REMOTE AEROSOL TESTING OF LARGE SIZE HEPA FILTER BANKS

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ABSTRACT

Different methods of testing HEPA filter banks are described. Difficulties in remote testing of large banks of HEPA filters in series with minimum distances between banks, and with no available access upstream and downstream of the filter house, are discussed. Modifications incorporated to make the filter system suitable for remote testing without personnel re-entry into the filter house are described for a 51,000 m^3/hr filter unit at the WIPP site.

INTRODUCTION

Air Filtration Systems are an integral part of hazardous waste handling, nuclear fuel processing and nuclear power plants. The removal of gross particles from the air stream using rough and medium efficiency filters; small particles (less than 1 micrometer) using HEPA filters; and radioactive gases (such as Methyl Iodide) using charcoal filters has been used for several decades. The state of technology and regulatory requirements have increased in complexity although the design of the actual testing equipment within the filter houses has not kept pace. To demonstrate the present status of development and shortcomings of HEPA filter bank testing, this paper is presented. Discussion is limited to HEPA filter bank leak testing.

HEPA TESTING METHODS

HEPA filters are tested individually at the factory or at a DOE test station and again on site either individually or in banks.

The test is basically to challenge the filters with DOP (Dioctyl Phthalate) aerosol of particles of approximately 0.7 micrometers mass mean diameter. The concentration measured downstream of the filters divided by the concentration measured upstream is the filter bank penetration. The difference between this number and unity is the leak efficiency. Equipment and testing is generally described in ANSI/ASME Standards N509-1980 and N510-1980 (1986 revision in process). These standards provide guidelines but do not specify detailed test methods, consequently, different test methods and procedures have been developed through the years The most common are described below:

Single Point Sampling

The taking of a single sample as representative of the challenge aerosol concentration over a defined area. To validate this method, test data must be taken to verify that the single sample is actually representative of the entire area defined.

Shroud Test Method

The use of a shroud to limit testing to one or more filters in a bank. The shroud is moved from one filter to another to complete the testing of the entire bank.

Component Removal Method

The removal of components, such as prefilters upstream of the filter bank to be tested, for ease in test access and to keep from diluting the challenge aerosol.

Selective Insertion Method

Selectively inserting or installing filter components in a bank to allow testing of only that bank; for example, install and test only the upstream HEPA filters in a two bank system. This allows the DOP aerosol to pass through the upstream bank to provide an aerosol concentration adequate to test the downstream bank. Afterwards the downstream filters are installed and tested.

Multiple Sampling Method

The taking of many individual samples in defined cross sections of the filter bank. This is usually done by hand held sampling probes which are moved from point to point in the cross section to provide the total array of readings.

Test Manifold Method

The use of manifold devices to inject or sample challenge aerosols at many points over a defined cross section of the filter bank at one time. The concentration is averaged by physical mixing. This provides the equivalent of a single point sample of even distribution.

All these methods have advantages and disadvantages in terms of speed, accuracy, expense and exposure to contamination. The most reliable and cost effective method of testing filter banks is the test manifold method[1]. Presently it is the least used because of high initial cost of installation and calibration either at time of fabrication of the housing or at initial testing at site startup with all the constraints of schedule. However, the test manifold method is being used more often. This is due to increased recognition of the need for the retesting required during the life of the filter system, the probable danger due to contamination within the filter system; and the usual lack of access upstream and downstream of the filter house due to ductwork configuration, fans, dampers and other obstructions to distribute the challenge aerosol evenly.

Typically large HEPA filter banks (51,000 m^3/hr is the largest size usually recommended) are custom built with only a few of each design made. Therefore, the testing equipment portion must also be custom designed each time, with attention given to aerosol feed, distribution and sampling.

This equipment should be designed, installed and calibrated at time of manufacture. However, there may not be design quantity of air flow available at time of manufacture. Therefore site calibration is necessary to insure the test will be accurate. Site testing history and experience will of course aid in the manufacturer's design of the equipment.

