FACILITIES PROCESSING RADIOACTIVE MATERIALS

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1.0 SCOPE

This data sheet addresses hazards in and includes fire protection recommendations for facilities processing radioactive materials as an unsealed source. This includes laboratories in universities, research hospitals and commercial operations. It does not include operations where radioactive materials are used as sealed radiation sources, such as thickness gauges, X-ray machines, or cobalt sterilization chambers. Neither does it include operations involving fissionable materials, such as enriched uranium and plutonium that are commonly used in nuclear reactors. Detection of radioactive materials in scrap metals are described in Data Sheet 7-33, *Molten Metals and Other Materials.*

1.1 Changes

April 2025. Interim revision. Reaffirmed to be technically correct.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Construction and Location

2.1.1 Location

2.1.1.1 Locate buildings containing quantities of radioactive material that may become air or waterborne during fire, explosion, windstorm, flood, earthquake, or other peril away from other important buildings or operations where contamination could interfere seriously with plant operations or where radioactive substances could come in contact with materials susceptible to damage.

2.1.1.2 Provide separate storage areas for materials and supplies needed for operations outside process areas. Bring materials into process areas only on an as-needed basis.

2.1.2 Construction

2.1.2.1 Construct buildings of noncombustible materials, including interior finish, acoustical or insulating treatments, and partitions. Use nonporous materials (when practical) for ease in cleanup of contamination.

2.1.2.2 Construct enclosures in which radioactive materials are handled of smooth, impervious, noncombustible materials or FM Approved material tested and Approved using the FM Approvals Cleanroom Materials Flammability Test Protocol, Class 4910. Design enclosures with raised edges to contain spills.

2.1.2.3 Construct floors of noncombustible material and coat the surface with a seamless waterproof coating that extends 3 to 4 in. (76 mm to 102 mm) up the walls of the room.

2.1.2.4 Use one-story-high buildings without basements or other below-grade spaces, where possible.

2.1.2.5 Do the following where radioactive materials are processed in multistory buildings:

a) Locate radioactive material-handling operations on lower floors where contamination will have less chance to spread to other areas.

b) Waterproof and seal openings in floors when radioactive materials are handled on upper floors.

2.1.2.6 Provide curbs or ramps to prevent flow to adjacent areas.

2.1.2.7 Install drainage and holdup tanks where sprinkler and hose stream discharge could spread radioactive materials.

2.1.3 Ventilation

2.1.3.1 Provide ventilation for rooms, enclosures, hoods, gloveboxes, and hot cells containing radioactive material.

2.1.3.2 Design ventilation systems to safely contain contaminated air, gases, or vapors. Arrange systems so air flow is always from lowest contamination to highest contamination. For example, have air flow from administrative areas to laboratories to enclosures handling radioactive materials.

2.1.3.3 Locate filter systems that serve multiple enclosures, hoods, or gloveboxes processing radioactive materials in a dedicated area isolated from process areas. Provide one-hour fire-rated construction. Do not allow storage of combustible materials, including spare filters, within the enclosure.

2.1.3.4 Provide combustible gas analyzers in the filter plenum if processes involve low-flashpoint (less than 100°F [38°C]) ignitable liquids or flammable gases that could result in greater than 25% of the lower flammable limit in the enclosure. Arrange the analyzers to sound an alarm at a constantly attended location.

2.1.3.5 Use a prefilter to remove pyrophoric materials from the air stream before reaching the final filter assembly.

2.1.3.6 Use noncombustible duct work when possible. Ensure the strength and heat resistance is equivalent to No. 16 gage (1.6 mm) steel. Use duct that is FM Approved for fume and / or smoke exhaust if plastic duct is required. Do not use aluminum or plastics that are not FM Approved. Provide fire protection for plastic ducts that do not meet these criteria in accordance with DS 7-78, *Industrial Exhaust Systems*.

2.1.3.7 Arrange ventilation systems for continuous operation.

2.1.3.8. Follow the recommendations in Data Sheet 1-45, *Air Conditioning and Ventilation Systems,* for designing heating and air conditioning systems for rooms containing enclosures handling radioactive material and rooms not specifically related to the control of contamination.

2.2 Occupancy

2.2.1 Storage

2.2.1.1 Store radioactive materials in fire-resistant cabinets, safes, or equivalent enclosures, or in wells or pits below the lowest floor level.

2.2.1.2 Provide a separate storage area for wastes generated in laboratory operations.

2.2.2 Ignitable Liquids

2.2.2.1 Limit container size in process enclosures and hoods to 1 quart (1 L) unless FM Approved safety containers are used.

