The National Institutes of Health | Division of Technical Resources | Office of Research Facilities

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* $\frac{\partial}{\partial x_i}(\rho \bar{U}_i \bar{H})=\frac{\partial}{\partial x_i}\left(\lambda \frac{\partial \bar{T}}{\partial x_i}-\rho \overline{u_i' h'}\right)$ *biomedical research facilities.*

Leaching Biocides and Antimicrobials in Architectural Finishes

Covid's emergence in early 2020 added unfamiliar terms which had previously only found use in infection-control settings, such as "high-touch surfaces," to the broader lexicon. In response, the construction industry exploded with new and newly purposed architectural surfaces with a focus on infection control, specifically via indirect transmission mechanisms (e.g., touching surfaces previously touched by an infected person, potentially transferring viable pathogens). This article explores how the misapplication of certain architectural finish selections which tout biocidal and anti-microbial properties may have unintended effects.

Antimicrobial Architectural Finishes

These surfaces exhibit properties which inhibit the growth of microorganisms (some molds, fungi, bacteria, viruses, etc.). They work by having a material or coating that is toxic to microorganisms; adsorbing a peptide or polymer to the surface of a microorganism, changing its structure and ion exchange behavior; or utilizing a mechanism such as oxidative properties which tend to disrupt the cellular membranes of certain pathogenic organisms, inhibit nutrient uptake, or even rupture these membranes to render the microorganism inert. Other mechanisms exist and are exploited by various materials on the market.

Most antimicrobial agents can be sorted into two basic groups: unbound (where the antimicrobial agent is applied as a sanitizing wash or comprises a leaching coating); and bound (where the antimicrobial agent is molecularly bonded to the surface)[2].

Unbound Agents: include disinfecting washes, such as isopropyl alcohol, ethyl alcohol, quaternary ammonium (or quats), hydrogen peroxide, etc., as well as leaching materials/coatings, including certain heavy metal ions (frequently silver, copper, titanium dioxide, etc.). Unbound agents leach from the surface they are applied to, creating a zone of microbiological inhibition, and are metabolized by the microorganisms, rendering them inert.

There are several potential unintended consequences with leaching agents, including mobility, which is the transfer of the area of microbiological inhibition from the targeted surface to another through physical contact (these agents are frequently applied to high-touch surfaces, increasing the likelihood of unintentional transfer). Agent mobility is unlikely to have a negative impact in a patient care room, but in a laboratory studying the efficacy of a novel antibiotic, the science could be impacted by the unintended transfer of materials with antibiotic properties, potentially contaminating samples being studied. Another concern is that, as the antimicrobial agent is leached from the surface, the efficacy of that surface to impair microbial activity declines over time, on a scale of minutes to hours in the case of washes.[2,3]

Declining efficacy can contribute to emerging resistance to what was once an effective dose. As leaching progresses, there is less and less available biocidal agent available on the surface until the effectiveness of the available agent falls below the threshold needed to achieve the desired log kill of a pathogen. At this point, the available biocidal level may remain effective against weaker strains of this

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pathogen and other microorganisms in the environment. However, this promotes the growth and proliferation of microorganisms that are resistant to the agent at higher levels of the biocide and may result in increasingly difficult-to-control colonies. In the worst case, it may make infections of this microorganism more difficult to treat (MRSA and similar).

Bound Agents: include surfaces where the biocidal properties are chemically bonded to or suffused through the material. Unlike unbound agents, these materials may remain effective over considerable timelines (until worn away, subjected to oxidation/reduction, photodegradation, etc.) and achieve their biocidal effects by impacting the physical integrity of the microorganism. While bound agents are much more reliable, with minimal transfer potential, they are still subject to degradation. Few architectural finish surfaces are sampled, incubated, and tested to surveil for declining efficacy, which would necessitate replacement or initiation of or increase in the use of unbound agents as washes to maintain acceptably low pathogen levels. Failure to enroll high risk surfaces in a surveillance and replacement program may create a false sense of security that these surfaces are continuing to inhibit microbial growth.[1,2]

Conclusion

The use of antimicrobial and biocidal architectural finishes will likely continue to proliferate. Designers and reviewers should be aware that silver, copper, zinc, chitosan, and quaternary ammonium compounds (the most typical bound agents) have a limited effective lifespan. There is no substitute for an application cleaning and disinfection program, despite the marketing claims often associated with antimicrobial finishes. In applications such as high containment laboratories, aseptic processing facilities, operatories, etc., where aggressive sanitizing chemicals (e.g., peracetic acid, high molarity hydrogen peroxide, etc.)[1] are used regularly, unbound agents will likely degrade rapidly. A final cautionary note is that designers should scrutinize products made of materials, such as copper, which are reasonably touted for their biocidal properties but which are coated with urethanes or other coatings to prevent their oxidation, which effectively encapsulates them and renders the base material properties ineffective.

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Design Requirements Manual (DRM) Update

The first edition of the document that evolved into the *DRM* was published in 1996 as the *NIH Design Policies and Guidelines*. Since then, it has undergone many updates to stay relevant and current as the leading source of information for the planning, design, and construction of state-of-the-art biomedical research facilities.

