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Refrigeration Machinery Room Design and Construction

Introduction

Use this guidance when developing specifications for mechanical spaces which contain refrigerants and meet the definition of a refrigerant machinery room as defined by the local mechanical code and ASHRAE 15.

The University of Washington (UW) considers any room as defined by section 1104.2 of the International Mechanical Code to be a Refrigerant Machinery Room." If possible, to reduce the risk to personnel and minimize impacts to the environment, design systems to include environmentally friendly refrigerants in quantities that do not exceed the maximum allowable quantities that would require a refrigerant machinery room and/or locate refrigerant equipment outside where personnel exposure to refrigerant releases would be eliminated or minimized.

Such rooms shall be protected as described in the applicable sections of the locally adopted Mechanical (Chapter 11) and Fire Codes (Chapter 6) as Refrigerant Machinery Rooms. This basis of design standard provides the UW 's interpretation of those rules and guidance on how to apply them to UW projects.

Other spaces that contain refrigerant equipment, but are not considered Refrigerant Machinery Room, where a worst-case credible scenario could release refrigerant in quantities that exceed the occupational exposure limits or there is a risk of an oxygen deficient environment must be protected with a refrigerant leak detection system with audible and visual alarms with signage in accordance with this document. Examples of such spaces may include walk-in refrigerators or freezers where refrigerant loss from the evaporator inside an enclosed space without ventilation could result in a hazardous atmosphere or in a mechanical space where refrigerant equipment is located and where the configuration of the room or space could result in a microclimate due to inadequate mixing of the ventilation system resulting in non-homogenous concentrations of refrigerant leaks that may accumulate and create a hazardous atmosphere.

Excluded from this document: Systems utilizing hazardous Group A2, B2, A3, and B3 refrigerants are not recommended in UW facilities. However, if approved by UW Facilities Engineering Services and UW EH&S compliance with additional Mechanical and Fire Codes safety requirements for hazardous refrigerants (i.e., flammable, ammonia, toxic, etc.) beyond what is referenced in this document (i.e., pressure controls, emergency stops, exhaust treatment, etc.) is required. These additional requirements are required to be added to the design of the system as appropriate for the type of material used.

Reference Standards

This design standard is based on the requirements found in the current version of the International Mechanical, Building and Fire Codes and local adopted versions. Before applying any specific requirements, the requirements of the local jurisdiction should be reviewed for any modifications to these standards.

Definitions

Asphyxiant: A gas or vapor that lowers the concentration of oxygen in the atmosphere below life sustaining levels.
Hazardous atmosphere: means an atmosphere that may expose employees to the risk of death, incapacitation, impairment of ability to self-rescue (that is, escape unaided from a permit space), injury, or acute illness from one or more of the following causes:

1. Flammable gas, vapor, or mist in excess of 10 percent of its lower flammable limit (LFL).
2. Airborne combustible dust at a concentration that meets or exceeds its LFL; **Note to paragraph (2) of the definition of "Hazardous atmosphere".** This concentration may be approximated as a condition in which the combustible dust obscures vision at five feet (1.52 meters) or less.
3. Atmospheric oxygen concentration below 19.5 percent or above 23.5 percent.
4. Atmospheric concentration of any substance for which a dose or a permissible exposure limit is published in subpart D of this part (Occupational Health and Environmental Control), or in subpart Z of this part (Toxic and Hazardous Substances), and which could result in employee exposure in excess of its dose or permissible exposure limit; **Note to paragraph (4) of the definition of "Hazardous atmosphere"**. An atmospheric concentration of any substance that is not capable of causing death, incapacitation, impairment of ability to self-rescue, injury, or acute illness due to its health effects is not covered by this definition.
5. Any other atmospheric condition that is immediately dangerous to life or health. **Note to paragraph (5) of the definition of "Hazardous atmosphere".** For air contaminants for which OSHA has not determined a dose or permissible exposure limit, other sources of information, such as Safety Data Sheets that comply with the Hazard Communication Standard, § 1926.59, published information, and internal documents can provide guidance in establishing acceptable atmospheric conditions.

Machinery Room: An enclosed space that is required by Chapter 11 of the Mechanical code to contain refrigerant equipment and to comply with section 1105 and 1106 of the local mechanical code.

