage to avoid water flooding and excessive overflowing.

3. Each irrigation sprinkler head is design for different pressure. Spray heads such as pop-up heads are normally design for a maximum 2.5 bar operating pressure, impact heads such as rotor type have a maximum operating pressure of 6 bar, shrub heads and dripper are designed for 2 bar maximum operating pressure. Due to these different pressure requirements, it is necessary to group the head types and provide Pressure Regulating Valves (PRV).
4. Municipal TSE (Treated Sewer Effluent) or local TSE (from secondary Waste Water Treatment facility) shall be used in irrigation system. Domestic water shall in no case be used in irrigation system except in softscapes close to densely occupied areas, or as religious laws prohibits the use of TSE. When TSE is used, provide filtration after the control valve for dripper tubing.
5. For main pipe sizing, refer to Subsection 3.4.3 –Domestic Hot and Cold Water Piping. Design of distribution network and lateral sub-branches shall be reviewed and revised as needed by an Irrigation Specialist.
6. Dripper flexible tubes shall be anti-algae type and must be buried to avoid ambient air temperature promoting algae growth.
7. Selection of controller shall conform to the irrigation zoning consideration as per the Project Plan and Specification.
8. Provide ¾ inch quick connects in main lines for manual hand irrigation. Spacing shall be within 15mtrs. OC. Flushing valves shall be provided for every change of the main line direction and each sub-branch.
9. Use humidity sensor and dry-bulb temperature sensor to calculate the ambient air dew point temperature and irrigate when dew point is higher than the water temperature (compare during the day or night) to eliminate evaporation. To avoid excessive evaporation if the water temperature is prevalently higher than the ambient air dew point temperature for most of the season;
    a. Use water sprinkler and drippers in irrigation system in lieu of spray system providing fine droplets as possible.
    b. Use wind speed sensor to avoid irrigating greeneries during high winds.
10. Use rain water sensors to avoid irrigating greeneries when raining.

3.5 Equipment

3.5.1 Water Softeners

1. No mandated code requirements have been developed specifically for water softeners however the ASPE Plumbing Engineered Design Handbook, Volume 4 - Plumbing Components and Equipment, Chapter 10 - Water Treatment shall be used for the basis of design.
2. Refer to the project specification for plumbing equipment.
3. Water softening, when required, shall reduce and remove dissolved impurities that cause hardness in water. Water softening shall occur by passing the raw water through an ion exchange process.
4. Design criteria for water softeners
    a. Perform a water analysis.
        (1) Check with local authorities for water analysis.
    b. Determine water consumption.
        (1) Based on ASPE or Manufacturer sizing charts.

c. Determine continuous and peak flow rates.

(1) Use the fixture count flow rate from domestic hot water and cold water sizing information.

(2) Obtain flow rates for equipment requiring softened water.

d. Determine water pressure

(1) Water pressure at the service entrance. Provide pressure reducing valve for service pressure exceeding the maximum allowable softener operating pressure.

(2) Water pressure at the most remote plumbing fixture or piece of equipment. Provide booster pump incase pressure is not sufficient for plumbing fixture or equipment requirement due to pressure loss across the softening tanks, especially for centralized laundry usage.

(3) Determine minimum water flow and pressure requirement for regeneration/backwash. Incoming lines shall be sized accordingly to softener minimum flow and pressure requirements.

(4) Determine the capacity of the softener.

(a) Liters per day x grains per liter = Grains per day

(b) Select the smallest unit that can handle the maximum capacity between regeneration with a low salt dosage.

(c) Avoid sizing unit with a high dosage requirement unless there is a reason to do so, such as high pressure boilers.

3.5.2 Water Heaters

1. General

a. The ASHRAE Handbook - HVAC Applications, Chapter 50 - Service Water Heating shall be used for the basis of design in addition to the corresponding section of the Saudi Building Code Sanitary Requirements (SBC 701).

b. Water heater shall be sized based on the total volume of hot water required for the estimated duration of maximum demand. The required storage volume should consider the maximum usage or hot water demand and the water recovery rate.

c. Refer to the project specification for plumbing equipment.

d. Water heater sizing shall be determined by one of the following:

(1) Number of hot water plumbing fixtures - This sizing method calculates anticipated volume in liters of hot water for the peak duration of use and storage tank capacity.

(2) Population - This sizing method calculates anticipated volume when the quantity of plumbing fixtures does not correlate to the quantity of people.

(3) Plumbing fixture flow rates - This sizing method is typically utilized for specialized buildings, such as convention centers, sports areas, gymnasiums, etc., where peak usage periods occur.

3.5.2.1 Storage Tank Water Heaters

1. Refer to the project specification for plumbing equipment.

2. Design criteria based on quantity of fixtures:

a. Determine total number of each type of plumbing fixture and assign the liter per hour value for each fixture based on building type and system demand value.

b. Multiply the quantity of each fixture by the building type system demand value.

c. Add the sum of all individual fixtures system demand together to obtain a total connected load in liters of water per hour.

d. Find the actual hourly demand by multiplying the total connected load by a demand factor. This calculation will provide the actual volume of hot water that will be required during a one hour period of time.

e. In addition to the hourly hot water demand determine the quantity of hot water that will be stored.

(1) Storage capacity shall be determined by multiplying the total connected hot water demand by a storage capacity factor.

(2) Add an additional 30% to the calculated usable storage for the cold water correction factor.

3. Design criteria based on population

a. Determine the population of the building.

b. Using a recovery, storage capacity curve chart, determine the desired storage and recovery per person.

c. Determine the total required recovery, storage capacity by multiplying the population.

d. Add an additional 30% to the calculated usable storage for the cold water correction factor.

e. Add a system heat loss of 15 BTU / meter run of pipe to the gallon per hour recovery to make up for the heat loss of the entire system. Note: This is only required in the population method because no consideration for heat loss was made in the hot water usage criteria.

4. Design criteria based on flow rate

a. Determine the hours or minutes of peak use.

b. Determine the typical flow rate for all fixtures contributing to flow during peak duration.

c. Determine the amount of time the fixtures will actually be utilized during the peak duration.

d. Select a combination recovery rate and storage tank capacity that will supply the calculated amount of hot water during the peak duration.

3.5.2.2 Instantaneous and Semi-Instantaneous Water Heaters

1. The total volume of hot water requirement shall be determined based on a combination of hot water storage and the water heater recovery rate for semi-instantaneous water heater.

2. Instantaneous and semi-instantaneous water heater sizing shall be determined by the quantity of plumbing fixtures. This sizing method calculates anticipated volume in liters of hot water for the peak duration of use and storage tank capacity.

3. Design criteria based on number of fixtures:

a. Count the total number of each type of fixture and assign the gallon per hour value for each fixture based on building type and demand value.

b. Multiply the quantity of each fixture by the building type demand value.

c. Add the sum of all individual fixtures together to obtain a total connected load in liters of water per hour.

3.5.2.3 Solar Water Heaters

1. Refer to the project specification for plumbing equipment.

2. Efficiency cost of solar collectors, system installation costs, and availability of other fuels shall determine whether solar energy collections units should be used as a primary heat source.

3. Solar energy equipment and components can also be utilized to supplement other energy source water heaters.

4. The basic elements of a solar water heater include solar collectors, storage tank, piping, controls, and transfer medium.

5. Collector design shall provide uniform flow distribution in the collector bank and stratification in the storage tank.

6. Application of solar water shall depend on:
   a. Auxiliary energy requirements
   b. Collector orientation
   c. Temperature of the cold water
   d. Site conditions
   e. Installation requirements
   f. Available area for collectors
   g. Amount of storage required
7. Three types of active solar water heating systems include:
   a. Direct circulation system: Use pumps to circulate pressurized potable water directly through the collectors.
   b. Indirect circulation system: Pump heat transfer fluids through the collectors.
   c. Passive solar systems: Rely on gravity and the tendency for water to naturally circulate as it is heated.
8. Design criteria based on number of fixtures
   a. Determine total number of each type of plumbing fixture and assign the liter per hour value for each fixture based on building type and system demand value.
   b. Multiply the quantity of each fixture by the building type system demand value.
   c. Add the sum of all individual fixtures system demand together to obtain a total connected load in liters of water per hour.
   d. Find the actual hourly demand by multiplying the total connected load by a demand factor. This calculation will provide the actual volume of hot water that will be required during a one hour period of time.
   e. In addition to the hourly hot water demand determine the quantity of hot water that will be stored.
      (1) Storage capacity shall be determined by multiplying the total connected hot water demand by a storage capacity factor.
      (2) Add an additional 30% to the calculated usable storage for the cold water correction factor.
   f. Determine quantity of solar collectors, storage tank size, and component requirements.
9. Design criteria based on population
   a. Determine the population of the building.
   b. Using a recovery, storage capacity curve chart, determine the desired storage and recovery per person.
   c. Determine the total required recovery, storage capacity by multiplying the population.
   d. Add an additional 30% to the calculated usable storage for the cold water correction factor.
   e. Add a system heat loss of 15 BTU / meter run of pipe to the gallon per hour recovery to make up for the heat loss of the entire system. Note: This is only required in the population method because no consideration for heat loss was made in the hot water usage criteria.
   f. Determine quantity of solar collectors, storage tank size, and component requirements.
10. Design criteria based on flow rate
   a. Determine the hours or minutes of peak use.
   b. Determine the typical flow rate for all fixtures contributing to flow during peak duration.
   c. Determine the amount of time the fixtures will actually be utilized during the peak duration.

d. Select a combination recovery rate and storage tank capacity that will supply the calculated amount of hot water during the peak duration.

e. Determine quantity of solar collectors, storage tank size, and component requirements.

3.5.3 Pumps

3.5.3.1 Domestic Water Booster Pumps

1. Building domestic water booster pumps shall conform to the requirements of the Saudi Building Code Sanitary Requirements (SBC 701), Section for Water Supply and Distribution Systems, and the ASPE Plumbing Engineered Design Handbook, Volume 2 - Plumbing Systems, Chapter 5 - Cold Water Systems.
2. Two types of pressure booster pump drives can be utilized for adjusting the pressure and flow in the building water distribution system:
   a. Constant speed drive - This type of drive is recommended where water demands are relatively constant and low-to-medium boost pressure is required.
   b. Variable speed drive - This type of drive is recommended where there are large fluctuations in the water main supply pressure to the pump, there is a requirement for a high pressure boost, or there is a great variation expected in the system water demand.
3. Refer to the project specification for plumbing equipment.
4. Water pressure booster pump shall be a multiplex packaged system provided with pump suction to facility water storage holding tank, motors, control equipment, ASME hydro-pneumatic tank (for constant speed drive), valves, fittings, manifolds and associated appurtenances.
5. It should be assumed that a water pressure booster pump is required. The water pressure booster pump selection shall be determined based on the following design criteria:
   a. Determine the minimum static pressure available from the supply source.
   b. Determine the building height.
   c. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).
   d. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).
   e. Determine the minimum operating pressure of the farthest plumbing fixture from the booster pump.
   f. Calculate total dynamic head for the booster pump based on available pressure, pressure loss through system, and minimum pressure required at the most remote plumbing fixture.
   g. A hydro-pneumatic tank should be incorporated into the system for constant speed drive booster pump system design to meet low flow demand without operating a pump. Hydro-pneumatic tank shall not be required for variable speed drive booster pumping.

3.5.3.2 Sump Pumps

1. Building sump pumps shall conform to the requirements of the Saudi Building Code Sanitary Requirements (SBC 701), section for storm drainage systems, and the ASPE Plumbing Engineered Design Handbook, Volume 2 - Plumbing Systems, Chapter 1 - Sanitary Drainage Systems.
2. Building drains that cannot discharge by gravity shall discharge into a tightly covered and vented receiver from which effluent shall be lifted and discharged into the gravity drainage system by automatic pumping equipment.
3. There are three types of pumps that can be utilized
   a. Submersible pump with receiver - The submersible pump system is totally submerged in the effluent within a receiver.

b. Wet-pit receiver with vertical lift pump - The vertical lift system utilizes a vertical shaft centrifugal pump and separate driver, both mounted on the receiver cover.

c. Wet-pit receiver with cantilever, self-priming pump - The cantilever type utilizes horizontal centrifugal pump and close-coupled driver mounted on the receiver cover. A suction pipe is cantilevered from the pump down into the receiver.

4. Refer to the project specification for plumbing equipment.

5. The pump type shall be determined by:

   a. Range of head and capacity for the motor and impeller combinations

   b. Floor space requirements

   c. Pump and bearing construction

   d. Type of liquids to be pumped

   e. Headroom available to remove pump and impeller

6. Duplex pumping systems shall be provided and control shall be based on level of effluent in the basin.

7. Design criteria for sump pumps

   a. Pump head shall be calculated by adding the static height from the bottom of the basin to a level one meter above the anticipated highest point of discharge and friction loss of effluent through the pump discharge system. The calculation shall be calculated based on both pumps running.

   b. The pump shall be sized based on the pump running time of 1 to 5 minutes, with an optimum of six starts per hour. If these conditions cannot be achieved, the least amount of starts per hour shall be the basis of design.

   c. The receiver shall be sized based on:

      (1) From the invert of the inlet pipe, allow approximately 150 mm to the high-water alarm

      (2) From the high-water alarm, allow approximately 150 mm to pump two starts

      (3) From pump two start, allow approximately 150 mm to pump one start

      (4) Below pump one start level, the dimension of liquid capacity shall be determined based on a 1 to 5 minutes operating period for a pump. The lower level of the storage portion is pump stop.

      (5) Allow approximately 150 mm from pump stop to inlet of pump.

      (6) Allow approximately 300 mm to the receiver bottom from the inlet of the pump.

   d. Sump pump discharge pipe shall be a minimum of 50 mm. Pipe sizes can be larger to lessen the friction loss in the discharge piping system, if this results in a reduction of the motor size.

3.5.3.3 Sewage Ejector Pumps

1. Building sewage ejector pumps shall conform to the requirements of the Saudi Building Code Sanitary Requirements (SBC 701), Section 4 – Sanitary Drainage systems, and the ASPE Plumbing Engineered Design Handbook, Volume 2 – Plumbing Systems, Chapter 1 – Sanitary Drainage Systems.

2. Building sanitary that cannot discharge by gravity shall discharge into a tightly covered and vented receiver from which effluent shall be lifted and discharged into the gravity sanitary system by automatic pumping equipment.

3. There are three types of pumps that can be utilized:

   a. Submersible pump with receiver: The submersible pump system is totally submerged in the effluent within a receiver.

   b. Wet-pit receiver with vertical lift pump: The vertical lift system utilizes a vertical shaft centrifugal pump and separate driver, both mounted on the receiver cover.

c. Wet-pit receiver with cantilever, self-priming pump: The cantilever type utilizes horizontal centrifugal pump and close-coupled driver mounted on the receiver cover. A suction pipe is cantilevered from the pump down into the receiver.

4. Refer to the project specification for plumbing equipment.
5. The pump type shall be determined by:
    a. Range of head and capacity for the motor and impeller combinations
    b. Floor space requirements
    c. Pump and bearing construction
    d. Type of liquids to be pumped
    e. Headroom available to remove pump and impeller
6. Duplex pumping systems shall be provided and control shall be based on level of effluent in the basin.
7. Design criteria for sewage ejector pumps:
    a. Pump head shall be calculated by adding the static height from the bottom of the basin to a level one meter above the anticipated highest point of discharge and friction loss of effluent through the pump discharge system. The calculation shall be calculated based on both pumps running.
    b. The pump shall be sized based on the pump running time of 1 to five minutes, with an optimum of six starts per hour. If these conditions cannot be achieved, the least amount of starts per hour shall be the basis of design.
    c. The receiver shall be sized based on:
        (1) From the invert of the inlet pipe, allow approximately 150 mm to the high-water alarm
        (2) From the high-water alarm, allow approximately 150 mm to pump two starts
        (3) From pump two start, allow approximately 150 mm to pump one start
        (4) Below pump one start level, the dimension of liquid capacity shall be determined based on a 1 to 5 minute operating period for a pump. The lower level of the storage portion is pump stop.
        (5) Allow approximately 150 mm from pump stop to inlet of pump.
        (6) Allow approximately 300 mm to the receiver bottom from the inlet of the pump.
    d. Sewage ejector pump discharge pipe shall be a minimum of 75 mm. Pipe sizes can be larger to lessen the friction loss in the discharge piping system, if this results in a reduction of the motor size.

3.5.3.4 Elevator Pit Pumps

1. Building elevator pit pumps shall conform to the requirements of the International Building Code, Chapter 30 - Elevators and Conveying Systems and ASME A17 Safety Code for Elevators and Escalators.
2. Permanent provisions shall be provided to prevent the accumulation of ground water in the elevator pit.
3. Design criteria for elevator pit pumps
    a. Pump head shall be calculated by adding the static height from the bottom of the elevator pit to a level one meter above the anticipated highest point of discharge and friction loss of effluent through the pump discharge system.
    b. The elevator pit pump shall have the capability to discharge 11,356 liters per hour
4. Refer to the project specification for plumbing equipment.
5. Sump pump discharge pipe shall be a minimum of 50 mm.

3.5.4 Facility Water Storage Tanks

1. The capacity of the facility water storage tank shall be determined based on the type of building and quantity of fixtures served and storage requirements as summarized in the following table.

Water Flow (L / d / unit)			
Source	**Unit**	**Range**	**Typical**
Airport	Passenger	8 - 15	10
Automobile Service Station	Vehicle	30 - 50	40
	Employee	35 - 60	50
Hotel	Guest	150 - 220	190
	Employee	30 - 50	40
Industrial Building	Employee	3 -65	55
Laundry	Machine	1800 - 2595	2195
	Wash	180 - 200	190
Motel	Person	90 -150	120
Motel with Kitchen	Person	190 -220	200
Office	Employee	30 - 65	55
Restaurant	Meal	8 - 15	10
Rooming House	Resident	90 - 190	150
Store Department	Toilet Room	1600 - 2400	2000
	Employee	30 - 50	40
Store Center	Parking space	2 - 8	4
	Employee	30 -50	40
Hospital, Medical	Bed	500 - 950	650
	Employee	20 - 60	40
Hospital, Mental	Bed	300 - 650	400
	Employee	20 - 60	40
Rest Home	Resident	200 - 450	350
	Employee	20 -60	40
School, Day			
• With Cafeteria, Gym, Shower	Student	60 - 115	80
• With Cafeteria only	Student	40 - 80	60
• Without Cafeteria, Gym, Shower	Student	20 -65	40
School, Boarding	Student	200 - 400	40
Apartment	Person	200 - 280	220
Cafeteria	Customer	4 - 10	6
	Employee	30 - 50	40
Dining Hall	Meal served	15 - 50	30
Dormitory	Person	75 - 175	150
Theater	Seat	10 - 15	10

2. Design criteria for facility water storage tanks:
   a. Determine the total quantity of plumbing fixtures.
   b. Multiply the total number of plumbing fixtures by the lpm per fixture.
   c. Multiply the resulting plumbing lpm by the building type multiplier. This will determine the minimum plumbing water storage only.

d. Add the constant uses of water, such as HVAC make-up, fire protection water storage, and any process requirements to the plumbing water storage.

e. Select a tank size equal to or exceeding the total required storage capacity however the minimum storage tank size shall be 11,356 liters.

3.5.5 Interceptors

Types include but are not limited to:

3.5.5.1 Grease Interceptors

1. Building grease interceptors shall conform to the requirements of the Saudi Building Code Sanitary Requirements (SBC 701), Section for Interceptors and Separators, and the ASPE Plumbing Engineered Design Handbook, Volume 4 – Plumbing Components and Equipment, Chapter 8 – Grease Interceptors.
2. A grease interceptor shall receive the drainage form fixtures and equipment with grease-laden waste located in food preparation areas. Grease interceptors shall receive waste only from fixtures and equipment that allow fats, oils or grease to be discharged.
3. Refer to the projects specification for plumbing piping specialties.
4. Where food grinders connect to grease interceptors, a solids interceptor shall separate the discharge before connecting to grease interceptor.
   a. Solids separators and grease interceptors shall be sized and rated for the discharge of the food waste grinder.
   b. Emulsifiers, chemicals, enzymes and bacteria shall not discharge into the food waste grinder.
5. Grease interceptors shall have the grease retention capacity comparable with the established flow-through rates.
6. Grease interceptors shall be designed so as not to become air bound where tight covers are utilized. Each interceptor shall be vented where subject to a loss of trap seal.
7. Grease interceptors shall be equipped with devices to control the rate of water flow so it does not exceed the rated flow. The flow-control device shall be vented and terminate not less than 150 mm above the flood rim level or be installed in accordance with the manufacturer’s instructions.
8. Design Criteria
   a. Determine cubic volume of each plumbing fixture that will connected to the grease interceptor.
   b. Convert cubic volume of each plumbing fixture that will connect to the grease interceptor into liters.
   c. Determine the actual drainage load. The drainage load is typically equivalent to 75% of the fixture capacity.
   d. Determine flow rate and drainage period. A one minute drain period is typically utilized, however a two minute drainage period is permitted based on project limitations.
   e. Select grease interceptor based on calculated flow rate.

3.5.5.2 Solids Interceptors

1. Building solids interceptors shall conform to the requirements of the Saudi Building Code Sanitary Requirements (SBC 701), Section 4.19 - Interceptors and Separators.
2. Solids interceptors for heavy solids shall be designed and located so as to be provided with ready access for cleaning, and shall have a water seal of not less than 150 mm.
3. Refer to the projects specification for plumbing piping specialties.
4. Design Criteria
   a. Determine the liters-per-minute rate of flow through the drainage piping into the interceptor.

b. Determine the probable amount of substances to be separated.

c. Select interceptor size based on flow rate and separation requirements. Solids interceptors shall be sized to ensure solids will not be carried through the interceptor.

3.5.5.3 Lint Interceptors

1. Building lint interceptors shall conform to the requirements of the Saudi Building Code Sanitary Requirements (SBC 701), Section 4.19– Interceptors and Separators.

2. Laundry facilities not installed within individual dwelling units or intended for individual family use shall be provided with an interceptor with a wire basket or similar device, removable for cleaning, that prevents passage of solids 10 mm or larger in size, string, rags, buttons or other materials detrimental to the public sewage system.

3. Refer to the project specification for plumbing piping specialties.

4. Design Criteria

   a. Determine quantity of washing machines that will be connected to the interceptor.

   b. Select interceptor size based on quantity of washing machines connected, flow rate and pipe connection size.

3.5.5.4 Sediment Interceptors

1. Building sediment interceptors shall conform to the requirements of the Saudi Building Code Sanitary Requirements (SBC 701), Section 4.19 – Interceptors and Separators.

2. Sands and sediment interceptors shall be designed and located so as to be provided with ready access for cleaning, and shall have a water seal of not less than 150 mm.

3. Refer to the project specification for plumbing piping specialties.

4. Design Criteria

   a. Determine the liters-per-minute rate of flow through the drainage piping into the interceptor.

   b. Determine the probable amount of substances to be separated.

   c. Select interceptor size based on flow rate and separation requirements. Sediment interceptors shall be sized to ensure sediments will not be carried through the interceptor.

3.5.5.5 Oil Separators

1. Building oil interceptors shall conform to the requirements of the Saudi Building Code Sanitary Requirements (SBC 701), Section 4.19 - Interceptors and Separators, and the ASPE Plumbing Engineered Design Handbook, Volume 2 - Plumbing Systems, Chapter 12 - Special Waste Drainage Systems.

2. Oil separators shall be required at repair garages, car-washing facilities, at factories where oily and flammable liquid wastes are produced and in hydraulic elevator pits, before emptying the discharge into the building drainage system or other point of disposal.

3. Refer to the project specification for plumbing piping specialties.

4. Design Criteria

   a. The American Petroleum Institute (API) has established criteria for the large scale removal of globules larger than 150 micrometers and shall be used when sizing oil separators:

      (1) The horizontal velocity through the separator may be up to 15 times the velocity of the slowest-rising globule, up to a maximum of 0.91 m per second).

      (2) The depth of flow in the separator shall be within 0.9 to 2.4 m.

      (3) The width of the separator shall be between 1.8 to 6.1 m.

      (4) The depth-to-width ratio shall be between 0.3 and 0.5

      (5) An oil retention baffle shall be located no less than 305 mm downstream from the skimming device.

(6) Separators shall be designed so as not to become air bound where tight covers are utilized. Each separator shall be vented where subject to a loss of trap seal.

3.5.6 Special Waste Systems

1. Infectious and biological waste systems have the same basic characteristics as other types of laboratory and production facility waste, but with the addition of bio-hazardous materials. Bio-Hazardous material is material suspended in the waste stream with live organisms that, if not contained, have the potential to cause infection, sickness, and other various diseases.
2. Bio-hazardous waste may be discharged from many sources including:
   a. Fermentation tanks and equipment
   b. Process centrifuges
   c. Sink, both hand washing and process
   d. Containment area floor drains
   e. Janitor closet drains
   f. Necropsy table drains
   g. Autoclave drains
   h. Contaminated condensate drains
3. Containment design shall conform to acceptable and appropriate containment practices based on the hazard potential.
4. The classifications for biological containment consist of four different bio-safety levels.
   a. Biosafety Level 1 (BSL1) Containment: This is typical biological research facility classification for work with low hazard agents.
      (1) Viable microorganisms not known to cause disease in healthy adults
      (2) Standard features consist of easily cleaned, impervious bench surfaces and hand wash sinks.
      (3) Contaminated liquid and solid waste shall be treated to remove biological hazards before disposal.
   b. Biosafety Level 2 (BSL2) Containment: This level is similar to biosafety level 1 except the microorganisms may pose some risk.
      (1) Equipment and work surfaces shall be wiped down with a suitable disinfectant.
      (2) All liquid wastes shall be immediately decontaminated by mixing with a suitable disinfectant.
   c. Biosafety Level 3 (BSL3) Containment: Involves organisms posing a significant risk or represents a potentially serious threat to health and safety.
      (1) Liquid waste is kept within the space or facility and steam sterilization prior to discharge or disposal.
      (2) A hand washing sink routed to sterilization shall be locate adjacent to the facility.
      (3) Vents from plumbing fixtures shall be filtered.
   d. Biosafety Level 4 (BSL4) Containment: Activities in this type of facility require a very high level of containment.
      (1) The organisms present have life threatening potential and may initiate a serious epidemic disease.
      (2) All BSL3 requirements apply plus showers shall be provided for personnel at the air lock where clothes are changed upon entry and exit.
      (3) A bio-waste treatment system shall be provided within a facility to sterilize liquid waste.

5. Liquid waste decontamination system shall be provided to collect and sterilize decontaminants in liquid waste. System components include:
   a. Sump Pit: Shall consist of a gasketed water proof cover with controls similar to those provided for a plumbing sump pump with the provisions for chemical treatment and sterilization.
   b. Kill Tank Assembly: Shall consist of a duplex tank arrangement, allowing one batch to be decontaminated while the other is filling.
      (1) Tank size shall be based on facility type however common practice is for each tank to have the capacity to contain one day's effluent plus the chemicals used for decontamination.
      (2) A fully automatic control system shall be provided to ensure that chemicals are injected in the correct amounts and for the required duration for deactivation of the bio-matter.
   c. Drainage System: The drainage system shall be closed with sealed floor drains and valved connections to equipment when not in use.
      (1) Floor drains shall have a minimum seal of 65 mm deeper than the negative difference in air pressure.
      (2) Floor drains shall be filled with a disinfectant solution when not used to eliminate the possibility of spreading organisms between different areas served by the same connected sections of the piping system.
      (3) Drainage pipe material shall be based on the expected chemical composition of the effluent and the sterilization method.
      (4) Treated discharge from a containment system shall be piped completely separate from the sanitary piping until it reaches the exterior of the facility. Prior to connecting to the sanitary drainage system, the treated discharge shall be provided with a monitoring system and sampling port.

3.5.7 Backflow Preventers

1. Building backflow preventers shall conform and be provided in accordance with the requirements of the Saudi Building Code Sanitary Requirements (SBC 701), Section for Water Supply and Distribution.
2. The potable water system shall be designed to prevent contamination from non-potable liquids, solids, or gases being introduced into the potable water system supply through cross contamination.
3. Refer to the project specification for plumbing piping specialties.
4. Backflow preventers shall be "Lead Free" and selected based on degree of hazard.
   a. Reduced pressure backflow (RPZ) preventer for high and low hazard applications:
      (1) Shall conform to ASSE 1013; AWWA C511-92, NSF 61, and be certified for continuous application.
      (2) Shall be provided with non-rising stem shut off valves on inlet and outlet; test cocks; and pressure-differential relief valve with air-gap fitting located between two positive-seating check valves.
   b. Dual Check backflow preventer for low hazard applications:
      (1) Shall conform to ASSE 1012, ASSE 1024, NSF 61 and be certified for continuous pressure application.
      (2) Shall be provided with inlet screen, two independent check valves, and intermediate atmospheric vent.
5. Clearances
   a. Location of backflow preventers shall be designed not to require platforms, ladders, or lifts to access. Adequate clearances from floors, ceilings and walls is as follows:

(1) Backflow assemblies shall be designed with a centerline height from 760 mm to 1525 mm above the floor.

(2) RPZ backflow assemblies shall be designed with a 460 mm minimum clearance between the bottom of the relief valve and the floor.

(3) A minimum of 300 mm of clear space shall be maintained above backflow assemblies to allow for servicing check valves and for operation of shut-off valves.

(4) A minimum of 200 mm of clearance shall be maintained from the back side of the backflow assembly to the nearest wall or obstruction.

3.5.8 Trap Seal Primer Valve

1. Refer to the project specification for plumbing piping specialties.
2. Each fixture trap shall have a liquid seal of not less than 50 mm and not more than 100 mm, or deeper for special design related to accessible fixtures.
3. Where trap seal is subject to loss by evaporation, a trap seal primer valve shall be provided.
4. Trap seal primer valves shall connect to the trap at a point above the level of the trap seal.
5. Shall conform to ASSE 1018 or ASSE 1044.

3.5.9 Water Meters

1. Refer to the projects specification for meters and gauges for plumbing piping.
2. Domestic water meters are available in four different types:
   a. Disc Meter: This type of meter shall be provided for residential and small commercial installations and is adaptable for remote readout systems
   b. Compound Meter: This type of meter shall be provided when most of the water flow is low, but flows are anticipated.
   c. Turbine Meter: This type of meter has the characteristics of a compound meter but is more suitable for systems associated with a variety of flows. This type of meter shall not be used for very low flow or in tandem with proportional type float valve for tanked system. Only with the use of altitude float valve that this type can be used.
   d. Propeller Meter: This type of meter shall be provided where low flow never occurs. This type of meter shall not be used for very low flow or in tandem with proportional type float valve for tanked system. Only with the use of altitude float valve that this type can be used.
3. Requirements
   a. Shall have capability of continuous operation up to the rated maximum flow as listed by the manufacturer without effecting accuracy or any component wear.
   b. Measuring chamber consisting of measuring element, removable housing, and electric register.
   c. Operate properly without leakage, damage, or malfunction up to a maximum working pressure at 1379 KPA.
   d. Located outside of building in a meter vault. Exact location shall be coordinated with the Entity Lead Engineer.
4. The following design criteria shall be used in selecting a water meter:
   a. Building type
   b. Minimum and maximum demand in liters per minute
   c. Water pressure available where the meter will be installed
   d. Size of building water service
   e. Pressure loss related to system piping, valves, and elevation pressure loss

f. Refer to AWWA M22 for additional guidelines

3.5.10 Pressure Gauges

1. Refer to the projects specification for "meters and gauges" for plumbing piping.
2. Pressure gauges shall be installed so as to be readable from the floor.
3. Pressure gauges shall be provided where differential pressure information is needed, such as on suction and discharge connections to pumps, at domestic water heaters, strainers, etc.
4. The gauges shall be capable of reading to approximately twice the working pressure with an accuracy +1/2 of 1 percent.
5. Shall be provided with:
   a. 115 mm diameter aluminum case with chrome slip ring, white face, with black figure gradations.
   b. High-grade shutoff cocks shall be provided between gauge and piping to permit gauge removal while system is under pressure.

3.5.11 Thermometers

1. Refer to the projects specification for meters and gages for plumbing piping.
2. Temperature gauges shall be installed so as to be readable from the floor.
3. Anticipated maximum system pressure shall fall midway of the thermometer dial.
4. Shall be provided where temperature information is needed such as at domestic water heaters, hot water systems, hot water return systems, discharge temperature of mixing valve, water service entrance, etc.
5. Shall be provided with:
   a. Shall be 225 mm scale, organic liquid filled thermometers with cast aluminum case and clear glass window, and shall read degrees Celsius.
   b. Stem shall be halfway of the pipe internal diameter and 65 mm brass extension neck. In case of small bore piping, thermometer shall be installed with the use of WYE fitting.
   c. Scale range shall be from -1°C to 85°C
   d. 2°C scale divisions

3.6 Plumbing Fixtures

3.6.1 Quantities

1. Building plumbing fixtures and quantities shall conform to the requirements of the Saudi Building Code, Sanitary Requirements (SBC 701), Section for Fixtures, Faucets and Fittings.
2. Coordinate plumbing fixture location, style, quantities, and clearance requirements with the building architect.

3.6.2 Quality

1. Plumbing fixtures shall be constructed of approved materials, with smooth, impervious surface, free from defects and concealed fouling surfaces.
2. Plumbing fixtures inclusive of shower mixers and flush valves must be able to operate at 1 bar flow pressure to reduce pump operating power. Capacity of plumbing fixtures (in liter per flush and liters per seconds) shall be the best current available in the market. Showers and faucets with aeration technology shall be selected.
3. Refer to the project specification for plumbing fixtures.

3.6.3 Type

1. Accessible plumbing facilities and fixtures shall be provided in accordance with the International Building Code, Chapter 11 - Accessibility.
2. Water Closets
   a. Flush Valve Type, wall or floor mounted:
      (1) Water closet shall be 4 LPF vitreous china with elongated bowl, siphon jet flush action, and 40 mm inlet spud.
      (2) Standard mounting height (wall mounted) shall be 380 mm from rim to floor.
      (3) ADA mounting height (wall mounted) shall be 430 mm rim to floor.
      (4) Toilet seat shall be extra heavy weight, solid plastic injection molded, elongated open front, with external stainless steel check hinges and posts.
      (5) Flush valve shall be manual or sensor operated based on building type.
   b. Flush Tank Type, floor mounted:
      (1) Water closet shall be vitreous china with tank and elongated bowl, with flushing device, trip lever, and flow control with the following flushing type and capacity:
         (a) For women's toilet – dual flush 1.9/3.6 LPF
         (b) For man's toilet with urinals – single flush 3 LPF
         (c) For man's toilet w/out urinals - dual flush 1.9/3.6 LPF
      (2) Toilet seat shall be extra heavy weight, solid plastic injection molded, elongated closed front with cover, external stainless steel check hinges and posts.
3. Bidet, Floor Mounted
   a. Bidet shall be vitreous china with flushing rim, vertical cleansing spray, integral overflow, with deck mounted controls.
4. Sink
   a. Toilet Room
      (1) Wall Hung
         (a) Vitreous china, with front over flow, self-draining deck area with contoured back and side splash shields and faucet ledge. Mounting height shall be 865 mm rim to floor.
         (b) Faucets shall be manual or sensor operated. The type of faucet shall be determined based on project type and Entity requirements.
      (2) Countertop Drop-In
         (a) Vitreous china with front over flow, self-draining deck area, and faucet ledge.
         (b) Faucets shall be manual or sensor operated. The type of faucet shall be determined based on project type and Entity requirements.
      (3) Under Countertop Mount
         (a) Vitreous china, front over flow, and unglazed rim for under countertop mount.
         (b) Faucet shall be manual or sensor operated. Type of faucet shall be determined based on project type and the Entity requirements.
   b. Kitchen
      (1) Countertop Drop In
         (a) Type 302 nickel bearing stainless steel self-rim sink. Sink shall be seamlessly drawn, with undercoated bottom. Compartment and deck shall be recessed 5 mm below outside edge of sink.

(b) Faucet shall be manual or sensor operated. Type of faucet shall be determined based on project type and Entity requirements.

(2) Under Countertop Mount

(a) Type 302 nickel bearing stainless steel. Sink shall be seamlessly drawn, with under countertop mount and under coated bottom.

(b) Faucet shall be manual or sensor operated. Type of faucet shall be determined based on project type and Entity requirements.

5. Bathtub

a. Shall be one piece recess bath with acid resisting heavy gauge porcelain enameled steel, sloped back, and patterned slip resistant bottom.

b. Shall meet the requirements of ANSI Z112.19.4M and ASTM F-462 slip resistance.

c. Shall have outside dimensions of 1524 mm long x 762 mm wide x 356 mm high.

d. Shall be provided with tempering water valve, integral volume control, built-in temperature limit stop, shower head, arm, and flange.

6. Showers

a. Rectangular Enclosure

(1) Showers shall be a molded seamless acrylic enclosure with integral soap tray.

(2) Showers shall have a backside flame spread rating of less than 30 and shall meet the requirements of ANSI Z124.2.

(3) Showers shall have outside dimensions of 1040 mm wide x 940 mm wide x 2135 mm high.

(4) Showers shall be pre-drilled and provided with:

(a) One 610 mm vertical grab bar with mounting plates

(b) One 787 mm x 381 mm wrap around grab bar with mounting plates

(c) Molded soap tray

(d) One stainless steel curtain rod with mounting plates

(e) Brass drain with stainless steel strainer

(f) A tempering water valve, integral volume control, built-in temperature limit stop, shower head, arm, and flange.

b. Square Enclosure

(1) Showers shall be a molded seamless acrylic shower enclosure with integral soap tray and fold up seat.

(2) Showers shall have a backside flame spread rating of less than 30 and shall meet the requirements of ANSI Z124.2

(3) Showers shall have inside dimensions of 915 mm x 915 mm x 2135 mm high.

(4) Enclosure shall be pre-drilled and provided with:

(a) One 610 mm vertical grab bar with mounting plates

(b) One 790 mm x 380 mm wrap around grab bar with mounting plates

(c) Molded soap tray

(d) One stainless steel curtain rod with mounting plates

(e) Brass drain with stainless steel strainer

(f) A tempering water valve, integral volume control, built-in temperature limit stop, shower head, arm, and flange.

c. Roll-In Enclosure (Handicapped)

(1) Showers shall be a molded seamless acrylic shower enclosure with integral soap tray.

(2) Showers shall have a backside flame spread rating of less than 30 and shall meet the requirements of ANSI Z124.2

(3) Showers shall have inside dimensions of 915 mm x 915 mm x 2135 mm high.

(4) Enclosure shall be pre-drilled and provided with:

(a) One 610 mm vertical grab bar with mounting plates

(b) One 790 mm x 380 mm wrap around grab bar with mounting plates

(c) Molded soap tray

(d) One fold-up seat

(e) One stainless steel curtain rod with mounting plates

(f) Brass drain with stainless steel strainer

(g) A tempering water valve, integral volume control, built-in temperature limit stop, shower head, arm, flange, and hand held shower.

7. Electric Water Coolers

a. Single (Wall Mounted)

(1) Self-contained, wall hung electric refrigerated water cooler with self-closing push bars on front and both sides

(2) Provide with stainless steel finish and stainless steel bubbler.

(3) Standard mounting height shall be 1015 mm from bubbler top to floor.

(4) ADA mounting height shall be 915 mm from bubbler top to floor.

b. Bi-Level (Wall Mounted)

(1) Self-contained, bi-level wall hung electric refrigerated water cooler with self-closing push bars on front and apron for upper unit.

(2) Provide with stainless steel finish and stainless steel bubbler.

(3) Standard mounting height shall be 1015 mm from bubbler top to floor.

(4) ADA mounting height shall be 915 mm from bubbler top to floor.

c. Single (Recessed)

(1) Self-contained, recess mounted electric refrigerated water cooler with self-closing push bars on front.

(2) Provide with stainless steel finish and stainless steel bubbler.

(3) Standard mounting height shall be 1015 mm from bubbler top to floor.

(4) ADA mounting height shall be 915 mm from bubbler top to floor.

d. Bi-Level (Recessed)

(1) Self-contained, bi-level recess mounted electric refrigerated water cooler with self-closing push bars on front and apron for upper unit.

(2) Provide with stainless steel finish and stainless steel bubbler.

(3) Standard mounting height shall be 1015 mm from bubbler top to floor.

(4) ADA mounting height shall be 915 mm from bubbler top to floor.

8. Service Sinks

a. Floor Mounted (Square)

(1) Terrazzo mop basin, 610 mm x 610 mm x 305 mm with, integral drain

(2) Provide with Service Faucet, Hose / Bracket, and Mop Hanger, stainless steel caps on all curbs, and stainless steel wall guards.

b. Floor Mounted (Rectangular)

(1) Terrazzo mop basin, 915 mm x 610 mm x 305 mm with, integral drain

(2) Provide with Service Faucet, Hose / Bracket, and Mop Hanger, stainless steel caps on all curbs, and stainless steel wall guards.

c. Wall Mounted

(1) Enameled cast iron service sink with, 610 mm x 510 mm bowl with 230 mm back splash, wall hanger, rim guard, and trap

(2) Provide with Service Faucet, Hose / Bracket, and Mop Hanger.

9. Floor Drain

a. Refer to project specification for plumbing piping specialties.

b. Toilet Room

(1) Cast iron body with bottom outlet, trap primer connection, combination membrane clamp and adjustable collar with strainer

c. Mechanical Room

(1) Cast iron body with bottom outlet, seepage pan, combination membrane clamp and cast iron slotted grate

10. Roof Drains

a. Refer to project specification for plumbing piping specialties.

b. Primary

(1) 380 mm diameter with cast iron body, roof sump receiver, under deck clamp, adjustable extension, and combination membrane flashing clamp/gravel guard

c. Secondary (Emergency)

(1) 380 mm diameter with cast iron body, roof sump receiver, under deck clamp, adjustable extension, 50 mm water dam and combination membrane flashing clamp/gravel guard

3.7 Laboratory Piping and Appurtenances

3.7.1 Materials

1. Shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.
2. Shall be selected in consideration of the environmental conditions, ease of shipment, installation and maintenance.
3. Shall meet applicable system temperature, pressure, and content requirements.
4. Shall meet the requirements of the contract.
5. Due to high ground water aggressiveness, all pipes placed below grade shall have external protection by using epoxy coating or tape wrap.

3.7.2 Installation

1. Pipe shall be installed within shafts, chases, ceiling cavities, or other accessible locations.
2. No laboratory piping shall be embedded in wall or floors.

3.7.3 Non-Potable Hot and Cold Water Piping

1. No mandated code requirements have been developed for non-potable hot and cold water piping and fittings however they shall conform one of the standards listed in the Saudi Building Code, Sanitary Requirements (SBC 701), Section for Water Supply and Distribution Systems.

2. Non-Potable Hot and Cold Water Piping

   a. Each laboratory, animal vivarium, or other critical facilities shall be provided with a dedicated non-potable hot water and non-potable cold water piping system that is isolated from the domestic water system.

   b. A non-potable laboratory water backflow preventer shall be arranged parallel with the domestic water service backflow preventers, to eliminate the cumulative pressure drop of backflow preventers in series.

   c. A non-potable hot and cold water system shall be designed for research laboratories teaching laboratories, vivariums, and other similar type buildings and spaces.

   d. The non-potable water distribution systems shall be designed and pipe sizes selected based on under peak demand and shall conform to accepted engineering trade practices and sizing.

   e. Where street water main pressure fluctuates, the building non-potable water distribution system shall be designed for the minimum pressure.

   f. Where the water pressure is not sufficient to supply the minimum pressure and quantities require for proper operation of laboratory plumbing fixtures and components, the non-potable water supply shall be supplemented with a hydro-pneumatic pressure booster system, a water pressure booster system, or an elevated water tank.

   g. Design shall include provisions for expansion and contraction in the piping systems, to prevent undue stress or strain on piping, building anchor points, and connections to equipment.

   h. Water velocities in excess of 1.5 to 2.5 m per second are not permitted inside the building.

3. Design criteria for hot water and cold water piping

   a. Determine the minimum static pressure available from the supply source.

      (1) It is essential that enough pressure is available to overcome all system pressure drop caused by friction and building height.

      (2) The water systems shall be designed based on the lowest pressure available to ensure proper operation of plumbing fixtures; Refer to the Saudi Building Code, Sanitary Requirements (SBC 701), Chapter 3 – Water Supply and Distribution Systems, Design Criteria Required Capacity At Fixture Supply Pipe Outlet Table

   b. Determine the plumbing fixture demand

      (1) When determining peak demand, Water Supply Fixture Units (WSFU) associated with each fixture type shall be used; Refer to the International Plumbing Code, Appendix E - Load Values Assigned to Fixtures Table.

      (2) The WSFU is a numerical factor that measures the load producing effect of a single plumbing fixture.

      (3) The WSFU shall then be converted into liters per minute flow rate for determining pipe sizes; Refer to the International Plumbing Code, Appendix E – Tables for Estimating Demand.

   c. Determine pipe sizes:

      (1) Based on system pressure requirements and losses

      (2) The sum of the liters per minute required for each pipe branch and main

      (3) Water flow velocities between 1.5 to 2.4 m/sec

3.7.4 Tepid (Emergency) Water Piping

1. Building hot water piping, cold water piping, and fittings shall conform to NSF 61 and one of the standards listed in the Saudi Building Code Sanitary Requirements (SBC 701), Section for Water Supply and Distribution Systems.

2. Refer to the project specification for plumbing piping.
3. Tepid water supply shall be determined as potable by the Entity.
4. Structures equipped with emergency plumbing fixtures such as emergency showers, emergency eyewashes, and / or emergency face washes shall be provided with a tepid water supply in the volume and pressure required by ANSI Z-358.1.
5. The tepid water distribution systems shall be designed and pipe sizes selected based on peak demand and shall conform to accepted engineering trade practices and sizing.
6. Design shall include provisions for expansion and contraction in the piping systems, to prevent undue stress or strain on piping, building anchor points, and connections to equipment.
7. Design criteria for tepid water piping
    a. Determine the minimum static pressure available from the supply source.
        (1) It is essential that enough pressure is available to overcome all system pressure drop caused by friction and building height.
    b. Determine the emergency plumbing fixture demand:
        (1) Emergency Showers: 75.7 lpm for 15 minutes
        (2) Emergency Eye/Face Wash: 11.4 lpm for 15 minutes
        (3) Emergency Eye Wash: 1.5 lpm for 15 minutes
    c. Determine pipe sizes:
        (1) Based on system pressure requirements and loses
        (2) The sum of the liters per minute required for each pipe branch and main
        (3) Water flow velocities between 1.5 to 2.4 m/sec

3.7.5 Laboratory Grade Water Piping

1. No mandated code requirements have been developed specifically for laboratory grade water systems however water treatment shall comply with one or more of the following, depending on the purity of the water desired:
    a. ASPE Plumbing Engineering Design Handbook, Volume 4 – Plumbing Components and Equipment, Chapter 10 – Water Treatment shall be used for the basis of design
    b. College of American Pathologists (CAP) and American Society for Testing and Materials (ASTM) reagent grade water
    c. U.S. Pharmacopeia (USP) standards for water purity
    d. Association for the Advancement of Medical Instrumentation (AAMI) standards
    e. Clinical and Laboratory Standards Institute (CLSI) standards
    f. Semiconductor Equipment and Materials International (SEMI) and ASTM electronics grade water
2. Pipe Material
    a. High purity water is very aggressive and therefore corrosive.
    b. The following are some recommended pipe materials that can be used with laboratory grade water:
        (1) Stainless Steel Tubing
        (2) Stainless Steel Pipe Type 304 and Type 316L
        (3) Polyvinyl fluoride
        (4) Polypropylene
        (5) Polyethylene

(6) Polyvinyl chloride

(7) Aluminum Type 3003

c. Design shall include:

(1) Piping in a loop and / or continuously recirculating configuration to the faucet to eliminate stagnant water conditions.

