

Air Shower Effectiveness in the Contamination Control Process

Arguments, test results and design features

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Abstract

The controversy over the use of air showers in the contamination control process has been ongoing for many years. In addition, the effectiveness of an air shower entry system relates directly to its proper design and use. This document discusses arguments for and against air showers, results of published test reports, and features to be considered in a properly designed air shower entry system.

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Introduction

A conventional air shower should only be incorporated within the design of an engineered cleanroom "entry system." For the purposes of our discussions, "entry system" is defined as a well designed garmenting area incorporating proper class identification, garment storage and garmenting procedures. Its overall goal is the prevention of particulate entering the cleanroom on garments or as a result of the garmenting process. An air shower is defined as an isolated chamber equipped with a self contained blower and motor, interlocking doors, hepa/ulpa filtration, and a recirculating exhaust system.

The features, functions, and benefits of an air shower entry system depend largely on its proper design and use. This paper concentrates on:

- A review of the proper air shower design features and operation to insure an operational and economic benefit
- An examination of the arguments of the supporters and critics of the use of air showers
- An analysis of recently published test reports

The information in this document is presented for the reader's evaluation and conclusion. Where appropriate, editorial comments are included. The ultimate goal is to provide information to assist in making an informed decision regarding the value of implementing an air shower.

Supporters

The most widely published supporter of the use of air showers in the contamination control process is John Nappi Jr. of Liberty Industries Inc., a manufacturer of air showers. In one article, Nappi is quoted as saying:

"The air shower is still a controversial issue in the cleanroom industry. Opponents of air showers argue that they only create turbulence that redeposits particles on other parts of the

clothing. Another argument is that the showers are not efficient in removing large particles. One factor that has helped promote this theory is the inefficient design and construction of various models."

Nappi continued, "A second factor is that showers are not used properly: Personnel try to avoid the airflow. Another factor is that there has been little published data measuring the actual reduction of contamination by use of an air shower. Tests of air shower effectiveness by researchers from industry, the military, a university professor and an independent health consultant show the contribution of air showers in reducing contamination."

It should be noted the tests referred to by Mr. Nappi show efficiency of 90% particle removal on particles 5-20 micron, 60-65% on loose lead oxides, and that the use of a two air shower particle removal system, one prior to the change room and one prior to the cleanroom is considerably more effective than one.

Non-supporters

Perhaps the most widely debated air shower evaluation test was performed at GEC Marconi Avionics in Edinburgh, Scotland by William Whyte from the University of Glasgow and Derek McGeorge from GEC Marconi Avionics.

In an article reviewing the evaluation, Whyte and McGeorge state:

"Although air showers are a common feature in industrial cleanroom facilities, their contribution to a successful particle control program has been questioned. In the study reported here, tests were carried out to determine the effectiveness of an air shower within a cleanroom suite. The particle dispersal rates from volunteers who had passed through or walked around outside of an air shower were measured in a test chamber, and it was found that the use of an air shower had no significant effect. Further tests showed that airborne particle counts within the cleanroom were not significantly effected by employees' use of the

air shower. Thus it was concluded that air showers have little value in reducing particle dispersion from cleanroom personnel."

In defense of air showers they go on to say further:

"Research has shown that air showers will remove particles from the surface of garments (referencing Nappi's test reports), but the cost-effectiveness of air showers as part of an overall contamination control program has been questioned."

It should be noted that within the article, Whyte and McGeorge make a statement which seems contradictory to their position:

"One factor that may have caused problems in appraising their effectiveness is that air showers also act as an airlock, preventing contamination from entering a cleanroom from an outer dirty area. In one report of a substantial reduction in the air contamination in a cleanroom when an air shower was used, the reduction was so large that one might reasonably doubt whether it could have been caused by the air showers function as an airlock, which may have prevented contamination from entering the cleanroom from the adjacent area..."

The question should be asked of Whyte and McGeorge is if they considered the costs of the air shower against the costs of the airlock that they recommend when making conclusions on the cost effectiveness of air showers?

Furthermore, Whyte and McGeorge made a fundamental judgment error within their test, assuming the air shower they characterize as:

". . .at least as efficient in removing surface particles from clothing as most other air showers and therefore particularly suitable for testing."

They concluded it was appropriate for testing, even though they note the air shower tested had "an unconventional design," thus confirming Nappi's contention that the inefficient design and construction of various models used for testing leads to the controversy.