The distribution of the challenge aerosol concentration which enters the HEPA filter must be uniform within $\pm$ 20% over the entire filter bank cross section, to meet the ANSI/ASME requirements.

TEST WORK AT WIPP

The two 51,000 m^3/hr HEPA filter exhaust filtration units at the WIPP site at Carlsbad, New Mexico are typical of large walk-in custom made HEPA filter houses where distribution sampling of both aerosol feed (upstream of the filter) and test (downstream of the filter) are equally important to allow for accurate testing. The following is a description of one of the units and the site testing and development work which led to the acceptance of this unit.

Background

The WIPP site exhaust HEPA filter houses were designed by Bechtel Corporation of San Francisco; detailed, and manufactured by American Air Filter Company of Louisville, installed by the Foley Company of Kansas City; and site tested by American Air Filter Company.

The description of the entire system was presented at the 19th DOE Air Cleaning Conference[2]. Since details of the system are beyond the scope of this paper, the 51,000 m^3/hr filter house will be discussed in limited detail only to provide the background for the development and test work involved.

Description

The filter house consists of banks, (3) filters high x (7) filters wide. There are (2) HEPA banks in series which follow (2) prefilter banks as shown in Fig. 1.

Aerosol distribution manifolds are located 1.4 m upstream of the HEPA bank to be tested. These were permanently installed by the factory for this project. The challenge aerosol is distributed through (24) holes, each 1.6 mm in diameter, in each of the (7) 12.7 mm diameter vertical pipes which are all fed from the 50.8 mm diameter horizontal header as shown in Fig. 2.

The factory placement of the 1.6 mm diameter holes allowed the aerosol to be injected at 90°, perpendicular to the normal house air flow direction - Fig. 3a.

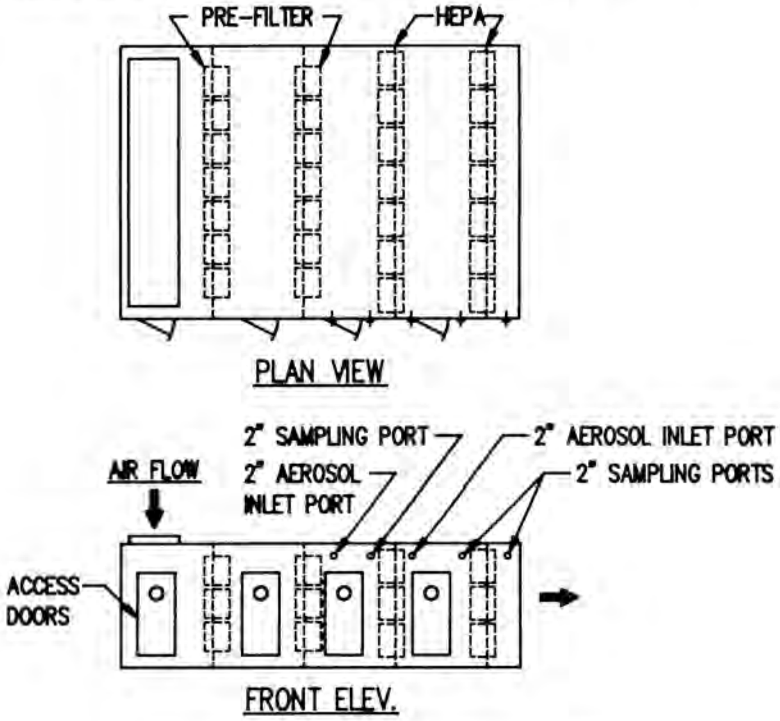

Fig. 1. Filter House Assembly at WIPP.

