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DESIGN, TESTING, AND MAINTENANCE CRITERIA FOR NORMAL VENTILATION EXHAUST SYSTEM AIR FILTRATION AND ADSORPTION UNITS OF LIGHT-WATER-COOLED NUCLEAR POWER PLANTS

A. INTRODUCTION

General Design Criteria 60 and 61 of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," require that filtering systems be included in the nuclear power unit design to control suitably the release of radioactive materials in gaseous effluents during normal reactor operation, including anticipated operational occurrences and fuel storage and handling operations. In addition, §§50.34a, "Design objectives for equipment to control releases of radioactive material in effluents—nuclear power reactors," and 50.36a, "Technical specifications on effluents from nuclear power reactors," of 10 CFR Part 50 require that means be employed to ensure that release of radioactive material to unrestricted areas during normal reactor operation, including expected operational occurrences, is kept as low as is reasonably achievable.

Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," to 10 CFR Part 50 provides guidance and numerical values for design objectives to help applicants for, and holders of, licenses for nuclear power plants meet the requirements of §§50.34a and 50.36a. Appendix I requires that each light-water-cooled nuclear power reactor unit not exceed an annual dose design objective of 15 mrem to any organ of any individual in an unrestricted area by all exposure pathways from airborne radioactive iodine and particulate releases. Appendix I also requires that additional radwaste equipment be provided if the equipment has reasonably demonstrated technology and the cost-benefit ratio is favorable.

This guide presents methods acceptable to the NRC staff for implementing the Commission's regulations in 10 CFR Part 50 and in Appendices A and I to 10 CFR Part 50 with regard to the design, testing, and maintenance criteria for air filtration and adsorption units installed in the normal ventilation exhaust systems of light-water-cooled nuclear power plants. This guide applies only to atmosphere cleanup systems designed to collect airborne radioactive materials during normal plant operation, including anticipated operational occurrences, and addresses the atmosphere cleanup systems, including the various components and ductwork in the normal operating environment.

This guide does not apply to postaccident engineered-safety-feature atmosphere cleanup systems that are designed to mitigate the consequences of postulated accidents. Regulatory Guide 1.52, "Design, Testing, and Maintenance Criteria for Postaccident Engineered-Safety-Feature Atmosphere Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants," provides guidance for these systems.

B. DISCUSSION

Particulate filtration and radioiodine adsorption units are included in the design of the ventilation exhaust systems of light-water-cooled nuclear power plants to reduce the quantities of radioactive materials in gaseous effluents released from building or containment atmospheres during normal operation, including anticipated operational occurrences. All such cleanup systems should be designed to operate continuously under normal environmental conditions.

In this guide, cleanup systems that should operate to meet the "as low as is reasonably achievable" guidelines of Appendix I to 10 CFR Part 50 inside the primary containment (recirculating units) are desig-

nated as "primary systems." Primary systems generally include a containment cleanup system (kidney filtration system). Systems that operate outside primary containment are designated as "secondary systems." Secondary systems generally include cleanup systems installed in the ventilation exhaust systems for the reactor building, turbine building, radwaste building, auxiliary building, mechanical vacuum pump, main condenser air ejector, and any other release points that may contain particulates and gaseous radioiodine species. In some instances, filtration equipment installed in a postaccident hydrogen purge exhaust system may be designed to the recommendations of this guide, e.g., where a removal efficiency of 90% or less for radioiodine species is sufficient for the hydrogen purge exhaust system when the sum of the calculated loss-of-coolant accident (LOCA) dose and the post-LOCA hydrogen purge dose is less than the guideline values of 10 CFR Part 100.

Normal environmental conditions that these atmosphere cleanup systems should withstand are inlet concentrations of radioactive iodine in the range of 10^{-6} to 10^{-13} $\mu Ci/cm^3$, relative humidity of the influent stream up to 100%, temperatures of the influent stream up to 125°F (52°C), and atmospheric pressure. The system should be operated in such a manner that radiation levels of airborne radioactive material and radioiodine buildup on the adsorber do not deleteriously affect the operation of the filter system or any component.

