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GENERAL DESIGN GUIDE FOR VENTILATION SYSTEMS OF PLUTONIUM PROCESSING AND FUEL FABRICATION PLANTS

A. INTRODUCTION

Each applicant for a license to possess and use special nuclear material in a plutonium processing and fuel fabrication plant as defined in § 70.4 (r) of 10 CFR Part 70, "Special Nuclear Material," must satisfy the provisions of § 70.23, "Requirements for the Approval of Applications." Paragraphs (a)(3) and (4) of § 70.23 require that the applicant's proposed equipment and facilities and proposed procedures be adequate to protect health and minimize danger to life or property.

At plutonium processing and fuel fabrication plants, a principal risk to health and safety is the release and dispersal of radioactive materials. The prevention of such release and dispersal is an important function of the ventilation systems. This regulatory guide presents methods acceptable to the Regulatory staff for complying with §§ 70.23 (a)(3) and (a)(4) with respect to the design of ventilation systems for plutonium processing and fuel fabrication plants.

B. DISCUSSION

Ventilation systems for a plutonium processing and fuel fabrication plant may consist of air supply, recirculating air, process ventilation, and exhaust air systems together with associated air filters, fans, dampers, ducts, and control instrumentation. The air supply system draws in and conditions fresh air and distributes it throughout the plant. A portion of supply air enters the process ventilation system through glove boxes, hoods, and other components and is removed together with other plant air through the exhaust ventilation system which discharges through a stack to the environment. Part of the occupied-area ventilation air may be recycled to the air supply system through the recirculating air system.

Ventilation systems are important to safety because they serve as principal confinement barriers in a multiple confinement barrier system which guards against the release of radioactive or other potentially dangerous materials during normal or abnormal conditions. Ventilation systems will be subject to variations in operating temperatures and pressures and to environmental conditions associated with normal operation, maintenance, plant shutdown, and testing. They may also be subject to effects of natural phenomena such as seismic motion and floods, missiles, fire and explosion, and other accidents.

The systems must continue to perform their safety functions effectively under all conditions by confining radioactive or other potentially dangerous materials. The systems must assure that the concentration of radioactive materials in the effluent gases is as low as practicable.

The continuity of necessary ventilation can be assured by means such as standby equipment and fail-safe control systems. The ability of the systems to perform their safety functions effectively can be assured by periodic testing of safety-related components during normal operation of the systems to demonstrate their ability to perform at design efficiency and to verify their availability for emergencies.

C. REGULATORY POSITION

The ventilation systems of a plutonium processing and fuel fabrication plant should assure the confinement of hazardous materials during normal or abnormal conditions including natural phenomena, fire, and explosion. The release of radioactive material to the environment, or to an area in which levels of radioactivity are normally sufficiently low to permit personnel access, should be reduced to a level as low as practicable in accordance with the provisions of 10 CFR Part 20.

1. General Safety

a. The ventilation systems should confine radioactive materials within the process areas as close to the point of origin as practicable. They should also confine and prevent uncontrolled release of radioactive aerosols, noxious fumes, and vapors into rooms and areas normally occupied by personnel.

b. Confinement of radioactive materials should be provided by multiple zones. Each zone is bounded by barriers such as vessel and glove box walls, building walls, and internal room walls. The primary confinement zone (Zone I) should be the process ventilation system for glove boxes, conveyors, transfer boxes, and other spaces that may contain plutonium or other radioactive materials during normal operations. A secondary confinement zone (Zone III) should be the operating and other potentially contaminated areas surrounding the process ventilation system. Areas inside the building, potentially free of contamination and surrounding the primary confinement zone, but interposed between Zones I and III, would constitute an additional secondary confinement zone (Zone II).

c. Pressure differentials should be maintained between building confinement zones and also between the building confinement zones and the outside atmosphere to assure that air flow is from zones of lesser potential for contamination to zones of greater potential for contamination, i.e., from the environs into the building, thence to secondary and primary confinement zones. Devices should be provided to control and indicate pressure differentials between confinement zones. Alarms should be provided to indicate when pressure differentials are not maintained in a prescribed range.

d. All ventilation systems should be designed so that the failure of any one component (equipment or control device) will not affect the continuous operation of the ventilation systems. Ventilation systems and components should have fail-safe features with provision for alarm indication.

e. Onsite emergency power supply systems should be provided to operate the ventilation systems and components as well as other systems and components important to safety. Ventilation systems should be capable of operating, during normal power outage, at capacities required to maintain confinement of contaminants. The onsite emergency power sources and the electrical distribution circuits should have independence and testability to assure performance of their safety functions assuming a single failure.

