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A WASHABLE POROUS METAL HEPA FILTER

Abstract

Glass fiber HEPA (High Efficiency Particulate Air) filters are used on High Level Waste (HLW) tank ventilation systems at various nuclear sites around the country. The glass filters are subject to deterioration from moisture condensation, and must be disposed of when spent, at considerable cost to the facility.

A new washable HEPA filter system using porous metal filter media has been developed which is washable and more durable than the glass fiber filters. The filter is cleaned by washing the dirty surface with a spray of cleaning solution. The metallic media is not affected by temperature, humidity, moisture, high pH, and other factors associated with the HLW tanks. It is anticipated to have a very long service life, at least 15 years. The filter has multiple tubular elements welded to two tube sheets for reliable sealing and integrity. All materials of construction are stainless steel or nickel.

The filter design is unique in that it incorporates the dirty gas flow to the inside of the metal elements. A single spray wash nozzle providing a full cone spray pattern is located at the top of each double open ended element. A solution sprayed onto the surface of the element flushes dirt and accumulated materials out the bottom of the element into a waste tank or back into the HLW tank. Nearly full recovery of clean pressure drop can be achieved by the spray wash. Additionally, the spray wash can be accompanied by a reverse flow of air to remove imbedded materials from the media's porous structure.

The filter also incorporates a cyclonic inlet separator to remove heavy entrained particles or droplets. This separator has been demonstrated to remove up to 50% of AC fine test dust fed to the filter. The initial separation of materials should extend the operating interval between cleanings.

A nickel filter media has achieved 99.9995% removal of a 0.3 micrometer aerosol DOP when tested according to the standard ASTM DOP test for HEPA filters. A design air flow velocity of 30 feet per minute results in a pressure drop of about 40 inches of water. While this is higher than traditional glass fiber HEPA filters, the increased pressure drop is accommodated by a vacuum pump of appropriate capacity.

The concept of a washable metallic media HEPA filter has been proven by testing on a HLW simulation by the Savannah River Technology Center (SRTC). The proposed filter design has been tested at the Mott Corporation laboratory with stainless steel media and has proven that washable metallic media can function reliably.

Future work will include development of alternative metallic media and single element prototype testing at SRTC.

A WASHABLE POROUS METAL HEPA FILTER

INTRODUCTION

Liquid nuclear wastes at the various DOE (Department of Energy) nuclear processing sites are stored in tanks underground. The wastes undergo slow decomposition which generates hydrogen gas as a decomposition product. To prevent a hazardous accumulation of hydrogen, the tanks have an installed ventilation system which passes ambient air through the tank and exhausts back to atmosphere. The air sweeps across the tank head space and picks up hydrogen before it can accumulate to dangerous levels. The air is filtered both incoming and outgoing by glass fiber HEPA (High Efficiency Particulate Air) filters.

The traditional filter of choice is a glass fiber pleated unit provided by suppliers such as Flanders. While the filters meet the filtration specification they are fragile and sensitive to moisture and humid conditions. They require periodic testing to ensure integrity and require disposal at the end of their useful life. The Defense Nuclear Facility Safety Board issued a report(1) which describes safety concerns in the utilization of the glass fiber filters. It has long been a desire to find a suitable substitute with greater durability and reliability, and if possible, cleanable.

One of the impediments to a suitable replacement has been the pressure drop. The search for a suitable substitute has, in the past, specified an operating pressure drop similar to the conventional glass fiber filters. Various materials, including metal and ceramic filter media, have been identified as suitable for HEPA filters based on the DOP (Dioctyl Pthalate) HEPA efficiency test, ASTM D 2986-91. However these materials have had significantly higher operating pressure drops. With the acceptance of the fact that replacement filters would have to operate at higher pressure drops, and the accommodation of that requirement with suitable air blowers and vacuum pumps, investigations could be conducted into the cleaning and reuse of these filters.

Feasibility testing of various cleanable filter materials by the Savannah River Technology Center (SRTC) demonstrated satisfactory recovery of pressure drop after cleaning.(2) The release of this information prompted the DOE's Federal Energy Technology Center, now a National Energy Technology Laboratory, to solicit proposals for new filtration technologies. The Mott Corporation submitted a proposal, and was subsequently awarded a development contract, to use its porous metal filtration technology as a cleanable HEPA filter system.

