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

A. INTRODUCTION

General Design Criteria 41, 42, and 43 on containment atmosphere cleanup systems in Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," require, in part, that these systems be provided as necessary to reduce the amount of radioactive material released to the environment following a postulated design basis accident (DBA) and that these systems be designed to permit appropriate periodic inspection and testing to assure their integrity, capability, and operability. General Design Criterion 61 requires, in part, that fuel storage and handling, radioactive waste, and other systems which may contain radioactivity be designed to assure adequate safety under normal and postulated accident conditions and be designed with appropriate containment, confinement, and filtering systems. Furthermore, General Design Criterion 19 requires, in part, that adequate radiation protection be provided to permit access to and occupancy of the control room under accident conditions and for the duration of the accident without the personnel receiving radiation exposures in excess of 5 rem whole body. This guide presents methods acceptable to the Regulatory staff for implementing the Commission's regulations in Appendix A to 10 CFR Part 50 with regard to air filtration and adsorption units used as atmosphere cleanup systems in light-water-cooled nuclear power plants for the purpose of mitigating the consequences of postulated accidents. This guide addresses the entire atmosphere cleanup system, including the various components and ductwork and postulated DBA environmental considerations.

It is the policy of the U.S. Atomic Energy Commission to encourage, support, and give priority consideration to activities leading to greater standardization of nuclear power plants. The basic objective of greater standardization is to secure added assurance of the safety of nuclear power plants. Regulatory Guides which provide detailed information concerning design, construction, testing, operation, and inspection of specific systems provide important mechanisms to establish technical bases for standardized plants. This guide provides detailed information on design, testing, and maintenance for air filtration and adsorption units of atmosphere cleanup systems in light-water-cooled nuclear power plants.

B. DISCUSSION

Atmosphere cleanup systems are included as engineered safety features in the design of light-water-cooled nuclear power plants to mitigate the consequences of postulated accidents by removing from the building or containment atmosphere radioactive material that may be released in the accident. All such cleanup systems must be designed to operate under the environmental conditions resulting from the accident. In this guide, atmosphere cleanup systems that must operate under postulated DBA conditions inside the primary containment (recirculating systems) are designated as primary systems. Systems required to operate under conditions that are generally less severe are designated as secondary systems (recirculating or once-through systems). Secondary systems typically include the standby gas treatment system and the emergency air cleaning systems for the fuel handling building, control room, and shield building. The DBA environmental conditions for a given system must be determined for each plant. DBA environmental conditions for typical primary and secondary systems are tabulated below. In addition to those conditions listed, primary systems must be designed to withstand the radiation dose from water and plateout sources in the containment and the corrosive effects of chemical sprays, if such sprays are included in the plant design.

Typical Accident Conditions for Atmosphere Cleanup System

Environmental Condition	Atmosphere Cleanup System	
	Primary	Secondary
Pressure surge	Result of initial blowdown	Generally less than primary
Maximum pressure	60 psi	~ 1 atm
Maximum temperature of influent	280°F	180°F
Relative humidity of influent	100% plus condensing moisture	100%
Average radiation levels		
Airborne radioactive materials	10^6 rads/hr[a]	10^5 rads/hr[a]
Iodine buildup on adsorber	10^9 rads[a]	10^9 rads[a]
Average airborne iodine concentrations		
Elemental iodine	100 mg/m^3	10 mg/m^3
Methyl iodide and particulate iodine	10 mg/m^3	1 mg/m^3

(a) This value is based on the source term specified in Regulatory Guide 1.3[1] or 1.4,[2] as applicable.

An atmosphere cleanup system consists of some or all of the following components: demisters, heaters, prefilters, high-efficiency particulate air (HEPA) filters, adsorption units, fans, and associated ductwork, valving, and instrumentation. The purpose of the demister is to remove entrained water droplets from the inlet stream, thereby protecting prefilters, HEPA filters, and adsorbers from water damage and plugging. Heaters, when used on secondary systems, normally follow the demisters in the cleanup train and are designed to mix and heat the incoming stream to reduce its relative humidity before it reaches the filters and adsorbers. Prefilters and HEPA filters are installed to remove particulate solid matter, which may be radioactive. Prefilters remove the larger particles and prevent excessive loading of HEPA filters; demisters may also perform this function. The HEPA filters remove the fine discrete particulate matter and pass the air stream to the adsorber. The adsorber removes gaseous iodine (elemental iodine and organic iodides) from the air stream. Additional HEPA filters collect carbon fines exhausted from the adsorber which may contain radioactivity. The fan is normally the final item in an atmosphere cleanup train.

