INEEL/CON-98-00660
PREPRINT

Improved HEPA Filter Technology for Flexible and Rigid Containment Barriers

Paul Pinson

July 15, 1998 – July 17, 1998

American Glovebox Society 1998 Conference

Paul Pinson
Idaho National Engineering and Environmental Laboratory (INEEL)
Lockheed Martin Idaho Technologies Co. (LMITCO)
Idaho Falls, ID 83415

IMPROVED HEPA FILTER TECHNOLOGY FOR FLEXIBLE AND RIGID CONTAINMENT BARRIERS

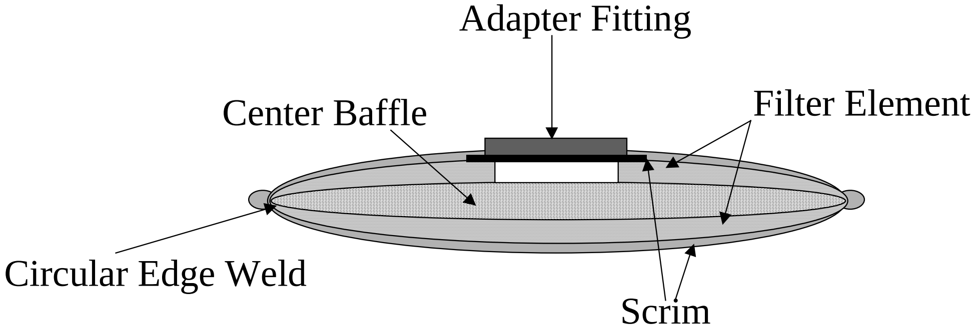
Abstract: Safety and reliability in glovebox operations can be significantly improved and waste packaging efficiencies can be increased by inserting flexible, lightweight, high capacity HEPA filters into the walls of plastic sheet barriers. This HEPA filter/barrier technology can be adapted to a wide variety of applications: disposable waste bags, protective environmental barriers for electronic equipment, single or multiple use glovebag assemblies, flexible glovebox wall elements, and room partitions. These reliable and inexpensive filtered barriers have many uses in fields such as radioactive waste processing, HVAC filter changeout, vapor or grit blasting, asbestos cleanup, pharmaceutical, medical, biological, and electronic equipment containment. The applications can result in significant cost savings, improved operational reliability and safety, and total waste volume reduction. This technology was developed at the Argonne National Laboratory-West (ANL-W) in 1993 and has been used at ANL-W since then at the TRU Waste Characterization Chamber Gloveboxes. Another 1998 AGS Conference paper titled "TRU Waste Characterization Gloveboxes", presented by Mr. David Duncan of ANL-W, describes these boxes.

INTRODUCTION

High flow capacity, flexible, and rugged High Efficiency Particulate Air (HEPA) filters similar to the one shown in Figure 1 are typically made from a cloth-like material called blown microfiber (BMF) polypropylene.

FIGURE 1

TYPICAL CIRCULAR FLEXIBLE BREATHING AIR MASK FILTER (FILTER SECTIONED FOR CLARITY)



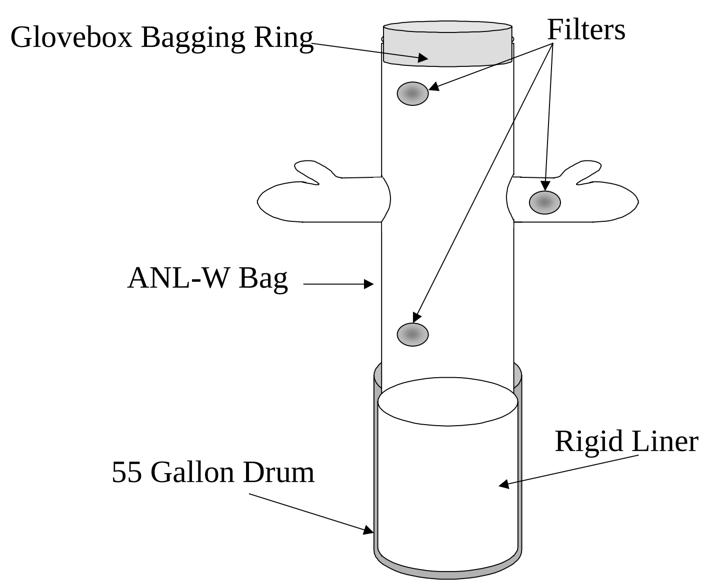
Polypropylene is sprayed in molten form onto a flat or large cylindrical surface to create long thin mats of nonwoven fabric. These mats are layered to produce the filtering efficiency needed. This media has excellent wet strength and will not support the growth of mold, mildew, fungus, or bacteria. The BMF fabrication process can be tailored to produce a variety of media that is suitable for specific services such as air filters, waste containment box liners, filter vented waste bags, or clean room environment barriers. Because the filter media is made in large rolls like regular cloth, the size of the filter is easily adaptable within reasonable limits to meet the needs of the application.