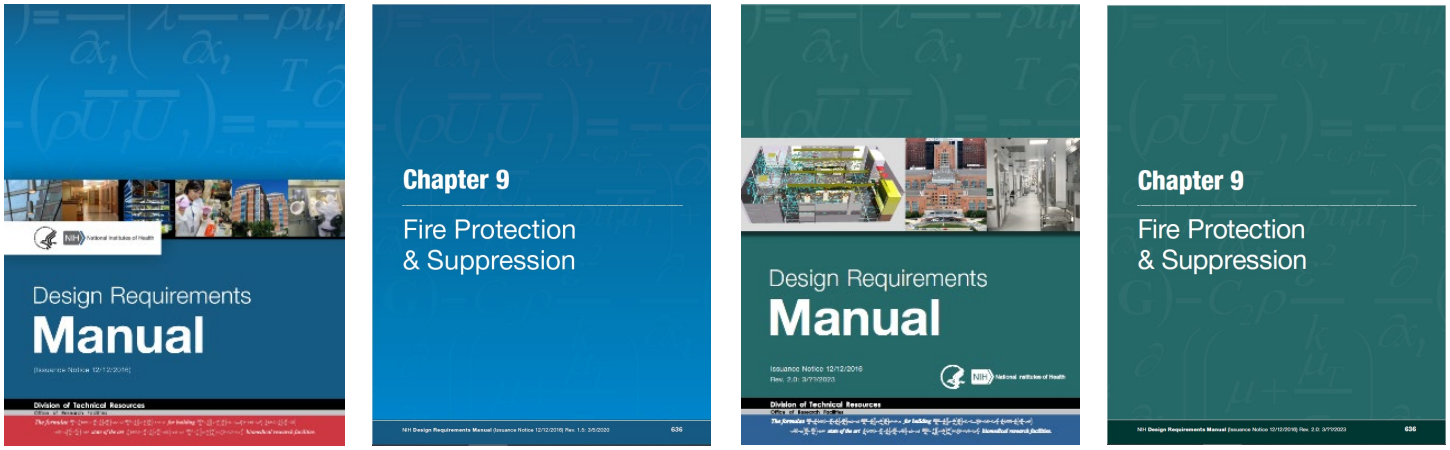
The last comprehensive revised edition was published in 2016, and since that time, numerous focused revisions have kept it up to date. The current edition of the document is Rev. 1.5. However, in response to developments in in the industry, the Division of Technical Resources has been working on the latest comprehensive edition, which will be published chapter-by-chapter as each chapter is completed to release the information as quickly as possible.

On March 12th, the 2024 edition of the *DRM* was launched with the publication of the following revised chapters: "Chapter 3: Civil Engineering and Site Development," "Chapter 5: Structural Design," and "Chapter 9: Fire Protection & Suppression." All other chapters and appendices will remain unchanged until they are revised in turn. This edition will be denoted as *DRM* Rev. 2.0, and subsequent versions will be denoted as 2.1, 2.2. 2.3, etc. as additional revised chapters and appendices are published. To distinguish new content, the *DRM* cover and the covers of all revised chapters and appendices will be green, as opposed to the blue covers in Rev. 1.5 and previous.

A special "News to Use" update will be distributed to announce each publication update, both to spread news of publication and, if a chapter has undergone significant changes, to review these changes and their rationale.

The *DRM* has always been a living document, enhanced by frequent updates and revisions. When used as a reference document for a design project, it is important to acknowledge which version is in force. It is recommended that project team members (Project Officers, A/Es, and consultants) download the current version of the *DRM* on the date of award and reference that version for the duration of the project. It is important to note the version being referenced in the Basis of Design and the Construction Documents.

We look forward to supporting NIH and the international community as a reliable resource for best practices in biomedical facility design. If you have any questions about the *DRM*, please email DRM@nih.gov or contact communications editor Nika Lilley at nika.lilley@nih.gov.



Left: Old DRM Rev. 1.5 manual and chapter covers, in blue; right: New DRM Rev 2.0 manual and chapter covers, in green

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Stormwater Management

Stormwater management is the process of managing the rainfall that strikes an impervious area, such as a building or road, or a pervious area that is saturated from previous stormwater events. Stormwater management uses various methods aimed at controlling and mitigating the adverse impacts of stormwater runoff on the environment. Best Management Practices (BMPs) help manage stormwater runoff effectively and can prevent pollution, flooding, and erosion. This article explores some stormwater management techniques used to address diverse environmental challenges.

Detention Basins

Detention basins temporarily store stormwater runoff, reducing peak flow rates and minimizing the risk of downstream flooding. They then return to their normal dry state, allowing stored stormwater to gradually flow out through an outlet that controls the rate of discharge, mimicking natural drainage patterns. These are commonly used as part of a comprehensive stormwater management strategy. Because they are normally dry, they do not present the risks associated with stagnant water, but they do require periodic maintenance, such as mowing and trash removal.

Retention Basins

Retention basins are designed to permanently retain a certain level of stormwater and to temporarily detain additional capacity immediately following a storm event. This mitigates the immediate discharge of excess stormwater from the site, reducing the immediate demand on the local storm sewer pipe system and natural hydrologic features and thereby reducing the likelihood of downstream flooding. Retention basins can be designed to be aesthetically pleasing and are often combined with recreational features while still contributing significantly to improving water quality. These basins generally require maintenance programs to prevent them from becoming public health risks.

Bioretention Basins

Bioretention basins (including rain gardens and engineered wetlands) utilize specifically selected plants and engineered soils to filter pollutants from stormwater, which improves water quality. The vegetation helps reduce the urban heat island effect, enhancing local climate resilience and improving the overall quality of the environment. Moreover, these basins capture excess runoff, improving groundwater recharge. They can be easily integrated into landscape designs.

Bioretention basin infrastructure can be challenging to implement on a scale necessary to manage stormwater effectively in areas with space constraints. Regular maintenance, including pruning, weeding, and sediment removal, is necessary to sustaining these basins and ensure their effectiveness. The initial costs associated with designing and installing green infrastructure can be higher compared to conventional engineered stormwater management approaches.

