Chapter 9

Primary Engineering Controls

Richard C. Capps

Introduction

Primary and secondary engineering controls (PECs; SECs) work together to create the particle-free atmosphere required for compounding sterile preparations. Allowing for certain exceptions discussed later in this chapter, the PEC is placed in an ISO Class 7 buffer room to create the environmental conditions favorable to sterile compounding. The PEC controls airborne contamination from the point of filtration to the critical site and beyond so that airborne contamination is virtually eliminated from the working environment. During the compounding of hazardous drugs (HDs), engineering controls are also designed to ensure containment of the hazardous agents for the protection of patients, personnel, and the environment. Containment PECs (C-PECs) are externally ventilated devices that provide a particle-free work environment that also minimizes HD exposure through negative pressure or controlling the direction and speed of airflow into the device. USP Chapter <797> Pharmaceutical Compounding—Sterile Preparations and USP Chapter <800> Hazardous Drugs—Handling in Healthcare Settings require the PEC and C-PEC to provide a unidirectional ISO Class 5 environment during the compounding of sterile preparations.[1,2] PECs and C-PECs are available in a variety of styles and configurations to meet a facility's needs, but all of the designs appropriate for sterile compounding use the following concepts to maintain the required environmental conditions within the critical compounding area.

Unidirectional Airflow

USP Chapter <797> states the following:

> The airflow in the PEC shall be unidirectional (laminar flow), and because of the particle collection efficiency of the filter, the "first air" at the face of the filter is, for

Note: The author acknowledges James T. Wagner who authored this chapter in the previous edition of this text.

the purposes of aseptic compounding, free from airborne particulate contamination. HEPA filtered air shall be supplied in critical areas (ISO Class 5) at a velocity sufficient to sweep particles away from the compounding area and maintain unidirectional airflow during operations. Proper design and control prevents turbulence and stagnant air in the critical area. In situ air pattern analysis via smoke studies shall be conducted at the critical area to demonstrate unidirectional airflow and sweeping action over and away from the product under dynamic operating conditions.[1]

Particle management is either by flow control using unidirectional airflow or dilution control using turbulent airflow or some combination of the two. Generally, flow control is used for the PECs and dilution control is used for the SEC (i.e., the cleanroom). Although some cleanrooms do employ unidirectional airflow, those used in compounding facilities tend to be turbulent flow.

Unidirectional airflow showers the work zone with a continuous flow of filtered high-efficiency particulate air (HEPA). By definition, *unidirectional airflow* is "air that flows in a single pass in a single direction through an air device or clean zone with generally parallel streamlines" (**Figure 9-1**).[3] By showering the work area with relatively uniform airflow and using well-placed air returns, PECs can sweep process-generated contamination from the work area and prevent the influx of environmental contamination from the surrounding area. In an enclosed space such as a biological safety cabinet (BSC) or a compounding aseptic isolator (CAI), the design and placement of air return or exhaust grilles are at least as important as the design of the supply air diffusers. Placement of materials inside the work area and process manipulations must be carefully positioned and planned to take advantage of the push-pull of a unidirectional airflow system. The supply HEPA filter pushes air into the work area, and the return grilles pull the air across the work area eliminating turbulence and removing process-generated contamination.

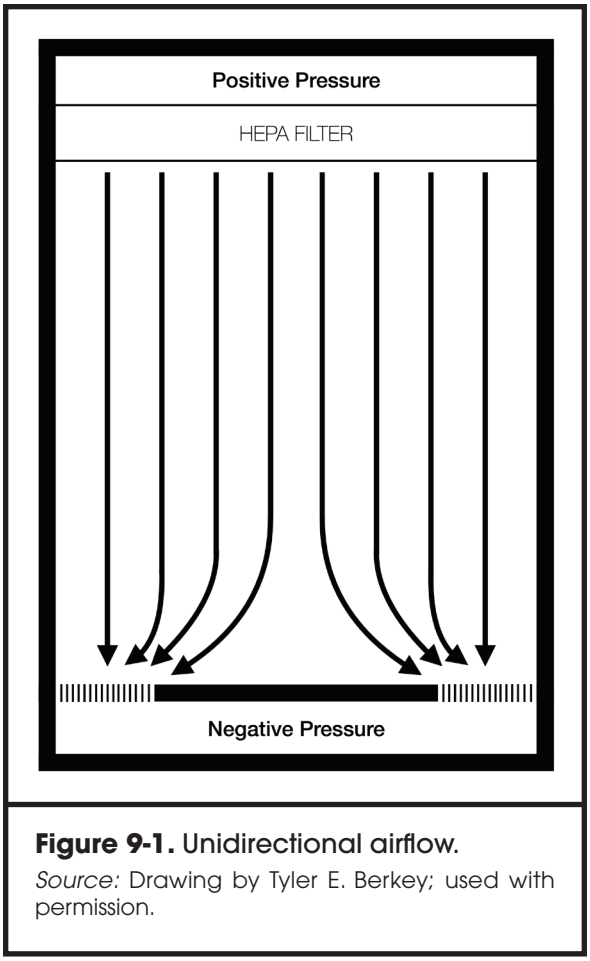

Figure 9-1. Unidirectional airflow.
Source: Drawing by Tyler E. Berkey; used with permission.

First Air—Direct Compounding Area

USP Chapter <797> defines the *direct compounding area* (DCA) as "A critical area within the ISO Class 5 PEC where critical sites are exposed to unidirectional HEPA-filtered air, also known as first air."[1] USP Chapter <797> defines *first air* as "The air exiting the HEPA filter in a unidirectional air stream that is essentially particle free" (**Figure 9-2**).[1]

Many of the processes employed during compounding of sterile preparations create particulate contamination. For example, opening and removing the overwrap from sterile syringes and needles creates thousands of particles.[4] The PEC must be designed so that a particle-free stream of HEPA-filtered air sweeps across the DCA without re-entrainment, refluxing, or dead air zones that prevent the removal of process-generated contamination from the critical area. Open devices such as