

Lessons Learned Procedure on Aseptic Processing Facility Projects

Introduction

The Lessons Learned procedure is intended to provide feedback on events that happened during a project which may be beneficial to future projects. At project initiation, the Contracting Officer Representative (COR) is responsible for reviewing and implementing relevant Lessons Learned from previous projects into new projects.

Meetings

There are two types of meetings that can be used during a Lessons Learned process: Interdepartmental Meetings, conducted between two or more departments; and Intradepartmental Meetings, conducted within a department. The intent of these meetings is to collect the Lessons Learned data from previous successes and failures that can be transferred to other Aseptic Processing Facility (APF) projects, facilities, and programs. These meetings can be held in-person or virtually and should be held at the end of at least the Construction and Project Turnover Phases (e.g. a minimum of twice per project). All observations and suggestions need to be fully documented during these meetings.

Roles & Responsibilities

A person or department should be appointed the role of facilitator to lead and coordinate the procedure efforts for a project. The facilitator also supports the department(s) meeting sessions if needed and will develop the Lessons Learned Summary Report for senior management.

The Lessons Learned procedure requires participation from all involved parties within an organization throughout all phases of an APF project lifecycle, including contractors and consultants outside of the organization. These responsible parties conduct Lessons Learned sessions and review and approve the Lessons Learned Summary Report.

Lessons Learned Process

In a standardized process, a Lesson Learned should be identified, documented, analyzed, actioned, monitored, assessed, and stored in a manner and place to facilitate retrieval for the use on future projects.

Identification

A Lesson Learned is characterized by relevant phase of the project: Planning, Design, Construction, Commissioning, Qualification and Validation (CQV), or Turnover Phase. The procedure describes the requirements for conducting a survey to identify the Lessons Learned gained from executing the project; this survey is conducted at the conclusion of each phase, which helps ensure important information is captured accurately and contextually. The survey includes questions to capture information such as, asking parties to identify what went well, what did not go well, early warning signs, and improvement recommendations.

Documentation

All informational data gathered by surveys, tracking worksheets, and meetings should be documented in an organized database that is accessible to all project stakeholders. A summary report should also be generated and shared with project stakeholders and senior management.

Analysis

For Lessons Learned, the lead department will review, organize, and analyze the comments and recommendations gathered, then identify actionable items for improvement.

Action

The lead department will generate specific tasks to implement identified recommendations, including performing the necessary actions, delegating them, or referring them to the appropriate group(s) for development and implementation.

Monitoring

The lead department will monitor and report on the schedule and progress of implementing the Lessons Learned based on reporting from the assigned group(s) responsible for each action item.

Assessment

The lead department will assess the impact of action items to measure whether the changes have effectively mitigated the issue as intended, and whether an action has had any discernable unintended consequences. The lead department will work with the responsible group(s) to adjust mitigations which perform poorly, or which yield negative unintended consequences.

Storage & Retrieval

The Lessons Learned data is stored electronically in a location that is accessible for all project stakeholders, where it can be used for current and future projects. Reports are also stored in this location and may be made available on a recurring basis to senior management via email or other means.

Conclusion

It is important to implement a Lessons Learned procedure from the beginning of an APF project, and the process should be continuous throughout the life of a facility. One key factor to remember is to view Lessons Learned as a constructive procedure and not simply a process to place blame or point fingers. The focus should be on the knowledge obtained from both the successes and failures of the project and the opportunity to use the collected knowledge to create a more efficient process for future projects.



Air Barriers in Biomedical Buildings with HVAC-Induced Differential Pressures Part II

Introduction

In April 2020, DTR published a Technical News Bulletin called “Building Envelope Air Barriers” that gave a brief introduction to the subject of air barrier systems, which are comprised of continuous membranes, sheets, tapes, and fluid-applied coatings. In October 2020, DTR published a second Technical News Bulletin on Air and Water Barrier (AWB) applications in biomedical buildings with HVAC-induced differential pressures. This month’s article will delve deeper into how dewpoint is a critical consideration for the designer to ensure proper placement in the system for intended performance.

AWBs work in concert with vapor barriers and insulation systems to control the infiltration/exfiltration of air through the exterior envelope of a building and to ensure that condensation within the wall or roof cross section will not occur during normal temperature and humidity ranges. Good design further ensures that, should condensation occur, provisions exist to drain and dry the condensation plane without causing damage or promoting microbiological growth while mitigating the infiltration of outdoor air with its odors, molds, spores, fungi, bacteria, moisture, heat/cold, etc.

Uncontrolled Moisture in the Building Envelope

There are two sources of uncontrolled moisture in the building envelope:

Externally Generated Moisture: Includes (1) wind-driven moisture entering seams, cracks, and joints between dissimilar materials; (2) vapor diffusion through the exterior cladding materials; (3) infiltration of outdoor moisture-laden air and condensation within the envelope (it is worth noting that infiltration of outdoor air due to air leakage related to HVAC system-induced negative differential pressure is considered an external source, and that warm, moist air has higher vapor pressure than cooler, drier air); and (4) leakage from above via failed flashing, roofing, drains, and ice damming due to gravity, capillary action, surface tension effects, etc. Lower air pressure within the structure can “drive” moisture from the exterior inward until it encounters a surface cool enough to induce condensation.

Internally Generated Moisture: Includes (1) air-diffused moisture generated by building occupants and use of the building, such as respiration, handwashing, cooking, cleaning, etc., in excess of what is removed by the operation of the HVAC system; (2) indoor air leakage that is allowed to enter the building envelope and condense on cool surfaces within the assembly; and (3) leakage from piped utilities which penetrates the building envelope assembly.

Good design for the management of air and moisture within the building envelope includes:

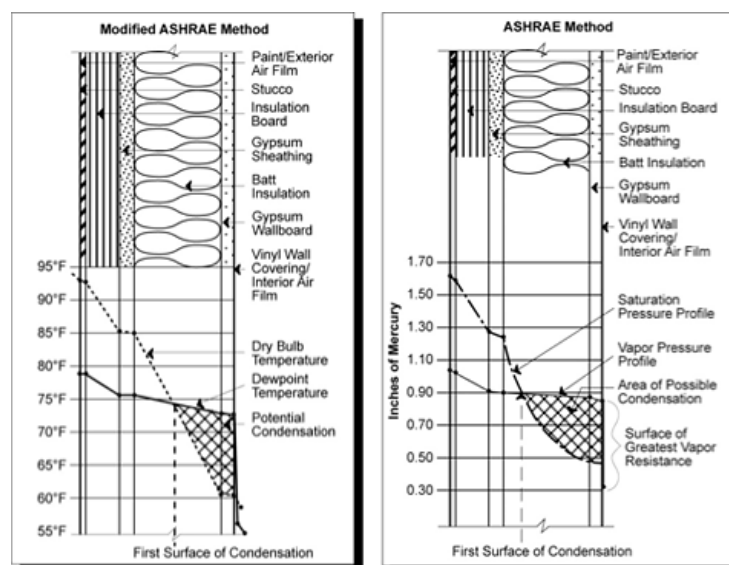
Weather Barrier: Must include water shedding and control of water penetration capabilities to drain and dry without damage. Should be resistant to blockage of drainage pathways and entry by pests. The expectation is that the material selection, detailing, and installation of this layer be nearly perfect, but this layer must be robust enough to continue to perform as intended despite any failures in execution.

