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SINTERED POROUS METAL HEPA FILTER

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ABSTRACT

An all-metal High Efficiency Particulate Air (HEPA) filter has been recently developed as an alternative to traditional HEPA filters fabricated with conventional glass fibers. This metal filter was developed utilizing sintered porous metal media fabricated from nickel metal powder. One specific application is the potential for replacement of glass fiber HEPA filters currently used in High Level Waste (HLW) tank ventilation systems at various Department of Energy (DOE) nuclear waste storage sites in the US. The glass filters are subject to a shortened life span due to their deterioration from moisture condensation and therefore must be disposed of when spent. The disposal process is costly, creates solid waste, and is hazardous since the site personnel are at risk of exposure to radiation. Savannah River Technology Center (SRTC) began investigating the use of porous metal as a HEPA filter material in 1996. This effort subsequently lead to a DOE funded development.

This project, under DOE funding, developed novel technology to replace the glass fiber HEPA filters with a regenerable and more durable filter. A cylindrical nickel sintered porous metal filter element was developed for this application. The nickel filter is cleaned by washing the dirty surface with an in situ spray wash. Temperature, humidity, moisture, and other factors associated with the HLW tanks do not affect the metallic media; thereby resulting in an anticipated long service life of 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 incorporates two means for particle collection – cyclonic inlet separator and metallic HEPA filter elements. The cyclonic inlet separator, which assists in removing heavy particles or droplets, has demonstrated removal efficiencies of 50 to 70% of ISO 12103-1, A-2 (fine grade) Arizona test dust. After exiting the cyclonic filter separator, the dirty gas stream then passes into the inside of the cylindrical metal filter elements and flows radially from inside to outside of the filter media, with particulate collecting primarily on that inner diameter surface. When a terminal pressure drop is reached, the particles that collected on the inner diameter surface are removed with an in situ spray wash, thereby reducing radiation and eliminating contaminant accumulation. Each filter element possesses its own spray-wash nozzle.

The nickel filters have achieved removal efficiencies, of a 0.3 micrometer di-octyl phthalate (DOP) aerosol, ranging from 99.975 to 99.999% when tested according to the standard ASTM DOP test for HEPA filters. A total of 32 filters have undergone HEPA efficiency testing. One of the elements that achieved a 99.999% removal efficiency was subsequently plugged and cleaned in situ 7 times with simulated sludge/salt particles and atmospheric dust. After these rigorous tests, subsequent DOP testing showed the filter still achieved 99.999% removal efficiency.

The media design flow specification is 9.1 $m^3/min/m^2$ (30 CFM/ft^2) at a maximum differential pressure of 0.24 bar (3.5 psi). All nickel metal filters have tested at or below that design pressure drop. While this is a higher pressure drop than traditional glass fiber HEPA filters, this system pressure is accommodated by a vacuum pump of appropriate capacity.

INTRODUCTION

High efficiency particulate air (HEPA) filters, traditionally comprised of glass fiber media, are widely used in air and gas filtration systems throughout the Department of Energy (DOE) nuclear sites. These HEPA filters, usually employing a highly pleated thin sheet of media in a compact filter element, are intended as single-use disposable filters. By definition, a HEPA filter has a minimum particle collection efficiency of 99.97% for 0.3 micrometer (μm) thermally generated di-octyl phthalate (DOP) particles.

HEPA filters, as shown in Figure 1, are employed in the inlet and outlet ventilation systems used with high level waste (HLW) liquid radioactive waste storage tanks found at DOE nuclear processing sites. There are about 300 underground tanks, each approximately 3800 m^3 (1 million gallons) in size, and equipped with a ventilation system designed to maintain the gas within the tank at a slight negative pressure of approximately 250 Pa (1 inch water), to prevent leakage of radioactive contamination and avoid hydrogen buildup in the tank head space. The wastes slowly undergo a decomposition process resulting in the generation of hydrogen gas. The ventilation air, which is continuously passing through the tank headspace at a flow rate of approximately 850 m^3/hr (500 CFM), is intended to entrain any hydrogen before it accumulates to dangerous levels. The glass fiber HEPA filters are subject to a shortened life span due to their deterioration from moisture condensation and therefore must be disposed of when spent. The disposal process is costly and hazardous because the site personnel are at risk of exposure to radiation. In 1999 the Defense Nuclear Facility Safety Board reported their safety concerns associated with the traditional disposable glass fiber HEPA filters [1].