HEPA filters are practicable for many applications in industries serviced by glovebox and glovebag manufacturers. The filters are made to attach to breathing air masks by the adapter fitting. Thermal impulse heat sealing is the preferred method to join BMF HEPA filters to polyethylene plastic barrier material because it produces a permanently welded high integrity joint that is flexible and tough with a much longer life than an adhesive joint. The thermal heat sealing joint is better than rigidly mounted filters because it can flex around corners that could tear barrier material from rigid filters and it provides improved operational safety.

Other barrier materials such as polyvinyl chloride (PVC) and polyurethane are not directly heat sealable to BMF filters and require special adaptations to bond the filter to the barrier. ANL-W, where this technology was developed, currently uses PVC glovebags similar to the one in Figure 2 with this type of filter installed.

FIGURE 2

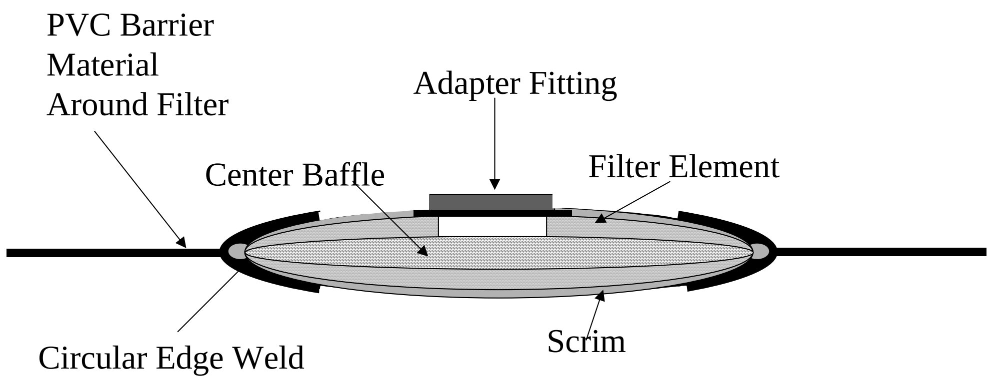
Argonne National Laboratories-West Bag with Filters Installed



Their method of mounting the filter is to create a pocket for the filter within the bag as shown in Figure 3.

FIGURE 3

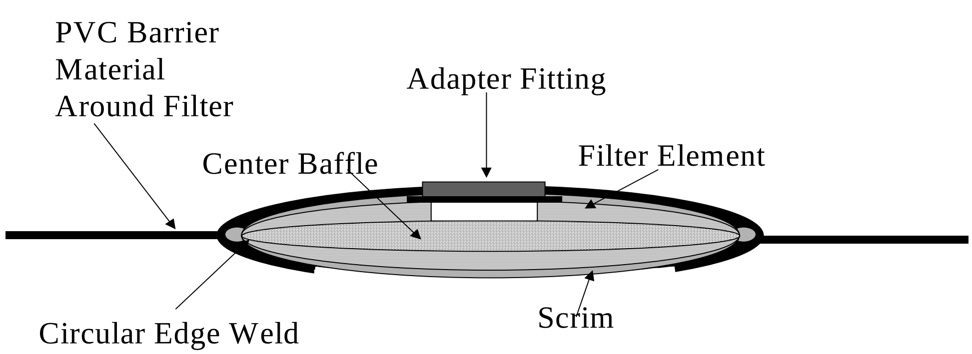
CONTINUOUS VENTING PVC POCKET AROUND FILTER (FILTER SECTIONED FOR CLARITY)



Other methods are being developed for sealing to PVC and polyurethane that would improve the durability of the filter mounting. A similar pocketing technique identified in Figure 4 can be made airtight by sealing the barrier material to the flange of the adapter fitting. Special fittings or tape can cover the outlet of the adapter fitting to seal the bag.

