DA-13-012 (RP-1344)

Cleanroom Pressurization Strategy Update—Quantification and Validation of Minimum Pressure Differentials when Using Auxiliary Devices (Part 2)

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This paper is based on findings resulting from ASHRAE Research Project RP-1344.

ABSTRACT

Pressurization technology utilized in cleanroom facilities is typically used to minimize airborne contamination from less-clean rooms into a cleaner room. Pressurization design has been traditionally based on intuitive suggestion instead of well-established guidelines. A pressure differential of 0.05 in. (12.5 Pa) as a single and uniform criterion is believed to be oversimplified for more complex conditions, such as when an auxiliary device is utilized inside a cleanroom.

As the second part of the research, the research team quantitatively evaluated the effectiveness of common auxiliary devices in room cleanliness control, such as a clean bench, a mini-environment, a containment hood, and a pressure stabilizer. It was found that some of these devices could contribute to a possible reduction in room cleanliness requirements, air change rates, or pressure differential values, while others may not. A summarized table is included as a general recommendation, along with the minimum pressure differential table listed in Part 1 of this research (Sun 2013).

INTRODUCTION

In Part 1 of this research, it was illustrated that not only the pressure differential (PD) but also the room airtightness impact the air leakage rate in a pressure-controlled room (Sun 2013). The overall air leakage rate (mathematical sum of all leakages) is the airflow offset value, which is the differential airflow rate between room incoming and leaving airflows. The lab testing further revealed that the particle exchanges from a dirtier room into a cleaner room are driven not only by pressure differential but also by particle concentration differential. The Part 1 research also concluded with an important table called "Minimum Pressure Differential (PD) Requirements Across Cleanroom Envelope," sorted by the cleanliness class difference. This PD Table was generated only from particle migration testing under pressure differentials and cleanliness class differences across a cleanroom envelope; microbial migration under these conditions was not in the work scope. This table is intended to replace the existing single pressure differential criterion.

In the second part of this study, barrier effectiveness of common auxiliary devices will be quantitatively evaluated in room cleanliness control. These auxiliary devices include a clean bench/mini environment, a containment hood, and a pressure stabilizer. These auxiliary devices are examined to see if some could reduce room cleanliness requirements, air change rates, or pressure differential values.

TEST DATA RESULTS, ANALYSIS AND FINDINGS

Test Floor Plan, Setup and Photos

Refer to Part 1 of this research for basic experiment setup, test devices, and equipment accuracies, etc (Sun 2013). Figure 1 shows the test lab configuration.

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Clean Bench/Mini-Environment Tests

Figure 2 illustrates some photos during clean bench tests, and Figure 3 indicates test results. The tested clean bench was manufactured for cleanliness per FS209 (IEST 1992). For air cleanliness at the physical center of the height, width, and depth of the clean bench: when the surrounding room is at class 1,000, 10,000 or even 100,000, whether at 0.5 or 1.0 µm particle size, there is no significant impact on the cleanliness inside the center of the bench. However, at 2 in. from front

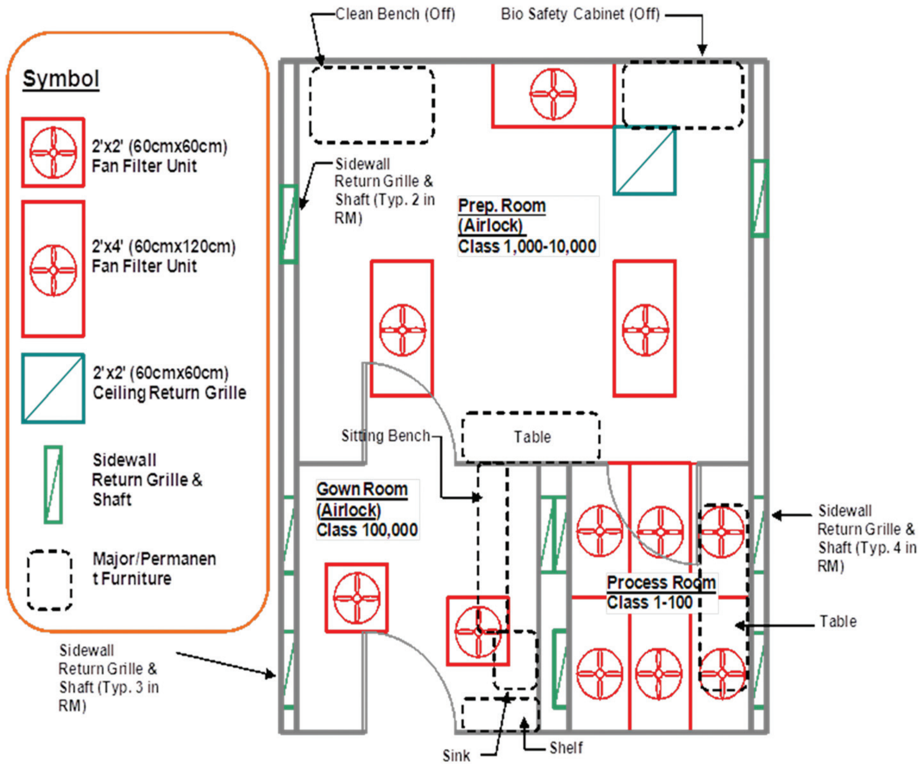
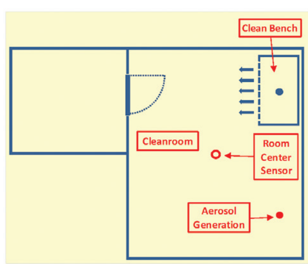