Permeable Pavements

Permeable pavements allow stormwater to infiltrate through the surface, reducing runoff volume and promoting groundwater recharge. The permeable surface filters pollutants, such as oil and sediments, thereby improving water quality. Permeable pavements also help reduce surface temperatures and enhance overall microclimate conditions. However, they are not suitable for areas requiring higher load-bearing capacity and are often combined with more robust paving systems for driving and turning areas. Permeable pavements alone are generally utilized in passenger vehicle parking areas, walkways, and similar spaces. The freeze-thaw cycles in cold climates may damage the pavement, though changes in the mixture design and subsurface drainage detailing are currently being studied to allow more widespread use in areas that see more freeze-thaw cycles throughout the year. These pavements require regular maintenance, including regular flushing and vacuuming, or they can become clogged with debris, reducing their percolation rate over time.

Conclusion

Successful implementation and management of a stormwater program demands a clear understanding of stormwater management BMPs, site characteristics, local hydrology, landscape, regulatory compliance, and long-term maintenance. Stormwater management BMPs offer many advantages in improving water quality, ground water recharge, and flood prevention. However, they also come with some limitations. These limitations can be managed with early community engagement and proper monitoring and adaptation.

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Guidance on Bird-Safe Glazing for New Construction

Large windows allow people to connect with the natural world, contributing to human wellness. An unintended consequence of using large windows in building design has been that, during the daytime, the reflectivity or the transparency of glass can mirror the adjacent landscape or provide a seemingly clear path to birds. In the U.S., it is estimated that nearly one billion birds per year die from collisions.[1] Between 1970 and 2014, collisions and other factors contributed to the net loss of 3 billion North American birds, or 29% of 1970's bird population.[2] Bird-strike reduction can be achieved through a variety of methods, including design choices such as utilizing glazing which deters birds.

Standards and Legislation

Government agencies and private organizations promote sustainable design policies and methods to preserve ecological stability by reducing bird strikes. The U.S. Fish and Wildlife Service Division of Migratory Bird Management provides a list of best practices.[3] In Congress, H.R. 1986 – Federal Bird Safe Buildings Act of 2021 seeks "to incorporate practices and strategies to reduce bird fatality resulting from collisions with certain public buildings."[4] The Council for the Conservation of Migratory Birds was created in 2009 to oversee the implementation of Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*, which requires "integrating bird conservation principles, measures, and practices into agency activities and by avoiding or minimizing, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions."[5]

The National Institutes of Health

The National Institutes of Health's (NIH) main campus is located in Bethesda, Maryland, with other regional field stations located in Baltimore, Frederick, and Poolesville. NIH participates in regional government initiatives. Within the mid-Atlantic region, New York,[6] Maryland,[7] and Washington, DC[8] have passed legislation to require the use of bird-safe glazing

The *Design Requirements Manual (DRM)* (Section 1.1.2.3) advises that "local government mandates…and other unique geographic design criteria are not specifically mentioned in the *DRM* because the design shall comply with state and local regulations in addition to *DRM* requirements."[9]

The upcoming Revision 2.1 of the *DRM* will address regional geographic design criteria in Section 4.1.4: Windows by requiring new construction of NIH building facades to be consistent with federal direction as follows: "Incorporate appropriate bird strike mitigation as recommended by the most recent version on the *U.S. Fish and Wildlife Service: Reducing Bird Collisions with Buildings and Building Glass Best Practices* and as required by state and local laws and ordinances." By incorporating these best practices, NIH can help reduce one of the leading causes of bird mortality while supporting the campus by reducing risks associated with animal remains.

Bird-safe glazing options continue to evolve. The American Bird Conservancy's *The Glass Collisions Products & Solutions Database*[10] lists options by deterrent type, manufacturer, and efficacy. Glazing selections include transparent, ultraviolet coatings, screen printing, fritted (patterned ceramic paint), frosted, and acid etching on glass.

Conclusion

Determining how best to mitigate bird strikes is a multi-faceted problem which is best addressed with landscape strategies and architectural features. Utilizing bird-safe glazing at areas of high reflectivity and transparency, such as at glass corners, courtyards, skyways, walkways, and glass railings, reduces the likelihood of bird strikes. New exterior glazing projects for NIH owned buildings should include a review of the U.S. Fish and Wildlife Service: *Reducing Bird Collisions with Buildings and Building Glass Best Practices* for appropriately designed and detailed glazing.

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Locker Room Design Considerations

Research facilities consist of labs and support spaces which follow strict safety requirements, including ones dictating the activities that can be conducted and the items that can be stored within. Eating, drinking, smoking, handling contact lenses, and applying cosmetics are not permitted in any NIH laboratory, per the *Biosafety in Microbiological and Biomedical Laboratories* (*BMBL*). The NIH *Design Requirements Manual* (*DRM*) indicates that wet laboratories require lockable storage for personal items. This necessitates lab personnel having storage lockers outside of the lab to secure their belongings or to change clothes prior to entering labs. The following overview highlights the primary factors to ensure that lab personnel have a safe and convenient place to secure their personal property.

Users and Storage Levels

When designing a locker room, consider who the primary users are, what type of labs or facilities they work in, and their storage requirements. These requirements should be determined through programming, including questionnaires and interviews with laboratory users, principal investigators, and other stakeholders. Afterwards, calculate how frequently the lockers will be used, which helps decide if the users will have assigned personal units (permanent) or day use units (temporary, non-designated).

At the most basic level, storage is required for coats, backpacks, purses, and other personal items. This type of storage is typically associated with BSL-2 labs and other functions where changing clothes is not required. Storage space can be small lockers in a corridor, entry alcove, locker room, or other convenient location. Finishes are non-lab grade and not critical.

When lab requirements include changing into protective clothing (i.e., scrubs, PPE, cleanroom gowns, etc.), a locker room is required with larger lockers, benches and mirrors, and provisions for privacy. These locker rooms may be co-located with restrooms, which require more durable and water-resistant finishes. These requirements are associated with BSL-3 labs, animal facilities, and cleanrooms and are designed as part of lab entry/exit sequence.

