

CriticalPoint Pearls of Knowledge Considerations for Design, Construction, and Start-up of Cleanrooms

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Introduction

Sterile compounding pharmacies planning a new build or renovation may quickly find themselves navigating unfamiliar territory. Cleanroom construction projects involve far more than selecting walls, ceilings, and equipment—they require careful planning, multidisciplinary collaboration, and a clear understanding of regulatory expectations. Successfully designing and constructing a compliant sterile compounding facility is rarely a one-person effort. Instead, it requires coordinated input from pharmacy leadership, facilities engineering, architects, contractors, certification specialists, and regulatory experts.

For pharmacy leaders who may be overseeing a construction project for the first time, the process can feel daunting. While every project has unique constraints and challenges, several foundational elements can help guide the planning and execution of a successful cleanroom build or renovation. This month's Pearl provides some key elements to help lay the groundwork for a successful construction project.

Connect with pharmacy colleagues

Searching for cleanroom design guidance online can quickly become overwhelming. Information can be fragmented, outdated, or lacking the practical insights needed to navigate a real construction project. Instead, one of the most valuable resources available is the experience of peers.



Reach out to pharmacy colleagues who have recently completed cleanroom construction or renovation projects. These professionals can offer firsthand insights into working with state boards of pharmacy, selecting contractors, developing facility layouts, and choosing construction materials. They can also share lessons learned and highlight potential pitfalls encountered during their projects.

If possible, consider visiting recently constructed facilities to evaluate the finished environment and understand how design decisions translate into daily operations. Observing other cleanrooms in practice often reveals valuable details that are not obvious in architectural drawings.

Engage industry experts early

Cleanroom design and construction involve specialized knowledge that extends beyond traditional building projects. Engaging experienced industry experts early in the planning process can significantly improve the likelihood of success.

Consultants who specialize in sterile compounding environments can perform gap analyses of existing facilities, assess workflow and operational needs, and provide recommendations aligned with current regulatory standards such as USP <797> and USP <800>. It is important to remember that these standards represent minimum requirements, not necessarily optimal design targets.



Experienced consultants often provide detailed action plans that outline facility improvements, design considerations, and compliance strategies. Their recommendations can help pharmacies build facilities that not only meet regulatory expectations but also function efficiently in day-to-day operations.

Review relevant standards and guidance

While USP chapters provide the regulatory foundation for sterile compounding facilities, additional standards offer valuable guidance during design and construction. The ISO 14644-4 provides detailed guidance on cleanroom design, construction practices, project responsibilities, and commissioning activities. Other standards such as ISO 14644-1 and ISO 14644-3 outline classification requirements and testing methodologies commonly used during cleanroom certification.

These documents are not specific to sterile compounding pharmacies but provide important context regarding cleanroom engineering principles, airflow control, and facility qualification.

Work closely with facilities and engineering

Hospital facilities and engineering departments play a critical role in determining whether existing infrastructure can support a new or renovated cleanroom suite. They can evaluate available space, assess HVAC system capacity, and determine whether mechanical upgrades are required to achieve the necessary airflow and pressure relationships.



In many organizations, facilities departments are responsible for hiring architects, engineers, and construction contractors. However, these decisions should never occur without active pharmacy involvement. The sterile compounding environment ultimately supports pharmacy operations, and the pharmacy is responsible for maintaining regulatory compliance for compounded sterile preparations.

Pharmacy leadership should remain directly involved in design discussions, ensuring that workflow, contamination control, and operational efficiency remain central considerations throughout the project.

Conduct an independent design review

Once a preliminary design has been developed, an independent design review is strongly recommended. Design reviews performed by experienced cleanroom professionals help identify potential issues before construction begins.

Elements such as millwork selection, pass-through chambers, surface materials, lighting fixtures, and engineering controls are sometimes chosen primarily for aesthetic reasons rather than contamination control performance. Independent reviewers can evaluate whether the proposed design supports appropriate airflow patterns, pressure relationships, cleanability, and workflow.

Although a design review may represent an additional upfront cost, it often prevents expensive modifications later. Identifying design flaws before construction begins can save tens or even hundreds of thousands of dollars in potential rework.