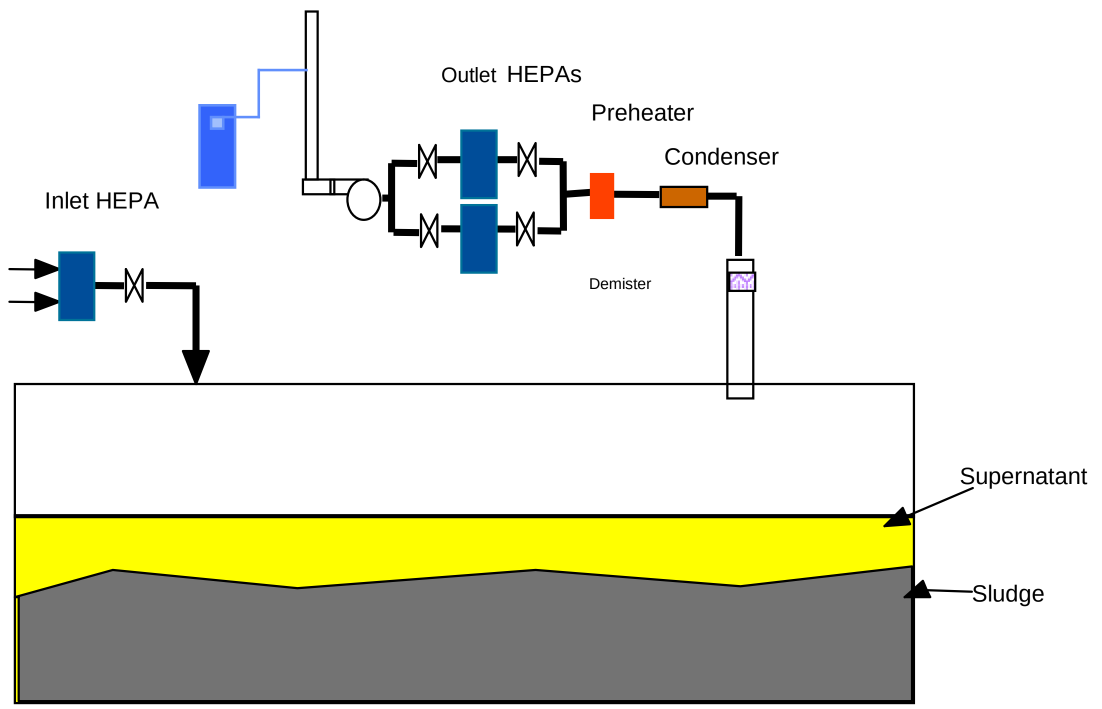

Figure 1. Schematic diagram of a typical HLW tank ventilation system.

This project, under DOE funding, involved the development of a porous metal HEPA filter, and the subsequent design of a full-scale regenerable HEPA filtration system (RHFS) [2]. This RHFS could replace the glass fiber HEPA filters currently being used on the HLW tank ventilation system with a system that would be moisture tolerant, durable, and cleanable in place, thereby increasing the filter service life from the current 1 year to a design specification of 15 years. The origins of this project are a 1996 investigation at the Savannah River Technology Center (SRTC) regarding the use of porous metal as a HEPA filter material. The project tasks included:

- Development of a filter media meeting the HEPA filtration efficiency that would also be regenerable using prescribed cleaning procedures;
- Testing of a single element system prototype at SRTC;
- Full-scale system design.

The performance requirements for the new filter systems, as required by DOE, were:

- Fifteen year service life;
- Filtering capacity of 1360 m^3/hr (800 CFM) at 20 - 80 ^{o}C;
- Maximum pressure drop of 0.51 bar (7.4 psi);
- Capable of radiation fields of 250 mR/hr gamma;
- Moisture tolerant;
- Tolerate high pH up to 14;
- In-situ regeneration system;
- Satisfy the HEPA efficiency standard.

To meet the project design requirements, the full-scale design of the RHFS incorporated several important features in its design and operation. Cylindrical nickel sintered porous metal filter elements were developed for this application, which were welded into an all-welded element bundle assembly. This assembly could be removed and replaced as a unit if the elements ever needed replacement. A spray nozzle was mounted directly above each element for cleaning. Furthermore, the elements can be cleaned in place by a soak and backwash technique. The inlet nozzle incorporated a cyclonic separator to initially remove large suspended material and droplets. Tests indicated that incorporating a cyclonic separation into the filter significantly reduced the dirt load passing to the filter elements, which would extend the operating time between cleanings. A high capacity blower was selected to overcome the higher pressure drop of the metallic elements. This blower is capable of operating the system at higher pressure drops than those currently used with the glass fiber HEPA filters. This additional capacity further increases the operating duration of the filter.