In addition to the possible combination of environmental factors existing during a postulated DBA, the environmental history preceding such an accident may affect the performance of the atmosphere cleanup system. Industrial contaminants, pollutants, temperature, and relative humidity contribute to the aging of filters and adsorbents and reduce their effectiveness. Therefore, aging and weathering of these components, which vary from site to site, must 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 should be determined by scheduled testing during operation.

All components of atmosphere cleanup systems should be designed for reliable performance under accident conditions. Initial testing and proper maintenance are primary factors in assuring the reliability of the system. Careful attention during the design phase to problems of maintaining the system should contribute significantly to the reliability of the system by providing ease of maintenance. Of particular importance in the design is a layout that provides accessibility and sufficient working space to safely perform the required functions. Periodic testing during operation to verify the efficiency of the components is another important means of assuring reliability. Built-in features that will facilitate convenient in-place testing are important in system design.

At present there is no comprehensive standard for the design and testing of atmosphere cleanup systems. However, isolated standards are available for the construction and testing of certain components of systems. Where such standards are acceptable to the Regulatory staff, they are utilized in this guide. Where no suitable standard exists, acceptable approaches are presented in this guide. ORNL-NSIC-65, "Design, Construction and Testing of High-Efficiency Air Filtration Systems for Nuclear Application,"[3] offers a comprehensive review of air filtration systems. It is not a standard but a guide which suggests several design alternatives.

C. REGULATORY POSITION

1. Environmental Design Criteria

a. The design of each engineered-safety-feature atmosphere cleanup system should be based on the maximum pressure and pressure differential, radiation dose rate, relative humidity, maximum and minimum temperature, and other conditions resulting from the postulated DBA and on their duration.

b. The design of each system should be based on a 30-day integrated radiation dose, following the postulated DBA, to essential services in the vicinity of

the adsorber section. The radiation source term should be consistent with the assumptions found in Regulatory Guides 1.3,[1] 1.4,[2] and 1.25.[4] Other engineered safety features, including pertinent components of essential services such as power, air, and control cables, should be adequately shielded from the atmosphere cleanup systems.

c. The design of each adsorber should be based on the concentration and relative abundance of the iodine species (elemental, particulate, and organic), which should be consistent with the assumptions found in Regulatory Guides 1.3,[1] 1.4,[2] and 1.25.[4]

d. The atmosphere cleanup system should be compatible with other engineered safety features such as a containment spray system.

e. Components of systems connected to compartments that are unheated during a postulated accident should be designed for post-accident effect of both the lowest and highest outdoor temperatures used in the plant design.

2. **System Design Criteria**

a. Atmosphere cleanup systems designed and installed for the purpose of mitigating accident doses should be redundant. The systems should consist of the following sequential components: (1) demisters, (2) prefilters (demisters may serve this function), (3) HEPA filters before the adsorbers, (4) iodine adsorbers (impregnated activated carbon or equivalent adsorbent such as metal zeolites), (5) HEPA filters after the adsorbers, (6) ducts and valves, (7) fans, and (8) related instrumentation. Heaters are required when the humidity is to be controlled before filtration.

b. The redundant atmosphere cleanup systems should be physically separated so that damage to one system does not also cause damage to a second system. The generation of missiles from high-pressure equipment rupture, rotating machinery failure, or natural phenomena should be considered in the design for separation and protection.

c. All components of an engineered-safety-feature atmosphere cleanup system should be designated as seismic Category I (see Regulatory Guide 1.29[5]) if failure of a component would lead to the release of significant quantities of fission products to the working or outdoor environments.

d. The atmosphere cleanup system should be protected from pressure surges resulting from the postulated accident. Each component should be protected with devices, such as pressure relief valves, so that the overall system will perform its intended function during and after the passage of the pressure surge.