OBJECTIVE

The program objective was to develop, design, and test a cleanable HEPA filter system which would be suitable for the HLW tank ventilation. The long term objective is to replace the glass fiber HEPA filters with the new technology, thereby saving the Department of Energy significant dollars in the handling of the existing filters.

Some of the performance requirements desired for the new filter technology as put forth by the DOE are:

- A fifteen year operating life
- A filtering capacity of 800 CFM at 0-115°F

- A maximum pressure drop of 15” Hg
- Capable of radiation fields of 250 mR/hr gamma
- Be moisture tolerant
- Tolerate pH 14 materials
- Be cleanable in place
- Satisfy the HEPA efficiency standard

A development and test program would be conducted to verify elements of the design and satisfaction of the performance requirements. The test program would first be conducted on a laboratory scale and then move into the evaluation of a full-scale prototype. The initial development work was to design a suitable filter system to meet the requirements of in-situ cleaning, and provide a suitable filter media.

THE MOTT APPROACH

Mott is a manufacturer of backwash process filters using porous metal as a filter medium for both gas and liquid systems. Some of the porous metal Mott manufactures is used in the purification of gases used in semiconductor chip manufacturing where the solids removal requirement far exceeds that needed for HEPA filters. There was a high level of confidence that a HEPA filter could be designed for the HLW tank ventilation system.

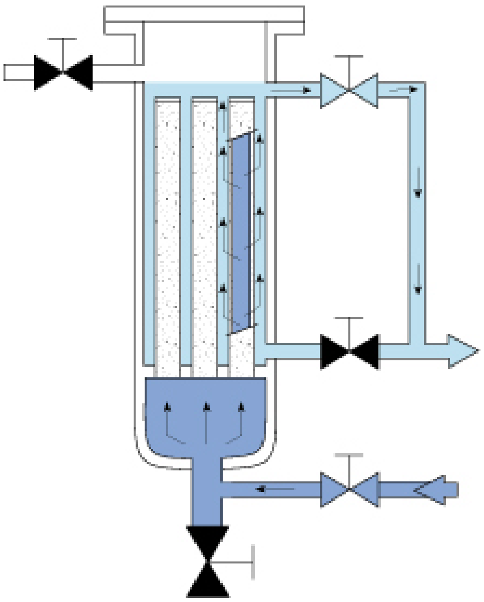
The filter design

Most Mott process filters use the same material for backwash as they are filtering. Liquid filters use a liquid for backflush; gas filters use air or an inert gas for blowback. It is known that liquid cleaning is more efficient than with a gas. The liquid picks up the contaminant particulate by wetting attraction and flushes it out of the porous structure. A gas uses a pneumatic conveyance principle to move particles out of a porous structure or off of its surface. Filter element cleaning is quite often performed by immersion of the element in a liquid solution, then, blowing air through it to create turbulence and remove the cleaning solution and contaminant particulate from the media. Mott had not used a spray wash technique for filter cleaning, but the research at the Savannah River Technology Center (SRTC), under the direction of Mr. Terry Phillips and Duane Adamson, demonstrated that spray wash cleaning was possible.

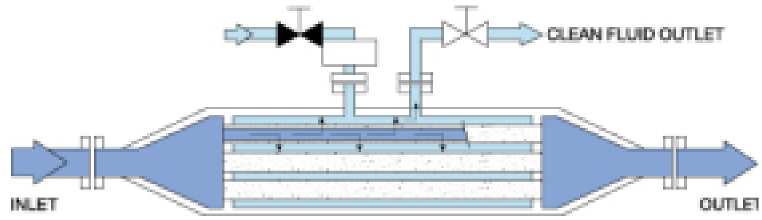
The vast majority of Mott process filters use cylindrical filter elements arranged in a bundle to provide the needed filtering surface area. The typical filter element is between two and three inches in diameter and up to 80 inches long. While the SRTC had demonstrated the ability to clean one cylindrical element exposed to four spray nozzles, the effective cleaning of a bundle of elements would create quite a plumbing challenge for the required spray nozzles. Not to mention the required housing size to accommodate the spray nozzle plumbing between the elements.

