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The Effectiveness of Air Showers in the Contamination Control Process

By Timothy M. Loughran and Michael J. Shea

The controversy over the use of air showers in the contamination control process has been ongoing for many years. The effectiveness of an air shower entry system relates directly to its proper design and use. In recent years, tests have been conducted and articles written which show air showers to be 35 to 90 percent efficient in the removal of contamination dependent upon the size of the particle, the design of the air shower, garment type, garment procedures, shower utilization technique, cycle time, and cleanroom classification.

A conventional air shower should only be incorporated within the design of an engineered cleanroom "entry system." For the purposes of this article, an "entry system" is defined as a well-designed garmenting area incorporating proper class identification, garment storage, and garmenting procedures, with the overall goal being 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. Within the following pages we will concentrate largely on the air shower and its proper design to ensure it delivers an operational and economic benefit.

PROPER AIR SHOWER DESIGN FEATURES

Let`s not lose sight 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. However, it is a tool to control contamination levels within the cleanroom, just as the garment itself should be considered. At all times we must remember, the garment is the tool within the cleanroom which comes in closest contact, and in contact must often, to the product.

The authors believe that a properly designed air shower should include the following features.

Filtration. It is the guiding premise of cleanroom design and should not be overlooked in air shower design. It should not be assumed that air showers recirculate clean air, therefore they do not require filtration themselves. Air showers, as cleanrooms, should follow the basic concept of filtering and moving air–to both remove contamination from the garment and extract the removed contaminant from the environment. The authors suggest the use of ULPA filtration–99.9995 percent at 0.12 microns.

Proper Protocol. The proper protocol in using an air shower weighs greatly on its effectiveness. Although not part of an air shower design, it is a large factor in designing the cleanroom "entry system." As is commonly accepted, training is of utmost importance in ensuring reduced contamination levels in cleanrooms, additionally it is of utmost importance in extracting maximum effectiveness from an air shower. Proper protocol suggests personnel should be trained to rotate 360 degrees continuously during the air shower cycle to ensure contamination removal is as efficient as possible. For further effectiveness, hands should be placed on head while rotating.

Multiple points of impact. Multiple points of impact during the rotating process will ensure 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 within the air shower, should be 3/4 to 11/2 inches in diameter, be distributed evenly throughout the walls and ceiling of the air shower, and directed toward the

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marked spot where personnel should be rotating. As a rule of thumb, air should be delivered through between 20 to 26 nozzles in a single person chamber.

Airflow. As a minimum, airflow should range between 6,000 to 7,500 feet per minute (fpm), or the equivalent of 60 to 90 mph, to ensure that the air is turbulent enough to dislodge surface particulate from a cleanroom garment. There have been studies done which proclaim the advantages of still higher velocities, that of up to 12,000 fpm, and of lower velocity, as low as 90 to 150 fpm which approach laminar airflow design levels. As neither of these alternative tests have been documented, the authors could not evaluate the tests` effectiveness; however, it is their opinion that airflow upwards of 12,000 fpm may be of substantial speed to actually impregnate particles on cleanroom garments. In addition, lower velocity air showers (90 to 150 fpm) although effective in preventing the infiltration of particulate into the cleanroom during the entering process, (acting more as an air lock than an air shower) will not dislodge particulate which has settled on the garment. It should be noted that the 6,000 to 7,500 fpm rate is suggested as part of a design which incorporates multiple points of impact and is widely accepted by air shower manufacturers.

Cycle time. This is considered to be the most critical aspect of air shower effectiveness. Studies have suggested that a minimum of 20 seconds is required to properly remove contamination from garments. More intriguingly, our own studies tend to indicate 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 using a real-time clock and calendar to increase cycle time during the later stages of garment use. Or better yet, an air shower design utilizing particle count technology to control exit would probably produce a benefit which far outweighs the additional cost.

Dwell time. If designed into the air shower control system, dwell time will ensure that contamination removed by the unit is allowed to settle out upon completion of the air showering cycle. This helps prevent removed contamination from being swept into the cleanroom with the turbulence caused during the door opening/entry process. Dwell time is defined as the period of time between completing the air showering cycle to opening the air shower exit door and entering the cleanroom.

Constant purge. The technology is available to constantly purge an air shower during its non-use periods. However, this technology is not yet embraced by either air shower users or manufacturers. Constant purge is the continuous flow of low velocity air–during down time within the air shower–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, and its cost pales next to its benefit. Optimum effectiveness of constant purge is through vertical laminar airflow in the air shower`s ceiling.

Selection of the proper flooring. Using the proper flooring in an air shower can benefit the control of contamination. Often times larger particles (over 25 microns) settle out of the airstream 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 we suggest the use of a permanent-type sticky flooring which will control particle migration. It should be noted that several air shower tests have been conducted utilizing air showers which deliver air from the floor. At all times we suggest an air shower design that uses return air at or in the floor to utilize gravity as an aid to particle removal from the chamber. This design will alleviate the possibility of constant re-agitating of settled particles.

Door interlocks. These are features commonly used in air shower design, but in principal go against good contamination theory. Using door interlocks in an air shower design implies that personnel will not follow protocol training on air shower use. Instead, restrict exits from the air shower until such time as the cycle and dwell times have been elapsed. For practical purposes interlocks should be utilized to ensure protocol compliance; however, they should not be used as a replacement for proper training.

AIR SHOWER TUNNEL TECHNOLOGY

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One of the most significant criticisms of air shower use is the time delay that occurs at shift change. It is at this time that personnel must move through the shower and get to work; however, the delay in entry far outweighs the detriment 50 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. Multi-person air showers are becoming more prevalent. Even tunnels designed to shower personnel appropriately, while walking its length, are being considered and utilized in state-of-the-art cleanroom design. When designing multi-person air showers, a minimum length of four feet per person should be designed-in 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.

