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The formulae $\frac{\partial \rho \bar{U}_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ for building $\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}-\rho \overline{u_i u_j}\right)+g_i(\rho-\rho_0)$ state of the art $\frac{\partial}{\partial x_i}(\rho \bar{U}_i \bar{H})=\frac{\partial}{\partial x_i}\left(\lambda \frac{\partial \bar{T}}{\partial x_i}-\rho \overline{u_i h}\right)$ biomedical research facilities.

Maintaining Water Systems from Construction Through Occupancy

Maintaining water systems from construction completion to building occupancy and use is a critical but often overlooked element of renovation and new construction projects. It's important for construction teams and engineers to be aware of water system hazards; potential issues must be identified during design and planning, which should follow DRM guidance to ensure good water management practices. Establishing a water start-up plan can also help project teams ensure potable water systems maintain residual disinfectant levels and mechanical water systems maintain required corrosion protection levels.

Risks and Recommendations for Low-Use/Stagnant Water Systems

In buildings which are not readily occupied, low-use and stagnant water systems can be potential breeding grounds for microorganisms, which can cause corrosion of metals and their alloys up to 100 times faster than normal corrosion occurs,[1] and lead to growth of undesirable pathogens, such as *Legionella.*[2] Water chemistry changes may also increase corrosion as well as metal and alloy leaching.[3] Post-hydrotest conditions where water is not fully drained or dried can lead to stagnant water, resulting in potential biofilms and piping corrosion.

The DRM encompasses requirements from the 2018 IPC Section 610 – *Disinfection of Potable Water Systems*. Guidance in DRM 8.3: *Water Systems,* along with applicable codes and industry guidance can prevent uncontrolled levels of piping biofilm, bacteria proliferation, and corrosion that occur in stagnant/wetted piping systems. In particular, Section 8.3.12 provides water management requirements to maintain the integrity of water systems, and Section 8.3.16 provides guidance on pressure testing, flushing, disinfecting, commissioning, and water quality testing of new and renovated water systems. Project specifications must contain requirements for important continuous control measures for wetted systems (cleaning, disinfection, treatment, flushing, etc.[2]) and should also include defined testing and reporting criteria. It's important to note that there are standards for flushing large public water mains, but no consensus standard for flushing and disinfecting plumbing systems within buildings.[4,5] Once water piping construction is complete, tested, and flushed, an appropriate hand-off to building maintenance is necessary to ensure continued turn-over and maintenance of water systems throughout building occupancy.

To combat low or no use water systems, the Environmental Protection Agency (EPA) recommends proactive measures to minimize piping degradation and public health risks.[3] The Centers for Disease Control (CDC) recommends that construction in retrofit projects should avoid excess vibrations and rapid changes in water pressure, which can cause biofilm in pipes to dislodge, freeing sediment into water systems.[6] As water temperature influences the growth of *Legionella* between 77˚F and 113˚F, hot water systems shall be maintained above 120˚F and cold-water systems maintained below 77˚F at all points (growth slows below optimal range).[2] Other considerations include evaluating if proactive chemicals or high-temperature disinfection are necessary, along with establishing a Water Management Program (WMP) for water systems and associated water devices per A*SHRAE Standard 188-2018*. *ASHRAE Building Readiness – Domestic Water Systems* provides industry guidance related to building shutdowns and re-opening.[7]

Water System Maintenance During Construction and Renovation

For shutdown of dry systems, where water is drained in an offline state, care should be taken to ensure low points and dead legs are fully drained. A compressed air blowout system (dry, oil-free air) can be used to force water out of low points. Once fully dried, piping systems should be kept closed using valves and end caps until start-up. For a standby (wet) state, water shall be replaced and flushed in returning to service, including a pre-flush baseline to compare to the post-flush water quality.[5] Construction must confirm that appropriate level of biocides and corrosion inhibitors are added to non-potable systems.[2] Refilling systems may result in destabilization of sediments and biofilm or introduction of external contaminants; in these cases, flushing the system before and after disinfection may improve results.[8] Start-up teams should verify and validate that appropriate disinfectant levels reach all piping outlets and are maintained in the pipes for a specified duration. Follow-up water testing should be performed to confirm water systems are ready for service.

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Vestibule Types: Airlocks, Anterooms, and Other Functions

The terms vestibule, anteroom, and airlock are applied somewhat indiscriminately and interchangeably. However, in many cases the distinction between these terms has real engineering, safety, and procedural implications; in other instances, there is a regulatory requirement that must be met. Unfortunately, the building science, code, standard, and guideline usage of these terms also tends to be inconsistent. This article aims to clarify appropriate usage of terminology.

Definitions and Usage

A vestibule is an architectural space which serves as a transitional room between exterior and interior or between rooms of differing uses, quality, or classification. Similar definitions could be given for airlocks and anterooms, but with additional requirements pertaining to airflow control, so it is more appropriate for these terms to serve as functional classifiers of vestibule types rather than as stand-alone terms.