2.2.2.2 Store ignitable liquids in process areas in FM Approved ignitable liquid storage cabinets, metal shipping containers or FM Approved safety containers. Limit the amount of ignitable liquids stored in the process area to the minimum practical (i.e., enough for one shift).

2.2.2.3 Store bulk amounts of ignitable liquids in FM Approved ignitable liquid storage cabinets outside the process area and in accordance with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*.

2.2.2.4 Return bulk containers to the FM Approved ignitable liquid storage cabinet immediately after filling bottles used in hoods or enclosures.

2.2.3. Combustible Solids

2.2.3.1 Store combustible solids in covered metal containers.

2.2.3.2 Isolate organic solids, such as wipes, that may have come in contact with nitrates. Do not store near ventilation intakes.

2.2.4 Waste Materials

2.2.4.1 Limit storage of waste materials in process areas as follows:

a) Store solid waste within the enclosures in covered metal containers. Size the containers to hold no more than that needed for one day's use.

b) Store bulk solid waste within the laboratory in covered metal containers in a designated area while awaiting transportation to a waste-processing facility. Tightly seal all containers that are full, and ensure only the container currently being filled with bulk waste is unsealed.

c) Ensure ignitable liquids are in FM Approved safety containers or metal containers in an FM Approved ignitable liquid cabinet.

2.2.4.2 Process waste materials in areas separate from production areas. Provide these areas with ventilation systems that are independent of production areas.

2.3 Protection

2.3.1 Ceiling Protection

2.3.1.1 Provide automatic sprinkler protection for buildings and laboratory areas processing radioactive materials. Combustible furniture, carton storage, packing materials, open waste containers, ignitable liquids or gases, or other combustibles call for automatic protection, even though construction and other occupancy are noncombustible. Use the following design criteria:

a) Where plastic enclosures or gloveboxes are used, design automatic sprinkler protection for 0.30 gpm/ft^2 over 2,500 ft^2 (12 mm/min over 230 m^2) for wet systems, and 0.30 gpm/ft^2 over 3,500 ft^2 (12 mm/min over 330 m^2) for dry systems.

b) Where hoods, gloveboxes of metal construction with plastic viewing windows, hot cells, or plastic enclosures constructed of FM Approved 4910 plastics are used, design automatic sprinkler protection for 0.20 gpm/ft^2 over 2,500 ft^2 (8 mm/min over 230 m^2) for wet systems, and 0.20 gpm/ft^2 over 3,500 ft^2 (8 mm/min over 330 m^2) for dry systems.

c) Provide quick response, 160°F (71°C) temperature-rated, automatic sprinklers for wet systems, and quick response, 280°F (138°C) temperature-rated, automatic sprinklers for dry systems. Design for a 500 gpm (1890 L/m) hose stream allowance and a duration of 60 minutes.

2.3.2 Enclosure Protection

2.3.2.1 Provide automatic protection for enclosures of combustible construction or that contain combustibles. The following protection is considered acceptable, provided it is FM Approved, if applicable, for the hazard. Base the selection on compatibility with the radioactive substance being protected:

A) Constantly inerting gas system. Provide an inerting system in accordance with Data Sheet 7-59, *Inerting and Purging Vessels and Equipment,* to a maximum oxygen concentration of 5%.

Do all of the following where a constantly inerting gas system is used:

1. Purge the enclosure with an inert gas (normally argon or nitrogen).
2. Use a concentration of inert gas sufficient to prevent ignition of the material in the enclosure.
3. Install oxygen monitors with alarms to verify the necessary concentration of inert gas is maintained.

B) Automatic sprinkler system. Design automatic sprinkler protection to provide 0.20 gpm/ft^2 (8 mm/min) over the enclosure area. Provide quick response, 165°F (74°C) temperature-rated automatic sprinklers.

2.3.3 Filter Protection

2.3.3.1 Provide fixed water spray protection activated by heat detection for the following filter systems:

A. Combustible filters, such as activated charcoal filters.

B. Filters that collect combustible material.

C. Banks of HEPA filters serving multiple enclosures handling radioactive materials. Arrange the system to operate in two stages (see Figure 1).

1) Arrange the first-stage water spray system to be operated by heat detector(s) monitoring the gas-air temperature entering the filter enclosure. Use 200ºF (93ºC) rated heat detectors. Arrange the spray to be directed onto a metal pre-filter. The objective is to cool incoming gases and prevent ignition of the filters.