THE AIR SHOWER TEST

Recently, Dryden Engineering (Fremont, CA) was commissioned to review test procedures and to perform testing of air shower effectiveness. The purpose of the test was to determine the effect of air shower protocol and particulate removal on cleanroom garments. Utilizing Dryden`s QIII surface particle counter, we attempted to quantify air shower effectiveness by means not available during previous air shower tests. The purpose of the test was not to prove the viability of air shower effectiveness but more to quantify its effectiveness.

THE PROCEDURE

The test utilized a 4-ft (W) X 5-ft (L) air shower. The air shower was equipped with adjustable, high velocity nozzles, and constant purge during non-active showering periods. Tests were performed at Dryden Engineering (Fremont, CA) where the air shower was integrated with Dryden`s Class 10 test facility, to minimize the effect of results by uncontrolled events.

Two conditions of two types of garments were tested: clean garments removed from their package at test time, and contaminated garments left sitting in an uncontrolled area prior to testing. Tests were performed on a Gortex and hybrid polyester-type garment. A single test operator, trained in proper garmenting and air shower protocol was utilized, to control the variable of garment soiling during the garmenting process and procedural differences during testing. The operator utilized a clean Gortex inner garment under the test garments to control particulate generated during the garmenting process. The operator then wore the test garment over the inner garment. An appropriate hood, Dryden “Shield” system, booties, and clean latex gloves were used during testing, and changed for each test.

Baseline test data of the air shower was taken prior to testing to establish its proper design and operation.

TEST MEASUREMENTS

To determine optimum cycle time, the test shower was equipped with a Gorpler aerosol sampler located in the return air chase. Aerosol samples were measured at 11 second intervals measuring one-sixth of a CFM per sample. The operator entered the air shower and completed a predetermined cycle (15 seconds). At the end of a cycle, the particle counter measured and recorded the particle count. The cycle was repeated until no significant particle reduction was recorded.

To determine particle removal effectiveness, the garments were tested using the surface particle counter (measuring particles 0.3 microns and larger), prior to the a cycle time test, and immediately upon the exit from the air shower upon completion of the cycle time test. Surface particle tests were taken in four identical locations (chest, arm, thigh, and knee) on each garment. The test procedure was performed a total of 24 times, six tests were performed, on six separate garments, for both the clean and soiled garment types of the Gortex and polyester-type garments.

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TEST RESULTS

1. The garment laundering process is determined to be effective in removing contamination from cleanroom garments as evidenced by the QIII surface particle counts on freshly laundered garments.

2. Results from air sampling tests determined that the optimum time required to reduce significant contamination–0.1 microns or larger in size–from entering the cleanroom during the entry process is 30 seconds. Additional time does not offer a significant benefit. In addition, the use of a purge cycle (low-speed air circulation through the air shower prior to personnel exit) will significantly reduce migration of particles on both new and soiled garments into the cleanroom after the air shower cycle. This conclusion is evidenced by the results of the Gorpler tube tests.

3. Results from surface particle tests show that air showers are effective at removal of particulate on soiled/used garments. Average particle reduction was between 56 percent (polyester) to 62 percent (Gortex) effective in the removal of contamination of 0.3 microns and larger.

Air showers are an effective tool in the prevention of contamination from migrating into the cleanroom during the entry process. If garment usage is greater than one change per entry into the cleanroom, an air shower will be a significant tool in removing contamination from garments and controlling contamination from entering the cleanroom. Without a purge and dwell time, an air shower`s significance in controlling the migration of particles–removed from soiled garments–from entering the cleanroom, will be greatly reduced.

CONCLUSION

Most technologists 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 don`t generate contamination. The only question seems to be how much do air showers contribute to the contamination control process 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? Are we playing the particle dilution game, or trying to keep every particle possible from reaching our process? If $4,000,000 worth of semiconductor chips fit in an average briefcase, what is that one particle 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 not supporting 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.

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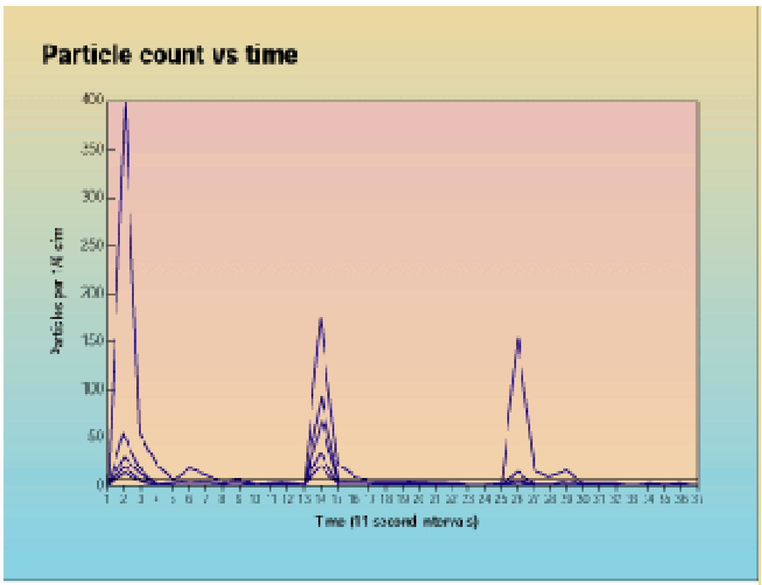

Shown are the results of particle counts from aerosol samples taken at 11-second intervals measuring one-sixth of a CFM per sample during the air shower test.

Courtesy of

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