CriticalPoint Pearls of Knowledge

Airflow Smoke Pattern Testing

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Introduction

Various standards covering sterile operations, including USP <797> (2023)[1], the FDA Aseptic Processing Guidance[2], and state boards of pharmacy, require an airflow visualization study to prove that the primary engineering controls (PEC) are suitable for the intended activity. The airflow must be unidirectional and devoid of turbulence and updrafts. Historically, compounding pharmacies have turned to their certifiers for this critical test, turning it into a checkbox for compliance rather than the important training tool it is intended to be.

Who should perform airflow smoke pattern testing?

We would like you to consider performing this testing yourselves. Pharmacies that plan to perform smoke pattern testing should initially work with their certifiers to determine the best compounding process while working in unidirectional airflow. Certifiers and pharmacies working together can share insights from each other's perspectives. Pharmacy personnel can share their knowledge about compounding activities using their procedures, while certifiers can provide insight on airflow behavior in PECs. Together, they can observe how the airflow behaves during compounding to verify that appropriate airflow behavior washes over the critical site.

Airflow smoke pattern testing concepts

Airflow smoke pattern testing can be performed under both static and dynamic conditions, depending on what you want to learn from the test. A dynamic airflow smoke pattern test is used to train and instruct compounding personnel in proper aseptic technique for every type of PEC in which they work. Working in a horizontal-flow laminar airflow workbench (LAFW) is different from working in a vertical-flow biological safety cabinet (BSC) or restricted access barrier system (RABS). Airflow must be traced from the entrance plane (the HEPA filter diffuser screen) across the direct compounding area (DCA) to the exit plane. The DCA is the area within the PEC where critical operations are conducted.

Elements of airflow pattern concepts

- The entrance plane in a horizontal-flow LAFW is the HEPA filter at the rear of the work surface. The exit plane is the area behind the operator. Air must be traced from the HEPA filter diffuser screen across the critical sites in the DCA to and across the operator, and the air should not reflux (reverse flow) into the work area after passing through it.

- The entrance plane in a vertical-flow unidirectional airflow device is the HEPA filter diffuser screen above the work surface. In a unidirectional vertical-flow PEC, the diffuser screen will traverse the entire entrance plane from the front wall to the back wall and from side wall to side wall. The exit plane in a vertical-flow device is the work surface. For example, BSC vertical air must be traced from the diffuser screen, across the critical sites in the DCA, to and into the air grilles at the front and rear of the work surface of the device.
- The air in the center of the work area at the work surface of a vertical-flow device is typically the worst airflow in many devices.
- In BSCs, the area where air is being drawn closest to the front intake grille is often the best airflow within the vertical-flow device.
- In both vertical and horizontal airflow, the airflow through the DCA must be shown to be smooth and without turbulence and updrafts.
- Air must be shown to sweep across the critical site.
- Air flowing out of the HEPA filter diffuser screen is considered “first air” until it hits an obstruction such as an IV bar, the operator’s hands, vials, bags, and other supplies. First air must be shown to exist at all critical sites.

This video presents dynamic smoke pattern testing in horizontal and vertical airflow. You will see the characteristics of the smoke sweep smoothly over the critical site at the DCA with no airflow disruptions or backstreaming. This visual demonstration proves that first air is effectively being delivered to the critical site in each type of airflow with the aid of proper aseptic technique.

Click the photo to view the video

Getting the most out of smoke pattern testing

A dynamic airflow smoke pattern test can be the best aseptic technique training tool in your training and process setup arsenal. You can use these tests to:

1. Determine how to place materials within the PEC to minimize turbulence.
2. Differentiate the area within the PEC where sterile materials are unwrapped before placement in the DCA.
3. Demonstrate that the air from the particle-generating unwrapping process does not migrate into the DCA.
4. Demonstrate that the air that passes over the critical sites flows into the air returns or past the operator and does not flow back into the DCA.
5. Demonstrate how hands must be positioned in vertical airflow versus horizontal airflow.
6. Demonstrate how vials, syringes, and other equipment and supplies used in compounding must be manipulated to ensure first air at the critical site.

Smoke pattern testing can also be used to determine how to position large objects within the DCA:

- Large, especially flat objects like the base of automated compounding devices (ACDs) will create turbulence. Use static airflow smoke pattern tests to position objects in a manner that mitigates the turbulence and prevents turbulent airflow from affecting the DCA. Air must flow over, across, and

under all objects. Often, feet or risers must be installed to create a gap between ACDs (or other large, flat objects) and the work surface.

- For many years, Baker and NuAire sold LAFWs with a lip at the back of the work surface. These units can be retrofitted with a diffuser screen from the manufacturer that will eliminate turbulence caused by this lip. If you have one of these units that has not been retrofitted with a diffuser screen, there is a zone of turbulent airflow on the work surface. An EM 2400 compounding device placed in this LAFW will create a significant area of turbulence, and if the air cannot flow under the compounder, it will roll over the top of it in a very turbulent manner. This will prevent first air at the critical sites on top of the compounder. Installing feet on the bottom of the compounder that raise it above this turbulent zone will greatly reduce the refluxing air.