2) Arrange the second-stage water spray system to automatically activate upon fire detection and discharge against the upstream face of the first bank of HEPA filters. Use 400ºF (204ºC) rated heat detectors.

3) Locate FM Approved deluge valve assemblies for both the first-stage water spray system and the second-stage water spray system in an area that can be safely accessed in an emergency to manually operate the mechanical override on the deluge valves.

D. Provide drainage to a safe area or containment of water used for this purpose.

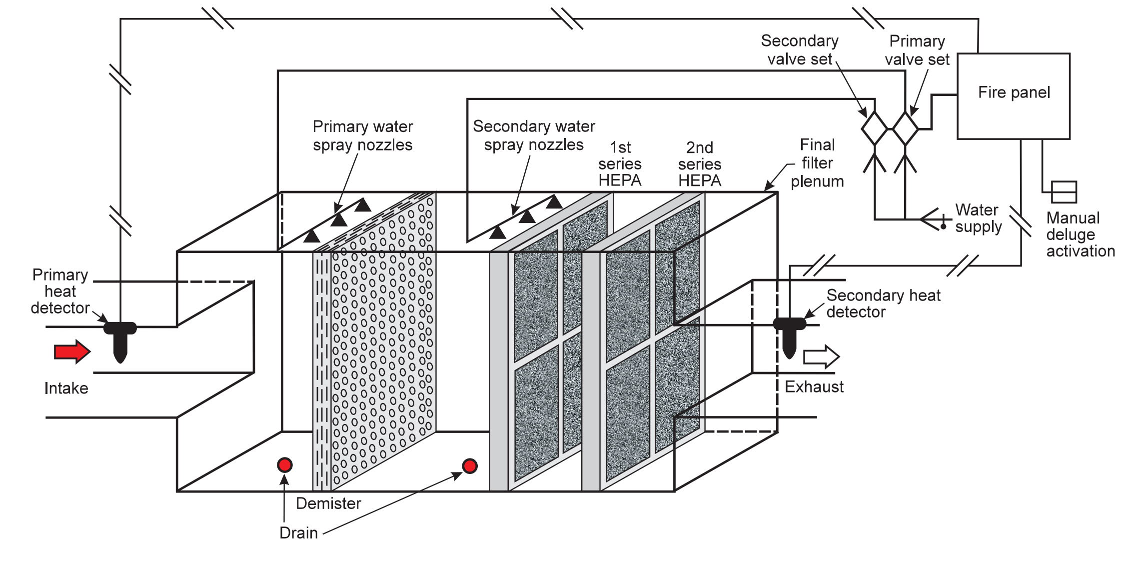

Fig. 1. Protection for multiple banks of HEPA filters

2.3.3.2 Provide fire extinguishers as recommended in Data Sheet 4-5, *Portable Extinguishers*. Small hose when provided with spray nozzles is an acceptable alternative to 50% of the recommended extinguishers.

2.4 Equipment and Processes

2.4.1 Provide the following for critical systems, such as ventilation and refrigeration:

a) A backup power supply

b) Redundant electrical circuits located in a separate fire area, or protection for one of the two circuits with a one-hour fire rating and automatic sprinkler protection.

2.5 Maintenance

2.5.1. Establish the highest possible standards of housekeeping.

2.5.2. Limit accidental releases of radioactive material to the smallest practical area or volume. Promptly and completely clean up all spills. Undertake the cleanup in accordance with local environmental regulations.

At a minimum, use the following steps:

A. Move from the outside of the spill inward; from least contaminated areas to most contaminated areas.

B. Place absorbent paper towels or blue pads over liquid spills. Place dampened towels over spills of solid materials. Ensure the material used to dampen the towels will not react with the spilled material.

C. Place towels in a plastic bag and seal them for transfer to a radioactive waste container. Do not leave any liquids behind. Add contaminated gloves and any other contaminated disposable material to radioactive waste container.

D. For further decontamination, use a mild soapy solution or a commercial decontaminant to clean up the remains of the spill.

E. Monitor area, hands, and shoes for contamination with an appropriate survey meter or method, e.g., Geiger counter or swipes (Some isotopes can only be detected with swipes). Remove anything contaminated and decontaminate or store for decay.

F. Repeat cleanup / decontamination until contamination is no longer detected.

G. Draw a map and take extensive swipes of the entire area, including floors, equipment, handles, etc. Document final survey showing area to be free of contamination and that proper spill procedures were followed.

h) Keep records of the spill, cleanup methods, and all survey results.