Microclimate: A reduced or localized area where there can be an accumulation of gases or vapors due to the configuration of the space, design of ventilation and the physical properties of the contaminant e.g., pits or vaults where heavier than air gases may accumulate.

Refrigerant Detection System: A detector, or a sampling tube that draws air to a detector, shall be

provided at an approved location where refrigerant from a leak is expected to accumulate. The system shall be designed to initiate audible and visible alarms inside and outside each entrance to the refrigerating machinery room and transmit a signal to an approved location where the concentration of refrigerant detected exceeds the lesser of the following: 1) the corresponding TLV-TWA values shown in the IMC for the refrigerant classification 2) 25% of the lower flammable limit (LFL). If the upper detection limit or 25% of the LFL is exceeded, the detection system shall stop refrigerant equipment in the machinery room in accordance with 605.9.1 of the locally adopted fire code for flammable refrigerants.

Refrigerated Space/Room: Industrial occupancies and refrigerated rooms containing equipment such as condensers, evaporators, control or pressure relief valves for condensers or evaporators, and connecting piping.

General Design Requirements

Refrigerants are considered hazardous as system leaks can create a hazardous atmosphere within the space where the leak originated. In addition, some types of refrigerant gases may be flammable or may be a physical health hazard. The following design criteria are intended to protect life safety and to meet the prescriptive requirements of the governing codes.

1. Machinery Room Determination

The following steps should be followed to determine if code compliance will govern refrigerant storage and use. The code must be reviewed to ensure a complete code analysis. Follow the steps below to determine if a machinery room or at a minimum, a leak detection and alarm system is required.

Step 1: Identify all rooms or areas containing refrigerant at the site, including Refrigerated Spaces/Rooms. Outdoor locations do not require analysis, unless located within 20 feet of an opening to a building.

Step 2: Identify the type of refrigerant used

Step 3: Identify the quantity of refrigerant used in a single, independent circuit

Step 4: Identify the fire, building, and mechanical codes the room or building is constructed and permitted under. These are usually available with the architectural drawings for the building.

Step 5: Calculate the room volume. The Mechanical Code may provide guidance for the calculation.

- Refrigerant components located in different spaces that do not communicate through ducts or permanent openings, use the smallest sized space to perform the calculations.
- Refrigerant evaporator or condensers located inside an air handling duct or system, use the total amount of the air handling CFM unless the air flow to an enclosed space can be reduced below 25% of the maximum flow.
- Where the space above the ceiling is continuous and part of the supply or return air plenum that space may be included in the volume calculations.

Step 6: Identify the maximum allowable quantity (MAQ) in a single, independent circuit for the refrigerant in the Mechanical Code. For VRF systems, include the refrigerant condensing unit, controller, fan coil and all associated piping.

Step 7: Calculate the amount of refrigerant per 1,000 cubic feet and determine if the MAQ is exceeded.

Step 8: If the MAQ is exceeded, design the space in accordance with the code requirements and this standard for a machinery room or refrigerated space

Step 9: If the MAQ is not exceeded, perform an employee exposure risk assessment. If code compliance does not govern refrigerants in a particular application, a review of employee exposure hazards is required to ensure that hazards to staff are addressed. Common refrigerants also have Permissible Exposure Limits (PEL)/Threshold Limit Values (TLV). In addition to exposure thresholds for a particular refrigerant, the site should be mindful of the high Immediately Dangerous to Life and Health (IDLH) for the refrigerants and the additional hazard of oxygen deficiency prior to reaching IDLH levels. Consult with UW EH&S to conduct a risk assessment and/or review exposure modeling to determine if occupational exposure limits for the specific refrigerant are exceeded or a hazardous atmosphere could result based on the equipment, configuration of the room and design of the ventilation system.

Exemption: The International Mechanical Code (and locally adopted code) exempts single circuits containing less than less than 6.6 pounds of any type of refrigerant in listed equipment regardless of the system classification if the system is installed per the equipment's listing and the manufacturer's installation instructions

2. Construction

Ancillary spaces used for refrigerant machinery rooms are considered incidental use areas and shall not occupy more than 10% of the area of the story that they are located on and shall be of one-hour fire rated construction unless provided with automatic sprinkler protection.

3. Openings

a. Ducts and air handlers that operate at a lower pressure than the room need to be sealed to prevent any refrigerant from entering.
b. Doors shall be self-closing and tight-fitting.