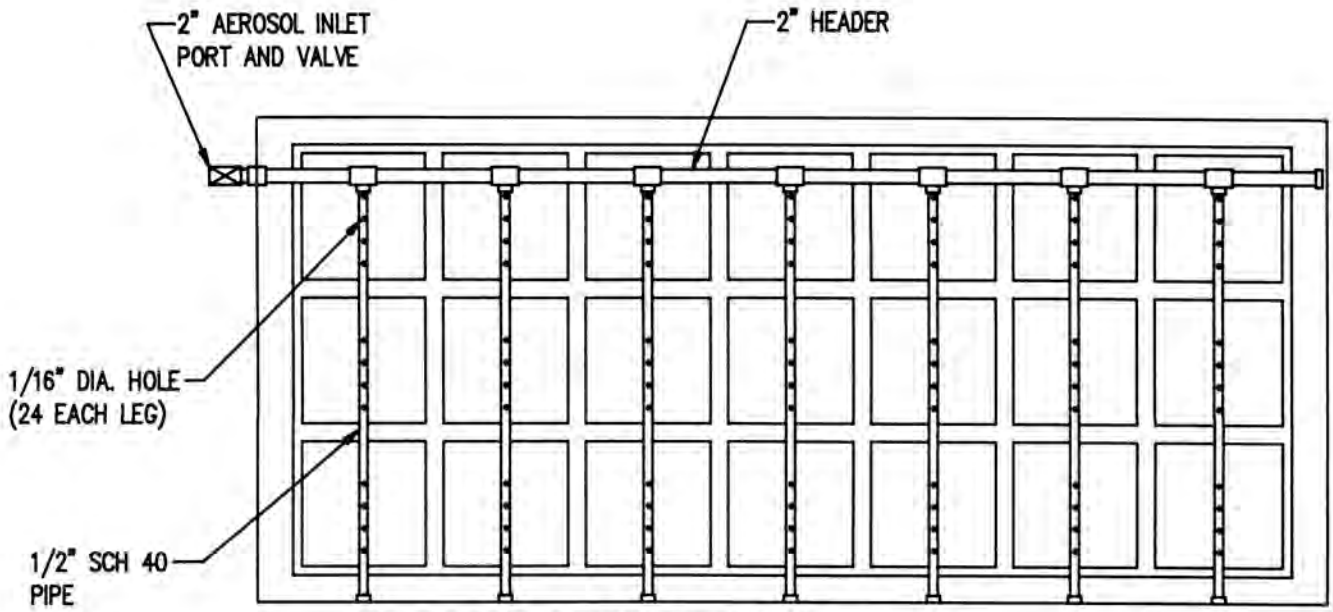

Fig. 2. DOP Aerosol Distribution Manifold (Viewed Upstream from the HEPA Bank).

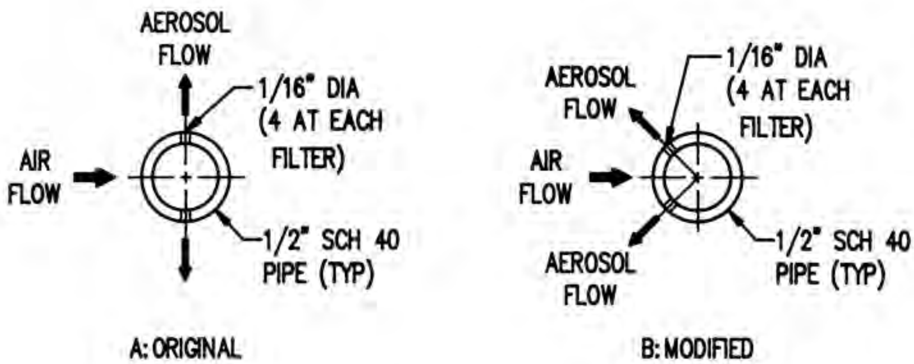

Fig. 3. Aerosol Feed Pipe Cross Section.