(2) Provisions for expansion and contraction in the piping systems, to prevent undue stress or strain on piping, building anchor points, and connections to equipment.

d. Determine pipe sizes:

(1) Based on system pressure requirements and loses

(2) Flow rates shall be based on 1.9 lpm per faucet and a minimum flow velocity of 1.5 m/sec.

(3) The sum of the liters per minute required for each pipe branch and main

3.7.6 Laboratory Waste and Laboratory Vent Piping

1. No mandated code requirements have been developed specifically for laboratory waste and laboratory vent systems however the ASPE Plumbing Engineering Design Handbook, Volume 3 – Special Plumbing Systems, Chapter 2 – Plumbing Design for Healthcare Facilities and the standards listed in the International Plumbing Code, Chapter 7 – Sanitary Drainage and Chapter 9 – Vents shall be used for the basis of design.
2. Refer to the project specification for plumbing piping.
3. Structures equipped with laboratory plumbing fixtures shall be connected to the laboratory waste drainage system or an entity approved disposal system.
4. Horizontal laboratory waste drainage piping shall be designed with uniform alignment at uniform slopes. The minimum velocity of flow to achieve scouring action is 0.60 m per second.
5. Laboratory waste discharging into the sanitary drainage system shall have a temperature of 60° C or less. When higher temperatures exist, an approved cooling method shall be provided.
6. Building laboratory waste that cannot discharge by gravity shall discharge into a tightly covered and vented sewage ejector from which the effluent shall be lifted and discharged into the gravity laboratory waste system by automatic pumping equipment and components.
7. Connections and changes in direction shall be designed with drainage fittings. The fittings shall not have interior ledges, shoulders, or reductions capable of retarding or obstructing flow.
8. Cleanouts

   a. Shall be indicated at every change of horizontal direction greater than 45 degrees. Where more than one change of direction occurs in a run of piping, only one cleanout is required for each 12 m of developed length of sanitary pipe.

   b. Shall be provided at the base of each laboratory waste drainage stack or riser.

   c. Refer to the project specification for plumbing piping specialties.
9. Laboratory waste drainage systems within a building shall be completely independent of the sanitary and storm drainage system.
10. Design criteria for sanitary piping:

   a. Determine the plumbing fixture demand

   (1) When determining peak drainage demand, Drainage Fixture Units (DFU) associated with each fixture type shall be used. The DFU is a numerical factor that measures the load producing effect of a single plumbing fixture; Refer to the Saudi Sanitary Drainage System Code (SBC 701), Section for Drainage Fixture Units for Fixtures and Groups Table.

   (2) Values for continuous and semi-continuous flow into the drainage system shall be computed on the basis that 0.06 liters per second is equivalent to two DFU.

b. Determine pipe sizes

(1) Each pipe branch and main shall be determined based the number of DFU's connected; Refer to Saudi Sanitary Drainage System Code (SBC 701), Section 4.10 - Building Drains and Sewers Table and Horizontal Fixture Branches and Stacks Table.

(2) Horizontal stack offsets shall be sized as required for building drains.

(3) Vertical stack offsets shall be sized for straight stacks.

11. Design criteria for vent piping;

a. The diameter of individual vents, branch vents, circuit vents, and relief vents shall be at least one half the required diameter of the drain served.

b. Vent pipes shall not be less than 30 mm in diameter.

12. Vent exceeding 12 m in developed length shall be increased by one nominal pipe size for the entire developed length of the vent pipe.

3.7.7 Laboratory Compressed Air Piping

1. No mandated code requirements have been developed specifically for compressed air systems however the Compressed Gas Association, The National Fire Protection Association Standards and ASPE Plumbing Engineering Design Handbook, Volume 3 – Special Plumbing Systems, Chapter 9 – Compressed Air Systems shall be used for the basis of design.
2. Refer to the project specification for medical and laboratory air, gas, and vacuum system.
3. The laboratory compressed air system shall be controlled, regulated, and sized to ensure that an adequate volume of air, at a pressure and purity to satisfy user requirements, is delivered during peak demand.
4. The entire laboratory compressed air system, including but not limited to air dryer, pre-filters, after filters, controls etc. shall be mounted on a single heavy-duty structural steel support frame.
5. Design criteria for laboratory compressed air piping:

a. Identify each process, work station, or piece of equipment requiring compressed air.

b. Determine the volume of air and pressure required for each location.

c. Determine the condition requirements for each location, such as the allowable moisture content, particulate size, and oil content.

d. Determine how much time the individual tool or process will be in actual use for a one minute period of time (duty cycle).

(1) To determine the duty cycle, the user should be consulted, they are the only authority capable of providing the length of time an individual tool is in use.

e. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).

(1) It may be difficult to accurately determine the simultaneous use factor so sufficient receiver capacity or larger compressor capacity must be provided to allow for variances in use.

f. Determine the extent of allowable leakage.

(1) Leakage is a function of the number of connections to the system and the quality of the pipe assembly.

(2) Many smaller tools and operations will generally have a greater leakage than a few larger ones.

(3) Leakage rates

(a) A well-maintained system may have a leakage rate of approximately 2 to 5 percent.

(b) A typical system may have a leakage rate of approximately 10 percent.

(c) A poorly maintained system may have a leakage rate of approximately 25 percent.

g. Determine an allowance for future expansion.

h. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).

i. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).

j. Select the laboratory air compressor type, conditioning equipment, equipment location, and air inlet, making sure that cubic meters / minute, liters / minute, or liters / second is consistently used for both the system and laboratory compressor capacity rating.

(1) Systems are typically sized based on no more than three starts per hour.

(2) Quantity of compressors shall be determined based on a project basis however the minimum shall be a duplex system.

6. Pipe sizing shall be determined based on the more stringent of the following:

a. Maximum of 7 kPa pressure drop per 30 m

b. Maximum friction loss to the furthest outlet of 35 kPa

7. Minimum pipe sizes; Exact pipe sizes shall be determined based on project requirement:

a. 15 mm for single connections on branch piping

b. 20 mm for multiple connections on branch piping

c. 25 mm for main piping

3.7.8 Laboratory Vacuum Piping

1. No mandated code requirements have been developed specifically for laboratory vacuum systems however ASPE Plumbing Engineering Design Handbook, Volume 2 – Plumbing Systems, Chapter 10 – Vacuum Systems shall be used for the basis of design.

2. Refer to project specification for medical and laboratory air, gas, and vacuum system.

3. The laboratory vacuum system shall be controlled, regulated, and sized to ensure that an adequate vacuum is provided during peak demand.

4. The entire laboratory vacuum system shall be mounted on a single heavy-duty structural steel support frame.

5. Design criteria for vacuum piping

a. Identify each process, work station or piece of equipment requiring vacuum.

b. Determine the laboratory vacuum required for each location.

(1) Total connected load based on cubic meter per minute of every device requiring vacuum in the building.

c. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).

(1) It is difficult to accurately determine a simultaneous use factor so sufficient receiver capacity must be provided to allow for variances in use.

d. Determine an allowance for future expansion.

e. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).

f. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).

g. Select the meter, regulator, equipment, equipment location, and components, based on the equivalent length and total cubic meters per hour demand.

(1) Systems are typically sized based on no more than three starts per hour.

(2) Quantity of vacuum pumps shall be determined based on a project basis however the minimum shall be a duplex system.

6. Cleanouts shall be strategically located throughout the piping system to allow for the removal of debris.

7. A properly sized, constantly working laboratory vacuum pump usually requires less maintenance than a compressor that runs intermittently.

8. Minimum pipe sizes; Exact pipe sizes shall be determined based on project requirement:

a. 20 mm for multiple connections on branch piping

b. 25 mm for main piping

3.7.9 Specialty Piping

1. The Compressed Gas Association and the National Fire Protection Association Standards shall be used for the basis of design.

2. Typically used for organic and inorganic chemistry, physics, and biological laboratories, and those used for research and development. The gases used in these types of facilities are characterized by low delivery pressure, low and intermittent volume, and high purity requirements of the specialty gas and delivery system.

3. It is extremely rare that the quantity of specialty gases for laboratory and research laboratories would justify large central systems. Specialty gas systems typically refer to point-of-use cylinder bottles, manifolds, piping, and appurtenances.

4. Specialty gases are classified in the following categories:

a. Oxidizers: These are non-flammable gases but they support combustion. No oil or grease is permitted to be used with any device associated with the use of this gas, and combustibles cannot be stored near these types of gases.

b. Inert Gases: These are gases that do not react with other materials. If released into a confined space, the will reduce the oxygen level to a point that asphyxiation could occur. The room or area where inert gases are used shall be provided with oxygen monitor and be well ventilated.

c. Flammable Gases: These are gases that when combined with air or oxidizers, will form a mixture that will burn or possibly explode if ignited. The room or area where flammable gases are used shall be well ventilated; use approved electrical devices for explosive atmospheres, and be restricted from ignition sources.

d. Corrosive Gases: These are gases that will attack the surface of rubber, metals, and will damage human tissue on contact. Protective clothing and equipment shall be used around these types of gases.

e. Toxic and Poisonous Gases: These gases will harm human tissue by contact or ingestion. Protective clothing and equipment shall be used around these types of gases.

f. Pyrophoric Gases: These gases spontaneously ignite upon contact with air under normal conditions.

g. Cryogenic Gases: These gases are stored as extremely cold liquids under moderate pressure and are vaporized when used. Protective clothing and equipment shall be used around these types of gases.

5. There are numerous grades of pure and mixed gases. The end user shall be consulted for the maximum acceptable level of impurities permissible base on the type of instrument used and the analytical work being performed.

6. Design criteria for laboratory compressed air piping:

a. Identify each process, work station, or piece of equipment requiring type of specialty gas.

b. Determine the quantity and grade of specialty gas required for each location.

c. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).

d. Determine an allowance for future expansion.

e. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).

f. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).

g. Select the specialty gas, manifold, controls, and appurtenances.

7. Pipe sizing shall be determined based on the more stringent of the following:

   a. Maximum of 7 kPa pressure drop per 30 m

   b. Maximum friction loss to the furthest outlet of 35 kPa

8. Minimum pipe sizes; Exact pipe sizes shall be determined based on project requirement:

   a. 15 mm for single connections on branch piping

   b. 20 mm for multiple connections on branch piping

   c. 25 mm for main piping

3.8 Laboratory Equipment and Appurtenances

3.8.1 Tepid (Emergency) Water Mixing Valve

1. Tepid (emergency) water mixing valve shall meet ANSI Standard Z358.1 and shall be capable of providing a minimum of:

   a. 75.5 lpm for of water for 15 minutes at 18° - 35° C to serve an emergency showers

   b. 11.4 lpm of water for 15 minutes at 18° - 35° C to serve an emergency eye / face washes

   c. 1.5 lpm of water for 15 minutes at 18° - 35° C to serve an emergency eyewash

2. Tepid (emergency) water mixing valve shall employ two fully independent control mechanisms which split the water flow in half, blend each half to the design temperature and then integrates each stream at the outlet. The valve shall control outlet temperature over a wide range of flow and shall be suitable for deluge emergency showers and/or emergency eyewashes applications.

3. Tepid (emergency) water mixing valve shall include three thermometers to measure the temperature of each stream and the merged flow. Temperature adjustment shall be vandal resistant.

4. Each independent control mechanism shall employ a liquid-filled thermostatic motor to drive the valve. Each control mechanism shall employ a stainless steel sliding piston control device with reverse seat closure and both fixed and variable cold water bypass.

5. In the event that one liquid motor fails, the control mechanism shall close off the hot water port with the reverse seat and shall fully open the internal variable bypass to allow cold water flow. The other control mechanism shall be unaffected by the failure and shall maintain design temperature.

3.8.2 Laboratory Neutralization Tanks

1. Corrosive liquids, spent acids or other harmful chemicals that will destroy or compromise the sanitary drainage system, create noxious or toxic fumes, or interfere with the sewage treatment process shall not discharge into the sanitary drainage system without being thoroughly diluted, neutralized, or treated by passing through a neutralization tank.

2. Refer to project specification for plumbing equipment.

3. Neutralization requirements shall be determined based on the chemical properties being discharged.
4. Laboratory waste neutralization can be accomplished utilizing:
   a. Dilution - The mixing of chemical waste with water in order to stabilize the laboratory waste prior to discharge into the sanitary drainage system.
   b. Limestone - Laboratory waste is drained through a neutralization tank filled with high purity limestone.
   c. Chemical Dosing - Laboratory waste is drained through a neutralization tank that is injected with sodium hydroxide solution to automatically raise the pH when required and sulfuric acid solution to automatically lower the pH when required.
   d. Design Criteria:
      (1) Maintain an effluent pH downstream of the neutralization system between 5.5 and 8.5.
      (2) Neutralization tank size shall be determined by the quantity and type of laboratory fixtures connected to the neutralization system.
      (3) Neutralization tank shall have a minimum dwell time of 2-1/2 to 3 hours.

3.8.3 Laboratory Grade Water Systems

1. Refer to project specification for plumbing equipment.
2. The degree of water purity required for a building depends on the intended use of the water. There are primarily four grades of laboratory water typically used in most hospitals, clinical laboratories, research laboratories, teaching laboratories, and industrial type buildings.
   a. Type I Reagent Water (Ultrapure): Used when maximum accuracy and precision are required. The grade water is produced by distillation of supply water with a maximum resistivity of 0.05 megohm-cm at 25° C Followed by polishing with a mixed-bed ion exchange system to 16.7 megohm-cm and 0.2-um filter.
   b. Type II Reagent Water: Used for all procedures requiring organic-free, sterilized, pyrogen-free water. The grade of water is produced by distillation through the use of a still designed with special baffling and degassing features or by double distillation to produce water with a resistivity greater than 1.0 megohm-cm at 25° C.
   c. Type III Reagent Water: Used for general laboratory purposes, including the preparation of solutions, routine quality control tests, washing and rinsing of laboratory glassware. This grade is produced by ion exchange, distillation, or reverse osmosis followed by polishing with 0.45-um membrane filter.
   d. Type IV Reagent Water: Used when large amounts of moderate-purity water are required, particularly in the preparation of test solutions for wash test or ion exchange resin evaluation. This grade is produced by ion exchange, distillation, reverse osmosis or electro dialysis.
3. Water treatment process consists of three primary type of systems:
   a. Ion Exchange (Deionization / Demineralization): Removes impurities by passing water through synthetic resins which have an affinity for dissolved ionized salts and gases.
      (1) This type of system will not remove bacteria, pyrogens, particulates, or dissolved organic compounds.
      (2) Can generate a 15 – 18 megohm-cm purity
      (3) Requires regeneration with sulfuric acid and caustic
   b. Distillation: Removes impurities from water by converting a liquid to a gas and then recondensing it as distilled water.
      (1) This type of system removes pyrogens, bacteria and viruses except dissolved ionized gases.

(2) Can generate 1 – 800,000 megohm-cm purity if the system supply water has been pretreated.

c. Reverse Osmosis: Utilizes hydraulic pressure to force pure water through a membrane and is usually used in water with high TDS.

(1) This type of system removes some bacteria, pryrogens and viruses but will not remove dissolved ionized gases.

4. Design Criteria

a. Ion Exchange (Deionization / Demineralization) System

(1) Confirm the capacity of the floor drain that will be receiving the backwash from the demineralization. Backwash rates are typically several times higher than the demineralizer flow rate.

(2) The equipment shall be completely automatic.

(3) If specific demand requirements are not available for the project, demineralizer equipment, components, and appurtenances shall be sized based on:

(a) Assume 2 – 3.8 lpd per student station for classroom laboratories. Assume two classes per day if exact number of uses is not known.

(b) Assume 3.8 – 5.6 lpd per person for non-classroom laboratories.

(c) Assume 19 lpd for classroom preparation room pipette washers.

(d) Assume 95 lpd for pipette washers.

(e) Add feeding still and glass-washer demand to total based on manufacturer requirements.

b. Distillation System

(1) If specific demand requirements are not available for the project, distillation tanks, equipment, components, and appurtenances shall be sized based on

(a) Assume two people per 3 m x 6 m module.

(b) Assume 2- 3.8 lpd per person plus 50% for future.

(c) Assume 3.8 - 5.6 lpd per person for non-classroom laboratories.

(d) Assume 170 lph for each glass-washer or 606 lpd.

c. Reverse Osmosis System

(1) Confirm the capacity of the floor drain that will be receiving the backwash from the reverse osmosis filters. Backwash rates are typically several times higher than the demineralizer flow rate.

(2) The equipment shall be completely automatic.

(3) If specific demand requirements are not available for the project, reverse osmosis equipment, components, and appurtenances shall be sized based on

(a) Assume 2 - 3.8 lpd per student station for classroom laboratories. Assume two classes per day if exact number of users is not known.

(b) Assume 3.8 - 5.6 lpd per person for non-classroom laboratories.

(c) Assume 19 lpd for classroom preparation room pipette washers.

(d) Assume 95 lpd for pipette washers.

(e) Add feeding still and glass-washer demand to total based on manufacturer requirements.

3.8.4 Laboratory Compressed Air System

1. Refer to project specification for medical and laboratory air, gas, and vacuum systems.

2. There are two general categories of air compressors:
    a. Positive displacement: Operates at a constant volume and are capable of operating over a wide range of discharge pressures at a relatively constant capacity
    b. Dynamic: Operates over a wide range of capacities at a relatively constant speed.
3. Compressor Types
    a. Reciprocating: This type of compressor is recommended where the potential for a trace of oil in the discharge air is not a problem however "oil free" compressors are manufactured.
    b. Sliding Vane: This type is recommended where low capacity is required in the range of 2832 lpm to 517 lpm.
    c. Liquid Ring: This type is recommended for hospital and laboratory use.
    d. Straight Lobe: This type of compressor is available as "oil free" and are recommended for pressures up to 1379 kPa and 4285 lpm
    e. Rotary Screw: This type of compressor produce pulse free air and are available for pressures from 1304 – 2068 kPa and 8496 lpm.
    f. Centrifugal: This type of compressor produces large volumes of air at relatively low pressures. Higher pressures can be attained by adding stages with intercooling between stages.
4. Compressor Accessories (when provided)
    a. Silencers: There are two types of silencers
        (1) Reactive: This type of silencer shall attenuate low frequency sound in order of 500 hertz and are most often used with reciprocating compressors
        (2) Absorptive: This type of silencer shall attenuate higher frequency sound above 500 hertz and are most often used with screw and centrifugal compressors
    b. After-coolers
        (1) Shall lower temperature of compressed air immediately after leaving the compressor.
            (a) The discharge air temperature shall be provided between 21.1°C and 43°C.
            (b) The primary reason to lower the discharge air temperature is to remove moisture that would otherwise condense elsewhere in the piping system
            (c) Select the after-cooler based on pressure drop through the unit, space, and clearance requirements for maintenance.
    c. Filters
        (1) Filters shall remove or reduce impurities or contaminants in the air stream to an acceptable or predetermined level.
        (2) Filters can consist of:
            (a) Inlet filters: Shall remove large amounts of contaminants and particles from the inlet of the compressor.
            (b) Pre-filters: Shall remove contaminants and particles from the inlet of a dryer.
            (c) After-filters: Shall be placed after the dryer to remove contaminants and particles that the pre-filter was not able to remove.
            (d) Point-of-Use filters: Shall be placed immediately prior to the tool or individual piece of equipment that requires removal of particulates, oil, or moisture to a greater extent than was done by the after-filter.
    d. Separators
        (1) Shall remove large quantities of liquid water or oil from the air steam.
        (2) Shall be located downstream of the air compressor and after cooler.
    e. Compressed Air Dryers

(1) Are provided to remove water vapor from the air steam.

(2) There are five categories of dryers:

(a) High pressurization of the compressed air: Reduces the quantity of water vapor by compressing air to pressure greater than those required for actual use.

(b) Condensation: Lowers the temperature of the air stream through a heat exchanger to produce a lower dew point.

(c) Absorption: Uses either a solid or liquid medium and operate when the airstream containing water vapor passes through or over a deliquescent material.

(d) Adsorption: Uses a porous, non-consumable material that causes water vapor to condense as a very thin film on the desiccant materials surface.

(e) Heat of compression: Uses a desiccant to absorb the moisture in the compressed airstream.

(3) The most important requirement in the selection of a dryer is to determine the lowest required temperature dew point for the intended application.

(a) Refrigerated dryers shall be provided for dew point temperatures down to 4°C.

(b) Desiccant dryers shall be provided for dew point temperatures 3°C and below.

f. Receivers

(1) Air receivers shall be provided for

(a) Storage of air

(b) Equalization of the pressure variations (pulsations)

(c) Collection of residual condensate

(d) Reduction of compressor cycling / run time

(2) Determination of need for a receiver shall be based on the type of regulation the system uses.

g. The compressed air system shall be provided with an air intake that extends to the exterior of the building.

3.8.5 Laboratory Vacuum System

1. Vacuum Types (two most commonly used)
   a. Liquid Ring: This type is recommended for hospital and laboratory use.
   b. Sliding Vane: This type is recommended where low capacity is required.
2. The vacuum system shall consist of:
   a. Two or more pumps designed to operate as system requires
   b. A receiver to provide a vacuum reservoir to separate liquids from the air stream.
   c. Interconnect piping and alarms.
3. Laboratory vacuum typically serves general chemical, biological, and physics laboratories for the purposes of drying, filtering, fluid transfer, and evacuating air from apparatuses.
   a. Standard vacuum system working pressure is typically in the range of 40.6 kPa to 67.7 kPa.
   b. High vacuum working pressure is typically in the range of 81.3 kPa to 98.2 kPa.
4. The vacuum pump system shall be provided with an exhaust pipe that extends to exterior of the building.

3.8.6 Laboratory Nitrogen System

1. Nitrogen is an inert, colorless, and tasteless gas used primarily to control the atmosphere for high sensitive equipment and procedures.
2. Nitrogen gas shall be provided to control oxygen levels, humidity, and temperature in laboratory equipment and tests.
3. Nitrogen supply shall be provided through either point-of-use:
   a. Nitrogen cylinders: Available in various sizes and pressure ratings.
      (1) A manifold with regulators, shut off valves, gauges, pig tails, interconnect piping, and appurtenances shall be provided when connecting multiple cylinders together to meet the demand requirement.
      (2) When intermittent demand is low, a single cylinder shall be provided.
   b. Nitrogen generator: The generating units have their own filters and purifiers that generate high purity nitrogen.
      (1) Shall be provided where the installation of cylinders is inconvenient and the change out will cause disruption of continuing work and / or experiments.
      (2) Typically, these units provide pressures around 415 kPa and flow rates up to 300 cc/min.

3.9 Medical Piping and Appurtenances

3.9.1 Materials

1. Shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.
2. Shall be selected in consideration of the environmental conditions, ease of shipment, installation and maintenance.
3. Shall meet applicable system temperature, pressure, and content requirements.
4. Shall meet the requirements of the contract.
5. Due to high ground water aggressiveness, all pipes placed below grade shall have external protection by using epoxy coating or tape wrap.

3.9.2 Installation

1. Pipe shall be installed within shafts, chases, ceiling cavities, or other accessible locations.
2. No piping shall be in-bedded in wall or floors.

3.9.3 Nitrous Oxide Piping

1. No mandated code requirements have been developed specifically for nitrous oxide systems however the National Fire Protection Association Standard 99 and ASPE Plumbing Engineering Design Handbook, Volume 3 – Special Plumbing Systems, Chapter 10 – Plumbing Design for Healthcare Facilities shall be used for the basis of design.
2. Refer to project specification for medical and laboratory air, gas, and vacuum systems.
3. The nitrous oxide system shall be controlled, regulated, and sized to ensure that an adequate volume of nitrous oxide, at a pressure and purity to satisfy user requirements, is delivered during peak demand.
4. Design criteria for nitrous oxide piping:
   a. Determine the volume of nitrous oxide and pressure required for each outlet. If a specific flow is not requested, typically 0.28 lpm is assigned to each outlet.

b. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).

c. Determine an allowance for future expansion.

d. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).

e. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).

5. Pipe sizing shall be determined based on the more stringent of the following:

   a. Maximum friction loss of 6.90 kPa per 30 m

   b. Maximum friction loss to the furthest outlet of 35 kPa

6. Minimum pipe sizes; Exact pipe sizes shall be determined based on project requirement:

   a. 15 mm for single connections on branch piping

   b. 20 mm for multiple connections on branch piping

   c. 25 mm for main piping

3.9.4 Carbon Dioxide Piping

1. No mandated code requirements have been developed specifically for carbon dioxide systems however the National Fire Protection Association Standard 99 and ASPE Plumbing Engineering Design Handbook, Volume 3 – Special Plumbing Systems, Chapter 10 – Plumbing Design for Healthcare Facilities shall be used for the basis of design.

2. Refer to project specification for medical and laboratory air, gas, and vacuum systems.

3. The carbon dioxide system shall be controlled, regulated, and sized to ensure that an adequate volume of carbon dioxide, at a pressure and purity to satisfy user requirements, is delivered during peak demand.

4. Design criteria for carbon oxide piping:

   a. Determine the volume of carbon dioxide and pressure required for each outlet. If a specific flow is not requested, typically 28 lpm is assigned to each outlet.

   b. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).

   c. Determine an allowance for future expansion.

   d. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).

   e. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).

5. Pipe sizing shall be determined based on the more stringent of the following:

   a. Maximum friction loss of 6.90 kPa per 30 m

   b. Maximum friction loss to the furthest outlet of 35 kPa

6. Minimum pipe sizes; Exact pipe sizes shall be determined based on project requirement:

   a. 10 mm for single connections on branch piping

   b. 20 mm for multiple connections on branch piping

   c. 25 mm for main piping

3.9.5 Oxygen Piping

1. No mandated code requirements have been developed specifically for oxygen systems however the National Fire Protection Association Standard 99 and ASPE Plumbing Engineering Design Handbook, Volume 3 – Special Plumbing Systems, Chapter 10 – Plumbing Design for Healthcare Facilities shall be used for the basis of design.
2. Refer to project specification for medical and laboratory air, gas, and vacuum systems.
3. Oxygen main control valves shall be integrated with the building Fire Detection and Alarm System.
4. The oxygen system shall be controlled, regulated, and sized to ensure that an adequate volume of oxygen, at a pressure and purity to satisfy user requirements, is delivered during peak demand.
5. Design criteria for oxygen piping:
   a. Determine the volume of oxygen and pressure required for each outlet. If a specific flow is not requested, typically 28 lpm is assigned to each outlet.
   b. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).
   c. Determine an allowance for future expansion.
   d. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).
   e. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).
6. Pipe sizing shall be determined based on the more stringent of the following:
   a. Maximum friction loss of 6.90 kPa per 30 m
   b. Maximum friction loss to the furthest outlet of 35 kPa
7. Minimum pipe sizes; Exact pipe sizes shall be determined based on project requirement:
   a. 10 mm for single connections on branch piping
   b. 20 mm for multiple connections on branch piping.
   c. 25 mm for main piping.

3.9.6 Medical Air Piping

1. No mandated code requirements have been developed specifically for medical air systems however the National Fire Protection Association Standard 99 and ASPE Plumbing Engineering Design Handbook, Volume 3 – Special Plumbing Systems, Chapter 10 – Plumbing Design for Healthcare Facilities shall be used for the basis of design.
2. Refer to project specification for medical and laboratory air, gas, and vacuum systems.
3. The medical air system shall be controlled, regulated, and sized to ensure that an adequate volume of medical air, at a pressure and purity to satisfy user requirements, is delivered during peak demand.
4. Design criteria for medical air piping:
   a. Determine the volume of medical air and pressure required for each outlet. If a specific flow is not requested, typically 28 lpm is assigned to each outlet.
   b. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).
   c. Determine an allowance for future expansion.
   d. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).

e. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).

5. Pipe sizing shall be determined based on the more stringent of the following:
   a. Maximum friction loss of 6.90 kPa per 30 m
   b. Maximum friction loss to the furthest outlet of 35 kPa
6. Minimum pipe sizes; Exact pipe sizes shall be determined based on project requirement:
   a. 10 mm for single connections on branch piping
   b. 20 mm for multiple connections on branch piping
   c. 25 mm for main piping.

3.9.7 Medical Vacuum Piping

1. No mandated code requirements have been developed specifically for medical air systems however the National Fire Protection Association Standard 99 and ASPE Plumbing Engineering Design Handbook, Volume 3 – Special Plumbing Systems, Chapter 10 – Plumbing Design for Healthcare Facilities shall be used for the basis of design.
2. Refer to project specification for medical and laboratory air, gas, and vacuum systems.
3. The medical vacuum system shall be controlled, regulated, and sized to ensure that an adequate volume of medical air, at a pressure and purity to satisfy user requirements, is delivered during peak demand.
4. Design criteria for medical vacuum piping:
   a. Determine the volume of medical vacuum required for each outlet. If a specific flow is not requested, typically 50 lpm is assigned to each outlet.
   b. Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).
   c. Determine an allowance for future expansion.
   d. Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).
   e. Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).
5. Cleanouts shall be strategically located throughout the piping system to allow for the removal of debris.
6. Minimum pipe sizes; Exact pipe sizes shall be determined based on project requirement:
   a. 20 mm for multiple connections on branch piping
   b. 25 mm for main piping

3.9.8 Specialty Systems Piping

1. Waste Anesthesia Gas Disposal Piping
   a. No mandated code requirements have been developed specifically for waste anesthesia gas disposal systems however the National Fire Protection Association Standard 99 and ASPE Plumbing Engineering Design Handbook, Volume 3 – Special Plumbing Systems, Chapter 10 – Plumbing Design for Healthcare Facilities shall be used for the basis of design.
   b. Refer to project specification for medical and laboratory air, gas, and vacuum systems.

c. The waste anesthesia gas disposal system shall be controlled, regulated, and sized to ensure that an adequate volume of medical air, at a pressure and purity to satisfy user requirements, is delivered during peak demand.

d. Design criteria for waste anesthesia gas disposal piping:

(1) Determine the volume of medical vacuum required for each outlet. If a specific flow is not requested, typically 50 lpm is assigned to each outlet.

(2) Determine maximum number of locations that may be used simultaneously on each branch and main (use factor).

(3) Determine an allowance for future expansion.

(4) Determine the developed length of pipe (The length of pipe measured along the centerline of the pipe and fittings).

(5) Determine the equivalent length of pipe (The length of pipe of a specific diameter that would produce the same frictional resistance of a particular pipe or line comprised of pipe and fittings).

e. Minimum pipe sizes; Exact pipe sizes shall be determined based on project requirement:

(1) 20 mm for multiple connections on branch piping

(2) 25 mm for main piping

3.10 Safety Equipment

3.10.1 Eyewashes

1. Shall be provided:
   a. Within 10 seconds travel distance (approximately 17 m) of hazard
   b. On the same level as the hazard and with no obstructed path
   c. With “hands-free” stay-open valve that activates in one second or less
2. Unit must provide a minimum of 1.5 liters of tepid water per minute for 15 minutes.

3.10.2 Emergency Showers

1. Shall be provided:
   a. Within 10 seconds travel distance (approximately 17 m) of hazard
   b. On the same level as the hazard and with no obstructed path
   c. With “hands-free” stay-open valve activates in one second or less
2. Unit must provide a minimum of 75.5 liters of tepid water per minute for 15 minutes.
3. Shower shall be installed between 2083 mm and 2438 mm above floor.

3.11 Vibration Control

3.11.1 General

1. Provisions shall be made to control equipment induced vibration.
2. The use of vibration isolators between equipment and foundations and/or building structures shall be required to minimize transmitted vibration.
3. Effective vibration control is required to reduce noise transmission through the piping systems. Machines, equipment, and components shall be provided with vibration and shock mounting through the use of:
   a. Compressed Cork

(1) Typically manufactured of pure granules of cork without any foreign binder that is compressed and baked under pressure with accurately controlled density.

(2) Compressed cork is typically used for floor slab isolation.

b. Elastomers and Neoprene Rubber

(1) Has very good sound isolation characteristics and is acceptable for low frequency shock absorption and is useful as vibration isolators for frequencies above 1,200 cpm

(2) Molded elastomer mountings are generally only used for light and medium weight machines.

c. Steel Spring Isolators

(1) Steel spring isolators provide the most efficient method of isolating vibration and shock.

(2) Steel spring isolation can provide deflection up to 255 mm.

(3) Rubber spring sound isolation pads shall be provided under spring isolators to prevent high frequency noise transmission into the floor or other critical installations.

4. Refer to and incorporate the basic design techniques as described in ASHRAE Applications Handbook, Sound and Vibration Control.

3.11.2 Design Objective

1. All vibrating, reciprocating, or rotating equipment shall be mounted such that it does not transmit significant levels of vibration into the surrounding or supporting structure.
2. Provide vibration isolation for all attachments to a vibrating machine, including structural mounts, cooling or drainage pipe connections, exhaust air ductwork, and electrical connections, etc.
3. It is very important that equipment operating frequencies be isolated from natural frequencies of the building.
4. Ensure that the supporting structure has sufficient stiffness and mass.
5. Where it might be impractical or too expensive to meet the design criteria, then sound engineering judgment shall be applied to limit noise and vibration effect on building occupants and to protect the equipment.

3.11.3 Vibration Criteria

1. Design Criteria shall be as per ASHRAE Fundamentals and Applications Handbook, recommended acceptable vibration criteria for vibration in a building structure.
2. Vibration Isolators Selection

   a. Vibration isolators must be selected not only to provide required isolation efficiency but also to compensate for floor stiffness.

3.11.4 Vibration Isolators

1. Vibration isolation mounts shall be used for the support of mechanical or vibrating equipment.
2. Isolators shall be specified by type and by deflection, not by isolation efficiency.
3. See ASHRAE Fundamentals for Selection of Vibration Isolators and ASHRAE Application Handbook for types and minimum deflections.
4. All vibration isolators shall be selected in accordance with ASHRAE and manufacturer's recommendations.
5. Isolation performance shall be within the responsibility of the equipment supplier.

3.11.5 Piping Hangers and Isolation

1. Isolation hangers shall be used for all piping in mechanical rooms and adjacent spaces, up to a 15.2 m distance from vibrating equipment.
2. The pipe hangers closest to the equipment shall have the same deflection characteristics as the equipment isolators.
3. Other hangers shall be spring hangers with 19 mm deflection. Positioning hangers shall be specified for all piping 200 mm and larger throughout the building.
4. Spring and rubber isolators are recommended for piping 50 mm and larger hung below noise sensitive spaces.
5. Floor supports for piping may be designed with spring mounts or rubber pad mounts.
6. For pipes subject to large amounts of thermal movement, plates of Teflon or graphite shall be installed above the isolator to permit horizontal sliding.
7. Anchors and guides for vertical pipe risers usually must be attached rigidly to the structure to control pipe movement.
8. Flexible pipe connectors shall be designed into the piping before it reaches the riser.

3.11.6 Piping Supports

1. Provide channel supports for multiple pipes and heavy duty steel trapezes to support multiple pipes.
2. Hanger and support schedule shall have manufacturer's number, type and location.
3. Comply with MSS SP69 for pipe hanger selections.
4. Spring hangers and supports shall be provided in all the mechanical rooms.

3.11.7 Mechanical Equipment Isolation

1. Floating isolation bases shall be considered for major mechanical equipment located in critical areas.

3.11.8 Concrete Inertia Bases

1. Inertia bases shall be provided for all pumps and other equipment installed in suspended slabs. Equipment installed in ground slabs generally do not require inertia bases since the natural frequency are low and the ratio of the disturbing frequency to the slab natural frequency is higher than 3.5. Inertia bases shall only be required for ground slab installed equipment if the ratio is below 3.5.

3.11.9 Mechanical Shafts and Chases

1. Mechanical shafts and chases shall be continuous and closed at the top and bottom.
2. Any piping and ductwork shall be isolated as it enters the shaft to prevent propagation of vibration to the building structure.
3. All openings for piping must be sealed.

3.12 Condensate Drainage and Collection Systems

1. Cooling coil condensate drain shall be generally provided with traps to (1) avoid foul smell from the drainage system to enter the air handling equipment, and (2) to provide water seal to ensure continuous flow of condensate due to fan static head.
2. Draw-thru cooling equipment condensate drain shall be provided with traps if continuous condensate is anticipated, otherwise provide suitable check valve installed with sufficient head to overcome design fan static head (for low ambient %RH application).

3. For project pursuing LEED credits or non-LEED project pursuing energy and water optimization, condensates from cooling coil shall be provided with separate drain and shall be collected via condensate tank. Coldness of condensate can be recovered using heat exchangers for applicable cooling system with higher temperature requirements (such as radiant cooling where chilled water supply and return temperature can be 15°C and 18°C respectively, or higher) before using to other non-potable water use (such as irrigation system, gray water for plumbing fixture flushing, or evaporative cooling).
4. Refer to Mechanical Design Guideline Chapter 4.0, HVAC.

3.13 Specialty Plumbing Systems

3.13.1 Water Hammer Arrester

1. Shall be provided on water distribution systems to reduce water flow velocities immediately adjacent to equipment and where quick-closing valves are installed
    a. Water hammer arrestors for piping serving equipment shall be provided within a few meters of the equipment isolation valve
    b. The location of the water hammer arrestor associated with plumbing fixtures shall be determined based on the start of the horizontal branch pipe to the last plumbing fixture on that branch. If the branch pipe exceeds 6.1 m in length, an additional water hammer arrestor shall be provided and each water hammer arrestor shall be sized based on half of the fixture unit value.
2. Shall conform to ASSE 1010.
3. Shall be nested stainless steel bellows type contained within a sealed stainless steel chamber
4. Sizing
    a. Obtain the total number of fixture units on each branch pipe. This information is then applied to manufacturer sizing charts to determine the required size.
    b. When water pressure exceeds 448 kPa, select the next larger size water hammer arrestor.
    c. If the fixture unit value total includes a decimal, the number shall be rounded up to the next largest whole number.
    d. Flow velocities shall not exceed 2.5 m/sec.

3.13.2 Strainers

1. Strainers shall be provided on the incoming building water service to protect the check valves of the backflow preventer from fouling due to foreign matter and debris in the building water supply.
2. Shall conform to ASTM A-126 Class B.
3. Strainers shall be arranged to permit the flushing of accumulated debris and to facilitate removal and replacement of strainer screen without disconnecting from piping system.
    a. Valved dirt flush out connections for strainers shall be installed such that the valve is located 153 mm to 305 mm below the strainer.
    b. Flush out connection shall be terminated in an approved manner at a point where there shall be no risk of flooding or damage.

3.14 Valves

3.14.1 General

1. Valves shall comply with US EPA section 1417 of the Safe Drinking Water Act or equivalent local regulations for the “Reduction of Lead in Drinking Water Act”.
2. Valves shall be of same minimum working pressure and materials as specified for fittings of the system in which they are installed. Regardless of service, valves shall be designed for a minimum

PN16 pressure rating. Valve pressure rating shall be 1.5 times the anticipated system working pressure.

3. Provide shut-off valves at each plumbing fixture and / or equipment requiring plumbing service.
4. Valves shall be provided in accessible locations and so that the tops of the valve stems are above the horizontal.
5. Valves shall be provided with stem extensions when installed on insulated piping.

3.14.2 Butterfly Valve

1. Butterfly valves provide bubble-tight closure with excellent throttling characteristics. They can be used for full open, closed and throttling applications. Required when using flanged piping.
2. There are three primary body types:
   a. Wafer: Held in place between two pipe flanges
   b. Lug: Body has tapped lugs matching up to bolt circle of based on valve ~~Class 125 / 150~~ and flange pressure class.
   c. Grooved: Direct connect to pipe using iron pipe size couplings
3. Has a thin rotating disk which operates with a quarter turn from fully open to fully closed; however, the disk is always in the flow path.
4. Primary Function:
   a. Start and stop fluid flow
   b. Used either as fully open or fully closed
   c. Used for high temperatures and / or corrosive materials

3.14.3 Gate Valve

1. Gate Valves provide full flow, minimum pressure drop, minimum turbulence, and minimum fluid trapped in piping.
2. They use a wedge-shaped disk or gate as the closure member that operates perpendicular to the flow.
3. Primary Function:
   a. Start and stop fluid flow
   b. Used either as fully open or fully closed
   c. Flow can be bi-directional

3.14.4 Ball Valve

1. Ball valves are light, easily installed and provide tight closure.
2. Ball valves may have one of three primary body types:
   a. One-piece: Has no potential body leak path, but requires use of reduced port ball.
   b. Two-piece: Most commonly used ball valve that can be provided as a reduced port, standard port, or full port ball.
   c. Three-piece: Is a repairable valve that can be provided as a reduced port, standard port, or full port ball.
3. Port Sizes
   a. Reduced Port: Have more than one pipe size flow restriction and are not recommended for building service piping, have a high pressure drop, but recommended for process piping in hazardous material transfer.

b. Standard Port: Are up to one pipe size smaller than the nominal pipe size, have a better pressure drop than reduced ports, but have significantly better flow characteristics than globe valves.

c. Full Port: Have pressure drop equal to equivalent length of pipe and have better flow characteristics than gate valves.

4. Primary Function:

    a. Start and stop fluid flow

    b. Used either as fully open or fully closed

3.14.5 Check Valve

1. Check valves are designed to prevent backflow by automatically seating when the direction of fluid is reversed.
2. Automatically check or prevent the reversal of flow
3. There are three basic types of check valves:

    a. Swing Check: Has a hinged disk that swings on a hinge pin. When flow reverses, the pressure pushes the disk against the seat. This type of check valve has little resistance to flow.

    b. Lift Check: Has a guided disk that is raised from the seat by upward flow pressure. Reversal of flow pushes the disk against the seat, stopping backflow. This type of check valve has considerable resistance to flow and is suited for high pressure service.

    c. Wafer Check: manufactured in two types:

        (1) A dual flapper that is hinged on a center post

        (2) A single flapper that is hinged on a pin

        Single or double spring loaded wafer check valves are preferred type to eliminate water hammering and hydraulic shock due to the stopping and activation of pumps.

3.14.6 Plug Valve

1. A plug valve is a quarter turn valve that uses a tapered cylindrical plug that fits a body seat of corresponding shape.
2. They are manufactured in two types:

    a. Lubricated: Designed with grooves in the surface of the plug. The grooves are connected to a lubricated channel in the stem. When the grooves are filled with lubricant, a tight seal develops between the plug and valve body.

    b. Non-Lubricated: Have two basic types

        (1) Lift: Is mechanically lifted while being turned to disengage it from the seating surface.

        (2) Sleeved: Has a fluorocarbon sleeve that surrounds the plug, providing a continuous seal.

3.14.7 Balancing Valve

1. A balancing valve is a measurement and regulation device, required to balance hot water and hot water return systems.
2. The main purpose of a balancing valve is to provide a consistent flow through the hot water return system.
3. Balancing valves generally shall be bronze body, brass ball valve with differential pressure read out ports, check valve, tapped drain / purge port, memory stop, and calibrated nameplate.
4. Balancing valve for hot water are classified into three (3) types, namely:

    a. Conventional double regulating low flow valves

b. Low flow automatic balancing valves

c. Low flow temperature balancing valves

Since balancing for hot water recirculation system requires total closure of all water outlets during the course of balancing, it is always advisable to use low-flow temperature balancing valves in lieu of other methods to avoid shut-down of the system especially during retro-commissioning.

4.0 HVAC

4.1 General

4.1.1 Authority Having Jurisdiction

1. The Entity is the final Authority Having Jurisdiction (AHJ) unless specifically stated otherwise in project documents.

4.1.2 Coordination and Integration

1. The design of HVAC systems requires coordination and integration with other discipline designs such as, but not limited to, the fire alarm system related to smoke control design, the BMS for control and monitoring of various HVAC equipment and systems, the plumbing design for make-up water supply to hydronic systems and various drains, the electrical design for power to the HVAC equipment, and all physical discipline designs for space to install piping, duct, and equipment.
2. HVAC system design shall be completed in full accordance with the respective health and safety requirements established by the Kingdom of Saudi Arabia, the AHJ, and the Entity.

4.1.3 Abbreviations

1. Abbreviations in general are included in Volume 6, Chapter 2 - Definitions and References (EPM-KE0-GL-000011).
2. Abbreviations specific to this section for the design of HVAC systems appear below:

Abbreviations	Description
AAC	Advance Application Controller
ABMA	American Boiler Manufacturers Association
ACH	Air Change per Hour
A/E	Architect/Engineer
ASC	Advance Specific Controller
ADC	Air Diffusion Council
AGA	American Gas Association
AHJ	Authority Having Jurisdiction
AIA	American Institute of Architects
AIHA	American Industrial Hygiene Association
AMCA	Air Movement and Control Association
ANSI	American National Standards Institute
ARI	Air Conditioning and Refrigeration Institute
API	American Petroleum Institute
ASA	Acoustical Society of America
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BACNet	Building Automation Network
BAS	Building Automation System
BC	Building Controller
BMS	Building Management System
CAV	Constant Air Volume

Abbreviations	Description
CFD	Computational Fluid Dynamics
CHPP	Combined Heat and Power Plant
CRAC	Computer Room Air-conditioning Unit
CRAH	Computer Room Air Handling Unit
DDC	Direct Digital Controller
DOAS	Dedicated Outside Air System
DONCP	Device Object Naming Convention Plan
DPS/T	Differential Pressure Sensor/Transmitter
DX	Direct Expansion cooling unit
EMCS	Energy Management and Control System
EPA	Environmental Protection Agency
ETS	Energy Transfer Station
EUI	Energy Utilization (or Use) Index
FACP	Fire Alarm Control Panel
FDDI	Fiber Distributed Data Interface
FLS	Fire and Life Safety System
HVAC	Heating, Ventilating, and Air Conditioning
HEI	Heat Exchange Institute
HEPA Filter	High Efficiency Particulate Air Filter
I2SL	International Institute for Sustainable Labs
IBC	International Building Code
IEC	International Electric Code
IMC	International Mechanical Code
I/O Point	Input/Output Point
ISA	Instrument Society of America
Labs21	Laboratories for the 21st Century
LAN	Local Area Network
MAC Address	Media Access Control Address
MSS	Manufacturers Standardization Society of the Valves and Fittings Industry
NEBB	National Environmental Balancing Bureau
NEBS	Network Equipment Building System
NEMA	National Electrical Manufacturers Association
NIST	National Institute of Science and Technology
NFPA	National Fire Protection Association
NPSH	Net Positive Suction Head
OSHA	Occupational Safety and Health Administration
PDU	Power Distribution Unit
P&ID	Process and Instrumentation Diagram (for BMS)
PICV	Pressure Independent Control Valve
PPFA	Plastic Pipe and Fittings Association
PTAC	Packaged Terminal Air Conditioning unit
PUE	Power Usage Effectiveness
RCL	Refrigerant Concentration Limit
RH	Relative Humidity
SBC	Saudi Building Code
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SMC	Saudi Mechanical Code
SOO	Sequence of Operation (for BMS)
SSPC	Steel Structures Painting Council
SSR	Solid State Relay
TSE	Treated Sewer Effluent
UL	Underwriters Laboratories Incorporated
ULPA Filter	Ultra Low Particulate Air Filter
UMC	Uniform Mechanical Code
UPS	Uninterruptible Power Supply
VAV	Variable Air Volume
VFD	Variable Frequency Drive
VOC	Volatile Organic Compound

Abbreviations	Description
VRF	Variable Refrigerant Flow
VNI	Virtual Network Interface
VRLA Battery	Valve Regulated Lead Acid Battery
ZSCS	Zoned Smoke Control System

4.1.4 Definitions

1. Definitions in general are included in Volume 6, Chapter 2 - Definitions and References (EPM-KE0-GL-000011).
2. Definitions specific to this section for the design of HVAC systems appear below:

Definitions	Description
Atmosphere	The same as outdoors.
Concealed Exterior	Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures.
Concealed Interior	Concealed from view and protected from physical contact by building occupants.
Conditioned	Spaces directly provided with heating and cooling.
Energy Utilization Index	The measure of the total energy consumed by a building expressed as energy consumed per gross building area (kJ/M²)
Exposed, Exterior	Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions.
Exposed Interior	Exposed to view indoors (not concealed).
Finished Space	Space other than mechanical rooms, electrical rooms, furred spaces, pipe chases, unheated spaces immediately below roof, space above ceilings, unexcavated spaces, crawl spaces, tunnels, and interstitial spaces.
Furnish	Supply and deliver to project site, ready for unloading, unpacking, assembly, installation, and similar subsequent requirements.
Indoors	Located inside the exterior walls and roof of the building.
Install	Operations at project site, including unloading, unpacking, assembly, erection, placing, anchoring, applying, working to dimension, finishing, curing, protecting, cleaning, and similar requirements.
Outdoors	Located outside the exterior walls and roof of the building.
Provide	Furnish and install, complete and ready for intended use.
Unconditioned	Spaces without direct heating or cooling including ceiling plenums.