e. In the mechanical design of the system, the high radiation levels that may be associated with buildup of radioactive materials on the system components should be given particular consideration. System construction materials should effectively perform their intended function under the postulated radiation levels. The effects of radiation should be considered not only for the demisters, fans, HEPA filters, adsorbers, and heaters, but also for any electrical insulation, controls, joining compounds, dampers, gaskets, and other organic-containing materials which are necessary for operation during a postulated DBA.

f. The volumetric air flow rate of a single cleanup train should be limited to approximately 30,000 cfm. If total system air flow in excess of this rate is required, multiple trains should be used. For ease of maintenance, a filter layout consisting of three 1000 cfm HEPA filters high and ten wide is preferred.

g. The atmosphere cleanup system should be instrumented to signal, alarm, and record pertinent pressure drops and flow rates at the control room.

h. The power supply and electrical distribution system for the atmosphere cleanup system described in section C.2.a. above should be designed in accordance with IEEE-308.[6] All instrumentation and equipment controls should be designed to IEEE-279.[7] The system should be qualified and tested under IEEE-323.[8] To the extent applicable, IEEE Standards 334,[9] 336,[10] 338,[11] and 344[12] should be considered in the design.

i. *Permanently installed arrangements* which allow unfiltered air to bypass the system should be avoided. A temporary bypass of the adsorber or HEPA filters for testing purposes, such as blanking off downstream units from the test agent, is acceptable if operation of the bypass is indicated by alarms or signals both locally and in the control room.

j. For protection of workers from radiation exposure resulting from a DBA, the atmosphere cleanup train should be totally enclosed and installed in a manner which permits replacement of the train as an intact unit without removal of components i.e., demisters, prefilters, heaters, HEPA filters, adsorbers, and fan.

k. 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.

l. Recirculating primary atmosphere cleanup system housings and ductwork should be designed to exhibit on test a maximum total leakage rate of 10 cfm per 1000 cfm of system flow. Recirculating or once-through secondary system housings and discharge ductwork located in a high radiation zone should be designed to exhibit on test a maximum total leakage rate of 0.5 cfm per 1000 cfm of system flow. Filter mounting frames and ducts should be designed to withstand DBA pressure surges without permanent distortion or breach of integrity.

m. Any atmosphere cleanup system which is not classified as, and is not given credit as, an engineered safety feature but is expected to collect airborne radioactive material should be designed to retain collected radioactive materials during and after a postulated DBA. The atmosphere cleanup system should not deleteriously affect the operation of

engineered-safety-feature systems. Appropriately designed arrangements which isolate non-engineered-safety-feature filtration systems from the environment in a postulated design basis accident are acceptable.

3. **Component Design Criteria and Qualification Testing**

a. The demisters installed in engineered-safety-feature atmosphere cleanup systems should meet qualification requirements similar to those found in MSAR 71-45, "Entrained Moisture Separators for Fine (1-10μ) Water-Air-Steam Service: Their Performance, Development and Status."[13] Demisters should meet Underwriters' Laboratories (UL) Class 1[14] requirements.

b. Adsorption units function efficiently at a relative humidity of 70%. If heaters are used on secondary systems, the heating section should reduce the relative humidity of the incoming atmosphere from 100% to 70% during postulated DBA conditions. A prototype heating element should be qualified under postulated DBA conditions. Consideration should be given in system design to minimizing heater control malfunction. The heater should not be a potential adsorbent ignition source.

c. Materials used in the prefilters should withstand the radiation levels and environmental conditions prevalent during the postulated DBA. Prefilters should meet UL Class 1[14] requirements and be listed in the current UL Building Materials List.[15] The prefilters should have not less than a 40% atmospheric dust spot efficiency rating (Section 9 of the ASHRAE Standard 52, "Method of Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter").[16]

d. The HEPA filters should be steel cased and designed to military specifications MIL-F-51068C and MIL-F-51079A. The HEPA filters should satisfy the requirements of UL-586.[17] The HEPA filter separators should be capable of withstanding iodine removal sprays. HEPA filters should be tested individually by the appropriate Filter Test Facility listed in the current USAEC Health and Safety Bulletin for Filter Unit Inspection and Testing Service.[18] The Filter Test Facility should test each filter at 100% and 20% of rated flow, with the filter encapsulated to disclose frame and gasket leaks.