The initial system design did not include the installation of permanent manifolds for sampling the challenge aerosol either upstream (for distribution) or downstream (for penetration) of the HEPA filter banks. Therefore at site, temporary manifolds were fabricated from PVC plastic pipes and fittings, Fig. 4.

These sampling manifolds are similar to the feed manifolds except the horizontal headers are 19.4 mm diameter. These were arranged as shown in Fig. 5.

Although not shown, the DOP challenge aerosol was generated by four (4) aerosol generators, each connected as shown in Fig. 6.

An aerosol photometer (not shown) was connected to the sampling manifold outside of the house and was used to measure the concentration of the DOP aerosol, which is typically 80 mg/m^3, to measure the penetration of the challenge gas downstream of the HEPA bank.

To measure distribution of the challenge gas, the DOP aerosol concentration is reduced to approximately 1 mg/m^3 per liter and measured at the upstream sample manifold. (However as explained below, the (24) downcomer holes were changed to (3) holes, 6.4 mm diameter). For banks with (10) or more HEPA filters, the upstream concentration at the center of each filter is measured. The greater difference between the highest or lowest reading and the average reading is compared to the average reading. This is considered to be the distribution.

The Site Tests

The test program was initiated with the DOP aerosol distribution tests to determine the uniformity of distribution across the HEPA banks.

Only one of the four DOP aerosol generators was required to generate the small amount of aerosol for the distribution determination.

After adjusting air flow to the design specification of 51,000 m^3/hr, it was observed that most of the DOP in liquid form dripped from the first two of the vertical legs to the housing floor. This problem was due to agglomeration of the small DOP particles with the larger DOP

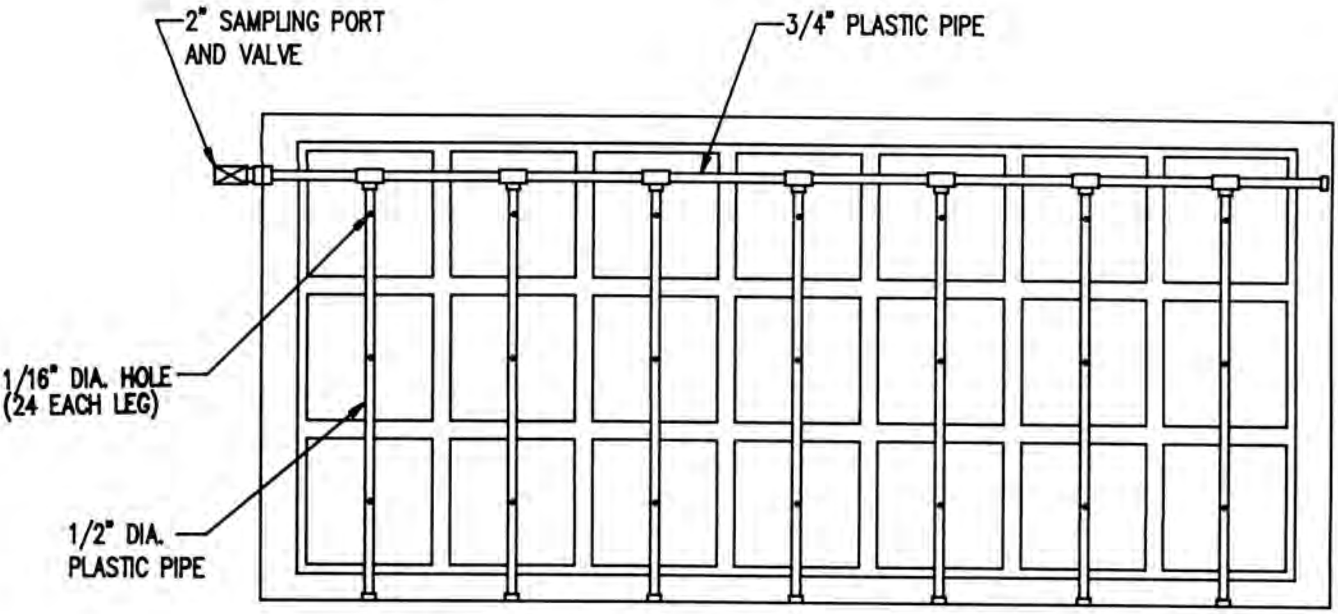

Fig. 4. Temporary Sampling Manifold
(used for upstream & downstream sampling)