SINTERED POROUS METAL FILTER MEDIA

Sintered porous metal media are widely used for industrial gas [3-6] and liquid [5-10] filtration in various processes found in the chemical process, petrochemical, power generation and semiconductor [11,12] industries where filtration is required to protect downstream equipment, for process separation, or to meet environmental regulations. Filters with semi-permanent media are cost effective, since such units lend themselves to minimal downtime, closed and automatic operation with minimal operator intervention, and infrequent maintenance. The proper selection of filter media with appropriate pore size, strength and corrosion resistance enables long-term filter operation with high efficiency particle retention.

Sintered powder metal filter elements have been commercially available for more than 40 years. They are made from various alloy powders to meet corrosion and strength requirements. The primary benefits of sintered metal filters are:

- Strength and fracture toughness;

-High pressure and temperature capabilities;
-High thermal shock resistance;
-Corrosion resistance;
-Cleanability;
-All-welded assembly;
-Long service life.

The inherent toughness of the metal filters provides for continuous, back pulsed operation for extended periods. For high temperature applications, additional criteria such as creep-fatigue interactions, and high temperature corrosion mechanisms need to be addressed.

The sintered metal media are available in different alloys - including stainless steel 316L, Hastelloy® B, C-22, C276, N and X; Inconel® 600, 625, and 690; Monel® 400; nickel 200; alloy 20 and titanium - to handle wide-ranging corrosion and temperature environments. Sintered metal filters are manufactured by pressing pre-alloyed powder either into tubes or as porous sheet, followed by high temperature sintering. The combination of powder size, pressing, and sintering operations defines the pore size distribution, strength, and permeability of the porous element. An advantage of metal filters is that they are welded to metal hardware to obtain strong sealed joints. Sintered metal filters are available in gas filtration ratings from <0.05 to 20 μm [3,4].

Sintered metal filter media, for process gas applications, have been designed to achieve ultra-high efficiency levels exceeding >99.9999999% (log reduction values >9) in both 316L stainless steel and nickel media [11,12]. These filters are primarily intended for use in the filtration of process gases used in the semiconductor industry where filter lifetimes in exceed of 5 to 15 years are desired, in part due to the low particle loading, high cost and service issues associated with filter changeout.

Understanding of the ability of a filter to remove particles from a gas stream passing through it is key to successful filter design and operation. For gases with low levels of particulate contamination, filtration by capturing the particles within the depth of a porous media is key to achieving high levels of particle efficiency. The structure of sintered metal provides a tortuous path in which particles are captured. Particles capture continues as a cake of deposited particles is formed on the media surface; however, particles are now captured on previously deposited particles. The life of such filters will depend on its dirt holding capacity and corresponding pressure drop. For gases with high dust loading, the operative filtration mechanism becomes cake filtration. A particle cake is developed over the filter element, which becomes the filtration layer and causes additional pressure drop. The pressure drop increases as the particle loading increases. Once a terminal pressure is reached during the filtration cycle, the filter element is blown back with clean gas and/or washed to dislodge the filter cake. If the pore size in the filter media is chosen correctly, the pressure drop of the media can be recovered to the initial pressure drop. However, if particles become lodged within the porous media during forward flow, and progressively load the media, the pressure drop may not be completely recovered after the cleaning cycle.

The effectiveness of the cleaning cycle and the pressure drop recovery is a critical function of the properties of the cake. The cake strength depends upon the dust particle morphology and size distribution, electrostatic and chemical interactions, and cake moisture levels.

Particle capture is dependent on particle size and gas velocity. For particles in the vicinity of the most penetrating particle size (MPPS), the dominant particle collection mechanisms are diffusion and inception. The combination of these two mechanisms leads to an overall particle penetration curve that first increases with increasing particle, then decreases with further increases in the particle size. Of particular importance is maximum penetration point, which is also the point of minimum particle capture

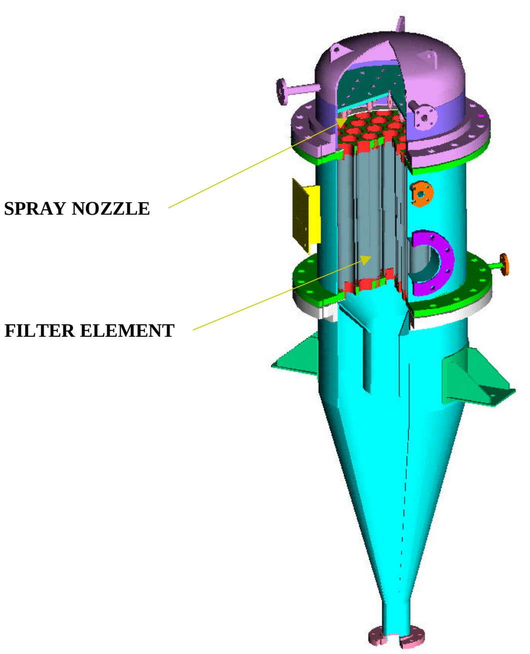

Figure 2. HEPA filter showing location of spray nozzles and tubular filter elements.

efficiency. The corresponding particle is referred to as the MPPS. Still larger particles are captured via the mechanisms of inception and inertial impaction. The particle penetration for all filter materials exhibit the same basic shape, with the level of penetration and the location of the MPPS dependent on the filter media and its usage. In general the location of the MPPS is typically in the range of 0.1 to 0.3 μm; thus leading to the use of the traditional 0.3 μm DOP test for filter efficiency.

