ORNL-TM-4463

HIGH-EFFICIENCY PARTICULATE AIR FILTERS — STATE OF THE ART SUMMARY PERTAINING TO PLUTONIA AEROSOLS

Wallace Davis, Jr.

MASTER

OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION • FOR THE U.S. ATOMIC ENERGY COMMISSION

ORNL-TM-4463

Contract No. W-7405-eng-26

CHEMICAL TECHNOLOGY DIVISION

HIGH-EFFICIENCY PARTICULATE AIR FILTERS - STATE OF THE ART SUMMARY PERTAINING TO PLUTONIA AEROSOLS

Wallace Davis, Jr.

APRIL 1974

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

HIGH-EFFICIENCY PARTICULATE AIR FILTERS - STATE OF THE ART SUMMARY PERTAINING TO PLUTONIA AEROSOLS

Wallace Davis, Jr.

ABSTRACT

High-efficiency particulate air (HEPA) filters now being manufactured commercially routinely exceed the specification of removing 99.97% of 0.3 μ-diameter particles of a monodisperse dioctyl phthalate (DOP) aerosol. Laboratory tests indicate that when such filters are properly installed in series, at least up to three, each will perform at this same level with plutonia aerosols, leading to decontamination factors in excess of 3×10^{10}. Filter media that are resistant to serious degradation by hydrogen fluoride and fluorine are now in the process of assembly into filter units for testing.

1.0 SUMMARY

High-efficiency particulate air (HEPA) filters now being manufactured commercially routinely meet or exceed the specification of removing 99.97% of 0.3 μ-diameter particles of a monodisperse dioctyl phthalate (DOP) aerosol. Guides for installing such HEPA filters in nuclear energy installations have been written, and the AEC guide states that a filter efficiency of 99.95% can be achieved for a single bank, if the installation is constructed according to the guidelines. In addition, laboratory tests have shown that each of a series (up to 3) of properly installed filters can perform at the above stated efficiency, leading to the conclusion that plutonia-aerosol decontamination factors in excess of 3×10^{10} can be achieved. Considerable uncertainty occurs in defining the effects of changes in particle-size distribution, particle concentration, air flow rate, humidity, etc., in assessing the efficiency of large filter banks in an installation of two or more banks in series. Consequently, lower efficiency ratings are being used in current evaluations of series type installation until more experimental data is available from large installations.

The question of what filter medium to use in filters in systems that may contain hydrogen fluoride or fluorine has not yet been completely answered. Corrosion-resistant media have been developed; tests of these

BLANK PAGE

in filters are now being performed.

2.0 INTRODUCTION

Airborne radioactive particulate matter, both solid and liquid, will be generated during normal operations in the fuel reprocessing and fuel fabrication steps of the nuclear fuel cycle. In addition, such airborne matter will also be generated within other spaces of the fuel cycle, such as in the reactor containment, under accident conditions. Some of this airborne activity will enter plant ventilation systems; however, it will be nearly completely removed by high efficiency filters before the air is discharged to the atmosphere. In all cases the filter will be a high-efficiency particulate air (or aerosol) filter, or HEPA filter. This type of filter has been in use for many years in the atomic energy program. As a result of its extensive use and the need to reduce radioactive emissions to the lowest attainable levels, there are ongoing programs to evaluate more accurately, and to improve, the HEPA filter. As a consequence, summary reports[1-5] have been written more or less regularly to describe the present status of knowledge concerning these filters. The purpose of this memo is to provide a brief updating pertinent to 1973. Although some of the references antedate 1967, the scope of this memo is primarily to summarize information reported during the last 6 years.

