Advances in Balance Enclosure Technology Bring Safety Enhancements to the Pharmaceutical Industry

Abstract

The Pharmaceutical Research and Manufacturers of America reports its members spent an estimated $33.2 billion on researching and developing new medicines and introduced 35 new medicines and 51 additional drugs in 2003 alone.[1] Prescription drug development continues to increase in importance. Pharmaceutical, biotechnology, chemical and healthcare companies are involved in the effort to identify new compounds that will ultimately become the drugs of tomorrow. To find appropriate methods for handling and weighing toxic compounds while minimizing exposure among workers developing and producing these advanced medicines, scientists rely on industrial hygienists and environmental health and safety officers.

Because laboratory workers risk exposure to many toxins and suspected carcinogens, engineering controls and safe work practices should be used to reduce worker exposure as much as possible.[2] Rapid advancements in biotechnology and pharmaceutical research mean companies shoulder the constant challenge and responsibility of protecting workers using and measuring toxic agents in dynamic laboratory environments. This paper investigates the challenges inherent in using current laboratory containment equipment to safeguard workers handling powdered toxic substances, and the opportunities provided by new solutions designed to better protect workers.

Labconco XPert™ Balance Enclosure

Current Solutions

Traditional Fume Hoods

Laboratory fume hoods provide a safe ventilated environment for handling toxic vapors and fumes. These enclosures contain toxic vapors and fumes, direct airflow away from the operator and remove contaminants through an exhaust system. Fume hoods are powered by exhaust blowers that pull air from the laboratory room into the hood. In the hood chamber, contaminated air is diluted with room air before being exhausted through an exhaust system to the outside. Used properly, fume hoods effectively contain hazardous fumes and minimize worker contact with potentially harmful substances.

However, traditional fume hoods are less effective in meeting user requirements when measuring fine toxic powders with a propensity to become airborne. Factors that impact the ability of traditional fume hoods to reduce worker exposure when weighing and dispensing powders include:

Airflow Velocity. *Industrial Ventilation: A Manual of Recommended Practice* recommends laboratory hood ventilation rates of 60-100 fpm.[3] The higher the air speed, the greater the probability that balances, instruments, fragile apparatus and the materials being measured will be disturbed.

Filtration. Fume hoods offer little or no environmental protection from particulate contamination. Typical chemical fume hoods exhaust air via ductwork to the outside, where fumes and vapors are diluted to acceptable levels of concentration. With toxic powders, ANSI/AIHA Z9.5 guidelines require a secondary air-cleaning device, such as a HEPA filter, to control particulate contamination.[4]

Fume hoods, such as Labconco's Protector® Premier® Laboratory Hood shown above, are designed to exhaust vapors and fumes and often include built-in accessories such as service fixtures and electrical receptacles.

Performance and safety are not the only arguments for an alternative solution. The costs associated with utilizing large chemical fume hoods for precise weighing operations also require consideration. These costs include the following:

> ***Initial costs.*** While a traditional 4' hood has an average price of approximately $5,000, the hood itself is just one component of a fume ventilation system. Accessory expenses include blowers, ductwork, electrical, plumbing and mechanical installation costs. Once all accessory and ancillary components are determined, a certified crew must be contracted to install the system before final operating validation can be completed.

> ***Ongoing energy costs.*** A typical 4' wide fume hood with a 28" high sash opening exhausts approximately 735 cubic feet per minute of air when operated at 100 fpm. Using a conservative estimate of $4.00 to heat or cool a cubic foot of air, the cost per year to operate a 4' hood, 24 hours per day, 5 day per week, is $2750/year.

Because traditional fume hoods generally exceed the size necessary for weighing operations, they are not an economically viable or efficient mechanism for weighing and dispensing toxic powders, an essential operation in many pharmaceutical and biotechnology laboratory operations.

Conventional Balance Enclosures

Since the early 1990's, various manufacturers have introduced "balance enclosures" that address some of the shortcomings of traditional fume hoods. Designed specifically for applications in pharmaceutical, biotechnology and compounding laboratories, balance enclosures provide maximum containment of airborne particulates during weighing procedures, offering an economical and effective solution. In general, design components found on this relatively new type of task-specific enclosure include:

> ***Smaller dimensions.*** Since balance enclosures are designed specifically for weighing operations, they do not require the height or width of a traditional fume hood. Most balance enclosures range from two feet to four feet in width compared to fume hoods, which are usually a minimum of four feet wide. In addition, the sash opening is generally of a smaller fixed height. As a result, these enclosures offer greater installation flexibility, require less bench space and use less energy.