Figure 1 *Cleanroom test lab configuration.*



Clean Bench Test Floor Plan

Room concentration sensing is at center of room

Sensing point is at physical center of clean-bench.

Sensing point is at 2" above table surface, and 2" from clean bench edge.

Figure 2 *Photos during clean bench tests.*

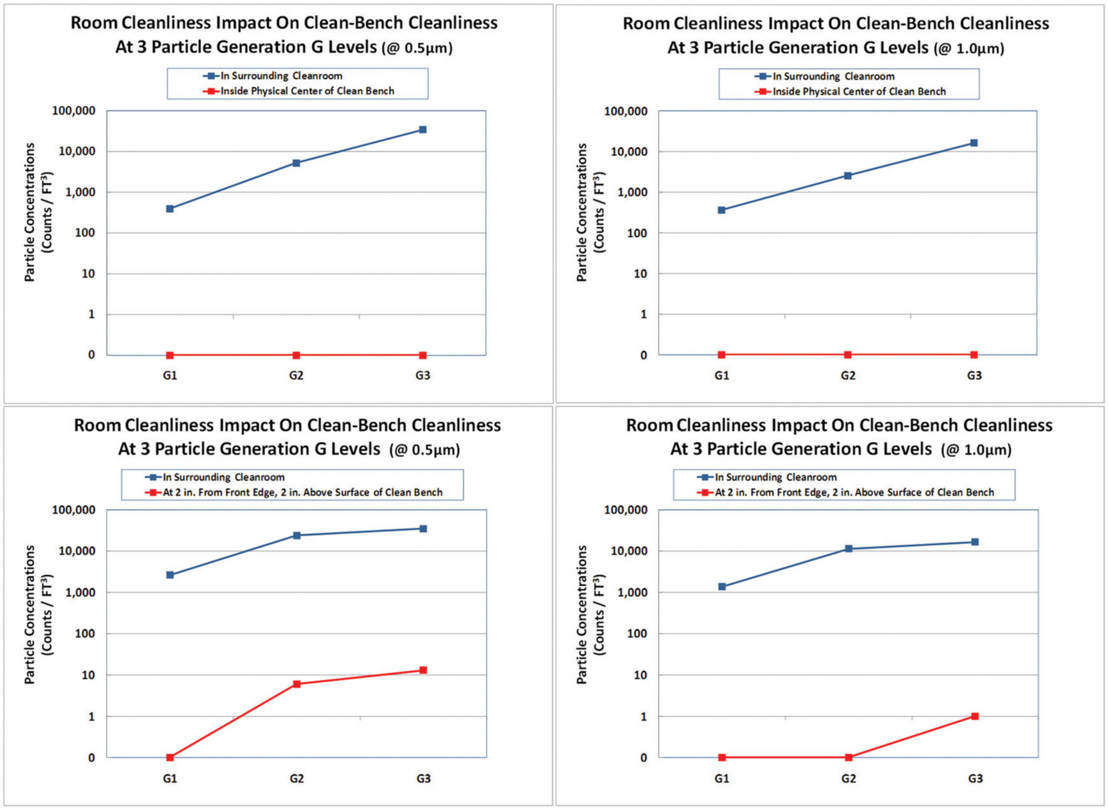


Figure 3 Clean bench/mini-environment test results.

edge, and 2 in. above surface of the clean bench (at the edge of the hood): when the surrounding room becomes dirtier than the class 100,000 level, especially for 0.5 µm particle size, there is a noticed increase in particle concentration and the cleanliness drops and is above class 10.