3.0 DESCRIPTION, TESTING, AND INSTALLATION OF HEPA FILTERS

Construction and testing of HEPA filters have been described in great detail by Burchsted and Fuller[5] and in proposed standard[6] ANSI N510 presently being balloted. Before being delivered to contractors or licensees, individual HEPA filters may be tested at one of the two USAEC Quality Assurance Stations. Each filter is required to meet the specification of 99.97% removal[3,6-8] of the standard 0.3 μ dioctyl phthalate (DOP) aerosol at the manufacturer's rated flow of 125 or 250 scfm per square foot of filter area, depending on filter depth. In addition, each filter must be tested at 20% of rated flow for the purpose of determining the extent of pinholing. Penetration of the test aerosol through the filter must not exceed 0.03% during this second test.[6,7]

Installing properly tested HEPA filters in a properly constructed housing should lead to a process filter assembly that performs as well as the individual filters. In particular, passing aerosol-containing air through a series of, say, three HEPA filters in series, each having an efficiency of 99.97%, should permit passage of no more than $(3 \times 10^{-4})^3$, corresponding to a penetration fraction of 27×10^{-12} or to a decontamination factor of about 3×10^{10}, of the 0.3 μ-diameter particles; larger or smaller particles should be removed even more effectively, if the 0.3 μ particles are actually the most difficult to remove by filtration. Ettinger and his coworkers[9,10] have obtained data with plutonium aerosols that demonstrate the validity of the multiplicative effect of properly installed filters. However, properly-tested filters do not guarantee a properly installed production filter system, although a guide[11] for installing such filters and a standard[6] for testing them are now available. As recently as August 1972, G. A. Schurr stated (p. 776 of ref. 12) in reference to the Savannah River Plant:

"Our operating experience with HEPA filters has shown that, in place, in operation, monitored day after day, the single HEPA filter is not necessarily a highly efficient system. In banks of parallel filters, of course, statistics improve."

Also in reference 12, p. 778, Ettinger stated:

"Our experience has been that if you want to have a HEPA filter bank properly installed, you must put an engineer at the site during installation. Workmen do not understand that their fingernails can ruin a filter while lifting it up to get it out of the box."

Beyond the potentiality of improperly installed filters, the presence of hydrogen fluoride and/or fluorine in the gas stream being filtered is of some concern. These chemicals are of major importance in the facilities producing uranium hexafluoride where, however, little plutonium will be present.

The most recent summary of the status of development of HEPA filters with fibers that are not significantly damaged by hydrogen fluoride was given by Anderson[13] at the 12th Air Cleaning Conference in 1972.

His report on this topic indicates that fibers resistant to attack by hydrogen fluoride are being tested but that production-scale manufacture of filter units has not yet been achieved.

4.0 FILTER EFFICIENCIES AND PARTICLE SIZE

As mentioned above, efficiencies of individual filters can meet or exceed[3,6-8] 99.97% removal of particles of DOP of size 0.3 μ. More significantly, Ettinger and his coworkers[9,10] have recently shown that even higher efficiency can be attained with plutonia aerosols in a series of two or three successive filters. Their data, summarized in Table 1, correspond to measured decontamination factors through three filters of about 10^{13} in all cases, well in excess of about 3×10^{10} that is calculated from the 99.97% efficiency required of 3 individual filters.

Ranges of sizes of plutonium-containing aerosols at three facilities (Rocky Flats, Mound Laboratory, and Los Alamos Scientific Laboratory) have been reported by Ettinger, Elder, and Gonzales.[12,14,15] Their results are summarized in Fig. 1; also in this figure is a curve of particle size distribution presented 12 years ago by Arnold, Gresky, and Nichols[16] in an early effort to evaluate the properties of aerosols. It is apparent from this figure that the size distribution of plutonium aerosols impinging on the first of a series of filters cannot be characterized by a single curve.

TABLE 1

OVERALL HEPA FILTER EFFICIENCY WITH PLUTONIA AEROSOLS[a]

Range of Size (μm)		HEPA	No.	Efficiency Range, %		
Amad[b]	σ_g[c]	Filter Stage	of Runs	Mean	Min	Max
0.70 - 2.1	2.07 - 3.0	1	14	99.99876	99.99728	99.99991
0.45 - 0.82	1.5 - 2.04	2	14	99.99817	99.99703	99.99927
0.37 - 0.70	1.27 - 1.84	3	11	99.86492	99.49495	99.99291

[a]See references 9 and 10.