FIGURE 4

AIRTIGHT SEALABLE PVC POCKET AROUND FILTER (FILTER SECTIONED FOR CLARITY)



Containment bags with BMF filters could increase the loading of Pu^{238} contaminated radioactive waste in 55-gallon drums (thus decreasing costs associated with packaging and shipping) destined for shipment to the Waste Isolation Pilot Plant (WIPP). Some waste packaging is limited by the ability of the bag filters to diffuse hydrogen and keep the concentration below the lower explosive limit. Specialized, inert, or controlled flowing gas environments can be established inside barriers while maintaining filtered inlets and outlets. Inserting the high flow capacity HEPA filter into an otherwise airtight barrier allows the barrier to breathe quickly and adjust to pressure changes. The time needed to deflate a sealed containment bag can be significantly reduced and sudden pressure changes or reversals will not cause loss of containment.

A parallel technology exists in polypropylene athletic garments (such as, layered inside a Gortex shell) made from BMF. The resulting product is both waterproof and breathable. Like athletic garments, this filter technology can be expanded by tailoring the mat material or by selectively layering the mat with other media to include enhanced features that are available by layering or bonding the BMF with special materials that adsorb, absorb, or chemically react with vapors, mists, or gasses.

TECHNOLOGY BASIS

BMF filter material is made by spray forming a thin mat of polypropylene fibers into large sheets of filter media in a manner similar to the way paint is sprayed from a paint gun onto a surface. The thin mats are layered with as many filter mats as desired to perform the needed filter function. Each filter is usually covered with a BMF scrim, or cover material, to protect it from abrasion and add enough structural integrity for the filters to be used in large sheets. The BMF filter material can also be layered with other media or absorbent materials to filter nuisance levels of various mists. The resulting filters are rugged, flexible, and easily sized to meet any application.

These filters are ideal for filter mask applications because they are relatively inexpensive, reliable, and simple to manufacture. Safety respirator mask manufacturers including 3M, North Safety, and US Safety are using polypropylene blown microfibers (BMF) to produce small, flexible, rugged, and high capacity HEPA filters. The 3M and US Safety filters rely on electrostatics to enhance filtering with charged fiber filters, while the North system relies on mechanical filtering. By using various additives, 3M tailors media to specifically filter out nuisance levels of acid gas and organic vapors.

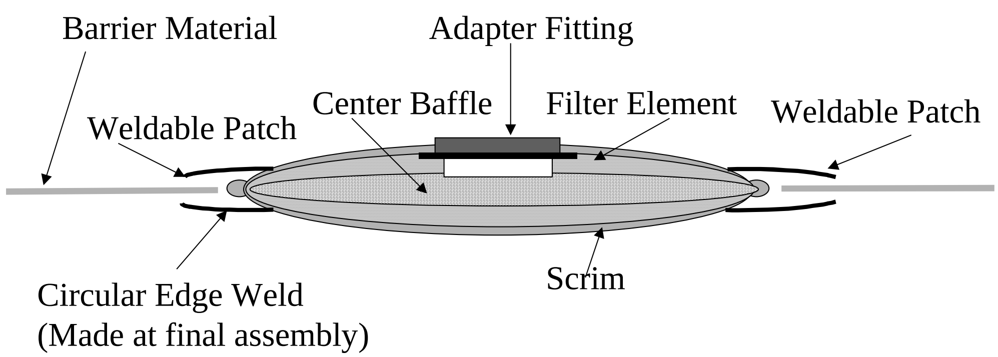
TECHNICAL CHALLENGES

A problem in fabricating filter/barriers is that polypropylene filters will only heat seal to polyethylene or polypropylene sheeting. Directly bonding a polypropylene filter into a polyethylene barrier by a thermal impulse heat seal is the preferred method of barrier construction. The two materials are similar enough in chemical structure that a satisfactory weld can be achieved with appropriate equipment. This method of direct plastic welding has not been achieved for filter attachment to PVC or polyurethane sheets. Radio frequency (RF) and ultrasonic welding methods have been attempted unsuccessfully. PVC and polyurethane require other methods that include physical attachment within a pocket to hold the filter in place and adhesively bond the filter scrim to the barrier to prevent filter bypass. This method is used in the ANL-W application shown previously in Figure 4.