e. Filter and adsorber mounting frames should be constructed of corrosion-resistant unpainted steel, designed for horizontal air flow, and designed in accordance with the recommendations of Section 4.3 of ORNL-NSIC-65.[3] For ease of maintenance, mounting frames should limit installation of HEPA filters and adsorbers to a maximum height of seven feet above the walking surface. Each filter should be independently clamped in place at a minimum of four pressure points. Common bolting of filters or adsorbers should not be allowed. Mounting of filters on the downstream side of mounting frames is recommended.

f. System filter housings should be of all-steel construction and designed in accordance with the ORNL-NSIC-65[3] recommendations on steel floors, housing doors, and other filter housing requirements contained in Sections 4.5.5, 4.5.7, and 4.5.9, respectively.

g. Water drains should be designed in accordance with the recommendations of Section 4.5.6 of ORNL-NSIC-65.[3]

h. Because of radiation effects, mounting frames and internal welds should not be painted. Material selected for ducts should be compatible with the cooling and containment spray solutions. The use of aluminum and zinc are discouraged.

i. The adsorber 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 will be discussed in this guide. If activated carbon is the adsorbent, the adsorber should be designed for an average atmosphere residence time of 0.25 sec per two inches of adsorbent bed. The adsorbent bed should consist of at least two inches of 8 by 16 Tyler mesh (nominal) impregnated activated carbon with an apparent bulk density of 0.5 ±0.05g/cc and a size distribution by weight-percent as follows:

Retained on #6 ASTM E11[19] Sieve:	0.0%
Retained on #8 ASTM E11[19] Sieve:	5.0% maximum
Through #8, retained on #12 Sieve:	40% to 60%
Through #12, retained on #16 Sieve:	40% to 60%
Through #16 ASTM E11[19] Sieve:	5.0% maximum
Through #16 ASTM E323[20] Sieve:	1.0% maximum

If other size distributions and greater residence times are used, the system design should provide for methyl iodide and elemental iodine removal from the atmosphere equivalent to that provided by the minimum bed thickness and recommended size distribution.

The design of two-inch-deep tray-type and one-inch-deep pleated-bed adsorbent canisters should be as stated in CS-8T, "Tentative Standard for High Efficiency Gas-Phase Adsorber Cells."[21] The activated carbon should be totally restrained in the adsorber. A qualification test on a prototype adsorber should be performed in accordance with paragraph 7.4.1 of CS-8T[21] except that the design basis earthquake parameters particular to the site should be used. The adsorber should be tested[30] with a gaseous halogenated hydrocarbon refrigerant both before and after the qualification test and should show no significant increased penetration. Each original or replacement batch of activated carbon used in the adsorber section should meet the qualification and batch test results summarized in Table 1 of this guide. A batch of activated carbon is defined in RDT Standard M-16-1T, "Gas-Phase Adsorbents for Trapping Radioactive Iodine and Iodide Compounds."[22]

To assure that the adsorber section will contain carbon of a uniform packing density, written procedures for filling should be prepared and followed by the user.

The adsorber should be designed for a maximum loading of 2.5 mg of iodine per gram of activated carbon. No more than 5% of impregnant (50 mg of impregnant/gram of carbon) should be used. The radiation stability of the type of carbon specified should be demonstrated and certified. (See regulatory position C.1.b. for the design source term.)

j. The design of the adsorber section should consider possible iodine desorption and adsorbent autoignition that may result from radioactivity induced heat in the adsorbent and concomitant temperature rise. The system design should provide for water sprays to inhibit adsorber fires. Combustible gas generated by an adsorbent fire should be considered in the design.

k. The system fan should have sufficient capacity to pull the rated air flow through the entire system and maintain the specified negative pressure at the maximum pressure drop for which the system has been designed.

l. The fan or blower used on the cleanup system should be capable of operating under the environmental conditions postulated, including radiation.

