Issue 129
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Division of Technical Resources
Office of Research Facilities
National Institutes of Health
Technical News BULLETIN

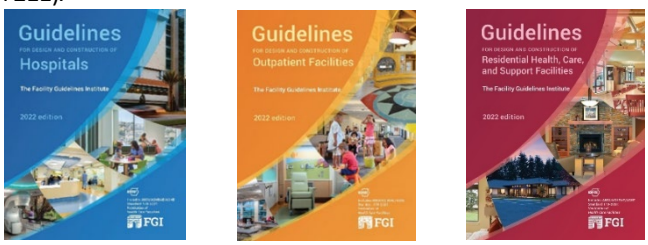
DTR Permit Review: Code Compliance for Health Care Projects

Introduction

NIH-funded health care capital projects go through the DTR Permit Review process to ensure compliance with the Design Requirements Manual (DRM),[1] including all referenced codes and standards listed in DRM 1.2.1. These include the National Fire Protection Association (NFPA) 101 Life Safety Code, NFPA 99 Health Care Facilities Code, the International Building Code (IBC), and the Facilities Guidelines Institute (FGI) *Guidelines for Design and Construction of Hospitals, Guidelines for Design and Construction of Outpatient Facilities,* and *Guidelines for Design and Construction of Residential Health, Care, and Support Facilities.*[2]

Digital Access to the 2022 FGI Guidelines

The *Guidelines* are the consensus-based minimum construction standards in 43 states for health care facility building performance. The origins of the *Guidelines* date to 1947 when their predecessor, the *General Standards*, established hospital standards for receiving federal funding under the Hill-Burton Act. In 1984, the American Institute of Architects assumed publication of the *Guidelines*, and in 1998, the Facility Guidelines Institute was formed to continue the work. Digital access to all three 2022 *Guidelines for Design and Construction* documents is available at https://shop.fgiguidelines.org (reference books are available in Bldg. 13, Room 211).



Covers of the 2022 FGI *Guidelines*

Occupancy Classification/Statement of Conditions

The DTR Permit Review process requires use and occupancy classification to comply with the most recent NFPA 101 Life Safety Code. Construction, renovation, alteration, major equipment installation, or change of use health care projects may be classified under one or more Occupancies within Chapter 6 of NFPA 101 based on the life safety risk to building occupants.

NIH projects in a Health Care Occupancy are designed for medical treatment on an inpatient basis (where patients are incapable of self-preservation) and must comply with the *Guidelines for Design and Construction of Hospitals*.

NIH projects in an Ambulatory Health Care Occupancy are designed to provide services or treatment on an outpatient basis. They must comply with the *Guidelines for Design and Construction of Outpatient Facilities*.

NIH projects in a Business Occupancy are designed for the transaction of business and must comply with the IBC.

The NIH/OD/ORF Office of Hospital Physical Environment (OHPE) maintains the NIH Hospital Environment of Care Statement of Conditions (SOC) documents for the Clinical Center, which include drawings depicting the boundaries between different occupancies. Division of Design and Construction Management (DDCM) Project Officers (POs) have access to the Occupancy classification, fire barriers, fire rated partitions, means of egress, and other information shown in the SOC. POs must make this information available to designers to ensure that the most current information is used.

Use Designation/Space Nomenclature

There may be different use designations within a health care building occupancy. Uses are governed by FGI *Guidelines* sections. The terminology used to describe functional areas, categories, spaces, building systems, and organizational assets may be standardized according to the *2022 Hospital Health Care Facility Nomenclature Conventions,* published by FGI in an annex to the *Guidelines*. Of special value to designers and Permit Reviewers are the Space Nomenclature tables, which easily link the *Guidelines* section that applies to each type of use.

Summary

Health care projects must have a documented occupancy classification and FGI *Guidelines* use designation on the Life Safety Plan in order to comply with DRM required codes and standards. Recent broad access to the 2022 FGI Guidelines as well as the NIH Hospital Statement of Conditions documentation of Occupancy Classification should improve compliance of Construction Documents at DTR Permit Review.

Additional Reading

1. The National Institutes of Health (NIH). Design Requirements Manual, (Issuance Notice 12/12/2016) Rev. 1.5: 03/5/2020 https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx
2. The Facility Guidelines Institute. American Society for Healthcare Engineering https://fgiguidelines.org/guidelines
3. NIH/OD/ORF Office of Hospital Physical Environment, NIH Hospital Environment of Care Statement of Conditions \\ors-fs.ors.nih.gov\OHPE_USMP_DOCS\DWFs.

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Heating and Cooling Coil Freeze Protection Design for 100% Outside Air AHUs

Introduction

Mechanical systems serving many NIH facilities are designed using 100% outside air (OA) Air Handling Units (AHUs) to protect occupants from hazardous materials, including aerosolized chemicals or pathogenic materials generated in biomedical, chemical, animal, and aseptic processing labs. In cold weather, 100% OA systems are particularly at risk for freezing and bursting heating and cooling coils, causing building flooding, which may result in shutdowns that impact large areas of the facility that disrupt ongoing research and require costly repairs. Freeze protection design should therefore be considered a critical requirement on all 100% OA AHUs. This article considers several freeze protection design elements.