The term airlock is particularly problematic in conversational usage, as it is often used to describe any space with doors which must be simultaneously closed during transit through the space, whether by administrative control (e.g., Standard Operating Procedure) or engineering control (interlocking door hardware). The airlock function, however, specifically describes an airtight assembly, inclusive of interlocking airtight doors, which is quite unusual even in biomedical construction. The BMBL was clearer on this point in the fourth edition, but the current sixth edition has lost some of this clarity.[1]

The term “anteroom” is less problematic in conversational usage, as it suggests allowing air passage to maintain differential pressure, directional airflow, etc., with or without interlocking door hardware and/or additional administrative controls.

Vestibule Terminology

Vestibule with Airlock Function: Designed to prevent undesirable airflow from one area to another using hard-interlocked airtight door assemblies (typically only found in BSL3/4, fumigation chambers, and other hazardous specialty laboratories). Maintaining this level of control is meant to prevent fumes, particulate matter, and/or microbial contamination from egressing one space and contaminating other connected spaces (mitigation of contamination, cross contamination, or safety risk). Airlocks should be designed to accommodate donning and doffing PPE and gowning as well as the transit of cleaning and sanitizing materials through the airlock.[2]

Vestibule with Anteroom Function: Utilized to complement the HVAC system in mitigating airflow between areas and to improve the effectiveness of the pressurization systems via hard - or soft - interlocked door assemblies (i.e., engineering and/or administrative controls). As in the airlock function, maintaining air pressure control in an anteroom function is intended to prevent migration of particulate matter and microbial contamination between connected spaces. What differentiates an airlock from an anteroom function is how airflow (and differential pressure) is managed: in an airlock, airflow is prevented, but anteroom function vestibules allow managed airflow, either as a bubble (where the anteroom is positive to adjoining spaces), sink (where the anteroom is negative to adjoining spaces), or cascade (higher pressure exists on one side of the anteroom, which transitions to lower pressure in another adjacent space). Anterooms should be designed to accommodate donning and doffing PPE and gowning as well as the transit of cleaning and sanitizing materials through the anteroom.[2]

Vestibule with Exterior Access Control Function: Utilized to control access to the facility, manage the impacts of the exterior environment on the interior of the building (which can impact energy usage and occupant comfort), and minimize dirt and moisture being tracked into the building. These are required at building entrances.[3]

Vestibule with Interior Access Control Function: Utilized to control access to spaces by unauthorized persons and to manage the directional flow of personnel, materials, equipment, or wastes (i.e., access limited by time, room recovery, etc.). Interior access control functions may be combined with airlock or anteroom functions.

Conclusion

While codes and standards generally maintain internal consistency of usage, the lack of consistency between documents remains problematic. In certain cases, such as BSL-3/ABSL-3 laboratories and elevator lobbies, project language must utilize the language of the applicable regulations. In other instances, representing the majority of uses in the DRM, the language should be examined and revised as necessary to conform with a single, standard taxonomy, as provided here.

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Veterinary Surgical Suites, Part-ll

Last month, this series discussed the veterinary surgical suite, which is designed around a workflow that maximizes unidirectionality of animals and staff from clean to dirty spaces. Part I explored the Personnel, Animal, Material, and Equipment Flows. This month's article focuses on Operating Room (OR) design.

Large Animal Operating Rooms: The ceiling around the operating table requires a high level of coordination to accommodate general lighting, boom-mounted surgical lights, monitors, C-arms, video displays, medical gasses, Waste Anesthetic Gas recovery, pumps, robots, or other components as required to support the program. These structural loads may require extensive structural support above the ceiling. These rooms often utilize vertical laminar airflow, dedicating much of the ceiling to supply air diffusers (often HEPA-filtered) which deliver unidirectional airflow around the surgical field to reduce the likelihood of contamination. Low sidewall exhaust grills are placed around the room to promote uniform airflow and eliminate areas of stagnant airflow. Some facilities may require horizontal laminar flow, where the supply air is delivered by HEPA-filtered diffusers across one wall of the room and the exhaust air is removed on the opposite wall. Either approach will significantly impact room design; regardless, veterinary ORs should be designed to maintain 2.5 Pa positive pressure to adjacent spaces.

ORs should be sized to accommodate the potential largest animal and the most equipment and personnel-demanding procedure. The number of doors should be minimized using bidirectional flow into the Scrub Room and unidirectional flow from the Surgical Prep and Recovery Rooms. All doors must be automatically closing and configured for hands-free operation. ORs where animal dentistry is performed pose a heightened risk of aerosolization of infectious particles and require additional engineering and administrative controls to reduce exposure to pathogens, saliva, blood, and bacteria-laden debris. Similar risks exist for resuscitation activities that may occur in Recovery.