[b]Activity median aerodynamic diameter.

[c]Standard deviation of Amad.

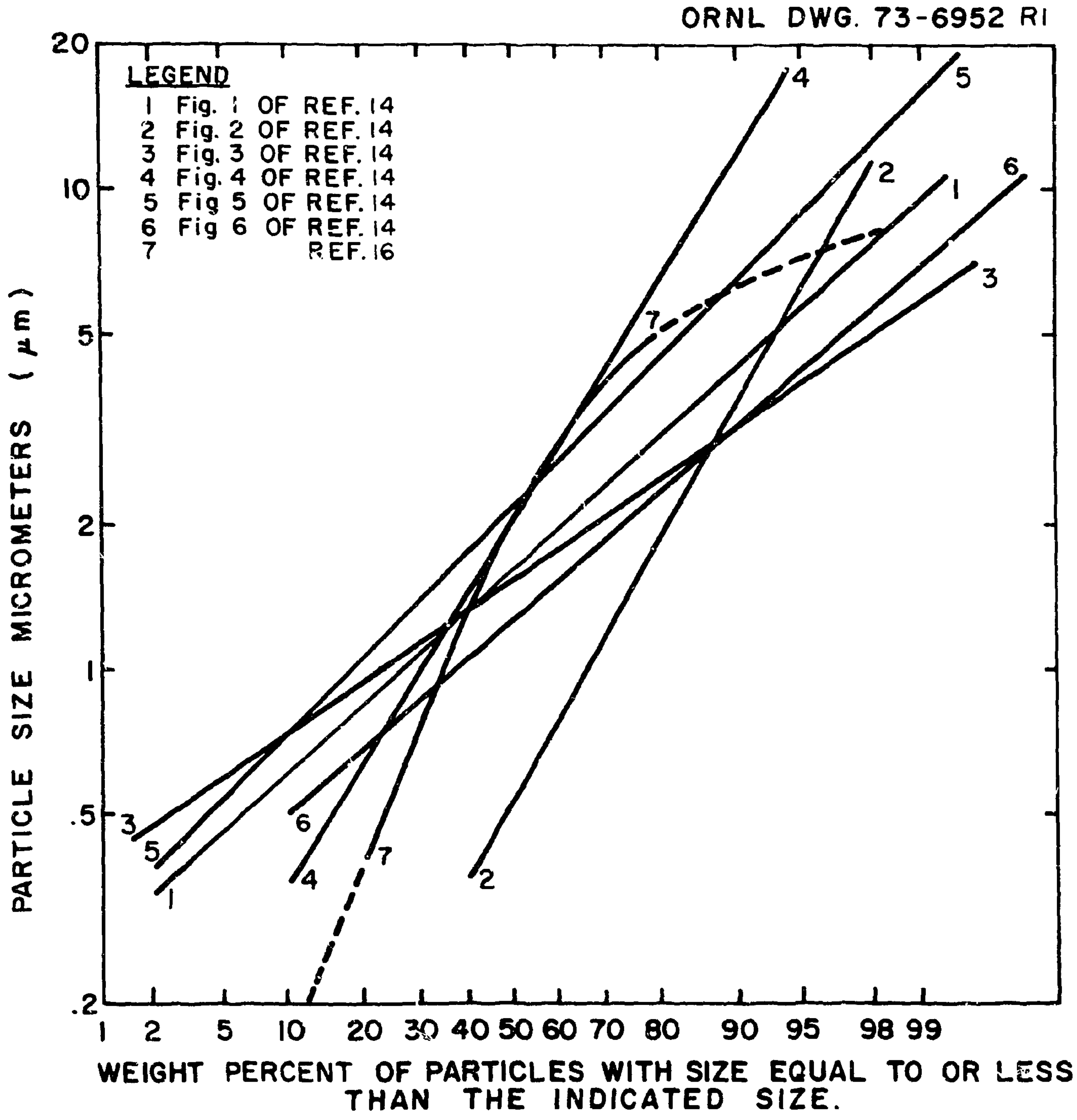

Fig. 1. Particle Size Distribution of Plutonium-Containing Aerosols (Curves 1-6) and of Thorex Evaporator Mist.