An atmosphere cleanup system installed in a normal ventilation exhaust system consists of some or all of the following components: heaters or cooling coils used in conjunction with heaters, prefilters, high-efficiency particulate air (HEPA) filters, iodine adsorption units, fans, and associated ductwork, dampers, and instrumentation. Heaters are designed to heat the influent stream to reduce its relative humidity before it reaches the filters and adsorbers. HEPA filters are installed to remove particulate matter, which may be radioactive, and pass the air stream to the adsorber. The adsorber removes gaseous iodine (elemental iodine and organic iodides) from the air stream. HEPA filters downstream of the adsorber units collect carbon fines and provide redundant protection against particulate release in case of failure of the upstream HEPA filter bank. The fan is the final item in an atmosphere cleanup system. Consideration should be given to installing prefilters upstream of the HEPA filters to reduce the particulate load and extend their service life.

The environmental history will affect the performance of the atmosphere cleanup system. Industrial contaminants, pollutants, temperature, and relative humidity contribute to the aging and weathering of filters and adsorbers and reduce their capability to perform their intended functions. Therefore, aging, weathering, and poisoning of these components, which may vary from site to site, need to be considered during design and operation. Average temperature and relative humidity also vary from site to site, and the potential buildup of moisture in the adsorber warrants equal design consideration. The effects of these factors on the atmosphere cleanup system can be determined by scheduled testing during operation.

All components of the atmosphere cleanup system installed in normal ventilation exhaust systems need to be designed for reliable performance under the expected operating conditions. Initial testing and proper maintenance are primary factors in ensuring the reliability of the system. Careful attention during the design phase to problems of system maintenance can contribute significantly to the reliability of the system by increasing the ease of such maintenance. Of particular importance in the design is a layout that provides accessibility and sufficient working space so that the required functions can be performed safely. Periodic testing during operation to verify the efficiency of the components is another important means of ensuring reliability. Built-in features that will facilitate convenient in-place testing are important in system design.

Standards for the design and testing of atmosphere cleanup systems include ANSI /ASME N509–1976, "Nuclear Power Plant Air Cleaning Units and Components" (Ref. 1), and ANSI N510–1975, "Testing of Nuclear Air Cleaning Systems" (Ref. 2).

Other standards are available for the construction and testing of certain components of systems. Where such standards are acceptable to the NRC staff, they are referenced in this guide. Where no suitable standard exists, acceptable approaches are presented in this guide. ERDA 76–21, "Nuclear Air Cleaning Handbook" (Ref. 3), provides a comprehensive review of air filtration systems. It is not a standard but a guide that discusses a number of acceptable design alternatives.

Not all of the documents mentioned in ANSI N509–1976 (Ref. 1), ANSI N510–1975 (Ref. 2), or other standards referenced in this guide have been the subject of an evaluation by the NRC staff as to their applicability or acceptability. It should be noted that ANSI N509–1976 and ANSI N510–1975 refer to ORNL–NSIC–65, "Design, Construction and Testing of High-Efficiency Air Filtration Systems for Nuclear Application" (Ref. 4), which has been replaced by ERDA 76–21 (Ref. 3).

C. REGULATORY POSITION

Section 2 of ANSI N509–1976 (Ref. 1) and Section 2 of ANSI N510–1975 (Ref. 2) list additional documents referred to in these standards. The specific applicability or acceptability of these listed documents, as well as documents listed in other standards referenced in this guide, has been or will be covered separately in other regulatory guides, where appropriate.

Where reference is made to ORNL–NSIC–65 (Ref. 4) in ANSI N509–1976 and in ANSI N510–1975, it

should be interpreted to mean the corresponding portion of ERDA 76–21 (Ref. 3).

1. Environmental Design Criteria

a. The design of each atmosphere cleanup system installed in a normal ventilation exhaust system should be based on the maximum anticipated operating parameters of temperature, pressure, relative humidity, and radiation levels. The cleanup system should be designed based on continuous operation for the expected life of the plant or the maximum anticipated service life of the cleanup system.

b. If the atmosphere cleanup system is located in an area of high radiation during normal plant operation, adequate shielding of components from the radiation source should be provided.

c. The operation of any atmosphere cleanup system in a normal ventilation exhaust system should not deleteriously affect the expected operation of any engineered-safety-feature system that must operate after a design basis accident.

d. The design of the atmosphere cleanup system should consider any significant contaminants such as dusts, chemicals, or other particulate matter that could deleteriously affect the cleanup system's operation.