2.5.3. Seal fixed contamination with two layers of fixative coatings of different colors. Apply additional coating when the bottom color appears.

2.6 Ignition Source Control

2.6.1 Provide over-temperature control for hot surfaces that may be used in enclosures handling radioactive materials.

2.7 Emergency Response

2.7.1. Conduct pre-fire training exercises with the public fire service annually so the majority of firefighters will know what to expect and the actions to take when they arrive on scene.

2.7.2. Conduct training for firefighters so they are familiar with the hazards of radioactive materials and other materials present at the facility.

2.7.3. If a plant fire brigade is formed, provide personnel with proper training and equipment.

2.7.4. Develop pre-fire plans for all facility areas storing and processing radioactive materials. Include tasks for both the facility personnel and the public fire service. Review and update pre-fire plans annually.

2.7.5 Include the following items in the pre-fire plan:

A) Clearly identify areas with radioactive substances.

B) Identify the radioactive substances present, their quantity, and how they are stored. Also include all radioactive waste.

C) Identify fire protection systems and equipment within all areas containing or licensed to contain radioactive material (including waste).

D) List special firefighting instructions to minimize the risk of increasing potential fire damage and contamination.

E) Give instructions on how to isolate utilities (e.g., gas, power, heating, cooling) and ventilation systems (both normal and emergency).

F) Identify companies to contact for cleanup, decontamination, and waste removal.

G) List and identify the location of monitoring equipment to access the potential contaimination.

H) Identify a person responsible for co-ordinating the monitoring of radioactivity and the decontamination activities.

2.7.6. Ensure accurate hazard identification (health, flammability, reactivity, etc.) per NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* or a locally recognized equivalent.

2.8 Management Controls

Management controls include process procedures, preventive maintenance, and material handling (including waste materials).

2.8.1 Document procedures used to control operations involving radioactive material. Provide the following as part of this documentation:

A. Written instructions that describe the procedures to be followed.

B. Review and sign-off by safety personnel designated to review the procedures.

C. Periodically review and update procedures as needed.

2.8.2 Establish a documented preventive maintenance program for all equipment supporting nuclear processes.

2.9 Security

2.9.1. Restrict access to areas where radioactive materials are used or stored.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

Storage and use of radioactive materials, with rare exceptions, will not affect frequency of fires or the extinguishing agent needed. Radioactive materials do not make other materials radioactive. Materials may be made radioactive by nuclear reactors, cyclotrons, or accelerators. Radioactive materials, escaping from containment during a fire, can reduce effectiveness of manual firefighting, and substantially increase cleanup costs. For this reason, greater reliance should be placed on automatic fire protection systems. Emphasis should also be placed on containment and disposal of water from both automatic sprinklers and hose streams to avoid contaminating buildings and equipment.

3.2 Sealed Sources

Sealed sources of dry radioactive materials, such as radium sulfate in metallic capsules with screwed and soldered tops, present only a slight hazard of contamination provided the fire does not melt either the tube containing the radioactive material or the solder holding the cap in place. Radioactive materials in containers should be kept completely free of moisture.

Solid, metallic forms of radioactive materials, such as cobalt 60 sources, or metals containing radioactive materials present small likelihood of extended interruption to production from widespread radioactivity after a fire.

3.3 Unsealed Sources

Unsealed sources are intended to be opened at the facility. When work is done on radioactive material in the open, an enclosure is used to contain radioactive material contamination. The type of enclosure used depends on the radioactive material processed. The enclosure may be a hood, plastic enclosure, glovebox, or hot cell depending on the type of radioactivity emitted from the source. Enclosures are ventilated to confine radioactive material. Exhaust from the enclosure is filtered before being exhausted to outside (see Figure 2).

3.3.1 Enclosure

The type of enclosure depends on the need for shielding. The higher the penetrating power of the radiation, the greater the need for shielding, and the thicker the enclosure needs to be.

3.3.1.1 Hoods and Gloveboxes

Radioactive material emitting either alpha or beta particles would be processed in a hood, a plastic enclosure, or a glove box. Figure 3 shows a glovebox and two plastic enclosures.

Enclosures are ventilated so the pressure in the enclosure is lower than the pressure in the room. Ventilation systems contain radioactive contamination to the enclosure. The air exhausted from the enclosure is filtered by HEPA filters or an absorbent material, such as activated carbon, depending on the material processed.