Mott has a variety of process filter configurations for both gases and liquids. Three of the liquid filters filter on the inside of the filter element. Two of those filters use the flow of a liquid across the media surface to remove accumulated solids while filtering. One of the gas filters is designed based on the bag house nozzle/venturi blowback principle. The gas nozzle is positioned over the center of a venturi for gas flow amplification. The idea was conceived to use this concept, applied to spray nozzles, along with inside/out filtration to simplify the filter design for the washable HEPA filter. Porous metal is sufficiently strong to maintain its shape as a cylinder under the conditions of cleaning and filtering pressure drop.

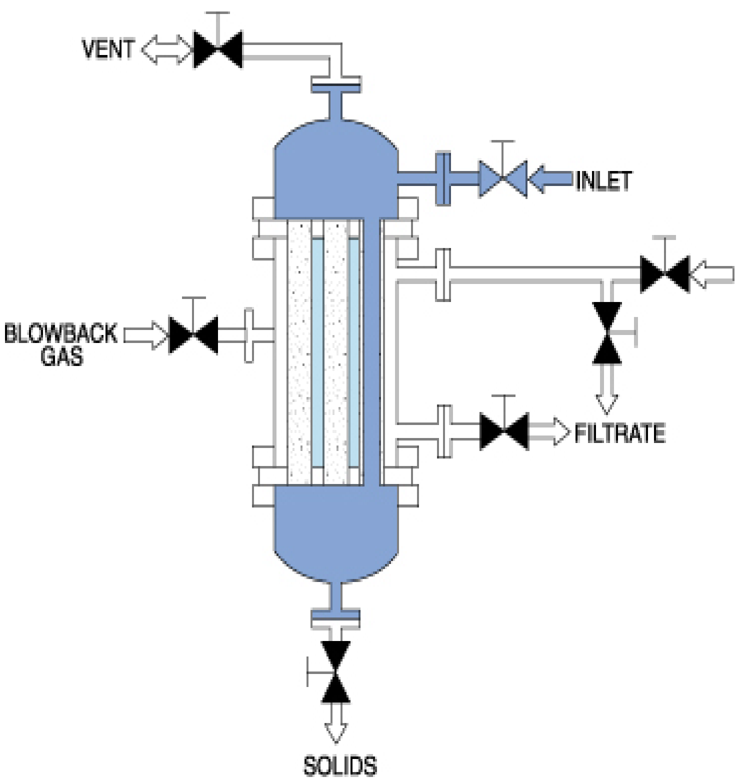
LSI FILTER



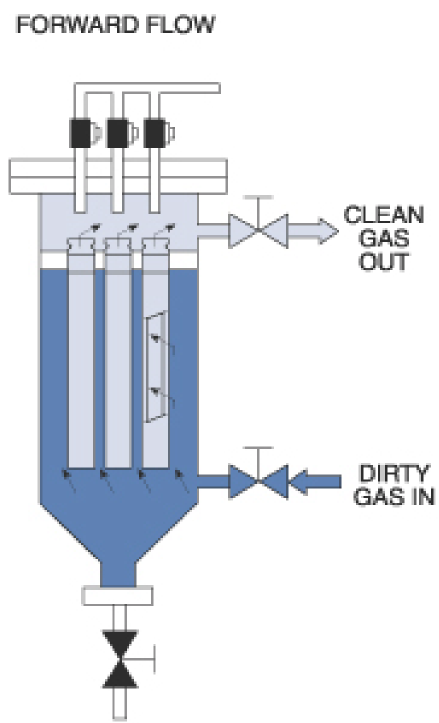
LSX FILTER



LSM FILTER



GSV FILTER



The filter media
The heart of every filter is the filter media. Mott manufactures metallic filter media based on powder metal processing. The desired filtration objective determines the powder metal raw material and the necessary processing parameters. To achieve a HEPA efficiency with a reasonable pressure drop, a fine powder, low-density structure is needed for a high capture surface area. Fine nickel powder is suitable for HEPA filters and can be fabricated into cylindrical filter elements. This same nickel material has been used to make high efficiency gas filters for semiconductor processing. The nickel is processed to provide the HEPA filter capture efficiency along with a reasonable pressure drop and the required mechanical strength to maintain its shape. A nickel filter element achieved 99.9995% removal efficiency in a DOP test.