m. Ductwork should be designed in accordance with the recommendations of Section 2.8 of ORNL-NSIC-65.[3]

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

4. Maintenance

a. Cleanable or replaceable elements of the atmosphere cleanup system should be designed for ready removal and minimal radiation exposure of personnel.

b. The system layout should be designed to minimize reaching, stooping, and the use of ladders or temporary scaffolding for gaining access to filters for testing and maintenance. Designs requiring physical contortions or the climbing of ladders to remove and replace filters should be avoided.

c. The system design should provide rigid, hinged doors on filter housings with dimensions that will permit a man walking erect and carrying a loaded filter carton (26 x 26 x 12 inch x 40 lb) to pass through without stooping or twisting, and should include vacuum breakers to aid in opening a door with the fan in operation.

d. For ease of maintenance, the system design should provide for a minimum of five linear feet from mounting frame to mounting frame between banks of components. If components are larger than two and a half feet by two and a half feet, more than five linear feet should be provided: the dimension to be provided should be the maximum length of the component plus approximately three feet.

e. The system design should provide for aligning and supporting filter elements during filter change in accordance with Section 4.3.5 of ORNL-NSIC-65.[3]

f. For manual handling the system design should provide at least 2 inches of clearance between filter elements in the same bank.

g. Use of materials-handling facilities, including dollies for moving new and used filters to and from the installation site and elevators for moving loaded dollies up and down within the building, should be provided for in the design and layout.

h. The system design should provide for permanent test probes with external connections. Preferably, the test probes should be manifolded at a single convenient location with due consideration given to balancing of line lengths and diameter to produce reliable test results for refrigerant gas, resistance, flow rate, and dioctyl phthalate (DOP) testing.

i. The entire standby atmosphere cleanup train should be operated at least 10 hours per month, with the heaters on (if so equipped), in order to reduce the buildup of moisture on the adsorbers and HEPA filters.

j. The cleanup components (e.g., HEPA filters, prefilters, adsorbents) should not be installed while active construction is still in progress.

k. Adequate vapor-tight lighting should be provided in the filter housing.

l. Electrical (115-V, 15-Amp convenience outlets), water, and compressed air services should be nearby but not inside the filter housing.

m. Ledges and sharp corners should be avoided in design and construction.

5. In-Place Testing Criteria

a. The air flow distribution to the HEPA filters and adsorbers should be tested for uniformity and should be within ±20% of averaged flow per unit.

b. The in-place HEPA DOP test should conform to ANSI N101.1-1972, "Efficiency Testing of Air Cleaning Systems Containing Devices for Removal of Particles."[29] HEPA filter sections should be tested in place initially, and semiannually thereafter, to confirm a penetration of less than 0.05% at rated flow. An engineered-safety-feature air filtration system satisfying this requirement can be considered to warrant a 99% removal efficiency for particulates in accident dose evaluations. HEPA filters that fail to satisfy this requirement should be replaced. If for any reason, the HEPA bank is entirely or only partially replaced, an in-place DOP test should be conducted. During the DOP testing, the adsorber units should be temporarily bypassed. The use of silicone sealants or any other temporary patching material on filters, housing, mounting frames, or ducts should be prohibited. If necessary, welding repairs should be performed on the housing or mounting frame prior to periodic testing, filter inspection, and in-place testing.

c. The activated carbon adsorber section should be leak tested with a gaseous halogenated hydrocarbon refrigerant in accordance with USAEC Report DP-1082 "Standardized Nondestructive Test of Carbon Beds for

The adsorber should be designed for a maximum loading of 2.5 mg of iodine per gram of activated carbon. No more than 5% of impregnant (50 mg of impregnant/gram of carbon) should be used. The radiation stability of the type of carbon specified should be demonstrated and certified. (See regulatory position C.1.b. for the design source term.)

j. The design of the adsorber section should consider possible iodine desorption and adsorbent autoignition that may result from radioactivity induced heat in the adsorbent and concomitant temperature rise. The system design should provide for water sprays to inhibit adsorber fires. Combustible gas generated by an adsorbent fire should be considered in the design.