SINTERED NICKEL HEPA FILTER ELEMENT

The RHFS is based on existing media and process filter system technology, which were further developed for this HEPA application. Mott manufactures a variety of cylindrical filter elements fabricated from sintered metal media, some filtering on the inside of porous sintered metal media. The HEPA filter, as shown in Figure 2, has multiple cylindrical elements, fabricated with sintered nickel media, welded to two tube sheets for reliable sealing and integrity. All materials of construction are stainless steel or nickel. The dirty gas stream passes into the inside of the cylindrical metal filter elements and flows radially from inside to outside of the filter media, with particulate collecting primarily on the inner diameter surface. When a terminal pressure drop is reached, the particles that collected on the inner diameter surface are removed with an in situ spray wash, thereby reducing radiation and eliminating contaminant accumulation. As illustrated in Figure 2, each filter element possesses its own spray-wash nozzle.

The nickel-based media developed for the RHFS encompassed all of the sintered porous metal characteristics described in the prior section. The nickel media can be welded by a variety of standard industrial welding techniques to stainless steel or nickel hardware. This avoids the use of seals or o-rings and allows for the fabrication of completely welded filtration units.

The filter media selected was a sintered nickel media, fabricated from nickel powder, already under development, which exceeded the HEPA filtration efficiency requirement. The media was modified somewhat to provide better pressure drop. Double open-ended elements of this media were provided to the SRTC for HLW simulation testing in the single element prototype filter. These elements performed well and further demonstrated the practicality of a metallic media regenerable HEPA filter system. An evaluation of the manufacturing method on more than 30 elements demonstrated the reproducibility to meet the HEPA filtration requirement.

An extensive series of evaluations were conducted at Mott, SRTC, and ATI. SRTC conducted challenge testing, with simulated wastes, on small and full-size elements. Full-scale filter element evaluation included:

- -Collapse pressure;
- -Efficiency;
- -Pressure drop;
- -Particle loading and element cleanability.

Figure 3 shows a scanning electron photomicrograph of the nickel media, which is fabricated from nickel 200 powder. The flow pores are tortuous in nature and flow path lengths are long. Therefore, even though the pore dimensions on the porous surface appear to be micrometer size due to high surface roughness, the finer subsurface pores, high tortuosity and long flow paths provide effective obstacle to the passage of submicrometer particles through the media. Therefore, the physical pore size of the media does not represent the filtration efficiency or rating of the media.

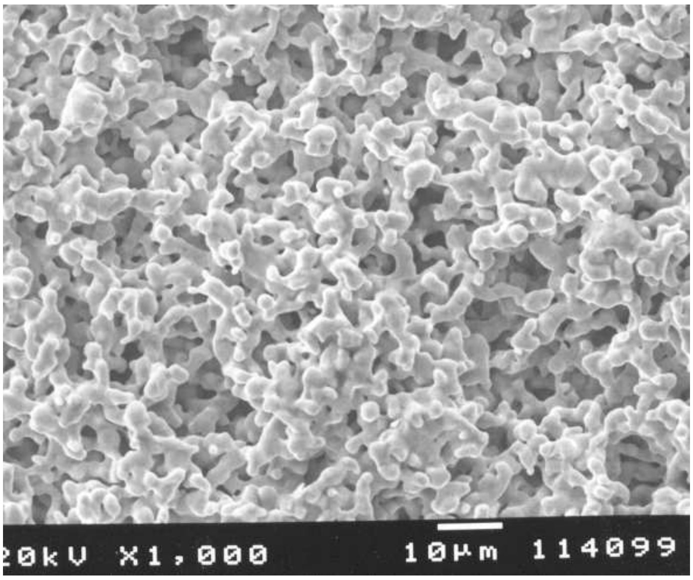

Figure 3. Photomicrograph of sintered nickel media.

The photomicrograph also shows that the metal powder particles are well sintered, thereby providing intrinsically high mechanical strength. The strong media can be back-pulsed to dislodge particle cake formed during filtration and recover the gas flow. The high media strength provides high collapse, i.e., in excess of 100 psi for a 5.71 cm (2.25 inch) diameter tube. Note that the maximum design differential pressure for this HEPA filter is not to exceed 0.69 bar (10 psi).