Single enclosures may be 6 x 3 x 4 ft high (1.8 x 0.9 x 1.2 m). Figure 4 shows one plastic enclosure containing Class A combustible and an ignitable solvent. Single enclosures may be joined end-to-end to speed the processing of material. The overall dimension may be some multiple of 6 ft (1.8 m) depending on the number joined. Pass-through ports are provided so material can be transferred from one enclosure to another.

3.3.1.2 Hot Cells

Hot cells are used to process radioisotopes with a wide range of radiation types (beta, x-ray, gamma, auger electrons, etc.). The radiation may be emitted by the source material, from impurities that may exist in the

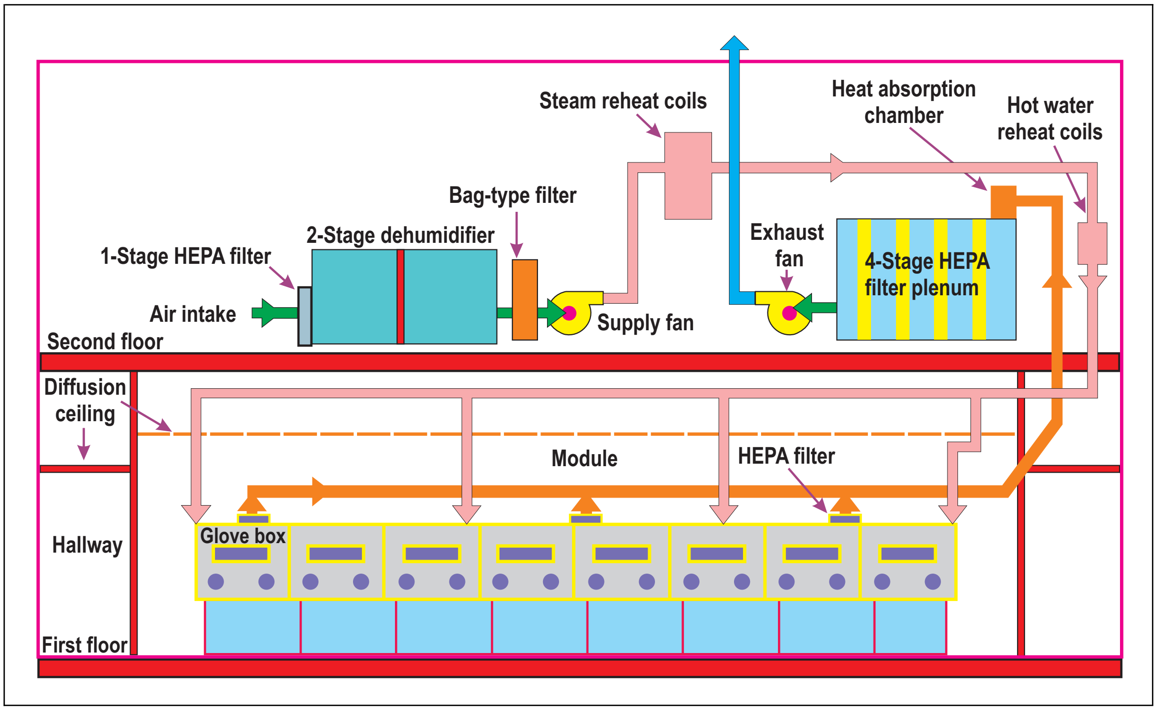

Fig. 2 Typical glovebox arrangement including dry air ventilation system

Fig. 3 Glovebox and two plastic enclosures

Fig. 4 Plastic enclosure containing a Class A combustible and an ignitable solvent

source material, or from secondary radiation liberated during the interaction processes of shielding material. Hot cells may be used to process materials with other hazardous exposure potentials, such as carcinogens, corrosives, etc. Typical isotopes processed in a hot cell include Strontium 90 (90Sr), Yitrium 90 (90Y), Phosphorus 32 (32P), Chromium 51 (51Cr), Indium 111 (111In), and other gamma sources.

Hot cells may be constructed of steel, lead, plexi, polymers, or PVC. The design is roughly as follows: The bottom: ½ in. (12.7 mm) steel on outside; 1 to 2 in. (25.4 to 50.8 mm) of lead; then another ¼ in.(6.4 mm) steel plate, possible plastic liner for the inside floor. Side walls are made up of ½ in. (12.7 mm) steel and interlocking lead bricks approximately 4 to 7 in. (102 to 178 mm) thick, then another ¼ in. (6.4 mm) steel plate. The ceiling: ½ in. (12.7 mm) steel; layer of lead bricks. (Refer to Figure 5.)