4. Access

Refrigerant systems having a circuit containing more than 220 pounds of Group A1 or 30 pounds of any other group will be accessible at all times for testing and maintenance and to the fire department for emergency response.

5. Exits

a. Refrigerant Machinery rooms larger than 1,000 square feet shall have two exits or exit access doors and the doors shall swing in the direction of egress.

b. The exit or exit access doors shall be separated by a distance equal to one-half of the horizontal dimension of the room.
c. The distance to each exit or exit-access door shall not exceed 150 feet from anywhere in the room, unless allowed to be increased due to automatic sprinkler protection (per the code).

6. Emergency Signs/Hazard Warnings

NFPA Placards with the name of the refrigerant and the NFPA ratings shall be posted on all entrance doors and on tanks containing refrigerant.

7. Refrigerant Detection and Alarm Systems

a. The machinery room will contain a refrigerant leak detection system termed a "refrigerant detection system" throughout this document. Refrigerant detection system must be per UWF Preferred Vendors list.
b. The refrigerant detection system shall be compatible with and connect to the building fire alarm system for purposes of audible and visual alarms and for communicating with the central monitoring service for the building.
c. Locate refrigerant detection panel inside the Refrigerant Machinery Room, with at least one remote panel connected to that system located outside the main entrance to the Refrigerant Machinery Room. If the remote panel is in an accessible common area, install panel in lockable cabinet. The remote panel shall report the amount of refrigerant in parts-per-million (ppm) refrigerant. Consult with UW Facilities Engineering Services for the key number used for the lockable cabinet.
d. The refrigerant leak detection system shall be provided with **emergency power.**
e. Audible and visual notification devices shall be activated by the refrigerant detection system and controlled by the building fire alarm system in accordance with the UW Fire Alarm Specification.
f. Audible and visual notification devices shall be located on the interior of the refrigerant machinery room and outside of all access doors to the space.
g. All visual and audible alarms must be distinguishably seen or heard by all personnel in affected portions of the workplace.
h. Design and install visual alarms to provide distinguishable notification coverage for spaces per NFPA 72 Notification Appliances where required by the IFC, IBC, or NFPA 1/101.
i. Visual notification devices shall be mounted 80 inches AFF and within six inches from ceiling height.
j. Visual notification devices shall be equipped with a blue acrylic light cover.
k. If not required to align with the UW FA specification, then visual devices shall meet the following:

    i. Visual alarms other than those utilizing the FA notification devices shall follow the requirements of OSHA 1910.165 and ADAAG Technical Bulletin 4.28 not otherwise required by NFPA 72.
    ii. All warning lights that do not meet the FA specification for notification devices must be of the flashing, rotating, or oscillating type. Requirements include:

iii. Flash rates must be less than 2 Hz.
iv. Beacons are required for visual notification devices.
v. Strobes must not be used unless they are from the same original equipment manufacturer as the fire alarm system strobes and can be seamlessly synchronized with the FAS strobes.
vi. All alarms and visual devices must be tamper-resistant.
vii. Strobe devices from different manufacturers are not permitted where they can both be operational and visible in the same field of view.

l. Audible devices shall be in accordance with the UW Fire Alarm Specification.

i. The sound level of alarms must exceed the average ambient noise level by 15 dBA or exceed any maximum sound level with duration of 60 seconds by 5 dBA (whichever is greater) and measured five feet above the floor in the occupiable area per NFPA 72 and ADA requirements.
ii. Sound levels for alarms must not exceed 120 dBA.
iii. Areas designated as sensitive to loud noises must be exempt from audible notification criteria following EHS acceptance (e.g., vivarium suites).

m. Leak detectors

i. Leak detectors must be installed on dedicated electrical circuits to avoid the possibility of disabling the gas detection system while de-energizing other equipment.
ii. Refrigerant detector placement will be based on the room configuration and the type of refrigerant used. Placement will be reviewed and approved by UW Facilities Engineering Services and UW EH&S prior to installation.