k. The system fan should have sufficient capacity to pull the rated air flow through the entire system and maintain the specified negative pressure at the maximum pressure drop for which the system has been designed.

l. The fan or blower used on the cleanup system should be capable of operating under the environmental conditions postulated, including radiation.

m. Ductwork should be designed in accordance with the recommendations of Section 2.8 of ORNL-NSIC-65.[3]

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

4. Maintenance

a. Cleanable or replaceable elements of the atmosphere cleanup system should be designed for ready removal and minimal radiation exposure of personnel.

b. The system layout should be designed to minimize reaching, stooping, and the use of ladders or temporary scaffolding for gaining access to filters for testing and maintenance. Designs requiring physical contortions or the climbing of ladders to remove and replace filters should be avoided.

c. The system design should provide rigid, hinged doors on filter housings with dimensions that will permit a man walking erect and carrying a loaded filter carton (26 x 26 x 12 inch x 40 lb) to pass through without stooping or twisting, and should include vacuum breakers to aid in opening a door with the fan in operation.

d. For ease of maintenance, the system design should provide for a minimum of five linear feet from mounting frame to mounting frame between banks of components. If components are larger than two and a half feet by two and a half feet, more than five linear feet should be provided: the dimension to be provided should be the maximum length of the component plus approximately three feet.

e. The system design should provide for aligning and supporting filter elements during filter change in accordance with Section 4.3.5 of ORNL-NSIC-65.[3]

f. For manual handling the system design should provide at least 2 inches of clearance between filter elements in the same bank.

g. Use of materials-handling facilities, including dollies for moving new and used filters to and from the installation site and elevators for moving loaded dollies up and down within the building, should be provided for in the design and layout.

h. The system design should provide for permanent test probes with external connections. Preferably, the test probes should be manifolded at a single convenient location with due consideration given to balancing of line lengths and diameter to produce reliable test results for refrigerant gas, resistance, flow rate, and dioctyl phthalate (DOP) testing.

i. The entire standby atmosphere cleanup train should be operated at least 10 hours per month, with the heaters on (if so equipped), in order to reduce the buildup of moisture on the adsorbers and HEPA filters.

j. The cleanup components (e.g., HEPA filters, prefilters, adsorbents) should not be installed while active construction is still in progress.

k. Adequate vapor-tight lighting should be provided in the filter housing.

l. Electrical (115-V, 15-Amp convenience outlets), water, and compressed air services should be nearby but not inside the filter housing.

m. Ledges and sharp corners should be avoided in design and construction.

5. In-Place Testing Criteria

a. The air flow distribution to the HEPA filters and adsorbers should be tested for uniformity and should be within ±20% of averaged flow per unit.

b. The in-place HEPA DOP test should conform to ANSI N101.1-1972, "Efficiency Testing of Air Cleaning Systems Containing Devices for Removal of Particles."[29] HEPA filter sections should be tested in place initially, and semiannually thereafter, to confirm a penetration of less than 0.05% at rated flow. An engineered-safety-feature air filtration system satisfying this requirement can be considered to warrant a 99% removal efficiency for particulates in accident dose evaluations. HEPA filters that fail to satisfy this requirement should be replaced. If for any reason, the HEPA bank is entirely or only partially replaced, an in-place DOP test should be conducted. During the DOP testing, the adsorber units should be temporarily bypassed. The use of silicone sealants or any other temporary patching material on filters, housing, mounting frames, or ducts should be prohibited. If necessary, welding repairs should be performed on the housing or mounting frame prior to periodic testing, filter inspection, and in-place testing.

c. The activated carbon adsorber section should be leak tested with a gaseous halogenated hydrocarbon refrigerant in accordance with USAEC Report DP-1082, "Standardized Nondestructive Test of Carbon Beds for

Reactor Containment Application,"[30] to ensure that bypass leakage through the adsorber section is less than 0.05% for units with an assigned adsorption efficiency (see Table 2 of this guide) of greater than 95%, and 0.1% for systems with an assigned efficiency of 95% or less. During the test the upstream concentration of refrigerant gas should be no greater than 20 ppm. 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 whenever DOP testing is done.