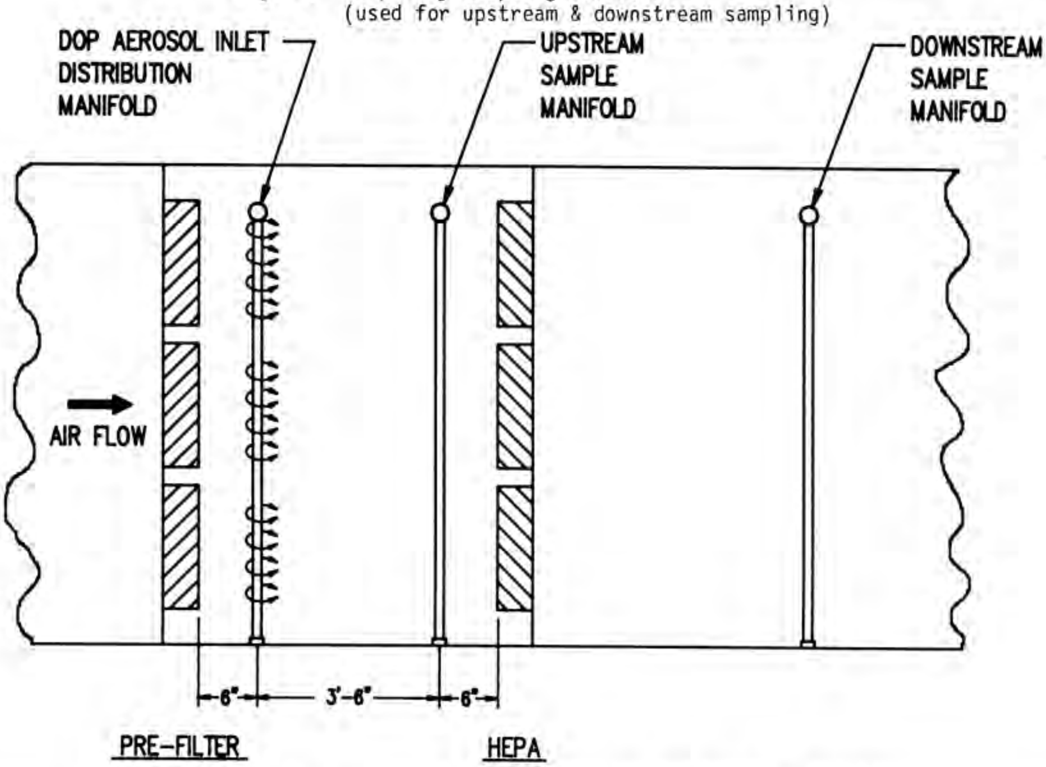

Fig. 5. Arrangement of Distribution and Sample Manifolds

particles in the small diameters of the manifold distribution pipes and is not an unusual problem when feeding through large manifolds. This could be a generic problem since much testing is done without observation of the feed manifolds. This problem was solved by adding a dropout leg between the aerosol generator at the feed manifold inlet, Fig. 6 to allow the larger diameter DOP droplets to move out of the way and enable the smaller diameter aerosol particles to diffuse through the feed ports without coagulation.

After correcting this condensation problem, low concentration aerosol distribution was measured across the filter bank inlet side to determine distribution. Consistent readings of the sample were not obtained. This was due to the presence of the test technician, who was inside the house for scanning the filter faces and thus blocked the air flow within the short mixing distance between the feed manifold and the face of the HEPA filters. This is resolved by taking the readings remotely from outside of the house without the test technician inside the house. (Actually at WIPP, the test technician stood in a corner within the house which was in dead air space.)