Hydronic Coils

Hydronic preheat coils use a mixture of glycol and water. Proper glycol concentration lowers the freezing point of the system's working fluid, which lowers the temperature at which the coils would freeze and rupture. Regular inspection, monitoring, and refilling of system glycol is necessary. Energy heat recovery coils using a glycol/water mixture can provide additional heating capacity to the preheat coil and prevent coil freezing. These coils are installed upstream of the preheat coil and provide free heating from the leaving exhaust air stream.

The weakest portion of the coil is its return ends, so fissures typically occur there. As a result, both preheat and cooling coils may be provided with freeze burst protection via removable pressure relief caps on all ends. Hydronic coils must be drainable at the coil level, which allows water to be removed from the coil in case of emergency.

Circulation pumps ensure that the coil maintains turbulent flow at reduced load. N+1 circulation pumps are required on hydronic preheat coils, installed in the bypass position and operating whenever there is a call for heating. Coil circulation pumps also provide circulation if the preheat system fails which delays the coil from freezing. Single circulation pumps are required on the cooling coils, installed in the bypass position and running whenever the temperature of the air leaving the preheat coil is less than 40F (temperature value adjustable). Cooling coil pumps also lower the probability of coil freezing. All coil circulation pumps shall be powered from an emergency power source.

Control valve selection is critical to ensure that a change in valve position will have a commensurate change in coil output. It is not possible to maintain adequate control if the valves are oversized.

Steam Coils

Steam coils must be used carefully. Distributing steam coils, which have inside and outside tubes, are typically used for 100% OA AHUs. Steam in the inside tubes keeps the condensate in the outside tube from freezing when air passes across the coils at less than 32F (adj.). A vertical integral face and bypass damper (IFB) steam coil is another option. These have a bypass area between coil tubes and bypass (clamshell) dampers on both sides of the coil. The clamshell dampers open to the fins if heating is needed. Typically, when entering air is near or below 32F (adj.), the steam supply modulating control valve is controlled to a minimum valve position or fully open to ensure there is continuous flow, which is less likely to freeze. The face and damper assembly then achieves temperature control. However, IFB steam coils are not always an option because there must be sufficient space downstream of the coil to allow airflow to mix properly and equalize before reaching the cooling coil.

Steam must be effectively distributed through all the circuits in a steam coil, particularly at low loads. Coils must also be properly vented to relieve pressure and keep cold spots from developing. Vacuum breakers must be installed on steam headers, and condensate must be effectively drained from the coils so that it does not freeze or cause cold airflow that could freeze downstream coils. Redundant steam trap assemblies on the preheat coil are required to ensure that condensate is removed when a trap fails or is plugged. The bottom of the steam coil should be adequately elevated to allow for the critical head on the condensate to ensure it drains effectively. Typically, a 14" fill leg is recommended.

Designs shall avoid using a single modulating steam-control valve because it will typically create sub-atmospheric pressure in the coil and tends to hold condensate in the coil. A one-third/two-third valve arrangement helps controllability.

Freeze Stats

Freeze stats, or low limit safety switches, are positioned between the preheat and chilled water coil and monitor the inlet air temperature. They are typically set at 37F (adj). When the freeze stat senses cold, it sends a signal to shut down the unit and start the circulating pump for added protection. This freeze stat then requires a manual reset.

Typically, multiple freeze stats are installed. They must be adequately distributed over the face area of the entire cooling coil, as the control only responds to the area near the lower ends of the capillary tube.

Other Considerations

Automated isolation valves may be required on chilled water supply pipes to the air hander coil to prevent chilled water from flooding the mechanical room if a chilled water coil bursts. The isolation valve closes automatically to prevent flooding when a leak detector sensor, located in or around the AHU, trips. A check valve in the return pipe then allows the excess water to flow out of the coil and prevents water from back-feeding into the ruptured coil.

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Flood Risk Mitigation Measures for Plumbing Systems

Introduction

Plumbing systems provide potable and laboratory cold, hot, and purified water to laboratories, vivariums, clinical centers, and administrative support areas and convey sanitary waste, storm water, and equipment condensate from these areas for appropriate collection and treatment. These systems, which travel across and between all levels in a building, impose a risk of flooding if they are improperly designed, coordinated, or installed. This article highlights several plumbing design considerations—addressed in the NIH *Design Requirements Manual (DRM)*—whose implementation can reduce the potential for flooding.

Critical Areas

System designers can avoid damage to critical infrastructure by locating piping outside of (but not above) sensitive areas such as electrical, data, storage, and clean rooms. Designers must submit justification to the Office of Research Facilities (ORF) if they cannot avoid installing piping within electrical or switchgear rooms and must also provide secondary protection like monitored double containment piping or drip pans with alarms connected to the Building Automation System (BAS).