6. Laboratory Testing Criteria for Activated Carbon

a. If the activated carbon adsorber section meets the requirements given in regulatory position C.5.c. and the adsorbent meets the test requirements of Tables 1 and 2 of this guide, the adsorber section should be assigned the decontamination efficiencies for a DBA analysis as given in Table 2 for elemental iodine and organic iodides. If for any reason the carbon fails to meet the test requirements in Table 2, it should not be used in engineered-safety-feature adsorbers.

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 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 for estimating the amount of penetration of the system adsorbent throughout its service life. Where the system activated carbon is greater than two inches deep, each representative sampling station should consist of multiple two-inch samples in series whose aggregate length equals 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 flow during service conditions. The activated carbon adsorber section should be replaced after the last representative sample has been removed and tested or if any preceding representative sample has failed to meet the testing requirements of Table 2.

c. The user should prepare detailed procedures for each required field and laboratory test suggested by this guide. The test procedures typically should identify:

(1) The specific item to be tested.

(2) Its location.

(3) Any arrangements that should be made and equipment provided prior to the test.

(4) Physical conditions to be met.

(5) Any equipment lockouts or other precautions necessary for safety of personnel or adjacent equipment.

(6) The persons who should be notified prior to the test.

(7) The acceptance criteria.

(8) The corrective action that should be taken in the event of nonconformance to the acceptance requirements, and

(9) Addressees to receive copies of test reports.

REFERENCES

1. Regulatory Guide 1.3, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors." Directorate of Regulatory Standards, USAEC.
2. Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors." Directorate of Regulatory Standards, USAEC.
3. C. A. Burchsted & A. B. Fuller, "Design, Construction, and Testing of High-Efficiency Air Filtration Systems for Nuclear Application," ORNL-NSIC-65, Oak Ridge National Laboratory, January 1970.
4. Regulatory Guide 1.25, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors," Directorate of Regulatory Standards, USAEC.
5. Regulatory Guide 1.29, "Seismic Design Classification," Directorate of Regulatory Standards, USAEC.
6. IEEE Std 308-1971, "Criteria for Class IE Electric Systems for Nuclear Power Generating Stations." Institute of Electrical and Electronics Engineers.
7. IEEE Std 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations."
8. IEEE Std 323-1971, "General Trial-Use Guide for Qualifying Class I Electric Equipment for Nuclear Power Generating Stations."
9. IEEE Std 334-1971, "Trial-Use Guide for Type Tests of Continous-Duty Class I Motors Installed Inside the Containment of Nuclear Power Generating Stations."
10. IEEE Std 336-1971, "Installation, Inspection and Testing Requirements for Instrumentation and Electric Equipment During the Construction of Nuclear Power Generating Stations."
11. IEEE Std 338-1971, "Trial-Use Criteria for the Periodic Testing of Nuclear Power Generating Station Protection Systems."
12. IEEE Std 344-1971, "Trial-Use Guide for Seismic Qualification of Class I Electric Equipment for Nuclear Generating Stations."
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20. ASTM E323-70, "Specifications for Perforated-Plate Sieves for Testing Purposes."
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22. RDT Standard M-16-1T, "Gas-Phase Adsorbents for Trapping Radioactive Iodine and Iodine Compounds," USAEC Division of Reactor Development and Technology, June 1972.
23. ASTM D2862-70, "Test for Particle Size Distribution of Granulated Activated Carbon."
24. MIL-C-17605B, "Charcoal, Activated, Technical, Unimpregnated," Military Specification.
25. Brunauer, S., Emmett, P. H. and Teller, E. J., J. Am. Chem. Soc. 60,309 (1938).
26. ASTM D2867-70, "Test for Moisture in Activated Carbon."
27. ASTM D2866-70, "Test for Total Ash Content of Activated Carbon."
28. ASTM D2854-70, "Test for Apparent Density of Activated Carbon."
29. ANSI N101.1-1972, "Efficiency Testing of Air Cleaning Systems Containing Devices for Removal of Particles," American National Standards Institute.
30. D.R. Muhlbaier, "Standardized Nondestructive Test of Carbon Beds for Reactor Confinement Application," USAEC Report DP-1082, Savannah River Laboratory, July 1967.