> ***Filtration mechanism.*** Balance enclosures use a HEPA, carbon or a combination of filters to remove toxic particulate and/or gaseous contaminants from the exhaust air. Many of these enclosures duct the filtered exhaust air back into the laboratory instead of to the outside, thus saving energy and installation costs.

> ***Lower face velocities.*** To reduce the influence of airflow on sensitive balances, manufacturers recommend that balance enclosures be operated at the lower end of the 60-100 fpm range recommended for a typical fume hood. Besides less air turbulence, lower face velocities reduce the volume of air exhausted from the laboratory, thus saving energy.

> ***Limited electrical and plumbing.*** Costly components such as gas and water service fixtures, lighting and electrical outlets are generally not found on balance enclosures since space is limited and services, especially gas or water, are not needed for powder weighing operations. Installation is less complicated and less expensive than a traditional fume hood.

With the many advantages balance enclosures have over traditional fume hoods, considerations still exist. A variety of conditions affect the performance of the equipment in providing accurate weighing and containment that promotes worker safety.

> ***Static.*** Static becomes a problem in balance enclosures when static charges exist in the materials of construction, the substance being weighed, on the person using the balance, on draft shields or in weighing vessels. Static electricity negatively affects weighing operations in several ways. First, static electricity exerts a force, which is readily detectable by analytical and micro balances, affecting their precision. Second, static can result in loss of sample or inaccurate readings if the sample clings to vessels. Third, static can be a safety concern if hazardous powders that cling to the surfaces of the enclosure are left behind when the enclosure is not operating. Finally, static can lead to cross contamination of samples if sample is left behind.

> Sources of static include carpets, plastic draft shields, plastic weighing vessels, and Formica* table tops.[5] Impurities within the air impinging upon surfaces dictate the polarity and magni-

**Formica® is a registered trademark of Formica Corporation.*

tude of the electrostatic charge. The ability of a material to become polarized is a property known as permittivity. On highly insulative materials, like acrylic, ions or charged molecules are strongly bound to the surface by polarized forces. The higher the force, the higher the permittivity value of the material. High permittivity materials, such as plastic, hinder the accuracy of the balance.

Since static electricity is a surface phenomenon, materials can also be classified by their surface resistivity, measured in ohms per square. Figure 1 indicates the surface resistivity of various classes of material and demonstrates the materials most likely to retain a charge, potentially impacting balance precision.

Figure 1

Surface Resistivity Table

Material	Surface Resistivity	Example
Conductive	$0 - 10^5$ Ω per sq.	Skin, Metals
Static dissipative	$10^5 - 10^9$ Ω per sq.	Glass
Antistatic	$10^9 - 10^{12}$ Ω per sq.	Polyethylene bag
Insulation	$\geq 10^{12}$ Ω per sq.	Acrylic box, Packing foam, Styrofoam

Since static electricity is a surface phenomenon, materials can be classified by their surface resistivity measured in ohms per square. Figure 1 lists the surface resistivity of various classes of material. Glass and metal has less surface resistivity than acrylic.

Low ambient humidity intensifies static problems. Maintaining relative humidity levels between 45 and 60% assists in minimizing static.[6]

Vibration. Balances also exhibit sensitivity to vibration. Vibration can stem from instability in the work surface, equipment in the laboratory or even movement in the building. While advanced balances offer improved reliability, minimizing vibration can be accomplished by using rigid and stable work surfaces and attaching the bench to the floor or wall, but not both to avoid simultaneous transmission of vibrations from wall and floor. Tubular stands or carts that have the potential of moving when touched should be avoided. Also consider that the corners of a building typically have less vibration than the center. Within the balance enclosure, marble, granite or epoxy balance slabs provide additional protection from vibration.[7]

Temperature. Except for balances with temperature compensation, the accuracy and overall performance of most laboratory balances are affected by the room temperature. For best stability and performance, the room temperature should be regulated to within 1° F without interruption.[8] Minimizing the potential for temperature variations can be achieved by installing balances away from heat sources, and avoiding incandescent lighting and exposure to direct sunlight. Sample and room temperatures should be nearly equal so that thermal drafts are not created within the draft shield.[9]

Laboratory currents. Moving air and currents within the laboratory can affect a balance reading and require positioning the balance enclosure away from high traffic areas, HVAC diffusers, fans, radiators or other lab equipment producing air currents, or next to doorways or windows that may open.