It was also realized at this time that the (24) 1.6 mm holes in each manifold downcomer,

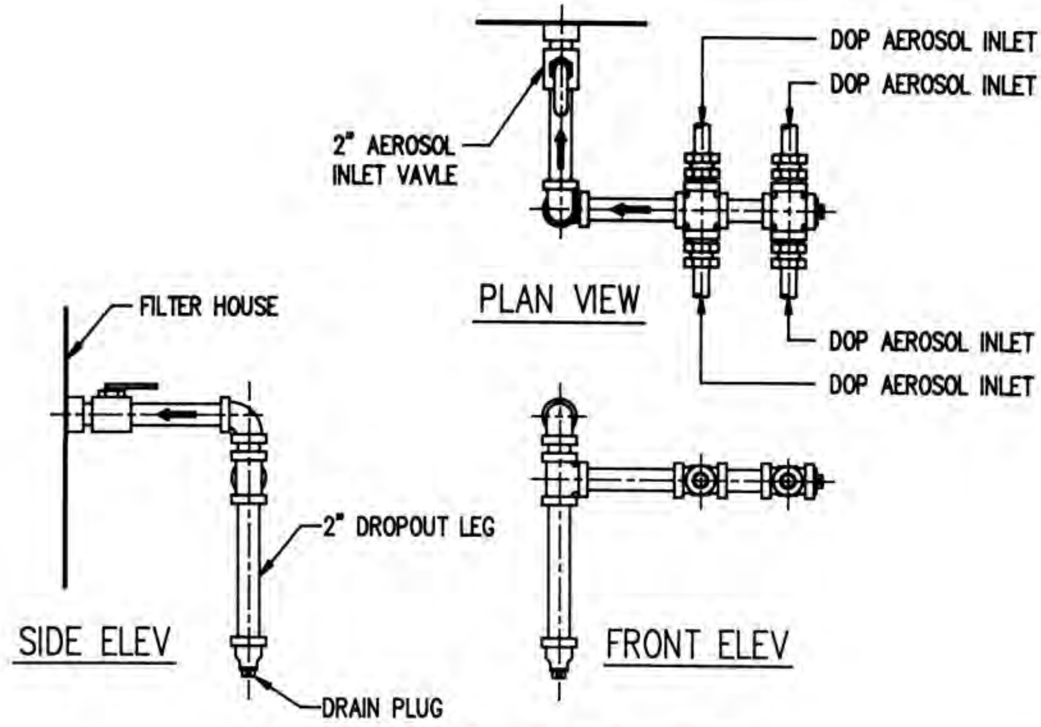

Fig. 6. DOP Feed Piping Arrangement

provided (8) holes to sample each HEPA filter. This array will not measure the center of the HEPA filter as required by the ANSI/ASME specifications. Therefore, the vertical downcomers of the sampling manifold were replaced with pipes containing (1) 6.4 mm diameter hole located at the center of each of the (3) HEPA filters in each vertical row, Fig. 7.

These fewer, larger diameter holes now made for more accurate samples taken of the challenge DOP test aerosol. During the run, samples were taken from one hole at a time, the rest of the holes temporarily closed by masking tape. Repeatability showed this sampling to now be consistent. However, distribution was well outside of the allowable ± 20% limits, with distribution as high as 110% above allowable as seen in Table I.