The filter element
The full-scale filter element selected for this application is a double open-ended cylinder, approximately 24 inches of porous length, and about 3 inches in outside diameter. The elements are fixed to a tube sheet at the top and bottom. The dirty gas enters the element from the bottom and flows up and through the porous wall. When the filter needs cleaning, the spray nozzle located at the top of the element sprays down on the dirty surface and washes out the accumulated solids through the bottom of the element. This is a simple and effective arrangement and can be scaled for any flow requirement by adding elements to a bundled assembly.

The cleaning process
The element cleaning process provides for several options. The simplest procedure is to use the spray nozzle to wash down the element surface. An additional step provides for a gas blowback through the media to remove imbedded solids and residual liquid from the porous structure. A further step provides for a flooding of the filter chamber and a full liquid backwash. These options ensure the ability to reliably clean the filters under any conditions.

THE DESIGN DESCRIPTION

The filter assembly consists of three parts: a top spray section; a middle element bundle; a bottom inlet section. See figure 1.

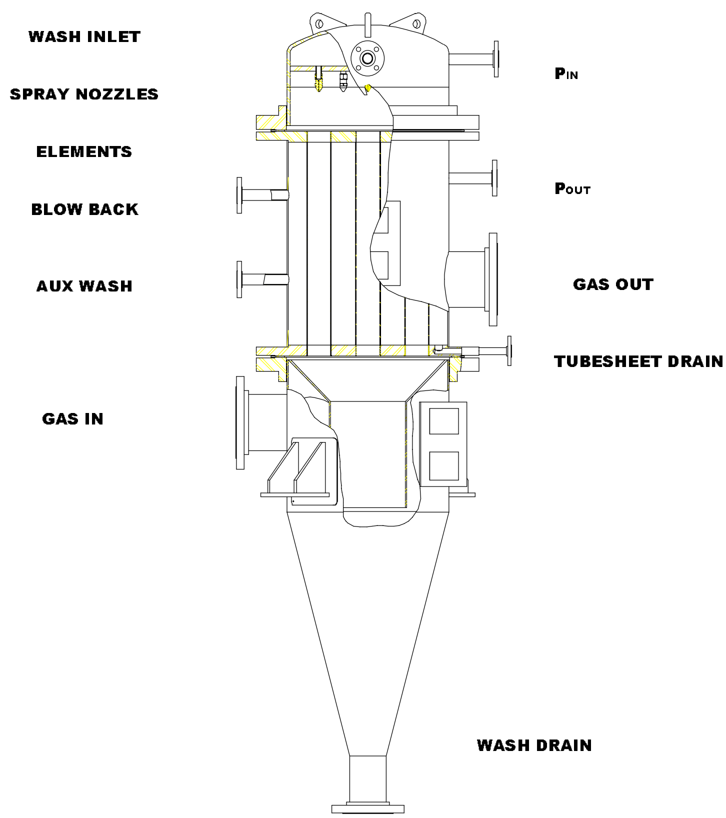
The top section contains a chamber, which is flooded with cleaning solution. The spray nozzles are located on the underside of the chamber and are located over the center line of each element. The top section is attached to the middle bundle assembly by a flanged connection.

The middle bundle assembly contains the elements welded to tube sheets, top and bottom. The shell side of the bundle assembly has a clean gas outlet nozzle and a blow back gas inlet nozzle. It is the working part of the filter.

The bottom section contains a cyclonic separator on the inlet gas to provide an initial removal of entrained droplets and large particles. The incoming gas spins around a cylinder acting as a vortex finder. The solids and droplets are directed downward to a cone where they collect for drainage. The spun gas flows up into the vortex finder and then into the filter elements. The gas is filtered by the elements and is exhausted through the middle shell outlet nozzle.

