ALTERNATE AIR FILTRATION SYSTEM TO MINIMIZE WASTE GENERATION IN NON-REACTOR NUCLEAR FACILITIES

Gurinder Grewal, Zoran Milatovic', and Frank L. Landon
Advanced Technology Business Unit
Fluor Daniel Inc.
Irvine, California

ABSTRACT

Sand filters, Deep Bed Glass Fiber filters, and remotely replaceable High Efficiency Particulate Air filters have been successfully used for filtration of exhaust air from highly contaminated exhaust air streams. However, none of these technologies satisfy all requirements of an optimum filtration system design. An ideal filtration system should generate minimum waste, be easy to decontaminate and decommission, and meet all requirements of nuclear grade air filtration. High Efficiency Metal Fiber filters are a new technology and provide a suitable alternative to the currently used nuclear air filtration technologies. This paper investigates the possibility of reducing nuclear waste by using the High Efficiency Metal Fiber filters in nuclear exhaust air systems.

INTRODUCTION

One goal of nuclear facilities design is to minimize their impact on the environment. All exhaust air from these facilities is filtered to minimize the release of radioactivity. The nuclear air cleaning filters are normally designed with minimum efficiency of 99.95% for 0.3 micrometer size particles. Nuclear grade High Efficiency Particulate Air (HEPA) filters provide this efficiency and have been used satisfactorily in nuclear air cleaning applications. HEPA filters are fragile and can fail due to over pressurization caused by high concentration of water droplets or dust in the exhaust air stream. HEPA filters are disposable type and are replaced periodically. HEPA filter failure is always a concern in severe service applications, such as off-gas cleaning, exhaust air filtration from highly contaminated process enclosures, and safety related facility exhaust systems. HEPA filters exposed to high radioactivity, severe acids, and moisture are protected by scrubbers, high efficiency mist eliminators, and heaters to assure that acids will not degrade filter media and moisture accumulation will not cause over pressurization and filter failure. Redundancy is provided in HEPA filter units for reliability and safety. HEPA filters in high radioactivity service are designed for remote maintenance to reduce radiation exposure of operating personnel. Highly radioactive HEPA filters are difficult to dispose.

Sand filters and Deep Bed Glass Fiber (DBGF) filters have been used as alternatives to HEPA filters for severe applications in the U.S. Department of Energy (DOE) nuclear facilities for many years. They are described in detail in the Nuclear Air Cleaning Handbook (1) and the proceedings of the DOE/NRC Nuclear Air Cleaning Conferences. The sand filters and the DBGF filters are non-replaceable types and are designed to last the life of the facility. Their design is empirical and performance is difficult to predict. The sand filters and the DBGF filters are normally designed for a target efficiency of 99.95%, but the efficiency is difficult to test reliably due to their large size. The sand filters provide excellent protection from explosions and fire because of the enormous mass of sand, but are difficult to qualify seismically. The acceptable decontamination and decommissioning procedures for the sand filters and DBGF filters have not been developed so far and to date none of these has been decontaminated and decommissioned.

Owens Corning glass fiber type 115K was found to be the most suitable media for the DBGF filters (1). No DBGF filters have been constructed in recent years and this media is not commercially available.

High Efficiency Metal Fiber (HEMF) filters have many desirable characteristics of HEPA filters, sand filters, and DBGF filters. They have high efficiency of HEPA filters, and permanence and ruggedness of the sand filters and the DBGF filters. HEMF filters are constructed of stainless steel and can be seismically qualified. HEMF filters would not be damaged by corrosive vapors, large amounts of moisture droplets, heavy dust, and burning embers in the air stream. HEMF filters are non-replaceable type and are cleaned in-place using water, nitric acid or other chemical solutions compatible with the process application. The resulting liquid waste can be treated by the facility radioactive liquid waste treatment system. Presently, the capital cost of the HEMF filter systems is competitive with other filter systems (i.e. remotely replaceable HEPA filters, sand filter, etc.) used for filtration of highly radioactive, high temperature, and high moisture content gas streams. The life cycle cost of HEMF filters is expected to be lower than that of HEPA filters, sand filters and DBGF filters.

The HEMF filter media is relatively new to the industry, having been commercially available in the U.S.A. for only the past six years. However, HEMF filters have been successfully used in Europe for high efficiency filtration of gases in the chemical and food industries. These filters have the following potential gas cleaning applications in the nuclear industry:

1. Highly radioactive off-gas systems.
2. Air exhaust from highly contaminated processing cells.
3. Vent filters for radioactive waste storage tanks.
4. Exhaust from Plutonium processing glove boxes.
5. Incinerator off-gas.

Demonstration testing is in progress of a 1,000 cfm, HEMF filter unit at the U.S. DOE Y-12 Plant at Oak Ridge (4), Tennessee and a 300 cfm HEMF filter unit for the Hanford Waste Vitrification Plant melter off-gas system at Richland, Washington. The manufacturer has a number of non-nuclear gas cleaning applications to demonstrate that the HEMF filter module assembly performance and efficiency can be reliably scaled up from the performance of a single filter module.