Visual observation of the DOP vapor trail showed very little DOP was being injected into the far end of the feed distribution manifold. Therefore, it was assumed the 3.4 KPa line pressure drop across the feed pipe was insufficient. The pressure drop was increased in steps of 3.4 KPa and distribution measured at each step. At 15.2 KPa pressure drop, which was the highest available at the site, the distribution was ± 30% which was still not satisfactory. Since air pressure could not be increased, it was assumed that modification of the direction of injection of the aerosol could obtain the desired

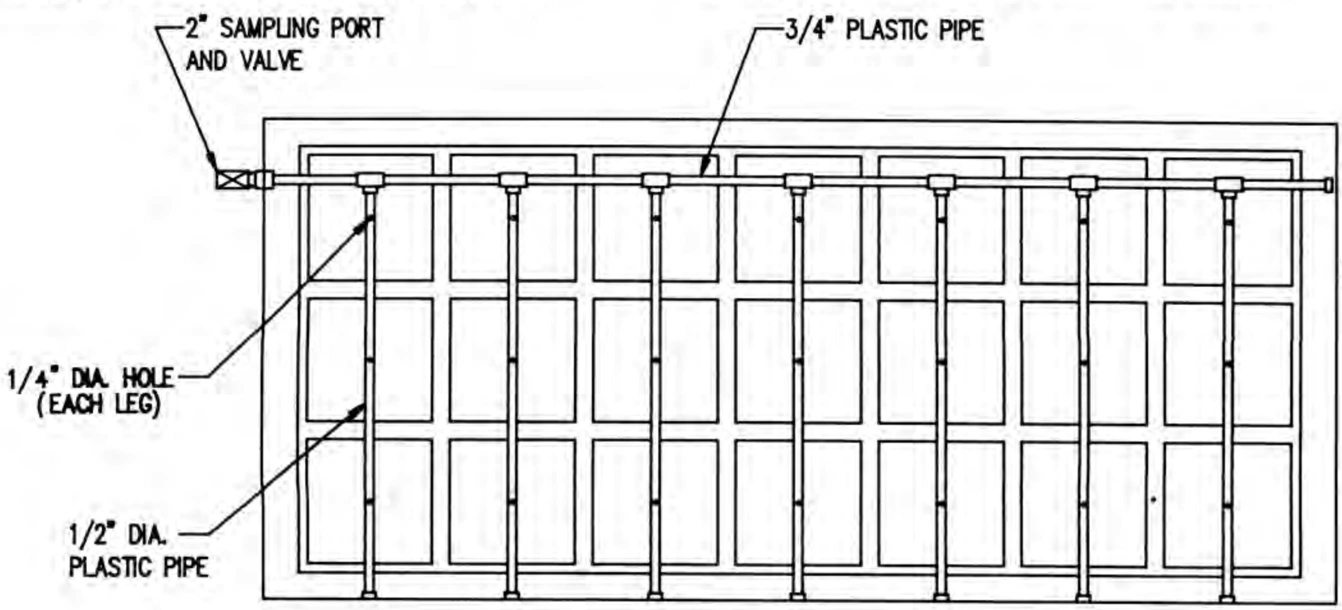

Fig. 7. Temporary Distribution Sample Manifold
(viewed upstream from the HEPA bank)

Table I

Initial Aerosol Distribution Concentration
(Average: 0.89 mg/m^3)

1.5	1.3	.91	.85	.73	.50	.10
1.8	1.4	.90	.83	.75	.53	.12
1.8	1.6	.87	.86	.74	.52	.14

distribution of the aerosol. Therefore, the existing feed pipe holes, which were at 90^{o} right angles to house air flow as shown in Fig. 3a, were blanked off and new holes were drilled to allow the aerosol to be injected at 45^{o} into the air stream, as seen in Fig. 3b. In addition, the quantity of holes in the first two downcomers of the feed distribution manifold were reduced from (24) to (18). When retested with the above modifications, the maximum distribution was reduced to $\pm$ 6% of average. This was well within the allowable range. Refer to Table II.

These modifications were incorporated into the rest of th HEPA banks. The specified distribution was obtained afterwards without any further changes.

These revised feed distribution manifolds could now be left in place as permanent test manifolds and would continue to give even distribution in future testing throughout the life of the filter house.