Exhaust system performance. There are several laboratory standards guidelines widely used today to provide directions on exhaust system performance required for laboratory enclosures. Recommended average laboratory fume hood face velocities range from 60 to 100 fpm, with no face velocity measurements more than plus or minus 20% of the average.[10] Although dependent on application and safety officer recommendation, balance enclosures are most commonly operated at 60 to 80 fpm. Options to connect to the house exhaust system or use a filtered portable exhauster depend upon the properties of the materials being weighed and room design.

Operator practices and technique. The training and work practices of the professional using the conventional balance enclosure also play a role in the safety enclosures provide. Both ANSI/AIHA Z9.5 and Prudent Practices recommend safe work practices to contain toxic agents in the laboratory and warn against leaning into the hood, blocking airflow, incorrect use of the sash, and frequent and rapid opening and closing of the sash while working in the enclosure.[11] In addition to proper use of the enclosure, the operator's weighing techniques greatly impact the level of containment.[12]

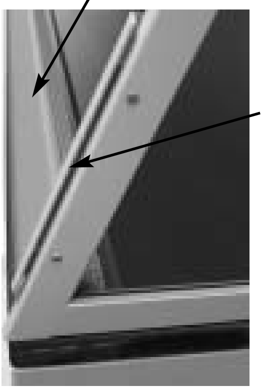
Evolving Solutions

Labconco XPert™ Balance Enclosure

Balance Enclosure Advancements

Recent advancements in balance enclosure design have resulted in products with high performance features that provide greater containment capabilities and safety for workers when compared to conventional balance enclosures used in pharmaceutical applications. For example, the XPert™ Balance Enclosure by Labconco Corporation offers features designed to direct airflow and provide enhanced containment to minimize worker exposure to contaminants. These features include:

Patented* aerodynamic air foil with Clean-Sweep™ openings. The low-profile shape of the air foil allows air to sweep the work surface by creating a constant protective barrier from contaminants. Should the operator inadvertently block the airflow entering the air foil, air continues to pass under the foil and through the Clean-Sweep openings, providing maximum containment.



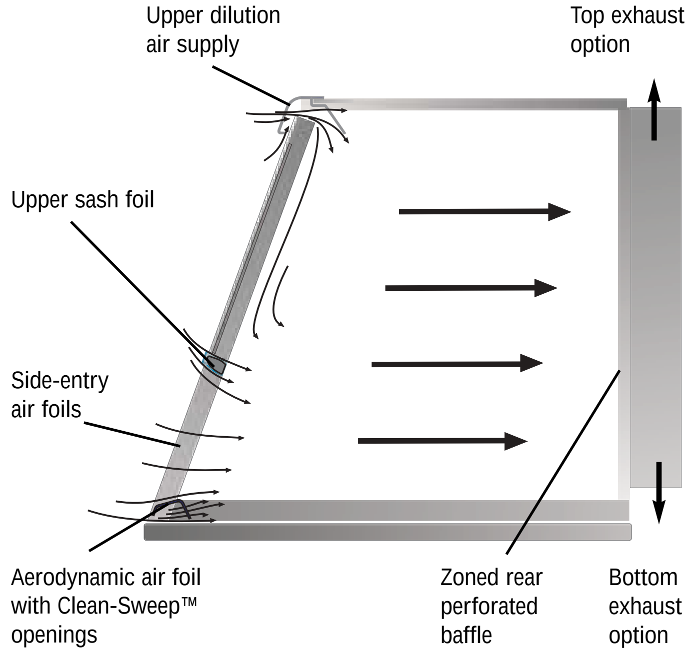
Side-Entry Air Foils. Air enters the enclosure through these foils, creating turbulence-free clean air that sweeps the interior sidewalls of the enclosure.

Upper Sash Foil. The air passage directly atop the sash foil bleeds air into the hood chamber and directs chemical and powder concentrations away from the sash opening. The radiused design of the sash foil sweeps airflow into the enclosure with minimal turbulence.