2. System Design Criteria

a. Atmosphere cleanup systems installed in normal ventilation exhaust systems need not be redundant nor designed to seismic Category I classification, but should consist of the following sequential components: (1) HEPA filters before the adsorbers, (2) iodine adsorbers (impregnated activated carbon or equivalent adsorbent such as metal zeolites), (3) ducts and dampers, (4) fans, and (5) related instrumentation. If it is desired to reduce the particulate load on the HEPA filters and extend their service life, the installation of prefilters upstream of the initial HEPA bank is suggested. Consideration should also be given to the installation of a HEPA filter bank downstream of carbon adsorbers to retain carbon fines. Heaters or cooling coils used in conjunction with heaters should be used when the humidity is to be controlled before filtration.

b. The volumetric air flow rate of a single cleanup train should be limited to approximately 30,000 ft^3/min. If a total system air flow in excess of this rate is required, multiple trains should be used. For ease of maintenance, a filter layout that is three HEPA filters high and ten wide is preferred.

c. Each atmosphere cleanup system should be locally instrumented to monitor and alarm pertinent pressure drops and flow rates in accordance with the recommendations of Section 5.6 of ERDA 76–21 (Ref. 3).

d. To maintain the radiation exposure to operating personnel as low as is reasonably achievable during plant maintenance, atmosphere cleanup systems should be designed to control leakage and facilitate maintenance in accordance with the guidelines of Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable" (Ref. 5).

e. Outdoor air intake openings should be equipped with louvers, grills, screens, or similar protective devices to minimize the effects of high winds, rain, snow, ice, trash, and other contaminants on the operation of the system. If the atmosphere surrounding the plant could contain significant environmental contaminants, such as dusts and residues from smoke cleanup systems from adjacent coal burning power plants or industry, the design of the system should consider these contaminants and prevent them from affecting the operation of any atmosphere cleanup system.

f. Atmosphere cleanup system housings and ductwork should be designed to exhibit on test a maximum total leakage rate as defined in Section 4.12 of ANSI N509–1976 (Ref. 1). Duct and housing leak tests should be performed in accordance with the provisions of Section 6 of ANSI N510–1975 (Ref. 2).

3. Component Design Criteria and Qualification Testing

a. Adsorption units functon efficiently at a relative humidity of 70% or less. If the relative humidity of the incoming atmosphere is expected to be greater than 70% during normal reactor operation, heaters or cooling coils used in conjunction with heaters should be designed to reduce the relative humidity of the incoming atmosphere to 70%. Heaters should be designed, constructed, and tested in accordance with the requirements of Section 5.5 of ANSI N509–1976 (Ref. 1) exclusive of sizing criteria.

b. The HEPA filters should be designed, constructed, and tested in accordance with the requirements of Section 5.1 of ANSI N509–1976 (Ref. 1). Each HEPA filter should be tested for penetration of dioctyl phthalate (DOP) in accordance with the provisions of MIL–F–51068 (Ref. 6) and MIL–STD–282 (Ref. 7).

c. Filter and adsorber mounting frames should be designed and constructed in accordance with the provisions of Section 5.6.3 of ANSI N509–1976 (Ref. 1).

d. Filter and adsorber banks should be arranged in accordance with the recommendations of Section 4.4 of ERDA 76–21 (Ref. 3).

e. System filter housings, including floors and doors, and electrical conduits, drains, and piping installed inside filter housings should be designed and constructed in accordance with the provisions of Section 5.6 of ANSI N509–1976 (Ref. 1).

f. Ductwork associated with the atmosphere cleanup system should be designed, constructed, and

tested in accordance with the provisions of Section 5.10 of ANSI N509–1976 (Ref. 1).

g. The adsorber section of the atmosphere cleanup system may contain any adsorbent material demonstrated to remove gaseous iodine (elemental iodine and organic iodides) from air at the required efficiency. Since impregnated activated carbon is commonly used, only this adsorbent is discussed in this guide. Each original or replacement batch of impregnated activated carbon used in the adsorber section should meet the qualification and batch test results summarized in Table 1 of this guide.