TABLE 1

SUMMARY TABLE OF NEW ACTIVATED CARBON PHYSICAL PROPERTIES

TEST	ACCEPTABLE TEST METHOD	ACCEPTABLE RESULTS		TEST SCHEDULE ON BASE MATERIAL	TEST SCHEDULE ON FINISHED ADSORBENT
1. Particle Size Distribution	ASTM D 2862[23]	Retained on #6 ASTM E11[19] Sieve: Retained on #8 ASTM E11[19] Sieve: Through #8, retained on #12 Sieve: Through #12, retained on #16 Sieve: Through #16 ASTM E11[19] Sieve: Through #16 ASTM E323[20] Sieve:	0.0% 5.0% maximum 40% to 60% 40% to 60% 5.0% to maximum 1.0% to maximum	–	Batch[c]
2. Hardness Number	MIL-C17605B para.4.6.4[24]			Batch	–
3. Ignition Temperature	RDT M16-1T, Appendix C[22]	340°C minimum at 100 fpm		–	Batch
4. Surface Area	BET Surface Area[25]	1000 m²/gr minimum		Batch	–
5. Radioiodine Removal Efficiency					
a. Elemental Iodine, DBA Temperature and Pressure	RDT M16-1T[22], para.4.5.2 except DBA Temperature and pressure are used[a]	99.9%		–	Qualification[b]
b. Methyl Iodide, DBA Temperature and Pressure	RDT M16-1T[22], para. 4.5.4 except DBA Temperature and pressure are used[a]	95% for 95% relative humidity 99.5% for 70% relative humidity		–	Batch
c. Retention	RDT M16-1T[22], para. 4.5.5	99%		–	Qualification
6. Moisture Content Efficiency	ASTM D2867, Xylene Method[26]	3% maximum		–	Batch
7. Ash Content	ASTM D2866[27]	6% maximum		Qualification	–
8. Bulk Density	ASTM D2854[28]	Report value		–	Batch
9. Impregnant Content	State Procedure	State type (not to exceed 5% by weight)		–	Batch
10. Impregnant Leachout	State Procedure	Report value		–	Qualification

[a] DBA Maximum Temperature (rounded to the next highest decade in °F, i.e., 252°F is 260°F) and Maximum Pressure (rounded to the next highest decade in psig, i.e., 51 psig is 60 psig).

[b] Qualification test: Test which establishes the suitability of a product for a general application, normally a one-time test reflecting historical typical performance of material.

[c] Batch test: Test made on a production batch of product to establish suitability for a specific application.

TABLE 2

LABORATORY TEST REQUIREMENTS FOR ACTIVATED CARBON

Activated Carbon[a] Bed Depth[d]	Assigned Activated Carbon Decontamination Efficiencies		Laboratory Test Requirements for a Representative Sample[b]
2 inches. Air filtration system designed to operate inside primary containment.	Elemental Iodine Organic Iodide	90% 30%	Test initially, and yearly thereafter, under 95% relative humidity, maximum design temperature[c] and design face velocity for an elemental iodine penetration of <1.0 and <10% for methyl iodide.
2 inches. Air filtration system designed to operate outside the primary containment and relative humidity is controlled to 70%.	Elemental Iodine Organic Iodide	95% 95%	Test with methyl iodide initially, and yearly thereafter, under 70% relative humidity, maximum design temperature[c] and design face velocity for a penetration of <1.0%.
4 inches. 6 inches. 8 inches. 15 inches. Air filtration system designed to operate outside the primary containment and relative humidity is controlled to 70%.	Elemental Iodine Organic Iodide	99% 99%	Test with methyl iodide in two-inch increments initially and semi-annually thereafter for the 4-inch bed, every eight months for the 6-inch bed, and annually for the 8- and 15-inch beds under 70% relative humidity, maximum design temperature, and design face velocity for a penetration of <0.175%.

[a]The activated carbon, when new, should meet the requirements stated in this guide.

[b]See regulatory position C.6.b. for definition of Representative Sample.

[c]A maximum postulated DBA temperature (°F) rounded to the next highest decade (e.g. 181°F should be rounded to 190°F).

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