4.1.5 Codes, Standards, and References

3. Codes and standards specific to this section for the design of HVAC systems appear below:
    a. AIA Guidelines for Design and Construction of Health Care Facilities
    b. ANSI/AIHA Z9.5 – Laboratory Ventilation
    c. ASHRAE Handbook – Fundamentals
    d. ASHRAE Handbook – Refrigeration
    e. ASHRAE Handbook – HVAC Applications
    f. ASHRAE Handbook – HVAC Systems and Equipment
    g. ANSI/ASHRAE/ASHE Standard 170 – Ventilation of Health Care Facilities
    h. ASHRAE Standard 15 – Safety Standard for Mechanical Refrigeration
    i. ASHRAE Standard 34 – Designation and Safety Classification of Refrigerants
    j. ASHRAE Standard 52.2 – Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size
    k. ASHRAE Standard 62 – Ventilation for Acceptable Indoor Air Quality

l. ASHRAE Standard 62.2 – Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

m. ASHRAE Standard 90.1 – Energy Standard for Buildings Except Low Rise Residential Buildings

n. ASME Boiler and Pressure Vessel Code

o. NFPA 30 – Flammable and Combustible Liquids Code

p. NFPA 45 - Standard on Fire Protection for Laboratories Using Chemicals

q. NFPA 54 – National Fuel Gas Code

r. NFPA 70 – National Electrical Code

s. NFPA 90A – Standard for Installation of Air Conditioning and Ventilation Systems

t. NFPA 92 – Standard for Smoke Control Systems

u. NFPA 96 – Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations

v. NFPA 99 – Health Care Facilities Code

w. NFPA 101 – Life Safety Code

x. NFPA 820 – Standard for Fire Protection for Waste Water Treatment

y. Saudi Building Code

z. SBC 501 Mechanical Code

aa. SBC 601 Energy Conservation

4. Refer to Volume 6, Chapter 5 – Codes, Standards, and References (EPM-KE0-GL-000014) for a list of additional codes, standards, and references.

5. In the event of a conflict between the codes, standards, and this document, the more stringent requirement shall govern.

4.1.6 Approvals

1. The Entity shall review and approve all design reports, plans, drawings, and specifications as outline in Volume 6, Chapter 6 - Project Submission Standards and Requirements (EPM-KE0-GL-000015).

4.1.7 Design Criteria

1. Outdoor Design Criteria

   a. For Buildings:

      (1) Thermal design parameters for heating and cooling shall be in accordance with the requirements of the Saudi Energy Conservation Code (SBC 601).

   b. For air-cooled condensers

      (1) 46 º C for general location in KSA, all units must be capable to run at 50°C ambient

      (2) Refer to KSA Meteorological Data for prevailing ambient dry-bulb temperature for project location

   c. For cooling towers and evaporative condensers

      (1) 26º C wet bulb temperature maximum

      (2) Refer to KSA Meteorological Data for prevailing ambient wet-bulb temperature for project location

   d. Sun Days per year

      (1) Assume 300 sun days per year

e. Wind

(1) Assume frequent sustained and gusty winds to velocities of 18 m/s

2. Indoor Room Design Criteria

a. For commercial, religious, educational, government, health care and laboratory facilities:

(1) Cooling

(a) 24º C +/- 1 º C

(b) Refer to ASHRAE, SBC 601, and other standards for allowable %RH range

b. For retail and residential facilities:

(1) Cooling

(a) 23 º C +/- 1 º C

(b) Refer to ASHRAE,SBC 601,and other standards for allowable RH range

c. For all industrial, maintenance and service type facilities or spaces that are normally occupied:

(1) Cooling

(a) 26 º C +/- 1 º C

d. For normally unoccupied mechanical and electrical spaces:

(1) Cooling

(a) 28 º C +/- 1 º C to protect electronics that may be part of the mechanical or electrical equipment.

e. For warehouses

(1) Cooling

(a) 28 º C

f. Heating requirements – refer to Section 4.1.8.1 for heating.

3. Ventilation

a. The outdoor air ventilation rates from ASHRAE Standard 62 – Ventilation for Acceptable Indoor Air Quality shall be used for all spaces unless otherwise directed by the Entity.

b. Ventilation rates from ANSI/ASHRAE/ASHE Standard 170 – Ventilation of Health Care Facilities shall be used for design of hospital spaces.

c. Ventilation for variable air volume systems shall ensure proper ventilation rates at low and high system airflow.

d. Instrumentation and controls shall be provided to assure outdoor air intake rates are maintained during occupied hours.

e. The placement and location of outdoor air intakes are critical to the safety of the occupants inside a building and must comply with the security requirements of the building.

f. Fresh air intakes shall be designed and located to minimize dust entrainment.

g. Minimum separation distances between ventilation air intakes and other building features shall be kept as per the Saudi Building Code (SBC 501- Mechanical Requirements) for non-hospital applications and the AIA Guidelines for Design and Construction of Health Care Facilities for hospital applications.

4.1.8 Heating Load Calculations

1. General

a. Heating is not applied for buildings where application allows wide range of %RH fluctuation for a given room temperature and the anticipated RSHF (Room Sensible Heat Factor) change due to variation in solar heat load during the day and night is within the acceptable limit. Reheat is applied for the following application;

(1) For application with high latent load where %RH can exceed the maximum allowed by the Standards due to steep RSHF; such as natatoriums, dancing hall, fitness rooms, religious or prayer rooms. Reheat can be obtained through the HVAC Software.

(2) For application with minimum ACH (Air Change per Hour) requirements to compensate for overcooling; such as hospitals, laboratories, cleanrooms, medicine factories. Reheat is calculated manually through the psychrometric process.

(3) For projects with winter season where building facade construction has low thermal mass, or with higher thermal mass but cold ambient timing exceeds the façade thermal time lagging, therefore all rooms attached to the façade will require heating. Reheat requirement is obtained through the HVAC Software.

(4) For outdoor/fresh air reheat in winter season to exceed room dew point temperature avoiding condensation. Reheat can be obtained through the HVAC Software or calculated manually.

(5) For outdoor/fresh air reheat in winter season to the room adiabatic condition for not to imposed additional heating load in recirculating unit within rooms attached to the building façade with low thermal mass. Reheat requirement can be obtained through the HVAC Software or calculated manually.

b. The A/E shall provide psychrometric analysis especially for complex HVAC System to identify requirement for reheat. It is strongly advised the use of heat pipes as source of reheat simultaneously with the pre-cooling of outdoor air or recirculated-mixed air.

c. Reheat systems are prohibited except for applications meeting the exceptions listed in ASHRAE Standard 90.1 – Energy Standard for Buildings except Low-Rise Buildings.

d. Since heating and cooling load calculations are normally completed with a single computer program, the software and procedure requirements are listed below in Subsection 4.1.9– Cooling Load Calculations.

2. Heating Load Components

a. Heating load calculations shall include heat losses from outside surfaces (roofs, walls, windows, raised floors); interior non-conditioned spaces (partitions, ceilings, floors); make up air and infiltration; duct and plenum losses.

b. The heating load calculations shall be done without credit for occupants and internal gains.

4.1.9 Cooling Load Calculations

1. General

a. HVAC loads calculations must be performed with a computer-based program using the latest ASHRAE Handbook of Fundamentals and ASHRAE Load Calculation Toolkit; Heat Balance Method (HB), Radiant time Series (RTS) Method, or any ASHRAE future developed computer program.

b. Outdoor AHU off-coil condition shall rest within the adiabatic line of the room design condition to reduced required number of cooling coil rows especially during cooling requirements (summer condition).

c. Submit the final load calculations to the Entity prior to the completion of the final design phase for Entity review and acceptance.

d. The HVAC loads calculations report shall include all input and output used in the heating and cooling calculation program, and shall include zone peak heating and cooling loads results, and whole building “block” loads, air-handling unit coil selections, and psychrometric process charts.

e. Zoning for the load calculations shall match the temperature control zoning.

f. Block and zone peak loads shall be calculated.

g. Residential method shall only be used for residential application.

h. If Displacement Ventilation strategy for high volume spaces (above 3 meters ceiling height) is used for reason of energy savings and contaminant removal, where supply air diffusers are located at low level and the return/exhaust is located at ceiling level, Space Temperature Gradient for occupied control zone to be considered in the design and calculation shall not be greater than 3°C. Comfort zone height shall not exceed 2 mtrs. from floor level and the supply air temperature shall not be lower than 16°C. Computational Fluid Dynamic (CFD) can be used to assist determine thermal gradient and required air flowrate for complex application and very high ceiling. To increase the capacity of Displacement Ventilation, radiant cooling can be used to offset source of high sensible heat gain.

i. Account for anticipated supply duct leakage and supply duct heat gain or loss in the load calculations.

j. For final cooling load calculations, base the lighting heat gain on the actual lighting design.

k. Base the occupancy load on the code allowable square foot per person criteria, assuming that the building could be occupied to that maximum at some time.

2. Load Calculations Computer-Based Program

a. General

(1) It is preferred that any software used for completing HVAC designs or drafting be commercially available or public domain software available to the general public. The use of software developed in-house by the consultant is discouraged.

(2) Provide a list of any software that will be used for the HVAC system design or the drafting of the construction documents to the Entity at the beginning of the project for approval.

(3) Where the design involves calculations for which ASHRAE has prescribed procedures, such as cooling/heating load calculations, ductwork or piping pressure drop calculations, or acoustic calculations, the software algorithms and subroutines be based on the procedures prescribed by ASHRAE.

(4) Provide the input and output files for all software programs utilized in each design phase for HVAC calculations to the Entity for review and approval in pdf format so they are readily viewable by the Entity without purchasing the software licenses.

b. The program shall be capable of calculating each zone's peak heating and cooling load as well as the whole-building "block" loads. Each zone, room and portion of room with different load profile, orientation or sensible load shall be calculated. A separate block load for each air handling system shall also be calculated.

c. The program shall, at a minimum, calculate:

(1) solar gains through fenestration, internal gains from occupants including latent heat for cooling purposes, internal gains from lighting and equipment, outside air loads (sensible and latent) from ventilation and infiltration, and heat gains or losses through fenestration, walls, floors and roofs.

d. Software Program Features

(1) Store all necessary databases in addition to provision for editing.

(2) Calculates from manually entered data or directly from floor plans

(3) Automatically admits correction factors necessary for computing loads

(4) Analyzes up to 12 months per calculation

(5) Calculates 24 hours per design day

(6) Links with energy program software

(7) Transfers data to energy analysis programs

(8) Calculates in both metric and English units

(9) Allows entry of an HVAC system type from a menu and automatically differentiates between block and peak loads depending on the type of HVAC system chosen.

(10)Allows for roof and wall color effects

(11)Allows varying indoor conditions within a project

(12)Proper handling of return air plenum loads

(13)Accounts for people diversity in total building load

(14)Automates compliance with ASHRAE Standard 62

(15)Allows different summer and winter air rates

(16)Allows simultaneous infiltration, return air, exhaust air and ventilation air (where applicable)

(17)Computes supply fan horsepower and heat gains

(18)Accounts for both draw-thru and blow-thru fans

(19)Computes supply and return duct gains and losses

(20)Lighting and equipment watts along with number of people can be entered directly or on a per square foot basis.

(21)Leaving coil conditions can be specified with a desired dry bulb temperature or a relative humidity.

(22)Allows heating and cooling safety factors

(23)Calculates reheat requirements, if necessary

(24)Provision for both VAV and constant volume systems

(25)Performs psychrometric analysis

(26)Computes CFM air quantities with psychrometrics

(27)Allows specification of minimum supply air quantities

(28)Selects equipment from ARI databases

(29)Calculates runout and main trunk duct sizes

(30)Allows an unlimited number of zones which can be grouped into as many as 100 air handling systems

(31)Calculates chilled and hot water coil flow rates

(32)Printable comprehensive reports list the general project data, detailed zone loads, air handler summary loads, outside air loads, total building loads, building envelope analysis, tonnage requirements, CFM air quantities, chilled water flow rates (if applicable), and complete psychrometric data with entering and leaving coil conditions.

3. Cooling Load Components

a. During load calculations, all sensible and latent heat sources shall be considered.

b. Sensible cooling load shall be calculated for building envelope, people, lights, equipment, outside air that is introduced into the system by air make-up or by infiltration, and duct heat loss/gain.

c. Latent cooling load shall be calculated for people, outside air and any process in which moisture is given up to the air.

4.1.10 <u>Energy Modeling</u>

1. General

a. Building energy modeling during the design of a building or renovation shall serve several purposes. The primary objective is to inform design decisions in a way that guides the design toward Entity goals for building energy consumption performance. It is recognized that the detail and resolution of the model will refine as the design progresses from concept to design development. The objective of this modeling guideline is to yield results that are consistent between projects and more representative of eventual metered utility data. The process is one of continuous improvement; refinements will be made to the modeling guidelines as operating data is collected on modeled buildings.

2. Buildings Requiring Energy Modeling

   a. All projects, new construction and renovations, require an energy model with the exception of storage facilities, maintenance facilities, or facilities that do not require cooling or heating.

3. Modeling Software

   a. Trane Trace 700, Hevacomp, Carrier HAP or eQuest can be used to execute energy models. The modeler will make available the input and output files for the Entity's review and use. The use of other modeling software packages may be approved by the Entity upon specific request.

4. Climate Data

   a. The Entity recommends the use of TMY/2 climate data generated specifically for Saudi Arabia. Deviation from using this data set requires approval by the Entity.

5. Modeling Plan

   a. During the concept stage, prior to Schematic Design, the consultant shall present an energy modeling plan that describes the intended modeling approach through the course of design. This plan must be approved by the Entity prior to starting the Schematic phase. The plan shall define the following for each phase of design:

      (1) Model inputs that are anticipated to be known or assumed at that point of design

      (2) Modeling software to be used

      (3) Anticipated building and system options that will be evaluated at each phase

      (4) Model result level of detail, format and presentation method

6. Concept/Schematic Design Phase Model

   a. During this phase, decisions will be made that include building site, orientation, glazing, and massing. The intent of energy modeling at this phase is to evaluate concept variations relative to inherent differences in energy consumption of these variations.

   b. Evaluate the shape and orientation of the building for impact on cooling loads. As part of this phase, the architect may generate different massing concepts for the building. Each of these conceptual designs will be modeled during this phase.

   c. Provide key input assumptions for review by the Entity. Assumptions should be in line with ASHRAE Std. 90.1 Appendix G modeling protocols so as not to yield misleading results early in the design analysis process. Not all Appendix G detail will be used in this early modeling.

   d. It is preferred to model three HVAC system options (as appropriate). Inform the Entity of the three options to be modeled beforehand.

   e. Model wall insulation material and glazing options to optimize the cost/benefit of the envelope. (Coordinate glazing options with the architect.

   f. Model ventilation airflow reduction strategies such as carbon dioxide sensors.

   g. Model opportunities for electric lighting power density reduction and use of daylighting as much as possible. Consider high efficacy lighting and efficient ballasts. Focus on lighting control strategies for each space based on the energy model, such as occupancy and daylight sensors.

   h. Consider renewable energy possibilities wherever possible.

   i. Values for schedules, setpoints, occupancy density, and space loads shall be documented clearly and confirmed with the Entity so there is consistency between modeling phases.

7. Baseline Model

   a. Using the Building Performance Rating Method modeling protocols as detailed in Appendix G of ASHRAE 90.1 (without amendments), create a preliminary baseline building model for benchmarking. The baseline model shall comply with the mandatory provisions (Sections

5.4, 6.4, 7.4, 8.4, 9.4 and 10.4) of Standard 90.1. The model is to be used as a tool to inform design decisions, so it will transform as the process proceeds.

(1) All associated energy use and costs must be included. This baseline model should establish basic load calculation parameters using the conceptual / pre-schematic design.

(2) The model shall reflect the same values for schedules, setpoints, occupancy density, and space loads as the Concept/Schematic Design Phase model so there is consistency between modeling phases.

(3) Simulation output shall include the Energy Use Intensity (GJ/M²), total annual consumption of all utilities (monthly and annual), and central plant efficiencies. These values shall be compared to the results from the Concept/Schematic Design Phase model. The annual energy cost for the Concept/Schematic Design Phase model must be less than the annual energy cost for the Baseline Model.

(4) Alternatives shall be evaluated using a life cycle cost analysis. The energy model shall be used to determine differences in performance between options and the project cost consultant shall provide input on cost premiums of options.

8. Design Development/Construction Phase Models

   a. During the Design Development and Construction Document phases, final decisions will be made on equipment sizing and selection. Sizing of ductwork and piping will result in a refined value for systems pressures and horsepower. Continued work with the Entity will result in better information on equipment loads, occupancy schedules and space conditions. The models developed in Schematic Design should be updated with this new information and included with the DD and CD document submissions. Control system optimization strategies will be evaluated during these phases of design. Decisions made regarding glazing, insulation systems and lighting should be tested as part of this updated model. During these phases, cost estimates will be refined and life cycle cost analysis of options should be updated.

   b. Simulation output shall include the Energy Use Intensity (GJ/M²), total annual consumption of all utilities (monthly and annual), and central plant efficiencies.

   c. Where specific high performance components, such as heat recovery, are evaluated a parametric analysis may be used. This analysis is not a complete run of the building model but is a differential analysis of the performance improvement and cost premium for this component.

      (1) Examples of components that may best be evaluated by a parametric analysis are: heat recovery options, glazing options, wall and roof insulation, and boiler options.

9. Owner Review

   a. Provide documentation summarizing all results of the energy modeling exercise for review by the Entity.

10. LEED Energy Model (where applicable)

   a. This phase of the modeling effort prepares the model to be submitted as an important part of establishing the LEED certification for the facility.

   b. Make final modifications to the DD/CD model to finalize for LEED, (or other Environmental Standards entity recognized by the Entity incorporating comments made in previous phases.

   c. Document the Energy Model per the requirements of LEED EA Prerequisite 2: Minimum Energy Performance; and EA Credit 1: Optimize Energy Performance.

11. Post Occupancy Verification

   a. The Entity will compare the final LEED model results and actual metered energy use after 2 years of occupancy, or to coincide with the time period prescribed in the LEED Measurement & Verification Plan. The results will subsequently be shared with the consultant, who will provide the following post design services:

(1) If results are within 10% of total energy use, and metered use is consistent with the model breakdown, no further follow up will be required.

(2) If results vary from the model by 10 – 20% of total energy use, or metered use is not consistent with the model breakdown, the consultant shall respond in a written report to reconcile the discrepancy.

(3) If results vary by more than 20%, the consultant shall conduct a building walkthrough, participate in a reconciliation session, and issue a written report detailing their findings.

4.1.11 Building Envelope Thermal and Moisture Properties

1. General

a. Building envelope materials and assemblies must comply with the performance requirements specified in Chapter 5 of ASHRAE Standard 90.1.

(1) The requirements in Table 5.5-1 for Climate Zone 1 apply.

b. The Prescriptive Path, Building Envelope Trade-off Option and Energy Cost Budget Method, as outlined in ASHRAE Standard. 90.1 are all acceptable methods of compliance.

c. Coordinate with the Architect in the Concept/Schematic Design phase to assure the performance requirements for envelope materials and assemblies are understood.

d. As part of either the cooling/heating load calculation effort or the energy modeling effort, provide confirmation that the building envelope complies with ASHRAE Standard. 90.1.

4.1.12 Refrigerants

1. General

a. All new refrigeration equipment shall utilize compounds that are CFC and HCFC free and have an ozone depletion potential of zero (0).

b. Use of ammonia refrigerant is encouraged, and approval must be obtained from the Entity before considering any air-conditioning/refrigeration installations utilizing ammonia.

c. All installations of refrigeration equipment must comply with ASHRAE Std. 15.

2. Secondary Coolants (Brines)

a. In some refrigeration applications, such as food processing and freezing, secondary coolants (brines) are used. The selection of secondary coolants shall be carefully analyzed for each application. For example, for freezing unpackaged fish and other foods calcium chloride cannot be tolerated. Instead, ordinary salt (sodium chloride) brine may be used.

b. The following table provides guidance for typical brine systems applications.

TYPICAL BRINE SYSTEMS APPLICATIONS

Application	Sodium Chloride	Calcium Chloride	Ethylene	Propylene Glycol	Methanol Water	Ethanol Water	Chlorinated or Fluorinated Hydrocarbons
Chemical Plant	X	X	X		X	X	X
Dairies	X	X		X			
Food Freezing	X	X		X		X	
Meat Packing	X	X					
Preheat Coils (AC Systems)			X	X			
Skating Rings		X	X		X		
Low Temperature Systems		X	X				X
Ice Cream		X		X			X

c. In selecting brine, toxicity, flash point, specific heat, density, stability, viscosity, freezing point, vapor pressure, water solubility, and foaming shall be considered.

d. Sizing of brine piping systems shall be such that brine velocity is sufficiently low as to prevent erosion of piping by entrained air. To reduce the possibility of dirt and rust plugging in large salt brine systems, branch lines and valves smaller than 25 mm shall not be used.

e. To protect brine piping systems from corrosion, the refrigerating brine shall not be allowed to turn from all alkaline to an acid solution. Therefore, pH brine solution shall be kept at 7 or above. Brine pH can be raised by addition of caustic soda which has been dissolved in warm water. When pH can be controlled, brass valves and bronze fitted pumps may be used.

f. Steel, iron, or copper piping can be used with most of the brines, except salt brines where all-iron or steel piping shall be employed. All-iron or steel pumps and valves shall be employed with calcium chloride brine, to prevent electrolysis in the event of acidity.

4.1.13 Sustainability

1. Sustainability relating to HVAC design involves the implementing strategies to reduce energy, promote environmental protection, improve indoor air quality, and water consumption. Directions for minimizing energy, improving air indoor air quality and water use are addressed in numerous sections of this design guideline.

   a. Designs must meet the minimum requirements of ASHRAE Standard 90.1 – Energy Standard for Buildings, ASHRAE Standard 62.1- Ventilation for Acceptable Indoor Air Quality, as well as the Saudi Building Code (SBC 501- Mechanical Requirements) and the local Ministry of Electricity and Water.

   b. Strategies that exceed the minimum requirements of these codes and standards will be considered based on the results of life cycle cost analysis. Strategies should be proposed and analyzed during the initial phases of design to minimize the cost of implementation and optimize the effectiveness of the strategies.

2. Refer to Volume 15, Chapter 1 – Sustainability (EPM-KU0-GL-000001) for sustainability requirements relating to HVAC design.

4.1.14 Redundancy

1. General

   a. To maintain cost control, redundancy is mandated only in the case of critical systems and/or equipment.

   b. When a system failure would result in unusually high repair costs or costly replacement of process equipment, when activities would be disrupted that are vital to an application or the health/welfare of humans, a costly production process being manufactured; redundant systems or units are recommended.

   c. All redundant items of equipment shall have dedicated starters or VFD's, depending on the application.

   d. Controls shall be provided to operate the redundant equipment and automatically equalize the runtime of all identical items of equipment. The intention is to prevent premature bearing failure.

2. Redundancy Requirements

   a. Regardless of the system redundancy requirements of the program document, the design shall provide for redundancy in the following items of mechanical equipment. There is nothing in this document that prevents any equipment redundancy dictated by particular system requirements.

      (1) Chilled Water Pumps

         (a) In single chiller applications, a second, full sized pump/motor assembly shall be designed.

      (2) Primary Chilled Water Pumps

(a) In multiple chiller/dedicated pump applications, one spare primary chilled water pump motor shall be designed. The piping and valving arrangement shall accommodate the redundant pump operating with each of the chillers.

(3) Secondary Chilled Water Pumps

(a) Where used, secondary chilled pumps shall typically be minimum of two (2) pumps, VFD controlled, unless additional pumps are required to satisfy the flow volume range.

(b) A standby secondary pump is required.

(4) Condenser Water Pumps

(a) In dedicated chiller/tower applications, a second condenser water pump, full size shall be designed.

(5) Condensate (Steam) Return Units

(a) Duplex pumps with automatic alternators are required. The design shall be such that design flows will be handled by a single pump with 33% run time. This equipment shall be powered from the emergency generator, if an emergency generator is part of the project.

(6) Primary Hot Water Pumps

(a) In single boiler applications, a second, full sized pump/motor assembly shall be designed.

(b) In multiple boiler operations, there shall be one full size redundant primary hot water pump.

(7) Control Air Compressors

(a) A single tank is acceptable.

(b) The design shall incorporate duplex air compressors/motors with automatic alternator.

(c) The design shall be predicated on one-third run time and no more than six starts per hour for one compressor, with the second compressor designed as a full standby.

3. Standby Air Conditioning Capacity

a. All critical HVAC systems shall be provided with standby units/equipment.

b. Critical applications include hospitals, laboratories, data centers, UPS rooms and any application where the health and welfare of humans or animals or the longevity of expensive or critical equipment would be threatened by the failure of the HVAC system.

c. If the maximum design capacity of the system is supplied by 2 or more normally operating units, the capacity of the standby unit(s) shall be at least equal to the capacity of one of the normally operating units.

d. In case the maximum system demand is satisfied by one operating unit only, the capacity of the standby unit shall be equal to the capacity of the operating unit.

4.1.15 Units and Conversions

1. All units of measure utilized in documentation for Entity projects shall be based on the International System of Units (SI), better known as the metric system.

2. Conversion factors for converting units of measure for HVAC applications shall be from the Units and Conversions Chapter of the ASHRAE Fundamentals Handbook.

4.2 HVAC SYSTEMS

4.2.1 Central Heating and Cooling

1. General

   a. Guidelines related to individual items of central heating and cooling equipment are addressed in those items' respective sections in this document.

   b. Guidelines related to central heating and cooling are covered in Subsections 4.2.7 and 4.2.11.

2. Mechanical Space Design

   a. All mechanical rooms shall be designed and located to facilitate the removal, transport and replacement of the largest equipment component housed within each room.

   b. For early planning purposes, a minimum of 5% of the total building area for a new building shall be reserved for air handling equipment, and a minimum of 3% of the total building area for a new building shall be reserved for the central heating and cooling plant.

   c. The minimum clear height beneath the structural steel within a mechanical room shall be 4.0 m.

   d. Follow the egress requirements established by the Saudi Building Code. Egress doors shall be double doors, 2.0 m in total width.

   e. Mechanical room locations shall be illustrated in plan view at a scale of no less than 1:50.

   f. A minimum of two composite floor-to-ceiling sections shall be illustrated for each mechanical room at a scale not less than 1:50.

   g. All ductwork and piping larger than 15 mm in width shall be shown double line.

   h. Provide adequate space for maintaining all items of equipment. The clearances shall be measured from the edge of the equipment housekeeping pad.

      (1) Observe any code required clearance requirements, such as the ASME Boiler and Pressure Vessel Code.

      (2) The minimum clearance around pumps and similar size equipment shall be 0.5 m, unless the manufacturer's recommendations require greater clearance.

      (3) The minimum clearance around large equipment such as chillers, boilers and air handling units shall be 1.0 m.

         (a) Adequate space shall be maintained at one end of chiller evaporator and condenser bundles, and at one end of fire tube boilers for pulling tubes.

         (b) Adequate space shall be maintained at the side of air handling units for pulling coils.

         (c) Where multiple items of equipment having tube or coil pull clearance requirements are provided, arrange the equipment wherever possible so that the clearance requirements can be shared by multiple items of equipment.

      (4) Provide ladders and catwalks for any equipment requiring regular maintenance that cannot be maintained from floor level.

      (5) Provide ladders and catwalks for boilers in accordance with the ASME Boiler and Pressure Vessel Code.

      (6) The minimum clear head height within the clearance space around equipment shall be 2.0 m.

   i. The designated space for any future equipment and its service space requirements shall be clearly identified on the design drawings.

      (1) Show the intended path for moving the future equipment into the mechanical space, from the point of entry into the building to the equipment's final resting place.

(2) Coordinate any requirements for removal wall panels or other special means of entry with the Architect.

j. Wherever possible, mechanical rooms shall be located at grade. In multi-level buildings, a freight elevator stop shall be provided at each level with a mechanical room housing equipment with components weighing more than 45 kg.

k. When mechanical equipment must be roof mounted, structural considerations must be coordinated early in the design. Dunnage and roof curbs requirements shall be addressed.

(1) Address manufacturers required clearances

(2) Coordinate fall protection as required, depending on the proximity of the equipment to the roof edge

(3) Access to roof mounted equipment shall be by permanent stairs

(4) Doorways leading to roof mounted equipment shall be of adequate size for replacement of the equipment

l. Below grade equipment should be avoided, with the exception of sump pumps.

m. Mechanical rooms shall not be used as return air, outdoor air or mixed air plenums.

n. Mechanical rooms shall have floor drains located in close proximity to hydronic type equipment.

(1) Floor drains for cooling coil condensate shall be piped separately from the sanitary drainage system so that the condensate can be recovered for other non-potable water uses.

o. Housekeeping pads shall be provided under all items of equipment. The pads shall be 150 mm thick, and shall extend 150 mm beyond all sides of the equipment.

p. Ventilate all mechanical rooms in accordance with ASHRAE Standard 62 – Ventilation for Acceptable Indoor Air Quality.

(1) Refrigeration rooms shall be ventilated in accordance with ASHRAE Standard 15 – Safety Code for Mechanical Refrigeration.

q. Coordinate the design with all disciplines to assure that size and location of all required chases, soffits, access panels, louvers, etc. are indicated on the drawings.

4.2.2 Air Distribution System

1. General

a. Air handling distribution consists of ductwork, duct accessories such as balancing and fire dampers, constant and variable air volume terminals for controlling air flow for maintaining temperature or pressure relationships, and air inlet and outlet devices such as diffusers, registers and grilles.

(1) Ductwork design is addressed in this Section.

(2) Selection of terminal units is addressed in Subsection 4.3.1.2 – Room Air Distribution Equipment

b. For application where Life Safety Strategy permits, provide separate zoning for spaces/rooms attached to the building facade and internal rooms especially for locations with winter season, to reduce required heating for façade zone and utilized natural cooling for internal zones.

2. Pressure Drop Calculations

a. All pressure drop calculations for sizing ductwork and selecting fans shall be based on the data and procedures outlined in the Duct Design Chapter of the ASHRAE Fundamentals Handbook, or the SMACNA HVAC Systems Duct Design Manual.

b. Submit pressure drop calculations to the Entity prior to the completion of the final design phase for Entity review and acceptance.

c. Complete pressure drop calculations utilizing computer based software that has the ability to evaluate all circuits in a distribution system and identify the circuit with the greatest flow resistance.

d. Give careful consideration to safety factors in the calculations, recognizing that ductwork is rarely installed as designed, and that the addition of only a few fittings to a distribution system can have a significant effect on the overall flow resistance.

e. Careful consideration shall be given to conditions which fall outside the fittings and arrangements listed in that reference such as multiple fittings in series and poor inlet and outlet conditions.

(1) Provide added pressure drop allowance for fittings in series. Failure of the air to achieve uniform velocity across the ductwork prior to entering the second fitting will cause the pressure loss in the second fitting to be greater than that calculated by the ASHRAE method.

(2) Losses related to fan inlet and outlet conditions, better known as System Effect, shall be based on the data from AMCA Fans and Systems Publication 201.

3. Duct Design Criteria

a. Duct work is classified in accordance with its working pressure as follows:

(1) Low Pressure: Below 500 Pa.

(2) Medium Pressure: 500 to 2500 Pa.

(3) High Pressure: Above 2500 Pa.

b. The allowable air velocities for each of the duct pressure classifications are as follows:

(1) Low Pressure: 8.6 m/s and lower

(2) Medium Pressure: 8.7 m/s to 12.7 m/s

(3) High Pressure: 12.8 m/s to 17.8 m/s

c. The allowable friction loss rates for each of the duct pressure classifications are as follows:

(1) Low Pressure: 0.8 Pa/m and lower

(2) Medium Pressure: 0.9 Pa/m to 2.0 Pa/m

(3) High Pressure: 2.1 Pa/m to 4.0 Pa/m

d. Ductwork shall be sized using equal friction or static regain methods. The equal friction method shall be based on a pressure drop of 0.8 Pa per meter for supply, return, and exhaust ducts.

e. Duct air velocity shall be limited as shown in the following three tables in order to limit noise to acceptable levels.

MAIN DUCT AIR VELOCITIES IN SHAFT OR ABOVE DRY WALL CEILING

Space over or in which Duct will run	RECTANGULAR DUCT	ROUND DUCT
	Max Acceptable Duct Velocity (m/s)	Max Acceptable Duct Velocity (m/s)
Conference Rooms	8	10
Teleconference Rooms	6.5	8
Training Rooms	8	10
Auditoriums	8	10
Hospital/Clinic Rooms	8	10
Private Offices	8	10
Open Plan Offices	9	10
Corridors and Lobbies	10	12
Mosque	8	10

MAIN DUCT AIR VELOCITIES ABOVE SUSPENDED ACOUSTICAL CEILING

Space over or in which Duct will run	RECTANGULAR DUCT Max Acceptable Duct Velocity (m/s)	ROUND DUCT Max Acceptable Duct Velocity (m/s)
Conference Rooms	7.5	7.5
Teleconference Rooms	4.7	7.5
Training Rooms	7.5	7.5
Auditoriums	7.5	7.5
Hospital/Clinic Rooms	7.5	8
Private Offices	7.5	7.5
Open Plan Offices	8.9	8
Corridors and Lobbies	8.9	10
Mosque	7.5	7.5

MAIN DUCT AIR VELOCITIES LOCATED WITHIN OCCUPIED SPACE

Space Over or in which Duct will run	RECTANGULAR DUCT Max Acceptable Duct Velocity (m/s)	ROUND DUCT Max Acceptable Duct Velocity (m/s)
Conference Rooms	6.1	7.5
Teleconference Rooms	3.5	6.3
Training Rooms	6.1	7.5
Auditoriums	6.1	7.5
Hospital/Clinic Rooms	6.1	7.5
Private Offices	6.1	7.5
Open Plan Offices	7.4	8
Corridors and Lobbies	8.8	10
Mosque	6.1	7.5

f. Duct design shall be in accordance with the following:

(1) All galvanized sheet metal ducts and plenums which are not wrapped with insulation shall be field coated with epoxy.

(2) Round ducts shall be used as much as possible.

(3) Aspect ratios shall be close to unity as possible but not be more than 4:1, unless space consideration is a governing factor.

(4) Reduction in area due to obstructions shall not be more than 20%. Obstructions inside ducts shall be streamlined.

(5) Where duct work is connected to any fittings or equipment such as heating coils, cooling coils or filters, the transitions shall be as smooth as possible. Diverging transitions shall have a slope not exceeding 20º. Converging transitions shall have a slope not exceeding 30º.

(6) Increments in duct work sizes preferably shall be in one dimension only and shall not be less than 50 mm.

(7) Smooth radius elbows, round heal round throat, with a centerline radius equal to 1.5 times the duct diameter or width shall be used as much as possible. For round ducts, if a smooth elbow is not available, 3-piece elbow for velocity below 9 m/s and 5-piece elbow for velocity above 9 m/s shall be used. In all cases, the throat radius shall not be less than 3/4 of the duct diameter or width.

(8) Long conical tee shall be used for systems having a velocity above 8 m/s and a 45° tee for systems having a velocity below 8 m/s.

(9) Access doors or panels shall be provided in duct work for maintenance and service of the following equipment:

(a) Filters

(b) Cooling coil

(c) Heaters

(d) Sound absorbers

(e) Volume and splitter dampers

(f) Fire dampers

4. Special Applications

a. Kitchen Exhaust Systems

(1) Kitchen ventilation systems shall be designed in strict accordance with the Saudi Building Code (SBC 501-Mechanical Requirements) section regarding Domestic Kitchen Exhaust Equipment or the section regarding Commercial Kitchen Hood Ventilation System Ducts and Exhaust Equipment. Exhaust systems for commercial cooking operations shall also be designed in accordance with NFPA 96 – Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.

b. Paint Spray Operations

(1) Minimum ventilation rates for paint spray operations shall be 6 air changes per hour. All air must be exhausted. Recirculation is not permitted.

(2) Where solvent based paints are used, exhaust fans shall be Type A Spark Resistant Construction. All electrical components exposed to the paint vapors shall be explosion proof.

(3) Exhaust inlets for exhaust systems serving paint spray operations shall be filtered with minimum MERV 8 filters.

(4) The maximum air velocity at the filter face shall be 2.5 m/s.

(5) See Section 2, Fire Protection; Paragraph 4.1.7 (1) regarding fire protection requirements for paint spray operations.

c. Flammable Storage

(1) Ventilation for flammable storage areas shall be designed in accordance with NFPA 30 – Flammable and Combustible Liquids Code.

(2) See Section 2, Fire Protection; Paragraph 4.1.7 (2) regarding fire protection requirements for flammable storage.

d. Class I Division I and Division II Explosion Hazard Environments

(1) Exhaust fans for Class I Division I and Division II applications shall be Type A Spark Resistant Construction. Electrical components in the Class 1 Division I or Division II atmosphere shall be explosion proof.

e. Class II Environments Involving Explosive Dusts

(1) Exhaust fans for Class II explosive dust applications shall be Type A Spark Resistant Construction. Electrical components in the explosive dust atmosphere shall be explosion proof.

(2) Ductwork shall be bonded and grounded to prevent the build-up of static electricity.

f. Spaces Utilizing FM-200 Clean Agent Fire Suppression Systems

(1) Provide means to purge spaces protected by clean agent fire suppression chemicals after the chemicals have been released and the fire is extinguished.

(2) Purging can be accomplished with the building HVAC system if the flow to the space is adequate, and if the system can be controlled so that 100% of the chemicals can be exhausted and not returned to the HVAC air supply system. An air flow rate of 6 air changes per hour is generally considered adequate to purge the clean agent fire extinguishing chemicals.

(3) If the building HVAC system does not have adequate capacity or cannot be arranged to prevent recirculation of the chemicals back into the building, a dedicated purge system capable of producing 6 air changes per hour in the space protected by the clean agent fire suppression chemicals shall be provided.

(4) The clean agent fire suppression purge system shall be tested to prove effectiveness before the building is occupied.

(5) See Section 2, Fire Protection, Subsection 8.4. Clean Agent Systems for design requirements related to clean agent fire extinguishing systems.

4.2.3 In-Room Terminal Systems

1. Reference to other sections of the Mechanical Design Guidelines:
   a. Variable refrigerant flow systems are addressed in Subsection 4.2.9 – Variable Refrigerant Flow Systems.
2. General
   a. DX unit has higher ability for dehumidification and cooling due to lower off-coil temperature. In locations where extreme humidity is experienced as well as high infiltration is anticipated due to high wind velocity, it is advised to pressurized the building with cooled and treated fresh air (DOAS). Cooling the fresh air is mandatory to avoid condensation.
   b. Before using any in-room terminal units to supply and condition the ventilation air, obtain the approval of the Entity.
   c. In-room terminal units require special maintenance such as regular filter replacement and cleaning of cooling coils and cooling coil drain pans at each unit.
   d. HVAC system selection shall be based on a complete life cycle cost analysis. Include the maintenance and equipment replacement costs for all equipment in the analysis.
   e. Sloped tops are recommended for any floor mounted in-room terminal units to prevent room occupants from placing materials on the top of the units that would impede airflow.
   f. All in-room terminal units shall have minimum MERV 8 filters.
   g. In-room terminal units shall be controlled from wall mounted controls in lieu of unit mounted controls.
3. Types of In-Room Terminal Systems
   a. Fan Coil Units
      (1) Units may be floor or ceiling mounted. Floor mounted units are preferred for ease of maintenance.
      (2) Where ceiling mounted units are used, provide clear unobstructed access to the filter rack and the condensate drain pan.
      (3) Avoid locating ceiling units over desks and other furniture or equipment as dust and dirt almost always precipitate when the units are accessed.
      (4) Ceiling mounted units may require condensate pumps to transfer the condensate to the drain risers. The height above a ceiling is rarely adequate to develop the proper slope for condensate drainage.
      (5) Provide a condensate drain pan overflow switch to sense the condensate before the drain pan overflows, de-energize the unit fan and signal an alarm to the building management system.
      (6) Refer to the project specification for ducted fan coil units.
      (7) Refer to project drawings for HVAC standard details.
   b. Unit Ventilators
      (1) Unit ventilators are generally only used for primary and secondary school applications. Unit ventilators may have self-contained DX cooling or have chilled water coils for cooling.
      (2) Special attention shall be given to the noise levels generated by self-contained DX units. Most manufacturers offer options to reduce the noise level produced by the unit.

(3) Confirm the unit noise levels are within the limits established for the specific application in the ASHRAE Applications Handbook. It may be necessary to select all of the manufacturer's low-noise options to achieve acceptable noise levels.

(4) If unit ventilators are used to supply ventilation air to occupied spaces, each outdoor air intake must be protected by a sand trap louver.

c. Packaged Terminal Air Conditioning Units (PTACs)

(1) The noise levels generated by PTACs vary considerably from manufacturer to manufacturer. Clearly specify the acceptable noise levels for these units in accordance with the limits set forth in the ASHRAE Applications Handbook.

(2) Refer to the project specification for packaged terminal air conditioners.

d. Chilled Beam Systems

(1) Chilled beam systems are very sensitive to room humidity conditions. The fluid temperature passing through the secondary coil must be maintained above the wet-bulb temperature of the space.

(2) Chilled beams shall only be used in buildings where infiltration may be minimized.

(3) Passive chilled beams will not have adequate cooling capacity for most applications in Saudi Arabia, so use of chilled beams shall be limited to active chilled beams

(4) Provide a condensation sensor on at least one chilled beam in each room. Condensation sensors are less expensive and more reliable than dew point sensors.

(5) For larger rooms (50 m² and larger), provide a two-position supply air terminal and occupancy sensors to interrupt the flow of primary air to the chilled beams and shut off the secondary chilled water flow to the chilled beams whenever the space is unoccupied.

(6) Although Radiant Cooling is efficient compare to fan powered indoor units, high flowrate of DOAS to compensate latent load should be considered carefully by the designer before deciding to incorporate the strategy in the project.

4.2.4 Applied Heat Pump and Heat Recovery Systems

1. Reference to other sections of the Mechanical Design Guidelines:

a. Refrigerant compounds are addressed in Subsection 4.1.12 – Refrigerants

b. Direct expansion cooling coils are addressed in Subsection 4.3.1.6 – Finned Cooling Coils – Direct Expansion Type

c. Heat recovery is addressed in Subsection 4.3.1.8 – Air-to-Air Energy Recovery Devices

d. Direct expansion cooling is addressed in Subsection 4.3.1.13 – DX Packaged and Split

e. Residential heating is addressed in Subsection 4.3.2.2. – Residential Heating

2. Residential Applications

a. If heating is required for applications, air-source heat pumps shall be used. Heat pumps for residential applications should be selected to have adequate cooling capacity to meet the cooling load. The resulting heating capacity of the selected equipment is normally more than adequate to meet heating requirements for the application.

3. Geothermal Heat Pumps

a. Refer to the ASHRAE Applications Handbook chapter regarding Geothermal Energy for information regarding the design of geothermal heat pumps.

b. Geothermal technology may be cost effective for some applications in regions where the ground water table elevation is high. The following are considerations in determining the feasibility of a geothermal system:

(1) There is very little heating required in most areas of Saudi Arabia. The system will be utilized almost entirely for cooling. As such, the system will be rejecting heat to the well

field almost continuously year-round when it is in operation. To avoid thermal degradation of the well field over time as a result of the system rejecting heat to the ground, but absorbing very little heat, the site must have a high ground water level with regular ground water migration (and the distances between will be carefully considered).

(2) The sandy subsurface condition of the ground in much of Saudi Arabia is not conducive to developing deep well fields, and shallow wells are normally not economical. Therefore, a horizontal geothermal field may be necessary.

(3) Confirm if there is any past experience with well drilling in the area to determine if a vertical well may be feasible.

(4) Drill a test well to determine the maximum feasible depth for a well field. The challenge in sandy soil is preventing the well from caving in when the piping is being inserted.

(5) The design parameters to be determined for the ground material from the test well are:

(a) Thermal conductivity

(b) Thermal diffusivity

(c) Undisturbed soil temperature

(d) Volumetric heat capacity

(6) Consider a horizontal ground loop. Evaluate the annual heat rejection from the system vs. the thermal conductivity of the ground material and the potential ground water migration.

(7) Confirm if the site has the available ground area to support a horizontal ground loop with adequate heat exchange capacity.

c. Select equipment for entering water temperatures approximately 12ºC warmer than the ground temperature.

4. Healthcare and Industrial Applications

a. Applications that have a simultaneous need for heating and cooling may provide opportunities for heat recovery chillers or water-to-water heat pumps. Examples would be:

(1) HVAC supply air reheating for hospitals and labs where air is cooled and dehumidified and then reheated for temperature control.

(2) Industrial process where there is a simultaneous demand for cool water and warm water, either for space conditioning or for process use.

b. Hot water delivery temperatures of 40.5ºC are possible from heat recovery chillers.

c. If the heat demand involves a critical application, consider providing a redundant heat recovery chiller.

5. Refer to project specifications for the applicable equipment.

6. Refer to project drawings for standard HVAC details.

4.2.5 Forced Air Heating and DX Cooling Systems

1. Reference to other sections of the Mechanical Design Guidelines:

a. Refrigerant compounds are addressed in Subsection 4.1.12 – Refrigerants

b. Heat pumps are addressed in Subsection 4.2.4. – Applied Heat Pump and Heat Recovery Systems

c. Direct expansion cooling coils are addressed in Subsection 4.3.1.6 – Finned Cooling Coils – Direct Expansion Type

d. Direct expansion cooling is addressed in Subsection 4.3.1.13 – DX Packages and Split

e. Forced air heating is typically only used in residential applications.