The *DRM* prohibits drains in laboratories, electrical rooms and other high-voltage spaces, or areas where waste backup poses a risk to users or the facility. Key areas (e.g., a mechanical penthouse with central CHW service) must be evaluated for appropriate leak detection sensors (connected to the BAS) where the consequences of flooding may be catastrophic. Designers should work with NIH to coordinate placement of drains outside of sensitive spaces and at approved locations. NIH recommends that designers do not place rooms requiring heavy water use, drains, sinks, and drainage piping (e.g., ARF areas, mechanical rooms, food service or equipment washer areas) above or adjacent to critical areas.

Floor Penetrations, Drainage, and Backflow Devices

Failed piping systems resulting in water loss may damage facilities below the point of failure through floor penetrations that are improperly sealed against water intrusion. Minimizing damage depends on these penetrations being water-tight. Components like floor drains, floor sinks, and trough drains must use appropriate sealant and corrosion-resistant clamping collars and be installed with safing membranes for penetrations in wet areas. Designers can reference Exhibit 13.6 and Appendix L of the *DRM* for suitable types of sealants for floor and wall penetrations in non-lab, BSL, and APF facilities.

Drain assemblies serving high-temperature equipment must accommodate different rates of thermal expansion between the drain and connected piping to maintain waterproofing at penetrations. Floor drains in high traffic areas shall be sufficiently load-rated so as not to be displaced under pedestrian or equipment traffic. It is important to consider point loading of wheels from animal cages in ARFs and cage wash to prevent drain displacement or breakage.

The *DRM* also requires pipe sleeves to extend a minimum of 2 inches above the floor at all penetrations and be provided with a built-in water stop with seal and sleeves cast into the original floor slab construction. Where penetrations are created in existing floor slabs, core-drilled holes must be sealed with the appropriate UL-listed fire stop assembly.

Designers must consider the proper location for backflow preventers and required drainage. Where required, ASSE 1013 devices shall be placed in a readily serviceable location and provided with a drain receptor that can accommodate peak relief valve discharge flow, and shall not be located above ceilings or critical spaces.

Designers must tailor construction drawing details to reflect these and other water-proofing requirements for all devices that penetrate floors and provide backflow protection.

Testing Requirements

The designer must ensure all components of a pressurized plumbing system can withstand system working pressures, surge pressures, and operational temperatures. Water systems at NIH are hydrostatically pressure-tested with potable water to a minimum of 150% of the maximum working pressure but at least to 150 psig (whichever is greater) for four hours. Lab and domestic water systems are flushed, adjusted, commissioned, and disinfected prior to use to control biofilm and system corrosion. After testing and flushing, systems shall be maintained in operation or routinely flushed as a measure to control biofilm and prevent corrosion.

Summary

Designers must familiarize themselves with all potential causes of flood risks at NIH facilities. During the design process, they are encouraged to scrutinize the *DRM* and, if needed, contact the Division of Technical Resources (DTR) to clarify requirements.

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Flood Risk Mitigation Measures - Architecture

Introduction

Flooding is an expensive and disruptive event in any building, especially in high-value, mission-critical buildings like laboratory and healthcare facilities. Engineers, architects, contractors, commissioning agents, and others on the design and delivery teams are responsible for recognizing the criticality of these facilities and proactively mitigating flood risks. Experience, best practice, and risk analysis should drive design decisions, including the locations of mechanical and plumbing systems and equipment, the routing and types of piping, and safety and redundancy features, that will reduce the risk of flooding.

This article focuses on architectural requirements to minimize damage from a flood caused by the failure of a building's mechanical or plumbing system.

Protection from Floods

The first line of defense against flooding is mechanical and plumbing systems that are properly designed, detailed, located, and maintained to minimize the chance of a flood and reduce the impact of a flood on critical program areas. This was the subject of two recent Technical Bulletins, "Heating and Cooling Coil Freeze Protection Design for 100% Outside Air AHUs" and "Flood Risk Management Measures for Plumbing Systems." Archived Technical Bulletins can be accessed at Technical Bulletins (nih.gov). Of particular concern are systems containing large volumes of water and/or water under pressure. These systems are typically located in service areas, including interstitial levels, mechanical rooms, and penthouses, but should not be located above laboratories, clinical areas, animal facilities, or other critical, high-value functions. Architects must review designs with plumbing and mechanical engineers to plan for the access, inspection, and service of critical shut-off valves for these systems.

Service areas are the second line of defense. They must be designed and detailed to contain and drain water to protect other areas of the building. Service area floors must be made of concrete or another material that is solid, stable, and appropriate for the application of a slip-resistant, high-traffic, waterproof system. Designs should provide adequate containment and drainage and appropriate detailing at expansion joints and other points of potential stress and failure.

The waterproofing system must extend up the wall at least 6in. (152 mm) at all edge conditions, including walls, penetrations, and shafts, to contain water. Stairs, elevators, and other through-floor connections must be protected. Large floor areas should be subdivided by berms, sloped thresholds, and other design features that prevent the spread of water while maintaining accessibility and functionality. All areas must have leak detection systems with alarms and notifications, as well as floor drains with sufficient capacity.

Waterproofing systems must be regularly inspected, maintained, expanded, and repaired as the building is modified to ensure continued integrity.