Room pressure differential impacts the room cleanliness directly, especially around the cleanroom door, while the remote impact on the clean bench is somehow not directly but secondary if the bench is not located near the door. The tested clean bench was located about ten feet away from the door.

In Part 1 of the study, it was found that 0.04 in. (10 Pa) is an adequate pressure differential to minimize particle migration from a less-clean corridor to a cleanroom (Sun 2013). If only a small zone needs a cleaner class, adding a clean bench, which is adding small clean zone inside a less-clean cleanroom, is a cost-effective solution. Like an airlock, which has at least two doors as barriers between corridor and cleanroom, a clean-bench or a mini-environment is also imposing a second barrier after the first barrier—the cleanroom door. Therefore, when a clean-bench or a mini-environment is used as the critical area and is not placed in the vicinity of the door, a positive 0.02 in. (5 Pa) pressure differential across the cleanroom door (first barrier) would be adequate.

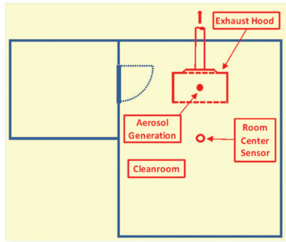
It is conservative to suggest that a room's cleanliness be maintained no more than two classes dirtier than the air cleanliness inside a clean bench, otherwise the room air could negatively impact the cleanliness inside the bench. Room pressure differential, in respect to the surrounding areas of the cleanroom, does impact the room cleanliness directly, but indirectly to the air cleanliness inside the clean bench.

Containment Enclosure/Hood Tests

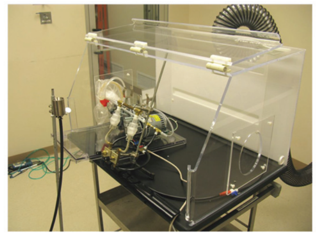
In these tests, a highly concentrated particle generation source was placed inside containment hood to examine the impact on the rest of the cleanroom concentration. Test conditions were as follows:

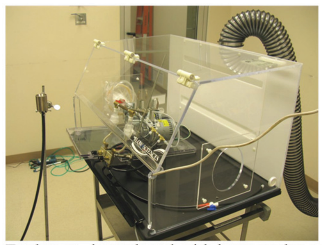
Table 1. Containment enclosure test procedures:

Test	Procedures
A	Generation off, sash open, exhaust fan off (background)
B	Generation on, sash open, exhaust fan off
C	Generation on, sash open, exhaust fan on
D	Generation on, sash closed, exhaust fan on