If an adsorbent other than impregnated activated carbon is proposed or if the mesh size distribution is different from the specifications in Table 1, the proposed adsorbent should have demonstrated the capability to perform as well as or better than activated carbon in satisfying the specifications in Table 1. If impregnated activated carbon is used as the adsorbent, the adsorber system should be designed for an average atmosphere residence time of 0.25 sec per two inches of adsorbent bed.

h. Adsorber cells should be designed, constructed, and tested in accordance with the requirements of Section 5.2 of ANSI N509–1976 (Ref. 1).

i. The system fan and motors, mounting, and ductwork connections should be designed, constructed, and tested in accordance with the requirements of Sections 5.7 and 5.8 of ANSI N509–1976 (Ref. 1).

j. The fan or blower used in the atmosphere cleanup system should be capable of operating under the environmental conditions postulated.

k. Ducts and housings should be laid out with a minimum of ledges, protrusions, and crevices that could collect dust and moisture and that could impede personnel or create a hazard to them in the performance of their work. Straightening vanes should be installed where required to ensure representative air flow measurement and uniform flow distribution through cleanup components.

l. Dampers should be designed, constructed, and tested in accordance with the provisions of Section 5.9 of ANSI N509–1976 (Ref. 1).

4. Maintenance

a. Accessibility of components and maintenance should be considered in the design of atmosphere cleanup systems in accordance with the provisions of Section 2.3.8 of ERDA 76–21 (Ref. 3) and Section 4.7 of ANSI N509–1976 (Ref. 1).

b. For ease of maintenance, the system design should provide for a minimum of three feet from mounting frame to mounting frame between banks of components. If components are to be replaced, the dimensions to be provided should be the maximum length of the component plus a minimum of three feet.

c. The system design should provide for permanent test probes with external connections in accordance with the provisions of Section 4.11 of ANSI N509–1976 (Ref. 1).

d. The cleanup components (e.g., HEPA filters and adsorbers) should be installed after construction is completed.

5. In-Place Testing Criteria

a. A visual inspection of the atmosphere cleanup system and all associated components should be made before each in-place airflow distribution test, DOP test, or activated carbon adsorber section leak test in accordance with the provisions of Section 5 of ANSI N510–1975 (Ref. 2).

b. The airflow distribution to the HEPA filters and iodine adsorbers should be tested inplace for uniformity initially and after maintenance affecting the flow distribution. The distribution should be within ± 20% of the average flow per unit when tested in accordance with the provisions of Section 9 of "Industrial Ventilation" (Ref. 8) and Section 8 of ANSI N510–1975 (Ref. 2).

c. The in-place DOP test for HEPA filters should conform to Section 10 of ANSI N510–1975 (Ref. 2). HEPA filter sections should be tested in place initially and at a frequency not to exceed 18 months thereafter (during a scheduled reactor shutdown is acceptable). The HEPA filter bank upstream of the adsorber section should also be tested following painting, fire, or chemical release in any ventilation zone communicating with the system in such a manner that the HEPA filters could become contaminated from the fumes, chemicals, or foreign materials. DOP penetration tests of all HEPA filter banks should confirm a penetration of less than 0.05% at rated flow. A filtration system satisfying this condition can be considered to warrant a 99% removal efficiency for particulates. HEPA filters that fail to satisfy the in-place test criteria should be replaced with filters qualified pursuant to regulatory position C.3.b of this guide. If the HEPA filter bank is entirely or only partially replaced, an in-place DOP test should be conducted.

If any welding repairs are necessary on, within, or adjacent to the ducts, housing, or mounting frames, the filters and adsorbers should be removed from the housing during such repairs. These repairs should be completed prior to periodic testing, filter inspection, and in-place testing. The use of silicone sealants or any other temporary patching material on filters, housing, mounting frames, or ducts should not be allowed.

d. The activated carbon adsorber section should be leak-tested with a gaseous halogenated hydrocarbon refrigerant in accordance with Section 12 of ANSI N510-1975 (Ref. 2) to ensure that bypass leakage through the adsorber section is less than 0.05%. After the test is completed, air flow through the unit should be maintained until the residual refrigerant gas in the effluent is less than 0.01 ppm. Adsorber leak testing

should be conducted (1) initially, (2) at a frequency not to exceed 18 months thereafter (during a scheduled reactor shutdown is acceptable), (3) following removal of an adsorber sample for laboratory testing if the integrity of the adsorber section is affected, and (4) following painting, fire, or chemical release in any ventilation zone communicating with the system in such a manner that the charcoal adsorbers could become contaminated from the fumes, chemicals, or foreign materials.