Hot cells may be constructed of high-density concrete. They may also have windows that are either solid glass or that have layers of glass separated by several inches with the space between the glass containing mineral oil to reduce reflection.

3.3.2 Filter Media

There are usually filters for each hood or enclosure. The type of filter depends on the material processed within the enclosure. There may be more than one type of filter for the material handled. For example, exhaust streams from enclosures processing Carbon 14 may have both activated charcoal and Sodium Hydroxide traps. There will also be a central filtration system. The central filtration system is the final filtration system before exhaust to the outside.

3.3.2.1 HEPA Filters

The core of the filter media of high efficiency particulate filters (HEPA) is aluminum and fiberglass. The core is contained within a metal or wood frame. The wood is usually fire-retardant treated. The core of the filter

Fig. 5 Hot Cell

is held in place by a seal. The seal may be polyurethane for ordinary temperature applications. It may be silicone for higher temperature applications. It may be fiberglass for very high-temperature applications such as the exhaust of an incinerator. (Refer to Figure 6.)

3.3.2.2 Activated Charcoal Filters

Activated charcoal filters may be used to adsorb radioactive materials. Individual filters on each enclosure may not be a fire hazard. The need for fire protection for larger filters serving a number of enclosures should be evaluated.

3.3.2.3 Scrubbers

Tritium may be removed from the exhaust gas stream using a scrubber system. The most common scrubbers have metal internal baffles used to bring the gas stream in contact with water spray.

3.4 Receiving and Handling Radioactive Materials

Radioactive materials may be shipped adsorbed on the surface of other materials. For example, tritium is adsorbed on the surface of depleted uranium. The uranium tetra tritide (utt) is heated in a furnace to 752°F (400°C). Tritium gas is liberated from the depleted uranium, captured in pressure tanks (bottles), and the quantity is measured using a pressure gauge.

C14 may be received as solid barium carbonate. It is weighed and dissolved in liquid. Depending on the end use, an ignitable liquid (ethanol or methanol) may be used.