ORs are classified as "wet locations" and protected by either isolated ground or ground fault circuit interrupters as well as by wet location-listed in-service covers (not weatherproof covers, which only protect unused electrical receptacles). Facility design should provide ample electrical and data receptacles around the room and on ceiling-mounted columns (where provided). Surgical tables may also require power for heating and lifting systems.

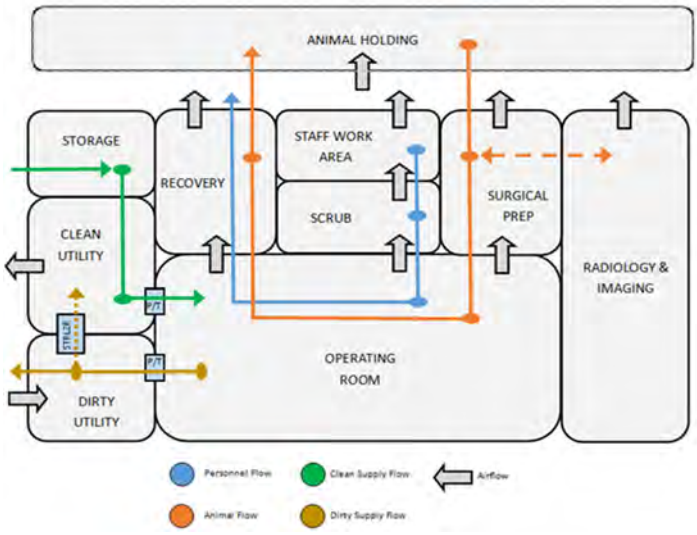

Figure 1: *Diagram of various flows through a veterinary OR*

Small Animal Operating Rooms: Small animal surgeries may be performed within procedure rooms; however, dedicated small animal surgical rooms are preferred, with downdraft tables to contain aerosols and anesthetic gas. In such cases, an entry anteroom should be considered to allow for positive pressurization of the surgical area without expelling suite air into the corridor.

Conclusion: The veterinary surgical suite is a complex facility that, regardless of facility program, must make every effort to minimize the risk of infection and the amount of time animals must be kept under anesthesia, the latter of which is directly correlated with minimized transport distances. Efficient, unidirectional flows of soiled utilities both reduce infection risk and the turnover time between surgeries.

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Veterinary Surgical Suites, Part-I

The veterinary surgical suite is a critical component of an animal research program. This suite may consist of one or more operating rooms and their support spaces, all designed and operated with the intent to maximize the effectiveness of the infection control program. Surgical suites require stringent sanitation and decontamination, which are executed by Standard Operating Procedure (SOP) on a regular basis and as needed to remove and neutralize pathogens. The materials of construction and detailing must be resistant to degradation from regular exposure to harsh cleaning and sanitizing chemicals. Personnel are a major source of microbial organism load, so reduction of personnel movement should be integral to the design; this can be achieved by including elements like intercoms, pass-through chambers, interior glazing, etc. The focus of this article series is on the relatively uncommon large animal surgical suite, which allows for a fuller exploration of the issues and best practices of this use type, but also includes commentary on the more typical procedure rooms where small animal surgeries are performed on downdraft tables or in biological safety cabinets (BSC)s.

Design Around Workflows: The surgical suite is designed around a workflow that maximizes unidirectionality of animals and staff from clean to dirty spaces, including:

Personnel Flow: Personnel enter the Operating Room (OR) via the Scrub Room, where they don clean surgical scrubs, bouffant, mask, and booties (and/or dedicated OR plant shoes, depending on facility SOP). Immediately outside the OR, provide a scrub sink for personnel to appropriately scrub their hands and arms prior to aseptic gowning and gloving (an SOP-specified handwash dispenser shall be provided in this area, as required). Provide a door from the Scrub Room directly into the OR that is configured for hands-free operation. In small animal operating rooms (often dual-function procedure rooms provided with downdraft tables or BSCs), the scrub area may be a vestibule connected to the OR (where allowed by regulation), but in such cases the space must be negatively pressurized to ensure particles released by gowning and scrubbing are exhausted, thereby minimizing the risk of migration toward the operating table.

Animal Flow: This flow is generally from the Animal Holding Room to a Surgical Prep Room immediately adjacent to the OR. The OR, Prep, and Recovery rooms must be sized and configured to accommodate the largest anticipated animal in the facility. The Prep Room must be designed to facilitate anesthetizing, clipping the body part where the surgical incision will be made, and performing rough prep. Proximity to diagnostic imaging is often necessary for preoperative imaging (common), though in some programs interoperative (rare) and postoperative imaging (common) are also required. Transport time and distance between support spaces should be minimized to reduce the risk of infection and the amount of time animals spend under anesthesia. In large animal OR suites, a postoperative Recovery Room should be provided with space and cages sufficient for the size, type, and number of animals. The Recovery Room should be staffed or located near where monitoring staff are stationed and should be designed to accommodate emergency care supplies and equipment, including anesthesia equipment, to respond to any postoperative complications.