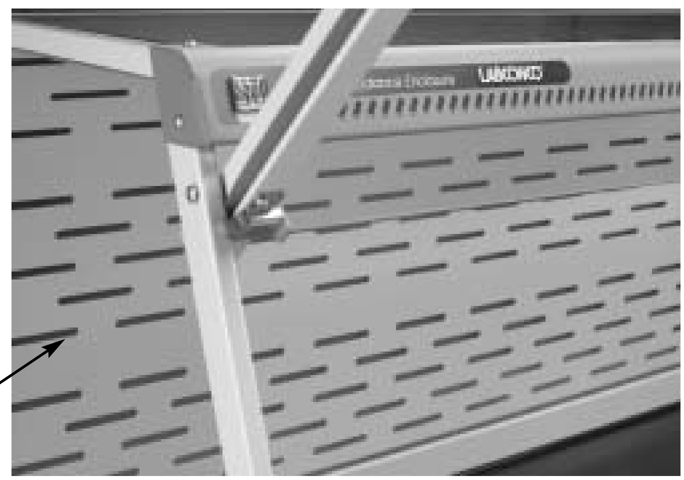
View from the top of the XPert Balance Enclosure showing the upper dilution air supply openings

Upper Dilution Air Supply. This feature introduces air from above the work area, which constantly bathes the sash interior. This greatly reduces powders and chemical fumes along the back of the sash and provides maximum containment away from the critical breathing zone of the user. It also diminishes stagnant pockets of air in the upper interior.

Patented* Zoned Rear Perforated Baffle. In traditional enclosures, there is a tendency for contaminants generated in the interior to roll forward creating the potential for high concentrations of contaminants behind the sash in close proximity to the user's breathing zone. The design of the XPert Balance Enclosure counteracts this tendency for "roll" or "vortex" by directing laminar-like air streams horizontally to the three zoned sections of the perforated baffle; air sweeps through the enclosure in a single pass. The lower section of perforations provides more airflow at the bottom to help form the directional airflow, minimizing the potential for air to roll forward, and keeping contaminated air from moving toward the sash opening.



This side view illustration shows the various containment-enhancing features working together to promote direct airflow toward the baffle and away from the operator.



The baffle has perforations in three zones to direct airflow in laminar-like streams from the face of the enclosure to the baffle.

The solid construction and other features provided by the XPert Balance Enclosure offer additional advantages. The epoxy-coated aluminum and steel framework provides corrosion resistance, stability and durability. Tempered safety glass sides and sash dissipate static, resist scratching, crazing and discoloration and simplify cleaning. The enclosure is fire resistant and appropriate for solvent use.[13] The internal dimensions accommodate analytical and micro balances, such as those manufactured by Mettler-Toledo,[14] making weighing procedures simpler and more efficient and providing additional safety for workers.

**U.S. Patent No. 6,461,233*

Use with FilterMate™ Portable Exhauster

The XPert Balance Enclosure was designed to be ducted to the outside or to be connected to the FilterMate Portable Exhauster. The FilterMate Portable Exhauster comes in models that use a HEPA filter for filtering particulates, a carbon-based filter for filtering vapors or fumes, or a combination of both filters. Models for use with a HEPA filter have a true bag-in/bag-out filter disposal system for safely removing and replacing the filter without detaching the hose. The FilterMate provides up to 100 fpm face velocity for the XPert Enclosure and only one FilterMate is needed for any 2', 3' or 4' XPert.

Other XPert models, called XPert Filtered Balance Enclosures, include a HEPA filter mounted within the upper chamber. These enclosures also incorporate the true bag-in/bag-out filter disposal system and may be ducted to the outside or back into the laboratory.

The XPert Balance Enclosures is shown connected to the FilterMate Portable Exhauster by a flexible hose. Use of a telescoping base stand is not recommended when using balances sensitive to vibration.

Validated Performance

Independent ASHRAE 110-1995 testing, conducted by ECT, Incorporated, Cary, North Carolina, concluded that the XPert Balance Enclosure maintained containment at face velocities greater than 50 fpm. Average concentrations during tracer gas tests were less than 0.05 ppm and no escape was observed during the smoke tests.[15] With acceptable containment as low as 50 fpm, the minimum recommended face velocity of 60 fpm provides an additional margin for safety. Per Labconco's recommendations, the airflow monitor equipped with the XPert Balance Enclosure should be utilized to alert the user when velocities fall below set value.

During the independent ASHRAE 110-1995 testing, tracer gas in the breathing zone of the mannequin was less than 0.05 ppm at face velocities 50 fpm and greater.