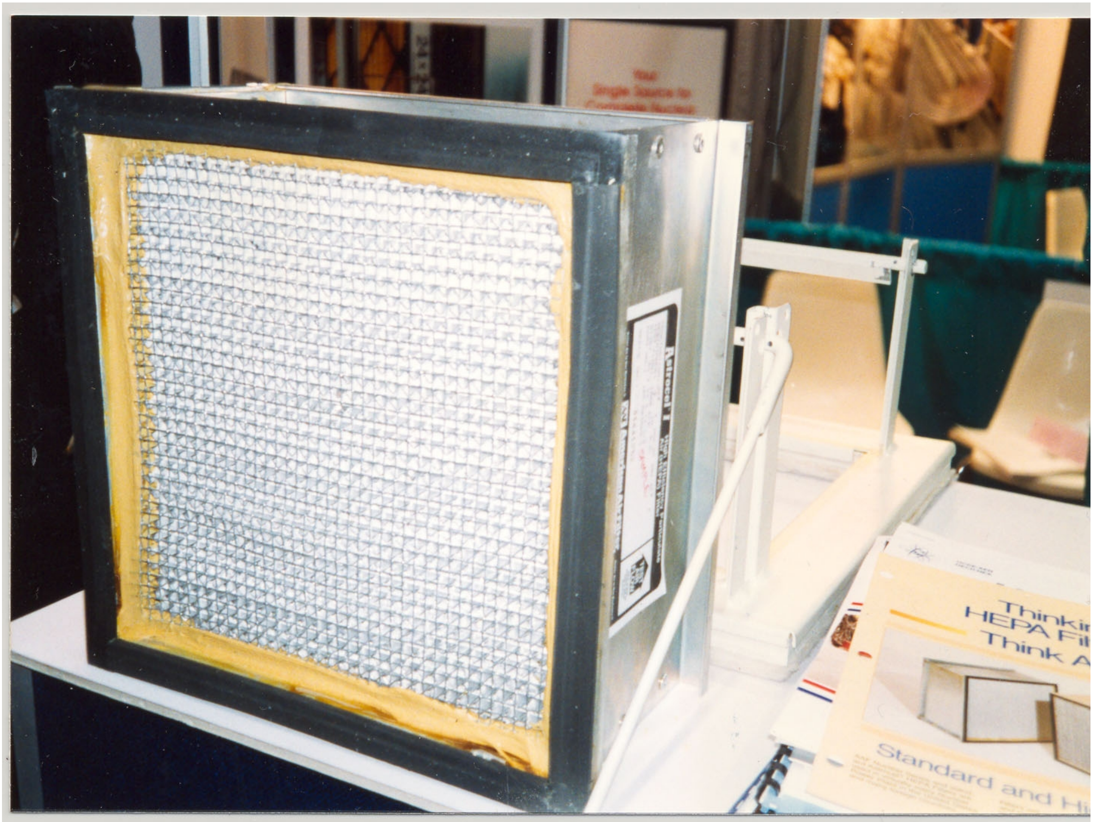

Fig. 6 HEPA filter within a metal frame

3.5 Procedures

Procedures are used to describe work needed to turn a radioactive material into a useful end product. The procedures may be general or specific. Specific procedures apply to the fabrication of a specific end product. Both types of procedures are reviewed by in-house safety committees. Specific procedures should have titles that clearly identify the product formulated. One location making 1,000 products might have general procedures that cover 25 products and specific procedures that cover 975 products.

3.6 Waste Disposal

Waste is separated into a number of different categories. The categories depend on: (1) type of radioactive material in the waste, (2) whether the waste is solid or liquid, (3) whether the liquid is water or an organic solvent, and (4) if solid, whether the solid is compressible. Waste may be separated into 10 or more categories. Pyrophoric wastes are usually handled separately by licensed waste disposal vendors.

3.7 Loss History

3.7.1 U.S. Department of Energy (DOE) Loss History

A search of DOE's loss database using the keyword ''laboratories,'' and loss reports using the keyword ''radioactive'' from 1991 to 2006 were reviewed. Contractors operating DOE facilities are required to report any fire involving radioactive material or any fire lasting longer than 10 minutes or involving the operation of a fixed protection system, regardless of value. There are full-time fire services at most DOE facilities. There were 21 fire incidents in laboratories and 6 fires under the radioactive category.

Of the six under the radioactive material category, two fires involved waste disposal operations, two involved laboratory experiments, and two were exposure fires to buildings containing radioactive material. One of the factors in waste disposal was ignition of combustible (polyethylene plastic) containers. In one laboratory experiment, combustible shielding for the experiment fire was ignited. Ignition was believed to be from a faulty electrical connection. The fire burned itself out and radioactive material was released into the building. In another experiment, the fire was controlled by portable extinguishers with no release of radioactive materials.

There were 21 incidents in laboratories. There were a number of different fire causes, indicating the wide range of activities that occur in a laboratory (e.g., over-heated hot plate, leaking hose to Bunsen burner, exothermic reaction, overheated oven, loss of cooling fluid). Most fires were controlled by portable extinguishers, and, in one case, by a fixed gaseous agent system.

4.0 REFERENCES

4.1 FM

Data Sheet 4-9, *Halocarbon and Inert Gas (Clean Agent) Fire Extinguishing Systems*

Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*

Data Sheet 7-33, *Molten Metals and Other Materials*

Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*

Data Sheet 7-78, *Industrial Exhaust Systems*

4.2 Others

National Fire Protection Association (NFPA). *Standard System for the Identification of the Hazards of Materials for Emergency Response.* NFPA 704.

National Fire Protection Association (NFPA). *Fire Protection for Facilities Handling Radioactive Materials.* NFPA 801.

U.S. Department of Energy. Standard Fire Protection Design Criteria. DOE-STD-1066-00.

APPENDIX A GLOSSARY OF TERMS

ALARA: As low as reasonably achievable. Term used in connection with radiation safety exposure to personnel, intended to mean that, while there are legal thresholds of radiation exposure allowed for different types of workers, the overall intent should be to reduce exposure to radiation to as little as possible.

Alpha particle: A positively charged particle identical to the nucleus of a helium atom.

Beta particle: An elementary particle, emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to an electron (1/1837 that of a proton).

Commercial decay: Radioactive waste stored for decay at a licensed facility.

Contamination: The deposition of unwanted radioactive material on surfaces of structures, areas, or objects. It may also be airborne, external, or internal (inside components).

Curie: A unit of radioactivity, defined as 37 billion disintegrations per second. This is about the activity of 1 gm of the radium 226 isotope. It is usually expressed as microcurie or millicurie.

Decontamination: The reduction or removal of radioactive material from a structure, area, person, or object. A surface may be treated, washed down, or swept to remove the contamination. Contamination can also be controlled by isolating the area or object contaminated and letting the material stand.