Protection From Flood Damage

If flood water reaches a program space, the area must be detailed to minimize incurred damage and required repair. One material vulnerable to damage is standard gypsum board, which will absorb moisture and is susceptible to mold growth. To minimize this risk, a mold-resistant gypsum board should be considered. Regardless of type, all gypsum board walls in flood-prone areas must be detailed following the requirements from DRM Section 4.3.1.1.C Flood Resistant Detailing, which requires that the gypsum board is installed above a 3½ in. (90 mm) tall base of cement board or other non-absorbent material to reduce the chance of flood damage. Areas prone to flooding or water damage include:

- Areas adjacent to or under service areas, large-piped utilities, or other flood risks
- ARFs and other facilities requiring wash-down
- Areas containing glasswashers, autoclaves, chillers, kitchens, and other water-intensive equipment
- Areas with exposure to the exterior

Conclusion

Floods are risks in facilities with large, complex mechanical and plumbing systems. Thoughtful design can substantially reduce the risk of flooding and limit the resulting damage if flooding does occur.

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Fan Arrays in Air Handling Systems

Introduction

Fan array (or "fan wall") systems within air handling units (AHUs) provide airflow and static pressure via a bank of fans grouped in an array, with each fan directly connected to its motor shaft. Unlike traditional centrifugal single-fan applications that house a scroll to discharge into a separate plenum or directly into the ductwork, direct-drive fan arrays pressurize the plenum that houses them. Fan arrays at NIH typically accommodate no more than eight fans, as there is a diminishing return in terms of cost, redundancy, and maintenance beyond that number.

Manufacturers, designers, and end users apply these characteristics to reduce the length of AHUs, increase redundancy, and, as the use of multiple small fans reduces the need to shut down the entire fan system, make replacing fans and motors easier.

General Array Selection Criteria

The system designer shall select fan arrays for parallel airflow where all fans in the array have identical motors, fan speeds, and system performance curves. As with housed belt-driven fans, performance curves for fan arrays shall show volumetric flowrate of a fan as a function of total pressure, brake horsepower, and fan efficiency and should define regions of system instability. Performance data for fan arrays should define the data for individual fans in the array and each additional fan operating in parallel. Where arrays are designed to provide N+1 fan redundancy, designers must verify that fan systems in the N operating condition perform within a stable region so as to avoid uneven airflow and pressure, increased noise, and mechanical damage.

Designers shall also select isolation dampers for each fan in the array to prevent backwards rotation of the fan during startup and to close when a fan fails or is stopped for service or maintenance. These dampers differ in material, thickness, seals, differential static pressure, and leakage rate. A damper can close by gravity or by linkages that operate the blades with a motorized actuator.

Manufacturers test dampers in accordance with ANSI/AMCA Standard 500-D, which determines air leakage, pressure drop, dynamic closure, and operational torque characteristics of a damper under uniform conditions.

Typically, fans in the array are stacked, so designers must select proper structural supports for each fan to minimize vibration. The operating frequency of the fan/motor needs to be selected outside of out of the natural or resonant frequency band of the isolator.

Designers should limit the motor size of each fan in the array to 30 HP and provide lifting point(s) or support to facilitate fan and motor replacement.

Redundancy and Variable Frequency Drives

The NIH *Design Requirements Manual* (*DRM*) specifies that designers shall provide multiple AHUs or exhaust fans for laboratories and critical facilities (*DRM* 6.1.8.1.B) to achieve N+1 equipment redundancy. By specifying that an array of direct-drive fans must still meet design airflow requirements if a fan in the array fails, designers can provide additional redundancy at the fan level. The level of fan redundancy required will be project- and application-specific.

System redundancy extends to the speed control for each fan. Per NIH *DRM* 6.2.8.2.1, the designer shall provide a variable frequency drive (VFD) for each primary and standby motor. The *DRM* also requires manual bypasses independent of the drive that permit full speed fan motor operation when the drive is deenergized; however, in an array that includes fan and AHU redundancy (N+1), VFD bypass is neither justified nor required. Where designers consider VFD bypass, they must carefully select direct-drive fans so the operating speed in VFD bypass mode does not exceed the maximum allowed fan rpm. *DRM* 6.2.4.2 requires that direct-drive fan motors operating with VFDs shall not operate above 90 Hz frequency and that motor size be based on operating frequency.

Improper selection may result in inefficient operation far from the operating point as well as excessive noise and duct pressurization. A single VFD shall not be used to control multiple fans within an AHU.

A current technology VFD can be mounted close to the air handling unit it serves, which minimizes motor circuit-conductor length issues that lead to damaging high peak voltages at the motor terminal.