(1) Residential heating is typically done with heat pumps (see Subsection 4.3.2.2. – Residential Heating)

2. Reheating is done in Hospitals (see Subsection 4.1.8.1.4 and 4.2.4.4 – HVAC for Hospitals and Clinics) and in Laboratories (see Subsection 4.1.8.1.2– HVAC for Laboratories).
3. Refer to project specifications for forced air heating and DX cooling equipment.
4. Refer to project drawings for HVAC standard details.

4.2.6 Steam Systems

1. Reference to other sections for the Mechanical Design Guidelines:
   a. Redundancy is addressed in Subsection 4.1.14 – Redundancy
   b. Boilers are addressed in Subsection 4.3.2.1 – Boilers
   c. Heat exchangers are addressed in Subsection 4.3.4.4 – Heat Exchangers
   d. Water Treatment is addressed in Subsection 4.4.1.6 – Water Treatment
2. General
   a. The use of steam shall be limited to applications for which there are no substitutes, such as large scale humidification, sterilization and laundry applications in hospitals, and some industrial applications.
   b. Confirm the availability of fuel for a steam boiler with the Entity. Boiler fuel will likely be fuel oil or natural gas.
   c. All steam systems and equipment shall be designed in strict accordance with the requirements of the ASME Codes and Standards.
   d. Carbon steel or alloy steels shall be used for piping material.
   e. Sizing of pipes shall be such as to allow reasonable velocities. The steam velocity shall not create objectionable noise especially for heating systems in office buildings and dwellings.
   f. Either globe or gate valves shall be used wherever possible. In general, gate valves shall be used in locations where pressure drop through the valve is a consideration and where the valve will be either wide open or entirely closed. Globe valves shall be used in water, steam, and air lines for throttling purposes, as the globe valve permits closer regulation of the flow. A gate valve shall always be installed preceding a globe valve used for throttling purposes.
   g. Check valves shall be used in feed lines close to a boiler to prevent water or steam blowing back from the boiler, if the feed line ruptures or its pressure falls. Check valves shall also be used in individual pump or trap discharges before they join a common header, and where different lines are joined together to discharge into a common header. In pump discharges where the header remains under pressure after the pump is shut down, a gate valve shall be installed in addition to the check valve.
   h. Each boiler shall have at least one safety valve and two or more safety valves, if it has more than 46.5 m2 of heating surface or if the steam generating capacity exceeds 1000 kg/h. The safety valve capacity for each boiler shall be such that all the steam that can be generated shall be discharged without allowing the pressure to rise more than 3%. The complete range of pressure settings of all the saturated steam safety valves on a boiler shall not exceed 10% of the highest pressure to which any valve is set.
   i. All safety valves shall be of direct spring-loaded pop type. They shall operate without chattering.
   j. Except in the case of small, low-pressure boilers, vents from safety valves shall be terminated outside of the building at least 1.8 m above the roof. To reduce the high noise level caused by the discharge, the vent pipe end shall be fitted with a baffled silencer, or the pipe end shall be cut on a bias to increase the discharge area and reduce exit velocity.
   k. Steam systems piping shall be insulated to reduce heat losses.
3. Operating Pressure and Pressure Control

a. The operating pressure shall not be higher than 1 bar above the minimum pressure required for the application.

(1) Humidification can usually be served with 1 bar steam pressure.

(2) For hospital laundry and sterilization applications, a steam pressure of 12 bar and 3.5 bar accordingly, are usually adequate.

(3) Industrial applications may require higher steam pressures. Confirm the required pressure with the Entity.

b. Steam pressure reducing valves shall be self-powered pilot-operated type.

(1) Single-stage pressure reducing valves are permitted for low pressure applications operating at 1 bar or lower pressure.

(2) Two-stage pressure reducing valves are required for high pressure applications.

(3) Pressure reducing stations shall be located such that they can be serviced from the floor for safety purposes.

4. Steam Demand Profile

a. Develop a full steam demand profile for the system.

b. Utilize the steam demand profile to determine the number and capacities of boilers required to meet the demand.

c. Critical systems shall have one redundant boiler.

d. Boilers shall be sized so that one boiler remains online at low fire when demand is lowest. Boiler efficiency drops dramatically when boilers cycle on and off. If demand is seasonal, it is acceptable to cycle all boilers off when there is no steam demand.

5. Feedwater Heating and Deaeration

a. Feedwater for a steam boiler must be heated to prevent shocking a boiler with cold water.

(1) Cold water shocking could cause tube leakage and may cause water contraction in a boiler, causing water level fluctuations.

b. Live steam from the system shall be used to heat feedwater.

c. Specify a spray-type deaerator with the capacity to remove all carbon dioxide from the feedwater and reduce oxygen levels in the feedwater to 0.005 cc/liter (7 ppb).

d. Boiler feedwater pumps shall be modulating flow type with variable frequency drives.

(1) Operating pump capacity shall be 1.25 times the boiler capacity.

(2) Design feedwater pump head shall be equal to the boiler safety relief valve setting.

(3) Confirm the inlet pressure at the feedwater pump is greater than the net positive suction head requirement for the pump.

(4) Provide one redundant feedwater pump.

6. Steam Traps

a. All steam traps shall have a capacity to load factor of 2:1.

b. Provide thermodynamic traps for all high-pressure drip legs.

c. Provide float & thermostatic traps for all heat exchangers.

d. Protect all steam traps with strainers. Strainers shall have valves on the cleaning ports

7. Pressure relief valves

a. All sections of the steam piping system shall be protected by ASME pressure relief valves with adequate capacity to relieve the upstream steam capacity of the system.

(1) The discharge of all safety relief valves shall be piped to the outdoors.

8. Shutoff Valves

a. Shutoff valves 50 mm diameter and smaller for low pressure steam shall be ball valves with bronze body, 316 stainless steel ball and stem, and reinforced Teflon 15% glass-filled double seal seat.

b. Shutoff valves 50 mm and smaller of high pressure steam shall be ball valves with ASTM A216 WCB carbon steel or stainless steel body, 316 stainless steel ball and stem, and high temperature reinforced Teflon double seal seat.

c. Shutoff valves larger than 50 mm. for low pressure and high pressure steam shall be ANSI 150 high performance butterfly valves with carbon steel tapped lug full flange body, 316 stainless steel disc and double offset stem, and high temperature reinforced Teflon fully bidirectional seat design for dead-end service in either direction.

9. Piping Materials

a. Steam supply piping shall be Schedule 40 black steel.

b. Condensate return piping shall be Schedule 80 black steel.

10. Steam Piping Design

a. Steam supply piping shall be designed in strict accordance with the guidelines established in the ASHRAE Fundamentals Handbook.

b. Specify pipe insulation in strict accordance with ASHRAE Standard 90.1 – Energy Standard for Buildings except Low-Rise Residential Buildings.

11. Expansion Compensation

a. Expansion loops are preferred over expansion joints.

b. Fully detail the dimensions of all expansion loops on the construction drawings.

c. Clearly show anchor and guide locations on the construction drawings.

d. If adequate space cannot be provided for expansion loops, expansion joints may be used. Provide means of shutting off steam service within the general vicinity of expansion joints on both the upstream and downstream sides to avoid shutting down the entire system to service a joint.

12. Refer to the applicable project specifications for equipment.

13. Refer to project drawings for HVAC standard details.

4.2.7 Hydronic Heating and Cooling

1. Reference to other sections of the Mechanical Design Guidelines:

a. Redundancy is addressed in Subsection 4.1.14 – Redundancy

b. Condenser Water systems are addressed in Subsection 4.2.8 – Condenser Water Systems

c. Boilers are addressed in Subsection 4.3.2.1 – Boilers

d. Conventional chillers are addressed in Subsection 4.3.3.2 – Chillers (Vapor Compression)

e. Absorption chillers are addressed in Subsection 4.3.3.3 – Chillers (Absorption)

f. Cooling towers are addressed in Subsection 4.3.3.4 – Cooling Towers

g. Centrifugal Pumps are addressed in Subsection 4.3.4.1 – Pumps (Centrifugal)

h. Turbine pumps are addressed in Subsection 4.3.4.2 – Pumps (Turbine)

i. Heat exchangers are addressed in Subsection 4.3.4.4 – Heat Exchangers

j. Water Treatment is addressed in Subsection 4.4.1.6 – Water Treatment

2. General

a. Hydronic systems are preferred for cooling large buildings because they are more efficient for cooling large buildings than DX systems, and cooling may be provided through a central chiller plant which provides an efficient method for addressing variable cooling loads

b. This subsection criteria addresses design of systems and equipment utilized for hydronic cooling utility systems.

c. These criteria provide mandatory, minimally acceptable requirements for both new and retrofit projects for the Entity.

d. These criteria provide the basis on which the hydronic cooling and heating utility systems and services shall be programmed, designed and installed.

e. These criteria provide planning, design, construction, sustainment, restoration, and modernization criteria for hydronic heating and cooling utility systems.

f. This document contains policy and technical criteria to be used in the programming, design and documentation of Entity projects.

g. The provisions of this document are not intended to prohibit the use of alternative systems, methods or devices not specifically prescribed by this document, provided the Entity has approved such alternatives.

h. Project conditions may dictate the need for design that exceeds these minimum requirements.

i. Any conflict between these criteria and other project specification requirements shall be resolved at the discretion of the Entity.

3. Materials Selection

a. All materials used shall meet the requirements of the Contract.

b. All materials used shall be selected to meet applicable system requirements (temperature, pressure, etc.).

c. All material shall be selected in consideration of the environmental conditions.

d. In selecting material, special attention shall be given to corrosion resistance. Either corrosion resistant material or corrosion resistant plating, coating or painting on ordinary material shall be as specified in accordance with the project specification for corrosion control.

e. All material shall also be selected in consideration of the ease of shipment, installation and maintenance.

f. Due to high ground water aggressiveness, all pipes placed underground shall have external protection by using epoxy coating, or tape wrap.

g. Materials shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.

4. Equipment Selection

a. Energy Efficiency

(1) The Entity is committed to energy efficient design within the limit of budget constraints and within the bounds of good practice.

(2) Energy efficiency can be achieved through use of efficient equipment and effective computer-based control.

(3) All equipment shall be selected to meet the requirements of ASHRAE Std. 90.1.

b. Life-Cycle Cost Analysis

(1) Equipment shall not be selected with the lowest first cost, but based on Life-cycle cost analysis, an analytical method that calculates costs over the “useful” or anticipated life of equipment.

(2) Equipment shall be selected to meet environmental conditions requirements. Special provisions shall be included for equipment installed outdoors.

(3) Due to high ground water table, special consideration shall be given to the physical location of electric motor drives for pumps and valves, in order to protect them from possible flooding. Consideration shall be given to using vertical assemblies with drive motors mounted on top.

5. Materials and Equipment Engineering

   a. Material and Equipment Qualifications

      (1) All materials and equipment shall be standard products of manufacturers regularly engaged in the manufacture of such products, which are of a similar material, design and workmanship.

      (2) Standard products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use shall include applications of equipment and materials under similar circumstances and of similar size. The product shall have been for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period.

      (3) Products having less than a 2-year field service record shall be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturer's factory or laboratory tests, can be shown.

   b. Service Support

      (1) All equipment items shall be supported by service organizations.

      (2) Submit a certified list of qualified permanent service organizations for support of the equipment which includes their addresses and qualifications.

      (3) These service organizations shall be reasonably convenient to the equipment installation and able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the Contract.

      (4) The spare parts shall be guaranteed after the warranty period.

   c. Certification of Compliance

      (1) The Contractor shall provide a Certificate of Compliance for all materials and equipment that shall be permanently incorporated into the work.

      (2) Certificates shall also be required for all safety related items. No payment shall be made for any item until the required certificates have been received.

      (3) The certificate shall show the following:

         (a) Date of certification.

         (b) Description of material supplied.

         (c) Product trade name.

         (d) Name of manufacturer and supplier.

         (e) Name of the Contractor to whom the material is supplied.

         (f) Project name and number to which the material is consigned.

         (g) Contract item number and Contract item name.

         (h) A statement that the material or assemblies provided fully meets the requirements of the pertinent Contract Specification.

         (i) Stamp and signature of a person having legal authority to bind the originator of the certificate.

   d. Storage and Handling of Materials and Equipment

         (a) Materials and equipment shall be stored, handled and transported to preserve their quality and fitness for the work.

         (b) Materials and equipment shall be stored to facilitate prompt inspection and shall be subject to inspection and retesting before incorporation in the work.

   e. Unacceptable Materials and Equipment

         (a) Materials and equipment not meeting the requirements of the Contract shall be considered unacceptable and shall be rejected and removed immediately from the project.

(b) If the Contractor fails to remove defective materials or equipment within the time indicated by the Entity in writing, the Entity will remove the materials at the Contractor's expense.

6. System Design

a. General

(1) Because of cost control, redundancy is mandated only in the case of critical systems and/or equipment.

(2) When a system failure would result in unusually high repair costs or replacement of process equipment, or when activities are disrupted that is vital to an application, redundant systems or units are recommended.

b. Redundancy Requirements

(1) Regardless of the system redundancy requirements of the program document, the design shall provide for redundancy in the following items of mechanical equipment. There is nothing in this document that prevents any equipment redundancy that is dictated by the requirements for the particular system.

(a) Chillers and Boilers

i. For critical applications, N+1 redundancy shall be provided for chillers and boilers in central utility plants. Critical applications shall be defined as hospitals, laboratories and other facilities where loss of cooling could threaten the health of humans, research or irreplaceable work or materials.

ii. If the utility plant serves critical and non-critical applications, the chillers and boilers shall be arranged so that in the event of a loss of a single boiler of chiller, service to no-critical application may be curtailed to prevent a loss of capacity for the critical applications. If this is not possible, the N+1 redundancy shall be provided for chillers and boilers.

iii. For non-critical applications, chillers and boilers shall be sized so that 67% capacity may be maintained in the event of a loss of a single chiller or boiler.

(b) Chilled Water Pumps

i. In single chiller applications, a second, full sized pump/motor assembly shall be designed.

(c) Primary Chilled Water Pumps

i. In multiple chiller/dedicated pump applications, one spare primary chilled water pump motor shall be specified.

(d) Secondary Chilled Water Pumps

i. Unless 2 pumps are needed to handle design flow, a second, standby secondary pump is required, with a dedicated VFD.

ii. In any case, loss of a single pump shall not result in more than a 25% reduction on flow.

(e) Condenser Water Pumps

i. In single chiller/tower applications, a second condenser water pump, full size shall be designed.

(f) Condensate Steam Return Units

i. Duplex pumps with automatic alternators are required. Pumps shall be size so that a single pump with can meet the flow requirement with 33% run time. Condensate pumps shall be powered from a normal/emergency source, if emergency power is provided as part of the project.

(g) Primary Hot Water Pumps

i. In single boiler applications, a second, full sized pump/motor assembly shall be designed.

7. Space Requirements

a. General

(1) The mechanical design shall be cognizant of the necessity to provide for the replacement of major equipment over the life of the building and shall insure that provisions are made to remove and replace, without damage to the structure, the largest and heaviest component that cannot be further broken down.

(2) Mechanical equipment rooms shall be designed with maintenance requirements in mind.

(3) All mechanical equipment rooms shall be a minimum of 4.0 m in height.

b. Accessibility

(1) Equipment must be fully accessible to allow for proper servicing, including adequate space to disassemble all pumps, motors and chillers.

(2) Chillers shall be placed to permit pulling of tubes without interrupting the operation of or moving other equipment.

(3) The mechanical rooms shall have adequate doorways or areaways and staging areas to permit the replacement and removal of equipment without the need to demolish walls or relocate other equipment.

(4) Sufficient service access space areas as noted by outlining manufacturer's recommendations and in compliance with applicable code requirements for routine maintenance and removal of mechanical system components shall be provided.

(5) In multi-stories building and to facilitate equipment access, maintenance, removal and replacement, a freight elevator stop can be provided to serve floors housing heavy equipment.

(6) Where stairs are required, they must allow for safe transport of equipment and components. Ship's ladders are not permitted for access and maintenance of any equipment.

(7) Catwalks, complete with railings, toe stops and stairways, shall be provided for all equipment that cannot be maintained from floor level.

(8) Where maintenance requires the lifting of heavy parts 45 kg or more, hoists and hatchways shall be installed.

(9) The arrangement shall consider the future removal and replacement of all equipment.

c. Clearance

(1) Horizontal Clearances

(a) Mechanical rooms shall be configured with clear circulation aisles and adequate access to all equipment. Required clearance shall be in accordance to manufacturer written instructions.

(2) Vertical Clearances

(a) Mechanical equipment rooms shall have clear ceiling heights of not less than 3.7 m or as per manufacturer recommendation, whichever is greater.

(3) Ceiling Clearances

(a) Provide adequate clearance and access for building systems installed between ceiling and structure above.

8. Location

a. General

(1) Mechanical rooms shall be normally located at or above grade level because of high ground water. Special provisions for water proofing and water removal must be

provided for below grade mechanical rooms, and approval must be obtained from the Entity.

(2) Large central equipment shall be situated to facilitate its replacement.

b. Roof Mounted Equipment

(1) When roof mounted equipment is specified, they shall be considered and coordinated in the roof structural early design phase.

(2) Provide clearance and access as per manufacturer recommendation.

(3) Access to roof-mounted equipment shall be by permanent stairs, not by ship's ladders.

(4) If a door is provided, it shall be of enough size to allow equipment replacement.

(5) Air conditioning condensate lines shall be discharged to roof drains. Dumping of water on roofs shall be avoided.

(6) Penetrations in the roof shall be per the roof's manufacturer's recommendation.

c. Below Grade Equipment

(1) Below grade equipment shall be generally avoided.

(2) Below grade equipment requires vehicular ramp, special provision to prevent rain flooding and additional ventilations, which have adverse impact on cost control.

(3) Exception of submersible pumps installations.

9. Drain Provision

a. Mechanical rooms shall have floor drains in proximity to the equipment they serve to reduce water streaks or drain lines extending into aisles.

b. Provide at least 1 floor drain for every 13 m² of each equipment room.

c. Locate drains away from walking areas, but not beneath equipment.

d. Slope floor to drain.

e. Provide vent.

f. Air handling units shall be drained considering air gap above the floor/area drain.

g. Provide trap primer at floor drain.

h. Provide access for all required trap primers.

10. Ventilation

a. Provide mechanical ventilation and exhaust in all equipment rooms in accordance with ASHRAE Standard 15 and ASHRAE Standard 62.

11. Housekeeping Pads

a. Housekeeping pads shall be at least 152 mm wider on all sides than the equipment they support and shall be 152 mm thick minimum.

12. Volumetric Expansion Compensation

a. Bladder-type diaphragm expansion tanks are to be utilized wherever possible.

(1) Consider locating the tank at the top of the building to minimize size.

b. Expansion Joints shall be used when piping flexibility design is impractical. Otherwise piping loops with appropriate guides and anchors shall be provided.

13. Make-Up Water/System Pressure.

a. Backflow prevention devices shall be provided per code.

b. A pressure control valve shall provide make-up water and consequently operate to maintain system pressure.

c. Make-up water shall be provided near the suction side of the system primary pumps, such that, the system pressure will always be above atmospheric pressure.

d. System Pressure will always remain positive at the high point of the system.

14. Air Removal/Drainage

a. Automatic and Manual Air Vents shall be provided at all system high points.

(1) Provide shut-off valves at the inlets of air vents,

b. Venting is intended to be utilized during system fill and operation.

c. Automatic Air Vents are NOT to be placed over critical areas.

d. Drain Valves shall be piped to floor drains when practical.

15. Pumping System Configuration

a. Variable primary pumping systems are preferred against primary/secondary chilled water piping arrangement for first cost and energy consumption savings point of view.

b. When variable primary pumping is used, a by-pass piping shall be provided to ensure minimum flow requirement across the chiller; and to protect the pump from very low flow, where the system curve shifts away from the Best Efficiency Point when pump is running at minimum frequency, thus resulting in excessive thrust loads in the impeller. Fast response control valve and actuator shall be provided in the by-pass line.

c. For large system where pipe runs are excessive, primary/secondary systems can be used provided that the designer shall prove by calculation the following;

(1) That using variable primary pumping system shall result in excessive pressure differential to the nearest terminal control valves which can result in force opening during normal operation and low flow condition. Calculation shall include only pressure differential across control valves and shall exclude effects of coil and piping appurtenances.

(2) Pressure differential for terminal control valve to be considered is 4 bar (currently highest in the market). Higher value can be used based on current available model in the market.

(3) Variable primary pumping and variable secondary pumping shall be employed using balance of flow in the de-coupler piping.

d. Pressure Independent Control Valve shall be used in lieu of conventional two-way control valve for chilled water system to resolved universal problem with low-delta T. Low delta T is a common problem with conventional 2-way control valves resulting in tremendous waste in chiller and pump power consumption, as well as piping first cost.

e. When using variable primary/secondary piping arrangement, provide by-pass close to the end of the main circuit to protect the system from BMS malfunction where fail safe-close control valve is used which can result in excessive pressure differential across the control valve when pump is running at full-speed. The by-pass shall also serve to protect the pump from very low flow as described in item 2.

f. Differential pressure sensor/transmitter (DPS/T) for secondary pumping variable speed control shall be located in the index point. DPS/T location shall be typical for variable primary pumping system.

g. Above condition shall be applicable for hydronic heating variable pumping system.

16. Chilled Water Plants

a. The systems will generally supply water between 4ºC and 7ºC.

b. Cooling coils should be designed for a chilled water temperature rise of 9ºC to 11ºC.

c. Multiple Chiller Applications should use the same capacity model/type of chillers; however, large tonnage applications should consider different size machines and prime movers depending upon the facility load profiles and available fuel sources.

d. Consider providing at least one chiller in each chiller plant with a variable frequency drive. An economic analysis shall be done to determine if this is warranted on larger chillers.

17. High Temperature Water Systems

a. High temperature water (HTW) systems are those that supply water at temperatures above 120°C and at pressures from 4 to 25 bars.

b. The pressure in any part of a high temperature water system shall always be above the pressure corresponding to the temperature at saturation in the system, to prevent flashing of the water into steam. Pressurization to prevent the water in system from flashing into steam shall be accomplished by steam or an inert gas such as nitrogen.

c. This pressure shall be maintained by employing either of the following schemes:

d. An automatic pressure pump.

e. Compression tank with inert gas.

f. A steam cushion in the steam air space, the steam space of the boiler, or in a separate expansion tank.

g. Based on load and design pressures, either water-tube, fire-tube, or scotch-marine type boiler shall be used.

h. Water-tube boilers usually require external tanks for pressurization, while fire-tube boilers, if pressurized by steam, have expansion space within the boiler, but require a separate tank if pressurized by inert gas.

i. When pressurizing with pump, the pressure control shall be set to operate the boiler feed pump, which causes feedwater to flow from the makeup tank to the boiler whenever the pressure falls.

j. Proper distribution of return water and of water flow shall be maintained in all types of boilers, to prevent tube or tube-sheet failures due to overheating or unequal expansion of the boiler.

k. Either iron pipe or copper tubing shall be used for high temperature water systems.

l. Sizing of piping shall take economic considerations of smaller pipe versus higher pressure drops through the system, and therefore, higher pump requirements.

m. Control valves shall be sized for 70 to 80% stem travel at full flow. The pressure drop across the valve shall not result in a downstream pressure below the saturation pressure at the temperature existing at any point, or flashing into stream will result.

n. Control valves shall be located in the return lines of heating units, in order to reduce valve operating temperature.

18. Water Velocities in Piping

a. Water velocity in HVAC piping shall not exceed the values shown in the following table in order to limit noise levels, avoid excessive energy consumption, and pipe erosion.

RECOMMENDED MAXIMUM WATER VELOCITY IN HVAC PIPING

SERVICE	MAXIMUM VELOCITY IN M/SEC
Hot Water	
50 mm Pipe and Under	1.2
Above 50 mm Pipe	limit to 2.5 m/s for general piping but shall not exceed 4.6 m/s for large piping. Uniform friction loss shall not exceed 400 pa/mtr. in any case
Cold Water	
50 mm Pipe and Under	1.2
Above 50 mm Pipe	limit to 2.5 m/s for general piping but shall not exceed 4.6 m/s for large piping. Uniform friction loss shall not exceed 400 pa/mtr. in any case
Pump Suction including Header	2
Drain Line	1.2

19. Piping Design

a. Piping design shall be in accordance with the following:

(1) Water flow, especially through heat transfer equipment, shall be in direction to permit natural air venting. Typically, the water outlet shall be higher than the water inlet to promote air elimination.

(2) Pipe friction loss for general applications shall not be more than 30 kPa per 30 m length of pipe.

(3) Reverse return piping arrangements may be acceptable for small hydronic systems, but is generally not cost effective for large systems. Provide adequate means for manual or automatic balancing and flow measurement.

(4) For hydronic piping using metallic piping, increase the pump calculated friction head as follows for aging allowance as per ASHRAE;

(a) Closed Piping using Black Iron – increased by 20%

(b) Open Piping System using Black Iron – increased by 75%

(c) Copper Piping in close or open system – increased by 30%

b. Systems Components

(1) Components for piping systems shall be as follows:

(a) Long radius elbows shall be used wherever possible. For offsets, 45° elbows instead of 90° elbows shall be used.

(b) Unions shall be provided for screwed pipes where equipment and piping accessories have to be disconnected for service.

(c) Flanges shall be provided for welded pipes, where equipment and piping accessories have to be disconnected for service.

(d) Ball, globe or butterfly valves shall be used for throttling services. 10 mm globe valves shall be provided as bypass valves for all globe valves above 200 mm.

(e) Recommended piping and fitting materials shall be as shown in the following table.

RECOMMENDED PIPE AND FITTING MATERIALS FOR VARIOUS SERVICES

SERVICE	PIPE	FITTINGS
Chilled Water	Black steel pipe	Welding, cast, malleable or black iron
	Hard copper tubing	Cast brass, wrought copper or wrought brass
Condenser or Make-Up Water	Galvanized steel pipe	Welding, galvanized, cast or malleable iron.
	Hard copper tubing	Cast brass, wrought copper or wrought brass
Drain or Condensate Lines	Galvanized steel pipe	Galvanized, cast or malleable iron
	Hard copper tubing	Cast brass, wrought copper or wrought brass
Steam	Black steel pipe	Wrought or cast iron
	Hard copper tubing	Cast brass, wrought copper or wrought brass
Steam Condensate	Schedule 80 Black Steel	Wrought or cast iron
Hot Water	Black steel pipe	Welding or cast iron
	Hard copper tubing	Cast brass, wrought copper or wrought brass

20. Valves and Accessories

a. Provide shut-off valves at inlet and outlet of each item of HVAC equipment, including but not limited to pumps, coils, fin-tube convectors, cabinet heaters, unit heaters, heat exchangers, and other similar equipment.

b. Provide valves at the top and bottom of all risers.

c. Provide valves at all branch take-offs from piping mains.

d. Provide non-slam check valves as indicated at pump discharges.

   e. Locate valves so that the tops of the valve stems are above the horizontal.
   f. Valves for equipment, coils, specialties, etc., shall meet the component's pressure rating listed, and as required for system pressures and temperatures.
   g. Valves shall be same as upstream piping unless otherwise indicated.
   h. In general, and unless otherwise noted, shut-off valves 50 mm size and smaller shall be ball valves. Shut-off valves 62 mm size and larger shall be butterfly valves.

21. Pumps
   a. Pumps 3.75 kW and larger shall have variable speed drives and shall be arranged so that flow is matched to the demand.
   b. Pumps shall be selected so that that flow may be increased by 15% with a corresponding increase in pump head by simply changing the impeller. Neither a change in the pump body size or pump a motor replacement shall be required.
   c. Select pumps for operation within a range of 66% to 115% of the flow at the point of highest efficiency.
   d. Select pump motors to prevent overloading over the entire flow range of the selected impeller, as well as for the entire flow range of one impeller size larger.
   e. For pumps operating in series or parallel, the series or parallel curves shall be plotted to confirm proper flow with multiple pumps operating.
   f. The following general guidelines shall be used for selecting the pumps seal material:
      (1) Standard seal for open or closed system with clear water
      (2) Single flushed seal for closed, clear water systems operating at high temperature or pressure
      (3) Double flushed seal for open or closed systems with high concentrations of abrasives
      (4) Packing gland seal for open or closed systems with large volumes of make-up water or solids build-up

22. Mechanical System Configurations
   a. Water Coils
      (1) All hydronic water coils shall have two-way control valves. Control valves shall be pressure independent type (PICV) with the simplest design and shall be located in the supply side of the cooling coil (not as practiced in the return side of the coil for conventional two-way control valve). Cartridge type shall be preferable due to simplicity and ease in testing and commissioning. PICV (Pressure Independent Control Valves) combined functions of auto-balancing valve, differential pressure regulator, and control valve.
      (2) A shutoff valve shall be installed on each supply and return pipe at each coil to allow for servicing of the coil without tampering with water balance.
      (3) A strainer shall be provided for each coil bank to protect the 2-way valve.

23. Refer to the applicable project specifications.
24. Refer to project drawings for standard HVAC details.

4.2.8 Condenser Water Systems

1. Reference to other sections of the Mechanical Design Guidelines:
   a. Cooling towers are addressed in Subsection 4.3.3.4 – Cooling Towers
   b. Centrifugal Pumps are addressed in Subsection 4.3.4.1 – Pumps (Centrifugal)
   c. Turbine pumps are addressed in Subsection 4.3.4.2 – Pumps (Turbine)
   d. Water Treatment is addressed in Subsection 4.4.1.6 – Water Treatment
2. General

a. Water of acceptable quality for a water-cooled condenser systems is in scarce supply in many areas of Saudi Arabia.

   (1) A life cycle cost analysis shall be performed to determine the overall cost effectiveness of a cooling tower system over air cooled condensing for refrigeration. The life cycle cost analysis shall include all cost associated with treating the water and disposing of blowdown.

b. Because of the environment in Saudi Arabia, cooling towers shall be constructed from stainless steel or fiberglass.

c. The A/E shall prepare a study regarding advantages using variable frequency drive fan for cooling tower against fixed drive fan. Variable frequency drive results in energy savings for the cooling tower cooling fan but fixed drive fan results in reduced power consumption for the chiller due to lower incoming condenser water temperature. In any case, energy-balance between the cooling tower and chiller shall be conducted to determine appropriate Cooling Tower "approach" and "range" for the given condenser heat dissipation.

d. Condenser water systems employing open cooling towers shall have side stream filtration to remove particulates from the condenser water. Side stream filtration systems shall filter between 5% and 10% of the total condenser water flow on each pass.

e. All sections of the piping system except the return line to the upper tower basin shall be kept below the basin level.

f. An approach of 4ºC to the design wet-bulb temperature is frequently considered an economically sound design for Saudi Arabia.

g. Piping from the tower sump to the pump is basically flowing due to gravity. The sump level shall be above the top of the pump casing for positive prime, and piping pressure drop shall be minimized such that there is always adequate net positive suction on the pump.

h. All sections of the piping system except the return line to the upper tower basin shall be kept below the basin level.

i. Confirm the water flow rate at the tower basin outlet does not exceed the manufacturer's recommended maximum to avoid vortex formation.

j. Piping to be sized for water velocities between 1.0 m/s and 2.5 m/s with maximum uniform friction loss of 400 pa/mtr.

k. When multiple cooling towers are to be connected; the piping shall be designed so that the pressure loss from the tower to the pump suction is exactly equal for each tower.

l. Provide adequate equalizing piping between sumps for multiple tower cells. Size equalizing piping liberally for gravity flow.

m. For tower arrangements with multiple cells, provide individual valving and level control for each cell so that any individual cell may be isolated for maintenance without completely interrupting the operation of all towers.

n. Variable flow nozzles shall be used for condenser water distribution above the cooling tower fill media to create a constant pattern of uniform water distribution thereby increasing cooling efficiency and reducing drift loss. Distribution piping shall be spaced accordingly to accommodate constant pattern of condenser water distribution.

o. Allowance for aging shall be considered as specified in section 4.2.7-Hydronic Heating and Cooling.

p. Closed circuit evaporative fluid coolers shall be used for hydronic heat pump and other systems water cooled unitary refrigeration equipment.

q. Where a condenser water system serves multiple pieces of refrigeration equipment, provide flow meters and balancing valves to assure the proper flow rate to each piece of equipment. Provide motorized isolation valves to modulate flow to each piece of equipment that may operate with variable flow, and to isolate refrigeration equipment when it is de-energized.

r. Refer to the applicable project specifications.

s. Refer to project drawings for HVAC standard details.

4.2.9 Variable-Refrigerant Flow Systems

1. General

a. Variable refrigerant flow (VRF) systems may be used in various applications, such as

(1) Multiple-tenant residential buildings

(2) Retail stores

(3) Hospitality centers, restaurants, banquet halls, hotels, and motels

b. Indoor units constantly react to changes in the zone cooling loads, and maintain conditions. The inverter compressors or combination of inverter and constant-speed compressors generally found in the VRF systems modulate refrigerant flow, and work in unison with the refrigerant volume required by the indoor units.

c. Ventilation air for a facility served by a VRF system should be provided by a direct outdoor air system.

d. VRF fan coil units should be equipped with MERV 8 filters.

e. The refrigerant expansion valve shall be a modulating valve responding to superheat at the refrigerant piping leaving the fan coil unit. Capillary tubes are not acceptable thermal expansion control devices.

f. An oil separator is recommended for all outdoor units.

g. For applications involving high occupant densities, select equipment with a “dry mode”, where the indoor unit fan operates at a low fan speed to keep the coil air flowing at sufficient capacity to remove moisture from the space without significantly lowering room temperature if the zone temperature drops below a designated set point shutoff.

h. VRF systems can utilize air-cooled or water-cooled condensers. Complete a life cycle cost analysis addressing all cost associated with purchasing and treating water, as well as with disposing of blowdown water prior to design a water-cooled system.

i. Consider a refrigerant-to-water heat exchanger for heating domestic service water.

j. Follow the VRF equipment manufacturer’s recommendations for refrigerant piping sizes and maximum to minimum vertical and horizontal lengths, based on refrigerant volumes and velocities required for efficient and stable system operation. System refrigerant charge is a calculated value, whereas additional charge is determined by liquid-line volume.

k. Given the complexities of integrating the operation of the indoor and outdoor units, the entire control package for the VRF system should be furnished by the VRF system manufacturer.

l. Safety Considerations for Refrigerants

(1) As with any HVAC equipment, VRF systems must include design and application safeguards that protect occupants. ASHRAE Standard 15 applies to the design, construction, testing, installation, operation, and inspection of mechanical refrigeration systems. This standard specifies safe design, construction, installation, and operation of refrigeration systems.

(2) Refer to ASHRAE Standard 34, which lists the most current information related to refrigerant designations, safety classifications, and refrigerant concentration limits (RCL). ASHRAE Standard 34 refers to common names of refrigerants used in HVAC systems, instead of using the chemical name, formula, or trade name. The standard establishes a uniform system for assigning reference numbers and safety classifications to refrigerants (including blends).

(3) The smallest space in which any of the indoor units or piping could be located must be capable of safely dispersing the refrigerant charge of the entire VRF system in the unlikely event of a catastrophic leak or failure. Examples of spaces that may require additional consideration include:

(a) Bathrooms

(b) Electrical rooms

(c) Closets

(d) Small offices

(e) Egress

(4) Several options are available to manage smaller spaces; however, care is needed not to violate other codes such as NFPA Standard 70. Options available to manage smaller spaces where the RCL would otherwise be exceeded include the following:

(a) Do not install an indoor unit, but allow the code-required ventilation to maintain conditions in the space.

(b) If cooling is required in the occupied space, one option is to increase the actual space volume by providing a permanent opening or connecting to an adjacent room, as described in ASHRAE Standard 15. A permanent opening can be included along the common wall between an electrical room and janitor closet to increase the size of the space; alternatively, install the ceiling high enough to provide the necessary volume, or omit the ceiling entirely.

(c) A ducted indoor unit could serve several smaller offices, thus increasing the overall occupied space served by the system.

(d) Central VRF systems can be subdivided into a series of smaller systems so that the total charge in a given system does not exceed the RCL limitations for a given space.

(5) System Expansion or Reconfiguration

(a) The modular nature of VRF systems lends itself to easy system expansion or reconfiguration as building needs change. During the design phase, consider any possible future or changing needs within the building envelope.

(b) VRF outdoor units can be upsized according to manufacturers' recommendations to anticipate supplementary indoor units without affecting the performance of initially installed indoor units. Indoor units can be added to the VRF system (up to the manufacturer's recommended limits) to address cooling needs in an adjacent space while the primary space is unoccupied. Indoor units can be exchanged for different models or capacities. Non-ducted indoor units such as ceiling cassette and wall-mounted units can be relocated within a given space as occupancy needs change.

(c) Indoor units are usually added, relocated, or exchanged with minimal disruption by simply reconfiguring indoor unit refrigerant piping, electrical wiring, control wiring, and drain piping. Note, however, that in some applications, piping sizes may change as capacity sizes change. Review manufacturer's recommendations on piping design and diversity parameters before performing any type of indoor unit installation or relocation.

m. Refer to the project specification for variable refrigerant volume HVAC systems.

n. Refer to project drawings for HVAC standard details.

4.2.10 Dust Collection Systems

1. General

a. Design all dust collection systems in strict accordance with Industrial Ventilation – A Manual of Recommended Practice, published by the American Council of Governmental Industrial Hygienists.

b. When collecting different types of dust in a single system, assure there is no fire or explosion danger when the materials mix.

c. If a facility has operations that require intermittent operation of the dust collection system and other operations that require round-the-clock operation of the dust collection system, consider providing two separate dust collection systems. Dust collection systems, due to the resistance of airflow in the ducts and the collectors, may be significant consumers of electricity. Having the option of shutting one of the systems off part time could save substantial energy.

d. Provide a full acoustical analysis for dust collection systems to assure objectionable sound levels will not result in the area where the collector is located, or in adjacent areas.

2. Collector Air to Cloth Ratio

   a. Recommended air to cloth ratio values vary depending on the dust material and the method of cleaning the collector.

      (1) For collectors with shaker and reverse air cleaning, acceptable air to cloth ratios range from 2 to 3.

      (2) For collectors with pulse jet cleaning, acceptable air to cloth ratios vary from 5 to 12.

3. Collector Cleaning

   a. Select the cleaning option that is best suited to the application and the budget

      (1) Shaker cleaning may be manual for small dust collectors, or motorized for larger collectors. Motorized shakers may be controlled to initiate automatically based on time intervals or pressure drop through a collector. Airflow is typically interrupted during the shaking process. This type of cleaning is the most economical, especially for small dust collectors.

      (2) Reverse air cleaning baghouse dust collectors are usually used in applications where hard dust cake would develop on the dirty side of the filter. These types of a dust collectors use fans to blow air in the opposite direction to remove the dust cake from the filter bag. These dust collectors are meant for continuous use and may clean without interrupting the production process. The pulse opposes and interrupts airflow for only a few tenths of a second.

      (3) Pulse jet cleaning uses compressed air to force a burst of air down through the bag and expand it violently. The filters maybe cleaned one row at a time, so an entire dust collector does not have to have airflow interrupted for cleaning.

   b. Provide clear space beneath the collector for a storage container to collect the dust filtered by the collector. Provide a clear access path to remove the storage container from the facility. If the dust material is hazardous, provide a path for container removal that does not present a hazard for building occupants.

4. Fire and Explosion Protection

   a. If the dust material offers any risk of fire or explosion, provide fire suppression to protect the inlet ducts at the collector and explosion venting for the collector.

      (1) Chemical suppression is preferred.

      (2) For collectors located outdoors, direct explosion venting in a safe direction away from buildings or personnel. For collectors located indoors, direct the explosion venting through the roof in a direction that will not be a threat to other buildings or personnel. The collector shall be located so that the explosion vent is within 1.5 m of the roof.

5. Fan Selection

   a. Provide complete duct pressure drop calculations for review by the Entity.

   b. Account for system effect at the fan inlets and outlets

   c. Select fans with at least a 20% safety factor for the fan total pressure.

   d. Fans shall be capable of material handling.

      (1) Radial Blade centrifugal fans are preferred.

   e. Provide variable frequency drives for duct collector fans 3.75 kW and larger.

6. Ductwork

a. Dust collection ductwork shall be round to so that uniform velocity is maintained over the entire cross section of the duct.

b. Size duct and duct hangers based on an assumption of 10% fill in the bottom of the duct from dust that dropped out of entrainment in the airstream.

c. If the dust material offers any risk of fire or explosion, the ductwork material must be of spark proof construction.

d. Fans for systems handling dusts that present an explosion hazard shall be Type A spark resistant construction.

7. Refer to the project specification for dust collectors.

8. Refer to project drawings for standard HVAC details.

4.2.11 District Cooling and Central Plant Systems

1. Reference to other sections of the Mechanical Design Guideline:

   a. Redundancy is addressed in Subsection 4.1.14 – Redundancy

   b. Hydronic heating and cooling is addressed in Subsection 4.2.7 – Hydronic Heating and Cooling

   c. Condenser Water systems are addressed in Subsection 4.2.8 – Condenser Water Systems

   d. Boilers are addressed in Subsection 4.3.2.1 – Boilers

   e. Conventional chillers are addressed in Subsection 4.3.3.2 – Chillers (Vapor Compression)

   f. Absorption chillers are addressed in Subsection 4.3.3.3 – Chillers (Absorption)

   g. Cooling towers are addressed in Subsection 4.3.3.4 – Cooling Towers

   h. Centrifugal Pumps are addressed in Subsection 4.3.4.1 – Pumps (Centrifugal)

   i. Turbine pumps are addressed in Subsection 4.3.4.2 – Pumps (Turbine)

   j. Heat exchangers are addressed in Subsection 4.3.4.4 – Heat Exchangers

   k. Water Treatment is addressed in Subsection 4.4.1.6 – Water Treatment

2. General

   a. District cooling systems are most applicable when used in areas where the thermal load density is high and the annual load factor is high. Both conditions will exist in many areas of Saudi Arabia. A high load density is needed to cover the capital investment for the transmission and distribution system, which usually constitutes most of the capital cost for the overall system, often ranging from 50 to 75% of the total cost for district cooling systems.

   b. The central plant may be any type of chiller system (or thermal energy). Combined heat and power (CHP) plants have a high energy-utilization efficiency. If natural gas is available, electricity could be produced by a gas-fired turbine generator. The exhaust from the turbine could pass through a waste heat boiler which could produce high pressure steam.

   c. Chilled water may be produced by:

      (1) Absorption refrigeration machines utilizing waste heat sources

      (2) Electric-driven compression equipment (reciprocating, rotary screw or centrifugal chillers). Centrifugal chillers shall be given preference from all refrigerant compression type chillers due to maximized efficiency, higher availability of capacity, and smaller footprint. The A/E shall provide justification if an alternate chiller type is proposed.

      (3) Gas and/or steam turbine or engine-driven compression equipment.

      (4) Combination of mechanically driven systems and thermal-energy-driven absorption systems.

d. The distribution or piping network that conveys the energy is often the most expensive portion of a district cooling system. The piping usually consists of a combination of pre-insulated and field-insulated pipe in both concrete tunnel and direct burial applications.

3. Economic Analysis

a. Provide a complete life cycle cost for the Entity to demonstrate the feasibility of a district energy system.

b. A larger central plant may achieve higher efficiencies than the sum of several smaller plants. Partial load performance of central plants may be more efficient than that of many isolated, small systems because the larger plant may operate one or more capacity modules as the combined load requires and may modulate output. Central plant systems shall operate at 0.51 kw/ton efficiency.

c. District energy systems are typically highly reliable and rarely have outages. Mature systems typically have reliability values greater than 99.98%.

d. Construction cost for the local construction environment and site conditions such as these cited below need to be considered:

(1) Labor rates

(2) Distance to ship equipment

(3) Permits and fees

(4) Local authorities and regulations

(5) Soil conditions

(6) Quality of equipment and controls

(7) Availability of materials

(8) Size of distribution piping system

(9) Type of insulation or cathodic protection for buried and above-ground piping system

(10) Type of distribution system installation (e.g., direct buried, tunnel)

(11) Distribution system depth of burial and restoration of existing conditions (e.g., city streets, green areas)

(12) Distribution systems below-grade conflict resolutions

(13) Economies of scale

(14) Capital costs

(15) Energy and utility costs

(16) Operations and maintenance costs

(17) Energy and resource usage

4. Central Utility Plant

a. The chilled-water supply temperature shall range from 4.5°C to 7°C. Chilled water return temperatures shall be set as high as practical to minimize the quantity of chilled water circulated in the system. The minimum temperature difference between chilled water supply and return shall be 8.3°C resulting in a flow rate of 0.13 lps/ton of refrigeration.

b. Consider thermal storage for district chilled water systems. Thermal storage may reduce chiller equipment requirements and lower operating costs by shifting part of the chilling load.

c. Both ice and chilled-water storage have been applied to district-sized chiller plants, however stratified chilled water is much more common as a thermal storage medium and is preferred.

d. The expansion tank for the entire system shall be located in the central plant building. Recognize that operating pressure will be lower than fill pressure, so the system requires a pressure reducing valve for initial fill which will be valved off after fill is complete and all air is purged, and then a second pressure reducing valve set at a lower operating pressure to account for the contraction of the chilled water as it cools.

e. On large chilled-water systems, consider a makeup water pump to overcome water loss. Control the pump from level switches on the expansion tank or from a desired pump suction pressure.

5. Distribution Design Considerations

a. The water distribution system shall be variable primary pumping system. Control valve shall be selected with differential pressure and pressure rating suitable for the anticipated maximum operating pressure and differential pressure. Primary/secondary pumping shall be allowed based on the provision as stated in section 4.2.7-Hydronic Heating and Cooling System.

b. Primary/secondary pumping system with distributed secondary pumping may be used for complex that contains multiple low rise to medium rise buildings, where the same contractor will install and commission the hydronic system. Liability for contamination of the hydronic system due to improperly flushed piping system shall reside only to one contractor. For this approach, the distribution pumps in the central plant are eliminated and relocated to the buildings, so all the electrical energy is borne by the pumps in the user buildings. When this approach is utilized, consider future system loads carefully when sizing the building pumps, so the pumps may properly share the pumping duty as the overall system flow rate increases in the future.

c. For systems with high rise buildings, account for the static head the tall buildings will create on the system. Consider using plate and frame heat exchangers in tall buildings to prevent the static head of the tall buildings from being imposed on the entire system. Pressure relief lines shall be provided upstream of the heat exchanger to protect the primary network from over pressure in-case of any heat exchanger damage.

6. Hydraulic Considerations

a. For systems with large distribution networks, model the flow hydraulics with a computer modeling program.

b. Distribution pipe sizing shall be based on a maximum friction loss of 400 Pa/ m of pipe. Velocity in piping shall not exceed 4.6 m/s in any case.

c. Use aging allowance for metallic piping as specified in section 4.2.7- Hydronic Heating and Cooling System.

7. Thermal Considerations

a. All piping shall be insulated in accordance with ASHRAE Standard 90.1.

(1) No insulation system is totally water and vapor tight.

(2) Corrosion may be minimized by making the insulation system highly water resistant by using a closed-cell insulation material coupled with a high-performance vapor retarder, and painting the pipe exterior with a strong rust-preventative costing (two-cost epoxy) before insulating. In addition, a good vapor retarder is required on the exterior of the insulation.

(3) Underground piping shall be a pre-engineered double-wall material with closed cell foam insulation between the carrier pipe and the outer pipe, and water proof joints.

b. Provide adequate means of expansion and contraction compensation.