- The return grilles in a vertical-flow PEC must be kept clear, but these grilles should be exploited when positioning large objects. Air is more efficiently pulled across an object than blown across it. Positioning an object close to the returns without blocking them will promote a sweeping action over and away from the critical sites.
- There is no design template for smoke pattern testing. Airflow smoke pattern testing is intended to find the "correct" airflow for the type of compounding conducted. For many ACDs, this may take some trial and error until the placement is just right for appropriate airflow behavior. The final placement of the compounder and applicable work instructions for setup, breakdown, placement, and operation will need to be added to internal SOPs.

Documenting the airflow smoke pattern test

There is some confusion surrounding whether airflow smoke pattern tests must be video-recorded per USP <797>. This is because the chapter gives an example of documentation achieved from video-recording but does not explicitly state this requirement. However, CETA's CAG-014 Airflow Visualization Study states that a video recording "is the method of documentation."[4] This is because video documentation is the only way to verify the device is suitable for the intended task and that compounders properly exploit first air. CriticalPoint recommends pharmacies require video evidence of dynamic airflow smoke pattern tests, whether they are performed in-house or by certifiers. We also recommend that static testing be video-recorded.

- Regulators expect to see that every PEC has been properly integrated into the facility and that compounders use first air and display proper aseptic technique. We suggest that compounders demonstrate these skills in every type of PEC in which they compound, but that does not mean you need a video of every individual in every PEC. Just use it as a training tool.
- Elaborate video equipment is not required. A contemporary cellphone camera can be used to video-record the test. Avoid GoPro fisheye lenses. In many cases, fisheye lenses are great for capturing live-action scenes; however, slow and intricate detail that requires precise angles is not captured well using an ultrawide-angle lens. If a cellphone is used, it must be vigorously and thoroughly wiped with an EPA-registered, one-step bactericidal disinfectant cleaner and followed by wiping with sterile IPA. The person charged with recording the video must be aware that their hands (and

the phone) are highly contaminated and must refrain from placing the phone or their hands on ISO 5 or ISO 7 surfaces.

- Practice is needed to determine the best camera angles to show the smoke effect inside the PEC. Often it is not clear what the video was designed to reflect. This can be avoided by making sure the smoke is flowing where the work is being done and that the angle confirms the flow is where you see it when standing at the PEC. Remember, angles are important to consider when capturing dynamic airflow demonstrations. Each PEC and compounding personnel is different. Choosing the appropriate material and shot angle is critical to ensure effective video documentation.
- The video must show where the smoke enters the DCA as it crosses the critical site and prove that it does not reflux into the DCA after exiting.

Choice and use of an appropriate smoke source

Think of Goldilocks when choosing the source of smoke…

- Too much smoke creates a large mass of white smoke that distorts the view and misrepresents what is occurring at the critical site. Refluxes and updrafts are masked by the sheer mass of smoke.
- Too little smoke does not show up well on video. You will not be able to discern the smoke from the background and will not be able to prove a lack of turbulence and updrafts.
- Through years of trial and error, we have found that the "just-right" amount of smoke is best produced by ventilation smoke tubes and a small air pump.

Larger fog generators, such as the °C Breeze, are available from Degree Controls, Inc. These units create a high volume of fog that can potentially mask some turbulence and are, therefore, best used on larger ISO Class 5 systems and not the standard-size PECs most often found in compounding pharmacies.

The equipment required to perform a smoke pattern test is not expensive and is easy to obtain. Ventilation smoke tubes with a battery-operated aquarium pump, tubing, and connectors are all you need.

1. Ventilation tubes and bulb
   - Dräger (appropriate for BSCs and RABS only) can be purchased online direct from Dräger, through Grainger (bulbs, plugs, and tubes) or SKC Inc. (air current kit).
   - Mine Safety Appliances (MSA) are appropriate for all PECs and can be purchased online from Grainger and Medline
2. Battery-operated aquarium pump
   - PetSmart: Top Fin® battery-operated aquarium air pump
   - Amazon: Uniclife portable battery-operated aquarium air pump
3. Aquarium tubing and regulator
   - Grainger: smoke tubes
   - PetSmart: aquarium air pump
   - Amazon: regulator
   - Amazon: tubing

Summary

Ultimately, it's the pharmacy's responsibility to meet and maintain compliance. If the certification company does not provide airflow smoke pattern testing, it is the responsibility of the pharmacy to perform that testing. The ability to perform in-house testing significantly improves your initial and ongoing training programs. Training has consistently been proven to be more effective if methods of visual feedback are incorporated, such as through dynamic airflow smoke pattern testing. Once pharmacy personnel are familiar with the process and procedures required to test and have the training to recognize desirable and undesirable characteristics of airflow in the DCA, the team may begin performing the airflow smoke pattern testing in-house. Remember, there is no one-size-fits-all approach to airflow smoke pattern testing. A lot of it is trial and error when finding the "sweet spot" in the DCA. Anyone familiar with sterile compounding can do it provided they can identify the best place to compound within the work zones of the PEC.

References

[1]United States Pharmacopeial Convention, Inc. <797> Pharmaceutical Compounding—Sterile Preparations. 2023.

[2]Food and Drug Administration. Guidance for Industry Sterile Drug Products Produced by Aseptic Processing — Current Good Manufacturing Practice. September 2004.

[3]Controlled Environment Testing Association. Airflow Visualization Study. CAG-014:2022.