Material and Equipment Flows: These flows should be segregated from the OR to the extent practicable. In a large animal OR, the Clean Utility Room should abut the OR and be connected to it by an active pass-through chamber. The Clean Utility Room should be stainless steel, with glass-fronted storage to support kitting equipment and materials needed for the surgery, which are put into the pass-through chamber where staff in the OR will retrieve it both pre- and intraoperatively. Post-surgery, tools and other reusable surgical equipment are sent to the Dirty Utility Room for cleaning and wrapping before being processed through a pass-through sterilizer into the Clean Utility Room for storage. In small animal ORs, the surgical supply functions may be co-located within.

This discussion of veterinary surgical suite design considerations will continue next month with the conclusion of this article.

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Understanding Nanotechnology & Nano Facilities

Nanotechnology is the science, engineering, and technology of functional systems that can be observed, conducted, and controlled at the molecular scale. The nanotechnology field is responsible for continued groundbreaking advancements in medicine; its impact on human health extends from prevention to diagnosis and treatment of diseases. Uses include nanoparticles for chemotherapy via nanocarriers, which focus on targeting cancerous cells and thereby reduce harm to healthy cells.

Advancements in nanotechnology have been accompanied by advancements in nano facility architecture. This is typically demonstrated in new construction, such as MIT's MIT. Nano building, which departs from standard nano facility design by incorporating above ground structures, expansive glass facades, natural light, and views into work areas. Regardless of other design choices, all nano facilities should adhere to a base set of requirements that accommodate the health, safety, and functional requirements associated with nano research.

Pre-Design

Prior to design, a risk assessment should be performed to ensure the success of the project and determine the degree of stringency required. Identifying the objectives, budget, and equipment requirements will aid in understanding the limitations of the facility and its ability to accommodate existing nano lab research and future technology.

General Design Criteria

General design criteria for nanotechnology lab space require the use of environmental control systems and the minimization of ground-borne vibrations from HVAC equipment, construction, and elevators. Additional facility design considerations include structural isolation from the main building, restricted access, air handling, regulated temperature, humidity control, and reduced particle concentration via air filtration. Site planning considerations include locating nano facilities far from high-voltage transformers, electrical power lines, roads, railway traffic, and parking lots to minimize ground-borne vibrations.

Specific Design Criteria

Specific design criteria for nano labs include non-recirculating ventilation systems with 100% exhaust air and ventilation rates of 6-12 air changes per hour. Lab pressurization should be negative to the hallway. Safety showers, eyewash stations, and other means of emergency irrigation must be accessible within the area where the work is to be performed. Offices and general-purpose workstations should not be located inside laboratories that handle nanomaterials. Additional specific design criteria for nano facilities include the following:

Storage. The primary storage location for a chemical is determined by the hazards of the material. Chemical incompatibility and chemical instability must be determined to ensure proper storage procedures.

Hazard Controls. While the health risks from exposure to nano particles are not known, standard laboratory practices regarding the use of hazardous chemicals and gases must be followed. Safety, work practice, and equipment controls must be adhered to when handling nano particles.

Chemical Fume Hood. Activities that are likely to release nano particles should not be performed in open work areas; a fume hood may therefore be required.

Furnace Exhaust. Exhaust from all furnaces used to produce nano particles must be trapped and ducted out of the room.

Vacuum Protection. Mechanical vacuum pumps must be protected using cold traps. The pump exhaust must be vented into an approved exhaust duct or chemical fume hood.

Conclusion

This article outlines several general planning fundamentals and specific design guidelines for nano lab facilities. Continued research is necessary to fully understand the benefits of nanotechnology and its role in healthcare.

Further Reading

NIH 2019 DRM Appendix O.2 Specialty Labs – Electron Microscopes and Nanotechnology

Nanotechnology- Big Things from a Tiny World

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/E's and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'. **Please address questions or comments to:** shawm@nih.gov

Further details on this month's topic are available on the DRM website DRM Chapter 2, Planning and Programming
https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx

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Design Requirements Manual **News to Use**

May 2021

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The formulae $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_j U_i)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ for building $\frac{\partial}{\partial x_j}(\rho\overline{U}_j\overline{U}_i)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U}_i}{\partial x_j}-\rho\overline{u_i'u_j'}\right)+g_i(\rho-\rho_0)$ state of the art $\frac{\partial}{\partial x_i}(\rho\overline{U}_i\overline{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial\overline{T}}{\partial x_i}-\rho\overline{u_i'h'}\right)$ biomedical research facilities.