Containment enclosure test floor plan


Enclosure door opened


Enclosure door closed with bottom slot opened

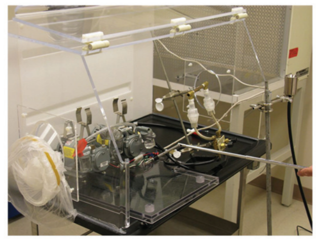

Hood face velocity measurement

Figure 4 *Photos during containment enclosure/hood tests.*

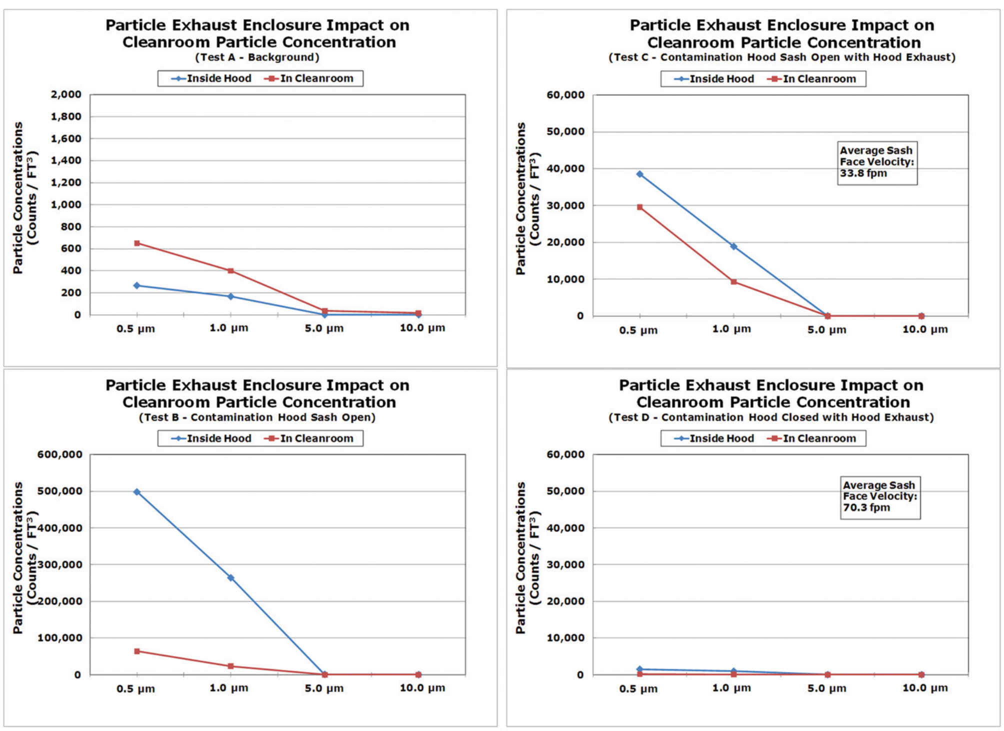


Figure 5 *Containment enclosure test results.*

Figure 4 illustrates photos during containment enclosure tests, and Figure 5 illustrates test results. A containment exhaust hood plays a significant role to lower room average particle concentration: when a particle generation source was placed inside an open enclosure that produces an equivalent of class 500,000 concentration (0.5 µm), the nearby room concentration could jump from initial 650 to 64,000 counts (0.5 µm). Obviously, to dilute the room concentration back to the 650 level would require much higher room airflow (higher air changes per hour [ACH]) and energy. Therefore, removal of particles from highly concentrated particle generation sources is critical and a cost-effective measure.

A small sash opening is required for any containment enclosure to provide makeup air for exhaust flow. However, the face velocity through the sash opening is also important. Under a constant exhaust flow, when the sash was moved down and face velocity became higher, room air was effectively isolated from contamination by the particles generated inside the enclosure.

For both 0.5 and 1.0 μm particle sizes, when the exhaust hood is placed to cover the particle generation source, nearby room particle concentration could be reduced about 50% to 60%. When the exhaust hood face velocity increased from about 34 to 71 fpm (10 to 21 m/min), the nearby room particle concentration was reduced over 99%, so it is desired to maintain a particle capture velocity at 70 fpm (20 m/min) or higher.

If a highly concentrated particle generation source exists inside a cleanroom, a containment exhaust hood can play a more significant role than the room pressure differential. However, if the opposite is true and the surrounding areas of a cleanroom are much dirtier than the major particle generation sources inside the cleanroom, then the room pressure differential plays a more important role and the capture hood may not be required.

Pressure Stabilizer Tests

Pressure stabilizer by nature is an adjustable automatic relief damper, it is a leakage regulator across a cleanroom envelope to maintain a much lower room pressure when a cleanroom door is opened for traffic. Table 2 lists the test procedures, Figure 6 illustrates photos during the test, and Figure 7 indicates test results.

In Concentration Test 1, particle counts at two locations are tested: one behind the cleanroom door (12 in. away), another below the relief damper (12 in. under). When the door opens, the relief damper instantly closes.

Even when the cleanroom is at positive 20 Pa as the initial condition, the area near the relief damper is dirtier than the area behind the door because the damper remains open when the door is closed. When the door starts opening, particles move quickly from the gown room into the preparation room, while particle concentration below the damper is getting lower since the damper is closing. Therefore, the damper opening during the door-closed position actually acts as an undesired leakage path that adversely impacts cleanroom particle concentration.

In Concentration Test 2, when the pressure stabilizer is blanked off and deactivated, concentrations inside the cleanroom at both near-door and near-damper locations become lower. In other words, deactivation of the pressure stabilizer in the very same cleanroom actually improves the cleanliness in the cleanroom. This is largely contributed form a higher room pressure differential since the damper is sealed, then the room leakage is reduced, and Δ P increases.

In Concentration Test 3, when the pressure stabilizer is deactivated, even when the cleanroom Δ P is reduced to its original level (20 Pa) at the same locations (near door and near stabilizer) and the concentrations are lower than these when the pressure stabilizer is activated.

The conclusion from the above three tests is that a pressure stabilizer is an ineffective device in terms of room pressure control and particle migration control in order to make a cleanroom less contaminated by sounding areas when a door opens.

CONCLUSION

Table 3 summarizes the findings and recommendations of Part 2 of this research, this table should be utilized in conjunction with the Δ P table in part 1 article of this research if any auxiliary device is used in a cleanroom (Sun 2013).