f. The ventilation systems should be designed to withstand any credible fire and explosion and continue to act as confinement barriers. Fire protection features of the ventilation systems should include fire doors and dampers or other proven devices to restrict the spread of fires, fire-resistant materials of construction, fire-resistant filters, heat and smoke detectors, alarms, heat removal devices, and fire-suppression equipment. The design of the fire protection system should include provisions to protect against adverse effects in the event of operation or failure of this system. For example, a drain system should be provided to prevent a criticality incident in the event of water discharge on activation of a water spray heat removal system or in the event of water leakage on failure of a heat removal system component, such as a spray nozzle, while the system is not in operation.

g. All ventilation systems should be capable of operating during a fire in the areas they ventilate and safely handle products of combustion through appropriate ventilation channels. A supply air system should remain operational; however, the option to discontinue air supply to the involved space or spaces should be maintained. Any system shut down should be protected from backflow.

h. The materials of construction for the ventilation systems should be fire resistant to protect against fires occurring within or without the systems. All filters should be of a fire resistant type and, where applicable, approved by Underwriters' Laboratories, Incorporated (UL).[1] Filters and exhaust fans, especially a final filter plenum and exhaust fan enclosure, should be located where they are not exposed to the direct effects of fire or explosion in the operating areas. Smoke detectors and thermostats for fire detection, approved by UL,[2] should be provided in the ventilation systems.

i. Fire- and smoke-suppression equipment should be so located as to assure that the integrity of final high-efficiency filters or filter systems is not degraded. Spark and flame arresters and isolation valves may be used at filter installations in intermediate stages of effluent cleaning. A heat removal system should precede the first stage of a high-efficiency filtration system serving as a final means of effluent cleaning (see regulatory position C.8.e).

j. If sources of combustible solvents, gases, and vapors are identified or postulated to be present in a ventilation system under normal or abnormal conditions, they should be monitored by suitable continuous monitoring systems as specified in Regulatory Guide 3.7.[3]

k. The ventilation systems should be designed to withstand tornado conditions without loss of confinement capability due to mechanical damage to the system or components or due to the reduced ambient pressure at the intake and exhaust openings of the building. Protection against missiles should be provided for the intake and exhaust openings.

l. Components of the ventilation systems should be designed to withstand the effects of earthquakes and remain functional to the extent that they will prevent the uncontrolled release of radioactive materials to the environment.

2. Occupied-Area Ventilation Systems

a. Supply air should be properly conditioned and distributed at or near the ceiling to the potentially contaminated areas of the facility.

b. Outdoor makeup air supply units should be protected from the weather. For example, intakes should be arranged so as to minimize the effects of high winds, rain, snow, ice, and debris on the operation of the system. Heaters may be necessary in areas where icing can cause significant supply filter damage. Screens should be provided over supply air inlets to protect moisture separators and filters from wind-blown debris.

c. Air from each Zone II or Zone III area should be removed near the floor through individual area grills or registers, each equipped with a fire-resistant medium-efficiency filter. The filter should have an atmospheric dust spot efficiency[4] rating of approximately 90% or better. Filtered air can be recirculated or can be discharged through an exhaust ventilation system.

d. Part of the Zone II or Zone III filtered air may be recirculated to reduce thermal loads. The point of Zone II or Zone III air withdrawal should be selected so that Zone I air streams cannot be drawn into the Zone II or Zone III air supply. Local exhaust effluent that may contain noxious, toxic, or corrosive gases and vapors should not be recirculated into a Zone II or Zone III area. Recirculated air should be passed through two stages of fire-resistant high-efficiency particulate air (HEPA) filters in series before it is returned to Zone II or Zone III areas.

e. Provision should be made for continuous monitoring of recirculated air prior to the second stage of HEPA filtration. Upon an indication that the limits for soluble isotopes of plutonium specified in Table I, Column 1 of Appendix B to 10 CFR Part 20 or in the license conditions have been exceeded, the air in the recirculating system should be diverted to a once-through exhaust ventilation system for discharge through a final filter plenum. The point of diversion of Zone II or Zone III filtered air into the once-through exhaust ventilation system should be prior to the heat removal system preceding the final filter plenum. Recirculation of Zone II or Zone III air may be resumed on correction of offending operations and/or equipment deficiencies.

f. A final filter plenum should have at least two stages of fire-resistant HEPA filters in series. HEPA filters should be designed to military specifications MIL-F-51068C[5] and MIL-F-51079A[6] and should satisfy the requirements of UL-586.[7] Final filtration systems incorporating high-efficiency filters other than HEPA filters and having equivalent efficiency and resistance to fire are also acceptable (see regulatory positions C.8.e. and C.8.g).

g. The filtered air should be discharged to the environs through a stack of sufficient height to reduce close-in ground-level concentrations of radioactive or other potentially dangerous contaminants.