The highest performance and hazard labs may also require interlocked doors, water or air showers, one-way traffic, and other control and containment features. The design of these locker rooms and associated spaces must be integral with the facilities they serve, including finishes and systems.

Traffic Flow

The type and use of laboratory will dictate the traffic flow. Clean rooms, aseptic facilities, and other specialized labs may require a dedicated flow to control access and contamination.

All locker rooms built or altered with federal funds shall be compliant with the Architectural Barriers Act Accessibility Standard (ABAAS). This is applicable for new construction, renovations, and leased facilities. The compliance shall include reach constraints, mandatory clearances, and turning radii for locker rooms and adjacent areas.

Locker Materials and Design

The most common materials are metal, plastic, and wood. The material selected can influence the locker's durability, cost, and appearance.

Metal lockers are typically the most affordable. Normal wear and tear may require the finish to be touched up periodically. Due to metal being susceptible to rust and corrosion, they are not ideal for humid conditions unless powder coated or constructed of stainless steel to increase resistance to corrosion. Metal lockers are prone to dents and scratches, but the material is often selected due to its low initial cost.

Plastic lockers are typically more durable, since they do not rust, dent, or delaminate. As a result, they are ideal for damp and humid environments. This includes high-density polyethene (HDPE), etc. but does not include phenolic resin, which is cellulose-based and therefore considered a wood material despite its resin content. Plastic can be customized to the user's needs and requirements and is easy to clean and maintain. The initial cost is higher than other materials, but the overall lifecycle cost is lower due to minimal maintenance needs.

Wood lockers are an option for storage in non-damp environments. This includes solid wood, veneer, MDF, melamine, and phenolic materials. While typically selected for its aesthetic appeal, wood materials are the least durable overall and may require more ongoing maintenance. Wood lockers are porous, chip easily, support microbial bacteria, and are prone to water damage. Since wood lockers are not easy to sanitize, they are not appropriate for supporting facilities which require regular sanitation, such as cleanrooms, ORs, infusion/dialysis bays, etc.

The size and configuration of the lockers will depend on the user's storage needs. Locker sizes can vary in width, depth, and height (e.g., cube, half-height, full height, Z-shaped, multiple tiers high). Due to modular sizing, multiple sizes can be mixed to allow for flexibility and customization. Depending on the level of security required, locks may be as simple as a padlock hasp lock (key or combination), a digital lock, a key card access, or a biometric scanner. Like other components, cost and convenience of the user shall be considered.

To prevent the accumulation of dust, lockers should be designed with sloped tops or to terminate against bulkheads. Cracks, holes, and solid toe kicks should be sealed to prevent pest movement and harborage.

Conclusion

When planning a new lab, the users typically emphasize functional requirements. During the predesign phase, it is incumbent on the designer to remind them that providing remote storage is an integral and essential element in lab design to mitigate the risk of contamination and stay compliant with the *BMBL* and *DRM*. Each design component shall be evaluated to allow for sufficient storage. Additional prerequisites for lockers and locker rooms are included in the *DRM* in multiple chapters, exhibits (design questionnaires), and appendices.

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Quality Assurance & Quality Control for Construction Documents

Quality assurance (QA) and quality control (QC) are increasingly crucial for the development of construction documents as projects become larger and more complex. The terms QA and QC are often mistakenly used interchangeably, but they are distinct processes which function together to ensure delivery of only the highest quality products. QA ensures the quality of a product, with a focus on defect prevention. QC ensures that a product meets established expectations, with a focus on defect detection. QA and QC are critical for construction projects to successfully meet programmatic requirements and avoid RFIs, change orders, and delays.

QA for construction documents is an integral part of the design team's internal processes, beginning with project initiation. QA processes must foster a culture of quality and include established procedures and policies. For a design project, these include:

- A well-defined set of quality and project criteria (e.g., design, functionality and performance, efficiency and flexibility, code compliance) aligned with the project's contractual requirement, scope, budget, schedule, and professional standards of care.
- A well-organized process flow, which establishes quality goals and priorities, gathers information, identifies problems, and sets schedules.
- An experienced staff with appropriate expertise, clearly defined roles and responsibilities, and adequate time, resources, support, oversight, and management.
- Processes for quickly and effectively addressing and coordinating review comments, programs modifications, site conditions, consultant information, and other changes, updates, and new information.
- An established set of systems for clear communication, effective project management, progress tracking, and process assessment and improvement.

Successful QA enables the complete and accurate development of documents and reduces the time and energy required for document production and subsequent QC activities.

QC for construction documents ensures and confirms that completed documents meet the contract requirements and the project quality criteria. A QC review is conducted by a team of professionals with the requisite experience and seniority who have not been directly involved with the document development and can provide a critical, unbiased assessment. QC typically begins with a review of project quality criteria and a 'page turn' of all documents. The scale and complexity of the project determines the extent of QC, including the potential use of a third-party QC team. A review typically includes:

- Confirmation of compliance with project quality criteria, contract requirements, and professional standards of care.
- Identification and documentation of discrepancies, unresolved comments, coordination and constructability issues, errors, and other issues that must be corrected.
- General assessment of document quality and required improvement of the production and QA processes.
- Back-check of corrections made and approval for release of documents. The QC team may be required to submit documentation, signed by firm principles, that a QC review has been conducted and successfully completed.

Successful QC ensures that documents meet contractual requirements and quality criteria and avoid the hazards of poor-quality documents, including excessive review comments, rejected submissions, and schedule delays.

***Design Requirements Manual* Compliance**

The requirements for quality documents are repeated in many sections of the *DRM*, and individual sections should be referenced as applicable. Appendix E specifically addresses both QA and QC with regards to general submission requirements for different aspects of document development, including:

- The design team and each firm must have a QA plan to review and document processes and procedures to assure coordination.
- A QC review must be conducted by an experienced professional interdisciplinary team for each submission.
- *DRM* Appendix E, "A/E Submission Requirements," should be referenced as the minimum required content for each submission.