ACKNOWLEDGEMENT

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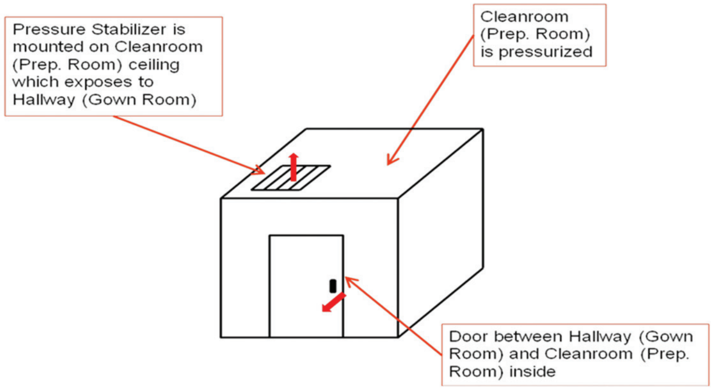
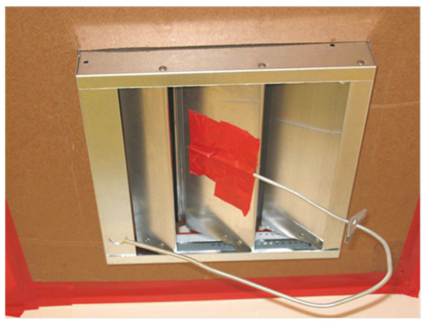
Table 2. Pressure Stabilizer Test Procedures

Test	Procedures	Conditions
1	Δ P set at 20 Pa across door to start, pressure stabilizer activated.	Pressure stabilizer (12 × 12 in.) is activated. It is mounted on room ceiling that is exposed to hallway when the stabilizer opens.
2	Pressure stabilizer sealed, Δ P across door naturally is increased to a higher pressure. (No leak through stabilizer.)	Pressure stabilizer blanked off to simulate no pressure stabilizer case.
3	Pressure stabilizer sealed, Δ P across door decreases back to 20 Pa by manually increasing return air (RA) value (No leak through stabilizer).	



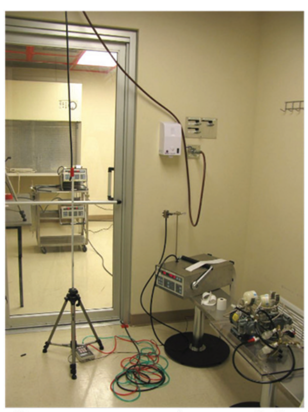
Pressure Stabilizer Test Plan



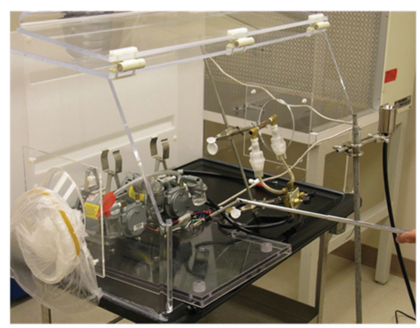
Test 1 Condition: Pressure Stabilizer (12"x12") is activated in operation. It is mounted on room ceiling which exposes to hallway. Door below also exposes to hallway when it opens.

Test 2 & 3 Conditions: Pressure Stabilizer is blanked off to simulate no pressure stabilizer case.

Inside Cleanroom (Prep. Room) tested



Gown Room is used for particle generation to challenge cleanroom when door is opened.



Particle generation maintained at the same level above the pressure stabilizer and outside the door.