Another option is to create a patch assembly (as shown in Figure 5) that relies on housing the filter in a scrim material that is weldable to the barrier material.

FIGURE 5

CIRCULAR PATCH WELDABLE FILTER
(FILTER SECTIONED FOR CLARITY)



ORIGINAL APPLICATION

The first known application of this type of flexible HEPA filter for other than respirator use was developed at ANL-W. In 1993, filters manufactured by 3M were thermal impulse heat sealed into polyethylene waste transfer bags that were to contain the contaminants while radioactive waste was transferred from a Plutonium glovebox into 55-gallon drums. The ANL-W Waste Characterization Area (WCA) Gloveboxes are used to open 55-gallon Pu contaminated waste drums for sampling and analysis. The WCA still uses this technology to safely separate 55-gallon waste drums from the bagout rings on the bottom of their glovebox. A 1998 AGS Conference paper titled “TRU Waste Characterization Chamber Gloveboxes,” presented by Mr. David Duncan, describes the gloveboxes in this facility.

The need for higher capacity HEPA filters for this purpose was identified during routine preoperational testing. The facility was being checked for all operating sequences before commissioning it for contaminated waste. The procedure for bagout of a 55-gallon drum was being tested. The flow capacity of the old style filter was not sufficient to rapidly deflate the bag without operators helping the filter by pushing on the bag. The solution for this problem was to search for a higher capacity, low physical profile HEPA filter and adapt it to the containment bag. The low profile requirement was necessary because the filter had to fit between the top of the 90-mil rigid liner and the drum lid. This was accomplished by direct thermal heat sealing a 3M 2040 filter to a polyethylene waste bag. The new filter had about 100 times the flow capacity of the previous filter and rapidly deflated the bag. The improved bagout system has been used for several hundred bagouts without any problems.

APPLICATIONS IN DIVERSE FIELDS

The following applications have been identified as concepts that could benefit from this technology.

- Medical isolation tents could be created to isolate patients to control contagious diseases. The filtered air inlet and outlet panels would filter air with the rest of the room or the tent could be sealed from the outside environment with specially purified and filtered atmospheres. This could be used to provide unique care conditions for a patient with special susceptibilities.

- Microenvironments for biological or medical experimentation could be created with specially filtered bags. The experimental environment could be controlled and after the test all the contents could be left in the bag and the entire experiment could be destroyed by incineration or rendered harmless by autoclaving.

- Biological hazardous waste containment could be evacuated by attaching a vacuum to the outlet of the filter for volume reduction and later destroyed by incineration or autoclaving.

- A sand, grit, or other particle blasting tent could be created to house the blast nozzle on applications where the byproducts are contained for ease of cleanup or safety.

- Containment for dry ice pellet blast cleaning of contaminated parts could be created that would result in the CO_2 evaporating and only the material removed from the part remaining inside the bag. This would be especially valuable for processes like lead cleanup where the blasting byproducts are hazardous.

- Protective packaging could be made for sensitive electronic equipment. In this application, special bags could be made with filtered inlet and outlets that are located at the same place the equipment normally draws and discharges air. This could be used for heavy construction, farming, or military equipment where the outside environment is not controllable.

- Pressure equalization barrier to withstand changes in pressure across the barrier could be created. An example is a series of barriers within a large area that creates smaller chambers where smaller areas can be decontaminated individually. The smaller areas remain isolated so they do not become recontaminated as the cleaning process is completed.

- Gloveboxes with HEPA filtered flow-through ventilation systems could be created. They would normally rely on negative internal pressure to prevent contaminating the outside areas. This method could minimize the possibility of contaminating the outside environment if pressure inside the box becomes positive.