Conclusion

Effective QA and QC procedures form an essential part of construction document production by both facilitating (QA) and assuring (QC) the production of quality documents. Benefits include time and cost savings throughout the design and construction processes and avoiding RFIs, change orders, and delays.

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NIH *Design Requirements Manual*/Revision 2.1

DRM Revision 2.1, published on August 2, 2024, is the latest installment of a comprehensive update of the *DRM*. It includes updates to Chapters 2 (Planning and Programing) and 4 (Architectural Design) and Appendices E (Construction Document Submission Requirements) and J (Research Facilities Questionnaires). https://orf.od.nih.gov/TechnicalResources/Documents/DRM/DRM2.108022024.pdf

DRM revision 2.0, published in March 2024, was the first installment, which included the revised Chapters 3 (Civil Engineering and Site Development), 5 (Structural Design), and 9 (Fire Protection & Suppression). As with previous revisions, 2.1 has been reviewed by a committee of experts to address current best practices, lessons-learned, and industry trends in the planning, design, and construction of state-of-the-art biomedical research facilities. Selected highlights of the updates include:

Chapter 2:

- Laboratory types have been classified as Primary or Support, and Wet or Dry. These classifications will help establish functional requirements.
- Laboratory planning and programming information has been substantially updated, including photographs and graphics.
- Additional requirements for facility planning and programming, including data collection, flexibility, and workplace enhancements.

Chapter 4:

- New requirements for flood protective design, including waterproofing mechanical rooms and interstitial spaces.
- New requirements for the certification of high-performance coating applicators and third-party inspections for applications.
- A new requirement for performance assessment and upgrade if more than 100 square feet of interior surface of exterior wall is removed.

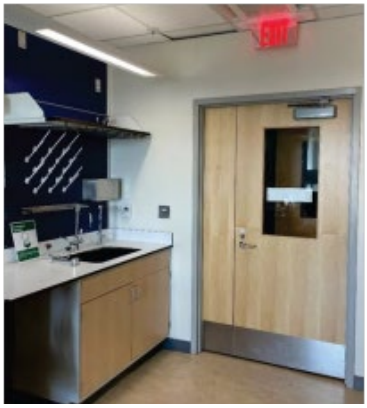
Appendix E:

- Increased content on the process of developing documents, including programming, data collection, and investigation of existing conditions.
- Provides information on the Permit Review process.

Appendix J:

- Research facility Questionnaires have been moved from Chapter 2 Exhibits to Appendix J (formerly *Lease Facilities DRM Checklist,* which has been removed).
- Expanded questions relative to Standard Operating Procedures, functional relationships, and other programmatic information.

As with revision 2.0, the revised chapters and appendices will be accented in green to distinguish them from the blue accents of chapters and appendices whose revisions are still pending.



New photographs and graphics illustrate key points

When using the *DRM* as a reference document for a design project, it is recommended that project team members (Project Officers, A/Es, and consultants) download the current version of the *DRM* on the date of award and reference that version for the duration of the project. It is important to note the version being referenced in the Basis of Design and the Construction Documents. DTR looks forward to supporting NIH and the international community as a reliable resource for best practices in biomedical research facility design.

We would like to thank our committee members and peer reviewers who generously lent their time and expertise and without whose help this revision would not have been possible.

If you have questions or need additional information about the DRM, please email DRM@nih.gov or contact communications editor Nika Lilley at nika.lilley@nih.gov.

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Design Considerations for Modulating Hydronic Control Valves

Variable flow applications for heat transfer - used in all terminal coils and equipment on variable frequency drive (VFD)-operated systems - require two-way modulating control valves to regulate water and glycol flow and meet the design conditions of the spaces served. Designers must consider multiple factors when selecting a valve for an application, including desired valve flow and coil characteristics, water temperature drop across the coil, and (when driven by modulating controls) control loop parameters fine-tuned to provide fast, stable, and accurate valve response to meet room setpoints. Even with fine-tuning, pressure fluctuations in a hydronic system may cause valves to overshoot or undershoot setpoints, leading to unsatisfactory temperature control and, with it, inefficient and expensive operation. This article discusses the basic function of and design considerations for control valves.

Control valves at NIH can be globe, ball, or butterfly type. Designers must select the valve's flow characteristic so that the hydronic coil served provides stable and predictable heat transfer as the valve position changes from fully closed to fully open. This characteristic describes how much flow passes through a valve as it opens. Hydronic coils at NIH utilize control valves with an equal percentage characteristic that guarantees flow through the valve increases an equal percentage for each equal increment the valve modulates open, providing stable output from the coil. Valves that control flow through building chilled water loops, which are not paired with a coil, utilize a linear characteristic to provide a more stable water flow over the entire range as the valve modulates.

Designers must ensure the valve experiences a pressure drop across its internal components sufficient to maintain control over flow regardless of valve position but limits pressure losses in the system the valve and coil serve. The ratio between the pressure drop across the valve to the pressure drop across all components on the branch piping serving the coil is called authority. The NIH *Design Requirements Manual* (*DRM*) requires an authority greater than 50% for modulating water control valves. Refer to *DRM* 6.3.4 and 7.6 for control valve requirements.

For pressure-dependent control valves, the pressure drop across the valve at the maximum design flowrate is expressed as a flow coefficient (Cv), published by the valve manufacturer, that provides the desired authority over the branch piping circuit. This Cv (see Figure 1) is only an estimate; designers typically assume a valve pressure drop of 5 psi, and fluctuations in other parts of the hydronic system result in changes to pressure drop, and thus flow, across the valve. These fluctuations alter flow and anticipated heat transfer through the coil. Control valve actuators governed by direct digital controls (DDC) must then apply Proportional, Integrated and Derivative (PID) control parameters to quickly restore and stabilize the design flow rate and temperature setpoints. Pressure-dependent control valves are paired with a balancing valve calibrated to maintain the system design flow through the branch piping.

$$C_v = Q\sqrt{\frac{S_g}{\Delta P}}$$

C_v = *required flow coefficient for the valve*
Q = *flow rate (in gal/min)*
S_g = *specific gravity of the fluid*
ΔP = *pressure drop (psi)*

Figure 1: Flow Coefficient Equation (Fluid Controls Institute, Inc.)