HEPA Efficiency Testing

HEPA filter efficiency tests were conducted on the nickel filter elements by Air Techniques International (ATI) in Oak Ridge, TN. A special filter housing was provided to accommodate the elements for HEPA efficiency as well as pressure drop testing.

Two of the initial nickel elements, 7.62 cm (3 inch) diameter, were tested at 56 m^3/hr (33 CFM) with the following results:

	Pressure Drop,		
Element	bar	psig	Penetration
#1	0.234	3.4	0.001%
#2	0.248	3.6	0.001%

The HEPA standard is a penetration of less than 0.03%. These two elements were subsequently sent to SRTC for particle challenge testing [13].

A more permeable nickel media, coupled with a smaller 5.71 cm (2.25 inch) diameter element, was subsequently development. Multiple manufacturing runs were performed to determine the variability, if any, of the manufacturing process on the resulting HEPA filter performance. A total of 29 elements were manufactured and tested at Oak Ridge. Only one failed the HEPA test with a penetration of 0.032% versus a requirement of 0.030%. The typical penetration for the other 28 elements was only 0.001%. Pressure drop at air flows of 42.5 – 59.5 m^3/hr (25-35 CFM) was typically between 0.179 – 0.224 bar (2.60 – 3.25 psi). These elements easily met the established criteria for particle collection efficiency and design specifications for pressure drop. Furthermore, the element flow rate in the final RHFS was reduced to further lower the operating pressure drop. This had the added benefit of decreasing the particle penetration or increasing the removal efficiency.

Pressure Drop

The initial nickel elements, with a 7.62 cm (3 inch) diameter, were found to have a high pressure drop. The average pressure drop ranges from 0.174 – 0.200 bar (70 – 80 inch water) at a flow of 51.0 m^3/hr (30 CFM). This higher pressure drop is a direct result of the manufacturing process. Since this is a rather large diameter for a long filter element in nickel, the media had to be compacted using a higher pressure, in order to achieve proper mechanical strength and avoid premature collapse.

Pressure drop data for the final filter element, 5.71 cm (2.25 inch) diameter by 55.9 cm (22 inch) long, are listed below:

Flow, CFM	Pressure Drop, inch water	Flow rate, SCFM	Velocity, ft/min
14.8	27.3	13.8	13.4
25.3	45.7	22.4	21.7
31.0	55.0	26.7	25.9
36.7	63.9	30.8	29.9
42.6	72.6	34.7	33.7
48.4	80.8	38.4	37.2

The pressure drop at 51.0 m3/hr (30 CFM) is 0.137 bar (55 inch water or 2.0 psi) as compared to 0.174 – 0.200 bar (70 – 80 inch water) for the 7.62 cm (3 inch) diameter element.

The design velocity for the filter system is 5.58 m/min (18.3 ft/min), which yields a clean pressure drop of about 0.096 bar (38 inch water or 1.38 psi).

Particle Loading and Element Cleanability

Simulation particle loading and element cleanability tests were conducted at Mott and SRTC over a 3-year period on a variety of elements. Initial testing was performed on metal elements fabricated from 316L stainless steel media while subsequent and final tests were performed on 7.62 and 5.71 cm (3 and 2.25 inch) diameter nickel elements, respectively. Particle simulants used in the SRTC tests included waste sludge, South Carolina soil dust, and salt. Arizona test dust was used as the simulate particles in the tests conducted at Mott.

The initial filter elements developed were sintered 316L stainless steel, 7.62 cm (3 inch) in diameter. This element was evaluated both at Mott and SRTC for fouling and cleaning characteristics [2, 13].

The nickel media was selected for further development and evaluation since it was ultimately discovered that the stainless media did not meet the HEPA efficiency standard. A nickel media had been under development and was known to exceed the HEPA efficiency standard. This media was further developed for RHFS use [2, 13].

The work conducted by SRTC dealt with the performance of the filter media in a simulated challenge test to determine the response of the filter media to filtration of tank waste products and regeneration on cleaning. The SRTC challenge consisted of three types of simulants: waste sludge, South Carolina soil dust, and salt. Each test would run for several hundred hours, depending on the time to reach a plugged condition, in order to perform 5 to 6 cleaning cycles. Flow and pressure drop, recorded against time, were monitored and recorded. The filter elements tested were small cylinders challenged on the outside and washed with multiple spray nozzles for cleaning. The testing indicated that the Mott sintered media did effectively filter the tank materials and be regenerated. The flow rate decreases with particle loading and then is restored (increases) after a backwash operation [13]. For example, one of the elements that achieved a 99.999% removal efficiency was subsequently plugged and cleaned in situ 7 times with simulated sludge/salt particles and atmospheric dust. After these rigorous tests, the filter again achieved 99.999% removal.