The downcomer pipes of the inlet sample manifold were now replaced with those originally installed and the leak test was completed using all four DOP aerosol generators. For consistency during these tests, the line pressure drop was maintained at 15.2 KPa.

Additional distribution tests after like modification of the feed distribution manifolds confirmed the earlier finding that 15.2 KPa pressure drop is the minimum required to obtain proper distribution in this system.

Similar testing was performed on the second HEPA bank and the second HEPA house utilizing the permanent distribution manifolds and test sample manifolds installed for the respective banks. Some of the manifolds serve a dual function such as sampling downstream of the first HEPA bank and feed distribution upstream of the second HEPA bank.

DISCUSSION

For most HEPA filter installations, by virtue of design and test conditions, aerosol distribution tests become secondary to filter leak tightness tests. But the roles are reversed for this system, because of the requirement for remote sampling and the close proximity of the aerosol feed manifold to the sample manifold. Most of the efforts during this test work were focused on solving distribution problems.

Four areas of difficulty encountered were previously discussed. Two of these areas responsible for the initial failure to evenly distribute the aerosol were condensation of DOP in the feed lines and lack of access to manually scan the filter face. These problems were simple to resolve but cannot be overlooked when remote feeding and sampling is a requirement. Of the other two difficulties, line pressure drop and the direction of aerosol injection, the former appears to be the major controlling mechanism for uniform distribution of the test aerosol.

Design of HEPA filter houses should consider proper distribution of pressure along the length of the aerosol feed manifold to avoid time consuming onsite corrections. The direction of the aerosol injection into the air flow becomes especially important when there is a short distance between the aerosol feed and sampling manifolds.

CONCLUSIONS

The bulk of published work, on techniques of leak testing, is related to the Air Treatment Systems in Nuclear Power Plants, where proper aerosol distribution can be achieved easily by feeding in plenums or through Type III carbon beds, if available. (Feeding DOP through carbon is allowed, but undesirable because of potential damage to the carbon.) Occasionally, systems with built-in feed distribution and sample manifolds are also mentioned, but most of these systems are small, generally consisting of one or two filters. For such small systems, perfect distribution is assumed and the distribution test requirement is waived. As compared to the systems normally described in the literature, the WIPP system is unique as far as testing is concerned. To the best of our knowledge, the problems associated in testing such a system have never been described. DOP testing of large HEPA filter banks is not a problem. Proper distribution of aerosol as the

Table II

Final Aerosol Distribution Concentration
(Average: 0.85 mg/m^3)

.90	.82	.82	.90	.90	.82	.82
.90	.90	.82	.90	.82	.82	.82
.82	.90	.82	.82	.82	.90	.82

concern when manifolds for feeding and sampling are separated by distances as short as 1.0 m. The initial failure of distribution tests may be due to applying data from small scale studies to design large manifolds. For small systems, operating parameters, in particular the pressure drop in the feed line has no importance, but for large systems where the manifold lines are 6 to 9 m long, the pressure drop becomes very important for proper distribution. Neglecting this important parameter can lead to failure or erroneous results with little indication of problems. The present work, though limited due to specific circumstances at the WIPP site, provides the basis for the future design of successful feed distribution and sampling manifolds for large systems with multiple banks, separated by short distances, where remote sampling is a requirement for accurate testing.

In spite of the advances in the design of Air Treatment Systems, minimal work has been published on the development of techniques for testing complex air filtration systems. We hope the present work is a step towards this direction.

REFERENCES

1. Cox, J. W. "Review of the Current Halide and Aerosol Leak Testing Methods of Nuclear Air Treatment System, Components and Banks", Proceedings of the 19th DOE Nuclear Air Cleaning Conference (1986).

2. Parthasarthy, P. S. and Sheme, J. "HEPA Filtration and Monitoring System for an Underground Nuclear Waste Repository", Proceedings of the 19th DOE Nuclear Air Cleaning Conference (1986).