Pressure-independent control valves maintain design flow across the valve by employing an internal mechanism to decrease flow across the valve when system pressure changes would otherwise increase valve pressure drop and flow, and increase flow across the valve when system pressure changes would otherwise decrease valve pressure drop and flow. This allows designers to select the valve's design flowrate independent of system pressure changes that alter flow so long as pressure drop across the valve remains within a manufacturer-prescribed range (typically 5-50 psi).

Facility personnel can adjust the maximum flowrate through connections with the Building Automation System (BAS) or by field-replacing a cartridge governing the valve flow. Per *DRM* 7.6, NIH prohibits replaceable cartridges due to maintenance concerns. Mixing pressure-independent valves and regular control valves in the same system is not preferred for renovation projects.

Building chilled water return control valves shall be selected for high turn-down ratios and proper control across significant plant-pressure differentials. Valves shall be of high quality and industrial grade, and actuators sized to close against anticipated system pressure so that valve seats are not forced open.

Conclusion

Control valve selection must consider the application served, type and magnitude of the control required over connected equipment, and adjustability and serviceability in the field. Designers should consult *DRM* design and control requirements in concert with manufacturer recommendations and industry best practices.

Additional Information

1. ASHRAE. (2020). ASHRAE Handbook—HVAC Systems and Equipment.
2. Fratelli Pettinaroli. The Definitive Guide to Pressure Independent Control Valves. Click Here for Link
3. NIH *DRM* (Rev 1.5) 3-5-2020
4. Schneider Electric. (2010). Control Valve Sizing Application Information

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Floor Area Considerations in Laboratory Design

The high value of laboratory space drives the need to utilize floor area as efficiently as possible. Although efficiency is a worthy goal, it must be tempered with the understanding that safety and function cannot be compromised. During the planning of a construction project, the designer must confirm that the identified floor area is sufficient to accommodate the program, including regulatory requirements, the needs of the specific laboratory activities, and good practice, without undue risk.

Regulatory requirements are issued by an authority having jurisdiction (AHJ) and are mandatory unless a given requirement is formally exempted by the appropriate AHJ. Regulatory requirements that affect floor area include:

- Building codes, including the International Building Code (IBC) and those published by the National Fire Protection Association (NFPA), provide minimum dimensions and clearances for building components, including egress and life safety. The NIH Fire Marshal is the AHJ for fire & life safety for NIH-owned facilities.
- Accessibility standards, including the Architectural Barriers Act (ABA) and the Americans with Disabilities Act (ADA), provide accessibility space requirements including turning radii, clear floor space, and clearances at doors. The US Access Board is the AHJ for accessibility.
- The NIH *Design Requirements Manual* (*DRM*) provides space requirements such as lab module size, lab aisle width, and Appendix A clearances. Additional requirements, including those published by the Facilities Guideline Institute (FGI), are required by reference. The Division of Technical Resources is the AHJ for the *DRM*, except for Chapter 9, for which the NIH Fire Marshal is the AHJ.
- The Occupational Safety and Health Administration (OSHA) and the NIH Division of Occupational Health and Safety (DOHS) are additional sources of regulatory requirements focused on safety.

Specific laboratory activities require movement and working clearances sufficient for laboratory functional operations to be conducted safely and without inefficiencies, congestion, and conflicts.

It is critical to develop a thorough understanding of the number and roles of staff, type, and frequency of work to be conducted, and materials, supplies, and equipment to be used. Workflow diagrams can illustrate critical flows (e.g., of personnel, materials, or waste) and help identify areas of congestion or conflict. Once the specific requirements of lab operations have been determined, areas of concern can be addressed, including:

- Sufficient space for staff to perform procedures safely, comfortably, and ergonomically.
- Ease of movement for materials, including equipment, supplies, carts, cylinders, and deliveries.
- Sufficient clearances for equipment replacement and for equipment covers and access panels to be opened or removed for maintenance, calibration, and service activities.
- Adequate space and dedicated locations for ancillary and support equipment, such as tanks, UPSs, chillers, carts, and mobile equipment.
- Adequate space for PPE, including storage, disposal, charging, and donning/doffing.
- Facilities for waste management/decontamination and waste flows.
- Allowance for future growth, which may include additional personnel, equipment, or procedures.

Good practices are standards that are proven through experience to produce positive outcomes. Some good practices are codified (in the *DRM*, for example) and others are recognized by design professionals based on successful past projects. Good practices that affect floor area include:

- Designating dedicated locations for waste containers (including hazardous waste and sharps), configured so they don't become obstructions.
- Providing adequate in-lab storage for frequent-use supplies so that benchtops and aisles don't become cluttered.
- Providing out-of-lab staff lockers so personal items remain outside of the lab.
- Providing an appropriate level of flexibility to accommodate reconfiguration and program changes.
- Ensuring unobstructed access to all equipment, including safety equipment (e.g., handwashing sinks, safety showers, hazardous materials receptacles, flammable storage cabinets, fire extinguishers, emergency shut-down switches).

Conclusion

Every laboratory project should aim to utilize the available floor area efficiently. The designer must confirm that floor area is sufficient to accommodate the program, including regulatory requirements, laboratory activities, and good practices, without compromise.