A series of 11 particle loading and washing tests were performed at Mott on the 5.71 cm diameter nickel elements using ISO 12103-1, A-2 (fine grade) Arizona test dust. In each test the element was loaded with 120 to 270 grams of test dust. The clean pressure drop (initial pressure) and terminal pressure drop were measured at a flow rate of 51 m^3/hr (30 CFM). The elements were subsequent regenerated using 3 liters

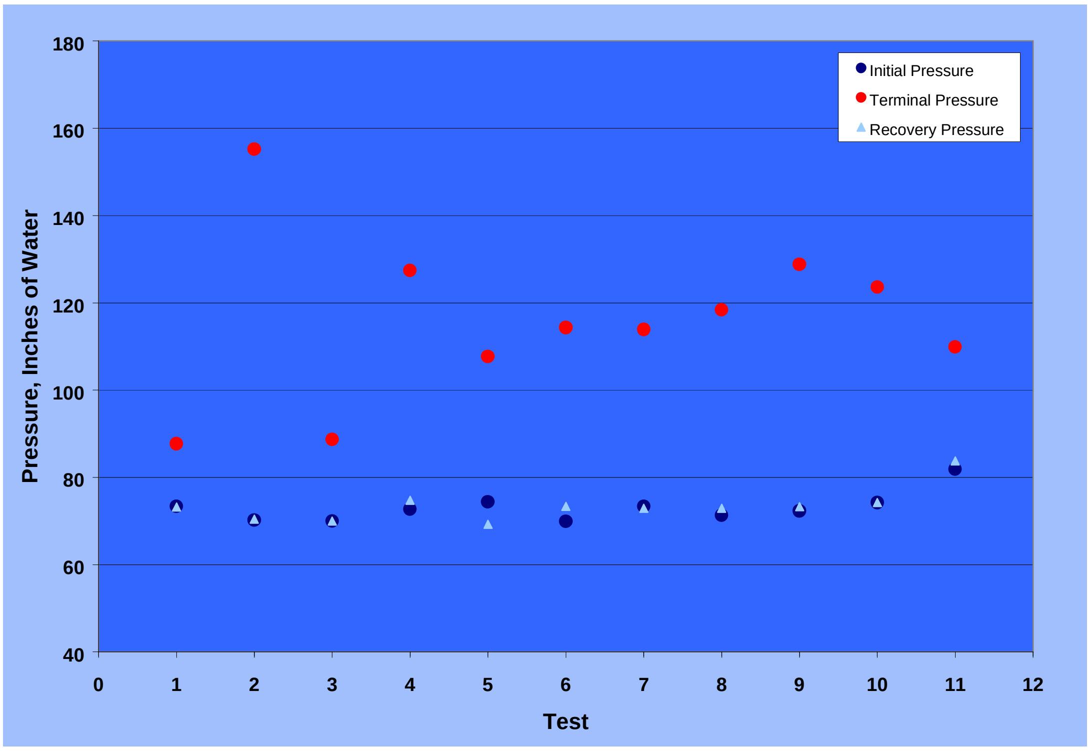

Figure 4. Pressure drop data showing the clean pressure drop (initial pressure), the effect of filter loading with ISO 12103-1, A-2 (fine grade) Arizona test dust (terminal pressure), and the subsequent regeneration (recovery pressure).

of wash solution and various reverse air flow ranging from 0 – 18.7 m^3/hr (0 - 11 CFM). Element drying times ranged from 18 to 120 minutes followed by measurement of the recovery pressure drop. Best dry times achieved with a reverse air pulse prior to water wash

Figure 4 shows the clean pressure drop (initial pressure), the effect of dust loading (terminal pressure) and subsequent regeneration (recovery pressure). The key data are:

-Clean flow pressure drop @ 51 m^3/hr (30 CFM) was 0.174- 0.200 bar (70 – 80 inch water);

-Terminal pressure drop: 0.220 – 0.388 bar (88 – 155 inch water);

-Recovery pressure drop within 0.0088 bar (3.5 inch water) of clean flow pressure drop for 11 tests.

REGENERABLE HEPA FILTER SYSTEM

The full-scale design of the Mott RHFS incorporated several important features in its design and operation. The element bundle is an all-welded assembly, which can be removed and replaced as a unit if the elements ever need replacement. Each element has a spray nozzle mounted above it for cleaning. In addition, the element can be cleaned in place by a soak and backwash technique. The inlet nozzle incorporates a cyclonic separator to initially remove large suspended material and droplets.