6. Laboratory Testing Criteria for Activated Carbon

a. The activated carbon adsorber section of the atmosphere cleanup system should be assigned the decontamination efficiencies given in Table 2 for radioiodine if the following conditions are met:

(1) The adsorber section meets the conditions given in regulatory position C.5.d of this guide,

(2) New activated carbon meets the physical property specifications given in Table 1, and

(3) Representative samples of used activated carbon pass the laboratory tests given in Table 2.

If the activated carbon fails to meet any of the above conditions, it should not be used in adsorption units.

b. The efficiency of the activated carbon adsorber section should be determined by laboratory testing of representative samples of the activated carbon exposed simultaneously to the same service conditions as the adsorber section. Each representative sample should be not less than two inches in both length and diameter, and each sample should have the same qualification and batch test characteristics as the system adsorbent. There should be a sufficient number of representative samples located in parallel with the adsorber section to estimate the amount of penetration of the system adsorbent throughout its service life. The design of the samplers should be in accordance with the provisions of Appendix A of ANSI N509-1976 (Ref. 1). Where the system activated carbon is greater than two inches deep, each representative sampling station should consist of enough two-inch samples in series to equal the thickness of the system adsorbent. Once representative samples are removed for laboratory test, their positions in the sampling array should be blocked off.

Laboratory tests of representative samples should be conducted, as indicated in Table 2 of this guide, with the test gas flow in the same direction as the flow during service conditions. Similar laboratory tests should be performed on an adsorbent sample before loading into the adsorbers to establish an initial point for comparison of future test results. The activated carbon adsorber section should be replaced with new unused activated carbon meeting the physical property specifications of Table 1 if (1) testing in accordance with the frequency specified in Footnote c of Table 2 results in a representative sample failing to pass the applicable test in Table 2 or (2) no representative sample is available for testing.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

This guide reflects current NRC staff practice. Therefore, except in those cases in which the applicant or licensee proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein is being and will continue to be used in the evaluation of submittals for operating license or construction permit applications until this guide is revised as a result of suggestions from the public or additional staff review.

TABLE 1

PHYSICAL PROPERTIES OF NEW ACTIVATED CARBON BATCH TESTS[a] TO BE PERFORMED ON FINISHED ADSORBENT

Test	*Acceptable Test Method*	*Acceptable Results*
1. Particle size distribution	ASTM D2862 (Ref. 9)	Retained on #6 ASTM E11[b] Sieve: 0.0% Retained on #8 ASTM E11[b] Sieve: 5.0% max. Through #8, retained on #12 Sieve: 40% to 60% Through #12, retained on #16 Sieve: 40% to 60% Through #16 ASTM E11[b] Sieve: 5.0% max. Through #18 ASTM E11[b] Sieve: 1.0% max.
2. Hardness number	RDT M16-IT, Appendix C (Ref. 10)	95 minimum
3. Ignition temperature	RDT M16-IT, Appendix C (Ref. 10)	330°C minimum at 100 fpm
4. CCl_4 Activity[c]	CCl_4 Activity, RDT M16-IT, Appendix C (Ref. 10)	60 minimum
5. Radioiodine removal efficiency		
a. Elemental iodine, 25°C and 95% relative humidity	RDT M16-IT (Ref. 10) para. 4.5.1, except 95% relative humidity air is required	99.5%
b. Methyl iodide, 25°C and 95% relative humidity	RDT M16-IT (Ref. 10) para. 4.5.3, except 95% relative humidity air is required	95%
6. Bulk density	ASTM D2854 (Ref. 11)	0.38 g/ml minimum
7. Impregnant content	State procedure	State type (not to exceed 5% by weight)

[a] A "batch test" is a test made on a production batch of a product to establish suitability for a specific application. A "batch of activated carbon" is a quantity of material of the same grade, type, and series that has been homogenized to exhibit, within reasonable tolerance, the same performance and physical characteristics and for which the manufacturer can demonstrate by acceptable tests and quality control practices such uniformity. All material in the same batch should be activated, impregnated, and otherwise treated under the same process conditions and procedures in the same process equipment and should be produced under the same manufacturing release and instructions. Material produced in the same charge of batch equipment constitutes a batch; material produced in different charges of the same batch equipment should be included in the same batch only if it can be homogenized as above. The maximum batch size should be 350 ft^3 of activated carbon.