5.0 REFERENCES

1. C. A. Burchsted, "Environmental Properties and Installation Requirements of HEPA Filters," Paper SM-110/40, in Treatment of Airborne Radioactive Wastes, International Atomic Energy Agency, Vienna, 1958.

2. G. W. Keilholtz, Filters, Sorbents, and Air Cleaning Systems as Engineered Safeguards in Nuclear Installations, Report ORNL-NSIC-13 (October 1966).

3. G. W. Keilholtz, C. E. Guthrie, and G. C. Battle, Jr., Air Cleaning as an Engineered Safety Feature in Light-Water-Cooled Power Reactors, Report ORNL-NSIC-25 (September 1968).

4. G. W. Keilholtz, "Air Cleaning Systems as Engineered Safeguards in Nuclear Reactor Containment," Nuclear Safety 8, 360 (1967).

5. C. A. Burchsted and A. B. Fuller, Design, Construction, and Testing of High-Efficiency Air Filtration Systems for Nuclear Application, Report ORNL-NSIC-65 (January 1970).

6. Standard for Testing of Nuclear Air-Cleaning Systems, American National Standards for Reactor Plant Components, ANSI N510, 1973.

7. F. D. Leckie and C. A. Thompson, ANSI N45-8 Nuclear Gas Systems Treatment Standards, Proc. 12th AEC Air Cleaning Conf., Oak Ridge, Aug. 28-31, 1972, USAEC Report CONF-720823, p. 848 (January 1973).

8. Filter, HEPA, Fire Resistant, A Materials Specification, Union Carbide Corp., Nuclear Div., Spec. 07-AZ-1d, August 5, 1971.

9. M. Gonzales, J. Elder, and H. Ettinger, Performance of Multiple High Efficiency Filters Against Plutonium Oxide Aerosols, Presented at Health Physics Society Annual Meeting, Miami Beach, Florida, June 17-21, 1973.

10. H. J. Ettinger, J. C. Elder, and M. Gonzales, Performance of Multiple HEPA Filters Against Plutonium Aerosols, Progress Report for Period January 1 through June 30, 1973, Report LA-5349-PR (July 1973).

11. General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants. Regulatory Guide 3.12, Directorate of Regulatory Standards, USAEC, August 1973.

12. Engineering Design of Air Cleaning Systems for Plutonium Facilities: Round Table. R. Yoder, Chairman, G. A. Schurr, H. Ettinger, W. E. Domning, J. L. Russell, Jr., and others. CONF-720823, pp. 738-785.

13. W. L. Anderson, Government-Industry Meeting on Filters, Media, and Media Testing, CONF-720823, pp. 731-737.

14. H. J. Ettinger, J. C. Elder, and M. Gonzales, Performance of Multiple HEPA Filters Against Plutonium Aerosols. Progress Report for Period March 1 through June 30, 1972, Report LA-5012-PR (July 1972).

15. H. J. Ettinger, J. C. Elder, and M. Gonzales, Performance of Multiple HEPA Filters Against Plutonium Aerosols for Period July 1 through December 31, 1972, Report LA-5170-PR.

16. E. D. Arnold, A. T. Gresky, and J. P. Nichols, "The Evaluation of Radioactive Releases from Chemical Plants," Presented at the Seventh AEC Air Cleaning Seminar, Brookhaven National Laboratory, October 10-12, 1961. (Also available as ORNL-TM-19).