Additional independent tests specifically address the ability to contain the airborne powders found in pharmaceutical laboratory environments. An industrial hygiene air-monitoring study, conducted by SafeBridge Consultants, Incorporated, Mountain View, California, validated the design and performance of the enclosure, confirming its ability to provide excellent containment of naproxen sodium.[16] Naproxen sodium, a non-potent active pharmaceutical ingredient, was selected as the surrogate for the study because it is safe to handle, readily detectable in air at low concentrations, has a high dustiness quotient and challenging electrostatic properties. The study was designed to assess potential exposure to airborne concentration of naproxen sodium for three operators of varying skill levels and physical statures. More importantly, it was to assess the containment performance of the XPert Enclosure relative to the likely concentrations of the surrogate generated by weighing and dispensing tasks at the access opening. Test results showed a personal exposure of 23 ng/m^3 when the enclosure operated at 78 fpm face velocity. The XPert Balance Enclosure demonstrated excellent containment when used by an operator

SafeBridge Consultants tested a 3' XPert Balance Enclosure's ability to contain airborne powders and found personal exposure to airborne concentrations of naproxen sodium was 23 ng/m^3.

using excellent technique and good containment when used by an operator using marginal technique. While no enclosure can compensate for improper technique, these tests confirm that the XPert Balance Enclosure provides a safe work environment.

Cost Benefits

There's no question that balance enclosures provide cost-saving benefits to laboratory operations. In addition to its smaller footprint and limited air volume requirements, compared to traditional fume hoods, the XPert Balance Enclosure offers the additional benefit of fitting over existing work surfaces, requiring only a level laboratory bench of solid construction.

The XPert Balance Enclosure has lower exhaust volumes ranging from 70 to 250 CFM compared to a typical 4-foot fume hood with exhaust volumes of 440 to 735 cfm [Figure 2, Exhaust System Tables], These lower volumes add up to substantial energy savings. For example, a 4' XPert Balance Enclosure operating at 80 fpm uses 200 CFM of air volume. Again using a conservative estimate of $4.00 to heat or cool a cubic foot of air, the cost per year to operate a 4' XPert Balance Enclosure, 24 hours per day, 5 day per week, is $800/year. Compared to operating a 4' fume hood at 100 fpm using 735 CFM, the XPert saves $1950 per year in energy costs. The savings increase further when the XPert Balance Enclosure is operated at face velocities lower than 80 fpm.

Figure 2
Exhaust System Tables

XPert Balance Enclosures, 22.75" high

Enclosure Description	Face Velocity (fpm)	Exhaust Volume (CFM)	Static Pressure (w.g.)
2' XPert	60	70	.02"
	80	95	.03"
	100	120	.05"
3' XPert	60	110	.04"
	80	145	.06"
	100	185	.10"
4' XPert	60	150	.06"
	80	200	.10"
	100	250	.16"

Traditional Fume Hoods, 59" high

Enclosure Description	Face Velocity (fpm)	Exhaust Volume (CFM)	Static Pressure (w.g.)
3' Benchtop	60	300	.06"
Fume Hood	80	400	.12"
	100	500	.22"
4' Benchtop	60	440	.03"
Fume Hood	80	590	.09"
	100	735	.18"

Conclusion

Significant engineering developments by Labconco have resulted in an enclosure that offers the advantages of superior airflow combined with other features that dissipate static and minimize turbulence to enhance overall safety. Specifically, the XPert Balance Enclosure:

- Has patented containment-enhancing features that permit safe operation at face velocities as low as 60 fpm.

- Uses glass and metal channel construction, which is scientifically proven to minimize electrostatics in comparison to acrylic.

- Accommodates the balances and accessories of industry-leading suppliers, providing airfoil clearance necessary for proper airflow.

- Works with the companion FilterMate Portable Exhauster to offer HEPA filtration, carbon filtration or combination HEPA/carbon filtration and air circulation.

Conventional balance enclosures provide effective containment of airborne particulates and energy savings in comparison to traditional fume hoods. However, advancements in balance enclosure technology mean new enclosures like the Labconco XPert Balance Enclosure offer even more benefits, including superior containment and materials of construction in a cost-effective solution designed specifically to protect laboratory workers in pharmaceutical, biotechnology and related research.

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[2] NIOSH, "Health Care Workers Guidelines," Chapter 3b.

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[4] ANSI/AIHA Z9.5, p 6, section 4.10.2; ASHRAE Handbook p.12.9; Industrial Ventilation-ACGIH, pp 7 -20 "Industrial Exhaust Recirculation"; Prudent Practices, p.192

[5] Douglas Morse, BS and Daniel M. Baer, MD, "Laboratory Balances: How They Work, Checking Their Accuracy," *Laboratory Medicine*, Issue One, 2004, www.labmedicine.com/2004/Issue_01/1000937.pdf

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