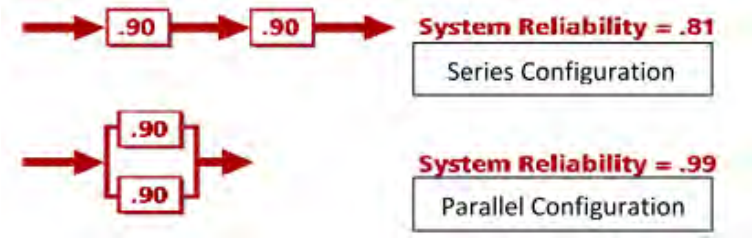
Reliability in Mechanical Systems Design

Mechanical reliability emphasizes the ability of a system or component to function without failure, under specified conditions, and for a specified time period. The Design Requirements Manual (DRM) addresses reliability in various chapters, as an entire system's failure can occur from a system component up to a utility service failure or interruption.

Definition and General Methodology

Failure rate is the frequency at which an engineered system or component fails; it is expressed in failures per unit of time. In any given system, overall reliability can be determined by reviewing the reliability of the system's components. This process requires generating reliability block diagrams using the reliability configuration of each component. These system components can be configured either in a series or in parallel.

Example 1 shows reliability block diagrams, one with a series configuration and another with a parallel configuration. In the series configuration, each component has a 0.90 reliability (90%) and the system reliability is estimated to be 0.81 or 81% using the equation $Rs=R_{C1}xR_{C2}$. When using a parallel configuration with the same component reliability, the system has a reliability of 0.99 or 99%, based on $Rs=1-(1-R_{C1})\ x\ (1-R_{C2})$, assuming both configurations have the same operational time period. The failure rate may not remain constant over the operational lifecycle of a system due to the number of components that may fail.



Example 1: Reliability block diagrams

There are various methods to estimate and create reliable mechanical systems which can be applied at a component or system level. For example, using better materials and advanced lubricants allows for improved system component reliability, and diversity or redundancy can reduce system failure for safety and critical systems.

Although redundancy can minimize single points of system failure, it may require serious consideration of factors such as cost-benefit return, also known as return on investment (ROI), and potential system service interruptions due to extended maintenance periods, which can negatively impact cutting-edge animal research facilities as well as the overall safety of NIH operations. Section 1.15 of the DRM states the above and expands on other requirements.

Design Requirements

There are several basic criteria that shall be maintained when designing reliable systems at NIH:

- The designer must consult with all stakeholders to determine the value of uninterrupted operations. This decision is the result of risk assessment and can vary from laboratory to laboratory at NIH, depending on the types of research conducted in the laboratory.
- Designers must establish a baseline of reliability requirements with all stakeholders to better understand the systems that require high reliability considerations.
- The budget/cost for implementing the required level of reliability must be established early on and based on risk assessment.
- The designer shall select system equipment with high reliability, quality, and durability. This may include equipment replication or redundancy.
- A required maintenance plan must be established to ensure reliable and safe system operation, assisted by the Building Automation system (BAS). For example, the BAS can notify personnel of a system component failure and enact an automatic switch to a redundant component to keep the system functional. See Chapter 7 of the DRM.

Additional Design Requirements and Considerations

Certain systems and facilities will require considering additional parameters to ensure maximum mechanical reliability. Per Section 6.1.2 of the DRM, HVAC systems require operational flexibility, adaptability, scalability (allowance for future program renovation and expansion), and serviceability, including the ability to perform routine maintenance due to single point failure. The DRM addresses the higher level of reliability design considerations necessary for designing Level 3 Biosafety Laboratory (BSL) and Animal Biosafety Laboratory (ABSL) in Chapters 6 through 12, and Chapter 13 covers reliability requirements for Aseptic Production Facilities (APFs).

Conclusion

The reliability engineer must apply an analysis method that best represents the expected systems failure for each component type and application. It is also important to keep in mind that the DRM requirements for reliability must be coordinated with the stakeholder for each given project. Adequate methodology must be applied when the reliability estimate does not accurately reflect the required system's operation.

Resources

NIH Design Requirements Manual (DRM) Revision 1.5: 03/26/2020
RBDs and Analytical System Reliability, Chapter 3
http://reliawiki.org/index.php/RBDs_and_Analytical_System_Reliability

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Further details on this month's topic are available on the DRM website DRM Chapter 6 Mechanical
https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx

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Design Requirements Manual **News to Use**

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Sealant Joints – Part 3: Quality Execution Performance

The last two months' News to Use articles covered sealant joint selection and detailing for 100% silicone (ASTM C920), referred to as JS-2 in the DRM. This month's article covers the best practices for ensuring quality joint design and execution. Sealant joints are critical because of the integral role they play in creating durable, joint-filling, and gap sealing conditions, but they are only as good as their installation. Quality execution is essential because the best materials and detailing cannot overcome deficiencies in preparation and execution of the joints.

Designers should develop a Sealant Execution Plan (SEP) that details the sealant joint design requirements, including:

- Sealant joint details
- Materials Of Construction (MOC), including material selection criteria
- Minimum qualifications for the installers, supervisors, and internal Quality Assurance personnel
- Inspection procedures and acceptance criteria for each sealant joint type

The SEP shall reflect the manufacturer's recommended and required procedures to ensure conformance with their warranty requirements. Other best practices include thoroughly documenting the preparation of multi-part sealants and ensuring substrates are adequately prepared (clean, dry, and free of mark at minimum, along with any requirements in the manufacturer's literature) before sealant application.