Additional Reading

ASHRAE Handbook—HVAC Systems and Equipment (2020), ASHRAE
ASHRAE Laboratory Design Guide, 2nd Ed. (2015), ASHRAE
Direct-Drive Plenum Fans and Fan Arrays, Volume 39–1 (2010), Trane Engineers Newsletter

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Capturing and Leveraging Lessons Learned and Leveraging for Continuous Improvement

Introduction

Lessons Learned (LL) programs are the effort to collect the experiences, both positive and negative, which result in further knowledge and understanding for the purpose of disseminating throughout an organization to improve the institutional knowledge. The aspiration of these programs is that by improving institutional knowledge, fewer similar mistakes will be made, quality and efficiency will improve, first costs and operational costs will decline, e.g., Continuous Improvement (CI) will be realized. In practice, however, LL/CI programs are notoriously prone to abandonment, failure, and decline. Although the potential causes for these programs to fail are multifold, the program described in this article seeks to address many of the common causes (accessibility of LL & CI, filtering of LL to actionable and applicable items to fit the subsequent need, LL are well documented, and the collection process is open and unobtrusive).

Lessons Learned Tool for APFs

DTR's Facility Compliance and Inspection Section (FCIS) developed the concept and business logic for a novel Lessons Learned web application tool, which was built and deployed by DTR's, Enterprise Facilities & Asset Management Information Technology (DTR EFAM IT). Currently, this tool is in the final testing stage and expected to be released for broad use in August 2023.

The tool's interface provides users with a procedural filtering system to allow users to narrow their search either via a typical keyword search, or additive filtering against pre-populated meta-data tags associated with each entry in the database. The additive filtering approach is intended to maximize the return of hits when the user is searching for the maximum number of potentially related LL/CI responses and is anticipated to be the most used navigational feature.

For example, LL/CI developed in temperature and humidity control of an electron microscope may be of value to someone executing a chemotherapy infusion bay, but the project team would likely overlook the data if conventionally presented (e.g., by project name or type instead of being meta-data tagged to include specific close-tolerance controls of temperature and airflow). The database is also designed to associate the LL with the phase of the project it may be associated with, so that the user can make use of the LL as early as possible in the development of the project, since cost and effort to implement changes increase rapidly over time (e.g., as design and construction progresses). The application also allows users to nominate new LL which would be reviewed for content, meta-data tagging accuracy, and actionability before being publicly viewable. Users can also provide feedback on how useful they found an LL/CI, to allow for filtering and eventual removal of LL/CI which are later found to not be practices.

Continuous Improvement

Although actionable LL can be identified and applied to any project type, the tool is directly integrated into an FCIS workflow for APF-related activities. This workflow includes data collected via change control activities, Root Cause Analysis (RCA), System Deviations (SD), Corrective and Preventative Actions (CAPA), and other QA activities, including design review, construction observations, oversight of DFOM activities, etc.

LL are tracked through implementation and post-execution assessment and data from these assessments are then added to the LL/CI cards and made available to all users of the system. Some LL are tracked over time to validate the effectiveness of those improvements over time, particularly those which need to demonstrate seasonal stability, long-term durability, or other characteristics which cannot be fully assessed immediately following execution.

Conclusion

Currently, the web app is pre-populated with a collection of LL/CI data, but it is open source, meaning individual users can and should contribute additional data that may be of use to others at NIH who will be doing similar work in the future. It is this user-dependent content creation which will be the measure of how successful this tool will become. This, however, will require participation by all stakeholders, both in content creation and use, which will lead to rapid improvement of the content and value of using this tool.

Access to actionable LL/CI information reduces the possibility of errors being repeated and the increased sharing of institutional knowledge of best practices encourages the likelihood of more implementation across similar instances/requirements. Across ORF there are several groups interested in developing LL/CI programs; it is the author's hope that this diversity of programs will not act as an unintentional barrier to the sustained development of an overall high-quality LL/CI program for the benefit of NIH.

Additional Reading

1. NIH Design Requirements Manual, Chapter 13

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Closed-Loop Systems Water Treatment

Introduction

Closed-loop water systems are water circulation systems that function in a contained environment where the water remains isolated from the atmosphere and the makeup requirements are minimal, typically less than 5% of the system's total volume in a year. These systems are used in modern buildings' heating and cooling systems to transfer thermal energy from one process or space to another without mixing the water with external sources.

Closed-Loop Water Treatment Challenges

Makeup Water

While closed-loop water systems are meant to be sealed, they can still suffer significant and undesirable water loss – losing 25% of system volume per month is not uncommon. This is typically due to minor leaks in mechanical seals or overflow from expansion tanks. The makeup water added to compensate for these losses introduces impurities like minerals, entrained air, dissolved gases, organic matter, microorganisms, and suspended solids. These impurities can exacerbate issues related to corrosion, scaling, fouling, and microbiological growth.

Microbiological Growth

Problematic microbiological growth, especially denitrifying and sulfate-reducing bacteria, can thrive in closed-loop systems and cause fouling, corrosion, and reduced heat transfer. Stagnant areas, like dead legs, are especially susceptible. Additionally, nitrite, commonly used as a corrosion inhibitor in closed-loop systems, provides a nutrient source for denitrifying bacteria.

Corrosion

Corrosion can manifest in closed-loop systems due to various contributing factors, including the presence of dissolved oxygen and low pH levels. Dissolved oxygen, which can infiltrate the system either through makeup water or system leaks, causes a chemical reaction with iron in steel pipes that leads to rust.