3. Process Ventilation Systems

a. Air or inert gas should enter each ventilated glove box or process enclosure through at least one fire-resistant HEPA filter and be discharged through at least one fire-resistant HEPA filter to exhaust ductwork leading to a final filter system (see regulatory position C.8.e). The inlet filter prevents any backflow of contaminants into the work areas, and the outlet filter minimizes contamination of the exhaust ductwork.

b. All process ventilation systems should have adequate capacity and appropriate controls to maintain at least 125 linear feet per minute inward air flow through the maximum credible breach and thereby prevent the escape of particulates.

c. Air or inert gas from glove boxes or other process enclosures where wet chemical operations take place should be treated to protect the ventilation ductwork, final filters, and filter plenums from exposure to wetting or deleterious chemical attack.

d. Consideration should be given to recirculation of exhaust air or inert gas to glove boxes and other process enclosures to minimize release of radionuclides to the biosphere. If recirculation is used, the exhaust gas from these enclosures should be filtered through two stages of fire-resistant HEPA filters in series before being recirculated.

4. Fans

a. Installed spare fans and isolation dampers should be provided for the supply air and exhaust air systems. When any one fan is inoperative in a system, a backflow damper should automatically isolate the idle fan from the system. Standby fans should automatically start and have sufficient capacity to maintain minimum system air flow.

b. Alarms should be provided to indicate malfunction of each ventilation fan (see regulatory position C.5.f).

c. Supply air fans should be interlocked with an exhaust air plenum pressure sensor to prevent supply fan operation unless the exhaust fans are running. This will prevent pressurization of any process room or area should exhaust ventilation fail.

d. Emergency power should be supplied to fans in the event of failure of the normal power supply (see regulatory position C.1.e).

5. Ventilation System Construction and Layout

a. The material of construction for the ventilation systems should be carefully selected according to such safety considerations as strength to withstand accident conditions; corrosion resistance, particularly when associated with chemical processes; fire resistance; long operating life to avoid frequent replacement of contaminated equipment; and smooth surface finish to aid in decontamination.

b. Ducts and housings should be designed, fabricated, and erected with a minimum of ledges, protrusions, and crevices that could collect dust and moisture or that could impede personnel or create a hazard in performance of their work. Duct runs and flow distributors should assure uniform, representative air flow past monitoring and sampling stations as well as through filter installations.

c. The design should permit convenient inspection, maintenance, decontamination, and/or replacement of critical components such as filters, fans, and dampers.

d. Housings, filter mounting frames, and ducts should be designed to withstand system pressure changes without distortion, fatigue, or yielding of such magnitude that inleakage or bypassing of the filters results.

e. Supply, recirculation, process ventilation, and exhaust ducting should incorporate manual and automatic dampers and controls to distribute and regulate the movement of air in each room, area, and ventilation system and to prevent possible backflow in case of pressure reversal.

f. The ventilation systems should be appropriately instrumented to read out and alarm in one or more central control areas. These areas should be designed to permit occupancy and actions to be taken to operate the ventilation systems safely during normal or abnormal conditions.

6. Ventilation System Testing and Monitoring

a. Provisions should be made so that components of ventilation systems can be tested periodically for operability and required functional performance. They should include capability for periodic measurement of air flows in exhaust ducts and in or at equipment, hoods, and glove boxes.

b. The capability should be provided to test, under conditions as close to design as practicable, the operating sequence that would bring ventilation systems into action, including the transfer to alternate power sources and the design air flow delivery capability.

c. All exhausting ducts and stacks which may contain plutonium contaminants should be provided with two monitoring systems: a continuous monitor [Continuous Air Monitoring System (CAMS)] and a fixed sampler. The probes for sampling purposes should be designed for isokinetic sampling and located to obtain representative samples. Each system should be connected to an emergency power supply (see regulatory position C.1.e). The continuous stack sampler should alert cognizant personnel through an audible and visual annunciator if the airborne radioactive effluents reach prescribed limits.

d. Air monitoring and warning systems (including CAMS) should be installed in areas where radioactive material is handled. Air sampling heads should provide a representative sample of the potential airborne radioactivity being breathed. Consideration should be given to locating continuously operating exhaust samplers after each stage of HEPA filtration.

e. In addition to a local station alarm, the CAMS and stack monitoring systems should have readout and alarm panels in the central control area(s).