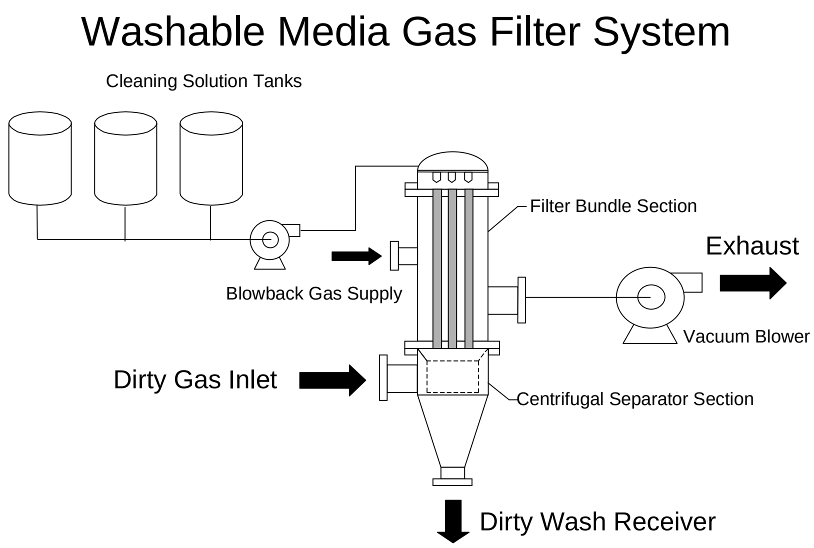

Figure 5. Schematic diagram of regenerable HEPA filter system (RHFS).

The RHFS design, as shown schematically in Figure 5, consisted of a single or dual Mott HEPA filter (Figure 2) incorporating liquid spray cleaning mechanisms, dual vacuum pumps for moving the gas through the filter from the waste tank, and a detached cleaning skid. The cleaning skid, capable of being transported to each HLW tank for cleaning filters, consists of tanks and a pump.

The filter design incorporates two means by which particles are collected – cyclonic inlet separator and metallic HEPA filter elements. The cyclonic inlet separator, which assists in removing heavy particles or droplets, has demonstrated removal efficiencies of 50 to 70% of ISO 12103-1, A-2 (fine grade) Arizona test dust. After exiting the cyclonic filter separator, the dirty gas stream then passes into the inside of the cylindrical metal filter elements and flows radially from inside to outside of the filter media, with particulate collecting primarily on the inner diameter surface. When a terminal pressure drop is reached, the particles that collected on the inner diameter surface are removed with an in situ spray wash, thereby reducing radiation and eliminating contaminant accumulation. Each filter element possesses its own spray-wash nozzle.

The HEPA filter contains metal elements, 5.72 cm (2.25 inch) diameter, welded to tube sheets top and bottom, which are in turn welded into a housing shell. The vessel design is per ASME section VIII, division 1 and the vessel is code stamped. A 61 cm (24 inch) diameter vessel, for example, would contain 48 elements and be capable of an overall air flow rate of 1360 m^3/hr (800 CFM). The media flux is 5.58 m/min (18.3 ft/min) with a projected filter system pressure drop of 0.138 bar (2.0 psi). Each element, as shown in Figure 2, has one high efficiency spray nozzle for cleaning. The element / shell assembly is connected to a cone bottom base. Tangential entry of the inlet gas creates a cyclonic effect, which serves as an initial solids separator. Except for the body flange and spray nozzle connections, the filter is an all welded assembly. The entire filter body could be replaced if filter element replacement were ever required.

Two regenerative blower vacuum pumps provide the energy for vent gas movement and filter drying. They are constant operation pumps requiring no oil or water cooling. There are no waste streams generated. Reliability has been proven in countless industrial applications. These high capacity blowers are required to overcome the higher pressure drop of the metallic elements.

The cleaning skid consists of three 50 gallon Nalgene tanks and one positive displacement air driven pump. The skid assembly is portable and is used to clean filters as needed. The tanks will hold acidic and caustic cleaning solutions, and water for rinsing. Compressed air is required for the pump.

Instrumentation is provided to monitor filter pressure drop. The need for filter cleaning is indicated by a preset maximum pressure drop across the filter. Due to the nature of the vacuum pumps, flow measurement is not required. Pressure gauges provide a visual check of system operation.

The filter cleaning is accomplished by a spray wash with an acidic cleaner, water rinse, caustic neutralization, water rinse, and then vacuum drying. In addition to the sprays, a reverse flow of air can assist in the cleaning by removing imbedded materials during the solution spraying. This feature provides the maximum cleaning flexibility possible. It is anticipated to require a total of 5 to 10 gallons per element to obtain effective cleaning.