To determine conventional air showers are not effective while using an air shower where "the cleaning action of the shower is not provided by air jets of the type normally found in air showers" seems to be somewhat unscientific and may only conclude that the air showers tested may not be effective.

Professor Stuart Hoenig P.E., Ph.D at the University of Arizona seems to agree with Whyte and McGeorge regarding the effectiveness of air showers, going so far as to state they are "worthless." That opinion seems somewhat contradictory to the findings of tests conducted under the supervision of Hoenig as detailed in Nappi's test reports. To be fair, the air shower tested by Hoenig and his staff was again not conventional, but modified to balloon the cleanroom garment to dislodge contamination trapped within the fabric. Hoenig's contention is that "much of the contamination comes from the treatment, and laundering of the garment" not the garmenting process; and therefore, an air shower designed to dislodge impregnated particles within the garment by ballooning the suit would be effective. It should be noted, Hoenig's testing was performed prior to the advancement of garment materials, and his findings do not address contamination added by air exiting the ballooned garment at the neck and wrist, which Hoenig discovered added significant contamination to cleanrooms in his "Semiconductor Manufacturing Facilities" article published Solid State Technology. Again, garment material technology, at least for class 10 (M2.5) and class 1 (M1.5) facilities, seem to address Hoenig's issues.

Proper Air Shower Design Features

Tests have been conducted and articles written that show air showers to be 35% to 90% efficient in the removal of contamination, with results dependent on particle size, air shower design, garment type, garment procedures, shower utilization technique, cycle time, and cleanroom classification.

It is important to not lose site of the fact that an air shower, if incorporated, should be part of an engineered entry system and is not designed as a watch dog to compensate for poor protocol. Rather it should be a tool to control contamination levels within the cleanroom, just as the garment itself should be considered. The garment is the item within the cleanroom that most frequently comes in close contact to the product.

Features which the authors believe should be part of a properly designed air shower include:

Filtration

Filtration, which is the guiding premise of cleanroom design, should not be overlooked in air shower design. It should not be assumed that air showers recirculate clean air, and therefore do not require filtration themselves. Air showers and cleanrooms should follow the basic concept of filtering and moving air to both remove contamination from the garment and extract the removed contamination from the environment. The use of ulpa filtration 99.9995% efficient @ .12 micron is suggested.

Proper Protocol

Proper protocol in using an air shower is a critical determinant of its effectiveness. Although not part of air shower design, it is a large factor in designing the cleanroom entry system. As is commonly accepted, training is of utmost importance in insuring reduced contamination levels in cleanrooms. In addition, it is of utmost importance in extracting maximum effectiveness from an air shower. Proper protocol suggests personnel should be trained to rotate continuously 360 degrees during the air shower cycle to insure contamination removal is as efficient as possible. Hands should also be placed on head while rotating.

Nozzles

Multiple points of impact during the rotating process will insure the garment is agitated during the act of air showering, thus creating the pulsating effect which will dislodge particulate.

The nozzles which deliver the air should be 3/4" to 1 1/2" in diameter, be distributed evenly throughout the walls and ceiling of the air shower, and be directed toward the marked spot where personnel should be rotating. As a rule of thumb, air should be delivered through 20 to 26 nozzles in a single person chamber.

Airflow

Minimum airflow should be between 6000 to 7500 feet per minute (fpm), or the equivalent to 60 to 90 miles per hour, to insure turbulent enough air to dislodge surface particulate from a cleanroom garment. There are studies that state advantages of higher velocities up to 12,000 fpm, and of velocities as low as 90 to 150 fpm which approach laminar airflow design levels. As neither of these alternative tests have been documented, it is not possible to evaluate their effectiveness. It is however suspected that airflow upwards of 12,000 fpm may be of substantial speed to actually impregnate particles on cleanroom garments. Low velocity air showers (90 to 150 fpm), although effective in preventing the infiltration of particulate into the cleanroom during the entering process by acting as more as an air lock than an air shower, will not however dislodge particulate which has settled on the garment. A rate of 6000 to 7500 fpm is widely accepted by air shower manufacturers as part of a design which incorporates multiple points of impact.

Cycle Time

Cycle time is considered to be the most critical aspect of air shower effectiveness. Studies suggest that a minimum of 20 seconds is required to properly remove contamination from garments. Studies also indicate that garments in the second and third day of use require longer air shower cycle times to remove contamination. These findings suggest a "smart" air shower design utilizing a real time clock and calendar to increase cycle time during the later stages of garment use. An air shower design utilizing particle count technology to control exit, could also provide significant benefit that could outweigh the additional cost.