[b] See Reference 12.

[c] This test should be performed on base material.

TABLE 2

LABORATORY TESTS FOR ACTIVATED CARBON

Activated Carbon[a] *Bed Depth*[b]	*Assigned Activated Carbon Decontamination Efficiencies For Radioiodine*	*Laboratory Tests for a Representative Sample*[c]
2 inches. Air filtration system designed to operate inside primary containment.	90%	Per Test 5.b in Table 1 for a methyl iodide penetration of less than 10%.
2 inches. Air filtration system designed to operate outside the primary containment, and relative humidity is controlled to 70%	70%	Per Test 5.b in Table 1 at a relative humidity of 70% for a methyl iodide penetration of less than 10%.
4 inches. Air filtration system designed to operate outside the primary containment, and relative humdity is controlled to 70%.	90%	Per Test 5.b in Table 1 at a relative humidity of 70% for a methyl iodide penetration of less than 10%.
6 inches. Air filtration system designed to operate outside the primary containment, and relative humidity is controlled to 70%.	99%	Per Test 5.b in Table 1 at a relative humidity of 70% for a methyl iodide penetration of less than 1%.

[a] The activated carbon, when new, should meet the specifications of regulatory position C.3.g of this guide.

[b] Multiple beds, e.g., two 2-inch beds in series, should be treated as a single bed of aggregate depth.

[c] See regulatory position C.6.b for definition of representative sample. Testing should be performed (1) initially, (2) at a frequency not to exceed 18 months (during a scheduled reactor shutdown is acceptable), and (3) following painting, fire, or chemical release in any ventilation zone communicating with the system in such a manner that the charcoal adsorbers could become contaminated from the fumes, chemicals, or foreign materials.

REFERENCES

1. American National Standard ANSI/ASME N509-1976, "Nuclear Power Plant Air Cleaning Units and Components." Copies may be obtained from the American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.
2. American National Standard ANSI N510-1975, "Testing of Nuclear Air Cleaning Systems," American Society of Mechanical Engineers.
3. ERDA 76-21, "Nuclear Air Cleaning Handbook," Oak Ridge National Laboratory, C. A. Burchsted, J. E. Kahn, and A. B. Fuller, March 31, 1976. Copies may be obtained from the National Technical Information Service, Springfield, Va. 22161.
4. ORNL-NSIC-65, "Design, Construction, and Testing of High Efficiency Air Filtration Systems for Nuclear Application," Oak Ridge National Laboratory, C. A. Burchsted and A. B. Fuller, January 1970. Copies may be obtained from the National Technical Information Service.
5. Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable," Office of Standards Development, U.S. Nuclear Regulatory Commission.
6. MIL-F-51068, "Filter, Particulate, High-Efficiency, Fire-Resistant" (latest edition), Military Specification. Copies may be obtained from the Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Penn. 19120.
7. MIL-STD-282, "Filter Units, Protective Clothing, Gas-Mask Components and Related Products: Performance-Test Methods," Military Standard, 28 May 1956. Copies may be obtained from the address given in Reference 6.
8. American Conference of Governmental Industrial Hygienists, "Industrial Ventilation," 14th Edition, 1976, Committee on Industrial Ventilation, P.O. Box 453, Lansing, Mich. 48902.
9. ASTM D2862-70, "Test for Particle Size Distribution of Granulated Activated Carbon." Copies

may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Penn. 19103.

10. RDT Standard M16-1T, "Gas-Phase Adsorbents for Trapping Radioactive Iodine and Iodine Compounds," USAEC Division of Reactor Research and Development, October 1973, Oak Ridge, Tenn. 37830.

11. ASTM D2854-70, "Test for Apparent Density of Activated Carbon," American Society for Testing and Materials.

12. ASTM E11-70, "Specifications for Wire Cloth Sieves for Testing Purposes," American Society for Testing and Materials.