Figure 6 *Photos during pressure stabilizer tests.*

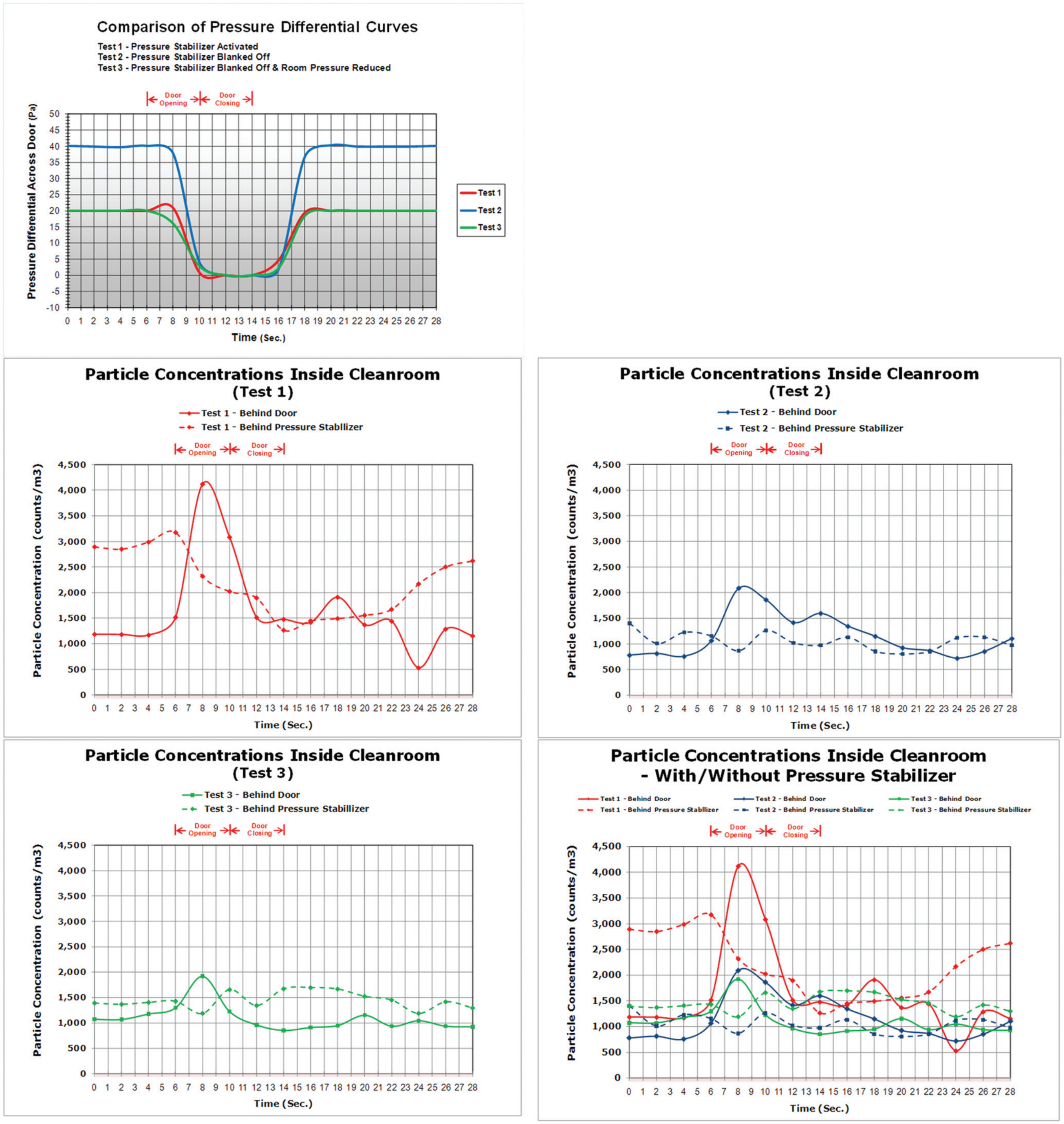


Figure 7 *Pressure stabilizer test results.*

Table 3. Benefits of Auxiliary Devices in Particle Contamination Control in Cleanrooms

Auxiliary Device	Possible Reduction of Room Cleanliness Requirement—ACH or ΔP
Clean Bench in Cleanroom	(1) Surrounding clean zones could be maintained at no more than two classes dirtier than the class inside the clean bench. (2) Minimum room Δ P could be reduced to 0.02 in. (5 Pa) if the clean bench is located at least 10 ft (3 m) away from the door. (3) Cleanroom ach could be reduced, case specific.
Mini-Environment in Cleanroom	(1) Surrounding clean zones could be maintained at no more than two classes dirtier than the class inside the mini-environment. (2) Minimum room Δ P could be reduced to 0.02 in. (5 Pa) if the mini-environment is located at least 10 feet (3 m) away from the door. (3) Minimum Δ P between the mini-environment and cleanroom is 0.02 in. (5 Pa). (4) Cleanroom ach could be reduced, case specific.
Containment Hood (Exhaust or Return with Filter) at Main Sources of Particle Generation in Cleanroom	(1) Surrounding clean zones could become cleaner. (2) Cleanroom ach could be reduced, case specific. (3) Follow the Δ P Table (in Part 1 article) for room Δ P requirement (Sun 2013).
Installation of Room Pressure Stabilizer	No reduction on room cleanliness requirement. No reduction on ACH or Δ P value.

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