Directed disposal: Disposal of different types and concentrations of radioactive material shipped to a licensed disposal facility.

Disintegrations per minute: The standard unit of measure for radioactive contamination. The number of radioactive transformations in a given quantity of radioactive material, in one minute.

Fissionable material: Material that is capable of undergoing nuclear fission by slow neutrons. Examples are Uranium-235, Plutonium-239, and Thorium.

Fixative coatings: A material applied to the surface of the contaminated object to prevent further contamination release into the environment. The coatings can take the form of a sprayed-on adhesive, synthetic materials that are wrapped around the object, or a box that the contaminated material is enclosed in.

Fixed contamination: Radioactivity remaining on a surface after repeated decontamination attempts fail to significantly reduce the contamination level.

Gamma rays: High-energy, short-wavelength, electromagnetic radiation

Glove box: A sealed enclosure in which items are handled using long rubber or neoprene gloves sealed to ports in the wall of the enclosure.

Half-life: The time required for the intensity of the radioactivity of the isotope to decrease by half. The decay could make the isotope stable (nonradioactive) or unstable (radioactive). If the substance decays into an unstable isotope, it will continue to decay until a stable isotope is achieved. Half-life varies from a fraction of a second to thousands of years depending on the isotope. For example, Iodine-131, an isotope used for medical applications, has a half-life of 8 days. Carbon-14, the isotope used in carbon dating, has a half-life of 5,700 years.

Hood: An enclosure with or without glove ports or doors, characterized by the flow of air from the room to the enclosure.

Hot cell: A heavily shielded enclosure in which radioactive material can be handled safely by persons from outside the shielded area using remote tools and manipulators while viewing the work through special leaded-glass or oil-filled windows or through optical devices.

Ignitable Liquid: Any liquid or liquid mixture that is capable of fueling a fire, including flammable liquids, combustible liquids, inflammable liquids, or any other reference to a liquid that will burn. An ignitable liquid must have a fire point.

Isotope: Any two or more forms of the same element (same number of protons, but a different number of neutrons).

License: Facilities processing radioactive materials are required to be licensed by a regulatory authority (either state or federal). The license specifies the types and maximum amounts of radioactive isotopes that can be at the facility at any given time.

Low activity: Radioactive waste containing very small concentrations of radionuclides. The concentrations are small enough that managing wastes may not require all of the radiation protection measures necessary to manage higher-activity radioactive material to fully protect public health and the environment.

Low level radioactive waste (LLRW): Radioactively contaminated industrial or research waste, such as paper, rags, plastic bags, and water-treatment residues. It is waste that does not meet the criteria for any of the other three categories of radioactive waste: spent nuclear fuel and high-level radioactive waste, transuranic radioactive waste, or uranium mill tailings.

Plastic enclosure: An enclosure constructed entirely of translucent plastic that allows operators to handle radioactive materials using gloves.

Radiation: The emission and propagation of energy through matter or space by means of electro-magnetic disturbances that display both wave-like and particle-like behavior.

Radioactivity: The spontaneous transformation of the nucleus of an atom resulting in a new element, generally with the emission of alpha or beta particles often accompanied by gamma rays.

Radioisotope: The isotopes of an element that have an unstable nucleus. Radioactive isotopes are commonly used in science, industry, and medicine. The nucleus eventually reaches a more stable number of protons and neutrons through one or more radioactive decays. Approximately 3,700 natural and artificial radioisotopes have been identified.

Removable contamination: Radioactivity that can be transferred from a surface to an absorbent material, such as filter paper or cotton swabs, by rubbing with moderate pressure and swabbing an area of at least 15.5 in^2 (100 cm^2).

Restricted area: Any area to which access is controlled by the employer for purposes of protecting of individuals from exposure to radiation or radioactive materials.

Volumetric release: Release of slightly contaminated radioactive material (usually building components or soils) that meets the criteria for Class I landfill disposal.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

April 2025. Interim revision. Reaffirmed to be technically correct.

January 2012. Terminology related to ignitable liquids has been revised to provide increased clarity and consistency with regard to FM Global's loss prevention recommendations for ignitable liquid hazards.

January 2010. Much of the following information is based on Data Sheet 7-61, *Radioactive Materials*. This data sheet was made obsolete. It is being reactivated as we have identified that some of our clients in life sciences and biomedical manufacturing are using these types of materials in various quantities. The following changes were made:

1. The need for protection is based on both the construction of the enclosure and the fire loading in the enclosure.

2. Recommendations include training of plant emergency organization and fire department personnel.