Furthermore, an acidic or low pH environment fosters the degradation of the protective metal oxide passivation layers, which hastens metal surface corrosion within the system. The low pH environment leads to an increased concentration of hydrogen ions, which further accelerates the corrosion rate of the metal surfaces. If left unaddressed, corrosion progressively deteriorates and weakens the metal surfaces within the system. This deterioration can result in equipment damage, reduced operational efficiency, and higher maintenance costs.

Chemical Treatment

Chemical treatment involves injecting or pumping specialized chemicals into the closed-loop water system to control the water chemistry, preventing corrosion and microbiological issues. A non-exhaustive list of chemical treatments typically includes oxygen scavengers, corrosion inhibitors, pH boosters, scale inhibitors, and biocides.

Oxygen scavengers, such as sulfite, react with and remove dissolved oxygen. Corrosion inhibitors, such as nitrites and azole, are used to form a protective layer that keeps steel and copper from corroding. Biocides kill or control microbial growth such as bacteria and biofilm. Automated control systems utilize real-time sensor data to adjust chemical dosing rates for optimal treatment, ensuring that chemical levels are appropriately balanced.

Closed-Loop System Monitoring

Water Test/Analysis

Water testing and analysis includes both real-time sensor readings and periodic water sample lab analyses. These tests and KPIs are performed to assess the quality of the water in the system and to identify any potential issues. A non-exhaustive list of important KPIs to monitor are pH, temperature, conductivity, dissolved oxygen, total hardness, and bacterial count. Regular water quality monitoring helps track changes over time and ensure that treatment measures remain effective.

Corrosion Coupons

Corrosion coupons are a testing method to measure system corrosion rates. They are small sacrificial metal strips, representative of the system's alloys, that are placed within the system's coupon rack for 90 days. Afterward, they are extracted and analyzed to determine the corrosion rates and types occurring within the system.

Microbiological Testing

Microbiological testing assesses the presence and concentration of bacteria within the closed-loop system. Water samples are collected in sterile containers from stagnation-prone spots like dead legs or low-flow areas. These samples undergo lab analysis, using tests such as ATP, total bacterial count, and specific microbial identification. Regular microbiological testing is important to track changes in microbial populations over time and ensure that control measures remain effective.

System Cleaning

In older buildings that lacked proper water treatment, closed-loop water systems may exhibit partial blockages due to the accumulation of corrosion products. To restore efficiency, a cleaning program may be necessary. Various chemical cleaner methods are available, including acidic, caustic, and neutral pH cleaning processes.

Additional Reading

Lane, R. W. (1993). Control of scale and corrosion in Building Water Systems. McGraw-Hill.
NALCO (2009). The Nalco Water Handbook, third edition. McGraw Hill Professional.

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Steam Safety Relief Valves

Introduction

The NIH uses steam for a variety of purposes, including domestic and hydronic water heating, humidification, cage washing, and sterilizing. Pressure for steam systems and associated equipment is regulated by pressure reducing valve (PRV) stations and control elements that monitor pressure, return condensate from steam lines to boilers at the NIH Central Utility Plant, and segregate steam and steam condensate of differing pressures. The pressure in steam piping and pressure vessels can rise above rated design pressures for many reasons, including control instrumentation failure and pressure surges. Excessive pressures risk damage, unpredictable steam supply through system components to end user equipment, and catastrophic failure.

The NIH *Design Requirements Manual* (*DRM*) requires Safety Relief Valves (SRVs) to be installed at appropriate locations in steam systems to vent steam above design pressure to the atmosphere. This article describes the components of SRVs, sizing and location considerations, and applicable codes and industry practices.

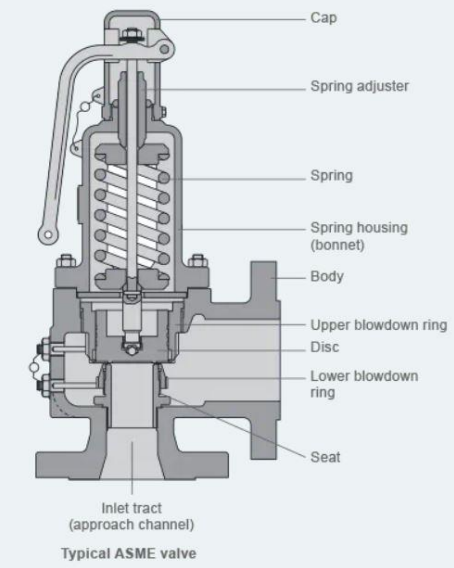
Safety Relief Valve Components and Basic Operation

Basic components of spring-loaded "conventional" SRVs include a vertical steam inlet, a horizontal discharge, and an inner valve disc held closed by a spring housed in a bonnet. Steam escapes through the discharge when the valve disc is lifted off its seat by steam entering the valve inlet above a set steam pressure, which the system designer selects by adjusting the spring. Set pressures are higher than the system's normal working pressure to avoid unnecessary discharge, but they must never exceed the system's maximum allowable working pressure. The valve relieves steam through outlet piping attached to the discharge with a flanged or threaded connection. Outlet piping is bent at an elbow where steam escapes into a vent piped to the roof. The elbow is fitted with a drip pan to ensure condensate from the valve or steam vent is piped to the nearest sanitary floor drain. The valve lifting action caused by the inlet steam then compresses the valve spring, creating a reaction force that closes the valve disc against its seat when the inlet steam can no longer sustain the set pressure.