VARIATIONS IN MOUNTING DESIGN CREATE DIFFERENT OPERATIONAL CAPABILITIES

The filters can be mounted in the barrier in several different ways to provide the following features:

- Airtight mounting of a single filter in a bag type barrier with an integral outlet fitting so the only exit from the filter is through the outlet, creating an airtight barrier. This barrier can then be used for deflating and sealing compressible waste. The waste would be sealed inside the bag with a linear heat seal (Seal-a-Meal type) and then the air would be vacuumed from the bag without spreading contaminants.

- Airtight mounting of two filters with outlet fittings on opposite sides of the volume enclosing barrier to create a microenvironment in which experiments could be performed with controlled atmospheric conditions. Both the inlet and outlet would be filtered to prevent introduction or escape of undesired products or contaminants. This is an ideal construction for contagious disease testing on mice or other biological testing systems.

- Open face mounting of small filters without fittings provide continuous venting of gasses generated inside the barrier. This is ideal for packaging that needs to vent radiolyticly generated hydrogen to prevent the buildup of explosive levels of gasses.

- Large panel mounted filters in walls or ceilings provide excellent protection from overpressure conditions. The sudden starting or stopping of a large air-circulating fan would not collapse a barrier that was made of this type of material. Such a barrier could zone a large contaminated area into smaller easier cleaned zones for individual reclamation.

- Panel or frame mounted filters could provide low flow resistance and pre-filters for HEPA or other filters that are subjected to high loading from dust or other contaminants. The pre-filters would reduce the complexity of changeout of the HEPA filter and if the design of the containment was amenable, the pre-filter could be collapsed and bagged out from inside of the containment with much greater ease than the main filter.

- Custom bags with special inlet and outlet HEPA filters could protect temperature or dust sensitive electronics or other items that require clean cooling air to be blown across the equipment. The bag filtered inlets and outlets would be strategically placed to direct the airflow across the normal equipment cooling paths.

HOW THIS TECHNOLOGY CAN BENEFIT INDUSTRY

This technology is being evaluated for use in packaging waste to ship to WIPP. Some radioactive waste forms are shipped to WIPP in sealed 55-gallon drums that have been fitted with HEPA drum vent filters in the lids to vent H_2 that might have been generated by radiolytic decomposition of hydrogenous materials.

The amount of radioactive waste that can be shipped in each drum is severely limited unless the plastic barriers inside the drums are also vented. H_2 diffusivity of the drum and bag vent filters must be adequate to prevent the buildup of the H_2 inside the drum from reaching an explosive level. The HEPA filters installed in plastic bags with this technology have a high enough diffusivity that they can eliminate the waste loading restrictions that are imposed because of H_2 buildup. It is feasible that a 20% increase in waste loading could be achieved. This would result in significant cost savings in shipping and storing WIPP waste.

SUMMARY

Filtering is not the only advantage BMF filter materials can provide to the glovebox and glovebag industries. Uncontrollable pressure differentials across flexible or rigid barriers can be mitigated if a large segment of the barrier is made from this material. Temporary plastic walls could be made to withstand sudden pressure transients that could occur when HVAC equipment starts or stops and specialized plastic covers could be created for electronic equipment that is exposed to contaminating environments. The bag could allow filtered air to enter and exit the cover thereby cooling the equipment and protecting it from dust and other contaminants. Developments in this field can enhance safety, significantly reduce costs, and simplify operations. Temporary and semi-permanent installations of gloveboxes and glovebags can be made faster, better and cheaper. Developing cheap, readily available, and disposable containment barriers could reduce the occurrence of cross contamination or recontamination of clean equipment.

ACKNOWLEDGEMENTS

This work was originally developed under federally funded research and development conducted at the Idaho National Engineering and Environmental Laboratory under U.S. Department of Energy Contract.

The original application of this technology was conceived and developed by Paul A. Pinson, who was granted US Patent No. 5.720,789 on February 24, 1998 titled “METHOD FOR CONTAMINATION CONTROL AND BARRIER APPARATUS WITH FILTER FOR CONTAINING WASTE MATERIALS THAT INCLUDE DANGEROUS PARTICULATE MATTER.” The rights for this patent were assigned to Lockheed Martin Idaho Technologies Company, Idaho Falls, ID.