8. Distribution System Construction

a. Provide access ports for underground systems at critical points, such as where there are:

(1) High or low points on the system profile that vent trapped air or where the system may be drained.

(2) Elevation changes in the distribution system that are needed to maintain the required constant slope.

(3) Major branches with isolation valves

b. Gravity venting of tunnels is good practice, and access ports and tunnels shall have lighting and convenience outlets to aid in inspection and maintenance of piping elements.

9. Leak Detection

    a. Techniques for leak detection vary from periodic pressure tests on the piping system to installing a sensor cable or wire along the entire length of the piping to continuously detect and locate leaks. Periodic pressure tests are most common.

10. Valve Vaults and Entry Pits

    a. The optimum number of valve vaults is that which affords the lowest life-cycle cost and still meets all design requirements, typically around 100 m. apart but usually no more than 150 m apart in the absence of other requirements, such as isolation valves for a building service.

11. User Interface

    a. The connection of a district energy system to a building is commonly called an energy transfer station (ETS).

    b. Provide a dielectrci isolation flange at the ETS to preserve system pipe integrity.

    c. Consider a plate and frame heat exchanger at the ETS for high rise buildings to prevent imparting the tall building static pressure head on the entire district system. This may prevent the requirement and associated cost of rating the entire distribution system for a higher pressure.

        (1) If water quality and the potential fouling of a heat exchanger is a concern provide two heat exchangers so that one may be removed from service for cleaning while the other heat exchanger remains in operation.

    d. Provide flow and temperature measurement devices at each ETS for assigning costs to each customer.

    e. For mid-rise and high rise building, negotiate with the district cooling provider to locate the ETS midway of the zoning distance instead of the basement level to reduce power requirements for pumping, considering the effect of the static head to the pressure rating of the district cooling equipment.

12. Control Valves

    a. All control valve actuators shall take longer than 60 seconds to close from full open to mitigate pressure transients or water hammer which occurs when valves slam closed. Actuators shall also be sized to close against the anticipated system pressure so the valve seats are not forced open, thus forcing water to bypass and degrading temperature differential.

    b. Electronic control valves shall remain in a fixed position when a power failure occurs and shall be manually operable. Pneumatic control valves shall close upon loss of air pressure.

    c. Avoid oversizing control valves as this limits flow control.

13. Refer to the applicable project specifications.

14. Refer to the project drawings for standard HVAC details.

4.2.12 Demand Control Ventilation

1. Reference to other sections of the Mechanical Design Guidelines:

    a. Air Distribution is addressed in Subsection 4.2.2 – Air Distribution System

    b. Chilled Beams are addressed in Subsection 4.2.3.3.d – Chilled Beam System

    c. BMS is addressed in Subsection 4.2.13 – Building Automation System

    d. Duct Construction is addressed in Subsection 4.3.1.1 – Duct Construction

    e. CAVs and VAVs Boxes are addressed in Subsection 4.3.1.2 – Room Distribution Equipment

f. Fans are addressed in Subsection 4.3.1.3 – Fans

g. Energy Recovery Equipment are addressed in Subsection 4.3.1.8 – Air to Air Energy Recovery Devices

h. Make-up Air Units are addressed in Subsection 4.3.1.10 – Make-up Air Units

2. Dedicated Outdoor Air System (DOAS) Application

a. Control of DOAS terminal VAV Boxes in the supply to regulate air flow shall be thru the use of CO2 sensor (for densely occupied space) or occupancy sensor (for non-densely occupied space). System control shall be dynamically reset to maintain CO2 concentration to 500 ppm and provide an alarm for the space if the concentration reaches 1000 ppm. VAV Boxes exhaust air rate for densely occupied space shall be balance with the supply air to maintain space pressurization required by the Standard. CO2 sensors shall be located at 3 to 6 ft. above the floor. For non-densely occupied space (below 25 person per 1000 ft.2) using occupancy sensor, control system shall dynamically reset to regulate the VV Boxes from the minimum ventilation requirements for the space pressurization (during unoccupied time) to the minimum requirements of AHSRAE Standard 62.1 for the occupants ventilation.

b. Heat Recovery Wheel (HRW) shall be used to promote energy and mass exchange between the fresh air and exhaust air therefore reducing energy consumption for conditioning the fresh air during summer and winter. HRW Effectiveness shall be the highest current available in the market.

c. Refer to Subsection 4.1.8 and 4.1.9 for outdoor air off-coil design condition during summer and winter season when DOAS is coupled with convective mixed-air cooling equipment.

d. For DOAS coupled with Radiant Type Cooling Equipment (e.g. chilled beams and ceilings), wrap-around heat pipes shall be used after the HRW discussed in item b above to further reduce cooling requirements of the cooling coil and to provide reheat for the fresh air to exceed the room dew point temperature, therefore avoiding condensation. Cooling coil off-coil condition shall be low enough to satisfy latent load demand and regulate the quantity of fresh air required.

3. Centralized Kitchen Exhaust Air Application

a. Control of individual kitchen hood exhaust requirements shall be thru the hood supplier own control system. Exhaust rates are normally regulated by the use of temperature sensor along the hood collar and infrared or optic sensor along the hood capture face. Fresh air supply are normally distributed along the ceiling and hood front face (or front perimeter bottom slots) and regulated by VAVs for group or zone of hoods. For multiple groups of kitchen hoods, close coordination between the hood controllers and the Building Management System controllers are required to maintain balance of air flowrates between the exhaust and fresh air. Fresh air flowrate is always maintained 10% less than the exhaust rate within the kitchen area and the difference in flowrate is supply in the area adjacent to the kitchen to maintain negative pressure in the kitchen.

4.2.13 Building Automation (Management) System

1. Data Point Schedule, Process and Instrumentation Diagram, and Sequence of Operation

a. The A/E shall provide a Particular Specification which contains requirements for the system architecture, system capacity, redundancy, data storage, expandability, Ethernet speed, etc. The Specification shall contain the Data Point Schedule required for the project for the control and monitoring of HVAC System, monitoring of Electrical Equipment, and monitoring of other Building Services Equipment.

b. The BMS Particular Specification shall include integration requirements for other Building Services Systems such as Lighting System, Security and Access Control, Wireless Network, Data Infrastructure, and Fire Alarm System.

c. The HVAC design plan shall include P&ID (Process and Instrumentation Diagram) and SOO (Sequence of Operation) for the HVAC Equipment, water distribution, and air distribution system.

d. The BMS System shall be properly commissioned, fine-tuned, and optimized. All pertinent commissioning document witnesses, verified, and signed by the Commissioning Authority and the Project Management shall be submitted as a proof for compliance.

2. Building Automation System Architecture

a. The building automation and control networking protocol shall be truly open, standard, interoperable, integrated architecture, in full conformance to current ANSI/ASHRAE 135.

b. The system must be fully BACnet compliant which means that the system must use BACnet as the native communication protocol between clients and servers on the network. The system should be duly listed as FM/UL listed for building control system package.

c. A web server with a network interface card shall gather data from this system and generate web pages accessible through a conventional web browser on each PC connected to the network.

d. Operators shall be able to perform all normal operator functions through the web browser interface.

e. The control system shall consist of a high-speed, peer-to-peer network of DDC controllers and a web-based operator interface.

f. Schedules, setpoints, trends and alarms specified as per sequences of operation shall be BACnet objects.

3. BACnet Device Object Naming Conventions

a. Device Object Naming Convention Plan (DONCP)

(1) The BAS manufacturer shall submit a BACnet Device Object Naming Convention Plan to the Entity.

(2) The DONCP shall be designed to eliminate any confusion between individual points in a facility wide EMCS system.

(3) It shall be designed for future expansion and consistency.

(4) Each device on a BACnet internetwork (including other manufacturer's devices) must have a unique device instance.

4. BACnet Addressing

a. Three types of addresses are important in the BACnet system, though all three can be thought of as addresses, they are very different, both in how they function and how they are assigned, they are as follows:

(1) Network Numbers – identify the network to which a BACnet device belongs. Every network on a BACnet LAN has a unique numerical identifier, a network number. This network number shall be used by BACnet devices only; it shall not rely on, nor does it affect any other network protocols. LANs connected by a router must have different network numbers. No interconnected BACnet network can have the same network number.

(2) Media Access Control (MAC) Addresses

(3) Device Instances

5. System Performance

a. Performance Standards

(1) System shall conform to the minimum standards over network connections.

(2) Systems shall be tested using manufacturers recommended hardware and software for server and browser for web-based systems (or operating workstation).

6. Communication

a. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork.

b. Use existing Ethernet backbone for network segments marked existing on job project drawings.

7. Operator Interface

a. BACnet system shall be accessed anywhere on the network, through standard browser interface. View a graphical menu system and dynamic color graphic screens that paint a picture of conditions throughout the facility.

b. Acknowledge alarms; track personnel; open and close controlled doors; adjust setpoints and comfort levels; turn lighting and equipment on and off; run reports; modify schedules; make and edit personnel records; and access pop-up windows of live trend data and event logs through one efficient interface.

c. Web browsing functionality shall be added to even the smallest existing system with ease, using the same graphic displays, user profiles and system database as a standard.

8. System Software

a. Operating System

(1) Web server shall have an industry-standard professional-grade operating system

(2) Acceptable systems shall be Microsoft compatible (version to be determined by the Entity).

9. Controllers

a. Provide Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required.

10. BACnet Communication

a. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.

b. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.

11. Controller Software

a. Shall reside and operate in system controllers.

b. Shall be editable through operator workstation, web browser interface, or engineering workstation.

12. Input and Output Interface

a. Hard-wire input and output points to BCs, AACs, ASCs or SAs.

13. Web Server

a. Web servers shall provide the interface between the LAN or Wan and the field control devices, and provide global supervisory control functions over the control devices connected to the web servers.

b. Web servers shall provide interface between BACnet based automation systems and popular color-graphic web pages that can dynamically display BACnet information.

c. Web servers shall support both a VNI (Virtual Network Interface) and RNI (Remote Network Interface) to ensure that an open solution is being provided and to ensure that the Entity has flexibility and choice for future network upgrades and additions.

14. Web Browser

a. Browser technology shall have the ability to interface with facility system from any on-line PC.

b. System shall be capable of supporting a minimum of 20 simultaneous client connections (or otherwise requested by the Entity) using standard Web browser such as Internet Explorer.

c. Web browser software shall run on any operating system and system configuration that is supported by the Web browser.

15. Power Supplies and Line Filtering
    a. Wiring and Raceways
        (1) Provide copper wiring, plenum cable, and raceways as specified in applicable sections of NEC.
        (2) Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service (local ambient temperatures shall also be considered).
    b. Fiber Optic Cable System
        (1) Optical cables shall be duplex, tight-buffer construction designed for intra-building environments.
        (2) Sheath shall be UL listed OFNP (Optical Fiber Nonconductive Plenum) in accordance with NEC Article 770.
        (3) Optical fiber shall meet the requirements of FDDI (Fiber Distributed Data Interface), ANSI X3T9.5 PMD (Physical Medium Dependent Layer) for 62.5/125mm.
    c. UPS
        (1) Uninterruptible Power Supply shall be required for Building Controller(s), and Application Controllers that monitor emergency equipment, if Normal/Emergency Power is not available in the building.
        (2) UPS back up time shall be 1 hour.
16. Refer to the applicable project specifications for control systems.

4.3 HVAC EQUIPMENT AND ACCESSORIES

4.3.1 Air Handling Equipment and Accessories

4.3.1.1 Duct Construction

1. All duct construction should be in strict accordance with the requirements of SMACNA. The applicable SMACNA standard shall depend on the service, operating pressure and application. Clearly specify the pressure class and seal class for each duct system so there is no misunderstanding on the part of the sheet metal fabricator regarding the duct pressure requirements.
2. Calculate the percent leakage based on the specified pressure and seal classes and include the calculated leakage percentage in the specifications.
3. Clearly specify the insulation requirements for duct systems.
    a. External insulation is strongly preferred over internal lining to avoid problems with the harboring of bacteria, dust and mold in the airstream.
4. Show all duct accessories such as balancing dampers, fire dampers, motorized fire/smoke dampers, access doors, etc. required for code compliance and proper operation of the systems. Relying on drawing notes and specification clauses to cover these items is not acceptable.
5. For exhaust of corrosive fumes, provide the proper duct construction (the proper grade of stainless steel or non-ferrous material) to avoid deterioration due to corrosion of the duct.
6. Provide fire dampers, smoke dampers and combination fire/smoke dampers in strict accordance with the Saudi Building Code (SBC), the Saudi Building Code (SBC 501-Mechanical Requirements) and NFPA Standard 90A.
    a. Coordinate smoke damper and combination fire smoke damper control with the building fire alarm system and the building automation system.
7. Refer to the applicable project specifications.
8. Refer to the project drawings for standard HVAC details.

4.3.1.2 Room Air Distribution Equipment

1. Select constant volume, variable volume, and fan powered terminals within the controllable flow range published by the manufacturer
    a. Schedule each terminal unit for a project individually, listing all performance criteria including maximum and minimum airflow, static pressure drop through the terminal at maximum airflow, inlet duct size, sound criteria, heating capacity of the terminal has a reheat coil, and fluid flow and temperature for the reheat coil.
    b. Select terminals within the flow ranges listed by the manufacturer for each terminal size. The maximum design flow for a given terminal shall not exceed 80% of the manufacturer's published maximum flow. Minimum flow shall not be less than the manufacturer's listed minimum controllable airflow.
        (1) Many manufacturers list 0.0 lps as the minimum airflow for their terminals, but this indicates that the terminal can be modulated to shut-off. Manufacturers also list a minimum controllable airflow range, and the minimum design airflow for a given terminal shall not be less than the minimum value in that listed range.
    c. Refer to the project specification for air terminal units, single & dual duct and fan-powered
    d. Refer to project drawings for standard HVAC details.
2. Select room air inlets and outlets with careful consideration to uniform air distribution, low resistance to airflow, and acceptable sound generation.
    a. The direction of air flow into a room shall be toward the faces of the occupants whenever possible. Air flow from the side may be acceptable under extenuating circumstances. Under no circumstances shall there be air flow toward the backs of occupants.
    b. Air distribution shall be as uniform as possible. In no case shall temperature variation in the air conditioned space exceed 1°C.
    c. Minimum room air movement shall be 0.1 m/s. Air outlets shall be provided proper throw, drop and spread at or above the 0.1 m/s.
    d. The air conditioning system sound generation shall be within the limits established in Subsection 4.4.1.4 – Noise Control.
    e. Location of air distribution devices shall be coordinated with the architectural features of the space, such as columns, doors and windows.
    f. For uniformly distributed loads, supply outlets shall be distributed uniformly within range of their throw as published by the manufacturer.
    g. Where heating loads are of the concentrated type, supply outlets shall be located near the source. Air around high heat load equipment shall be returned through grilles located near the equipment, to avoid mixing with room air.
    h. Supply and return outlets shall be located to obtain complete coverage of the entire space. There shall be no short circuiting between supply and return outlets.
    i. Refer to the applicable project specifications.
    j. Refer to project drawings for standard HVAC details.

4.3.1.3 Fans

1. In general, fans for HVAC applications should be centrifugal fans or vane axial fans with airfoil blades for maximum efficiency.
    a. Centrifugal fans with radial blades can be used for material handling applications where airfoil blades may clog from the materials in the airstream.
    b. Vane axial fans are preferred over centrifugal airfoil when space is restricted. Vane axial is highly compact than centrifugal air foil for the same duty. Any type of axial fan shall not be used in VFD or fixed speed application when sudden large air flow variation can occur.
    c. Propeller fans may be used for through-the-wall exhaust ventilation of unconditioned spaces.

2. Arrayed fan arrangement (Fan Wall Technology) are preferred for AHU where reliability and redundancy is of a major concern (e.g. healthcare). For some application, arrayed fan arrangement has less power requirements due to low noise operation which results in elimination of sound attenuators. Direct drive between motor and fan eliminate slips with belt driven centrifugal fans.
3. For a given air volume flow rate and static pressure, fans of several sizes may provide the desired performance. Larger fans operate at slower speeds and higher static efficiencies, and therefore require less power than smaller fans. Select fans for maximum static efficiency, which will generally result in selecting the larger fan for a given application.
4. The following criteria should be considered in fan selection, and should be included in the fan schedule in the construction documents:
    a. Air volume flow rate (lps)
    b. Static pressure (Pa)
    c. Fan type
    d. Drive type
    e. Fan class
    f. Number of fans in series
    g. Air density (temperature and altitude)
    h. Type of service (supply, return lab exhaust, toilet exhaust)
    i. Noise criteria
    j. Discharge direction
    k. Fan rotation
    l. Motor position/arrangement
5. Wherever possible, direct drive fans should be used.
6. Fans larger than 3.75 kW should be controlled through a variable frequency controller.
7. Fans should be carefully selected to operate close to their maximum efficiency condition.
8. Consider system effect in accordance with AMCA Fans and Systems Publication 201 when selecting fans.
9. Provide a graphical analysis of the system curve vs. the fan curve for all fans to illustrate the overall performance.
10. For fans operating in parallel, graph the parallel fan operation fan curve(s) for the maximum number of fans that will be operating simultaneously with the system curve to determine the actual performance of the combined group of fans.
11. Account for duct leakage in fan selection.
12. Total fan power requirements for any given project should be in accordance with the limits set forth in ASHRAE 90.1 – Energy Standard for Buildings except Low-Rise Residential Buildings.
13. Provide vibration control in accordance with Subsection 4.4.1.5 –Vibration Control.
14. Refer to the applicable project specifications:
15. Refer to project drawings for standard HVAC details.

4.3.1.4 Humidifiers

1. For hospitals, laboratories and similar facilities requiring wide area humidity control, provide humidifiers mounted in the central air handling units.
2. For areas where isolated humidity control is required, such as in libraries and museums, booster cooling coils, humidifiers, and reheat coils shall be installed in the duct work supplying air to these specific areas.
3. Humidifiers shall be steam dispersion type. Humidifiers that rely on evaporation of water directly in the airstream (ultrasonic) should not be used due to the water quality in Saudi Arabia. For point-of-

use humidifiers, type shall depend on water quality supplied to the unit. Use electric resistance humidifiers for pure water make-up (RODI water and the like) and use electrode type for normal water make-up.

4. Select the humidifier for the specific application, including airflow and air temperature.
5. Account for the impingement distance when determining the placement of a humidifier in an air handling unit or supply air duct. Allow the manufacturer's recommended impingement distance plus 300 mm wherever possible between the humidifier and downstream obstructions in the duct or air handling unit.
6. Specify the modulating humidifier control valve to be supplied with the humidifier by the humidifier manufacturer.
7. Provide a separate motorized two-position on-off control valve upstream from the manufacturer's modulating control valve to provide positive shut-off when additional humidity is not required. The manufacturer's valves do not provide tight shut-off.
8. Pay careful attention to the manufacturer's requirements for steam condensate drainage from the humidifier, and condensate trapping. Condensate must drain by gravity from the humidifier. Do not try to lift the condensate with steam pressure to a drain location.
9. Coordinate carefully the path for condensate drainage from duct mounted humidifiers. Condensate drainage is frequently a problem with duct mounted humidifiers, and the coordination of the drain piping route must not be left to the construction team. It must be part of the design.
10. The section of duct or the air handling unit section in which the humidifier is mounted shall be constructed from Type 304 stainless steel and must have a drain leading to a floor drain or a sanitary safe waste. Refer to the project drawings for standard HVAC details.
11. Refer to the applicable project specifications.
12. Refer to project drawings for standard HVAC details.

4.3.1.5 Air Cooling Coils

1. Finned Cooling Coils-Chilled Water Type
    a. Cooling coils shall be selected for the specific application of air velocity, entering and leaving air conditions, entering and leaving fluid conditions and maximum air and fluid pressure drops. Selections shall be made utilizing a manufacturer's computerized coil selection program.
    b. In general, it is desirable to maximize the cooling fluid temperature rise in a cooling coil. This minimizes pumping energy and typically maximizes the chiller efficiency. Temperature rises of 9ºC at maximum airflow and peak outdoor conditions are achievable in hot, humid climates. That should be the goal.
    c. The face velocity of air through cooling coils shall not be less than 1.75 m/s and not more than 2.25 m/s. Face velocities higher than 2.25 m/s increase moisture carryover, while velocities lower than 1.75 m/s increase the dehumidification effect and cost of the coil.
    d. Coils shall be selected to attain the required capacity with the lowest air pressure drop possible.
    e. Coil rows shall be even and shall be selected from the manufacturer's data to give the required cooling capacity and sensible heat ratio. Maximum cooling coil depth shall be 10 rows to facilitate cooling.
    f. No more than 10 fins per 25 mm shall be used.
    g. Where more than two sections are required, coils with the maximum tubes across the face shall be selected to reduce the number of sections and piping cost.

       For multiple vertically stacked sections, provide valves for balancing the coil sections with parallel fluid flow.
    h. Coils using any other cooling medium (brine or well water) except clean water shall have cleanout plugs at both ends of every tube on the headers, to permit cleaning at regular intervals.

i. Refer to the project specification for air coils

j. Refer to project drawings for standard HVAC details.

4.3.1.6 Finned Cooling Coils-Direct Expansion Type

1. When selecting cooling coils of the direct expansion type, the following factors of performance, size, and design which must be considered in relation to intended use:

   a. The face velocity of air through a cooling coil shall not be less than 1.75 m/s and no more than 2.25 m/s. Face velocities, in the higher range increase moisture carryover, while in the lower range they increase the dehumidification effect and cost of the coil.

   b. Coils shall be selected to attain the required capacity with the lowest air pressure drop possible.

   c. The number of rows selected shall be based on consideration of evaporating temperature to give required cooling capacity and sensible heat ratio. For a given coil performance, reducing the number of rows will necessitate lower evaporating temperature.

   d. An even number of rows shall be provided so that inlet and outlet connections shall be on the same end of the coil. No more than 10 fins per 25 mm shall be used. If additional rows are required to achieve the desired laving air conditions, multiple coils in series shall be used. Provide adequate space upstream and downstream of each coil for cleaning.

   e. Cooling coils shall be selected so that a coil and compressor combination will have the required cooling capacity at their respective suction pressures. The system will then balance at the designed suction pressure.

   f. The suction pressure or the corresponding evaporator temperature shall depend on the sensible heat ratio of space to be conditioned, and shall be determined from the manufacturer's data.

   g. The capacity versus suction pressure shall be plotted for a compressor and coil to find the balancing suction pressure curves. If the curves are not available from the manufacturer, they shall be developed from manufacturer's equipment data.

   h. When compressors are provided with step capacity regulation, cooling coils shall be divided into multiple sections so that each section will be equal to a compressor capacity step. Where an installation has more than one compressor, the minimum number of cooling coil sections and the cooling capacity of each shall be the same as that of the compressors. This arrangement will provide a positive method of dividing the load among the compressors and will also permit step capacity regulation. Each coil section shall be provided with its own expansion valve and distribution header.

   i. Both fins and tubes shall be made from copper to prevent corrosion on condenser coils, and evaporator coils shall be seamless copper tubing with copper fins. Phenolic shall be applied at a dry film thickness of 75 microns.

   j. When using packaged air conditioning units, the selected units shall meet both sensible and total heat loads. The unit manufacturer standard rated air quantity shall be used for sizing the fan motor, ductwork and related appurtenance.

2. Refer to the project specification for air coils.

3. Refer to the project drawings for standard HVAC details.

4.3.1.7 Dehumidifiers and Related Components

1. Dehumidification shall be provided where control of room humidity or removal of moisture is the main consideration; for example, in dehumidified warehouses used for preservation and long term storage of materials

2. The dehumidifiers shall be a dual bed, dry desiccant type. The total installed capacity shall be 1.5 to 2 times the calculated normal operating load, to provide capacity for initial pull-down and some standby capacity after pull-down. The lower factor of 1.5 shall be used where the space has two or more machines, and the higher factor of 2 shall be used when the operating load requires only one machine.

3. The capacity factors listed above must also be applied to regeneration capacity.
4. Proper air filtering must be provided upstream from all dehumidification. Upstream filtering should be minimum MERV 10.
5. Account for the air pressure drop through the dehumidification, as well as for dirty filter pressure drop in the fan system design.
6. It is recommended that bypasses be provided around dehumidification where the system is also used for other HVAC purposes, so that the dehumidification can be bypassed when not required to reduce fan energy requirements.
7. Provide highest quality temperature and humidity sensors upstream and downstream of dehumidifiers and regeneration systems. Accurate sensing is critical to proper functioning of the equipment
8. Provide complete graphical psychrometric analysis for all dehumidification and regeneration.
9. Refer to the project specification for room dehumidifiers.
10. Refer to project drawings for standard HVAC details.

4.3.1.8 Air-to-Air Energy Recovery Devices

1. Provide exhaust air energy recovery in accordance with the requirements of ASHRAE Standard 90.1. Provide exhaust air energy recovery when the system air volume flow rate exceeds the limit established by the Standard. Exhaust air energy recovery systems shall meet the minimum efficiency requirements of the standard.
2. Air-to-air energy recovery devices shall be refrigerant phase-change heat pipes (wrap around heat pipes) for the purpose of reducing the sensible load for DOAS (Dedicated Outdoor Air System) AHU while providing reheat to exceed the room condition dew point temperature. Heat Pipe can also be used for recirculating AHU to reduce cooling requirements if reheat is required after the cooling coil for high latent load application. Heat wheels are the most recommended type of air-to-air energy recover due to the highest efficiency it can offer by recovering both sensible and latent energy, and applicable for general application. For hospital and other critical application, consider the use of pleated-type air-to-air energy recovery for sensible recovery if heat wheels are unacceptable due to cross-contamination issues.
3. Filtering equivalent to MERV 10 must be provided upstream from all air-to-air energy recovery devices, both in the make-up airstream and the exhaust airstream.
4. Consideration should be given to evaporating the cooling coil condensate in the exhaust airstream upstream of the heat recovery coil. This will lower the exhaust air temperature prior to entering the exhaust heat recovery coil and can significantly increase the overall efficiency of the heat recovery system.
5. Provide temperature sensors upstream and downstream of heat recovery coils in both the exhaust airstream and the supply airstream to control the operation of the heat recovery and to calculate the real-time energy being recovered. Calculation should include instantaneous and cumulative energy recovered.
6. In the life cycle cost analysis for the air-to-air energy recovery devices, account for the air pressure drop of the energy recovery device and the air filter in the fan selection.
7. All air-to-air energy recovery system shall incorporate a by-pass when the ambient condition is close to the room air exhaust condition, since energy recovery at this point is minimal.
8. Refer to the project specification for air-to-air energy recovery units.
9. Refer to project drawings for standard HVAC details.

4.3.1.9 Air Heating Coils

1. Heating is used in very limited number of applications in Saudi Arabia. Heating coils will primarily be:
    a. Residential heating coils that will be part of a heat pump system. In this application, the indoor coil will serve as the evaporator coil during cooling and the condenser coil during

heating. Therefore the coil design should be in accordance with Subsection 4.3.1.5 – Air Cooling Coils.

b. Outdoor air preheat coils for hospital, laboratory and other similar applications where large quantities of outdoor air are introduced. Given the climate and the hours of operation per year, these coils can be electric preheat coils. Given the nature of the application, the coils should be tubular sheath electric resistance coils. The potential for sand entering the intake would preclude the use of open elements that could build-up on the element and finned sheath coils where the fins could clog with sand.

   (1) Assure that an electric disconnect switch is within close proximity to the coil.

   (2) Control should be silicon controlled rectifier (SCR) or solid state relay (SSR) for infinite control staging. Step control will not react fast enough for the sheathed element to provide the necessary temperature control stability.

   (3) The coils should be protected by minimum MERV 10 filters upstream.

c. Reheat coils for hospital, laboratory and similar applications where reheating of minimum air change or make-up air is required. These coils can be electric or hydronic hot water coils.

   (1) Electric coils may be open element or finned sheath. Assure that an electrical disconnect is within close proximity to the coil. Control should be silicon controlled rectifier (SCR) or solid state relay (SSR) for infinite control staging and proper response and temperature stability.

   (2) Hydronic coils shall be copper tubes and copper fins. Hydronic hot water temperature should not exceed 60ºC.

d. Refer to the project specification for air coils.

e. Refer to project drawings for standard HVAC details.

4.3.1.10 Make-up Air Units

1. Reference to other sections of the Mechanical Design Guidelines:

   a. Fans are addressed in Subsection 4.3.1.3. – Fans

   b. Air cooling coils are addressed in Subsection 4.3.1.5 – Air Cooling Coils

   c. Energy recovery is addressed in Subsection 4.3.1.8 – Air-to-Air Energy Recovery Devices

   d. Air Filtration is addressed in Subsection 4.3.1.11 – Air Filtration

2. Provide dedicated make-up air units for applications where there are no central HVAC air handling systems capable of providing the required make-up air, where the requirement for make-up air is intermittent, or where the required quality or temperature/humidity conditions for the make-up air are different from the air provide by the central HVAC system.

   a. Examples of applications for make-up air are industrial processes and kitchens.

3. Consider the required differential pressure condition in the spaces served relative to adjacent spaces when sizing make-up air systems, as well as the associated exhaust volume. It is generally prudent to provide some excess capacity in the make-up air system if the desire differential pressure condition is positive, as the space may not pressurize as well as expected as building and space envelopes generally leak more than expected.

4. Fans 3.75 kW and larger shall have variable frequency drives.

5. If direct expansion cooling is used, use cooling equipment especially designed for the sensible to latent heat ratio encountered with 100% outdoor air systems. Normal building direct expansion cooling equipment may not have the capacity to provide the required latent heat removal in coastal areas.

6. Consider energy recovery for make-up air systems. Submit a life cycle cost analysis to the Entity to demonstrate the cost effectiveness of providing vs. not providing heat recovery.

7. Refer to the project specification for outdoor air treatment units, CHW type.

8. Refer to the project drawings for standard HVAC details.

4.3.1.11 Air Filtration

1. Reference to other sections of the Mechanical Design Guideline
    a. Sandstorm provisions are addressed in Subsection 4.4.1.1 – Sandstorm Provisions, Design Criteria and Objectives.
    b. Air intake and exhaust considerations are addressed in Subsection 4.4.1.2 – Building Air Intake and Exhaust Design.
2. All re-circulating and outside air systems shall be provided with air filters.
3. All air filtration shall meet the requirements of ASHRAE Standard 62 – Ventilation for Acceptable Indoor Air Quality.
4. All filters shall be tested by the manufacturer to demonstrate performance in accordance with ASHRAE Standard 52 – Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size.
5. Built-up central HVAC systems shall be provided with pre-filters and final filters.
6. Filter racks shall be designed to minimize the bypass of air around the filter media with a maximum bypass leakage of 0.5%.
7. Differential pressure gages shall be provided across the filter assemblies.
8. Where occupancy requirements are likely to generate high levels of airborne particles, special air filtration shall be provided on the return air system, or dedicated and localized exhaust systems shall be utilized to contain airborne particulates.
9. Due to the decrease in system airflow as the pressure drop across the filter increases, size fans for the "dirty" filter condition. This will ensure that each fan has adequate capacity to deliver the design airflow as the filter becomes loaded. The "dirty" pressure drop is usually considered to be two times the clean pressure drop.
10. The recommended average air velocity over the filter face area is 1.25 m/s, and shall not exceed 2.5 m/s.
11. All filters shall conform to UL 900 Class 2 for combustibility and smoke generation. Systems serving areas carrying flammable gases shall have the additional fire resistance of Class 1 filters, where specified.
12. For healthcare and other application where Hepa or Ulpa filtration will be required in the terminals, it is recommended that the filter be installed internal to the AHU instead in the index of duct run to maximize speed reduction range of the VFD controlled fan. Locate the pressure sensor in the ¾ run of the total duct length from the AHU.
13. Refer to the project specification for air cleaning and filtration for HVAC systems.
14. Refer to project drawings for standard HVAC details.

4.3.1.12 Sand Filtration Equipment

1. General
    a. Sand filtration equipment is generally utilized for removing particulate from circulating water systems for chillers, condensers, heat exchangers and cooling towers.
    b. Sand filtration is most effective on fine light particles down to 0.45 microns. Avoid sand filtration for applications with a high concentration of coarse particles larger than 40 microns. Centrifugal separators are more effective for these applications.
    c. Sand filtration system should be packaged with dedicated pump, pipe manifolds, pressure gauges and strainer.
    d. Pump shall be end suction for flooded suction applications
    e. Pump shall be self-priming for negative suction applications

f. Sand filtration system shall have backwash cycle automatically initiated based on pressure difference across the filter media. Pressure difference setpoint for initiating backwash shall be adjustable.

g. Minimize the piping between the sand filtration equipment and the recirculating water system.

h. Coordinate the placement of a sanitary drain with the plumbing consultant for discharge of backwash water.

2. Refer to project drawings for standard HVAC details.

4.3.1.13 DX Packaged and Split

1. Reference to other sections of the Mechanical Design Guidelines:

   a. Refrigerant compounds are addressed in Subsection 4.1.12 – Refrigerants

   b. Heat pumps are addressed in Subsection 4.2.4. – Applied Heat Pump and Heat Recovery Systems

   c. Direct expansion cooling coils are addressed in Subsection 4.3.1.6 – Finned Cooling Coils – Direct Expansion Type

2. Equipment Selection

   a. All equipment efficiencies shall meet the requirements of the latest edition of ASHRAE Standard 90.1.

   b. Design of refrigeration piping for split systems shall be in strict accordance with the manufacturer's requirements. Pay particular attention to length of piping and changes in elevation.

   c. The capacities for DX packaged and split equipment are typically listed at Standard ARI conditions in the manufacturers' catalogs and literature. These conditions are radically different from the outdoor design conditions in Saudi Arabia. Selections for all units must be specific to Entity requirements/applications. Correct the catalog capacities to reflect actual outdoor design conditions. The correction factors are available from the equipment manufacturers.

   d. DX packaged and split equipment usually has limited ability to address high latent cooling loads that may be experienced in coastal areas. The equipment has fixed cooling coil and compressor capacity, and the sensible heat capacity ratio can be changed somewhat by varying the supply air volume across the cooling coil; however, the variability is minimal. Frequently the sensible heat ratio for the application will be lower than the actual sensible heat capacity ratio of the equipment. Match the actual sensible heat capacity ratio of the equipment as closely as possible to the sensible heat ratio of the application. This again requires correcting the catalog capacities of the equipment to reflect the outdoor design conditions for the actual project location within Saudi Arabia.

   e. Care should be taken to avoid oversizing of DX package and split equipment. Oversizing will result in short cycling of the equipment, and will further reduce the latent cooling capacity of the equipment.

   f. DX and package equipment has limited ability to address part load conditions. This is further reason to avoid oversizing of the equipment. Consider multiple pieces of equipment where the equipment does not have the capacity range to address part load conditions.

   g. If the DX packaged or split equipment does not have the ability to properly address part load conditions or the desired latent cooling capacity, options are available from some manufacturers to compensate for these problems. The options include:

      (1) Staged multiple compressors

      (2) Humidistat control with hot gas reheating

      (3) Variable speed evaporator fans

      (4) Wrap-around heat pipes or air-to-air heat exchangers at the evaporator coil to provide free reheating of the air after dehumidification

3. Variable Air Volume Applications

    a. Where packaged DX or split equipment provides the cooling for a variable air volume air handling system, special provision must be made for the cooling capacity control. Variable air volume applications usually operate with constant supply air temperature; however, cycling stages of refrigeration on and off for DX refrigeration can result in supply air temperature changes as great as 3ºC. Most manufactures of DX refrigeration offer an optional controller that is specifically designed for variable air volume applications. Specify this controller with the equipment.

        (1) Where the manufacturer does not offer an optional variable air volume controller, a method of false loading the evaporator known as "outdoor air trim" can be utilized. In this control method, as a stage of refrigeration is staged on, the outdoor air volume passing through the evaporator is increased to false load the refrigeration and prevent the refrigeration from cycling off. The same tactic can be used as the refrigeration load decreases to prevent the stages of refrigeration from cycling off prematurely.

4. Ducted Applications

    a. Most DX packaged and split equipment evaporator fans have limited capacity to overcome static resistance in the supply air duct system. Design supply air duct carefully to minimize resistance to airflow, calculate the air pressure drop in accordance with Subsection 4.2.2.2 - Pressure Drop Calculations.

5. Refer to the applicable project specifications.

6. Refer to the project drawings for standard HVAC details.

4.3.2 Heating Equipment and Accessories

4.3.2.1 Boilers

1. Reference to other sections of the Mechanical Design Guidelines:

    a. Redundancy is addressed in Subsection 4.1.14. - Redundancy

2. General

    a. Heating is rarely used in Saudi Arabia. Heating applications that may require the use of boilers would be reheating and humidification for hospital and laboratory HVAC systems, sterilization and laundries for hospital applications and industrial heating applications.

        (1) Humidification, sterilization, laundries, and some industrial applications require steam boiler.

        (2) Hot water boiler systems are preferred for all other applications because of reduced maintenance requirements and generally higher efficiencies.

    b. Before designing boiler systems, confirm the availability of adequate fuel.

3. Pressure and Temperature

    a. Boilers must be constructed in strict accordance with the ASME Boiler and Pressure Vessel Code, Section IV (SCIV), Rules for Construction of Heating Boilers (low-pressure boilers), or Section I (SCI), Rules for Construction of Power Boilers (high-pressure boilers).

        (1) Low-pressure boilers are constructed for maximum working pressures of 1 Bar for steam and up to 10 Bar for hot water. Hot-water boilers are limited to 120ºC operating temperature.

        (2) Low pressure boilers require less supervision and are more efficient to operate than high pressure boilers, and are therefore preferred over high pressure boilers.

        (3) High-pressure boilers are designed to operate above 1 Bar for steam, or above 10 Bar and/or 120°C for water boilers.

        (4) High pressure steam boilers are typically required for sterilization and laundry applications.

4. Fuel Used

a. Oil fired boilers or Electric are typically used in Saudi Arabia.

5. Boiler Types
   a. Hot water boilers shall be modular high efficiency condensing type boilers or steel fire tube boilers.
   b. Condensing boilers are subject to corrosion. Specify condensing boilers that are available with a minimum 10-year warranty.
   c. Steam boilers shall be steel fire tube boilers or industrial water tube boilers.
6. Boiler Burners
   a. Modular high efficiency condensing boilers, steel fire tube boilers and industrial water tube boilers will all utilized forced draft burners.
   b. Burners shall have a minimum 10:1 turndown ratio, and shall operate efficiently through all firing rates within that turndown ratio.
   c. Boiler burners shall also be low NOx emissions type burners.
7. Boiler Controls
   a. Given the complexity of maintaining fire rates for installations with multiple boilers to meet the load, it is recommended the boiler controls be supplied by the boiler manufacturer.
      (1) The controls must be able to stage all the boilers in the installation through the full range of firing rates.
      (2) The controls shall equalize the runtime for all boilers, and shall signal the failure of any boiler through an audible and visible alarm.
      (3) The controls shall have graphic capability to display all boiler functions.
      (4) The controls shall communicate with the building automations system through a serial interface, and all data including graphics that are available through the boiler controls shall also be available through the building automation system.
8. Selection Parameters
   a. Boiler selection depends on many variables of the individual application, including operating characteristics of actual loads, load distribution; total heating demand on the boiler plant, number of boilers in the plant, operational characteristics of individual boiler, reliability factors and the whole boiler burner and control package.
   b. Develop a detailed load profile for a boiler installation
   c. The boiler plant must be sized for the maximum system load. This is not merely the sum of connected loads, but shall also take in to account piping loss, warm-up loads, possible diversity standby requirements, etc.
   d. Select the boiler equipment so that one boiler can be kept on line without cycling at the lowest load conditions. Efficiency drops dramatically when boilers cycle due to purging prior to and after a firing cycle.
9. Boiler Breechings and Flues
   a. Specify breeching and flue material that is compatible with the combustion gases leaving the boilers
      (1) There are a limited number of breeching and flue materials that are compatible with combustion gases from condensing boilers.
      (2) Design breechings and flues in strict accordance with the guidelines in the ASHRAE HVAC Systems and Equipment Handbook.
10. Boiler Blowdown
   a. Boiler blowdown shall be located at the bottom to maintain TDS of the boiler water. Blowdown shall be programmed for single four (4) seconds every eight (8) hours.
   b. Provide heat recovery using flash vessel and heat exchanger for heating cold make-up water and deaerating purpose.

c. Effluent water shall be recovered and cooled in a blowdown vessel or blowdown pit prior to use in gray water system (such as flushing water for plumbing fixtures).

4.3.2.2 Residential Heating

1. Reference to other sections of the Mechanical Design Guidelines:
   a. Residential heating is addressed in Subsection 4.1.8 – Heating Load Calculations and Subsection 4.3.1.9 – Air Heating Coils
2. Design
   a. Residential heating equipment should be air source heat pumps. Since heating is rarely required, sizing of the heat pump shall be based on the required cooling capacity to meet cooling load.
   b. Controls shall be wall-mounted 7-day programmable electronic thermostats with night setback provisions and manual change-over from cooling to heating.
3. Refer to project drawings for standard HVAC details.

4.3.3 Cooling Equipment and Accessories

4.3.3.1 General

1. Chillers used for district cooling shall be centrifugal-variable frequency drive type. High voltage chillers shall be selected to reduce losses in motor windings as well as to reduce incoming cable size. For non-district cooling application and projects requiring LEED Certification, the designer shall consider the use Ammonia chillers as the regulation permits, to help avail credits related to Advance Refrigerant Management and Optimized Energy Performance. All necessary protection to ensure safe operation of the chillers shall be provided.
2. Whenever practical, chillers shall be arrange for variable primary flow. Variable speed chillers shall be selected for the required lowest minimum flow possible. Bypass in the chilled water piping shall be provided to protect the chiller from low-flow below the minimum value. The chilled water bypass shall be arrange that the minimum flow shall be maintained at any given point when the chiller is operating at minimum loading.
3. Motorized valves used for multiple chiller arrangement shall be slow actuating type (ranges from 90 seconds to 120 seconds) to avoid abrupt change of flow within the evaporator resulting in operational faults.
4. Chillers with the highest EER in the market shall be given preferences during the selection. For location with ambient condition lower than 13°C, chillers shall have free-cooling capability. The chilled water and condenser water system shall be design accordingly.
5. For projects having multiple chiller arrangements, consider the combined use of variable speed drives and fixed speed capacity controlled chillers to reduce power requirements during low cooling demand and reduce equipment first cost. VFD chillers are efficient in part load while fixed speed drive chillers are efficient in full-load.
6. Chiller compressor motor shall have low starting lock-rotor current.
7. Chillers shall be design for the highest evaporator chilled water delta T.
8. Chillers shall have a build-in flow switch.
9. Chiller capacity shall be indicated in nominal capacity. De-rating of the equipment shall be based on the highest de-rating factor available for chillers in the market.
10. The chiller main control board shall be designed in such a way that the Building Management System (BMS) is able to integrate and obtain information from the chiller without gateways the following parameters to provide unified and common reference for monitoring and control.
    a. Chilled water incoming and out-going temperature
    b. Evaporator barrel differential pressure
    c. Chiller capacity loading

4.3.3.2 Chillers (Vapor Compression)

1. Reference to other sections of the Mechanical Design Guidelines:
   a. Refrigerants are addressed in Subsection 4.1.12 – Refrigerants
   b. Redundancy is addressed in Subsection 4.1.14 - Redundancy
   c. Hydronic heating and cooling is addressed in Subsection 4.2.7 – Hydronic Heating and Cooling
   d. Condenser water systems are addressed in Subsection 4.2.8. – Condenser Water Systems
   e. District cooling and central plants are addressed in Subsection 4.2.11 – District Cooling and Central Plant Systems
2. General
   a. Vapor compression chillers can be either air-cooled or water-cooled, and can have reciprocating, scroll, rotary screw or centrifugal compressors.
   b. Select Free-Cooling Type Chillers if the ambient dry bulb temperature reaches below 13°C for air cooled chillers, and if the Cooling Tower incoming air wet-bulb temperature can fall below the design resulting in tower water basin temperature below 13°C.
3. Air Cooled vs. Water Cooled
   a. This topic is addressed in Subsection 4.2.8. – Condenser Water Systems.
   b. Water cooled equipment is more efficient than air cooled equipment, but water for condenser water systems is in short supply in Saudi Arabia.
   c. A typical life cycle cost analysis shall be performed to determine the overall cost effectiveness of a cooling tower system over air cooled condensing for refrigeration. The life cycle cost analysis shall include all cost associated with treating the water and disposing of blowdown.
4. Compressor Types
   a. Reciprocating compressors tend to be noisy, and cannot match the efficiency of other compressor types due to the general nature of the reciprocating cycle and the required clearance volume in the cylinders. Reciprocating compressors shall therefore be avoided if at all possible.
   b. Scroll compressors are efficient, quiet and reliable, but are only available in single compressor capacities up to 75 Tons. They are used in modular chiller arrangements, which can provide an inexpensive level of redundancy by simply adding one compressor to a unit. Capacity control is also provided by hot gas bypass and variable speed controls. Banks of scroll compressors are acceptable for loads up to 300 Tons.
   c. Rotary screw compressors are efficient, and provide very good part load efficiency; however, they can be noisy. Rotary screw compressors are acceptable for loads up to 750 Tons.
   d. Centrifugal compressors provide the greatest overall flexibility with regard to capacity and efficiency, and shall be used for machines larger than 750 Tons.
      (1) In the Saudi environment, hermetic machines have an advantage due to the fact the motor is refrigerant cooled, and not subject to the potentially high temperatures in the equipment room.
      (2) Consider dual compressor machines to provide a higher level of redundancy.
5. Heat Recovery Chillers
   a. Consider providing a heat recovery chiller for hospital or laboratory applications where hydronic reheating is required.
6. Chiller Controls
   a. Purchase all chiller controls from the chiller manufacturer.

b. The chiller control system must interface to the building automation system through a serial interface. All points and graphics available through the chiller control system shall be able to be viewed through the building automation system.

7. Refer to the applicable project specifications.
8. Refer to project drawings for standard HVAC details.

4.3.3.3 Chillers (Absorption)

1. Reference to other sections of the Mechanical Design Guidelines:
   a. Refrigerants are addressed in Subsection 4.1.12 – Refrigerants
   b. Redundancy is addressed in Subsection 4.1.14 - Redundancy
   c. Hydronic heating and cooling is addressed in Subsection 4.2.7 – Hydronic Heating and Cooling
   d. Condenser water systems are addressed in Subsection 4.2.8 – Condenser Water Systems
   e. District cooling and central plants are addressed in Subsection 4.2.11 – District Cooling and Central Plant Systems
2. General
   a. Absorption chillers shall only be considered where “free” waste steam or high temperature hot water is available, such as waste heat from a turbine generator or an industrial process.
   b. The inherent inefficiencies of absorption chillers eliminate any potential economic justification unless the heat to operate them is totally free.
   c. Prepare a full life cycle cost analysis and obtain Entity approval prior to designing a system with absorption chillers.
   d. Gas fired absorption chillers are complex to operate and have relatively short life spans, and shall not be provided.
3. Absorption Chiller Types
   a. Absorption chillers shall be double-effect type for maximum efficiency.
   b. The heating chamber shall be designed and constructed in strict accordance with the requirements of ASME for Pressure Vessels.
4. Refer to the project specification for the applicable equipment.
5. Refer to project drawings for standard HVAC details.