When executing a sealant joint, there are also several practices to avoid:

- Do not apply sealant in an area where significant particulates, or particulate generating processes, will be present for 48 hours after installation to allow for adequate skinning and curing of the sealant without adhered contaminants.
- Do not feather (or "smear") sealant to zero-thickness along the edges of the joint. Inadequate sealant thickness will result in peeling, pilling, and shedding of sealant material over time. In Aseptic Processing Facilities (APFs), this type of failure is a significant source of non-viable particles, which threaten the purity of the products being produced and the health and safety of patients.
- Do not use a finger or cloth wipe to shape the sealant joint. This approach, though common, results in uneven appearance, pinholes, inadequate joint compression, inadequate adhesion, and feathering – all of which contribute to accelerated joint failure.
- Do not use saliva or soapy water as tooling lubricants. Tooling lubricants should be avoided, but if required, must be the sealant manufacturer's recommended product for the application.
- Do not use application nozzles which are significantly smaller than the surface of the joint profile or cut at less than 90-degrees. Proper nozzle size and shape minimizes sealant waste and ensures adequate fill and compaction of sealant into the depth of the joint.
- Do not leave any bond breakers, backing rods, gaskets, or similar material exposed through the finished joint.
- Do not use a sealant that is incompatible with the substrates being joined. The sealant must be non-reactive and non-staining while developing adequate adhesion, and must possess the necessary elongation, flexibility, and resistance to degradation from cleaning materials and methods.
- Do not expose sealant joints in an APF environment more than 3/4" (19.5 mm) wide. Provide 316 stainless steel flashing or an escutcheon to minimize the exposed sealant area within the APF environment.

Conclusion

This series of News to Use articles has presented the importance of properly selecting, detailing, and assuring the quality installation of sealant joints in biomedical facilities; this guidance is especially applicable to APFs, but can also be applied to animal and high containment facilities. It is incumbent on the designer, construction contractor, and inspectors to be aware of and follow both ASTM and manufacturer's requirements to achieve quality installations.

Additional Information

ASTM C794 Standard Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants
ASTM C920 *Standard Specification for Elastomeric Joint Sealants*
ASTM C 1193 *Standard Guide for Use of Joint Sealants*

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Further details on this month's topic are available on the DRM website DRM Appendix-L Sealant Table
https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx

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Design Requirements Manual **News to Use**

March 2021

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Sealant Joints – Part 2: Joint Design

Last month's News to Use covered Part 1 of sealant joint design for 100% silicone (ASTM C920), referred to as JS-2 in the DRM, and was focused on sealant properties. This month's article delves deeper into joint design considerations. Joint design and installation must be in strict conformance with the manufacturer's written instructions and technical guidance; the best materials of construction (MOC) and perfect application technique cannot overcome poor joint design. The design directly impacts the flexibility, durability, and adhesion of the completed joint. Joint conditions include:

Flat Joint: A joint where substrates are coplanar and either abutting or gapped (see Image 1). Coplanar abutting joints should be avoided in design and detailing as there is inadequate accommodation for a sealant joint; other joining types may be appropriate in this condition. Coplanar gapped joints should have a closed-cell backer rod / bond breaker installed to ensure that the sealant only adheres to two sides of this three-sided joint. The ratio of the width of the joint to the setback of the backer rod should be 2:1, but the maximum setback should not exceed 3/8" (10 mm). The width of the joint shall not exceed the manufacturer's recommended limit for the sealant material. The sealant joint should be installed smooth and continuous to room-side edges of the adjoining surfaces and tooled flush to slightly concave.

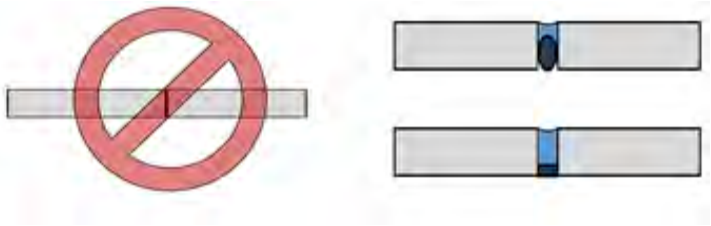

Image 1: Flat joints – abutting (left) and gapped (right)

Inside Corner Joint: Where substrates are abutting and no-to-minimal joint movement is anticipated, provide bond breaker tape in the corner extending no less than 1/4" (6 mm) out from the corner in BOTH directions (see Image 2). The sealant joint shall fully embed the bond breaker tape, extending 1/4" (6 mm) to 3/8" (10 mm) beyond the end of the tape in both directions. The sealant joint should be tooled concave, leaving a smooth, continuous joint.