Air and Water Barrier (AWB): The AWB retards air movement and includes water shedding properties (it may serve as the drainage plane behind the weather barrier or as a backup) but must not be classified as a vapor barrier to promote drying. In a warm climate, the AWB is generally located exterior to the primary thermal insulation, while in cold climates it

may be positioned beneath the outboard insulation, but to the exterior of the primary thermal insulation. The expectation is that the AWB material selection, detailing, and installation be as good as practicable, especially where exposed to negative pressure from the HVAC system that leaks past the vapor barrier – thus, the AWB and VB are a complementary system.

Vapor Barrier (VB): The VB prevents the diffusion of moisture. In warm climates, the location of the VB should generally be to the exterior of the thermal insulation, and VB material selection, detailing, and installation should be as good as practicable. In cold climates, the VB must occur interior to the thermal insulation, and VB material selection, detailing, and installation should be nearly perfect due to the likelihood of surfaces within the assembly being cold enough to induce condensation (this process should include assessment of interior finishes, especially paints, wallpapers, and wall protection panels which may act as unintended vapor barriers).

Assembly dewpoint analysis is discussed in the ASHRAE Handbook: Fundamentals (Chapter 27; ASHRAE, 2009). It is necessary to complete a version of the ASHRAE Handbook’s standard or modified method (see Figure 1) for calculating water vapor diffusion of each major assembly type to ensure these assemblies perform as intended. These methods analyze



(Figure 1 First Surface of Condensation)

each component in an assembly, including their thickness, permeance to vapor transmission, and thermal resistance. Graphs of the temperature profile are developed, progressing from the outdoor to indoor dry bulb and dewpoint temperatures; the intersection of these lines indicates potential saturation and condensation zones within the assembly. Manipulation of the depth and type of insulation are the primary, but not the only, factors in optimizing the section for a given site (climate) and application.

A good design is one where the weather barrier, AWB and VB work as a system in which condensation is only likely to occur in locations where its impact would be benign and where unintended air movement through the wall or roof section is fully mitigated.



Air Barriers in Biomedical Buildings with HVAC-Induced Differential Pressures

Introduction

In April 2020, DTR published a Technical News Bulletin, "Building Envelope Air Barriers," which gave a brief introduction to the subject of air barrier systems comprised of continuous membranes, sheets, tapes, and fluid-applied coatings. This article builds upon that introduction to explore Air and Water Barrier (AWB) application in biomedical buildings, particularly those designed and operated to maintain significant differential pressures relative to atmosphere.

AWBs are intended to control the infiltration and exfiltration of air through the exterior envelope of a building. Infiltrating outdoor air can entrain odors, mold, moisture, heat/cold, and more into the indoor environment. The results of this can be disastrous for buildings with indoor environments that support immunocompromised patients, cultured biological specimens, the production of pharmaceuticals, or other sensitive biomedical research and treatment activities.

AWBs work in concert with vapor barriers and insulation systems to ensure that condensation within the wall or roof cross section will not occur during normal temperature and humidity ranges, based on climate. Good design further ensures that, should condensation occur, provisions exist to drain and dry the condensation plane without causing damage or promoting microbiological growth. Air infiltration/exfiltration can also raise the energy required to maintain temperature setpoint considerably and add to the humidification/dehumidification load. Over the same section of building envelope, air leakage can transport orders of magnitude more moisture than vapor pressure-driven diffusion over the same period.

Understanding Modes of Failure

In certain applications, the HVAC system is designed to establish and maintain pressure differentials to mitigate and control the flow of airborne contaminants between rooms and/or between the interior of the building and the outdoor environment. These pressure relationships can be delicate, often relying on the building automation and controls system to adjust air valve and damper positions to overcome external factors, such as wind pressure, stack effect, and fan pressures created by other systems operating in the building, in order to maintain this differential. While a certain degree of infiltration/exfiltration can be compensated for, high leakage rates can make it difficult to maintain the facility in a state of control.

Defects in the continuity of the air barrier may include, but are not limited to:

- **Diffuse Flow:** Where the Materials Of Construction (MOC) are ineffective at controlling airflow through the wall or roof assembly. This may be due to field permeability (air moving through the material itself) or unsealed joints between modular building components (between sheets of sheathing, for example).
- **Orifice Flow:** Where the MOC are relatively impermeable, but the connection between sub-assemblies, such as a door in a rough opening, is inadequately sealed to prevent straight-through air movement.

- **Channel Flow:** Similar to orifice flow, except in lieu of straight-through air movement, the route is more circuitous, resulting in a greater likelihood of the infiltrating/exfiltrating air reaching dewpoint and condensing on surfaces within the assembly.

To mitigate these types of failures, continuity of the air barrier is essential, especially at the transition between vertical and horizontal assemblies and penetrations. The air barrier may be placed anywhere in the assembly and successfully mitigate air movement; the vapor barrier, however, must be placed in a specific plane of the assembly, as dictated by climate, to prevent condensation within the assembly. Failure to seal airflow at the AWB may reduce the effective insulating value of fibrous insulation due to convection of air within the assembly, which also increases the likelihood of condensation and condensation-related damage.

Combining the requirements set forth in ASHRAE 90.1, ICC IECC, and good building practice, an AWB system should be:

- (1) Continuous throughout all exterior envelope exposures.
- (2) Detailed to minimize penetrations and thermal bridging points.
- (3) Able to accommodate the maximum structural movement and pressure differentials (the AWB should not assume the continuity of the VB is sufficient to resist differential pressures developed by the HVAC system).

Air barrier materials should be selected with a permeance not to exceed 0.004 CFM/SF at 0.3" wg (1.57 PSF) [0.02 L/s.m² at 75 Pa] when tested according to ASTM E 2357. Engineering analysis is necessary to account for the impact on higher HVAC-induced differential pressures on the MOC, detailing, and placement of the AWB and VB within the assembly. The detailing of greatest concern is at fenestrations and transitions between roof-wall, wall-floor, and above/below grade, as these present the highest likelihood for gaps and movement-related failures over the life of the structure.

Conclusion

Air barriers are an essential subsystem of the exterior envelope of a building, particularly one subject to HVAC-induced loads. Failure of this subsystem can negatively impact indoor air quality and occupant health and safety. Infiltration, poor control of temperature/relative humidity, and the introduction of particles can be deleterious to the science and medicine conducted in affected spaces and may radically increase the energy required to maintain control of the building within specified limits. Failure is also associated with increased maintenance and decreased useful life of the building due to rot, corrosion, staining, and other damage. Building codes require the inclusion of air barrier systems but are often misunderstood and misapplied by designers and builders alike. The codes are relatively silent on the influence of HVAC-induced differential pressures across exterior envelope assemblies, which highlights the need for engineering analysis to characterize the potential risks associated with air and moisture leakage through these assemblies.