4.3.3.4 Cooling Towers

1. Reference to other sections of the Mechanical Design Guidelines:
   a. Outdoor design conditions are addressed in Subsection 4.1.7 – Design Criteria
   b. Redundancy is addressed in Subsection 4.1.14 - Redundancy
   c. Hydronic heating and cooling is addressed in Subsection 4.2.7 – Hydronic Heating and Cooling
   d. Condenser water systems are addressed in Subsection 4.2.8 – Condenser Water Systems
   e. District cooling and central plants are addressed in Subsection 4.2.11 – District Cooling and Central Plant Systems
   f. Vibration control is addressed in Subsection 4.4.1.5 – Vibration Control
   g. Water Treatment is addressed in Subsection 4.4.1.6 – Water Treatment
2. General
   a. Given the limited availability of water for cooling tower makeup in Saudi Arabia, cooling towers are typically only used in applications where TSE (Treated Sewage Effluent) water is available for cooling tower make-up water.

b. Towers shall be constructed of non-corrosive material, stainless steel or fiberglass for the applicable regional environment.

c. The A/E shall prepare a study regarding advantages using variable frequency drive fan for cooling tower against fixed drive fan. Variable frequency drive results in energy savings for the cooling tower cooling fan but fixed drive fan results in reduced power consumption for the chiller due to lower incoming condenser water temperature.

d. Provide generously sized equalization piping between tower cells.

e. Provide level controls and isolation valves for each cell of a cooling tower installation so cells can be taken out of service without shutting down the entire installation.

f. Variable flow nozzles shall be used for condenser water distribution above the cooling tower fill media to create a constant pattern of uniform water distribution thereby increasing cooling efficiency and reducing drift loss. Distribution piping shall be spaced accordingly to accommodate constant pattern of condenser water distribution

g. Provide walking platforms with railings around the complete periphery of cooling towers at the basin level. Provide ladders to the top of cooling tower and railings around the entire top periphery of all towers.

3. Open Cooling Towers

a. Forced-draft cross flow towers have the greatest overall efficiency of all tower types, and given the climate and water availability in the Saudi Region shall be used in lieu of other options.

4. Closed Circuit Fluid Coolers

a. Closed circuit fluid coolers shall be used for hydronic heat pump and other water cooled HVAC refrigeration equipment with tube-in-a-tube coaxial refrigeration condensers, where particulate in the condenser water from a cooling tower would clog the condensers.

b. Industrial fluid coolers shall have centrifugal fans for maximum efficiency.

5. Refer to the project specification for the applicable equipment.

6. Refer to project drawings for standard HVAC details.

4.3.3.5 Thermal Storage

1. General

a. Thermal storage can be utilized to reduce cooling equipment requirements and/or electrical demand where peak cooling demands are uncharacteristically high and of relatively short duration.

(1) Consultants proposing the use of thermal storage must demonstrate past experience with design of similar systems of the type and capacity being proposed.

b. Where the use of thermal storage appears justifiable, first propose the concept to the Entity. If the Entity concurs, they will authorize a preliminary design and life cycle cost analysis to determine the economic justification prior to authorizing the detailed design for the thermal storage system.

c. Although ice storage systems have been used in Saudi Arabia, stratified water thermal storage systems are much preferred.

(1) The life cycle cost analysis for ice storage systems must account for the inefficiency of operating refrigeration equipment at low temperatures to produce ice, as well as any parasitic losses inherent in thermal storage systems.

2. System Design

a. The following criteria must be specified in the design of a thermal storage system:

(1) Thermal Storage System Load for each hour of the design day, kW

(2) Operating mode of the Thermal Storage Refrigeration Equipment (charge, partial cooling or off) for each hour of the design day

(3) Design Heat Sink Rejection Temperature, ºC, for each hour of the design day

(4) Supply temperature to the Load during the hour of maximum load, T1, ºC, for each hour of the day

(5) Return temperature from the Load during the hour of maximum load, T2, ºC, for each hour of the day

(6) Flow rate (lps) to the Load during the hour of maximum load and for each hour pumping is used

(7) Maximum time (Hours) available to charge from fully discharged condition

(8) Minimum temperature available to charge from fully discharged condition, °C

(9) The Charge and Discharge fluids (e.g., water, 25% ethylene glycol/75% water, etc.)

(10) Parasitic and accessory heat load allowance (e.g., air compressor, dedicated recirculation pump, etc.) into the storage device, tons

(11) Ambient Heat Load allowance into the storage device due to ambient air temperature and solar radiation

(12) Net Storage Inventory, kWh

(13) Saturated suction temperature and refrigeration load or other design parameters for the refrigeration plant, when this equipment is to be supplied by other than the thermal storage supplier

(14) Temperatures of Fluid entering and leaving the Thermal Storage Device, and any other heat exchanger(s) included in the system, °C

(15) Flow rate of Fluid through the Thermal Storage Device and any heat exchanger(s) included in the system, lps

(16) Pressure drop across the Thermal Storage Device and any heat exchanger(s) included in the supplier's scope of supply, kPa

(17) Energy input to thermal storage refrigeration equipment included in the supplier's scope of supply, kWh (for electric chiller) or kBJ (for gas-fired chiller)

(18) Total heat rejection, kJ, and condensing temperature for the refrigeration system, ºC

(19) Energy input to essential storage device parasitic loads and accessories, i.e. air compressors or air pumps, in kWh

3. Refer to the applicable project specifications.
4. Refer to project drawings for standard HVAC details.

4.3.3.6 Liquid Desiccant Air-Conditioning Unit (LDAC)

1. General

a. LDAC can be utilized to reduce latent load cooling and power requirements in application with high latent loading and spaces which requires low %RH. The system also has the capability to remove pollutants in the process air naturally. LDAC is applicable for Outdoor AHU and recirculating AHU. LDAC can be combined with Dx cooling system or double effect absorption system to increase sensible cooling capacity if clean water source is scarce, or if water cost is high compare to the anticipated power savings for the reduced sensible cooling. Solar heating system is proposed as regenerator to maximized efficiency.

(1) Consultants proposing the use of LDAC must demonstrate past experience with design of similar systems of the type and capacity being proposed.

2. System Design

b. The following criteria must be specified in the design of LDAC system:

(1) Total cooling load, in Tons or kW

(2) Latent cooling capacity, in Tons or kW

(3) Air flowrate for space ventilation, in lps or cfm

(4) Total power consumption, in Hp or kW

(5) Initial process air psychrometric condition in dry bulb and wet bulb temperature, in °C

(6) Final process air psychrometric condition in dry bulb and wet bulb temperature, in °C

(7) Liquid desiccant type and concentration

(8) Unit COP (Coefficient of Performance

(9) Regenerator Type and heating capacity, in kW

3. Refer to the applicable project specifications.
4. Refer to project drawings for standard HVAC details.

4.3.4 Common System Components

4.3.4.1 Pumps (Centrifugal)

1. Reference to other sections of the Mechanical Design Guidelines:
   a. Redundancy is addressed in Subsection 4.1.14 - Redundancy
   b. Hydronic heating and cooling is addressed in Subsection 4.2.7 – Hydronic Heating and Cooling
   c. Condenser water systems are addressed in Subsection 4.2.8 – Condenser Water Systems
   d. District cooling and central plants are addressed in Subsection 4.2.11 – District Cooling and Central Plant Systems
   e. Vibration control is addressed in Subsection 4.4.1.5 – Vibration Control
2. General
   a. Pumps coupled to motors with a replaceable coupler are preferred for large pump and critical applications, as the motor or the pump may be repaired or replaced separately. Pumps with the impeller mounted on the motor shaft are more difficult and costly to repair or replace, and frequently require a special motor with a longer than normal shaft that may be a long lead delivery item.
   b. All pumps larger than 3.75 kW shall have variable frequency drives.
   c. Select pumps near the points of maximum efficiency on the pump curves. Best Efficiency Point falls at the 2/3 part of the pump curve. Avoid selections with flat performance curves.
   d. For parallel or series pump arrangements, plot the parallel or series curves to demonstrate how the pumps will perform in combined operation.
   e. Select pump motors to be non-overloading over the entire range of operation for one impeller size larger than the selected size impeller.
   f. Select pumps seals for the intended duty. Stuffing box seals should not be used due to wasting water.
   g. For cooling tower and other open pumping arrangements, prove by calculation and pump selection that the available NPSH (Net Positive Suction Head) of the installation is equal or higher than the pump NPSH to avoid cavitation.
   h. For closed-loop installations, especially if the pump is located at the highest point of the installation, prove by calculation and pump selection that the available NPSH (Net Positive Suction Head) of the installation is equal or higher than the pump NPSH to avoid cavitation. Otherwise, provide sufficient oversizing of the pump head to ensure the availability of pressure at the suction of the pump.
   i. Provide suction diffusers for pumps if the minimum suction straight piping lengths required by the manufacturer cannot be obtained due to space constriction. Liquid filled pressure gauges shall be provided in the discharge and suction side. Suction strainers can be eliminated if suction diffusers are provided.
3. In-line Pumps

a. Pipe-mounted horizontal shaft in-line pumps should be limited to sizes 1 kW and smaller.

b. Vertical shaft inline pumps may be used where space is at a premium for flow rates to 150 lps and pump heads of 10 bar. Motor sizes may be as large as 45 kW. Recognize the impellers are typically attached directly to the motor shaft in these applications.

4. Base Mounted End Suction Pumps

a. Base mounted pumps are preferred due to their reliability and serviceability.

b. Base mounted end suction pumps may be used for flow rates up to 250 lps and pump heads up to 15 bar. Motor sizes may be as large as 110 kW.

5. Horizontal Split Case Pumps

a. Horizontal split case pumps are used for industrial and large central and district applications. The may be used for flow rates up to 400 lps and pump heads up to 12 Bar. Motor sizes may be as large as 225 kW. They provide the advantage of being able to service the bearings, seals or impeller without affecting the piping.

6. Vertical Split Case Pumps.

a. Vertical split case pumps are also used for industrial and large central and district applications. The may be used for flow rates up to 250 lps and pump heads up to 18 Bar. Motor sizes may be as large as 225 kW. Like the horizontal split case pumps, they provide the advantage of being able to service the bearings, seals or impeller without affecting the piping. However, they have the additional advantage of requiring less space due to the pipe connections being vertical. There just has to be adequate height to accommodate the flex connections, valve train, strainers and other pump accessories.

7. Refer to the project specification for water pumps for HVAC service.

8. Refer to project drawings for standard HVAC details.

4.3.4.2 Pumps (Turbine)

1. Reference to other sections of the Mechanical Design Guidelines:

a. Centrifugal pumps are addressed in Subsection 4.3.4.1 – Pumps (Centrifugal)

2. General

a. Turbine pumps are centrifugal pumps with multiple impellers stacked in series to increase the pump's head capacity, and should be used for applications where the pump head is greater than the head capacity of a single impeller pump with identical flow rate.

b. Vertical turbine pumps are the most common type of turbine pump, where the impellers stack in a vertical arrangement.

c. In HVAC applications, vertical turbine pumps are most often used for large cooling tower applications and other "open system" applications where the pumping circuit is not a closed loop and open static head exists.

d. Vertical turbine pumps should also be used for any applications utilizing underground tanks for water storage.

e. Because of the multiple impeller arrangement, turbine pumps tend to have steep performance curves. Large changes in head have minimal effect on flow. This generally makes balancing more simple; however, it can also make the pump less forgiving if the flow requirement is underestimated. Estimate flow requirements carefully for turbine pumps.

3. Refer to the project specification for water pumps for HVAC service.

4. Refer to the project drawings for standard HVAC details.

4.3.4.3 Pumps (Positive Displacement for Fuel Oil)

1. General

a. Fuel oil pumps are generally gear pumps.

b. By design, positive displacement pumps are overloading. The pump horsepower increases exponentially as the pump head increases. For that reason it is prudent to oversize the pumps somewhat, and to use balancing valves to obtain the desired flow. Fuel systems should typically include a return line to adjust for modulating flow requirements.

2. Refer to the project specification for liquid fuel transfer pumps.

3. Refer to project drawings for standard HVAC details.

4.3.4.4 Heat Exchangers

1. Reference to other sections of the Mechanical Design Guidelines:

   a. Hydronic heating and cooling is addressed in Subsection 4.2.7. – Hydronic Heating and Cooling

   b. District cooling and central plants are addressed in Subsection 4.2.11. – District Cooling and Central Plant Systems

2. General

   a. Heat exchangers may be used in HVAC applications for steam-to-hot water production for hydronic reheat water in hospitals. These heat exchangers shall be shell and tube type.

   b. Heat exchangers may also be used to decouple tall buildings from campus and district chilled water systems. To achieve the minimum approach temperature, these heat exchangers should be plate and frame heat exchangers.

   c. Design fouling factors for steam, hydronic hot water and chilled water should be $9 \times 10^{-5} m^2/kW$.

   d. Plate and frame heat exchangers are subject to fouling. Consider providing two heat exchangers so one can be taken out of service for cleaning while the other heat exchanger remains in service.

   e. Where tandem heat exchangers are used, provide motorized isolation valves to stop flow through heat exchangers not required at low flow conditions.

3. Refer to the project specification for heat exchangers for HVAC systems.

4. Refer to project drawings for standard HVAC details.

4.3.4.5 Combined Aeration, Water Make-Up, Expansion System, and Pressurization Units

1. Reference to other sections of the Mechanical Design Guidelines:

   a. Hydronic heating and cooling is addressed in Subsection 4.2.7. – Hydronic Heating and Cooling

   b. District cooling and central plants are addressed in Subsection 4.2.11. – District Cooling and Central Plant Systems

2. General

   a. Combined aeration, water make-up, expansion, and pressurization units (such as Reflex degassing system) shall be included in the design. Degassing is required to eliminate the presence of oxygen in the system, which deteriorates metallic hydronic system components. Degassing shall happen in atmospheric or vacuum for effective oxygen removal.

   b. The system shall not be installed in the main piping so not to incur additional resistance in the pumping system.

   c. The combined system shall be design to cater requirements for system hydronic expansion due to change in system temperature and pressure.

4.3.4.6 Chemical Feed Tanks

1. Chemical pot feeders shall only be provided for small systems up to 500 Tons.

2. Pot feeders having a capacity of no less than 0.1% of the system water volume or which can accommodate at least one container of treatment chemical, with two shut-off valves and a by-pass

(with isolation valve) shall be installed between the chilled water pump suction and discharge line, in parallel with the chilled water pump.

3. Chemical pot feeders shall be made of stainless steel 316L.
4. For larger close and open hydronic systems, automatic chemical feed system shall be provided as per standard practice.

4.3.4.7 Air elimination

1. All hydronic systems shall have provisions for air elimination. A central air eliminator shall be provided near the inlet of main circulating pumps. Means for air elimination shall be provided at all high points as well. Wherever practical, manual air vents shall be provided. If automatic air vents must be used, they shall be accessible and shall have a manual shut-off valve upstream to facilitate maintenance of the air vent

4.3.4.8 Motors and Motor Controllers

2. Motors
   a. Coordination
      (1) Provide a complete list of all anticipated motors, complete with the HVAC system the motors will serve, the motor location, voltage, phase, horsepower and starter type, for the Entity Lead Electrical Engineer prior to the completion of the Schematic Phase of design. Update the list with each design phase as the design progresses.
   b. Ratings of Motors
      (1) Motors 0.37 KW and smaller shall be single phase.
      (2) All other motors shall be 3-phase. The following table is a guide to the range of sizes of 3-phase induction motors at the various system voltages. This is intended as a guide only and may be relaxed or made more restrictive depending on actual supply conditions.

THREE PHASE MOTOR VOLTAGE RATINGS

Motor Size	Nominal 3-Phase System Voltage	Motor Voltage Rating
0.5 - 150 kW	400Y/231	400
160 - 3000 kW	4160	4000
Above 3000 kW	13800	13200

      (3) Refer to the project specification for common motor requirements for HVAC equipment.
2. Motor Controllers
   a. General
      (1) Appropriate type of motor starters shall be selected for starting and smooth running of motor. The type of the starter depends on the type of motor it is starting and the means of control desired.
      (2) Small fractional horsepower motors such as exhaust fan motors can be operated from simple wall switch without conventional starter.
      (3) For motors 3.75 kW and larger, a “soft start” type starter shall be used.
         (a) Consider using variable frequency drives (VFDs) for motors 3.75 kW and larger, even in applications which do not require variable operation such as pumps and fans. They offer the opportunity to start the device at low RPM and ramp to the desired speed, and they simplify balancing.
   b. Variable Frequency Drives
      (1) VFDs shall be based on pulse width modulation technology, minimum 12 pulse type, and shall have the following features:
         (a) Automatic restart after a power line transient

(b) Adjustable number of restarts after a drive fault

(c) Auto/Off/Manual switch, local speed control, adjustable current limit, and adjustable acceleration and deceleration rates

(d) “On the fly” restart into a coasting load

(e) Phase loss and voltage over/under voltage protection

(f) Ground fault protection

(g) Output over current trip

(h) Stall protection

(i) Capability to accept external normally closed permissive contacts such as static pressure safeties

(j) Input power disconnect

(2) Where there is a central building automation system (BAS), VFDs for HVAC application shall interface with the BAS. Any interface devices (hardware or software) required for the VFD interface with the BAS should be provided by the BAS manufacturer.

(3) All VFDs provided on a single project should be furnished by the same manufacturer.

c. Reversing Starters

(1) Reversing starters for motors are used for various applications such as opening or closing of valves.

d. Starter type selection is dependent on the motor size and the application. The following table provides guidance on the selection of the starter types for the various motor sizes, voltages and applications. The final selection shall be determined by the engineer designing the specific application.

STARTER SELECTION

Motor Rating	Voltage	Application	Across the Line	Reduced Voltage	Close Transition Star Delta	Variable Frequency Drive
0.5 kW to 4 kW	400	All	□			
≥ 4 kW	400	All				□
< 37 kW	400	Fire Pump			□	□
≥ 37 kW	400	Fire Pump		□	□	□

e. Motor Control Center (MCC)

(1) When it is required to control multiple motors, it is preferred to control them from a centralized location such as a motor control center.

(2) Motor control center is comprised of individual controllers for various motors mounted on a fixed or draw-out type of chassis with each controller located in separate compartment.

f. Medium Voltage Controllers

(1) 4160 V motors shall use combination controllers with current limiting fuses and contactor. Standard motor controllers available for squirrel cage, wound rotor and synchronous motors shall be specified. Medium voltage circuit breakers may be used as motor starters, but are not preferred since they are not suitable for repetitive starting duty.

g. Refer to the project specification for common motor requirements for HVAC equipment.

h. Refer to project drawings for standard HVAC details.

4.4 HVAC Systems and Equipment Applications

4.4.1 General Design Considerations

4.4.1.1 Sandstorm Provision, Design Criteria, and Objectives

1. Frequent high wind gusts, often of long duration and well in excess of 18 m/s, produce humid, salty, dusty and sandy atmosphere. Provisions must be made to eliminate sand from outdoor air intakes prior to the air entering the HVAC filters, or the filters will clog quickly.
2. Where space is available, orienting the intake so that the air must rise vertically up into the intake, and orienting the intake louver in a horizontal plane helps to drastically reduce the volume of sand that is entrained in the airstream.
3. All intakes, regardless of whether the louver is in the vertical or horizontal orientation, should have prefabricated sand trap lovers at the face of the intake. Sand trap louvers shall have self-emptying sand drain holes at the base. Sand trap louvers shall be backed with 50 mm thick washable aluminum filters. The filters shall be washable for cleaning. Behind that and trap louvers and filter shall be a plenum with the same basic height and width dimensions as the louver, minimum 0.6 m deep with access doors for removing sand.
4. Maximum air velocity at the sand trap louver face shall be 1.0 m/s for general HVAC applications and 1.5 m/s for non-HVAC applications, such as a generator intake.
5. Refer to the applicable project specifications.
6. Refer to project drawings for standard HVAC details.

4.4.1.2 Building Air Intake and Exhaust Design

1. Reference to Other Sections of the Mechanical Design Guidelines:
   a. Building air intake design is addressed in Subsection 4.4.1.1 - Sandstorm Provisions, Design Criteria and Objectives.
   b. The design of laboratory exhaust is addressed in Subsection 4.4.1.14 – HVAC for Laboratories.
2. Intake height and orientation
   a. Locating intakes 8 M above grade greatly reduces the exposure to wind driven sand. Many buildings are less than 8 M in height; however, intakes should be located as high as practical to minimize the intake of wind driven sand.
   b. Locating intakes on the prevailing leeward side of the building further reduces the exposure to wind driven sand.
3. Intake Isolation Distances
   a. Isolation for outdoor air intakes for non-healthcare applications shall be in accordance with the Saudi Building Code (SBC 501-Mechanical Requirements).
   b. Isolation distances for healthcare applications shall be in accordance with the AIA Guidelines for Design and Construction of Health Care Facilities and with ANSI/ASHRAE/ASHE Standard 170 – Ventilation of Healthcare Facilities.
4. Intake Velocity
   a. The velocity over the entire face of the intake shall not exceed 2 m/s, with the exception of packaged HVAC equipment where the intake velocity shall not exceed 1.25 m/s.
5. Exhaust Discharge
   a. All exhaust must be discharged outdoors. Discharge to attics or crawl spaces is prohibited.
   b. The location of exhaust outlets shall comply with the Saudi Building Code (SBC 501-Mechanical Requirements).
   c. The height and velocity of laboratory exhaust discharges shall comply with ANSI/AIHA Z9.5 – Laboratory Ventilation.

d. Exhaust from cooking and food preparation applications shall be directed up and away from any building components or neighboring buildings

6. Nuisance or hazardous exhaust

a. Exhaust from diesel engines such as trucks in a loading dock or diesel generators are detectable and objectionable at concentrations well below the concentration that would constitute a health hazard.

b. Exhaust from cooking operations with high concentrations of spices are detectable and objectionable to many building occupants.

c. Exhaust from laboratory or industrial applications involving hazardous chemicals can pose a health risk if drawn into an intake and distributed in a building, especially in the event of a chemical spill.

d. For applications near nuisance or hazardous exhausts, sometimes following the recommended isolation distances between exhaust discharges and outdoor air intakes is not sufficient to prevent nuisance or even hazardous concentrations of fumes within a building. For these applications, careful consideration should be given to providing a higher level of design analysis such as computational Fluid dynamic (CFD) analysis or a wind tunnel study to confirm that adequate separation exists between air intakes and exhaust discharges.

(1) CFD analysis and wind tunnel studies involve complex science and must be completed by persons understanding the science and the application. Submit the names and resumes of the persons who will be completing the analysis to the Entity for approval.

7. Refer to the applicable project specifications.

8. Refer to project drawings for standard HVAC details.

4.4.1.3 Design and Application of Controls

1. DDC Systems Controls

a. All non-residential systems shall be direct digital type, distributed controls systems.

b. All actuators shall be electronic type.

c. For chillers, boilers and similar large items of equipment requiring control of integral components in the equipment such as compressors, inlet vanes, burners, motors, etc., it is preferable to have the controller for that equipment supplied by the equipment manufacturer. In such case, the controllers supplied by the equipment manufacturer must be compatible with the central control system provided for the building (i.e., the BAS). The controller for the individual equipment must be supplied with any required interface gateways so the manufacturer's controller can communicate seamlessly with the BAS.

d. Provide complete drawings for the control system. The drawings shall consist of:

(1) A drawing illustrating the control system architecture representing each floor of the facility and complete with the control network, all major expandable controllers, representative unitary controllers (multiple similar application unitary controllers on each floor can be represented by a symbol for the unitary controller application and then a note indicating that symbol is typical for a specific number of controllers, any necessary routers, all interfaces with other systems such as fire alarm or security, and all desired human machine interfaces.

(2) Complete control diagrams for all systems and equipment illustrating all required control devices to accomplish the desired sequences of operation.

(3) Complete written sequences of control for all systems and equipment. Sequences should be arranged so that short segregated paragraphs are provided for each component in a system. Long paragraphs specifying sequences for multiple components are confusing, and difficult for the programmers to follow. Programming is accomplished in short step function format, and the sequences should be arranged accordingly.

(4) Complete input/output (I/O) summary listing all control system components, the desired control functions and all desired alarms.

2. Apply reset control techniques (either CHW return reset or ambient air reset) for chilled water control system in non-%RH critical application. For fixed chiller supply temperature function where %RH is critical, set supply chilled water to higher temperature especially for low %RH region (such as Riyadh). Utilize CHW Differential Pressure Reset Control to maximize power savings if the index is multi-row coil with high water pressure drop.

3. Apply reset control techniques for centralized AHU supply air (Cold Deck Temperature) or Mixed Air temperature (MAT) reset for winter season when ambient air is colder than 13°C.

4. Apply temperature set-back or auto-shut off techniques during unoccupied time coupled to automatic occupant sensing.

5. Apply temperature set-back and reduce airflow techniques for application that requires continuous directional air flow such as isolation rooms, operating rooms, clean rooms, and other application that requires continuous directional flow.

6. Utilized fan and pump affinity law by distributing load to more variable speed equipment (pumps and fans) rather than single equipment during part load, thereby reducing the total power consumption due to lower speed requirement for multiple equipment compare to a single equipment at the same load. Power varies as the cube of rotating speed.

7. Use night pre-cooling techniques utilizing colder ambient air and/or mechanical cooling to store cooling effect in building façade and/or internal walls (walls and partitions with high thermal mass that is use as heat sink at daytime) thereby reducing cooling requirement during the day. Software calculated thermal time lag shall determine the time of starting the cooling equipment before sunrise.

8. DPS/T (Differential Pressure Sensor/Transmitter) for VFD pumping for close loop hydronic system must be located near the index (with the use of PICV) to maximize range in speed change for pumps. Maximized set-point for differential pressure (as low as possible to satisfy demand) to maximized potential power savings.

9. Pressure sensor for VFD AHU/Fan for air distribution system must be located ¾ lengths of the main duct run to maximize range in speed change for fans. Maximized set-point for pressure sensor (as low as possible to satisfy demand) to maximized potential power savings.

10. Refer to the applicable project specifications.

11. Refer to the project drawings for standard HVAC details.

4.4.1.4 Noise Control

1. General

   a. The ASHRAE Fundamentals Handbook – Sound and Vibration chapter and the ASHRAE Application Handbook – Sound and Vibration Control chapter; and this document shall constitute the noise and vibration control design criteria for Entity Projects.

   b. See the Table entitled Design Guidelines for HVAC-Related Background Sound in Rooms in the ASHRAE Applications Handbook – Noise and Vibration Control chapter for specific HVAC sound guidelines for various occupancy types. The following table lists HVAC sound guidelines for some representative spaces.

DESIGN GUIDELINES FOR HVAC RELATED BACKGROUND SOUND IN ROOMS

Space Type	Octive Band Analysis	Approximate Overall Sound Pressure Level	
	NC/RC	dBA	dBC
Private Offices	30	35	60
Open Offices	40	45	65
Conference Rooms	30	35	60
Libraries	30	35	60

Space Type	Octive Band Analysis	Approximate Overall Sound Pressure Level	
	NC/RC	dBA	dBC
Laboratories	50	55	75
Places of Worship	25	30	55
Classrooms	30	35	60

c. Sound and vibration are created by a source, transmitted along one or more paths, and reach a receiver.

d. Any sound analysis shall include source-path-receiver chain.

e. Treatments and modifications can be applied to any or all of these elements to achieve an acceptable acoustical environment.

f. It is most effective and least expensive to reduce noise at the source.

g. Adequate noise and vibration control in the mechanical systems is best achieved during the design phase.

h. The way the HVAC components are assembled into a system affects the sound level generated by the system and accordingly shall be considered in the design.

i. The basic elements of acoustics should be understood and used in order to work intelligently with SPL (Sound Power Level), PWL (Sound Pressure Level) and SIL (Sound Intensity Level) data for many types of electrical and mechanical noise sources, know the effects of distance (both indoors and outdoors), appreciate the significance of noise criteria, and be able to manipulate acoustic data in a meaningful and rational way.

2. The primary objective for the acoustical design of mechanical systems and equipment is:

   a. Ensure that the acoustical environment in a given space meet the design criteria.

   b. Consider practicality and simplicity.

   c. Consider total economy.

3. Several background sound rating methods are used to rate indoor sound. They include the A-weighted sound pressure level (dBA) and noise criteria (NC), the more recent room criteria (RC), balanced noise criteria (NCB) and the new RC Mark II.

4. Not all methods are equally suitable for the rating of sound in the variety of applications encountered.

5. The desired noise criterion curves for various indoor areas are published in the ASHRAE Handbook of Fundamentals and shall be used as the design criteria for Entity Projects.

6. It should be understood that lower values are quieter.

7. Select quieter equipment. Select manufacturers that involve ANSI, ISO, ARI, ASHRAE and ASTM standards to set up the equipment noise specifications and to evaluate acoustical equipment and products performance in the laboratory and in the field.

8. Equipment shall be oriented so that maximum sound radiation, such as from air intake and exhaust, is directed away from points of possible complaints.

9. Regular maintenance procedures such as tightening of loose parts and replacement of damaged components shall be enforced.

10. If areas have ambient noise levels exceeding 90 dBA; it shall be classified as Noise Hazard Areas.

11. Enclosures and Barriers

   a. Enclosing a sound source is a common means of controlling airborne sound transmission.

   b. Adequate wall and floor-ceiling constructions shall be designed to contain the noise and limit its transmission into adjoining areas.

c. Acoustic absorption material shall be used, if needed in either or both the sound transmitting room and the sound receiving room to absorb some of the sound energy that “bounces” around the room.

d. The sound transmission class (STC) rating of a partition or assembly is a single number rating used in architecture to classify sound isolation for speech (ASTM E90, ASTM E413).

e. Transmission loss data shall be used to select various types of construction materials for the design of noise enclosures.

f. Select partitions and floors on the basis of their one-third octave or octave band sound transmission loss values rather than single number ratings, especially when frequencies below 125 Hz are important.

g. Sound Transmission Class (STC) and Transmission Loss Values of typical mechanical equipment room wall, floor, and ceiling types in dB are found in ASHRAE Applications Handbook.

12. Noise Control in Duct Systems

a. System sound levels at maximum flow shall be carefully evaluated to ensure required acoustic levels.

b. The ductwork design shall appropriately consider and address airborne equipment noise, equipment vibration, duct-borne fan noise, duct breakout noise, airflow generated noise and duct-borne crosstalk noise.

c. Duct noise control shall be achieved by controlling air velocity.

d. Reduce fan-generated noise immediately outside of any mechanical room wall by acoustically coating or wrapping the duct.

e. Use sound attenuators for HVAC equipment and use corresponding duct velocity to attain the required noise criteria especially for noise sensitive areas. Upon selection of the HVAC equipment, the contractor shall submit an acoustic calculation to prove the insertion loss required for the selection of the sound attenuator model.

f. Terminal units shall be selected so that design air volume is approximately three-quarters of the terminal box’s maximum capacity.

g. Volume dampers shall be located at least 1.8 m from the closest diffuser.

13. Isolation from Exterior Noise Sources

a. Buildings located near airports, highways, rail corridors or other sources of significant environmental noise levels shall have exterior wall and window assemblies controlling noise intrusions.

14. Refer to the project specification for air noise attenuators.

15. Refer to project drawings for standard HVAC details.

4.4.1.5 Vibration Control

1. Design Objective

a. All vibrating, reciprocating, or rotating equipment shall be mounted such that it does not transmit significant levels of vibration into the surrounding or supporting structure.

b. Provide vibration isolation for all attachments to a vibrating machine, including structural mounts, cooling or drainage pipe connections, exhaust air ductwork, and electrical connections.

c. It is very important that equipment operating frequencies be isolated from natural frequencies of the building.

d. Ensure that the supporting structure has sufficient stiffness and mass.

e. Where it might be impractical or too expensive to meet the design criteria, then sound engineering judgment shall be applied to limit noise and vibration effect on building occupants and to protect the equipment.

2. Vibration Criteria
3. Design Criteria shall be as per ASHRAE Fundamentals and Applications Handbooks, recommended acceptable vibration criteria for vibration in a building structure.
4. Vibration Isolators Selection
   a. Vibration isolators must be selected not only to provide required isolation efficiency but also to compensate for floor stiffness.
5. Vibration Control
   a. Provisions shall be made to control equipment induced vibration.
      (1) Refer to and incorporate the basic design techniques as described in ASHRAE Applications Handbook, Sound and Vibration Control.
      (2) The use of vibration isolators between equipment and foundations and/or building structures shall be required to minimize transmitted vibration.
6. Vibration Isolators
   a. Vibration isolation mounts shall be used for the support of mechanical or vibrating equipment.
   b. Isolators shall be specified by type and by deflection, not by isolation efficiency.
   c. Refer to ASHRAE Fundamentals for Selection of Vibration Isolators and ASHRAE Application Handbook for types and minimum deflections.
   d. All vibration isolators shall be selected according to ASHRAE and manufacturer's recommendations.
   e. Isolation performance shall be within the responsibility of the equipment supplier.
7. Rotating Equipment
   a. All rotating equipment within the housing of units shall be mounted on vibration isolators.
   b. Reciprocating compressors shall be vibration isolated from the unit, and frame shall have vibration isolation (such as a vibration pad) between equipment and equipment base.
   c. All air handling units and fans casing shall be isolated from their ducts by flexible connections.
8. Ductwork
   a. The ductwork design shall appropriately consider and address equipment vibration.
   b. All ductwork connections to equipment having motors or rotating components shall be made with 150 mm length of flexible connectors.
   c. All ductwork within the mechanical room or serving critical rooms shall be supported with isolation hangers.
9. Piping Hangers and Isolation
   a. Isolation hangers shall be used for all piping in mechanical rooms and adjacent spaces, up to a 15 m distance from vibrating equipment.
   b. The pipe hangers closest to the equipment shall have the same deflection characteristics as the equipment isolators.
   c. Other hangers shall be spring hangers with 19 mm deflection. Positioning hangers shall be specified for all piping 200 mm and larger throughout the building.
   d. Spring and rubber isolators are recommended for piping 50 mm and larger hung below noise sensitive spaces.
   e. Floor supports for piping may be designed with spring mounts or rubber pad mounts.
   f. For pipes subject to large amounts of thermal movement, plates of Teflon or graphite shall be installed above the isolator to permit horizontal sliding.

g. Anchors and guides for vertical pipe risers usually must be attached rigidly to the structure to control pipe movement.

h. Flexible pipe connectors shall be designed into the piping before it reaches the riser.

10. Piping Supports

a. Provide channel supports for multiple pipes and heavy duty steel trapezes to support multiple pipes.

b. Hanger and support schedule shall have manufacturer's number, type and location.

c. Comply with MSS SP69 for pipe hanger selections.

d. Spring hangers and supports shall be provided in all the mechanical rooms.

11. Mechanical Equipment Isolation

a. Floating isolation bases shall be considered for major mechanical equipment located in critical areas.

12. Concrete Inertia Bases

a. Inertia bases shall be provided for reciprocating and centrifugal chillers, air compressors, all pumps, axial fans above 300 RPM, and centrifugal fans above 37.3 kW.

13. Mechanical Shafts and Chases

a. Mechanical shafts and chases shall be continuous and closed at the top and bottom.

b. Any piping and ductwork shall be isolated as it enters the shaft to prevent propagation of vibration to the building structure.

c. All openings for ducts and piping must be sealed.

d. Shafts dedicated to gas piping must be ventilated.

14. Refer to the project specification for vibration and seismic control for HVAC systems.

15. Refer to project drawings for standard HVAC details.

4.4.1.6 Water Treatment

1. Water quality for the HVAC system shall minimize corrosion, scale build-up and biological growth for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or the environment.

2. Specify water treatment systems for the following HVAC systems:

a. Closed loop chilled water

b. Closed loop heating water

c. Open loop cooling tower water

d. Steam boilers

3. Base all HVAC water treatment on the quality of water available at the project site, HVAC system and equipment material characteristics and functional performance characteristics, operating personnel capabilities and requirements and guidelines of the AHJ.

4. Obtain water samples at the site for testing to determine the required water treatment. Contract for an analysis of the water sample and a complete report of the water characteristics to be included with the specifications for the water treatment.

5. Specify water treatment requirements related to initially flushing all HVAC piping, for initially filling the piping systems and for maintaining the systems free of scale, corrosion and bacteria, and at the proper chemical concentrations and pH for efficient operation.

6. Water treatment shall maintain the following water quality parameters:

a. Closed Systems

(1) Conductivity: 1200 to 2500 µmhos

(2) pH: Not less than 7.5 or greater than 8.5 (except for piping flush and clean setup where the pH level shall be in the alkaline range of 9.5 to 10.5)

(3) Hardness: < 5 ppm

(4) Fouling factor: < 0.0005

b. Condenser Water

(1) Conductivity: 1500 to 1600 µmhos

(2) pH: Not less than 8.0 or greater than 9.5

c. Steam Boiler

(1) Boiler Conductivity: 3000 to 4000 µmhos

(2) pH: Not less than 9.0 or greater than 12.5

(3) Hardness: < 5 ppm

7. Refer to the project specification for water treatment chemicals for HVAC systems.
8. Refer to project drawings for standard HVAC details.

4.4.1.7 Evaporative Cooling

1. Evaporative cooling loses effectiveness at wet bulb temperatures above 26ºC. Therefore, it is not an appropriate strategy in some parts of Saudi Arabia for applications requiring year-round comfort conditioning to temperatures close to 24ºC.
2. Evaporative cooling can be effective for providing spot cooling in kitchens, laundries and industrial applications where higher than normal comfort temperatures are acceptable and delivering air at higher temperatures than would be delivered from refrigerated cooling equipment can have benefit.
3. Complete a life cycle cost analysis addressing the operating and maintenance cost of evaporative cooling to the Entity prior to starting detailed design.
4. Evaporative cooling should be done with 100% outdoor air.
   a. Provide a relief air path with proper controls to avoid over pressurization of the space served.
5. The air to be conditioned in an evaporative cooling process must first pass through filters with a minimum performance of MERV 8.
6. The water passing through the evaporative cooling device shall be passed through a Class 1 water filter with a minimum efficiency of 97% for particles 1 micron and larger in size.
7. Direct evaporative cooling or two-stage indirect/direct evaporative cooling are most effective for the applications listed previously.
   a. Rigid media or spray type direct evaporative coolers are preferred over wetted pad type because of the relative short life of the wetted pads (1 to 2 years).
8. The air velocity through the wet chamber shall be less than 2.5 m/s. Higher velocities can result in moisture carryover, as well as excessive fan horsepower requirements.
9. The wet chamber of the evaporative cooler shall be constructed of noncorrosive material. Stainless steel is preferred, but plastic or fiberglass may be accepted, based on review by the Entity. Obtain Entity approval for use of materials other than stainless steel for the wet chamber prior to bidding.
10. For evaporative coolers with rigid media, it is recommended the circulating pump remain operational even when the unit is not in use to avoid mineral deposits in the media.
11. A method must be provided for minimizing solids build-up in the sump. Time sequenced bleed-off or controls that activate bleed-off based on solids concentration are preferred because the limit water use.
12. Refer to project specifications for evaporative cooling equipment.
13. Refer to project drawings for standard HVAC details.

4.4.1.8 Electrical Considerations

1. Reference to other sections of the Mechanical Design Guidelines:

   a. Motors and motor starters are addressed in Subsection 4.3.4.8 – Motors and motor controllers.

2. General

   a. Consult the Entity Lead Electrical Engineer regarding the proper voltages for motors and equipment.

   b. Provide a complete list of HVAC equipment requiring electrical service with proposed voltage, phase and HP or maximum amperage to the Entity during the Schematic Design phase of the project. Update the list through each phase of the design process.

   c. Provide a complete list of equipment requiring power from an emergency source with proposed voltage, phase, horsepower of maximum amperage and starting priority to the Entity during the Schematic Design phase of the project. Update the list through each phase of the design process.

3. Generators

   a. Ventilation

      (1) The ventilation air shall satisfy the manufacturer's requirements for combustion and cooling.

      (2) Intake and exhaust louvers shall be located with sufficient separation to avoid short circuiting of the air which would result in equipment overheating.

      (3) Ventilation intakes shall incorporate motor operated dampers to close off the intake when not in use. These dampers shall be electrically held shut so that they will automatically open when the power fails.

      (4) The intake shall also be provided with filters to maintain clean air to the equipment room and to avoid degradation of equipment performance.

      (5) Indoor locations shall be selected to ensure that there is adequate intake and exhaust air to address the combustion and cooling air requirements.

      (6) Outdoor locations shall be coordinated with the surrounding facilities to ensure that adequate ventilation can be provided to address the combustion and cooling air requirements.

   b. Fuel Supply

      (1) Diesel engine-driven generators shall be used. Storage of diesel fuel shall be sufficient to support the back-up power loads for a minimum duration of 1½ hours but shall also accommodate routine exercising of the generator without requiring the fuel to be replenished after every routine test. Fuel storage tanks shall include capacity for 24 hours operation at full load or more as established by the criticality of the facility. The final storage capacity shall be confirmed for each facility with the Entity.

      (2) Fuel storage tanks shall be located above ground and they shall be double wall construction with integral leak detection to indicate if the fuel oil has entered the cavity between the inner and outer tank walls.

      (3) Fuel storage tanks may be base mounted below the generator or separate from the generator depending on the capacity and space requirements.

         (a) Indoor tanks are preferred. Outdoor tanks near traffic areas must be protected by bollards from being impacted by vehicles.

         (b) Fuel tanks must be contained by a dyke to limit amount of fuel spill in case of fuel leakage. Dyke must be sized to contain minimum of full fuel tank volume.

      (4) Fuel storage tanks and source piping shall be designed by the A/E. Refer to the following project specifications:

         (a) Facility Fuel-Oil Piping

(b) Facility Aboveground Fuel-Oil Storage Tanks

c. Engine Exhaust

(1) The engine exhaust system consists of the silencer and piping. These components will reach high temperatures and must be carefully designed to ensure that they will not impact the safety of the occupants or the building structure.

(2) The location of the discharge shall be carefully coordinated to ensure that the discharge will not affect the intake air to the building or the adjacent facilities.

(3) The exhaust silencer is typically provided with the generator unit and shall be specified with the sound attenuation characteristic suitable for the installed environment as follows:

(a) Residential grade silencer shall be utilized in light industrial areas where the background noise is relatively high and constant and the requirement for a higher level of silencing is minimal.

(b) Critical grade silencer shall be utilized for quiet residential areas where background noise is relatively low and critical grade silencing is required.

(c) Hospital grade silencer shall be utilized for noise reduction in heavy industrial areas where machinery operates in a quiet locality including, hospitals, schools, and quiet residential districts.

(4) The exhaust system piping shall be designed by the A/E. Refer to the project specification for engine exhaust systems.

d. Structural and Vibration

(1) The generator shall be provided with a foundation and housekeeping pad sufficient to support the weight of the equipment. This shall include the engine-generator, fuel storage, batteries, and engine exhaust silencer and piping.

(2) Vibration isolation shall be provided to avoid the transmission of vibration to the surrounding occupancies. The selection of the vibration isolation shall address any applicable seismic requirements and the sensitivities of the adjacent facilities.

e. Noise:

The engine exhaust noise is addressed by the silencer as described above. The radiated engine noise shall be addressed as follows:

(1) Indoor locations shall have the room designed to prevent transmission of the equipment noise to the adjacent spaces. The level of sound attenuation is dependent on the criticality of the adjacent spaces.

(2) Outdoor locations shall incorporate sound attenuation into the enclosure. The level of attenuation is dependent on the criticality of the adjacent facilities and control shall limit the sound level at the property line to meet all local codes and ordinances. In the absence of any ordinance, the sound attenuated enclosure shall be selected to limit the maximum noise at the property line to the following levels:

(a) Residential – 45 dBA

(b) Hospitals - 45 dBA

(c) Light Industrial – 55 dBA

(d) Heavy Industrial – 60 dBA

4. Refer to project drawings for standard HVAC details.

4.4.1.9 Integrated Building Design

1. Integrated building design is a process in which multiple disciplines and seemingly unrelated aspects of design are integrated in a manner that permits synergistic benefits to be realized.

2. It is a highly collaborative process that emphasizes the development of a holistic design.

3. The key to successful integrated building design is the participation of people from different specialties of design such as: general architecture, HVAC, lighting and electrical, interior design, and landscape design in a highly collaborative arrangement beginning at the very initiation of the concept design phase.
4. The key objectives in the design of any building include:
   a. Accessibility for people with special needs
   b. Aesthetics including physical appearance and image
   c. Economy relating to life cycle cost in addition to first cost
   d. Functionality in meeting the needs and requirements of the occupants as well durability and efficient maintenance
   e. Productivity of the occupants which is dependent on physical and psychological comfort
   f. Security and safety from natural and human threats
   g. Sustainability as it relates to the occupants and the environment
5. Each design objective is significantly important in any project, yet a truly successful one is where project goals are identified early on and held in proper balance during the design process; and where their interrelationships and interdependencies with all building systems are understood, evaluated, appropriately applied, and coordinated concurrently from the planning and programming phase. A truly high-performance building cannot be achieved unless the integrated design approach is employed.
6. By working together at key points in the design process, the design team can often identify highly attractive solutions to design needs that would otherwise not be found.
7. To accomplish truly integrated design, the engineering team must engage with the architectural team at the beginning of the concept design, and each team needs to understand the project program as well as each other's needs and constraints with regard to the project design. The engineering team cannot allow the architect to design to some early level of completion before they become engaged in the project.
8. In an integrated design approach, the engineering team will calculate energy use and cost very early in the design, informing designers of the energy-use implications of building orientation, configuration, fenestration, mechanical systems, and lighting options. The energy model will be used to inform the design, not simply confirm it.
9. Integration/collaboration must continue through all design phases of the project, although the effort has its greatest impact in the early stages of design where changes have lesser impact on the design production.

4.4.1.10 Fume Hood Exhaust Systems

1. Reference to other sections of the Mechanical Design Guidelines:
   a. Exhaust discharge design is addressed in Subsection 4.4.1.2 – Building Air Intake and Exhaust Design.
   b. Laboratory exhaust is addressed in Subsection 4.4.1.14 – HVAC for Laboratories.
2. General
   a. Fume hood exhaust systems shall be designed in accordance with the following codes and standards:
      (1) Saudi Building Code (SBC 501-Mechanical Requirements)
      (2) NFPA 45 – Standard on Fire Protection for Laboratories Using Chemicals
      (3) NFPA 90A – Standard for the Installation of Air Conditioning and Ventilation Systems
      (4) ANSI/AIHA Z9.5 – Laboratory Ventilation
   b. Complete the calculations to confirm if the exhaust airstream is or is not hazardous in accordance with the criteria listed in the Saudi Building Code (SBC 501-Mechanical Requirements).

c. Wherever possible, fume hood exhaust systems shall be manifolded systems to provide greater dilution of chemical fumes in the exhaust airstream, especially in the event of a spill, and for simplicity of providing exhaust fan redundancy.

(1) One redundant exhaust fan should be provided with each installation of laboratory exhaust fans.

d. Fume hood exhaust can be combined with laboratory exhaust in the manifolded system, but should not be combined with other building exhaust systems such as cooking, toilet or locker room exhaust systems.

e. Hoods which are high hazard or unique use, such as perchloric or other acid digestive systems, radio-iodination hoods, etc., shall not be installed in a manifolded system and must be separately exhausted.

f. Where the use of hoods reduces significantly at night, consider providing a lower capacity exhaust fan for night time operation, so the primary exhaust fans can be de-energized to reduce energy consumption.

g. For installations involving five or more fume hoods, the fume hood exhaust system should be variable air volume type.