COMPARISON OF HEPA, SAND AND HEMF FILTERS

HEPA filter units have been used in nuclear applications for a long time. Filter media have been tested for different processes and applications. Media performance is predictable and the filtration system can be designed to meet the filtration requirements. HEPA filter design guides are available to insure that filtration system designs are compatible with their application.

The most common operational upsets in the off-gas applications is the impingement of water-saturated process gas and/or liquid droplets that could affect filter elements.

The glass-fiber filter media provided in nuclear grade HEPA filters is water resistant. The filter media must pass the "wet over-pressure" test in accordance with standard MIL-F-51068, which requires the filter to maintain its efficiency after exposure to a 10" w.g. pressure drop at 95°F fog. However, aging and decay will reduce the strength of glass-fiber filter media organic binder. A statistical analysis of results for tests of more than 2,000 media samples revealed that wet folded samples on the average retained only 10% of their original strength (3). Additional losses in media strength can occur as a consequence of heat exposure or high radiation. Mist eliminators and heaters are installed upstream of the HEPA filters to prevent filter media failure due to the moisture in the air. Failure of either the mist eliminator to trap water droplets or the heater to reduce relative humidity could cause the HEPA media to rupture.

Other credible accident scenarios may involve a sudden upset which can produce a large cloud of particles, far in excess of normal loading. A high concentration of particles in the gas stream could lead to rapid plugging and over pressurization of the filter elements, which can quickly lead to rupture of the HEPA filter media. However, HEMF filters would not fail catastrophically due to their greater mechanical strength. HEMF media would retain its integrity even with gross quantities of free water impingement. The HEMF media should be kept dry to maintain high filter efficiency. The HEMF media fibers may corrode when exposed to moist acidic conditions for long periods of time.

The sand filters require little or no maintenance and have large dust holding capacity, high heat capacity, fire and explosion resistance. However, the sand filter design is empirical and its performance cannot be forecast with confidence. The sand filters cannot be easily seismically qualified and there is no experience or guidelines available for their decontamination and decommissioning.

HEPA filters in HVAC applications are not usually exposed to high moisture concentration as in off-gas applications. The HVAC HEPA filter banks are large and consequently their periodic replacement generates large amounts of radioactive waste. Dust loading of the filters depends on *the facility* cleanliness and the type of process performed.

The HEMF filters can be designed to have larger dust holding capacity than HEPA filters. The dust holding capacity parameter of a filter relates the pressure drop increase at constant airflow to the weight of contaminants being captured by the filter. The expected frequency of filter cleaning is estimated from:

1. Concentration of contaminants (i.e. weight/unit volume) in the gas stream
2. Filter replacement or cleaning pressure drop

The desired filter pressure drop and dirt holding capacity of HEMF filter units are achieved for a specific application by optimization of the filter media surface area, the unit geometry and construction of the upstream, downstream, and filter medium drainage layers.

VULNERABILITY OF HEMF FILTERS TO ACCIDENTS AND UPSETS

Fire

HEMF filters are made entirely of stainless steel and contain no flammable components. They are inherently resistant to high temperatures and over- pressurization. Although the finely divided filter media will not resist direct flame impingement, the media would not be destroyed by burning embers. The filters would get loaded with soot and other products of combustion and would experience high pressure differential, but the media would not rupture. The manufacturer has indicated that HEMF filters can operate continuously at 125 psi (860 kPa) differential pressure and 750°F (400°C), and for 10 minutes at 1000° F (535°C).

Seismic

The sand filter cannot easily be designed or qualified for seismic events. A bypass HEPA filter system may be required to maintain exhaust air flow after a seismic event.

HEPA filter systems have been qualified seismically.

HEMF filters offer an inherently greater degree of seismic resistance than either of the other options, because of their all welded construction and resultant high mechanical strength.

MAINTENANCE CONSIDERATIONS

HEPA Filter Units

HEPA filter units for highly radioactive service are installed in shielded cells and must be maintained remotely. In some applications the entire filter housing needs to be remotely disconnected and removed to a remote maintenance area. Remotely operated manipulators are used to open the filter housing and remove spent filter elements. After removal of the filter elements the filter housing is decontaminated and moved into a contact maintenance area. New HEPA filter elements are installed and the entire assembly is leak tested. The housing is returned into service using remotely operated mechanical equipment. Since part of the operation requires personnel contact with the filter housing, this type of operation does not meet the personnel exposure ALARA requirements. Several manufacturers have developed HEPA filter housings in which filter elements can be replaced in-place using remotely operated manipulators. All maintenance and testing of these housings is performed remotely.

Sand Filter

Sand filters do not require regular maintenance.

HEMF Filter Units

HEMF filter units are designed to be cleaned in place using either air pulses (4), or water/nitric acid wash (5). In most cases water wash cleaning should regenerate the filters sufficiently. The HEMF filter manufacturer estimates that this cleaning procedure will be about 85-95 percent effective.

Nitric acid decontamination solution can also be used to clean the elements if water washing alone proves to be less effective than anticipated. After cleaning with nitric acid solution, the housing is thoroughly flushed with demineralized water to remove any nitric acid solution deposits on the filter media. Prolonged contact of acid with filter may damage the stainless steel fibers.

DECONTAMINATION AND DECOMMISSIONING

HEPA Filter Units

HEPA filter elements can be disposed in the following manner:

a. The spent filter element can be bagged after removal from filter housing and placed in an appropriate burial container. The replacement and disposal cost can be determined by the radiation level of the element.

The following are the current estimated costs of disposing spent HEPA filters.

- low level beta/gamma waste emitting less than 200 millirem/hr at $1200- 2400 per element.
- elements classified as TRU waste (i.e. TRU concentration equal to or greater than 100 nano Ci/gram of element weight) at $3200-5300 per element.
- high level (remote handled) beta/gamma waste emitting more than 200 millirem/hr has no approved disposal method.

b. The alternate method of disposal of the spent HEPA filter elements is being currently developed at the Savannah River Site. The spent filter element is soaked and boiled in a tank of two weight percent solution of sodium hydroxide for 48 hours to dissolve the glass fiber media. This may be followed by the addition of five weight percent nitric acid and boiling to break the resulting gel.

It is expected that glass fiber media, resin binder, and HEPA filter sealant will completely dissolve, and the radioactive particulate will become dissolved or suspended in the liquid phase. This will be necessary to permit the remaining metal HEPA frames to undergo further decontamination, compaction, and final disposal as low-level solid waste. These frames can be compacted into 55- gallon drums (maximum three per drum) and disposed as low level waste. The cost of disposal is estimated to be $2,400. The incomplete dissolution of the HEPA media could require substantial additional decontamination to convert the metal frames to low-level solid waste.

Sand Filter

The decontamination and decommissioning of a sand filter is likely to be prolonged and expensive. None of the existing sand filters have been decontaminated and decommissioned.

Two methods for decontamination and decommissioning of a sand filter are being currently considered:

a. In-situ vitrification

Pacific Northwest Laboratory (PNL) has developed an innovative soil melting technology for hazardous waste treatment. The process uses an electric current that is passed between electrodes placed in the ground which converts soil and contained materials to a stable glass material. Heat from the electric current melts the soil and rocks and decomposes organic materials. During the process, metallic and other inorganic materials are dissolved into or are encapsulated in the vitrified mass. Gasses evolve from the melt or go into solution. Convective currents within the melt uniformly mix materials that are present in the soil. When electric current ceases, the molten volume cools and solidifies. The product of in-situ vitrification is a block of glass like material, with excellent chemical durability that will retain its physical and chemical integrity for geologic time periods. In-situ vitrification technology has been demonstrated through field scale for some applications, but it has not been used commercially on a large scale, and it would be extremely difficult to develop a realistic cost estimate.

b. Shipping of sand to a burial site

This method is based on non-TRU sand filter media, and it is assumed that the sand media is loaded into barrels (packaged) and prepared for shipment to a burial site. While satisfactory removal and disposal of sand filter media has been demonstrated, Savannah River Site has indicated that until specific requirements dictate otherwise, their intention is to seal and abandon the sand filters.

In general the decontamination and decommissioning for this alternative involves the following activities:

Spray decontamination of the inlet and outlet tunnels of the sand filter structure. Remove and package into the barrels the sand filter media. Spray decon of the sand filter structure. Evaporate used decontamination solutions and package evaporator bottoms (solids) into barrels and ship to the burial site.

HEMF Filter Units

At the end of their life the HEMF filter units can be decontaminated in a similar manner as other processing vessels in the facility and disposed as low level solid waste. If necessary the filter media fibers can be dissolved to facilitate decommissioning of the filter units.

CONCLUSION

Filtration systems using HEPA filter elements is a widely used technology for air filtration in nuclear industry. Replacement and disposal of highly contaminated HEPA filters is complex and very costly. The cost to replace and dispose HEPA filters is about $55 million per year for U.S. Department of Energy (DOE) nuclear facilities. Moore et al estimate that $50 million of the $55 million annual cost is due to waste handling. (6)

Decontamination, decommissioning and waste disposal of the sand filter is likely to be expensive, and there is little prior experience as guidance. There are a number of sand filters that are waiting for less costly technology to be developed for decontamination.

HEMF filters appear to offer equal or superior filtration efficiency to the other alternatives used in nuclear industry (5). Filter media is cleanable in-place using either water or dilute nitric acid. This represents a potentially significant advantage over the HEPA filters. The HEMF filter units can be decontaminated using proven decontamination techniques and disposed as low level waste.

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