(a) The location and number of sensors should be based on the following:

(1) Sample tubing length limits: Refrigerant detectors typically utilize a sample tube to detect leaks. Place the sample tube, with a filter, as close to the leak source as possible. Manufacturer literature will often provide more detailed information. Note: It is important that tubing length limits for the detection system are known. If a 200-foot tube is installed and the limit for the system is 100 feet, the gas detection system will not work.
(2) Manufacturer data
(3) Distribution of sources throughout the room – multiple sources co-located
(4) Number of levels in the room – for example: a 2-story room
(5) Number and type of obstructions in the room
(6) Microclimates: Since most models assume uniform distribution of leaks, when analyzing large spaces or unconfined spaces a site may choose to model a smaller room volume that may be more representative of what may occur during the spill or release. The volume selected may be based on a footprint within the room that services the refrigerant operations, based on ventilation system design/balancing/smoke tests, or the site may select a default volume that will be utilized when analyzing these types of scenarios.

n. Alarm activation level will be based on the type of refrigerant present. Alarm activation level will be established at the TWA-TLV for the specific refrigerant and will be reviewed and approved by UW Facilities Engineering Services and UW EH&S prior to installation.
o. The Fire Alarm System monitors status of the Refrigerant Detection System for alarm, supervisory, and trouble (including loss of power, fan failure, system trouble) conditions.
p. Alarm activation of a refrigerant leak detector shall result in the following:

    i. Refrigeration detection system will transmit an alarm signal to the building fire alarm system.
    ii. Local refrigerants audible and visual notification devices are activated via the FACP and the refrigerant detection system status will be monitored by BAS.
    iii. Fire alarm system will transmit a priority two signal to the central monitoring service with the text “Refrigerant Leak.” Room ventilation will shift to the emergency exhaust rate, if required.
    iv. Building general fire alarm will not be activated.

q. Gas or leak detection component failure

    i. A trouble signal is transmitted to the building fire alarm system.
    ii. The building fire alarm system relays the trouble signal to the central station monitoring company.
    iii. BAS notification

r. Mechanical ventilation interlock

    All interlocks required by the IFC designed to prevent injury, loss of life or property damage must be:

    i. Hard-wired
    ii. Controlled and monitored by the fire alarm system
    iii. Monitored by the BAS, with latching interlock alarms

s. Sequence of operations

    During normal operation, the refrigerant detection system commands the supply and exhaust fans to normal occupied airflow rate.

    i. Upon an alarm condition, the refrigerant detection system notifies the FACP which commands the ventilation system to the emergency exhaust and supply volumes. Transmit an alarm signal to building fire alarm system and the Building Automation System. The refrigerant detection system audible and visual alarms are activated by the FACP.
    ii. The building fire alarm system and the Building Automation System monitor normal exhaust and supply speed fan(s) status via current sensing relays. During failure of fan(s) to operate at normal speed in normal mode, a trouble signal at both the Fire Alarm System and the Building Automation System. Fans shall default to the emergency airflow rate. The audible and visual notification devices are activated.

iii. All refrigerant audible and visual devices will be installed with signs permanently hung below the device(s). Signs must be three-layer etched plastic with white letters on a blue background. Letters must be a minimum of 1/2" high.
iv. Signs within the refrigerant machinery room must read:

WHEN FLASHING

REFRIGERANT LEAK / NO FAN

EXIT SPACE

Contact: TBD by each site

v. Signs outside each refrigerant machinery room entrance must read:

WHEN FLASHING

REFRIGERANT LEAK / NO FAN

DO NOT ENTER SPACE

Contact: TBD by each site

8. Machinery Room Ventilation

a. Machinery rooms will have continuous mechanical ventilation, supply and exhaust with exhaust discharging directly to the outdoors.
b. Fire, smoke and/or fire/smoke dampers are not allowed on machinery room ventilation ducts.
c. Exhaust and supply ducts shall not serve other areas.
d. Ventilation rate will be in accordance with the Mechanical Code. Ventilation rates and exhaust and make-up air opening locations will be reviewed and approved by UW Facilities Engineering Services and UW EH&S.
e. Exhaust fans may be variable speed, in accordance with guidelines provided in the Mechanical Code.
f. For flammable or toxic refrigerants only: Remote controls for refrigeration system emergency shutoff and ventilation system on-control must be located outside of the Refrigerant Machinery Room.

9. Emergency Power and Legally Required Standby Power

Emergency power is required to be provided to the refrigerant leak detection system and Legally Required Standby power to the supply and exhaust fans. On the Seattle Main campus, this legally required standby power must be supplied from the central UW Emergency Power System.