The driver for the filter is a vacuum or blower system with sufficient gas flow and pressure (vacuum) capability to overcome the pressure drop of the wetted porous media. There are several types of gas pumps which are suitable for most applications. In the case of the High Level Waste tank ventilation systems, low pressure fans are replaced by higher pressure vacuum pumps.

Figure 1.
MOTT GSM FILTER



One such suitable pump is a two-stage regenerative blower manufactured by Siemens. A 36 HP blower will pull 490 CFM at 14” Hg vacuum. These pumps do not use flushing seal fluids which can generate a waste stream of as much as 5 gpm.

Other suitable pumps are capable of near 1000 CFM at 15” Hg vacuum.

The operating cost of this type of filter system is almost entirely the energy to operate the pump. This can be compared to the replacement and disposal costs of the existing HEPA filters.

ACCOMPLISHMENTS

The filter design has been tested in the laboratory with a sintered porous stainless steel element. The media bubble point was 2.0” Hg. Filter surface area of the 2.88” ID by 19.5” long element was 1.22 ft^2.

The challenge material was 10 grams of SAE Fine Test Dust, Lot 4443A. Challenge velocity was 33 FPM at the inlet. Clean, dry pressure drop was 43” H_2O.

The dust was added to the air stream over 43 minutes. At the end of the addition the pressure drop increased to 53” H_2O. Inspection of the cyclone bottom leg revealed that 5.3 grams of the loaded dust had been removed by the cyclone, leaving 4.7 grams deposited onto the element.

An additional solids load of 10 grams of a 50/50 mixture of the SAE dust and a Molybdenum/Iron Oxide catalyst was introduced into the filter in 39 minutes. The pressure drop increased to 78” H_2O. The cyclone removed 78% of the oxides, probably due to the higher particle density of the oxides: ~ 5gm/cc.

The element was spray washed with 3 liters of an acidic cleaning solution, then rinsed with two 3 liter rinses of clean water. The element was blown back with air for 20 seconds between rinses and the end of the last rinse. The wash and rinse water were drained out of the bottom of the filter housing for disposal.

The vacuum pump was turned on at constant speed to dry down the element. The initial wet pressure drop was 135” H_2O at 27 CFM. After 6 minutes the element recovered to about 45” H_2O at 33 FPM face velocity and was considered dry, as the pressure drop did not change from that point.

This is an example of what is possible with this type of filter design. It provides an effective filtering surface and is easily cleaned and returned to service. The success of spray washing will depend on the particular application, the filtered contaminant, and the chosen filter media.

BENEFITS

The benefits of this type of cleanable filter are many:

- Simple filter assembly.
- Easily scaled for high and low gas flow rates.
- Efficient construction of one spray nozzle for one element.
- High integrity welded element assembly.
- Initial cyclonic separation for solids load reduction to the filter.
- Immune to high moisture and humidity conditions.
- Reliable sintered metal filter media.
- Reduced or eliminated maintenance and media replacement.
- Reduced exposure to area personnel by minimizing filter change outs.

FUTURE ACTIVITIES

The concept of the washable HEPA filter has been demonstrated to be feasible. Testing of the filter media on HLW tank simulant at SRTC, and laboratory testing of the filter configuration on SAE fine dust demonstrated the working concept of the design. There is still much to be investigated. Some of the work anticipated for the future includes:

- Development of additional HEPA media in different alloys.
- HLW simulant testing of the single element full-scale design at SRTC.
- Testing on different dust materials and cleaning solutions.
- Full scale testing on a HLW tank.

- Evaluate the effectiveness of the inlet cyclone on dust and water mist.
- Any other investigations deemed necessary to prove the filter operation.

The present plan is to complete the testing of an approved full length element at SRTC on the HLW simulant. This will prove the filter operation on the nickel media in the single element test unit. Other media may be tested if time and budgets permit.

The real test will come when the full-scale trials begin on a HLW tank. Then, the actual conditions of the tank ventilation system will be evaluated. Timing for this testing has not yet been determined.

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1. DNFSB/TECH-23, "HEPA Filters Used in the DOE's Hazardous Facilities." May 1999
2. Adamson, Duane J. "Experimental Investigations of In-situ Cleanable HEPA Filters (U)." WSRC-TR-98-00382. October 1998.

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Oct 9, 2000