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Design Considerations for Active Chilled Beam System Control

Chilled beams are commonly used in HVAC design for BSL-2 laboratories at NIH. This creates a "hybrid" design that uses smaller primary air handlers (to provide ventilation and manage latent loads) and a water-side chilled beams system (to manage sensible cooling and heating loads). The heat transfer capacity of the water allows reductions of the overall fan, cooling, and heating energy and total capital cost as compared to a traditional all-air VAV reheat system. The four-pipe active chilled beam terminal units (with both a reheat water valve and a chilled water valve) are typically used in lab spaces to provide accurate temperature control. The two-pipe active chilled beam units (for cooling only) can be used for supplemental cooling spaces. Chilled beam terminal units require process cooling chilled water (not campus chilled water). Below are typical design considerations for active chilled beam system control.

Process Cooling Water System

1. **Heat Exchangers:** Chilled beam process cooling water is typically generated utilizing campus chilled water through N+1 water-to-water heat exchangers. Each heat exchanger is provided with a two-way modulating temperature control valve on the chilled water side and a two-way automatic isolation valve on the process cooling side. The two-way modulating valve on the primary side of each heat exchanger controls the leaving process cooling water. A low-limit temperature switch located on the discharge piping of each heat exchanger closes the respective chilled water control valve when the leaving process cooling water drops below 14.4°C (58°F).
2. **Pump and Flow Control:** The chilled beam process cooling water distribution system uses N+1 pumps. The system is designed as a variable flow with a VFD for each pump, modulating pump speeds at various flow conditions to maintain system differential pressure setpoint. A minimum flow bypass valve located near the end of the system allows pump operation at low load conditions.
3. **Temperature Control:** The process cooling system supplies chilled water to chilled beams. The chilled beam supply water shall be reset based on the highest space dewpoint temperatures from multiple locations in areas served by chilled beams. The chilled beam supply water temperature shall be not less than 14.4°C (58°F) and at least 1.1°C (2°F) higher than space dewpoint temperature. During startup, the chilled beam supply water temperature is initially set higher and gradually reduced to set point while maintaining a minimum 1.1°C (2°F) differential higher than the highest space dewpoint temperature.

Active Chilled Beam Terminal Units

1. **Four-Pipe Chilled Beam Control:** The following control requirements are used for a four-pipe active chilled beam unit in the lab:
   - Each pressure zone is provided with a pressure-independent supply air terminal unit and a pressure-independent exhaust air terminal unit. For negative pressure labs, the supply terminal unit tracks airflow offset with the exhaust terminal.
   - Each pressure zone is provided with one or more four-pipe chilled beam units.
   - Each active, four-pipe chilled beam unit shall be provided with an induction air connection, a cooling coil section, and a reheat coil section. Temperature control for each space will be provided by modulating the two-way control valves in the chilled beam cooling coils and reheat coils in sequence.
2. **Humidity/Condensation Control:** Because a chilled beam cannot remove latent load, provide the following instrumentation and control strategy to avoid condensation:
   - Provide a relative humidity sensor in select rooms served by chilled beams. The BAS shall then calculate the space dewpoint temperature based on the measured space temperature and relative humidity and send a signal to the process cooling water system to reset chilled beam supply water temperature as described in this article.
   - Provide a pipeline condensation sensor in the chilled beam supply pipe upstream of the control valve at each temperature control zone. Upon sensing condensation, the BAS shall close the chilled water control valve to chilled beams in the room and generate a critical alarm. The alarm must be manually reset when condensation clears.

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United States Geological Survey (USGS) ShakeMaps and ShakeCast for Post-Earthquake Facility Evaluation at the National Institutes of Health (NIH)

Earthquakes pose a significant risk to infrastructure, and timely evaluation of critical facilities at the National Institutes of Health (NIH) following such events is essential to ensure personnel safety and effectively prioritize facility recovery and repair efforts. The United States Geological Survey (USGS), a scientific agency within the U.S. government that conducts research and provides data on natural resources, natural hazards, and the landscape of the United States, has developed two tools — ShakeMaps and ShakeCast. These tools both play an integral role in post-earthquake situational awareness and response assessments. These technologies facilitate rapid evaluations of seismic impacts, enabling NIH engineers and upper management to make well-informed decisions.

ShakeMap

ShakeMaps are detailed, color-coded visualizations of ground shaking generated immediately after an earthquake. These maps leverage data from NIH and USGS regional seismic monitoring stations, reported intensities, geological analysis, and mathematical modeling to estimate the intensity and distribution of ground shaking across affected areas. Key metrics provided by ShakeMaps, such as peak ground acceleration (PGA), describe the severity of shaking and its potential impacts on structures to help structural engineers and first responders better respond to an event.

ShakeCast

ShakeCast is a software application that leverages ShakeMap shaking estimates to provide automated assessments of earthquake impacts on specific facilities and critical assets. Facility-specific structural-design information, including seismic design parameters and vulnerability data, are entered into the ShakeCast system. Following an earthquake, ShakeCast compares ShakeMap data with these facility details to evaluate potential damage levels, which can help to prioritize inspection needs.