Where minor to moderate joint movement is anticipated, gap the substrates 1/4" (6 mm) to 3/8" (10 mm) and provide a closed-cell backer rod to fill the gap, leaving half of the rod proud of the surface (see Image 2). The sealant joint should be tooled concave, leaving a smooth, continuous joint that provides between 1/4" (6 mm) to 3/8" (10 mm) of cover above the backer rod. The sides of the joint should be equal and not less than 1/4" (6 mm) from the inside of the corner.

Where moderate joint movement is anticipated, gap the substrates as required to ensure adequate structural movement and provide a closed-cell backer rod to fill the gap, leaving the rod between 1/4" (6 mm) to 3/8" (10 mm) below the surface of the joint. The sealant joint should be tooled concave, leaving a smooth, continuous joint that provides between 1/4" (6 mm) to 3/8" (10 mm) cover above the top of the backer rod to the inside of the concave surface. The joint should NOT be symmetrical in this case, tapering to flush on one side and extending between 1/4" (6 mm) to 3/8" (10 mm) up the other side.

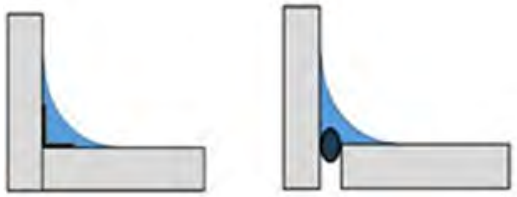

Image 2: Tight inside corner joints

Where joint width is greater than 3/4" (19.5 mm), provide a flashing to reduce the exposed width of the joint (stainless steel is preferred; see Image 3). The flashing must be designed accommodate the anticipated movement in the joint, and often must also be designed to be removable to facilitate any necessary maintenance.

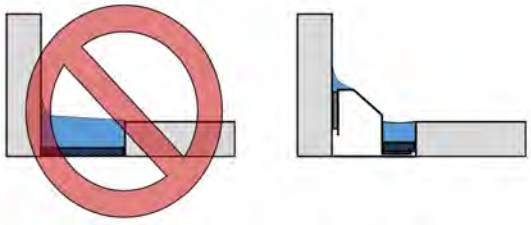

Image 3: Wide inside corner joints

Additional Information

ASTM C794 Standard Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants

ASTM C920 *Standard Specification for Elastomeric Joint Sealants*

ASTM C 1193 *Standard Guide for Use of Joint Sealants*

Next Month this series will continue with the article Sealant Joints - Part 3: Execution Quality Assurance.

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Further details on this month's topic are available on the DRM website DRM Appendix-L Sealant Table
https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx

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Design Requirements Manual **News to Use**

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Sealant Joints – Part 1: Sealant Properties

In construction, sealants are used to join and fill the gaps between materials to prevent the passage of energy, such as sound, and substances, such as liquids, air, pests, dust, smoke, etc., while mitigating the tendency for joints to accumulate soiling. The most ubiquitous sealant in biomedical facility construction is 100% silicone (ASTM C920), referred to in the DRM as JS-2 in both the Appendix-L Sealant table and the CH-13 Exhibit 13.6 Sealant Table for Aseptic Processing Facilities. This article will focus on the design of JS-2 joints.

Sealant Properties

The following sealant properties must be considered when selecting a sealant for an application:

- **Movement:** When joining materials, the designer must account for the anticipated differential movement of the surfaces being joined. Movement tolerance is expressed as a percentage of the joint width, per ASTM C920 Standard Specification for Elastomeric Joint Sealants.

- **Flexibility:** This characteristic describes the joint movement capacity of the sealant as well as the hardness of the material after it has cured. The selected sealant should be classified Non-Sag (NS), which means it is appropriate for both vertical and horizontal applications. It should be noted that, although low and medium modulus sealants are better at accommodating cyclic movement because they create lower stress at the sealant bond line, they are more susceptible to chemical damage, while high modulus sealants (Class 12-25) are generally more resistant to such damage.

- **Adhesion:** Sealant joint failures in the biomedical facility environment are frequently due to adhesion failures between the sealant and one or more of the substrates being joined. Adhesion failures are correlated to several factors, including poor Material Of Construction (MOC) selection, joint design, and execution (especially failure to adequately prepare the surfaces being joined).

- **Type:** Type-S (single-component) sealants are generally easier to use than Type-M (multi-component), although they tend to have longer cure times and higher unit cost. Type-M sealants are typically faster-curing and often have better durability, flexibility, and adhesion properties than Type-S, but introduce quality control concerns related to their preparation and frequently shorter installation working times. There is also an elevated risk of unacceptable variation in the field preparation of Type-M sealants, compared with Type-S.

- **Durability:** Generally, the durability considerations for sealants include their ability to withstand UV (which is seldom an issue for silicones as the energy required to break silicon-oxygen bonds is higher than that afforded by sunlight), heat, aging, cracking, chalking, and discoloration. Use in biomedical facilities, however, adds chemical resistance requirements, including exposure to oxidizers, such as hydrogen peroxide and peracetic acid.