Dwell Time

Dwell time designed into the air shower control system will insure that contamination removed by the unit is allowed to settle out upon completion of the air showering cycle. This prevents the removed contamination from being swept into the cleanroom by the turbulence caused during the door opening/entry process. Dwell time is defined as the period of time between the completion of the air showering cycle and the opening of the air shower exit door for entry into the cleanroom.

Constant Purge

Constant purge of an air shower during non-use periods is technology available, but not yet embraced by either air shower users or manufacturers. Constant purge is the continuous flow of low velocity air within the air shower, during down time to preventing settling of contamination. This settled contamination often gets swept into the cleanroom as personnel open and close air shower doors and walk through the contamination. Constant purge is a manufacturer's option which should be considered standard as its cost pales next to its benefit. Optimum effectiveness of constant purge is through vertical laminar airflow in the air shower's ceiling.

Flooring

Selection of the proper flooring within an air shower can benefit the control of contamination. Often, larger particles over 25 micron settle out of the air stream due to their size and weight. When possible, an air shower should be designed to sit on a raised access floor or utilize its own raised (grated) floor with clean out pan to allow contamination to settle out. At times, height restrictions, handicapped access and vibration issues require air showers to be utilized with non-raised floors. With this type of design, permanent type sticky flooring can be used to control particle migration. Several air shower tests have been conducted utilizing air showers which deliver air from the floor. At all times, it is suggested to utilize an air shower design with return air at or in the floor so gravity will act as

an aid to particle removal from the chamber. This design will alleviate the possibility of constant re-agitating of settled particles.

Door Interlocks

Door Interlocks are a design feature commonly utilized in air shower design, but in principal go against good contamination theory. Utilizing interlocks accepts the idea that personnel will not follow protocol training on air shower use, and instead restricts exit from the air shower until such time as the cycle and dwell times have been elapsed. Practicality suggests that interlocks should be utilized to insure protocol compliance, however, they should not be accepted as a replacement for proper training.

The Psychological Barrier

The integration of an air shower in the design of an entry system cannot be discussed without addressing the psychological barrier effect it delivers. The idea of passing through a chamber specifically designed to remove contamination that you bring into the room enforces the mindset that protection of the product from personnel is a significant concern. Although it cannot be quantified and a dollar value cannot be put on it, it should be a factor in the evaluation process. As always is the case with intrinsic value, it is difficult to debate either side of the argument.

Air Tunnel Technology

One of the most significant criticisms of air shower use is the time delay at shift change to get personnel through the shower and working. The delay, however, far outweighs the detriment that fifty people entering a cleanroom simultaneously could have on particle counts. Staggered breaks and shift hours have become part of cleanroom operating parameters to minimize square footage allotted to gown rooms. Air tunnel technology is evolving to help reduce the delays. Multiple person air showers are becoming more prevalent and even tunnels designed to shower personnel while walking

their length are being considered and utilized in state of the art cleanroom design. When designing multiple person air showers, a minimum of four feet in length should be designed for each person targeted to utilize the shower, per cycle. In a walk through tunnel design, optimum length for effectiveness is 32 feet to achieve acceptable contamination removal. Dimensions less than the above stated criteria will reduce air shower effectiveness and should be evaluated for cost benefit. In this instance a complete entry system technology concept should be utilized to achieve maximum effectiveness of gown room space and cost.

Conclusion

Even the most vocal critics agree that air showers have a degree of efficiency; however they question the cost effectiveness and the percentage of effectiveness. Most technologists also seem to agree that personnel are the largest contributors to contamination in cleanrooms and air showers contribute to contamination control. It also seems evident that air showers do not generate contamination.

The question seems to be, how much do they contribute and what is their contribution worth? If they remove that one particle that could destroy a semiconductor chip or contaminate a pharmaceutical batch, how much is that worth? The perception that air showers are costly or not cost effective may not hold up under this type of logic. Further, in the total scheme of cleanroom cost their inclusion in room design may not amount to a significant percentage. If they are viewed as a tool to control contamination the cost justification may not be so hard, especially if they can be utilized to incorporate less frequent garment changes. The cost to benefit ratio needs to be considered on a case by case basis.

Most tests reviewed, both supporting and disputing the use of air showers, are flawed due to the preconceived position of the party performing the tests. None prove conclusively

that air showers are either effective or ineffective.

A uniform test for air showers could standardize air shower comparison, create recognized design parameters, and allow further air shower development for enhanced effectiveness.

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