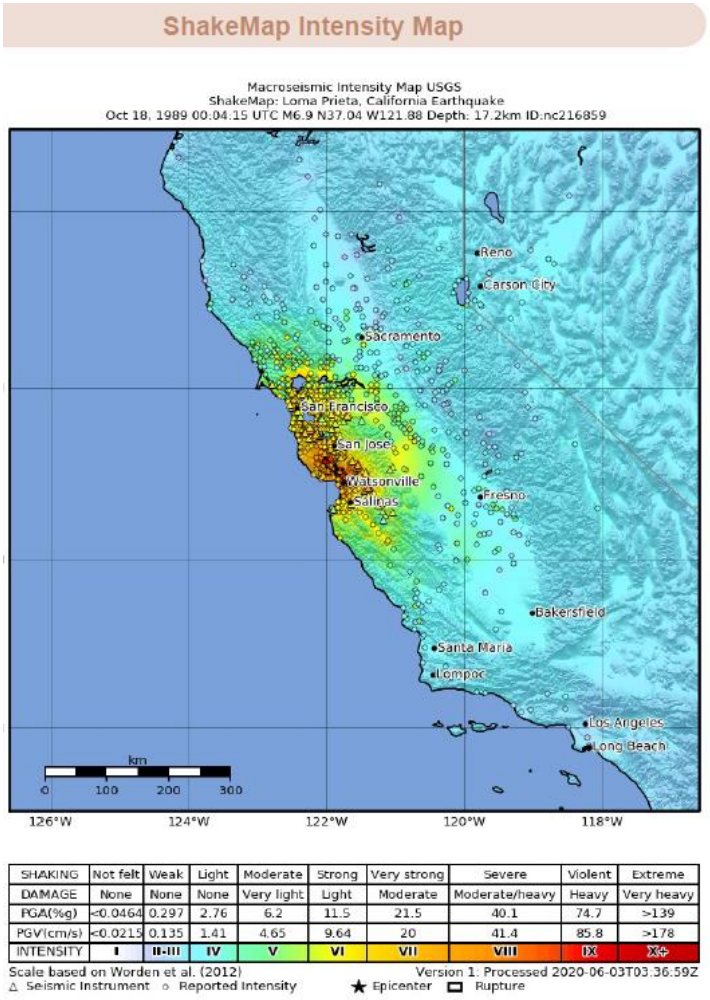

Figure 1: ShakeMap Intensity Map

ShakeCast delivers results within minutes of an event or earthquake, generating reports that categorize facilities by their likelihood of potential damage and inspection priority. These reports are color-coded, allowing users to quickly identify high-risk structures. For critical infrastructure on campus, such as the hospital and the Central Utility Plant, ShakeCast helps to streamline post-earthquake evaluations by prioritizing resources on the most vulnerable assets. Importantly, ShakeCast also has the potential to save resources when ShakeMap reported shaking levels are determined to be below those of concern— avoiding unnecessary inspections, or the shutdown of critical facilities.

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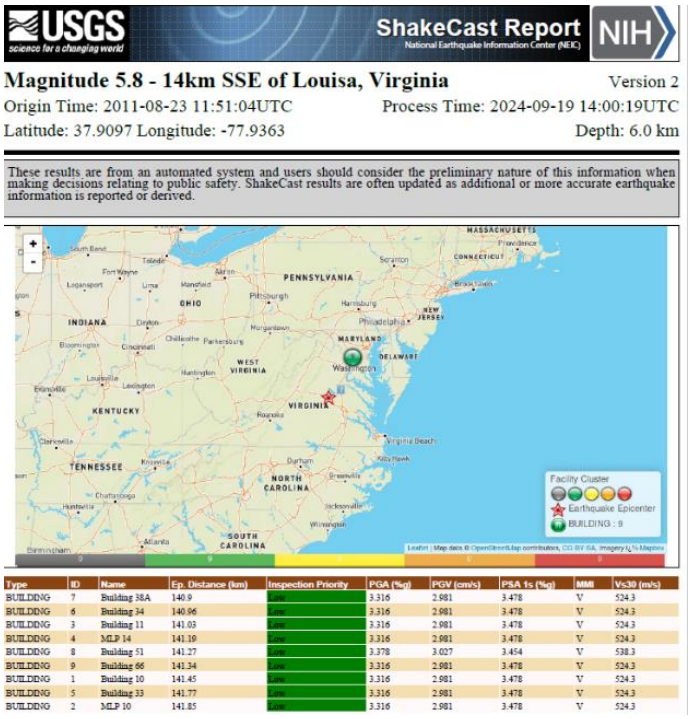

Figure 2: ShakeCast Report

ShakeCast is widely used across the Department of Homeland Security's 16 critical infrastructure sectors. It is also employed by international agencies, such as the International Atomic Energy Agency, to assess potential earthquake damage at critical sites. It has proven effective in identifying damaged infrastructure, such as during the South Napa Earthquake, where it flagged several bridges, later confirmed as damaged. Efforts are underway to expand its capabilities nationally with support from the California Department of Transportation (Caltrans) and the Federal Highway Administration (FHWA).

Post-Earthquake Facility Evaluation

ShakeMaps combined with ShakeCast are particularly effective for post-earthquake facility evaluations due to their speed and specificity. Facility managers can use ShakeMaps to gain a general understanding of the earthquake's impact and utilize the ShakeCast system for detailed, facility-level insights. This dual approach minimizes downtime, ensures site safety, and prioritizes repairs. Furthermore, ShakeMaps are used to calibrate ShakeCast, a supplementary tool for conducting facility-specific structural evaluations based on the ShakeMap shaking estimates at each location.

Both tools reduce the need for immediate exhaustive on-site inspections in low-risk areas, saving valuable time and resources. Additionally, they enhance preparedness by enabling NIH facility managers and engineers to pre-configure vulnerability data, ensuring rapid and accurate evaluations when an earthquake occurs.

Conclusion

By utilizing these newly acquired tools, NIH can better understand the geographic extent of an earthquake's impact to the NIH campus by identifying areas most likely to experience severe damage.

These USGS tools empower NIH to enhance its emergency preparedness and response capabilities by pinpointing facilities that may require immediate attention, ultimately protecting critical infrastructure and ensuring the safety of personnel and operations.

References

1. Following any earthquake, go to: https://earthquake.usgs.gov
2. More on ShakeMap: https://earthquake.usgs.gov/data/shakemap/
3. More about ShakeCast: https://code.usgs.gov/ghsc/esi/shakecast/-/wikis/home
4. ShakeCast Background: https://www.usgs.gov/news/featured-story/usgs-shakecast-system