- **Aesthetic vs Inspectability:** The sealant should be aesthetically compatible with the abutting materials being joined. However, it is even more important to select a sealant that promotes inspection of the joint both at installation and periodically throughout its service life to detect failure early in its progression and initiate repair or replacement. Clear sealants are difficult to inspect for cracks, holidays, and pinholes, so their use should be limited to glass to glass joints and glass/mirror to stainless steel joints. Opaque sealants are easier to inspect and should generally be white, except for stainless steel to stainless steel joints which should be gray, aluminum, or a similar color, depending on the manufacturer's naming convention. Other color options exist but should be similarly evaluated.

- **Other Considerations:** All sealant joints have a design life that is impacted by sealant joint MOC (including the substrate materials), sealant joint design, installation methods, and environmental exposure.

Additional Information

ASTM C794 Standard Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants
ASTM C920 *Standard Specification for Elastomeric Joint Sealants*
ASTM C 1193 *Standard Guide for Use of Joint Sealants*

Next Month This is the first article of a 3-part Sealant Joint series, which will be followed by Part 2: Joint Design and Part 3: Quality Execution Performance.

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https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx

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Design Requirements Manual **News to Use**

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The formulae $\frac{\partial \rho \bar{U}_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ for building $\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}-\rho \overline{u_i' u_j'}\right)+g_i(\rho-\rho_0)$ state of the art $\frac{\partial}{\partial x_i}(\rho \bar{U} \bar{H})=\frac{\partial}{\partial x_i}\left(\lambda \frac{\partial \bar{T}}{\partial x_i}-\rho \overline{u_i' h'}\right)$ biomedical research facilities.

Light Control for Laboratory Glazing

A welcome trend in laboratory design is increased use of interior and exterior glazing, especially in spaces formerly considered 'back-of-house' which are relegated to basements or deep within floorplans. There are many reasons to use glazing in any regularly occupied space, including:

- The benefits of natural light and views on human physiology and psychology
- Credits awarded by green and healthy building certification programs for direct and indirect access to natural light
- Less artificial lighting usage
- Improved work environment for staff
- Increased security and control, in the form of observation and situational awareness
- Increased transparency and a sense of openness where literal openness is not possible

However, increased glazing also leads to increased issues of light level control. The selection and use of control devices on glazing is therefore key to successful glazing implementation.

The Necessity of Light Control in Laboratories

Although an abundance of natural light is usually beneficial, too much can cause problems. Light levels, along with other environmental parameters, must be controlled for a laboratory to perform optimally.

Specific issues related to excessive light levels include:

Glare. Direct sunlight can cause glare, which can make computers and instrumentation unreadable.

Comfort. Excessive light may be physically uncomfortable. An important aspect of comfort is the ability to adjust one's workplace environment, including light levels, ergonomics, and temperature, to optimal conditions for an individual's comfort.

Function. Low light levels may be required for reading films and other detailed tasks. Imaging and optics rooms may require near or total black-out conditions during operations.

Flexibility. Rooms may serve multiple purposes and must be able to accommodate varying light conditions depending on the planned activity.

Privacy. Although the aesthetics of openness are generally desired, there are times when visual privacy is necessary for an office or conference room. Labs also may generally desire openness but require privacy during sensitive procedures.

Glazing Light Control Devices

Unlike temperature or humidity, light from glazing cannot be programmed, and unlike artificial lighting it cannot be dimmed or turned off. Laboratory glazing must be accompanied by appropriate light control devices. Common devices allowing control and adjustability include:

- Standard horizontal blinds. These are economical and widely adjustable, but they are not light-tight, and their dust-collecting horizontal surfaces are not appropriate in many types of clinical or controlled environments.
- Between-the-glass horizontal blinds. These solve the issue of horizontal surfaces and can be used in many clinical and controlled applications.
- Roller shades. These are available with a range of features, including light-tight and non-absorbent fabrics.
- Electrochromic glass (a.k.a. smart glass or dynamic glass). These provide a range of opacities and colors.

In addition to the type of control device, it is important to consider the method of operation (manual vs. automatic). Manual control provides occupants with direct and immediate control over their environment. Automatic control, operated by the building automation system, allows devices to be adjusted relative to various factors, such as the time of day or position of the sun, to minimize solar heat gain and reduce artificial lighting usage for optimal energy efficiency.

Fixed devices that do not allow adjustability include light shelves, sunshades, films, and tinted glass.

Conclusion

The increased use of interior and exterior glazing brings many advantages and is a positive trend in lab design. Increased glazing introduces light, however, which as an environmental aspect must be addressed during the design process. If excessive light is a concern, glazing can be reduced or eliminated, but a better approach is to manage the light with appropriate control devices.

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Further details on this month's topic are available on the DRM website DRM Section 4.2, Doors
https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx