HEPA FILTER DEFECTS ARE COMMON

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ABSTRACT

HEPA filters (High Efficiency Particulate Air) filters are claimed by vendors to have 99.97 % collection efficiency for particles down to 0.3 microns. We have found that relying on this claim may lead to employee exposures and emissions far in excess of those anticipated.

In an attempt to comply with a corporate goal of zero detectible emissions for both in plant and stack discharges high quality HEPA filter holders and filters were purchased. After installation unexpected particulates were found in routine sampling. Our response included trying filters from several vendors and having filters installed by both the vendor’s representative and our staff. This did not totally eliminate the problem and further investigation revealed that there were inadequacies in the certified HEPA filters delivered by several manufacturers. A relatively novel testing method was employed for testing both the HEPA filter material and gaskets seals.

HEPA filters, as delivered, can’t be relied on to perform as advertised. A test method for the evaluation of performance, although expensive, is available. With appropriate diligence HEPA quality filtration can be obtained, but not consistently using manufacturer certified filters and common HEPA filter holders.
A combination of inspection methods and special filter mounting methods is required in any critical application of HEPA filtration technology.

Design principles, testing methodologies and results of tests on various vendors’ filters will be presented.

**Key Words:** HEPA filtration, filter leaks, HEPA defects, and air filtration systems.

**INTRODUCTION**

HEPA filters were chosen as a means to assure compliance with a corporate goal of no detectable cadmium particles in the plant environment. A review of past and current cadmium levels demonstrated that the measured levels were always well below OSHA standards. Measurements of in-plant air showed occasional low levels substantially below the OSHA requirements. The corporate goal of no detectable metallic particulates was not consistently achieved. A comprehensive evaluation to determine sources of cadmium dust particles resulted in the correction of numerous potential small contributors. A Scanning Electron microscope and a combination of settling plates as well as NIOSH sampling methods indicated the likelihood of particulates from HEPA filtration units potentially sometimes in the plant air. An investigation to determine the root cause of the apparent failures was initiated. A basic assumption was that HEPA filters would remove all metallic particles at the rated efficiency.
PROBLEM AND HYPOTHESIS

Minute traces of metallic dust in the plant environment at the facility did not meet a corporate goal of “no detectable cadmium” in the workplace air. A structured evaluation program using atomic absorption and scanning electron microscope methods to analyze samples from the plant apparently eliminated all sources except the HEPA air filtration units which served as an exhaust on some equipment. These HEPA filtration units discharged into the plant atmosphere. A reputable manufacturer for the equipment and filters had been chosen and there were no visually obvious problems with the systems.

ASSUMPTIONS

1. The investigation of sources eliminated all potential in plant contributors to the metallic particulates found except the HEPA air filtration system.

2. Cadmium was not present in the ambient air outside the plant used as makeup air for the facility.

3. The sampling and analytical technique used was adequate for detection of cadmium at the levels reported.

4. The HEPA filters would remove all detectable cadmium particulates if operating at design efficiencies.

REVIEW OF BACKGROUND INFORMATION

HEPA filters are advertised as 99.97% effective on particulates of 0.3 microns or larger. Several filter vendors were contacted and their literature reviewed. It was apparent that the testing methods of the various manufacturers differed.
Discussions with manufacturers representatives and the review of periodical literature did not reveal a common industrial problem recognized which would obviously cause the finding of particulates in our in-plant atmosphere.

PROcedures

An extensive investigation of all potential metallic sources was initiated. This investigation included sampling and developing a method to recognize various species of cadmium compounds using a scanning electron microscope (SEM). The results of the SEM examination were compared to resulting uses NIOSH sampling methods and atomic absorption analysis for cadmium. Some minor potential contributors were found and corrected. The problem of measurable cadmium, well below OSHA limits, in the plant environment occasionally continued.

1. Filter housing used in the facility were constructed having all internal seems sealed with silicon adhesive and the filter mounting mechanism was designed to apply 600 lb force to the gasketed filter structure.

2. Subsequently filters were obtained from three vendors

3. These filters were all gasketed and rated by manufacturers as HEPA filters at the 99.97% 0.3 micron rated.

A visual inspection of the filters, which arrived at the facility, shows that there was some variance in the methods selected by the manufactures for the mounting of the filter media and the filter case as well as the gasketing of the filter case. The filter vendors assured us that the filters were all compatible with the equipment used on-site. Filters from some
vendors even came with certificates of inspection and testing from the manufacturing facility.

A testing service known as Mechanical Testing Service Inc from Grandville, MI was eventually selected to come on site to perform tests of the filters in service. The testing protocol chosen was in conformance with federal standards 209E and the Institute of Environmental Sciences Standard IES-RP-CC006.2 “testing clean rooms”. A Thompson model BC700 photometer along with a model TDA-5B aerosol generator was used to challenge the media and the test for leaks. In this system a known aerosol size distribution is generated and injected into the air stream entering the filter. The probe is then used to scan the entire filter surface for leaks.

**TEST 1: SCAN METHOD LOGARITHMIC PROCEDURE**

This test is performed by introducing specified aerosol upstream of the HEPA filter and searching for leaks by scanning the downstream side of the filters with the photometer probe. The design airflow velocity is set prior to performing the filter installation leak test. The HEPA and pre-filters are pictured below in Figure 1. This HEPA unit is 24” x 24” x 12” in size and weighs 41 pounds. A pre-filter is place in front of the HEPA filter to capture large particles and reduce the loading on the HEPA filters.
DESCRIPTION

I) Aerosol is introduced into the air supplied to the HEPA filters in a manner, which will produce a uniform challenge concentration at the HEPA filter.

II) The aerosol generator air supply pressure is set at 20 psig minimum. The number of nozzles operated is determined by the necessity to produce a concentration for detection by the photometer.

III) The logarithmic readout photometer is adjusted using the instrument calibration curve, and the upstream aerosol challenge concentration is measured.
IV) Passing the probe in slightly overlapping strokes so that the entire area of the filter is sampled the probe is used to scan the filter face and perimeter of the filter pack. The probe should be held approximately 1 inch (2.5 cm) from the area of testing during the scanning. Separate passes were made around the entire periphery of the filter, along the bond between the filter pack and the frame, and around the seal between the filter and the device, at a traverse rate of not more than 10 feet/min (3 m/min). Reference Figure 2 (below)

V) The logarithmic photometer results are indications of detected leaks greater than one scale division or less than 0.01 percent leakage.
**TEST 2: LINEAR TESTING PROCEDURE**

This test is performed by introducing aerosol upstream of the HEPA filter and monitored on the downstream side to determine the percent efficiency of the filter.

**DISCUSSION**

1. Aerosol is introduced into the air supplied to the HEPA filters in a manner, which will produce a uniform challenge concentration of the HEPA filter.

2. The aerosol generator air supply pressure is set at 20 psig minimum. The upstream concentration should be established using one or more nozzles adjusted to read 10 to 20 micrograms of air on the upstream concentration. The photometer is adjusted to read 100 percent. Reference Figure 2 (below).

3. Access to the duct system downstream from the filters must be established.

4. The system to be tested will maintain a flow rate (CFM) set at normal operation conditions.

5. Passing is specified as a measurement of less than 0.3 percent of upstream challenge for HEPA filters rated at 99.97 percent.
PRESENTATION OF SUMMARY OF RESULTS

A total of 34 HEPA filters were tested for this report. Out of the 34 tested filters only 12 filters (35%) passed on the initial testing. The 22 filters that failed the initial testing for a variety of reasons. Some filters contained poor gasketing (gaps in the gaskets material) resulting in leaks around the edges of the filter. Some of the gaskets were repaired using a gasket sealant and the filters were capable of being used. Other filters failed due to a poor seal with the filter housing. Some of these filters were retightened and passed a second test. Several of the filters tested had holes or poor filter media. These filters were not repaired they were discarded or returned to the vendor. The filter testing included both systems with a single HEPA filter and systems with multiple HEPA filters in one housing. Failures of these systems were determined in a combined result of the entire
system, which resulted in less than 99.97% efficiency. The following graphs highlight the results of this test.

HEPA FILTER TESTING RESULTS

NOTE: A failure is the detection of any particles passing through the filter, not an evaluation of the 99.7% efficiency claimed for the HEPA filters.
HEPA FILTER FAILURE ANALYSIS

HEPA Filter Failures

- System Failures: 14%
- Media Holes: 45%
- Install/Gasket: 41%

HEPA FILTER VENDER ANALYSIS

HEPA Filters- Passing First Test

- Vender A: 33%
- Vender B: 0%
- Vender C: 43%
DISCUSSIONS

Prior to conducting this evaluation of performance of HEPA filters we assumed that the manufacturer’s representation and certification were correct. We improperly assumed that careful installation of filter from a reputable vendor into the filter holder design for HEPA filters would provide essentially complete removal of particulates. Based on our investigation we conclude the following:

1. HEPA filters as manufactured by many US companies have significant defects when shipped.

2. Manufacturers certification of tests performed on individual filters prior to shipment are not a reliable indicator of filter quality.

3. Current common filter gasketing used in state of the art filter holders may leak even when following the recommendations of the manufacturers.
4. In critical applications it is essential to have an ongoing filter test program to assure HEPA filter system performance meets the anticipated goals.

Complying with corporate goals of zero detectible emissions is possible but requires extensive monitoring of the HEPA filtration system. To insure compliance, a testing Service is contracted twice a year to assist in installation and tests of filters. Installation and testing requires a staff including a maintenance employee, the EHS engineer, and a scissor lift operator for eight to ten hours. Also, it is necessary to keep a significant surplus of filters on site to compensate for the anticipated failed performance in a portion of the filters to be installed.

The installation of filters is not only time consuming, it also impacts the manufacturing process. Shut down of equipment for the filter change out and testing can take as long as an hour per filter. Often times, one or possibly two or three filters are installed and tested to achieve acceptable performance.