Establish clear design criteria

During the planning phase, the project team should develop a design criteria document that outlines the performance expectations for the cleanroom suite.

Standards such as USP <797> and USP <800> define minimum requirements for ISO classifications, pressure relationships, and air changes per hour (ACPH). However, many facilities choose to exceed these minimums to provide greater contamination control margins.

For example:

Name of Area	Feature	USP <797> Requirement	Example Facility Design Criteria that Exceeds USP <797>
ISO 8 anteroom serving nonhazardous buffer room	Air changes per hour (ACPH)	20	> 45
ISO 7 buffer room(s)	Air changes per hour (ACPH)	30	> 60

Establishing these criteria early ensures that contractors, engineers, and certification professionals understand the performance expectations for the facility.

Develop a capital improvement plan

Cleanroom construction projects require significant financial investment. Developing a detailed capital improvement plan (CIP) helps organizations understand the costs associated with design, construction, equipment, certification, and commissioning.

Engaging the state board of pharmacy early in the planning process can also be beneficial. Some boards are willing to review proposed facility plans and provide feedback before construction begins.

In addition, certification vendors and environmental monitoring data can provide valuable evidence to support capital investments when addressing known compliance deficiencies or contamination control issues in existing facilities.

Maintain active oversight during construction

Once construction begins, pharmacy leadership should remain actively engaged in the project. Regular meetings with contractors, architects, and facilities teams help ensure that the project continues to align with the approved design.

Routine walkthroughs during construction are equally important. Seemingly small details such as flush-mounted fixtures, ceiling penetrations, or surface transitions can significantly impact cleanability and contamination control.

Catching issues early during construction is far easier and less costly than addressing them after installation is complete.

Commission the cleanroom suite

After construction is complete, the facility must undergo commissioning to verify that the cleanroom suite performs according to its design specifications.



Commissioning typically involves comprehensive testing performed by a qualified cleanroom certification vendor. This testing may include nonviable particle counting, airflow velocity measurements, air change calculations, pressure differential verification, HEPA filter integrity testing, and airflow visualization studies.

Many facilities also adopt structured qualification approaches for equipment commonly used in pharmaceutical manufacturing, including design qualification (DQ), installation qualification (IQ), operational qualification (OQ), and performance qualification (PQ).

These evaluations ensure that the facility and the equipment not only meet minimum regulatory requirements but also perform according to the design parameters established during project planning.



Clean the facility and establish environmental monitoring baselines

Before compounding operations begin, the cleanroom suite should undergo a thorough cleaning process to remove construction debris, dust, and potential microbial contamination introduced during the build.

Initial cleaning involves multiple stages using facility-approved disinfectants followed by sporicidal agents. Once the facility is cleaned, environmental monitoring should be conducted to establish baseline contamination control conditions.

Baseline environmental data collected during commissioning provides important insight into the facility's performance and can be used to establish internal alert and action levels for the ongoing environmental monitoring program required by USP <797>.

Environmental sampling may be performed in multiple stages. Initially, viable air and surface sampling are conducted under as-built conditions to establish baseline environmental performance and confirm the cleanroom can maintain appropriate contamination control without personnel activity. Following this phase, simulated dynamic sampling is performed to verify that acceptable environmental

conditions are maintained during workflow and personnel activity representative of sterile compounding operations.

Dynamic sampling locations must be selected based on airflow patterns, personnel movement, and areas of highest contamination risk.

Summary

Cleanroom construction projects require thoughtful planning, strong collaboration, and sustained leadership from pharmacy throughout the entire process. While every facility presents unique challenges, engaging knowledgeable experts, establishing clear design criteria, and maintaining active oversight during construction can significantly improve the likelihood of success.





Decisions made during the design phase often become permanent features of the facility once construction is complete. Investing time and expertise early in the project helps ensure the finished cleanroom suite supports effective contamination control, regulatory compliance, and safe sterile compounding operations for years to come.

References

United States Pharmacopeia USP <797> Pharmaceutical Compounding—Sterile Preparation. 2024