Antimicrobial Technology in the Building Industry

Introduction

The use of antimicrobial technology in construction materials, fabrics, and building products has become increasingly prevalent. This may be attributed to the rise in hospital-acquired infections (HAIs) and is evident in the marketing of antimicrobial face coverings used to confront the COVID-19 pandemic. The benefits of adding antimicrobial technology to products continues to be challenged today due to past research that shows it has little to no effectiveness in reducing infections.¹ However, research has also shown success with copper alloys used to reduce bacteria that is present on the surfaces of hospital furniture, fixtures, and hardware.² Therefore, a clear understanding of the impact and benefits of different antimicrobial technology should be understood when determining its applicability.

Antimicrobial Function and Benefits

Antimicrobials are used to prevent the growth of bacteria, mold, and mildew on products and surfaces. Antimicrobial additives are integrated during the manufacturing process in a liquid or powder form. They are commonly found in interior finishes and bathroom fixtures, and work to eliminate existing microorganisms and prevent new ones from populating. Additives remain active for the lifespan of a product; they are also often used in various products to prevent spoilage over time. Commonly advertised benefits of antimicrobial technology in building products and finishes include:

- Increases a product's lifespan.
- Reduces stain and odor-causing microbes.
- Prevents harmful microbes from residing on surfaces.

The COVID-19 pandemic has led to an increase in the number of face coverings made with graphene fabrics on the market. Although graphene has inherent antibacterial properties, it should be noted that antibacterials reduce the presence of microbes such as bacteria and mold, which are not viral. Careful consideration must therefore be given when advertising or implying its usefulness against viruses.

Impact to Human Health & The Environment

Building materials utilize silver ion coatings in products such as hardware and flooring. However, caution should be exercised when selecting materials with antimicrobial additives because there is evidence that some additives may be harmful to human health.³ Triclosan, an antimicrobial additive found in cementitious construction materials such as concrete, has been investigated by the FDA regarding its use in soaps and handwashes, and the full environmental and health impacts of triclosan additives are still being studied.⁴ The Centers for Disease Control stated that "the human health effects from exposure to low environmental levels of triclosan are unknown... More research is needed to assess the human health effects of exposure to triclosan".⁵ Additionally, studies have shown that some antimicrobial substances can migrate from products to other surfaces.⁶ The use of graphene based materials is also a subject of debate due to "a lack of universal acceptance criteria" related to the toxicity associated with them.⁷

Conclusion

Frequent handwashing and cleaning and safely sanitizing surfaces remain the established strategies in combating the spread of infectious diseases. Although antimicrobial technology has the potential to be beneficial, there are still many questions about its potential impact and efficacy. Some face coverings advertising antimicrobial properties are non-medical and have not yet been evaluated by the CDC or FDA or in rigorous scientific studies, and although copper has proven to be effective against some bacteria and viruses, "a low quality of evidence" was cited in response to the studies indicating reduced rates of infection.^{1,8} Antimicrobial additives are an emerging field, and our knowledge of their impact to human health as well as their effectiveness against viruses is rapidly evolving. Thus, more controlled research on the efficacy of antimicrobials incorporated into building materials, fabrics, and products is needed to ensure a positive impact on the health of buildings and their occupants.

Products, materials, and technologies referenced in this article are not cited as an endorsement by NIH. The intent of this article is to encourage more research and dialogue regarding the use of antimicrobials in the building industry.

References

- 1 Ted Schettler, Antimicrobials in Hospital Furnishings: Do They Help Reduce Healthcare-Associated Infections? Healthcare Without Harm, accessed May 19, 2020.
- 2 T.J. Karpanen, A.L. Casey, P.A. Lambert, B.D. Cookson, P. Nightingale, L. Miruszenko and T.S.J. Elliott, The Antimicrobial Efficacy of Copper Alloy Furnishing in the Clinical Environment: A Crossover Study, Published online by Cambridge University Press: 02 January 2015
- 3 "Common disinfectant, benzalkonium chloride, CAS#8001-54-5 is a respiratory sensitizer per Association of occupational and environmental clinics Exposure Code Tool," www.aeec.org/tools.htm
- 4 US Food and Drug Administration. "FDA Issues Final Rule on Safety and Effectiveness of Antibacterial Soaps." FDA News Release, September 2, 2016.
- 5 Centers for Disease Control and Prevention. "Triclosan FactSheet," November 2009.
- 6 "US Department of Commerce, NIST. "NIST Manuscript Publication Search." Accessed March 29, 2016.
- 7 Parveen Kumar, Peipei Ho, Rongzhao Zhang and Bo Liu. "Antibacterial Properties of Graphene-Based Nanomaterials" Published online 2019 May 13, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6567318/>
- 8 Gregor Grass, Christopher Rensing, and Marc Solioz. "Metallic Copper as an Antimicrobial Surface." Applied and Environmental Microbiology 77, no. 5 (March 2011)



Automatic Receptacle Control

Introduction

Automatic receptacle control, also known as plug-load control, reduces building energy use and is required by ANSI/ASHRAE/IES Standard 90.1-2019: Energy Standard for Buildings Except Low-Rise Residential Buildings, as well as NIH DRM 10.5.3. It also helps federal buildings meet Executive Order 13834, Efficient Federal Operations. The benefit of implementing automatic receptacle control is limiting energy consumption at the electrical receptacles during non-occupied times, which reduces unnecessary energy usage and cost and supports sustainability efforts. In addition, many states require automatic controlled receptacles as part of their code requirement. NEC-2020 406.3(E) has recognized the need for identifying these controlled receptacles with a permanent marking of "CONTROLLED," which is now required on the contact device(s). See Figure 1 below for examples.



Figure 1: Marking of "Controlled" on Plug-Load Receptacles

Key Elements for Consideration

Automatic receptacle control was introduced in ASHRAE Standard 90.1-2010 and expanded on in later editions. Based on ANSI/ASHRAE/IES Standard 90.1-2019, Section 8.4.2, at least 50% of all 125V, 15- and 20-amp receptacles should be automatically controlled by a device that turns power on and off based on a schedule, occupancy sensor, or an automated signal from another control or alarm system. These automatic control devices may be in private offices, conference rooms, rooms used primarily for printers/copiers, break rooms, classrooms, and individual workstations. ASHRAE 90.1-2019, Section 8.4.2 also states that at least 25% of branch circuit feeders installed for modular furniture must be automatically controlled.

Even though ASHRAE 90.1 has recommended receptacle control for several revision cycles, controlling plug loads are typically the last energy conservation measure to be considered as part of project design. On average, General Services Administration (GSA) has found that plug loads account for approximately 30% of electricity in the office environment, while Department of Energy (DoE) data shows that performing a plug load inventory and implementing automatic receptacle controls can reduce energy use by 20-50%. Controlling plug loads stand to have an increasingly significant impact on energy conservation measures moving forward as

well: The DoE forecasts that overall energy consumption in a commercial environment will increase 24% by 2030 and plug and process loads will increase twice as much to 49%. Project engineers must therefore recognize the potential benefits of automatic receptacle control implementation to reduce energy use and meet EO 13834.

Design Principles

There are three types of automatic receptacle controlling methods specified in the ANSI/ASHRAE/IES Standard 90.1-2019, Section 8.4.2:

- Schedule-based/timer-based – This method turns receptacles off at specific programmed times. This standard requires an independent program schedule for controlled areas of no more than 5,000 ft² and not more than one floor. In addition, the occupant shall be able to manually override this device for up to two hours.
- Occupancy-based – An occupancy sensor must turn off electrical outlets within 20 minutes of all occupants leaving a space.
- System-based – A signal from another control or alarm system must turn off electrical outlets within 20 minutes after determining that the area is unoccupied.

Section 8.4.2 also indicates three exceptions that do not require an automatic control device:

- Plug-in devices in place of hardwired controls.
- Equipment required to be in continuous operation (24 hours a day, 365 days a year).
- Spaces where automatic control would risk the safety or security of room or building occupants.

Besides the 2020 NEC 406.3(E) requirements, ASHRAE 90.1-2019 also requires controlled receptacle marking.

NIH DRM Section 10.5.3, Wiring Device, requires that occupancy-based and schedule-based electrical outlets shall be considered for office cubicles and private workstations.

Conclusion

With EO 13834 mandating building energy use reduction and reduced electrical costs, project designers should follow the ANSI/ASHRAE/IES Standard 90.1-2019, Section 8.4.2. This will help achieve maximum energy conservation using properly marked automatic control devices in open workstations, conference rooms, printer/copier devices, break areas, classrooms, and individual offices.

Reference for Further Reading

1. Implementing Instructions for EO 13834, Efficient Federal Operations
https://www.sustainability.gov/pdfs/eo13834_instructions.pdf
2. ANSI/ASHRAE/IES Standard 90.1-2019, Energy Standard for Buildings Except Low-Rise Residential Buildings
<https://www.ashrae.org/technical-resources/bookstore/standard-90-1>
3. Energy Efficiency in Separate Tenant Spaces – A Feasibility Study
https://www.energy.gov/sites/prod/files/2016/04/f30/DOE%20-%20Energy%20Efficiency%20in%20Separate%20Tenant%20Spaces_0.pdf
4. Plug Load Frequently Asked Questions
<https://www.gsa.gov/about-us/organization/office-of-governmentwide-policy/office-of-federal-highperformance-buildings/resource-library/energy-water/plug-load-frequently-asked-questions-faq#6>
5. NREL – Assessing and Reducing Plug and Process Loads in Office Buildings
<https://www.nrel.gov/docs/fy13osti/54175.pdf>



Emergency Plumbing Fixtures in Classified Areas of Aseptic Processing Facilities (APFs) at NIH

Introduction

The safety of our workers is paramount to the NIH, but there are certain hazards inherent to the work performed in our Aseptic Processing Facilities (APFs), including the ubiquitous, persistent risks associated with accidental exposure to the various eye-damaging cleaning and sanitizing agents used to maintain these facilities as aseptic environments. There is a tension, however, between regulations which require the presence of emergency plumbing fixtures for worker safety and other regulations which discourage the introduction of biologically active potable water for patient safety related to potential product contamination.

Regulations Regarding Emergency Plumbing Fixtures

APFs are those facilities engaged in the production and/or testing of sterile and non-sterile drugs using aseptic processes, inclusive of sterile and non-sterile pharmaceuticals and biologics for human use, in NIH owned and leased facilities. These facilities include rooms and spaces that are International Organization for Standardization (ISO) Class 8, or better, classified areas. Entry into these areas requires donning appropriate Personal Protective Equipment (PPE) for two reasons: to protect the product being produced from contamination, and to provide a barrier to protect the worker from the products and components of manufacture, as well as from exposure to cleaning chemicals. Eye-protection PPE mitigates the risk of exposure, but does not eliminate it, and the need for readily accessible eye flushing fluid is recognized by regulation.

To maintain an appropriate environment for production, all surfaces, including ceilings, walls, floors, and all other exposed surfaces and components, are subject to regular cleaning and sanitization using chemicals demonstrated to be effective at removing and deactivating surface contaminants, including molds, spores, fungi, bacteria, etc. To achieve the required log reduction of viable particles on these surfaces, they are wiped and/or mopped with immediately successive passes, each utilizing different chemicals and disinfecting mechanisms in order to be impactful against a broad spectrum of potential pathogens. With near uniformity, these chemicals are characterized by an association of exposure with severe eye injury. With a few exceptions, these cleaning and sanitizing chemicals pose the greatest risk to worker safety in these facilities.

The U.S. Code of Federal Regulations 29 CFR 1910.151 states, "Where the eyes or body of any person may be exposed to injurious corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use." These requirements are further defined and quantified in the ANSI/ISEA standard Z358.1 for Emergency Eyewash and Shower Equipment. More specifically, as implemented, this generally requires a plumbed eyewash within the room where the hazard exists, with no intervening doors.

This regulation predates the advent of NIH APFs and similar facilities, where each room, regardless of size, shall be equipped with a plumbed

emergency eyewash/facewash/shower, depending on the site-specific nature of the risk. Monthly emergency fixture testing is performed to provide assurance that the fixture is ready for use in an emergency. NIH recognizes that the accepted method of providing emergency drenching and flushing of the eyes and body is through plumbed eyewash stations/emergency showers that meet the current ANSI Z358.1 standard. However, in addition to space and other practical considerations, this poses two unintentional consequences which, in APFs, increase the risk of product contamination and potential impact on patient safety via the product being produced. These consequences are:

- During monthly testing, emergency fixtures are discharged, spraying large volumes of tepid, potable water into the air and across surfaces. This water is significantly less sterile than these surfaces, which must be maintained clean. The droplets and aerosols from monthly flushing can contaminate surfaces well away from the fixture, depending on airflows and personnel movement.
- Drain openings are connected to traps which harbor and sustain diverse microflora, including persistent biofilms. During drain usage, these microflora aerosolize and discharge from the drain trap body into the air around the trap, contaminating the air nearby, settling onto surfaces and personnel. Regular trap maintenance cannot effectively mitigate the microbiologic activity here.

Regulations that govern aseptic environments, including Good Manufacturing Practice (GMP) and Good Practice (GxP), United States Pharmacopeia (USP) General Chapter <797> Pharmaceutical Compounding – Sterile Preparations, and others, prohibit the introduction of such insanitary conditions within APF production spaces to prevent contamination of the product being produced within the APF. Thus, there is a tension between the regulations, which respectively require and prohibit these fixtures in the ISO-8 or better classified spaces of the APFs.

Effective July 2nd, 2020, NIH Manual Chapter 1407 seeks to mitigate that tension and the inherent associated risks by excluding plumbed emergency fixtures from these areas; ensuring other areas of the APF conform to the ANSI/ISEA Z358.1 standard; providing a conventional, plumbed emergency eyewash/facewash and showers, as required, as close to the point of entry/exit from the APF's ISO classified areas as practicable; and providing and maintaining sterile, sealed, dual eyewash bottle stations nor more than one per room, and not more than 40'-0" apart in the ISO-8 or better spaces.

It is our belief that this approach is the appropriate balance to meet the intent of these otherwise conflicting regulations and standards for keeping workers and patients safe.

Reference

1407 - Emergency Eyewash and Shower Equipment in Classified Areas of Aseptic Processing Facilities
<https://policymanual.nih.gov/1407>



Fail Safe vs. Fail Secure Electronic Locksets

Introduction

To address the wide range of functions in research facilities and the requirements for life safety and security, the two designations associated with electronic locks are fail safe and fail secure. There are many factors to consider for determining the correct designation.

Fail Safe vs. Fail Secure

All electronic door locks are power activated; The terms “safe” and “secure” indicate the condition of the door on the secure side (key side, outside). Fail safe or fail secure refers to what happens when the door controller has failed and/or there is no power to the unit. Fail safe means when no power is applied the door is unlocked; fail secure means when no power is applied the door is locked.

Key Aspects for Design Considerations

Fail-secure locks should be used for most doors except where quick entrance is needed in emergency situations. The default position prevents the circumvention of the security system. A key override may allow access by emergency personnel; otherwise emergency personnel will use the necessary tools to allow entry during emergencies.

Note that there are situations, principally high-security functions, where doors may be electrically locked even on the egress side unless credentials are scanned.

Typically fail secure items use less power because they only require power to unlock the door. Fail safe products require continual power consumption.

Device Types

Electric strikes

An electric strike replaces the mechanical strike in a lockset to electrically control access. For electric strikes on fire-rated doors, fail secure strikes must be used, per NFPA 80. Fail secure strikes are typical, except when access is required by a fire alarm. There are only a few situations where access upon fire alarm is required. The use of an electric strike does not affect access by the fire department; they can gain access with a key or access-control credential in the key box or a tool.

Electromechanical Locks

An electromechanical lock is a lockset which has been electrified so it can be controlled by a card reader, remote release, or other access control device. Most allow free passage all the time and fail safe in an emergency.

A fail secure electromechanical lockset is locked on the secure side when there is no power to the lock. To unlock it, power is applied, and

the lever can then be turned to retract the latch. The latch remains projected until the lever is turned.

Electrified Panic Hardware

Electrified panic hardware typically works on the opposite side of panic hardware or fire exit hardware, as a lever operated trim. However, since it's on the opposite side of the door, whether it is required to be fail safe or fail secure differs based on a project's requirements.

Electrified Latch Retraction (EL) and Electromagnetic Locks

An electric latch retraction is a function on panic hardware or fire exit hardware that allows for latch retraction when power is applied; when there is no power, the latch is extended. Electric latch retraction functions are therefore fail secure. The touchpad of the panic hardware provides free egress. EL devices can be used on fire doors to allow push/pull function during normal use and provide positive latching during a fire alarm; a signal from the fire alarm system to the power supply is required for this application. Electromagnetic locks are typically fail safe, requiring a release device to allow for egress (e.g. a request-to-exit switch in panic hardware, pushbutton actuator and sensor combination, or fire alarm/sprinkler system trigger).

Determination

For electronically locked doors, it is necessary to coordinate with the appropriate Authorities Having Jurisdiction (AHJs). The Division of the Fire Marshal is the fire and life safety AHJ for NIH-owned facilities, and the Division of Physical Security Management is the security AHJ for all NIH facilities, including leased. In general, all doors serving high value or hazardous areas, including animal research and biocontainment facilities, shall be fail secure while meeting egress requirements. Specialty labs shall be assessed individually to meet the requirements of safety, security, and containment.

Conclusion

Before selecting access control hardware for a specific location, ensure that its function meets the programmatic requirements of the users, AHJs, and all applicable codes.

Consideration shall be given as to whether the hardware will be used on an interior, exterior, or fire rated door, as well as the relevant life safety regulations, security requirements, and the function of the facility.

Reference

- NFPA 101 Life Safety Code – Ch. 7 - Means of Egress
- NFPA 5000 Building Construction and Safety Code – Ch. 11 - Means of Egress
- NFPA 80 Standard for Fire Doors and Other Opening Protectives – Ch. 6 – Swinging Doors with Builders Hardware

*Updated 8/5/2020



Overspeed Motors

Introduction

Historically in the United States, with our 60 Hertz (Hz) alternating current electrical (AC) frequency, motors operate between minimum rotational speed (as low as 0 Hz/0 Rotations Per Minute (RPM)) and 60 Hz (maximum motor RPM). With the use of Variable Frequency Drives (VFD), motors can be run at higher than 60 Hz, known as an overspeed condition, typically as direct drive fan wall/plenum fans (per NIH DRM 6.2.4.2, the maximum operating speed is 90 Hz). Multiple important factors must be considered before allowing a motor to operate at this overspeed condition, whether it happens by design or to meet field conditions that are outside design intent.

Requirements for Air Barrier

The first important factor is the torque produced by the motor when operating at overspeed conditions. As motor speeds extend beyond 60 Hz, motor torque reduces. This torque reduction occurs because motor impedance increases as frequency does. Since a VFD cannot increase the voltage above its supply voltage, the current decreases as frequency increases, decreasing the available torque. Motor torque is calculated as:

$$\text{Torque} = (\text{Line Frequency}/\text{Extended Frequency})^2$$

or

$$\text{Torque} = (\text{Base Frequency}/\text{Extended Frequency})^2$$

As can be seen by the graph below, motor speed can potentially be increased to 120 Hz, but the torque output of the motor at that speed would only be 50% of the output at 60 Hz. Other factors such as bearing efficiency can reduce the torque output even further. Without careful design consideration, this could result in underpowered output for the application.

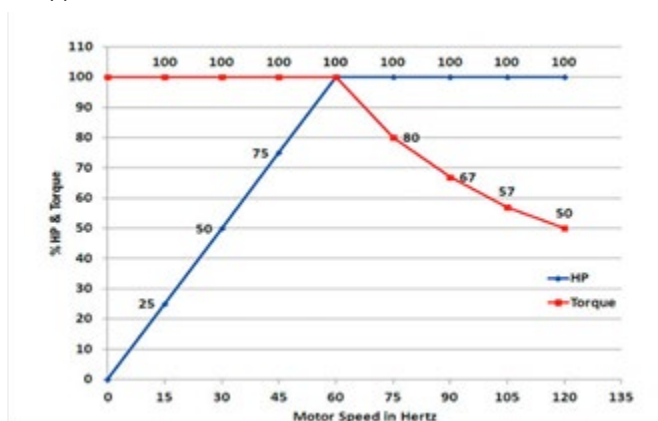


Figure 1: Motor Speed vs. Torque

The second important factor is confirmation that the motor can run at the overspeed frequency without being damaged. Operating motors at an overspeed frequency they are not capable of sustaining can result in a shortened life expectancy, or even motor break up. Among the motor features that must be considered when running at overspeed:

- Motor rating:
 - Many general duty motors are not rated to handle overspeed operation. At minimum, a motor should be rated for VFD operation and be equipped with shaft grounding such as an Aegis grounding ring. Even with this rating, the manufacturer should be consulted to confirm the motor can operate at the anticipated overspeed condition. Motor imbalance tolerance will be amplified at higher speed and will exacerbate vibrations, reducing the motor's useful life.
 - Motors rated as "Inverter Duty," which meet National Electrical Manufacturers Association (NEMA) Standard MG-1 Part 31, are designed to handle the voltage spikes associated with VFDs and can therefore be operated at overspeed without potential damage to the motor. It should be noted that inverter duty motors can also be operated at very low speeds without overheating.
- Bearing speed rating:
 - Bearing manufacturers provide tables for speed ratings where bearings can be operated without overheating. When confirming that a motor can operate at an overspeed condition, the motor manufacturer should provide tables and confirmation from the bearing manufacturer that their bearings can safely operate at the anticipated speed without heat buildup that could reduce operational life.

The third important factor to consider when evaluating a motor at overspeed conditions is the operation of the connected system when the VFD is set to bypass mode (frequency at 60 Hz). For motors on critical systems, such as fans handling pressure control for hospital or laboratory directional airflow, the motor speed is potentially critical to maintaining infection and containment control. For these types of applications, maintenance personnel may be required to operate the fans in bypass mode to keep a space in operation while addressing immediate maintenance or repair issues. In cases where motors are operating at an overspeed condition, this change in mode of operation could result in serious consequences, such as airflow reversals and impact to room air change rates.

The motor-driven machinery must also be carefully evaluated for operation. Fan wheels, pump impellers, drive belts, and other rotating devices have rotational / speed limitations that must be considered. Design engineers must analyze the operation of the systems when the VFD is operating in bypass mode to confirm all failure mode control sequences have been accounted for in order to prevent any serious consequences.

Conclusion

While it is possible for some types of motors to operate well over their nameplate frequency, there are critical factors that need to be carefully considered by the design engineer before allowing a motor to operate at these conditions. Failing to review these factors can result in significant consequences for both the motors and the spaces they operate in.

Building Envelope Air Barriers

Introduction

A building envelope's airtightness is a major factor in said building's overall energy performance. Uncontrolled air movement through the envelope will significantly increase the energy required to heat, cool, and humidify a building. In addition to increased energy use, uncontrolled air movement can lead to water migration into wall cavities, poor indoor temperature and humidity control, and compromised fire and smoke control measures. Uncontrolled air movement can also lead to condensation, which can cause mold, spalling of masonry, and general deterioration of assembly components.

Requirements for Air Barrier

Section C402.5.1 of the International Building Code (IBC) requires building envelopes to include a continuous air barrier to control air leakage in and out of all conditioned spaces within a building. The air barrier must be sufficiently durable to withstand damage during construction and last the life of the building. It must be sufficiently supported to resist positive and negative air pressure loads. All discontinuities and penetrations must be sealed and made airtight.

The air barrier type, material, and location within the assembly must be selected and specified as part of a comprehensive envelope design based on climate, energy modeling, daylight modeling, thermal comfort modeling, and heat transfer analysis. The construction documents must clearly identify all components of envelope assemblies on sections and plan details, specifically joints, interconnections, and penetrations. The air barrier material must have an air permeance not to exceed 0.004 cfm/sf at 0.3" wg [0.02 L/s.m² @ 75 Pa]¹ when tested in accordance with the American Society for Testing and Materials (ASTM) E 2178. The air barrier material of each assembly must be joined and sealed to the adjacent air barrier material in a manner which accommodates differential movement.

In buildings undergoing renovations, the state and condition of the existing air barrier should be determined. Destructive investigation may be required and undertaken based on an analysis of the cost and potential benefit of such an undertaking and the sensitivity and criticality of the facility's function. Problem conditions, such as gaps around windows or unsealed penetrations, should be corrected. It may be possible to seal small gaps and penetrations with spray polyurethane foam or another injectable expanding sealant. Note that air-permeable material like fiberglass insulation will not suffice as an air barrier.

Air Leakage Testing

To ensure the airtightness of the envelope, the project specifications should require that the construction contractor's

testing agency demonstrate performance of the continuous air barrier by the following tests:

1. Test the completed building in accordance with ASTM E 779 and ASTM E 1827. Testing shall occur when the air barrier installation is complete and repairs to the air barrier, if needed, are finished. If the building fails the airtightness test, corrective action must be taken until the building passes a subsequent test.
2. Inspect the completed building using infrared thermography. Perform inspections in accordance with ASTM C 1060. Determine air leakage pathways using ASTM E 1186. If the building does not pass the fan pressure test, perform corrective work as necessary to achieve the whole building air leakage rate specified in (1) above, then complete a second thermal scan.

Resources

ASTM E 779 *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*

This test method measures air-leakage rates through a building envelope under controlled pressurization and de-pressurization.

ASTM E 1827 *Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door*

These test methods describe two techniques for measuring air leakage rates through a building envelope in buildings that may be configured to a single zone.

ASTM E 1186 *Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*

These practices cover standardized techniques for locating air leakage sites in building envelopes and air barrier systems.

ASTM E 2170 *Standard Test Method for Air Permeance of Building Materials*

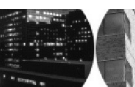
This test method is to determine the air permeance of building materials at various pressure differentials, with the intent of determining an assigned air permeance rate of the material at the reference pressure difference (ΔP) of 75 Pa.

ASTM C 1060 *Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings*

This practice is a guide to the proper use of infrared imaging systems for conducting qualitative thermal inspections of building walls, ceilings, roofs, and floors, framed in wood or metal, that contain insulation in the spaces between framing members.

Reference

¹USACE Engineering and Technical Bulletin, Building Tightness and Air Barrier Continuity Requirements, No. 2012-16



Performance Criteria for Resilient Flooring in Acute Care Hospitals

Introduction

Flooring is one of the largest surfaces in hospitals. It has significant impact on safety, infection control, appearance, maintenance, return-on-investment, clinical efficiency, and patient outcomes.