10. Design and Review

The engineer of record for any mechanical refrigerant system will provide UW Facilities Engineering Services with design calculations justifying their determination of refrigerant machinery room regulations to any space. Unless specifically directed by UW, machinery room regulations should not be applied to spaces that contain exempt amounts of refrigerants to qualify under the codes refrigerated spaces.

Design calculations must be accompanied by plan drawings indicating each separate communicating space included in the volume calculation, as well as clearly identifying the location and size of each opening intended to remain open and unobstructed. Design calculations must show:

a. Refrigerant type
b. Calculated refrigerant quantities of refrigerant machinery room, all rooms served by the refrigeration system, and all rooms with refrigerant piping routed through rooms.
c. Identify rooms with refrigerant that exceeds quantity threshold per code.
d. All rooms housing equipment or piping that contains refrigerant are considered occupiable spaces, including Mechanical Rooms, Elevator Machine Rooms, IDF or MDF Rooms, or storage closets.
e. An engineer of record shall be identified for the design of the safety systems to be included in the machinery rooms.
f. The engineer of record will provide a design submittal to the UW identifying all required safety features required for the machinery room.

Commissioning

1. The commissioning of the systems must be performed according to a documented Commissioning Plan per the UW requirement.
2. Commissioning must consist of inspection and pre-testing/calibration of completed individual systems and equipment before conducting cross functional testing of equipment and systems.
3. Life safety gas detection and alarm systems, sensors, and equipment must be commissioned by a third-party commissioning agent, or the Owner, at the time of installation.
4. Commissioning must include, but not be limited to, the following:

    a. Building automation interfaces
    b. Electrical interlocks
    c. Electrical shunting (if installed)
    d. HVAC interlocks (fan shutdowns, FSD closures if configured)
    e. Gas detection and alarm systems
    f. Fire alarm system interfaces (if installed)
    g. Process Control System interfaces (if installed)
    h. Battery charging shutdown interlocks

5. Commissioning documents, instrument data sheets, and calibration records must be provided to the UW for each life safety alarm system tested.

6. Testing of the life safety gas detection and alarm systems must be coordinated with the site fire protection representative.
7. Additionally, life safety gas detection and alarm systems must receive written UW acceptance before hazardous, toxic or highly toxic, flammable, or explosive materials are placed into use or storage.
8. Certificates of completion and testing records must be provided to the UW with the turnover package submittals.
9. Completed System Tests
    a. The installation contractor must perform a complete functional test of each system and submit a written report to the UW Project Manager attesting to the proper operation of the completed system prior to final inspection and commissioning.
    b. Gas detection and alarming critical control device interfaces, alarms, and failure conditions must be tested.
    c. Where the BAS (or PCS) is used for detection and alarming for life safety alarm conditions, the BAS (or PCS) must be verified by test that the alternate power system operates the system for the period and in the manner specified.
10. Retesting
    a. Deficiencies indicated by tests must be corrected and work affected by such deficiencies must be completely retested.
    b. The system test must be verified that the total system meets specifications and complies with applicable state and local codes and ordinances.
11. Report of Tests and Inspections
    a. A written record of inspections, tests, and detailed test results in the form of a test log must be provided with the commissioning plan.
    b. The test log of the satisfactory completion of tests must be submitted to the UW UWF and EH&S.

Maintenance (includes testing and calibration)

Appropriate maintenance requirements are required for the safeguards or controls identified, even if not listed here.

1. Gas Detection
    a. Gas detection systems are critical life safety controls and shall be tested annually. The testing shall include full functioning testing e.g., alarm set-points, visual and audible notification, fire panel status, ventilation interlocks, equipment shut-down interlocks, Emergency shut-off devices, etc.
    b. Sensors should be calibrated at the manufacturer's recommended frequency, at a minimum.
    c. Calibration tolerance should be established to ensure unsafe working conditions are detected. Therefore, the recommended acceptance ranges are +/- 0.5%.
2. Alerts – Audible and Visual

a. If not conducted as part of the sensor calibration, the associated visual and audible notification devices should be activated at least annually
b. If the gas detection system's alarm condition has an interlock associated with it, the interlock should be activated annually.

3. Ventilation

a. If the ventilation system is the primary safeguard that eliminates the need for refrigerant detection (i.e., the ventilation system failure causes high levels of refrigerant) the ventilation system may be subject to increased maintenance requirements. Systems such as these are not typical at the UW.