Installation Practices and Code & *DRM* Requirements

Designers must comply with ASME B31.1, the ASME Boiler Pressure Vessel Code (BVPC), and manufacturers' detailed installation requirements. Generally, valves must be installed vertically upright, above the steam pipe or equipment served, at any location where steam system components (PRVs, flash tanks, boilers, etc.) could be subjected to pressure above their ASME rating. Designers must minimize pressure drop at the valve inlet by maintaining or increasing the inlet pipe size, rounding any corners at the inlet tee, and installing SRVs at least 8-10 pipe diameters away from fittings.

When an SRV is located downstream of PRVs, the steam flow capacity of the SRV at set point must exceed the PRV's maximum flow capacity so that the SRV can handle the flow if the PRV were to fail open. Multiple SRVs may be used in places where a single SRV is not feasible due to capacity or physical limitations. All SRVs must have identical set points and capacities, and vent pipes must be sized to handle all the SRVs opening simultaneously.



Typical ASME valve diagram (from Spirax Sarco, Inc.)

Designers must provide sufficient structural support for the SRV and pipe to resist reaction forces in the system caused by steam discharge. Inadequately supported systems may suffer catastrophic failure due to bending moments caused by reaction forces. ASME B31.1's "Nonmandatory Appendix II: Rules for the Design of Safety Valve Installations" provides guidance for calculating these forces.

Per *DRM* 6.3.7.4.K, steam valves and specialties shall meet industrial high-performance standards and utilize stainless steel seats and discs. *DRM* 6.3.7.4.L requires that SRVs be vented separately from each other and other steam vents. When locating vent pipes, designers must ensure discharge is not entrained in air system outdoor intakes and occurs no less than seven feet above the roof and away from any location posing a risk to maintenance personnel. All SRVs shall meet ASME requirements, which include being stamped per BPVC, certified by the National Board of Boiler and Pressure Vessel Inspectors, and sealed to prevent tampering.

Maintenance personnel shall follow ASME BPVC, Section I and VIII requirements for testing SRVs to certify normal operation. Testing frequency depends on the risk a faulty valve poses to facilities operation and the safety of maintenance personnel or end users.

Additional Reading

1. Safety Valves, Spirax Sarco Inc., https://www.spiraxsarco.com/learn-about-steam
2. Pressure Relief Valve Engineering Handbook, Emerson https://www.emerson.com/documents/automation/pressure-relief-valve-engineering-handbook-en-gb-4244934.pdf

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Steam Flash Tanks

Introduction

Flash steam forms when hot condensate in a vessel passes from a higher pressure to a lower pressure, causing the condensate temperature to drop to the saturated temperature of the low-pressure area. The heat released evaporates a portion of the condensate, generating flash steam.

A flash tank is a pressure vessel used to separate condensate from flash steam in a controlled process so that the condensate can serve as boiler feedwater and flash steam can serve low-pressure applications (e.g., shell-and-tube hot water heat exchangers) or be vented if desired. Depending on the pressures involved, approximately 10%–40% of the energy content from the original condensate can be recovered from flash steam. This article describes flash steam applications, flash tank use and selection, installation considerations, and applicable sections of the Design Requirements Manual (DRM).

Flash Steam Applications and Pitfalls

If flash steam is used to supplement steam mains serving low-pressure equipment, designers must first ensure the pressure of the steam is reduced to that specified by the equipment manufacturer. Condensate lines must also be sized to accommodate the steam that flashes downstream of the condensate trap orifices. Undersized condensate lines risk developing a backpressure that can inundate the trap with condensate, causing steam to flow through the line at excessive velocities and generating waves of condensate that fill the pipe and damage the piping system (i.e., water hammer). High steam velocities can also carry condensate into the flash steam recovery system.

The higher temperatures of high-pressure flash steam delivered to low-pressure applications may result in temperature control issues on the water side of the equipment. The resulting high-temperature, high-pressure condensate may damage downstream low-pressure condensate components like traps and pumps. A properly sized flash recovery system addresses these concerns and ensures the steam is suitable for use.

Flash Tank Components and Sizing

Flash tanks feature an inlet for medium- or high-pressure condensate, an air vent, an outlet for low-pressure flash steam at the top, and an outlet for condensate at the bottom. To safeguard against steam flashing above design pressure, the tanks are fitted with safety relief valves vented to discharge the steam to a safe location above the roof line.

Flash tanks come in vertical or horizontal arrangements. The ASHRAE Handbook--HVAC Systems and Equipment recommends vertical tanks because they are better at separating the steam and condensate, which improves steam quality. Flash tanks shall be stamped in accordance with Section VIII of the ASME Boiler & Pressure Vessel Code, and tanks and condensate lines insulated per DRM Exhibit 6.4. Designers must consider several system pressure and flow metrics and equipment dimensions to properly size a tank. They must also know the pressure in the condensate line serving the tank, the condensate load (in pounds of condensate per hour, or lb/h) and the design pressure inside the tank. This information will determine the percentage of the condensate that will flash into steam, which dictates the necessary tank size.