(1) Coordinate with the specification of the fume hoods to assure that restricted bypass hoods suitable for variable air volume operation are specified.

(2) Where any single laboratory contains two or more hoods, consider motion and proximity sensors to reduce the airflow through the hood when no one is standing or moving near the hood.

(3) NIST Traceable tracking air valves shall be used for variable fume hood exhaust systems and make-up air. The air valve shall be interfaced with the hood control system and supply air VAV box to ensure negative room pressure is maintained. For fume hoods connected to other contaminated exhaust systems, provide an in-line exhaust fan to overcome the pressure drop across the fume hood HEPA filter, as required. Provide a differential pressure monitor and alarm (visual and audible) prior to the entry to the room containing the fume hoods.

h. The design exhaust air volume for each fume hood is generally based on operating at a maximum 45 cm height. Confirm this is appropriate for the applications involved in the project.

3. Materials

a. Duct materials between the fume hood and the exhaust mains shall be constructed of welded Type 316 stainless steel, unless it can be demonstrated that the vapors from the fume hoods are not corrosive.

b. If the exhaust main exhaust ducts convey fume hood exhaust only, they shall also be constructed of welded Type 316 stainless steel. If the main exhaust ducts convey general exhaust as well as fume hood exhaust, they may be constructed of galvanized steel in accordance with the SMACNA Duct Construction Standards.

(1) For systems conveying fume hood and general exhaust consider constructing the risers of Type 316 stainless steel, since they will be completely enclosed in the building construction, surrounded by other systems and nearly impossible to replace in the future should they corrode.

4. Fans

a. Fume hood exhaust fans should be constant volume for a single application to achieve constant dispersion of the effluent.

(1) Provide a modulating dilution damper for each fan to dilute outdoor air with the exhaust air dilution damper and maintain constant airflow through each exhaust fan as the fume hood and lab general exhaust airflow rates vary. The design pressure drop for the dilution damper at full flow shall be equal to the pressure drop in the exhaust duct system from the lab to the exhaust fan.

b. All fans for fume hood exhaust shall be jet fan type, induced flow AMCA Type B spark-resistant construction.

c. Many manufacturers produce high induction fans specifically designed for laboratory applications. Experience has shown that the performance of these fans with regard to dispersion varies with ambient wind velocity and direction, as well as the density of the exhaust and ambient air. When using these fans, the exhaust stack location, height and velocity requirements from the codes and standards sited at the beginning of this Section must still be followed. A wind tunnel or computational fluid dynamic dispersion study is still recommended.

d. Many manufacturers produce fan assemblies where multiple fans are factory assembled on a single intake plenum. Experience has shown that the manufacturers rarely account properly for system effect resulting from less than ideal inlet conditions to the fans. This can result in the actual exhaust capacity falling far short of the desire capacity. Address the results of system effect in every fume hood exhaust system design. Do not rely on the manufacturer of multiple fan assemblies to account for system effect.

e. Provide a low leakage isolation damper at the inlet of each fume hood exhaust fan. Where multiple exhaust fans are manifolded together or mounted on a single intake plenum, account for leakage through the isolation damper of any normally inoperable of redundant fans in the overall exhaust volume determination.

5. Controls

a. All fume hoods, constant or variable volume shall have an airflow monitor confirming the exhaust airflow rate through the hood is maintained at a velocity that provides a safe condition for anyone using the hood. The monitor shall have an audible and visible alarm indication of unsafe conditions, and shall transmit the alarm to the building automation system.

b. Variable air volume controls shall be designed specifically for laboratory fume hood applications and shall provide the response time and performance required by ANSI/AIHA Z9.5 – Laboratory Ventilation.

c. Variable volume fume hood controls shall include the following components:

(1) Face velocity display

(2) Visible and audible alarms for high and low face velocity

(3) Local alarm reset

(4) Standby velocity setting (for unoccupied mode)

(5) Sash position sensor

(6) Hood exhaust air volume feedback

(7) Dry contact for alarming transmission to the building automation system.

6. Refer to the applicable project specifications.

7. Refer to project drawings for standard HVAC details.

4.4.1.11 Lift Station Ventilation and Odor Control Systems

1. Methane gas is the primary byproduct of the biological degradation of waste that occurs in lift stations.

2. Methane gas is highly flammable and poses a potential for severe explosion in the presence of a spark.

3. Lift station ventilation systems shall be designed in strict accordance with NFPA 820 – Standard for Fire Protection in Waste Treatment and Collection Facilities.

4. Enclosed lift stations must be provided with Odor Removal Units capable of providing continuous lift station ventilation at minimum rate of 12 air changes per hour.

5. Fans for lift station ventilation shall be AMCA Type A Spark Resistant Construction.

6. Low and high exhaust shall be drawn from within 300 mm of the lowest maintenance access of the lift station space, and from within 300 mm of the ceiling of the lift station enclosure.
7. See Subsection 4.4.1.2 – Building Air Intake and Exhaust Design.
8. Refer to the applicable project specifications.
9. Refer to project drawings for standard HVAC details.

4.4.1.12 HVAC for Data Centers

1. General
   a. The most defining HVAC characteristic of data and communications equipment centers is the potential for exceptionally high sensible heat loads. In addition, the equipment installed in these facilities typically:
      (1) Serves mission-critical applications (i.e. 24/7/365 operation)
      (2) Has special environmental requirements (temperature, humidity, and cleanliness)
      (3) Has the potential for disruptive overheating and equipment failure if cooling service is interrupted.
   b. Expect that most computer equipment will be replaced multiple times with more current technology during the life of the facility. Typical equipment product cycles are 1 to 5 years, whereas facilities and infrastructure have life cycles of 10 to 25 years. Replacement equipment has historically required more demanding power and cooling requirements; therefore, expect the data center cooling load to increase over time. Plan how additional cooling capacity will be provided.
   c. Data Center Classification and Design Criteria.
      (1) Work with the entity to identify the environmental requirements for all data centers. A consortium of server manufacturers has agreed on a set of four standardized conditions (Classes 1 to 4), listed in *Thermal Guidelines for Data Processing Environments* prepared by ASHRAE Technical Committee 9.9 in 2011.
         (a) Class 1 – A data center facility with tightly controlled environmental parameters (dew point, temperature, and relative humidity) and mission-critical operations; types of products typically designed for these environments are enterprise servers and storage products.
         (b) Class 2 – A data center space or office or lab environment with some control of environmental parameters (dew point, temperature, and relative humidity); types of products typically designed for this environment are small servers, storage products, personal computers, and workstations.
         (c) Class 3 an office – A home, or transportable environment with little control of environmental parameters (temperature only); types of products typically designed for this environment are personal computers, workstations, laptops, and printers.
         (d) Class 4 – A point of sale or light industrial or factory environment with weather protection, sufficient winter heating and ventilation; types of products typically designed for this environment are point-of-sale equipment, industrial controllers, or computers and handheld electronics such as PDAs.
         (e) NEBS – A telecommunications central office with some control of environmental parameters (dew point, temperature and relative humidity); types of products typically designed for this environment are switches, transport equipment, and routers.
            i. Since Class 3 and 4 environments are not designed primarily for data center equipment, they are not covered further in this chapter.
2. Environmental Conditions
   a. The following table lists recommended and allowable conditions for Class 1, Class 2, and NEBS environments, as defined by the footnoted sources. Note that dew-point temperature and relative humidity are also specified.

CLASS 1, CLASS 2, AND SELECTED NEBS DESIGN CONDITIONS

Condition	Classes 1 and 2		NEBS	
	Allowable Level	Recommended Level	Allowable Level	Recommended Level
Temperature Control Range	15º to 32°C (Class 1) 10 to 35°C (Class 2)	18 to 27° C	5° to 40°C	18° to 26.7°C
Maximum Temperature Rate of Change	5°C/H		(cooling) 5°C/H	
Relative Humidity Control Range	20 to 80%, 17°C max. dew point (Class1) 21°C max. dew point (Class 2)	Dew point 5.5 to 15°C, RH less than 60%	5 to 85% 27.7°C max. dew point	Max 55%
Filtration Quality	65%, min. 30% (MERV 11, min. MERV 8)			Min. 85% (Min. MERV 13)

NOTE: The stated environmental conditions are measured at the inlet to the data and communications equipment, and not average space or return air conditions.

b. Outdoor Air Ventilation

(1) Provide adequate ventilation to pressurize the data center to aid in temperature and humidity control, dilute VOCs from the data center equipment, and provide acceptable indoor air quality conditions for human inhabitants in accordance with ASHRAE Standard 62 – Ventilation for Acceptable Indoor Air Quality. Ventilation air is typically cooled, dehumidified, filtered and delivered separately from the data center HVAC system.

(2) Uninterruptible power supplies (UPS) using vented flooded lead-acid batteries shall be exhausted at a minimum rate of 6 air changes per hour or 0.15 m^3/s, whichever is greater. UPS utilizing valve regulated lead acid batteries (VRLA) or modular cartridge batteries do not require special ventilation, other than the normal ventilation required to meet the ventilation requirements for human occupants.

(3) Refer to Paragraph 4.2.2.4.f for requirements relating to purging clean agent fire suppression chemicals.

c. Flexibility

(1) As mentioned earlier, technology is continually changing and data center equipment in a given space is frequently changed and/or rearranged during the life of a data center facility. In critical applications, it shall be possible to modify the system without shutdown. Modular in-rack cooling options provide the greatest overall flexibility. They can utilize chilled water or variable flow refrigerant for cooling.

d. Redundancy

(1) Provide N+1 redundancy for each item of equipment in a data center HVAC system.

3. HVAC Load Considerations

a. Calculate cooling loads in data center facilities in the same manner as for any other facility. Typical features of these facilities are a high internal sensible heat load from the data center equipment itself and a correspondingly high sensible heat ratio. However, other loads exist and it is important that a composite load comprised of all sources is calculated early in the design phase, rather than relying on a generic overall "watts per square meter" estimate that neglects other potentially important loads.

b. In addition, if the initial deployment or first-day data center equipment load is low because of low equipment occupancy, the effect of the other loads (envelope, lighting, etc.) becomes proportionately more important in terms of part-load operation.

c. In some cases, power distribution units (PDUs) are located in the data center equipment room as the final means of transforming voltage to a usable rating and distributing power to the data center equipment. The heat dissipation from the transformers in the PDUs shall be accounted for by referencing the manufacturer's equipment specifications.

d. Heat gains through the building envelope shall be included.

e. Lighting is normally a small part of the overall heat gain for a data center, but needs to be included in the HVAC load calculation.

4. Reheat

Reheat is only needed in data centers for humidity control when the infiltration of humid air is high as well as the anticipated presence of maintaining staffs resulting in a steep RSHF (Room Sensible Heat Factor). General applications do not require reheat, and it is discouraged for reasons of power savings and equipment first cost. Electric resistance reheat provides the best control and is the most economic method if reheating will be required.

5. Humidification

a. The data center envelope shall be carefully constructed of extremely low permeability materials to prevent humidity from permeating into or out of the data center. Work with the A/E and/or Construction Contractor to ensure envelope materials and construction details result in a “humidity tight” facility.

b. Humidification shall be provided by electric steam generators. Electric steam generators shall be provided with disposable water canisters that may be replaced when they become caked with precipitate from the water being evaporated.

6. Energy Conservation

a. Power usage effectiveness (PUE) is a metric for characterizing and reporting overall data center infrastructure efficiency, and is defined by the following formula:

$$\textbf{\textit{PUE}} = \frac{\textit{Total data center energy consumption or power}}{\textit{IT energy consumption or power}}$$

b. When calculating PUE, IT energy consumption shall be measured directly at the IT load. If necessary, at minimum, it could be measured at the output of the UPS.

c. The design goal for data center PUE shall be 1.6 or less.

7. HVAC Systems, Components and Arrangements

a. Consider the data center cooling load, the equipment density, the mission critical nature of the equipment, and the size of the data center.

(1) Computer room air conditioning (CRAC) and computer room air handling (CRAH) units are the most common data center cooling units. However, they are not necessarily the most efficient, especially at serving dense equipment loads

(2) Some larger data centers use central-station air handling units. These may not work well for getting the conditioned air to densely packed equipment, and it may be expensive to provide a high level of redundancy. If multiple air handling units can be manifolded together, only one additional AHU may be required to provide redundancy. Another option for manifolded air handling units is to oversize the units then operate them at reduced capacity when all units are operational. Then if one units fails or is taken out of operation for maintenance purposes, the capacities of the remaining units can be ramped up to meet the load.

b. Chilled-water distribution loops are frequently provided with taps and valves for future local fan coil units that are designed especially for data center applications. Careful design of the loop may provide for flow from either direction in the loop if a section must be isolated to provide a new tap.

(1) Chilled-water pipe insulation with a vapor barrier is required to prevent condensation, but not to prevent thermal loss in a cold plenum; therefore, minimum insulation thickness shall be considered as insulated piping may restrict underfloor air distribution.

c. Controls and Monitoring

(1) Control systems shall be capable of reliable control of temperature, relative humidity, and, where required, pressurization within tolerance from set point. Specify the required control accuracy to maintain the desired temperature and humidity tolerances.

(2) Monitoring shall include control system sensors as well as independent "monitoring-only" sensors and shall include data center equipment areas, critical infrastructure equipment rooms, command/network operations centers, etc., to ensure critical parameters are maintained.

(3) As a minimum, alarms shall be provided to signal when temperature or humidity limits are exceeded. Properly maintained and accurate differential pressure gages for air-handling equipment filters may help prevent loss of system airflow capacity and maintain design environmental conditions. All monitoring and alarm devices shall provide local indications as well as interface to the central monitoring system.

d. Data center equipment is typically mounted in racks or cabinets arranged in rows. In a typical configuration, the "front" of cabinets, racks, or frames faces one aisle, and the rear, which includes cable connections, faces another aisle. The cabinets or racks in a data center environment are usually 2 m high. Each cabinet or rack may contain a single piece of equipment, or it may contain any number of individual items of equipment.

e. Typically, supply air is drawn into the inlet of the equipment cabinet or rack, picks up heat internal to the equipment, and is then discharged from a different side of the equipment. The air then travels back to the HVAC cooling coil, where the heat is absorbed.

(1) Hot Aisle/Cold Aisle Configuration. Using alternating hot and cold aisles promotes separation of the cool supply and warm return streams which generally leads to lower equipment inlet temperatures and greater energy efficiency.

(a) Data center facilities often use an underfloor plenum to supply cooling air to the equipment. CRAC units push cold air into the plenum, from which it is introduced into data and communications equipment rooms via perforated floor tiles, tile cutouts, and other openings. The raised-floor design offers flexibility in placing computer equipment above the raised floor. Cool air can, in theory, be delivered to any location simply by replacing a solid floor tile with a perforated tile.

(b) With a hot-aisle/cold aisle configuration, perforated tiles are placed in the cold aisle. Cool air delivered by the perforated tiles is drawn into the front of the racks. Warm air is exhausted from the back of the racks into the hot aisle and is ultimately returned to the CRAC units.

(c) The underfloor plenum is often used for cables, electrical conduits, and pipes. These obstructions in the plenum may interfere with airflow. When determining plenum depth, below-floor obstructions shall be considered. It is recommended that the height of underfloor plenums be at least 300 mm.

(d) When adequate airflow is not supplied through the perforated tiles, internal fans in the equipment racks tend to draw air through the front of the cabinet from the path of least resistance, which typically includes the space to the sides of and above the racks. Because most of this air originates in the hot aisle, its temperature is high. Thus, cooling of the sides and upper portion of the equipment racks could be seriously compromised.

4.4.1.13 HVAC for Hospitals and Clinics

1. Reference to other sections of the Mechanical Design Guideline:

a. Exhaust discharge design is addressed in Subsection 4.4.1.2 – Building Air Intake and Exhaust Design.

2. General

a. HVAC systems for hospitals and clinics shall be designed in accordance with the following codes and standards:

(1) Saudi Building Code (SBC 501- Mechanical Requirements)

(2) AIA Guidelines for Design and Construction of Health Care Facilities

(3) NFPA 92 – Standard for Smoke Control Systems

(4) NFPA 99 – Healthcare Facilities Code

b. Refer to the ASHRAE Applications Handbook Health Care Facilities Chapter for further information and guidance regarding laboratory HVAC design.

c. The cooling demand for hospitals will usually dictate a central chilled water system.

d. Where chillers with water cooled condenser are utilized, consider collecting cooling coil condensate to be used for cooling tower make-up water. The peak production of cooling coil condensate will normally coincide with peak demand for cooling tower make-up water.

3. HVAC Air Handling System

a. Central air handling systems are preferred for hospitals. The central systems consolidate most of the equipment requiring maintenance into large mechanical rooms, and minimize the number of satellite equipment requiring maintenance, as well as the complexity of that maintenance.

b. Central air handling systems should be variable air volume systems that meet the airflow requirements of the Saudi Building Code (SBC 501- Mechanical Requirements) and the AIA Guidelines for Design and Construction of Health Care Facilities.

c. Zone reheating for space temperature control shall be accomplished by electric resistance heaters.

d. The central air handling system should be comprised of several identical air handling units. Units can be staged off as the supply air demand diminishes during periods of low occupancy. Multiple air handling units can be designed to operate at low velocities through coils and filters during normal operation for energy savings, and then ramped up to adjust for a unit that fails or is taken out of service for maintenance.

e. In air handling units, locating the supply fan downstream from the cooling coil but upstream from the final MERV 14 filters eliminates the risk of treated supply air contamination by untreated air infiltration due to highly positive pressure.

f. Energy recovery will generally be cost effective for large heath care facilities. Complete a life cycle cost analysis to determine the cost vs. benefit of an energy recovery system. Where practical, consider collecting condensate from the air handling unit cooling coils, and then passing the condensate through an evaporative cooling unit in the exhaust airstream upstream from the exhaust heat recovery coil. This will lower the exhaust air temperature and improve the overall performance of the heat recovery system.

g. Packaged terminal equipment and fan coil units are acceptable for clinics and small heath care facilities.

4. Air distribution System Design

a. Hospitals have rather high supply, return and exhaust air volume requirements. Careful design of the distribution ductwork can significantly reduce the fan horsepower, and the resulting electrical energy use.

b. The velocity in the duct system should systematically step down from the risers to the air outlets in the rooms. Maximum velocity in risers should be 10 m/s. Maximum velocity in main ducts should be 7.5 m/s. Maximum velocity in branch ducts to variable volume and constant volume terminals should be 6 m/s. Maximum velocity in duct downstream of the variable volume and constant volume terminals should be 5 m/s. Maximum velocity in diffuser necks should be 2.5 m/s. This systematic decreasing of velocity results in a phenomenon known as “static regain” which reduces the overall resistance to flow, and the corresponding fan horsepower.

c. Locate supply air diffusers and registers in patient rooms to avoid drafts at the patient bed.

5. Room Environmental Control

a. An individual room controller should be provided as part of the BAS for each room in a hospital.

b. Individual temperature (and humidity control where required) should be provided for occupied spaces.

c. Some spaces in hospitals require pressure control with respect to surrounding spaces. Examples are infectious isolation rooms, protective isolation rooms, operating rooms, other invasive procedure rooms, sterilization rooms and morgues. This is best accomplished by maintaining a constant offset between the supply and return/exhaust airflows for these spaces. The airflow can be measured by the airflow sensors in the supply and exhaust air volume control terminals and the offset can be controlled by the room controller.

(1) Differential pressure monitoring between a space and a corridor is useful for indicating and alarming a condition where the airflow tracking has failed. However, for pressure control, airflow tracking is much more reliable than active pressure control.

6. Refer to project drawings for standard HVAC details.

4.4.1.14 HVAC for Laboratories

1. Reference to other sections of the Mechanical Design Guidelines:

   a. Exhaust discharge design is addressed in Subsection 4.4.1.2 – Building Air Intake and Exhaust Design.

   b. Exhaust systems for fume hoods are addressed in Subsection 4.4.1.10 – Fume Hood Exhaust Systems

2. General

   a. HVAC systems for laboratories shall be designed in accordance with the following codes and standards:

      (1) Saudi Building Code (SBC 501- Mechanical Requirements)

      (2) NFPA 45 – Standard on Fire Protection for Laboratories Using Chemicals

      (3) NFPA 90A – Standard for the Installation of Air Conditioning and Ventilation Systems

      (4) ANSI/AIHA Z9.5 – Laboratory Ventilation

   b. Refer to the ASHRAE Applications Handbook Laboratory Chapter for further information and guidance regarding laboratory HVAC design.

   c. There are four fundamental concerns in the design of laboratory HVAC systems:

      (1) Safety is paramount.

      (2) Functionality – many processes and procedures in a lab are critical, and the systems must function and provide the support needed.

      (3) Flexibility – Over time the experiments in the labs will change. Some changes will be significant. The lab HVAC system must be able to adapt to those changes.

      (4) Energy Efficiency – Laboratory buildings consume more energy than most other building types. Careful attention must be paid in the design phase to minimize energy consumption.

   d. An initiative cosponsored by the U.S. Environmental Protection Agency and the U.S. Department of Energy (DOE) known as Labs for the 21st Century (Labs21) promotes the sharing of information related to reducing energy and water consumption in laboratories. This initiative has been continued by the International Institute for Sustainable Labs(I^2SL). Labs21 and I^2SL distribute Best Practice Guides with information on the design, construction, and operation of specific technologies that contribute to energy efficiency and sustainability in laboratories. The following Best Practice Guides should be considered in laboratory design:

      (1) Energy Recovery in Laboratory Facilities

      (2) Chilled Beams

      (3) Optimizing Laboratory Ventilation Rates

      (4) Commissioning Ventilated Containment Systems in the Laboratory

      (5) Laboratory Guidelines Using ASHRAE 90.1 - Appendix G

      (6) Metrics and Benchmarks for Energy Efficiency in Laboratories

      (7) Manifolding Laboratory Exhaust Systems

(8) Efficient Electric Lighting in Laboratories

(9) Minimizing Reheat Energy Use in Laboratories

(10) Right-Sizing Laboratory Equipment Loads

(11) Modeling Exhaust Dispersion for Specifying Acceptable Exhaust/Intake Designs

(12) Water Efficiency Guide for Laboratories

(13) Low-Pressure-Drop HVAC Design for Laboratories

(14) Daylighting in Laboratories

(15) Onsite Power Systems for Laboratories

3. HVAC System Capacity and Right Sizing

a. It is typical that the airflow requirements for some labs is determined by the exhaust demand, usually based on the number of fume hoods. The airflow requirements for other labs will be determined by the internal heat gain from equipment. Analyze the lab program to determine the determining factor for the airflow design and size the HVAC accordingly. Apply typical diversity factors for lab equipment as found in ASHRAE Applications Handbook Laboratories Chapter.

(1) For labs with high concentrated sensible heating loads from equipment, consider chilled water fan coil units to provide supplemental cooling and meet peak cooling demands.

(2) Provide a secondary chilled water distribution system in lab buildings for supplemental sensible cooling and for equipment cooling.

b. The air handling system for a laboratory building should be one single central system wherever possible. Issues of redundancy and flexibility can be addressed more simply if the building is served by one system.

c. Air from uncontaminated spaces such as offices, classrooms, conference rooms usually comprises a relatively small percentage of the total air requirement for a lab building, and 100% of this air can be returned to the central air handling system.

d. The central air handling system should be comprised of several identical air handling units. Units can be staged off as the supply air demand diminishes during periods of low occupancy. Multiple air handling units can be designed to operate at low velocities through coils and filters during normal operation for energy savings, and then ramped up to adjust for a unit that fails or is taken out of service for maintenance.

e. Energy recovery will generally be cost effective for large laboratory buildings. Complete a life cycle cost analysis to determine the cost vs. benefit of an energy recovery system. Where practical, consider collecting condensate from the air handling unit cooling coils, and then passing the condensate through an evaporative cooling unit in the exhaust airstream upstream from the exhaust heat recovery coil. This will lower the exhaust air temperature and improve the overall performance of the heat recovery system.

4. Air Distribution System Design

a. Laboratory buildings tend to be "supply air intensive". Careful design of the distribution ductwork can significantly reduce the fan horsepower requirement, and the resulting electrical energy use.

(1) The velocity in the duct system should systematically step down from the risers to the air outlets in the rooms. Maximum velocity in risers should be 10 m/s. Maximum velocity in main ducts should be 7.5 m/s. Maximum velocity in branch ducts to variable volume and constant volume terminals should be 6 m/s. Maximum velocity in duct downstream of the variable volume and constant volume terminals should be 5 m/s. Maximum velocity in diffuser necks should be 2.5 m/s. This systematic decreasing of velocity results in a phenomenon known as "static regain" which reduces the overall airflow resistance in the ductwork, and reduces the required fan horsepower and resulting electrical energy use.

b. Consider using "extended plenum" sections in the supply and exhaust air duct where the duct remains the same size for extended lengths. This will reduce the resistance, and will also contribute to the flexibility of the system. Sometimes heavy demands are imposed in the middle or at the ends of the distribution system. The extended plenum concept will accommodate high demands in almost any portion of the distribution system.

c. Opinions vary regarding safe minimum airflow rates for laboratories where chemicals are used. Unless active air monitoring is employed in labs where chemicals are present, the airflow rates shall not be less than 6 air changes per hour when the lab is occupied, and not less than 4 air changes per hour when the lab is unoccupied.

d. Supply air registers and grilles must be located carefully so as not to create air currents that will spread chemical fumes or cause fume spillage from fume hoods.

5. Room Environmental Control

a. An individual room controller should be provided as part of the BAS for each lab.

b. Individual temperature (and humidity control where required) should be provided for each lab room.

c. In general, it is desirable to maintain most labs at a negative pressure with respect to the adjacent corridor. This is best accomplished by maintaining a constant offset between the supply and exhaust airflows to each lab. The airflow can be measured by the airflow sensors in the supply and exhaust air volume control terminals and the offset can be controlled by the lab room controller.

d. Differential pressure monitoring between a lab and a corridor is useful for indicating and alarming a condition where the airflow tracking has failed. However, for pressure control, airflow tracking is much more reliable than active pressure control.

e. Because of the high air change rates in laboratories, as well as the characteristics of lab equipment to transfer heat to the space, location of temperature and humidity sensors must be considered carefully.

6. Lab Hoods

a. Lab hood types include fume hoods and canopy hoods.

b. Fume hood types include full bypass constant volume hoods and restricted bypass variable volume hoods. Coordinate with the engineer selecting the fume hoods to assure the proper hood is selected for the type of exhaust system being designed. Auxiliary air fume hoods should not be used for laboratory applications.

c. Ductless fume hoods are gaining popularity for applications with minimal chemical use. Recognize the chemical absorbing filters in these hoods will have to be changed while the hoods are in place. Provide proper access to the hoods, and confirm the maintenance staff who will be servicing the hoods has the staffing and the expertise needed to change the filters. Ductless fume hoods must comply with all applicable codes. Perform an assessment of the chemicals that will be used in a laboratory vs. the effectiveness and life of the ductless fume hood filters prior to specifying the ductless fume hood for any application.

d. Canopy hoods typically do not provide adequate capture for most applications in laboratories; however, they are used for some applications to remove sensible heat from ovens and similar equipment.

e. For applications where perchloric acid is used in experimentation and laboratory procedures, hoods specially design for perchloric acid should be used. Perchloric acid is a strong oxidizing agent, and the hood and connected ductwork must be constructed of materials that will resist attack from the chemical. The ductwork must be constructed of welded Type 316 stainless steel, and must have complete washdown capability.

f. Air flow through the open hood face area shall be 500 lps-m^2 for fume hoods and canopy hoods adjacent to a wall. Air flow through the open face area of island canopy hoods shall be 625 lps-m^2.

g. Biological safety cabinets are enclosures that employ an internal fan and filtration system to protect the environment inside the cabinet, as well as the environment in the lab. They are not fume hoods, and should not be used as such. There are several types of biological safety cabinets.

(1) Class II Type A cabinets are unducted.

(2) Class II Type B1 cabinets have an exhaust duct connection, but the connection usually includes a bypass where some exhaust air is drawn from the room. They therefore do not impart any airflow resistance to the lab exhaust air system.

(3) Class II Type B2 cabinets are hard connected to the exhaust system and impart as must as 500 Pa of resistance to the exhaust system. It is therefore advisable that a dedicated exhaust system be provided for Class II Type B2 cabinets to avoid operating the entire lab exhaust system at a much higher static pressure.

7. Refer to the applicable project specifications.

8. Refer to project drawings for standard HVAC details.

4.4.1.15 Contamination Control

1. Reference to other sections of the Mechanical Design Guidelines:

a. Air filtration is addressed in Subsection 4.3.1.11 – Air Filtration

b. Building automation systems are addressed in Subsection 4.2.13 – Building Automation System

c. Building air intake and discharge design considerations are addressed in Subsection 4.4.1.2 – Building Air Intake and Exhaust Design

d. Design of building automation systems is addressed in Subsection 4.4.1.3 – Design and Application of Controls

2. General

a. HVAC systems can assist in contamination control in research and healthcare facilities.

b. The air must be free from contaminants, must be distributed in a space in a uni-directional flow pattern to prevent contamination of occupants or processed in the room, and must provide the desired pressure relationship in the room with respect to surroundings.

3. Filtration

a. MERV 14 (95% efficient) filters are acceptable for most hospital applications in providing contamination control. MERV 14 filters are effective in removing bacteria from airstreams and located downstream of the AHU fan.

b. MERV 17 (HEPA) shall be utilized for operating theatres and protective isolation rooms for patients with suppressed immune systems or burn patients.

c. MERV 17 filters shall be used for contamination control in manufacturing processes or research related to electronic or computer equipment. MERV 20 (ULPA) filters are used for application with extreme cleanliness or very low particulate count requirements.

4. Uni-Directional Airflow

a. In the healthcare environment, contamination control shall be provided to protect the patient or the healthcare worker.

(1) In either case, the desire is to deliver filtered and conditioned air from high in the space, and to have the filtered air pass to the protected occupant, to the contaminated occupant, and then to the room return or exhaust air terminal.

(2) For healthcare and other similar applications, refer to ASHRAE or other applicable standards for the minimum required ACH (Air Change per Hour) for each application for contamination control.

b. In the product manufacturing and research environment, the intent of the contamination control is to protect the product from dust and other contaminants. The desire is to create a “shower” of clean air passing from the ceiling, over the product, and then to low, floor-level return air outlets.

(1) MERV 17 filters are typically located at the ceiling level.

(2) The airflow rate and ceiling filter coverage varies depending on the level of cleanliness desired.

(3) Refer to the ASHRAE Application Handbook Chapter regarding Clean Spaces.

5. Room Pressurization

a. Pressurizing a room to a pressure higher than the adjacent spaces will help prevent contaminants from entering the space; whereas, maintaining a contaminated room at pressure less than the adjacent spaces will prevent contaminants from migrating from the space.

b. It is generally accepted that a differential pressure equal to 12.5 Pa is adequate for contamination control.

c. Work with the Architect to ensure construction materials and methods to contain and maintain the desired pressure relationship.

6. Refer to the project specification for air cleaning and filtration for HVAC systems.

7. Refer to project drawings for standard HVAC details.

4.4.2 Building Operations

1. Energy Use and Management

a. Reference to other sections of the Mechanical Design Guidelines:

(1) HVAC equipment room design is addressed in Subsection 4.2.1 – Central Heating and Cooling

(2) Building Automation is addressed in Subsection 4.2.13 – Building Automation

b. The following are guidelines for minimizing energy use.

(1) The energy consumption for most buildings in Saudi Arabia is dominated by air conditioning systems and supply air fans.

(2) Optimize the selection of all components. Provide life cycle cost analysis for options to optimize the energy consumption.

(3) Review the results of all energy modeling with the building operators so they become familiar with assumptions made regarding how the building is to be operated, in order to understand how to operate the building efficiently.

(4) Specify adequate training for the building operators on the programming and functions of the building automation system so they can monitor the HVAC systems and energy use closely and make necessary adjustments to the programming and functions to reduce energy use.

(5) The Sequences of Controls should include special strategies to optimize the operation of systems and equipment. These strategies go beyond the normal functions required to achieve comfort in buildings. Review the BAS shop drawing submittals in detail to ensure the vendor providing the system understands the sequences and is incorporating them properly in the HVAC systems. Many building automation system vendors have standard, pre-programmed basic sequences for controlling different types of HVAC systems, and they will often substitute those standard sequences for the custom sequences specified in the construction documents.

(6) Clearly illustrate all of the required control devices on the control drawings, the plans and the standard detail drawings. Do not rely on the control sequences or standard notes to cover the requirement to provide control devices.

(7) Illustrate and specify all metering required to monitor energy use. Accurate monitoring will aid the building operators in determining how to fine tune the building operation to minimize energy use.

(8) Consider providing a central “energy dashboard” to display the energy use of the systems and equipment, as well as the performance of any energy savings strategies

such as photovoltaic or active solar systems, heat recovery and variable frequency drives for pumps and fans.

(9) Refer to Subsection 4.4.1.3 – Design and Application of Control for other energy optimization techniques related to building control system.

2. Owning and Operating Costs

a. Owning and operating costs include maintenance costs and replacement costs for equipment, in addition to the energy cost for operating the facility.

(1) The project specifications provide a standard of quality for systems and equipment that helps ensure cost effective reliability and longevity for HVAC Systems and equipment. Do not compromise on the standard of quality established in the project specifications during the shop drawing submittal review and approval process.

(2) The project drawings for standard HVAC details illustrate the features and accessories required for systems and equipment so they may be properly maintained. Failure to provide these features and accessories could limit the building operators' ability to properly maintain systems, which could seriously increase owning and operating cost over time. Failure to provide valves in proper locations, or valves that provide tight shut-off could limit the ability to provide maintenance, and could create the need for widespread system shutdown to replace one item of equipment, which will significantly increase maintenance costs. Failure to provide flow and pressure readout ports in proper locations could limit the ability to balance systems properly, which could lead to a long-term increase in owning and operating costs.

3. Testing, Adjusting and Balancing

a. General

(1) Systems that control the environment in a building change with time and use and must be rebalanced accordingly. The designer must consider initial and supplementary testing and balancing requirements for commissioning carefully when developing the design documents.

(2) Clearly illustrate all devices required for proper balancing on the construction documents. These devices include, in addition to valves and dampers, ports and flow meters required in the hydronic systems to properly measure flow rates. It is almost impossible to install ports and flow meters in a hydronic system after it is filled and operational. Surface flow measurement devices (Doppler type) have limited accuracy.

(3) Create documents that clearly list the design air and water flow rates for each item of equipment. These documents may be riser diagrams illustrating each item of equipment and/or terminal, or spreadsheets that list each item of equipment or terminal with an identifying number that corresponds to the information on the HVAC plans.

(4) Where items of equipment and terminals operate over a range of flow, list the maximum and minimum flow rates for each item.

(5) Where flow rates vary for occupied vs. unoccupied periods, list both the occupied and unoccupied flow rates.

(6) Specify balancing tolerances. Minimum flow tolerances are + 10% for individual terminals and branches in on-critical applications and + 5% for main air ducts. For critical water systems where differential pressures must be maintained, tolerances of + 5% are suggested. For critical air systems, recommendations are the following:

(a) Positive zones:

i.	Supply Air	0 to 10%
ii.	Exhaust and Return Air	0 to -10%

(b) Negative zones:

i.	Supply Air	0 to -10%
ii.	Exhaust and Return Air	0 to +10%

4. Operation and Maintenance Management

a. Documentation

(1) Information on the facilities, collateral equipment, and intended operation procedures is essential for planning facilities maintenance actions, efficiently performing facilities maintenance, documenting maintenance histories, following up on maintenance performance, energy reporting, and management reporting.

(2) Specify detailed Operation and Maintenance (O&M) Manuals for all HVAC systems and equipment. Deliverables shall support the expected maintenance strategy, skills of the maintenance and operation staff, and anticipated resources to be committed to performing operations and maintenance.

(3) The information shall be provided in hard copy and digital format.

(4) Information shall be compiled into the manual as soon as it becomes available. This information may be used to support design and construction activities, systems commissioning, training of operation and maintenance staff, start-up and troubleshooting. It is critical that all information required to operate the systems and maintain the equipment be compiled prior to project turnover to the owner's staff and be available to the entire facilities department.

(5) A complete operation and maintenance documentation package is to include following documents:

(a) The operation and maintenance document directory provides easy access to the various sections within the document.

(b) Emergency information, which shall include emergency and staff and/or agency notification procedures. In addition to being directly distributed to emergency response personnel, including emergency information in the operation and maintenance documents enables this critical information to be kept in a single place and be immediately available during emergencies.

(c) The operating information, which shall contain the following information:

i. General Information:
- Building function
- Basis of design
- Building description
- Operating standards and logs

ii. Technical information:
- System description
- Operating routines and procedures
- Seasonal start-up and shutdown
- Special procedures
- Basic troubleshooting

iii. The maintenance information:
- Equipment data sheets (specific to installed equipment)
- Operating and nameplate data
- Warranty information
- Manufacturer's installation, operation, and maintenance instructions
- Spare parts information
- Corrective, preventive, and predictive maintenance actions, as applicable
- Schedule of actions, including frequency
- Action descriptions

(d) Test reports with a record of observed performance during start-up and commissioning.

(e) Copies of construction documents ("As-Built").

b. Staffing and Training

(1) Training is a critical component in the overall operating and maintenance plan. Assess the skills and experience and knowledge of the operating and maintenance staff, and specify adequate training for them to become completely familiar with the requirements

for the building. Specify for the training to be videotaped for review and refresh by the staff, as well as for training future recruits. Training may be done in-house or by a contracted third party who provides training as a business.

5. Building Energy Monitoring
   a. General
      (1) Project specifications for commissioning and control and monitoring systems for HVAC Systems address the requirements for building performance monitoring and verification.
      (2) These requirements meet or exceed the standards for building performance and verification established in ASHRAE Standard 14 – Guideline for the Measurement of Energy and Demand Savings.
      (3) Carefully consider each system that consumes energy and provide the detailed metering so that they may be monitored individually in order for their contribution to the overall energy use of the building to be quantified. And to accurately determine the effect of changes in operations of the facility on the reduction in energy usage.
6. Supervisory Control Strategies and Optimization
   a. General
      (1) The project specification for sequence of operations for HVAC controls provides sequences that will optimize the operation of the HVAC systems with regard to energy use.
      (2) Confirm in the shop drawing review and commissioning that the building automation system vendor has followed the sequences to the letter.
7. Refer to the applicable project specifications.

4.5 HVAC Guidelines by Building Type

4.5.1 Public/Government

1. DX systems are most suitable for buildings with cooling demand 200 Tons or less. For buildings with cooling demands greater than 200 Tons, consider a chiller water system
2. Ventilation systems shall be designed in accordance with ASHRAE Standard 62 – Ventilation for Acceptable Indoor Air Quality and ASHRAE Standard 90.1 – Energy Standard for Buildings Except Low Rise Residential Buildings.
3. All outdoor air intakes shall have sand trap louvers.
4. Temperature control zones for public/government buildings should not exceed 200 sq m in floor area, except for large open assembly areas. Smaller control zones will generally provide better comfort, but may not be economical. For large open assembly areas, temperature control zones can be as large as 1000 sq m. Assembly areas with multiple levels should have a separate temperature control zone for each level.
5. For large assembly areas, air should be supplied so that it is directed at the front of the occupants' bodies. If air cannot be adequately distributed from the front of the occupants, it may be distributed from the side at a velocity not exceeding 0.15 m/S. In no case should air be delivered from the occupants' backs.
6. All supply air shall be ducted.
7. Ceiling plenums may be used for return air paths in accordance with the Saudi Building Code Mechanical Requirements (SBC 501), Section for Duct Systems.
8. Means must be provided for de-energizing HVAC when their space is unoccupied. Preference would be that the HVAC can be de-energized on a zone-by-zone basis.

4.5.2 Commercial

1. DX systems are most suitable for buildings with cooling demand 200 Tons or less. For buildings with cooling demands greater than 200 Tons, consider a chiller water system.
2. Ventilation systems shall be designed in accordance with ASHRAE Standard 62 – Ventilation for Acceptable Indoor Air Quality and ASHRAE Standard 90.1 – Energy Standard for Buildings Except Low Rise Residential Buildings.
3. All outdoor air intakes shall have sand trap louvers
4. Temperature control zones for commercial buildings should not exceed 200 sq m in floor area. Smaller control zones will generally provide better comfort, but may not be economical.
5. All supply air shall be ducted.
6. Ceiling plenums may be used for return air paths in accordance with the International Mechanical Code. A single ceiling return air plenum must not serve multiple tenants. Return air for each tenant must be kept separate back to the return fan or air handling unit.
7. Means must be provided for de-energizing each tenant's HVAC when their space is unoccupied.

4.5.3 Residential

1. Residential HVAC shall consist of DX cooling, with independent blower coil/air handling units for each dwelling unit.
2. Where heating is required, utilize a heat pump.
3. Any equipment requiring maintenance shall be located in an area that is accessible without entering the dwelling unit. Violating the privacy of the dwelling unit occupants is not acceptable. Equipment requiring maintenance includes Compressors, condensers, blower coil/air handling units and filters.
4. All supply air shall be ducted to the spaces served. Supply air system shall include an outdoor air intake with sand trap louver, minimum MERV 8 filters, DX cooling coil, centrifugal cabinet fan, supply air ducts and return air ducts.
5. Return air shall be ducted and shall not be transferred room-to-room.
6. Each dwelling shall have a minimum of one temperature control zone.
7. Residential bathrooms shall have an exhaust.
8. Control individual exhaust fans with a dedicated switch adjacent to the light switch.
9. Refer to the applicable project specifications.
10. Refer to project drawings for standard HVAC details.

4.5.4 Industrial

1. Reference to other sections of the Mechanical Design Guides:
    a. Dust collection is addressed in Subsection 4.2.10 – Dust Collection Systems
    b. Air intake and exhaust discharge design is addressed in Subsection 4.4.1.2 – Building Air Intake and Exhaust Design
    c. Fans are addressed in Subsection 4.3.1.3 – Fans
    d. Make-up air units are addressed in Subsection 4.3.1.10 – Make-up Air Units
    e. Sandstorm design criteria are addressed in Subsection 4.4.1.1 – Sandstorm Provision Design Criteria and Objectives
    f. Air intake and exhaust discharge design is addressed in Subsection 4.4.1.2 – Building Air Intake and Exhaust Design.
2. General

a. Industrial HVAC typically involves ventilation for the removal of excess heat or airborne contaminants that are generated in the workplace.

(1) Contaminants are generally airborne particulate, chemical contaminants or odors.

(2) All ventilation for industrial operations shall be designed in strict accordance with the following references:

(a) Industrial Ventilation – A Manual of Recommended Practice, published by the American Council of Governmental Industrial Hygienists

(b) ASHRAE HVAC Applications Handbook Chapter regarding Ventilation of the Industrial Environment

(c) ASHRAE HVAC Applications Handbook Chapter regarding Industrial Local Exhaust

b. Occasionally industrial HVAC will involve temperature and/or humidity control to support a production process.

3. Ventilation System Design

a. Dilution ventilation is marginally effective for most applications, and is highly inefficient.

b. Design ventilation systems that capture contaminants and/or heat as close to the source of generation as possible, and exhaust the contaminants and/or heat directly from the building.

(1) Reference Industrial Ventilation – A Manual of Recommended Practice, published by the American Council of Governmental Industrial Hygienists for guideline information regarding capturing contaminants such as ducts and vapors.

c. Design make-up air systems to adequately replace the exhausted air and maintain the desired pressure relationship relative to adjacent spaces.

d. Where ventilation is provided for worker comfort, local area and spot ventilation/cooling are preferred as methods of minimizing energy consumed for ventilation

(1) Reference the ASHRAE HVAC Applications Handbook Chapter regarding Ventilation of the Industrial Environment for guideline information on local area and spot cooling.

e. Where hot industrial processes or equipment expose workers to intense radiant heat, consider providing shielding to reduce the effect of the heat felt by workers in the area. Ventilation has little effect on worker's comfort when intense radiant heat sources are present. The only effective method for reducing radiant heat gain is to shield workers from the radiant source.

4. Industrial Air Conditioning

a. Occasionally an industrial process will require specific temperature and/or humidity conditions to support the process and achieve the desired results.

b. Where special industrial air conditioning is required to support a production process, work with the process engineers to determine the specific conditions required, as well as the tolerances or limits associated with those conditions.

c. Frequently, special control sequences will be provided to maintain the conditions within the limits or tolerances needed to support the industrial process.

d. Prior to developing the detailed HVAC design, develop Process and Instrumentation Diagrams (P&ID), and get sign-off from the process engineers that the process is understood and the design concept meets the requirements of the process.

4.5.5 Specialty Applications

1. General

2. Specialty applications include places of worship or assembly, educational facilities, museums, libraries and clean spaces.

a. All of these spaces have specific requirements for temperature and humidity control, as well as ventilation rates.

b. Refer to the ASHRAE Application Handbook for guidelines regarding the design of HVAC for each of these specialty applications. There is a dedicated chapter in the Applications handbook for each of these facility types.

c. Refer to the other sections of this Mechanical Design Guideline regarding the design conditions and guidelines relating to the equipment and systems design for the HVAC required to serve these facilities.

4.6 MECHANICAL FIRE AND LIFE SAFETY SYSTEM

4.6.1 General

1. General

a. Mechanical Fire and Life Safety Systems shall be designed in strict accordance with the Saudi Fire Code (SBC 801) Section for Smoke Control Systems and NFPA 92 – Standard for Smoke Control Systems.

(1) The SBC and NFPA are very specific regarding the a number of factors relating to fire and smoke management system design, including but not limited to: building stack effect, temperature effect of the fire, wind effect on the building, pressure differences across smoke barriers, velocity through intake openings, allowable height of smoke layer, fire heat release, exhaust fan capacity and construction, duct construction, damper ratings and control, electrical power sources, fire and smoke detection and control sequences and ratings. Design the systems in strict accordance with each and every one of these requirements.

b. Design of FLS systems is complex and the concept must be provided by an experienced Fire Engineer. The Fire Engineer shall assist the Mechanical Designer in the preparation of HVAC Drawings to ensure that the required fire and smoke management plan is implemented.

c. The preferred method of analysis for designing fire and smoke management systems is computational fluid dynamics (CFD) modeling. CFD modeling will normally result in the lowest overall airflow requirements which usually results in the simplest and lowest cost systems. CFD modeling must be completed by persons having experience with the science and the software.

(1) Submit the names and resumes of the persons who will be performing the CFD modeling.

(2) If a method of analysis other than CFD modeling is being proposed for designing fire and smoke management systems, submit the proposed method of analysis, as well as the names and resumes of the persons who will performing the analysis to the Entity for approval.

2. Coordination

a. Early coordination of the FLS system requirements with other design disciplines is critical to achieving effective functioning of the systems.

(1) Coordinate location of air intakes, fan locations and support, and discharge locations with the Architect. Quite often, doors and windows must be motorized to open when smoke exhaust is activated to provide adequate intake area. Strategically locating doors and windows that will be used for air intake is crucial to effective smoke exhaust, so coordinating early in the design process helps assure the optimum locations can be accommodated in the design.

(2) FLS systems must have at least two sources of power, and one source must be from a standby system. Coordinate the power requirements and the locations of the equipment needing power with the Entity Lead Electrical Engineer early in the design process to assure optimum design of the power sources.