7. Glove Boxes and Other Process Enclosures

a. Glove boxes should be constructed using the highest quality of materials and workmanship to assure total containment and minimize leakage. Combustible materials that are an integral part of the glove box should be held to a minimum.

b. The design of enclosures should be based on downdraft ventilation flow to minimize the spread of fire. Heat detectors and combustible gas and vapor detection meters should be provided on glove boxes or enclosures where fire or explosion hazards exist. Automatic fire suppression equipment should be provided in these boxes or enclosures. Where automatic systems are not required, fire detectors should be installed and provisions made for manual fire suppression.

c. Small glove box or enclosure systems supplied with gases under positive pressure should have positive-acting pressure-relief devices (discharging into an exhaust system) to prevent overpressurization. Further, should these systems be recirculating, all necessary cleanup and detection equipment for noxious, corrosive, or explosive vapors or gases should be considered.

d. The glove box or enclosure design should permit filter replacement with minimum exposure to personnel performing this task and with minimum release of contaminants to the environment outside of the glove box or enclosure.

e. The minimum instrumentation for a glove box or enclosure ventilation system should include devices to indicate the pressure differential between the box or enclosure and the surrounding work area, the filter resistance, and the exhaust flow rate from the box or enclosure. When box operations are not in full-time attendance for a continuous process, a sensor should be provided to monitor abnormal pressure or temperature and alarm at a point where cognizant personnel are stationed.

8. Filtration Systems

a. Each exhaust filter housing should have a rigid mounting frame for the filter. The complete housing structure should have minimum leakage from outside to inside, inside to outside, or across the filter sealing barrier (exclusive of the filter).

b. The filter access opening in these housings should permit filter removal and replacement with minimum exposure to personnel performing this task and with minimum release of contaminants outside of the housing.

c. The filter housings should be equipped with necessary test ports to permit reliable in-place testing of all filter stages with dioctyl phthalate (DOP).

d. Damper valves should be so located that a bank of filters can be completely isolated from the ventilation systems during filter replacement operations.

e. A HEPA filtration system serving as a final means of effluent cleaning should have at least two stages of fire-resistant filters in series in a filter plenum. A heat removal system and a spark arrester should precede the first stage of filters. If a cooling spray such as a water spray system is used for heat removal, it should be followed by a combination spark arrester/demister screen to also remove entrained droplets, thereby protecting filters from plugging and damage. A roughing filter should be mounted behind these components to remove the bulk of the draft-carried debris so as to avoid loading the HEPA filters installed downstream.

The cooling spray system should operate automatically (with a manual override) upon abnormal heat rise in the cooling chamber inlet indicated by detectors in exhaust ducts feeding the filter plenum. A manually operated valve actuating the spray system should also be provided as a backup. If a drain system is installed to prevent accumulation of liquid in the plenum, the collection tanks should be of favorable geometry.

f. HEPA filter systems should be tested after filter installation using a "cold DOP" test. Acceptance should be based on an efficiency of 99.95% or better for DOP having a light-scattering mean diameter of approximately 0.7 microns. Regular in-place testing of both on-line and standby filter installations should be performed because of system deterioration that can take place even when the installations are not being used. Test procedures used should comply with the recommendations contained in ORNL-NSIC-65, "Design, Construction and Testing of High-Efficiency Air Filtration Systems for Nuclear Application"[8] and in Regulatory Guide 3.2.[9]

g. Final filtration systems incorporating high-efficiency filters other than HEPA filters and having equivalent efficiency and resistance to fire are also acceptable.

9. Quality Assurance Program

A quality assurance program should be established for the design, construction, testing, operation, and maintenance of all structures, systems, and components addressed in this guide in accordance with the criteria in Appendix B of 10 CFR Part 50.

REFERENCES

1. Underwriters' Laboratories Building Materials List (latest edition). Copies may be obtained from Underwriters' Laboratories, Inc., 207 East Ohio Street, Chicago, Ill. 60611.

2. Underwriters' Laboratories Fire Protection Equipment List (latest edition). Copies may be obtained from Underwriters' Laboratories, Inc., 207 East Ohio Street, Chicago, Ill. 60611.

3. Regulatory Guide 3.7, "Monitoring of Combustible Gases and Vapors in Plutonium Processing and Fuel Fabrication Plants," Directorate of Regulatory Standards, USAEC.

4. ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) Standard 52-68, "Method of Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter," Section 9. Copies may be obtained from American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

5. MIL-F-51068C, "Filter, Particulate, High-Efficiency, Fire-Resistant," Military Specification. Copies may be obtained from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pa. 19120.

6. MIL-F-51079A, "Filter Medium, Fire-Resistant, High-Efficiency," Military Specification. Copies may be obtained from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pa. 19120.

7. Underwriters' Laboratories Standard UL-586, "High-Efficiency Air Filtration Units," (also designated ANSI B 132.1-1971). Copies may be obtained from Underwriters' Laboratories, Inc., 207 East Ohio Street, Chicago, Ill. 60611.

8. C. A. Burchsted and 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. Copies may be obtained from National Technical Information Service, U.S. Department of Commerce, Springfield, Va. 22151.

9. Regulatory Guide 3.2, "Efficiency Testing of Air-Cleaning Systems Containing Devices for Removal of Particles," Directorate of Regulatory Standards, USAEC.