Materials of construction for the filter are 316L stainless steel except for the nickel filter media. All piping exposed to the process gas is 316L stainless steel.

The system is designed according to accepted ASME codes and specifications provided by SRTC and NETL.

Regulatory and Safety

The design of the Mott RHFS is subject to all applicable design codes, including ASME VIII and IX, and any applicable nuclear codes. It is expected that it will meet all applicable regulatory requirements for similar types of equipment. Being an entirely enclosed system, it will comply with all environmental requirements.

The filter system is constructed as a metal housed filter with inert metallic filter elements which are durable in construction and not subject to degradation or mechanical failure. In operation, the system requires no local monitoring or operator attention. During filter element cleaning, manual operating valves are manipulated as necessary to move fluids to their appropriate destination. If desired some or all of these valves can be operated remotely. The installed location, on top of a HLW tank, provides a repository for cleaning materials into the waste tank. The volumes considered are small.

The mechanical reliability and integrity of the filter elements and the all welded seal design protect the atmospheric side of the filter. It is essentially a fail-safe design.

The mechanical blower that generates the vacuum to operate the system can be remotely located in a shed or other structure to minimize noise levels. Since the blower operates at higher discharge pressures than the current blowers, it can be located some distance away from the tank for easier access and maintenance.

The human exposure to radiation and other unhealthy materials is greatly minimized with the Mott RHFS. With a 15 year operating life, human exposure is greatly reduced when compared to the annual change outs and handling of the glass fiber HEPA filters. A Human Factors Assessment Report was prepared and reviewed by the International Union of Operating Engineers National Hazmat Program [14].

Project Reviews

Two formal project reviews were conducted during the life of this project. Each involved approximately 6 hours of oral presentations, coupled with written materials.

The first occurred in September 2000 at Richland, WA, as part of an American Society of Mechanical Engineers (ASME) Peer Review of the Alternative Filtration Program at DOE. The outcome of this review included a favorable evaluation by the ASME review panel [15].

The second review occurred on December 11, 2001 at the Savannah River Research Campus in Aiken, SC. This review covered the proposed full-scale design of the system and all development work. Details of element development, element testing, and full-scale system design were presented. The International Union of Operating Engineers National Hazmet Program also conducted a human factors assessment of the system [14].

SUMMARY

A novel HEPA filter using sintered nickel media has been developed to replace the traditional glass fiber HEPA filters employed in DOE HLW tank ventilation systems, thereby increasing the filter service life from the current 1 year to a design specification of 15 years. The feasibility of using cleanable semi-permanent filter media has been demonstrated, and a full-scale system design has been submitted and reviewed by both DOE and SRTC with approvals.

The benefits of using a sintered metal filter element include their long life, low maintenance, and predictable behavior. The sintered metal media are completely weldable; therefore, the temperature and corrosion resistance of the seals do not limit the applications.

Prototype filter element designs have been successfully tested and evaluated, resulting in confidence that the filter design meets the performance criteria established. The design is rugged, reliable, and consistent with mechanical designs typically used in nuclear facilities.

The chosen filter media, a sintered nickel, meets and exceeds the HEPA filtration efficiency standard of 99.97% removal of 0.3 μm aerosol particles, typically achieving 99.999% removal. The pressure drop is 0.0.96 bar (1.38 psi) at design gas flow velocities of 5.58 m/min (18.3 ft/min).

Simulation particle challenge testing has successfully demonstrated the capability of the filter to capture solids and then subsequently regenerate on cleaning. The simulation challenge was significantly more severe than the expected operating conditions on HLW tanks.

The full-scale design of the RHFS incorporates several important features in its design and operation. The filter element bundle is an all welded assembly, which can be removed and replaced as a unit if the elements ever need replacement. Each element has a spray nozzle mounted above it for cleaning; it could also be cleaned by a soak and backwash technique. The inlet nozzle incorporates a cyclonic separator to initially remove large suspended material and droplets. Tests indicate a significant reduction in the dirt load passing to the filter elements, which would extend the operating time between cleanings. A high capacity blower was selected to overcome the higher pressure drop of the metallic elements. The blower is capable of operating the system at higher pressure drops than those currently used with the glass fiber HEPA filters. This additional capacity further increases the operating duration of the filter.

The RHFS, at each stage of the development process, has met the design requirements for a suitable replacement system for the glass fiber HEPA filters, thereby enabling great cost savings. It remains to test a full-scale operating system on an actual high level waste tank to fully demonstrate the performance and anticipated cost savings of the RHFS.

While the nickel HEPA media and filter were developed for the HLT application, they have applicability as a replacement media for glass fiber HEPA media in numerous demanding applications requiring not only the efficiency requirements of a HEPA filter, but the attributes of sintered metal.

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