Steam inlet velocities for flash tanks range from 4000–6000 ft/min. DRM Table 6.3.7.4 requires that low-pressure steam flow at no greater than 6000 ft/min. The internal tank diameter must be large enough to slow the steam velocity in the tank to 10 ft/s, which will stop condensate from entering the recovered flash steam system. The flash steam outlet is typically sized for a velocity of 60 ft/s (3600 ft/min).

Designers must install a trap on the tank condensate outlet piping. Engineering literature commonly cites either a float and thermostatic (F&T) or inverted bucket type; however, DRM Table 6.3.7.3 requires disk thermodynamic type traps for medium- and high-pressure condensate applications. Other system considerations include pitching all condensate inlet lines towards the flash tank and installing swing check valves on these inlets to prevent condensate backflow.

Good design practice ensures that the steam load demand of the equipment using the flash steam is greater than the amount of steam that flashes in the tank. Designers shall also install backpressure regulators—set a few psi above the system design pressure—on the flash steam outlet pipe to prevent the recovery tank from becoming overpressurized in case the low-pressure system serving the connected equipment experiences excess pressure. This requirement is described in DRM 6.3.7.4.G.

Additional Reading

1. ASHRAE. (2020). ASHRAE Handbook—HVAC Systems and Equipment. https://www.ashrae.org/technical-resources/ashrae-handbook/description-2020-ashrae-handbook-hvac-systems-and-equipment
2. TLV Co. (n.d.) Condensate recovery: Mitigation of water hammer in vertical flashing condensate transport piping. https://www2.tlv.com/en-us/steam-info/steam-theory/condensate-recovery/mitigate-water-hammer-in-risers
3. Merrit, C. (2015). Process steam systems: A practical guide for operators, maintainers, and designers. (2nd ed.). Wiley. https://www.wiley.com/en-us
4. Watson McDaniel Product Catalog. https://www.watsonmcdaniel.com/Downloads/Literatures/Watson-McDaniel-Catalog.pdf

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Seismic Design Considerations

Introduction

Seismic design is the process of proportioning and detailing a structure to enable it to withstand movement from an earthquake event with acceptable performance.

In 2011, the NIH Bethesda campus felt the effects of a 5.8 magnitude earthquake. This quake prompted the Office of Research Facility's Division of Technical Resources (DTR) to undertake a seismic risk assessment study. The study reviewed available NIH geotechnical investigation reports, performed probabilistic seismic hazard analysis, and evaluated soil amplification effects in a simplified manner. The results of these evaluations led NIH to consider site-specific seismic design parameters more stringent than what is proposed in the ASCE 7 for specific building types on the Bethesda campus.

Seismic Design Parameters

The main NIH Campus, located in Bethesda, MD, has numerous structures, including critical facilities such as research laboratories, a central utility plant, and a hospital. These buildings range from risk category I to risk category IV buildings based on the classification of ASCE 7 Table 1.5-1. The risk categories are used to relate the criteria for maximum environmental loads or distortions specified in the ASCE 7 standard to the consequence of the loads being exceeded for the structure and its occupants (ASCE 7).

Building performance is not a function of the structural system alone. For a facility to remain operational after a seismic event, both structural and nonstructural systems must remain functionally safe. Reports based on geotechnical tests performed over the years at several locations within NIH Bethesda Campus indicate that the soil at most locations can be classified as site class C per ASCE 7 Table 20.3-1. DTR performed a push-over analysis at select buildings representing each building type on the NIH Bethesda campus. This analysis is a non-linear static analysis used to understand the performance characteristics and overall structural behaviors of structures subject to gravity load and increasing lateral load until the collapse state of the structure is reached. Nonstructural components of the facilities were evaluated based on observations performed during the site surveys. Findings from the analysis are used to guide future seismic retrofits.

In 2016, the federal government issues executive order EO 13717 to establish a Federal Earthquake Risk Management Standard. This EO encouraged federal agencies to consider going beyond the building code requirements to ensure that buildings are earthquake resilient. To this end and due to the specialized nature of NIH facilities, the NIH *Design Requirements Manual* requires parameters more conservative than those in the International Building Code (IBC) for select and critical buildings (see *DRM* Section 5.2.1.G).

Conclusion

DTR has installed two free-field strong motion seismic sensor stations on the NIH Bethesda campus. These stations were installed per the guidelines of the United States Geological Survey (USGS). These strong motion sensors can remotely sense ground motion information immediately after a seismic event. This information is used by NIH engineers and management to make informed decisions about potential impact to select facilities on campus and determine whether they are deemed safe for occupancy. To meet the seismic design requirements for NIH new and existing facilities, NIH *DRM* Section 5.2.1.G recommends that the designer contact DTR at the initial stage of the design process to determine whether NIH-specific seismic design parameters are applicable to the project, and the details of those parameters.