3. Design Considerations

a. Confirm with the Entity all design parameters that are influencing the design of the fire and smoke management systems.

b. Where egress time is a design parameter, assure that the egress time calculations are acceptable to the Entity prior to using them as a design parameter.

c. Where door-opening forces will be affected by the operation of the fire and smoke management system, confirm the allowable door opening force that will be permitted in the completed facility.

d. Smoke extraction fans and exhaust ducting utilized for smoke evacuation shall be fire rated exceeding the anticipated or calculated plum temperature for sprinklered or non-sprinklered building.

4. Control

   a. It is required that FLS systems be controlled from the Fire Alarm Control Panel (FACP). In case of complex system such as Zoned Smoke Control System and Staircase Pressurization utilizing VFD scheme where the FACP is incapable to control, the BMS or BAS shall take precedence. All controllers and field devices must have the proper listing in accordance with NFPA 92.

5. Commissioning

   a. FLS systems should be commissioned rigorously. Specify commissioning of each system independently. Prepare a comprehensive testing procedure to be used by the commissioning agent.

   b. Assure that the system is operating properly through all sequences of operation prior to the final testing which will be reported to the AHJ.

   c. The system must pass one complete final test through all sequences of operation without any functional problems.

   d. The results from all testing shall be reported to the Entity.

6. Refer to project specification for smoke extraction fans.

7. Refer to project drawings for standard HVAC details.

4.6.2 Stair Pressurization System

1. General

   a. Stair pressurizations systems shall be designed in strict accordance with the Saudi Fire Protection Code (SBC 801) Section for Smoke Control Systems and NFPA 92 – Standard for Smoke Control Systems.

   b. Design of stair pressurization systems is complex. The design must be completed by an experienced professional fire engineer.

2. Design Considerations

   a. Confirm with the Entity the number of doors to be considered open and the required pressure differential across the doors in calculating the airflow requirements. The require pressure differential results in equivalent air velocity across the doors to avoid egress of smoke in the protected staircase. It should be assumed that at minimum, the fire floor, plus the floors above and below the fire floor will be evacuated in the event of a fire. In addition, occupants will be exiting the egress door at the base of the stair. It probably is not prudent to assume a steady stream of occupants passing through all of the doors simultaneously, but at least three doors should be assumed to be open at any given time.

   b. Staircase Pressurization fans are not required to be fire rated.

   c. Confirm the allowable door opening force that will be permitted in the completed facility.

3. Control

   a. Control fans via pressure differential sensors and variable frequency drives. For very tall buildings, multiple pressure zones may be required.

b. A relief damper is recommended, in addition to the variable speed control of the fans, to stabilize the pressure as doors are opened and closed. The relief dampers should be a barometric type, or a fast acting actuator that can operate full stroke in 4 seconds or less.

c. The relief airflow should discharge in multiple directions to eliminate the effect of wind on the discharge.

d. The system shall be integrated with the Fire Detection and Alarm System.

4. Commissioning

a. Stair pressurization systems should be commissioned rigorously. Specify commissioning of each system independently. Numerous combinations of stair doors should be open simultaneously to test for proper pressurization. The system should also be tested with fewer than design number of doors open to assure over-pressurization does not occur, and with more than the design number of doors open to determine under what conditions the system becomes ineffective.

b. The results from all tests shall be reported to the Entity for review and acceptance.

5. Refer to the project specification for staircase pressurization fans.

6. Refer to project drawings for standard HVAC details.

4.6.3 Zoned Smoke Control System

1. General

a. Zoned Smoke Control System (ZSCS) shall be designed in strict accordance with the Saudi Fire Code (SBC 801) Section for Smoke Control Systems and NFPA 92 – Standard for Smoke Control Systems.

b. Design of the Zoned Smoke Control is the most complex of all smoke control and management system. The strategy includes providing pressure differential across zones to inhibit movement of smoke to other zones. The zone where fire is detected is put in negative pressure, while all other adjacent zones including floors below and above the fire zone are place in positive pressure. Design of ZSCS can be a dedicated system or non-dedicated system. The dedicated system utilized the ducting and equipment for HVAC use during normal operation and smoke control and evacuation during emergency condition. The design must be completed by an experienced professional fire engineer.

2. Design Considerations

a. Design requires determination of fire loading, heat release rates, and characteristics of smoke reservoir such as length, width, and depth of smoke layer to be maintained.

b. The system is normally employed for large premises so that sprinklers are usually provided. The sprinkler system lowers the resulting smoke plume temperature thereby reducing exhaust air requirements.

c. For simplification of calculation and to assure proper control and flow of smoke, CFD modelling is required after the location of exhaust point and make-up air is determined.

d. For building covered with sprinklers conforming to NFPA 13, fire rating of exhaust fan, ducting, and gaskets is limited to 300°C and 1-hour.

e. Confirm the allowable door opening force that will be permitted in the completed facility.

3. Control

a. Control of the system is via BMS. Pressure differential is maintained by closing the supply air and exhausting air in the fire zone, while providing supply air in the adjacent zones while its return is closed. Relief opening with fire dampers are provided across smoke compartment to let air pass to the negative zone.

b. In normal operation utilizing HVAC function, the exhaust fan runs at reduced speed. For hospital application, make-up air is about 25-30% of the supply air and 95% of the supply air is return to the AHU for building pressurization. The excess air (20-25% of the supply air) is exhausted directly outside the building or recovered using air-to-air energy recovery equipment. During fire condition, the exhaust fan runs at 100% speed and the return motorized damper of the AHU close.

c. Scheme for ZSCS differs from project to project and the fire engineer must be consulted for the proposed strategy.

d. The system shall be integrated with the Fire Detection and Alarm System.

4. Commissioning

a. ZSCS should be commissioned rigorously. Configuration and programming of the Fire Alarm Control Panel must be verified to ensure that smoke detectors are correctly zoned. Integration between Fire Detection and Alarm System (FDAS) and BMS must ensure that zones are properly configured and programmed to avoid pressurizing the fire zone while providing negative pressure in adjacent zone.

b. All zones shall be tested for Cause and Effect to ensure proper pressurization.

c. The results from all tests shall be reported to the Entity for review and acceptance.

5. Refer to the project specification for ZSCS fans.

6. Refer to project drawings for standard HVAC details.

4.6.4 Lift Lobby or Lift Shaft Pressurization System

1. General

a. Lift Lobby or Lift Shaft Pressurization Systems shall be designed in strict accordance with the Saudi Fire Code (SBC 801) Section for Smoke Control Systems and NFPA 92 – Standard for Smoke Control Systems.

b. Design of Lift Lobby or Lift Shaft Pressurization Systems is simpler compare to other FLS Systems. The purpose of the system is to avoid migration of smoke from a fire floor to another floor through the elevator shaft. Gaps between the sliding shaft door and elevator shaft is unavoidable which creates spaces for the passage of smoke. The design must be completed by an experienced professional fire engineer.

2. Design Considerations

a. Design requires calculation of air leakage across gaps of all elevator lobby shaft doors and shaft (gap between the sliding shaft doors and shaft is allowable up to 25mm.) and opening in the elevator machine room for cables using lift shaft pressurization. Differential pressure across the closed elevator shaft door is design at 12.5 pascals.

b. Design requires calculation of air leakage across gaps of elevator lobby shaft doors and shaft (gap between the sliding shaft doors and shaft is allowable up to 25mm.) and leakage across elevator lobby doors for lift lobby pressurization. Fire engineer must be consulted for number of floors to be considered for the design of pressurization fan. Differential pressure across the closed door is design at 12.5 pascals.

c. Lift Lobby or Lift Shaft Pressurization fans are not required to be fire rated.

d. Confirm the allowable door opening force that will be permitted in the completed facility.

3. Control

a. The system shall be integrated with the Fire Detection and Alarm System.

b. During smoke detection by the Fire Alarm Control Panel (FACP), the fan is immediately started to pressurize the lift shaft of lift lobbies. Motorized damper of duct supplying the pressurization air opens at all designed floors. At a minimum, three (3) floors shall be considered for pressurization of lift lobby.

4. Commissioning

a. Lift Lobby or Lift Shaft Pressurization System should be commissioned rigorously. Specify commissioning of each system independently. The system should also be tested to assure over-pressurization across close lift lobby doors do not occur.

b. The results from all tests shall be reported to the Entity for review and acceptance.

5. Refer to the project specification for lift lobby or lift shaft pressurization fans
6. Refer to project drawings for standard HVAC details.

4.6.5 Atrium Smoke Extraction System

1. General
   a. Atrium Smoke Extraction Systems shall be designed in strict accordance with the Saudi Fire Code (SBC 801) Section for Smoke Control Systems and NFPA 92 – Standard for Smoke Control Systems.
   b. Design of Atrium Smoke Extraction Systems is complex. An atrium is large open space connecting two or more floors. If the lower floor of the two (2) interconnected floors is a ground floor which is considered an exit, it is not considered an Atrium. The purpose of the system is to avoid migration of smoke from the Atrium to connecting spaces and vice versa. The design must be completed by an experienced professional fire engineer.
2. Design Considerations
   a. Design requires determination of fire loading, heat release rates, and characteristics of the atrium smoke reservoir such as length, width, and depth of smoke layer to be maintained.
   b. The system is normally employed for large premises so that sprinklers are usually provided. The sprinkler system lowers the resulting smoke plume temperature thereby reducing exhaust air requirements.
   c. For simplification of calculation and to assure proper control and flow of smoke, CFD modelling is required after the location of exhaust point and make-up air is determined.
   d. For building covered with sprinklers conforming to NFPA 13, fire rating of smoke extract fan, ducting, and duct gaskets is limited to 300°C and 1-hour. For buildings not covered by sprinkler system; the smoke exhaust fan, ducting, and ducting gaskets fire rating shall exceed the anticipated plume temperature.
3. Control
   a. The system shall be integrated with the Fire Detection and Alarm System.
   b. The Fire Detection and Alarm System initiating the activation of the smoke extract fans via beam smoke detectors shall be integrated to the Security and Access Control System to open the main entrance doors prior to the activation of the fans. Atrium smoke extract requirements are huge that main doors are used for air make-up.
4. Commissioning
   a. Atrium Smoke Extraction System should be commissioned rigorously. The system should be tested to assure excessive negative pressurization does not occur.
   b. The results from all tests shall be reported to the Entity for review and acceptance.
5. Refer to the project specification for atrium smoke extraction fans.
6. Refer to project drawings for standard HVAC details.

4.6.6 Car Parking Smoke Management System

1. General
   a. Car Parking Smoke Management Systems shall be designed in strict accordance with the Saudi Fire Code (SBC 801) Section for Smoke Control Systems and NFPA 92 – Standard for Smoke Control Systems. Car parking facilities are classified as open or enclosed car parking structures. To be classified as open car park, NFPA 88A and SBC requires the following conditions to be met for a non-combustible construction (NFPA Type I and II construction);
      (1) Each parking level shall have wall openings open to the atmosphere, for an area not less than 0.4 m2 for each linear meter of exterior perimeter.

(2) Such openings shall be distributed over 40% of the building perimeter or uniformly between two opposing sides.

(3) Interior wall lines and column lines shall be at least 20% open, with openings distributed to provide ventilation.

b. Open Car Parking structures do not require smoke extraction and sprinkler system. Enclosed Car Parking requires smoke management system and the code allows two (2) kind of approach, namely;

(1) Use of fire rated smoke extraction fan and fire rated ducting system.

(2) Use of fire rated smoke extraction fan and fire rated impulse fan (or jet fans).

2. Design Considerations

a. Design requires sizing of the main extract fan for 10 ACH for the whole parking space to reduce CO concentration.

b. For fire rated ducting system, exhaust air quantity shall be divided equally between low level and high level of extraction. Low level extract removes product of combustion heavier than air (such as sulfur oxides, nitrous oxides, etc.) while high level extract removes product of combustion lighter than air (such as carbon monoxide, carbon dioxide, etc.). Make-up air ducting system shall be provided and distributed evenly across the parking space. Exhaust duct gaskets shall be fire rated.

c. For jet fan system using impulse technique, CFD modelling is required to assure proper control and flow of smoke. CFD will also determine if make-up air in strategic location will be required. Carbon monoxide/Nitrous oxide sensors are placed on strategic locations at head level to ensure allowable concentrations. Main Smoke Extract fan, Jet fans, and CO/NOx detection system are controlled by dedicated control system independent of the FACP (Fire Alarm Control Panel).

d. For closed parking space covered with sprinklers conforming to NFPA 13, fire rating of main smoke extract fan, ducting, duct gaskets, and jet fans are limited to 300°C and 1-hour.

3. Control

a. The system shall be integrated with the Fire Detection and Alarm System.

b. For ducted system, normal operation requires 3 ACH up to 6 ACH. CO/NOx sensors are placed evenly across the parking area for speed control. Main extract fan is selected for three (3) speed configuration providing 3, 6, and 10 ACH (see explanation of required concentration for Jet Fan System). Make-up fans are also selected for the same configuration to ensure proper oxygen concentration in parking areas. Fans are integrated via BMS System. During detection by heat or combined heat/smoke appliance of the FDAS, a signal is send directly to the BMS system to command the main extract fan and make-up fan to run at full speed, thereby providing 10 ACH.

c. For Jet Fan System, function of the main extract fan is the same as for ducted system. During normal operation, the CO/NOx sensor detects allowable concentration of the product of combustion in the zone monitored by the sensor. If there excessive concentration, the jet fans within that zone will be activated to move the gases by thrust force towards the main extract fan. 3 ACH will be provided by the jet fans to limit concentration to 30ppm during low traffic, 6 ACH for medium traffic limiting concentration to 60ppm, and full speed if concentration is above 600ppm during heavy traffic or in-case of fire condition. If the controller of the jet fan system fails to react during fire, heat or combination heat/smoke detectors will send signal to FACP which in turn send signal to the jet fan system to run the main extract fan and jet fans at full speed.

4. Commissioning

a. Testing and commissioning of the Car Parking Smoke Management System is only limited to the Performance Testing of the main fan and jet fans. System Performance Testing is not required and CFD Analysis is sufficient enough for proving the Jet Fan System for smoke control and management.

b. CO/NOx concentration is monitored thru the display of the sensor. The jet fan system or the main extract fan using ducted system must be able to maintain the required product of combustion concentration.

c. The results from all tests shall be reported to the Entity for review and acceptance.

5. Refer to the project specification for Car Parking Smoke Management Extraction Fans and Jet Fans.
6. Refer to project drawings for standard HVAC details.

4.7 Commissioning

4.7.1 Testing and Commissioning Requirements

1. Ensure that air duct leakages complies with the maximum allowable leakage by codes to reduce fan power, chilled water pump power, and chiller power especially in areas with ceiling. Use appropriate duct sealant class based on pressure class rating.
2. Balance of hydronic system and air system distribution for pressure dependent systems shall be ensure for energy optimization.
3. Ensure pipe leakage tests are properly conducted to avoid frequent pump hunting due to leakage.
4. BMS control must properly commissioned, fine-tuned, and optimized.
5. Refer to Volume 10, Chapter 2 – Project Testing and Commissioning Guideline (EPM-KT0-GL-000003) for testing and commissioning requirements.

5.0 FUEL GAS

5.1 General

5.1.1 Authority Having Jurisdiction

1. The Entity is the final Authority Having Jurisdiction (AHJ) unless specifically stated otherwise in project documents.

5.1.2 Coordination and Integration

1. The design of fuel gas system requires coordination and integration with other discipline designs, such as, but not limited to, the architectural design, electrical design, fire alarm system, and other physical discipline designs.
2. Fuel gas work shall be completed in full accordance with the respective health and safety requirements established by the Kingdom of Saudi Arabia and the Entity.
3. Proposed fuel gas utilities shall be included in civil site plans.

5.1.3 Abbreviations

1. For a list of general abbreviation refer to Volume 6, Chapter 2- Definitions and References (EPM-KE0-GL-000011).
2. The following abbreviations apply to this Section:

Abbreviations	Description
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CFR	Code of Federal Regulation
DIN	German Institute for Standardization

Abbreviations	Description
EN	European Standard
ERW	Electric Resistance Weld
GPCS	General Procurement Construction Specifications
IMC	International Mechanical Code
IPC	International Plumbing Code
ISO	International Organization for Standardization
MSS	Manufacturers Standardization Society of Valves & Fittings Ind.
NEBB	National Environmental Balancing Bureau
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
SAES	Saudi Aramco Engineering Standards
SBC	Saudi Building Code
UL	Underwriters Laboratories Incorporated
SAMSS	Saudi Aramco Materials System Specification

5.1.4 Definitions

1. Definitions in general are included in Volume 6, Chapter 2- Definitions and References (EPM-KE0-GL-000011).
2. Definitions specific to this section for the design of fuel gas systems appear below:

Definitions	Description
Atmosphere	The same as outdoors.
Concealed Exterior	Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures.
Concealed Interior	Concealed from view and protected from physical contact by building occupants.
Conditioned	Spaces directly provided with heating and cooling.
Exposed Exterior	Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions.
Exposed Interior	Exposed to view indoors (not concealed).
Finished Space	Space other than mechanical rooms, electrical rooms, furred spaces, pipe chases, unheated spaces immediately below the roof, space above ceilings, unexcavated spaces, crawl spaces, tunnels, and interstitial spaces.
Furnish	Supply and deliver to the project site, ready for unloading, unpacking, assembly, installation, and similar subsequent requirements.
Install	Operations at the project site, including unloading, unpacking, assembly, erection, placing, anchoring, applying, working to dimension, finishing, curing, protecting, cleaning, and similar requirements.
Indoors	Located inside the exterior walls and roof of the building.
Outdoors	Located outside the exterior walls and roof of the building.
Provide	Furnish and install complete and ready for intended use.

5.1.5 Codes, Standards, and References

1. Applicable Codes
   a. NFPA National Fire Protection Association Codes
   b. SBC Saudi Building Code
   c. SFC Saudi Fire Protection Code (SBC 801)
2. The following are the list of Standards that apply to this Section.
   a. ANSI American National Standards Institute
   b. API American Petroleum Institute
   c. ASME American Society of Mechanical Engineers
   d. ASTM ASTM International
   e. AWS American Welding Society

   f. NFPA National Fire Protection Association Standards

3. Pumps
   a. ANSI/API 610 – Centrifugal Pumps for General Refinery Service
   b. ASME B73.1 – Specification for Horizontal End Suction Centrifugal Pumps
   c. ASME B73.2 – Specifications for Vertical In-Line Centrifugal Pumps
   d. DIN EN ISO 5199 – Technical specifications for Centrifugal Pumps
4. Tanks and Vessels
   a. API 620 - Design and Construction of Large Welded Low Pressure Storage Tanks
   b. API 650 - Welded Tanks for Oil Storage
   c. API 651 - Cathodic Protection of Aboveground Storage Tanks
   d. API 653 - Tank Inspection, Repair, Alteration and Reconstruction
   e. ASME Boiler and Pressure Vessel Code Section VIII– Rules for Construction of Pressure Vessels
5. Gas and Fuel Piping:
   a. ASME B31.1, Chapter 1, Code for Power Piping, for design of power facilities.
   b. ASME B31.3, Chapter 1, Code for Process Piping, for design of industrial facilities.
   c. ASME B31.4, Chapter 1, Code for Pipeline Transportation Systems.
   d. ASME B31.8, Chapter 1, Code for Gas Transmission and Distribution Piping Systems.
   e. 49 CFR 195, Subpart A, Transportation of Hazardous Liquids by Pipeline.
   f. 49 CFR 192, Subpart A, Transportation of Natural and Other Gas by Pipeline.
   g. NFPA 54 National Fuel Gas Code, for design of residential and commercial facilities with pressures up to 125 psig (8.6 barg).
   h. Saudi Building Code (SBC 501- Mechanical Requirements), Chapter 11, Fuel Oil Piping and Storage
   i. International Fuel Gas Code, Section 3.1.6, UMC Fuel Gas Piping Chapter and IPC Fuel Piping Chapter
6. Refer to Volume 6, Chapter 5 – Codes, Standards, and References (EPM-KE0-GL-000014) for a list of additional codes, standards, and references.
7. In the event of a conflict between the codes or standards and this document, the more stringent requirement shall govern.

5.1.6 Approvals

1. The Entity shall review and approve all design reports, plans, and specifications as outlined in Volume 6, Chapter 6 - Project Submission Standards and Requirements (EPM-KE0-GL-000015).

5.2 Commissioning

5.2.1 Testing and Commissioning Requirements

1. Refer to Volume 10, Chapter 2 – Project Testing and Commissioning Guideline (EPM-KT0-GL-000003) for testing and commissioning requirements..

5.3 Natural Gas Distribution

5.3.1 General Requirements

1. All materials used shall meet the requirements of the Contract.

   a. Refer to applicable project specifications.

2. All materials used shall be selected to meet applicable system requirements such as exposure, temperature and pressure.
   a. Refer to the design guidelines in the projects specifications.
3. All material shall be selected in consideration of the environmental conditions.
4. In selecting material, special attention shall be given to corrosion resistance. Corrosion resistant material or corrosion resistant plating, coating or painting on ordinary material shall be as specified.
   a. Refer the project specification for painting and coatings.
5. All material shall also be selected in consideration of the ease of shipment, installation and maintenance.
6. All pipes aboveground and placed underground shall have external protection by using suitable coating, or tape wrap. In addition, an impressed current or galvanic cathodic protection system shall be considered in the design of underground piping.
   a. Refer to project specification for painting and coatings.
   b. Refer to project specification for cathodic process corrosion protection
7. Materials shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.
   a. Refer to applicable project specifications for detailed material requirements.
8. Pipe diameter shall be selected to meet the following design criteria:
   a. Gas velocity
   b. Pressure drop providing required downstream gas pressure as specified by the end use.

5.3.2 Underground Gas Fuel Pipes and Fittings

1. Piping shall be fabricated to transport gas fuels under a pressurized system.
   a. Refer to the project specification for underground fuel gas pipe and fittings.
2. Design criteria shall take into consideration various materials, coatings, fittings, flanges, Valves and gas fuel specialties. Incorporate in the design the manufacturer's recommendations utilizing manufacturer's regular production components, parts and assemblies as detailed in manufacturer's material specifications.
   a. Steel Pipe
      (1) Pipe shall conform to ASTM A 106 or A53M, black, Grade B, seamless or electric resistance welded (ERW), Schedule 80 or 40 as a minimum.
      (2) Establish maximum load ratings with consideration for allowable stresses prescribed by the appropriate piping code (e.g., ASME B31.8).
   b. Fittings
      (1) Conform to ASTM A234M, wrought carbon steel or alloy steel or ASME B16.11, forged steel, butt-welded joints.
      (2) Conform to ASME B16.11 forged steel, socket welded joints.
      (3) Joints in high pressure piping shall be welded in conformance to the appropriate ASME code.
      (4) Joints in low pressure piping shall be made in accordance with the appropriate Fuel Gas piping code.
   c. Flanges
      (1) Flat Face Weld Neck
      (2) Raised Face Weld Neck

d. Valves

(1) Ball Valve

(2) Gate Valve

e. Specialties - Refer to the project specification for underground fuel gas specialties.

3. Road Crossing

a. Refer to the project specification for regulatory requirements.

4. Railroad Crossing

a. This subsection shall apply to the design and construction of pipelines carrying flammable fuels, non-flammable substances and casings containing wires, cables and carrier pipes across and along railroad property and facilities.

(1) General Requirements

(a) Use of Casing Pipe

i. A casing pipe Shall be required for all pipeline crossings carrying liquid or gaseous substances

ii. Pressure pipelines that are located within 8 m of the centerline of any track shall be cased.

(b) Location of Pipeline on Railroad Right-of-Way

i. Pipelines laid longitudinally along railroad right-of-way shall be located as far as practicable from any tracks or other important structures and as close to the railroad property line as possible. Longitudinal pipelines shall not be located in earth embankments or within ditches located on the right-of-way.

ii. Pipelines shall be located, where practicable, to cross tracks at approximate right angles to the track, but preferably at not less than 45 degrees.

iii. (iii) Pipelines shall not be placed within a culvert, under railroad bridges, nor closer than 14 m to any portion of any railroad bridge, buildings, or other important structure, except as approved by the Entity.

iv. Pipelines shall not be located within the limits of a turnout (switch) when crossing the track. The limits of the turnout extend from the point of the switch to 5 m beyond the last timber.

(c) Depth of Installation

i. Casing pipes under railroad tracks shall be not less than 2 m from base of rail to top of pipe at its closest point. On other portions of the right-of-way, where the pipe is not directly beneath the track, the depth from ground surface or from bottom of ditch to top of pipe shall not be less than 1 meter. Where 1 meter cannot be provided from bottom of ditch, a 15-centimeter thick reinforced concrete slab shall be provided over the pipeline for protection.

ii. Pipelines laid longitudinally on railroad right-of-way, 15 meter or less from centerline track shall be buried not less than 2 m from ground surface to top of pipe. Where the pipeline is laid more than 15 m from centerline of track, the minimum cover shall be at least 1.5 m.

(d) Modification of Existing Facilities

i. Any replacement or modifications of an existing carrier pipe and/or casing shall be considered as a new installation, subject to the requirements for new installations.

(e) Abandoned Facilities

i. Abandoned pipelines shall be removed or completely filled with cement grout, compacted sand, or other methods as approved by the Entity.

ii. Abandoned manholes and other structures shall be removed to a minimum depth of 1.6 m below finished grade and completely filled with cement grout, compacted sand, or other methods approved by the Entity.

(f) Insulation

i. Pipelines and casings shall be suitably insulated from underground conduits carrying electrical wires on the railroad right-of-way.

(g) Corrosion Protection and Petroleum Leak Protection

i. Pipelines on the railroad right-of-way that carry petroleum products or hazardous liquids shall be designed in accordance with current Entity or industry regulations that mandate leak detection automatic shutoff, leak monitoring, sacrificial anodes, impressed current rectifiers, and/or exterior coatings to minimize corrosion and prevent petroleum releases.

(h) Plastic Carrier Pipe Materials

i. Plastic carrier pipelines shall be encased.

ii. Plastic pipe material shall not be used to convey liquid flammable substances.

iii. Plastic carrier pipe may be utilized to convey flammable gas products provided the pipe material is compatible with the type of product conveyed and the maximum allowable operating pressure is less than 7 kilogram/centimeter^2.

5. Water Crossing

   a. Refer to project specifications for regulatory requirements and environmental protection and preservation.

6. Foreign Utility Crossing

   a. Refer to the project specification for regulatory requirements.

7. Miscellaneous foreign Structure Crossing

   a. Refer to the project specification for regulatory requirements.

5.3.3 Aboveground Gas Fuel Pipes and Fittings

1. Piping shall be fabricated to transport gas fuels under a pressurized system.

   a. Refer to the project specification for above ground fuel gas pipe and fittings.

2. Design criteria shall take into consideration various materials, coatings, fittings, flanges, Valves, pipe supports, hangers and gas fuel specialties. Incorporate in the design the manufacturer's recommendations utilizing manufacturer's regular production components, parts and assemblies as detailed in manufacturer's material specifications.

   a. Steel Pipe

      (1) Pipe shall conform to ASTM A 106, black, Grade B, seamless or electric resistance welded (ERW), Schedule 80 or 40 as a minimum.

      (2) Establish maximum load ratings with consideration for allowable stresses prescribed by the appropriate piping code (e.g., ASME B31.8).

   b. Fittings

      (1) Conform to ASTM A234M, wrought carbon steel or alloy steel or ASME B16.11, forged steel, butt-welded joints.

      (2) Conform to ASME B16.11 forged steel, socket welded joints.

(3) Joints in high pressure piping shall be welded in conformance to the appropriate ASME piping code.

(4) Joints in low pressure piping shall be made in accordance with the applicable Fuel Gas piping code.

c. Flanges

(1) Flat Face Weld Neck

(2) Raised Face Weld Neck

d. Valves

(1) Ball Valve

(2) Gate Valve

e. Specialties – Refer to the project specification for above ground fuel gas specialties.

3. Road Crossing

a. Under the road crossing

b. Over the road crossing

4. Railroad Crossing

a. This specification shall apply to the design and construction of pipelines carrying flammable fuels, non-flammable substances and casings containing wires, cables and carrier pipes across and along railroad property and facilities.

(1) General Requirements

(a) Use of Pipe Bridge

(b) Use of Casing Pipe

i. A casing pipe shall be required for all pipeline crossings carrying liquid or gaseous substances

ii. Pressure pipelines that are located within 8 m of the centerline of any track shall be cased.

(c) Location of Pipeline on Railroad Right-of-Way

i. Pipelines laid longitudinally on railroad right-of-way shall be located as far as practicable from any tracks or other important structures and as close to the railroad property line as possible. Longitudinal pipelines shall not be located in earth embankments or within ditches located on the right-of-way.

ii. Pipelines shall be located, where practicable, to cross tracks at approximate right angles to the track, but preferably at not less than 45 degrees.

iii. Pipelines shall not be placed within a culvert, under railroad bridges, nor closer than 14 m to any portion of any railroad bridge, buildings, or other important structure, except in special cases, and then by special design, as approved by the Chief Engineer of the Entity.

iv. Pipelines shall not be located within the limits of a turnout (switch) when crossing the track. The limits of the turnout extend from the point of the switch to 5 m beyond the last timber.

(d) Depth of Installation

i. Casing pipes under railroad tracks shall be not less than 2 m from base of rail to top of pipe at its closest point. On other portions of the right-of-way, where the pipe is not directly beneath the track, the depth from ground surface or from bottom of ditch to top of pipe shall not be less than 1 meter. Where 1 meter cannot be provided from bottom of ditch, a

15-centimeter thick reinforced concrete slab shall be provided over the pipeline for protection.

ii. Pipelines laid longitudinally on railroad right-of-way, 15 m or less from centerline track shall be buried not less than 2 m from ground surface to top of pipe. Where the pipeline is laid more than 15 m from centerline of track, the minimum cover shall be at least 1.5m

(e) Modification of Existing Facilities

i. Any replacement or modifications of an existing carrier pipe and/or casing shall be considered as a new installation, subject to the requirements of this specification.

(f) Abandoned Facilities

i. Abandoned pipelines shall be removed or completely filled with cement grout, compacted sand, or other methods as approved by the Entity.

ii. Abandoned manholes and other structures shall be removed to a minimum depth of 1.6 m below finished grade and completely filled with cement grout, compacted sand, or other methods approved by the Entity.

(g) Insulation

i. Pipelines and casings shall be suitably insulated from underground conduits carrying electrical wires on the railroad right-of-way.

(h) Corrosion Protection and Petroleum Leak Protection

i. Pipelines on the railroad right-of-way that carry petroleum products or hazardous liquids shall be designed in accordance with Entity or industry standards that mandate leak detection automatic shutoff, leak monitoring, sacrificial anodes, impressed current rectifiers, and/or exterior coatings to minimize corrosion and prevent petroleum releases.

(i) Plastic Carrier Pipe Materials

i. Plastic carrier pipelines shall be encased.

ii. Plastic pipe material shall not be used to convey <u>liquid</u> flammable substances.

iii. Plastic carrier pipe may be utilized to convey flammable <u>gas</u> products provided the pipe material is compatible with the type of product conveyed and the maximum allowable operating pressure is less than 7 kilogram/centimeter^2.

5. Water Crossing
   a. Refer to project specification for regulatory requirements and environmental protection and preservation.
6. Foreign Utility Crossing
   a. Refer to the project specification for regulatory requirements.
7. Miscellaneous foreign Structure Crossing
   a. Refer to the project specification for regulatory requirements.

5.4 Liquid Fuel Distribution

5.4.1 <u>General Requirements</u>

1. All materials used shall meet the requirements of the Contract.
   a. Refer to the project specification for underground liquid fuel piping.
2. All materials used shall be selected to meet applicable system requirements such as exposure, temperature and pressure.

a. Refer to the project specification for underground liquid fuel piping.

3. All material shall be selected in consideration of the environmental conditions.

    a. In selecting material, special attention shall be given to corrosion resistance. Corrosion resistant material or corrosion resistant plating, coating or painting on ordinary material shall be specified.

    b. Refer to the project specification for underground piping materials.

4. All material shall also be selected in consideration of the ease of shipment, installation and maintenance.

5. All pipes aboveground and placed underground shall have external protection by using epoxy coating, or tape wrap. In addition, an impressed current or galvanic cathodic protection system shall be considered in the design of underground piping.

    a. Refer to the project specification for high performance coatings.

    b. Refer to the project specification for cathodic process corrosion protection.

6. Materials shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.

7. Pipe diameter selection. Pipe diameter shall be selected to meet the following design criteria;

    a. Liquid fuel velocity

    b. Pressure drop providing required downstream fuel pressure as specified by the end use

5.4.2 Underground Liquid Fuel Pipes and Fittings

1. Piping shall be fabricated to transport gas fuels under a pressurized system.

    a. Refer to the project specification for underground liquid fuel piping.

2. Design criteria shall take into consideration various materials, coatings, fittings, flanges, Valves and gas fuel specialties. Incorporate in the design the manufacturer's recommendations utilizing manufacturer's regular production components, parts and assemblies as detailed in manufacturer's material specifications.

    a. Steel Pipe

        (1) Pipe shall conform to ASTM A 106, black, Grade B, seamless or electric resistance welded (ERW), Schedule 80 or 40 as a minimum.

        (2) Establish maximum load ratings with consideration for allowable stresses prescribed by ASME B31.4, ASME B31.8 or MSS SP58

    b. Fittings

        (1) Conform to ASTM A234M, wrought carbon steel or alloy steel or ASME B16.11, forged steel, butt-welded joints.

        (2) Conform to ASME B16.11 forged steel, socket welded joints.

        (3) Joints shall be welded in conformance to the applicable ASME code.

    c. Flanges

        (1) Flat Face Weld Neck

        (2) Raised Face Weld Neck

    d. Valves

        (1) Ball Valve

        (2) Gate Valve

    e. Specialties - Refer to the project specification for underground liquid fuel piping specialties.

3. Road Crossing

    a. Refer to the project specification for regulatory requirements.

4. Railroad Crossing

a. This specification shall apply to the design and construction of pipelines carrying flammable fuels, non-flammable substances and along railroad property and facilities.

b. General Requirements

(1) Use of Casing Pipe

(a) A casing pipe shall be required for all pipeline crossings carrying liquid or gaseous substances.

(b) A casing pipe shall be required for all pipelines within 8 m of the centerline of any track crossings carrying liquid or gaseous substances.

(2) Location of Pipeline on Railroad Right-of-Way.

(a) Pipelines laid longitudinally on railroad right-of-way shall be located as far as practicable from any tracks or other important structures and as close to the railroad property line as possible. Longitudinal pipelines shall not be located in earth embankments or within ditches located on the right-of-way.

(b) Pipelines shall be located, where practicable, to cross tracks at approximate right angles to the track, but preferably at not less than 45 degrees.

(c) Pipelines shall not be placed within a culvert, under railroad bridges, nor closer than 14 m to any portion of any railroad bridge, buildings, or other important structure, except in special cases, and then by special design, as approved by the Chief Engineer of the Entity.

(d) Pipelines shall not be located within the limits of a turnout (switch) when crossing the track. The limits of the turnout extend from the point of the switch to 5 m beyond the last timber.

(3) Depth of Installation

(a) Casing pipes under railroad tracks shall be not less than 2 m from base of rail to top of pipe at its closest point. On other portions of the right-of-way, where the pipe is not directly beneath the track, the depth from ground surface or from bottom of ditch to top of pipe shall not be less than 1 meter. Where 1 meter cannot be provided from bottom of ditch, a 15-centimeter thick reinforced concrete slab shall be provided over the pipeline for protection.

(b) Pipelines laid longitudinally on railroad right-of-way, 15 meter or less from centerline track shall be buried not less than 2 m from ground surface to top of pipe. Where the pipeline is laid more than 15 m from centerline of track, the minimum cover shall be at least 1.5 m.

(4) Modification of Existing Facilities

(a) Any replacement or modifications of an existing carrier pipe and/or casing shall be considered as a new installation, subject to the requirements of this specification.

(5) Abandoned Facilities

(a) Abandoned pipelines shall be removed or completely filled with cement grout, compacted sand, or other methods as approved by the Entity.

(b) Abandoned manholes and other structures shall be removed to a minimum depth of 1.6 m below finished grade and completely filled with cement grout, compacted sand, or other methods approved by the Entity.

(6) Insulation

(a) Pipelines and casings shall be suitably insulated from underground conduits carrying electrical wires on the railroad right-of-way.

(7) Corrosion Protection and Petroleum Leak Protection

(a) Pipelines on the railroad right-of-way that carry petroleum products or hazardous liquids shall be designed in accordance with current federal or state regulations that mandate leak detection automatic shutoff, leak monitoring, sacrificial anodes, impressed current rectifiers, and/or exterior coatings to minimize corrosion and prevent petroleum releases.

(8) Plastic Carrier Pipe Materials

(a) Plastic carrier pipelines shall be encased.

(b) Plastic pipe material shall not be used to convey liquid flammable substances.

(c) Plastic carrier pipe may be utilized to convey flammable gas products provided the pipe material is compatible with the type of product conveyed and the maximum allowable operating pressure is less than 7 kilogram/centimeter^2.

5. Water Crossing

a. Refer to project specifications for regulatory requirements and environmental protection and preservation

6. Foreign Utility Crossing

a. Refer to the project specification for regulatory requirements.

7. Miscellaneous foreign Structure Crossing

a. Refer to the project specification for regulatory requirements.

5.4.3 Aboveground Liquid Fuel Pipes and Fittings

1. Piping shall be fabricated to transport gas fuels under a pressurized system.

a. Refer to the project specification for above ground liquid fuel piping.

2. Design criteria shall take into consideration various materials, coatings, fittings, flanges, Valves, pipe supports, hangers and gas fuel specialties. Incorporate in the design the manufacturer's recommendations utilizing manufacturer's regular production components, parts and assemblies as detailed in manufacturer's material specifications.

a. Steel Pipe

(1) Pipe shall conform to ASTM A 106, Grade B, seamless or electric resistance welded (ERW), Schedule 80 or 40 as a minimum.

(2) Establish maximum load ratings with consideration for allowable stresses prescribed by ASME B31.4 or MSS SP58

b. Fittings

(1) Conform to ASTM A234M, wrought carbon steel or alloy steel or ASME B16.11, forged steel, butt-welded joints.

(2) Conform to ASME B16.11 forged steel, socket welded joints.

(3) Joints shall be welded in conformance to the applicable ASME code.

c. Flanges

(1) Flat Face Weld Neck

(2) Raised Face Weld Neck

d. Valves

(1) Ball Valve

(2) Gate Valve

e. Specialties - Refer to the project specification for above ground liquid fuel piping specialties.

3. Road Crossing

a. Refer to the project specification for regulatory requirements.

4. Railroad Crossing

a. This engineering design guideline shall apply to the design and construction of pipelines carrying flammable fuels, non-flammable substances, liquid or gaseous substances across and along railroad property and facilities.

b. General Requirements

(1) Use of Pipe Bridge

(2) Use of Casing Pipe

(a) A casing pipe shall be required for all pipeline crossings.

(b) A casing pipe shall be required for all pipelines within 8 m of the centerline of any track crossings.

(3) Location of Pipeline on Railroad Right-of-Way

(a) Pipelines laid longitudinally on railroad right-of-way shall be located as far as practicable from any tracks or other important structures and as close to the railroad property line as possible. Longitudinal pipelines shall not be located in earth embankments or within ditches located on the right-of-way.

(b) Pipelines shall be located, where practicable, to cross tracks at approximate right angles to the track, but preferably at not less than 45 degrees.

(c) Pipelines shall not be placed within a culvert, under railroad bridges, nor closer than 14 m to any portion of any railroad bridge, buildings, or other important structure, except in special cases, and then by special design, as approved by the Director of Engineering of the Entity.

(d) Pipelines shall not be located within the limits of a turnout (switch) when crossing the track. The limits of the turnout extend from the point of the switch to 5 m beyond the last timber.

(4) Depth of Installation

(a) Casing pipes under railroad tracks shall be not less than 2 m from base of rail to top of pipe at its closest point. On other portions of the right-of-way, where the pipe is not directly beneath the track, the depth from ground surface or from bottom of ditch to top of pipe shall not be less than 1 meter. Where 1 meter cannot be provided from bottom of ditch, a 15-centimeter thick reinforced concrete slab shall be provided over the pipeline for protection.

(b) Pipelines laid longitudinally on railroad right-of-way, 15 meter or less from centerline track shall be buried not less than 2 m from ground surface to top of pipe. Where the pipeline is laid more than 15 m from centerline of track, the minimum cover shall be at least 1.5 m.

(5) Modification of Existing Facilities

(a) Any replacement or modifications of an existing carrier pipe and/or casing shall be considered as a new installation, subject to the requirements of this specification.

(6) Abandoned Facilities

(a) Abandoned pipelines shall be removed or completely filled with cement grout, compacted sand, or other methods as approved by the Entity.

(b) Abandoned manholes and other structures shall be removed to a minimum depth of 2 feet below finished grade and completely filled with cement grout, compacted sand, or other methods approved by the Entity.

(7) Insulation

(a) Pipelines and casings shall be suitably insulated from underground conduits carrying electrical wires on the railroad right-of-way.

(8) Corrosion Protection and Petroleum Leak Protection

(a) Pipelines on the railroad right-of-way that carry petroleum products or hazardous liquids shall be designed in accordance with US CFR Title 49, Transportation of Hazardous Liquids by Pipeline, which mandates leak detection automatic shutoff, leak monitoring, sacrificial anodes, impressed current rectifiers, and/or exterior coatings to minimize corrosion and prevent petroleum releases.

(9) Plastic Carrier Pipe Materials

(a) Plastic carrier pipelines shall be encased.

(b) Plastic pipe material shall not be used to convey liquid flammable substances.

5. Water Crossing
   a. Refer to project specifications for regulatory requirements and environmental protection and preservation.
6. Foreign Utility Crossing
   a. Refer to project specifications for regulatory requirements and environmental protection and preservation.
7. Miscellaneous foreign Structure Crossing
   a. Refer to project specifications for regulatory requirements and environmental protection and preservation.

5.5 Storage Tanks

5.5.1 General Requirements

1. This Subsection defines the minimum mandatory requirements governing the selection and mechanical design of atmospheric and low-pressure storage tanks in accordance with API STD 650, Latest Edition or API STD 620, Latest Edition. This standard also defines the requirements for horizontal storage tanks in low-pressure service. All materials used shall meet the requirements of the Contract.
   a. For design criteria for pressure vessels, refer to ASME Pressure Vessel Code.
   b. For design criteria for atmospheric and low pressure tanks, refer to API-650 and API-620.
   c. For design criteria for small tanks, refer to API-650 and API-620.
2. All materials used shall be selected to meet applicable system requirements such as compatibility, exposure, temperature and pressure.
   a. The materials of construction for pressure and non-pressure components shall be based on the design temperature, minimum design metal temperature and service in accordance with applicable Standards.
   b. The A/E and/or EPC Contractor may propose alternative materials conforming to applicable standards to those specified at time of proposal, with prior approval of the Entity. Alternative materials shall comply with all the requirements of the applicable Code.
3. All material shall be selected in consideration of the environmental conditions.
   a. Refer to the project specification for environmental protection and preservation.
4. In selecting material, special attention shall be given to corrosion resistance.
   a. Either corrosion resistant material or corrosion resistant plating, coating or painting on ordinary material shall be as specified in accordance with the project specification for painting and coatings
5. All material shall also be selected in consideration of safety, the ease of shipment, installation and maintenance.

5.5.2 Underground Gas Storage Tanks

1. Tanks shall be fabricated to store gas fuels under a pressurized system.

2. Design criteria shall take into consideration various materials and coatings. Incorporate in the design foundations, ring walls, etc.
3. Wind and earthquake loads shall be determined by the vessel manufacturer.
4. Utilize foundations and supports to support systems under all conditions of operation.
5. All material shall also be selected in consideration of the ease of shipment, installation and maintenance.
6. All tanks placed underground shall have external corrosion protection by using an approved coating system.
7. Materials shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.

5.5.3 Aboveground Gas Storage Tanks

1. Tanks shall be fabricated to store gas fuels under a pressurized or atmospheric system.
2. Design criteria shall take into consideration various materials and coatings. Incorporate in the design foundations, and ring walls.
3. Establish maximum wind and earthquake load ratings with consideration for allowable stresses prescribed by API 650.
4. Utilize foundations and supports to support systems under all conditions of operation.
5. All material shall also be selected in consideration of the ease of shipment, installation and maintenance.
6. All tanks placed aboveground shall have external protection by using an approved coating system.
7. Materials shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.
8. Refer to the project specification for compressed gas storage aboveground.

5.5.4 Underground Liquid Fuel Storage Tanks

1. Tanks shall be fabricated to store liquid fuels under a pressurized or atmospheric system.
2. Design criteria shall take into consideration various materials and coatings. Incorporate in the design foundations and ring walls.
3. Establish maximum wind and earthquake load ratings with consideration for allowable stresses prescribed by API 650.
4. Utilize foundations and supports to support systems under all conditions of operation.
5. All material shall also be selected in consideration of the ease of shipment, installation and maintenance.
6. All tanks placed underground shall have external protection by using an approved coating system.
7. Materials shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.
8. Refer to the project specification for liquid fuel tanks aboveground.

5.5.5 Aboveground Liquid Fuel Storage Tanks

1. Tanks shall be fabricated to store gas fuels under a pressurized or atmospheric system.
2. Design criteria shall take into consideration various materials and coatings. Incorporate in the design foundations, ring walls, etc.
3. Establish maximum wind and earthquake load ratings with consideration for allowable stresses prescribed by API 650.

4. Utilize foundations and supports to support systems under all conditions of operation.
5. All material shall also be selected in consideration of the ease of shipment, installation and maintenance.
6. All tanks placed aboveground shall have external protection by using an approved coating system.
7. Materials shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.
8. Refer to the project specification for liquid fuel tanks aboveground.

5.5.6 Tank Appurtenances

1. External Floating Roof
    a. Primary and secondary seals shall be included in the design. Seals shall also apply to gauge poles and all penetrations of the roof.
2. Internal Floating Roof
    a. Primary and secondary seals shall be included in the design. Seals shall also apply to column supports, gauge poles, ladders and all penetrations of the roof.
3. Fixed Roofs
4. Floating Suction Lines
5. Clips and Attachments
    a. Ladders
    b. Platforms
    c. Stairs
6. Nozzles, Man ways and Gaskets
    a. Pump Suction Nozzle
    b. Fill Nozzle
    c. Water Draw Off Connections
    d. Cleanout Fittings
7. Vents
8. Mixers
9. Level Instrumentation
10. Roof Drain
11. Lighting
12. Grounding
13. Fire Protection System
14. Vessel Supports
    a. Support for Vertical Vessels
    b. Support for Horizontal Vessels

5.5.7 Under Tank Leak Detection and Sub-Grade Protection

1. Refer to applicable standards.

5.5.8 Painting and Coating

1. Refer to applicable standards.

5.5.9 Insulation

1. Refer to applicable standards.

5.5.10 Lighting

1. Refer to applicable standards.

5.5.11 Grounding

1. Refer to applicable standards.

5.5.12 Cathodic Protection

1. Refer to API 651.

5.5.13 Foundations

1. Refer to applicable standards.

5.6 Pumps

5.6.1 Transfer Pumps

5.6.2 Submersible Fuel Pumps

1. This Section specifies common requirements for the system design and installation of Submersible Liquid Fuel Pumps.
2. All material shall be selected in consideration of the environmental conditions.
3. Basis of Design Product: To satisfy demands to meet temperature and viscosity of all well environments during the delivery of fuel from a storage vessel to a receiving vessel.