Criteria

Flooring selection begins with the needs of the project, which are outlined in the basis of design during the schematic design phase.¹

The Facility Guidelines Institute (FGI) *Guidelines for Design and Construction of Hospitals and Outpatient Facilities*, 2018, identifies the essential criteria in section A2.1-7.2.3.1² as follows: floor softness vs. firmness; condition of the subfloor; performance under pressure; pattern; contrast; reflectivity; sound absorption; sound transmission; cleanability; slip-resistance; resistance to cleaning and disinfecting agents; absorbency; smoothness; monolithic construction; requiring an integral coved wall base; sealed joints; and transitions between flooring types.

The Center for Health Design (CHD) uses Evidence Based Design (EBD) methodology to identify flooring performance goals. Safety, including fall protection and infection control, is critical, along with acoustic performance, indoor air quality, return on investment, reduction of staff fatigue, and improved patient satisfaction. Sustainability, durability, warranty, life-cycle cost, and maintenance are also important factors.

Preparation of Substrates

ASTM F710-19e1 Standard Practice for Preparing Concrete Floors to Receive Resilient Flooring is the standard for preparation of the substrate. Manufacturers also have installation requirements, which, notably, guarantee warranties when followed. It is highly recommended that the most stringent requirements be met at every opportunity.

Interrelationship of Materials and Maintenance

Applications requiring homogeneous flooring necessitate vertically monolithic material; this selection is driven by considerations such as the effect of dropped knives and sharp objects. Where aesthetic is the priority, heterogeneous flooring, made up of layers that include a backing, an image, and a wear layer, are preferable. Health care-associated infections (HAIs) can be mitigated by specifying either homogeneous or

heterogeneous resilient floors in sheet form. According to the Centers for Disease Control (CDC), one in every 20 hospital patients acquires an infection while being treated for other conditions.³ Selecting never-wax, matte finish, high performance flooring eliminates sticky, high-gloss polish that attracts and holds dirt and microorganisms.

Traditional cleaning technology uses high concentrations of surfactants that contribute to residue. Residue harbors a biofilm of bacteria that stick to each other in an extracellular polymeric substance matrix. According to the CDC, "bacteria within biofilms are up to 1,000 times more resistant to antimicrobials than the same bacteria in suspension."⁴ Floor finish selection should consider whether the chemicals used to clean the floor will reduce residue, and thereby reduce biofilms. The need to strip biofilms from floors has driven the popularity of no-polish sheet flooring, which requires fewer steps to appear clean and be disinfected. The two-step cleaning process removes the dirt and biofilm layers with water, the universal solvent, then uses water and a light volume of anti-microbial neutral cleaner to disinfect, in combination with microfiber mopping and/or orbital machine or auto scrub options.

Conclusion

Sound flooring specification supports safety in clinical care settings. Efficacy and patient well-being can be improved by weighing the complex interrelationships of criteria during the schematic design phase and selecting resilient flooring appropriate to the applications.

References

1. Design Objectives (<http://www.wbdg.org/design-objectives>). Whole Building Design Guide, a program of the National Institute of Building Sciences. Web. 20 March, 2020.
2. The Facility Guidelines Institute. *Guidelines for Design and Construction of Hospitals and Outpatient Facilities*, 2018 ed. Chicago: American Society for Healthcare Engineering, 2018.
3. Guidelines for Environmental Infection Control in Health-Care Facilities: Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC) (<https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines.pdf>). U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention, 2003 Updated July 2019. Web. 20 March 2020.
4. Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008 Update: May 2019 (<https://www.cdc.gov/infectioncontrol/pdf/guidelines/disinfection-guidelines-H.pdf>). U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention. Web.



UV Lighting Part II - Fundamentals

Introduction

Ultraviolet Germicidal Irradiation (UVGI) technology can be used to deactivate or kill microbial and bacterial microorganisms. The technology was developed several decades ago, and its efficacy has been studied and analyzed since then, specifically in the healthcare industry. UVGI is not only used in healthcare facility HVAC applications, but also in the treatment of hard, non-porous surfaces such as stainless steel and plastics, where under certain ambient conditions viruses like influenza may survive 24 to 48 hours due to subpar ventilation. UVGI technology is also used in water treatment and has even been applied outside the healthcare industry.

UVGI Applications in Healthcare

The HVAC system maintains the ideal indoor air quality (IAQ) as well as the proper air pressurization for individual rooms and throughout the facility.



Figure 1 – Downward UVGI Lamps

However, despite the IAQ and air pressurization control, fungi, bacteria, and viruses (including those that cause non-infectious diseases) may still be present on clean surfaces.



Figure 2 – Robotized UV Disinfection

One common application of UVGI technology is disinfection: a passive UVGI fixture is installed in an occupied zone, where it produces a field of UV energy above the occupied area (see Figure 1). The efficacy of these UVGI lamps must be carefully evaluated in conjunction with other environmental factors. Serious consideration should be given to whether the room will be in use during UVGI operation; for example, if UVGI is used in an operating room (OR), occupants will need appropriate protective clothing and eye protection for the downward UV irradiation. Other types of UVGI room sterilization are also available, including robotized UV disinfecting units (see Figure 2).

Many studies indicate that a microorganism's size and DNA structure affect the efficacy UVGI. Specifically, UVGI may not be very effective on large bacteria and spores, and a capturing element such as a high-efficiency filter working in tandem with the UVGI is necessary. Many environmental factors influence the presence and activity of infectious agents, including air temperature, velocity, and room-to-room pressure differentials, and all

these factors should be considered when evaluating the efficacy of the grouping design.

UVGI can also be used to deactivate infectious and non-infectious viruses and bacteria as part of the water treatment process; however, such process cannot rely strictly on UVGI. As with HVAC system applications, UVGI should only be part of the equation, because deactivating harmful microorganisms in water requires a multi-step water treatment process. This process should begin with identifying the desired water treatment level, which will determine various elements of the system such as filters, flow rate, and UVGI lamp specifications. UVGI is normally the final step of the water treatment process because it purifies the water after larger microorganisms have been filtered out.

UVGI Maintenance

It is important to consider the human health risks that accompany the use of UVGI technology. A poorly designed and installed UVGI system may have harmful effects on humans, be they building occupants or maintenance personnel. As a result, whenever UVGI lamps are used, proper standard operating procedures (SOP) must be established for safe operation and maintenance. The reliability and efficacy of the UVGI depends on how the system has been designed and maintained, so installation and maintenance of UVGI lamps must be done with care. Manufacturer recommendations for proper installation and maintenance vary, but basic aspects of UV lamp design and care should be evaluated, including:

- Cleanliness: This will ensure its maximum UVGI power.
- Bulb lifecycle and decay: Selecting the correct lamp type with consideration for bulb power, distance to treated area will enhance efficacy, and UV lamp replacement plan.
- Room/equipment air quality: Environmental conditions such as humidity and temperature may negatively impact UV lamp efficacy.

Applications Beyond Healthcare and HVAC

UVGI is primarily used for sterilization and disinfection, but other industries have expanded its uses to include surface curing, disinfection of filtering facepiece respirator (a technique normally implemented during a pandemic of infectious respiratory diseases). In the food industry, UVGI enhances product shelf-life as part by implementing UVGI air and water treatment to sterilize products, packaging, and transportation. UV technology is also used in manufacturing as an inspection tool.

Conclusion

UVGI technology has many advantages and uses, but it should not be considered a standalone disinfection or sterilization source. Its use must be carefully planned and selected to achieve the proper level of efficacy necessary for the given application. UVGI technology must be part of a comprehensive disinfection and sterilization system and program, both to achieve the desired results and to keep people safe.

Reference for Further Reading

1. Solving Office Complex IAQ Issues Through Ultraviolet-C Technology <https://www.achrnews.com/articles/142371-solving-office-complex-iaq-issues-through-ultraviolet-c-technology>
2. A How UV-C energy works in HVAC applications: Part 2 <https://www.csemaq.com/articles/how-uv-c-energy-works-in-hvac-applications-part-2>
3. Bacteria-Killer Robot Armed with Ultraviolet Light <https://www.asme.org/topics-resources/content/bacteria-killer-robot-armed-with-ultraviolet-light>

UV Lighting Part I – Fundamentals

Introduction

Ultraviolet (UV) radiation is naturally occurring electromagnetic radiation that comprises approximately 10% of sunlight at ground level. There are four types of UV radiation, which are classified based on the wavelength range measured in nanometers (nm): vacuum-UV (VUV) with a wavelength between 100-200 nm, UV-C with a wavelength between 200-280 nm, UV-B with a wavelength between 280-315 nm, and UV-A with a wavelength between 315-400 nm.

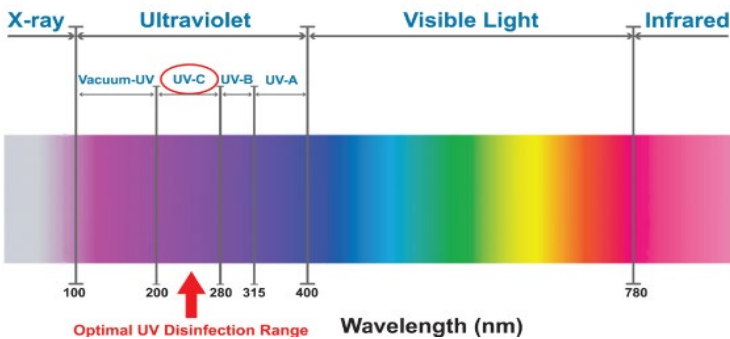


Figure 1 - The Electromagnetic Spectrum

between 315-400 nm. In addition to UV electromagnetic, the Sun's spectral composition also emits X-rays, visible light, and infrared radiations. Figure 1 shows the electromagnetic spectrum from the Sun which includes various types of UV and other electromagnetic radiations.

Ultraviolet (UV) Irradiation Effects on Human

UV radiation can be harmful or beneficial to humans, depending on the wavelength, range of the radiation, and duration of exposure. Approximately 95% of the UV radiation that reaches earth is UV-A, which is hazardous for humans because it can penetrate deep into the skin and have harmful effects. In contrast, UV-B cannot penetrate the skin any further than the surface layer, and instead works with the skin to generate vitamin D3. UV-C, although harmful to humans, is filtered by the atmosphere and does not reach the earth's surface. Vacuum UV (VUV) also does not reach earth's surface because it is absorbed by the oxygen in the atmosphere.

What is UVGI

Ultraviolet germicidal irradiation (UVGI) uses UV-C to deactivate

microorganisms, rendering them harmless. By changing the DNA structure of microorganisms, UV-C kills or deactivates them, making them incapable of performing vital functions including respiration, reproductive functions, and absorption of nutrients. Figure 2 graphically represents the direct effects of UVGI on the DNA of the microorganisms. Combined with an appropriate filtration system, UVGI is utilized for water treatment as well as for air disinfection applications in hospitals, health care facilities, research facilities, water treatment plants, and commercial and food industry. In each of these applications, it is important to remember that adequate support systems shall be in place when UVGI is used to prevent UV-C exposure, due to its effects on humans.

UVGI General Applications

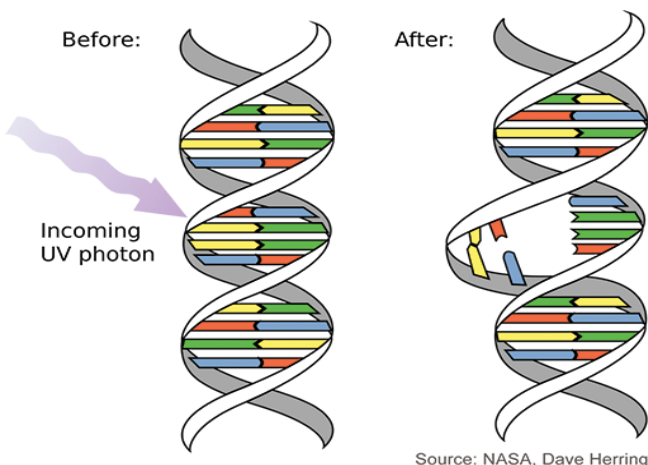
Water Treatment Basics: When UVGI is used for water treatment, its effectiveness is heavily dependent on the turbidity (small particulates or colloidal material suspended in the water) and the efficacy of the UV source used. UVGI uses UV light with an optimal wavelength of 254 nm. A water filtering system will be required to remove particulate matter such as heavy metals, salt, etc., for disinfection; the removal of chemicals such as chlorine should also be evaluated. By physically removing particles with the use of filters, the UV light can spread freely and reach the microbes. UVGI is used in HVAC systems to control microorganism growth on coil surfaces, condensate drain pans, and associated drain lines as well as other components exposed to UVGI. UVGI is also used in reverse osmosis (RO) systems. UVGI systems are an important component of research laboratories, boiler water systems, water treatment facilities, and aquatic research facilities, because they will ensure that any microbes that remain after passing through properly selected filters are irradiated with UVGI.

Air Disinfection Basics: The UVGI system is also widely applied in various forms to improve Indoor Air Quality (IAQ) through the HVAC system by neutralizing harmful airborne bacteria. In an HVAC system, just like in water treatment, the use of UVGI must be accompanied by a properly designed and selected filtration system. Air disinfection using UVGI also has many other applications outside of the HVAC system. For instance, in the health care industry, UVGI is being used in hospitals and many non-NIH research laboratories for disinfection of localized unoccupied areas, such as hospital rooms and ambulances interiors.

Part 2 will review further UVGI applications in detail. General design and maintenance considerations will also be addressed.

Reference for Further Reading

1. Analysis of Efficacy of UVGI Inactivation of Airborne Organisms Using Eulerian and Lagrangian Approaches
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3. The History of Ultraviolet Germicidal Irradiation for Air Disinfection
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Source: NASA, Dave Herring.

Figure 2 - Germicidal Effect on DNA