CHAPTER 11

OCCUPATIONAL SAFETY AND HEALTH

11.1 Industrial Hygiene

11.1.1 Chemical Safety and Hazard Communication

Ventilation systems control exposures to toxic and radiological materials, therefore, ventilation system filters can collect hazardous materials. In addition to exposure to the hazardous materials contained in the ventilation system or on filters, workers are often exposed to chemicals, such as test aerosols, when conducting testing. Workers can also be exposed to a wide variety of process materials including large amounts of inert gas. Equipment such as cryogenic systems can vent materials such as liquid nitrogen into ventilation systems. Such materials expand to produce large volumes of inert gas, which may produce an oxygen-deficient atmosphere. Some fire protection systems may also use large amounts of gas.

Workers can be exposed to toxic chemicals by several routes such as inhalation, ingestion, contact with or absorption through the skin, and penetration of the skin via wounds. Chemicals may produce a variety of undesirable effects in the body, including: asphyxiation, irritation, anesthesia sensitization, reproductive toxicity and cancer.

U.S. Occupational Safety and Health Administration (OSHA) standards (29 CFR 1910.1200, *Hazard Communication*)[1] require employers to implement a hazard communication program to inform workers about the risks associated with chemical use. The Hazard Communication Standard requires that employers take specific actions, including making material safety data sheets for each material available to employees and training employees to recognize hazardous materials and use them safely.

Hazards of materials are also described on container labels. Personnel should be in the habit of reading the labels of containers of materials they are using for the first time to become aware of potential hazards.

Workers may consult material safety data sheets for information on hazardous materials such as components, possible toxic effects, other hazards such as fire and explosion, sources of additional information, and recommended control measures. Exposure limits for specific chemicals are contained in 29 CFR 1910, Subpart Z.[2] Additional recommendations on exposure limits are contained in the American Conference of Governmental Industrial Hygienists Threshold Limit Value (ACGIH TLV) list.

11.1.2 Noise

Noise can be a significant concern for personnel working on ventilation systems. Motors, fans, and other machinery along with airflow can create significant levels of sound. Even when workers shut down ventilation systems, equipment rooms often contain other sound sources. Routine maintenance and surveillance activities may also expose workers to increased sound levels. It is common at most sites for facility engineers to make periodic walkthroughs to verify proper operation of filter systems, thus putting workers at risk in a high noise environment. The practice of removing hearing protection while in the high noise is discouraged. Removal of hearing protection increases the worker's exposure to noise and may violate regulations.

While sound can affect the human body in various ways, the most important is loss of hearing. Several types of hearing loss have been identified, but two, conductive and sensorineural (involving the sensory nerves), are more important in the workplace. Conductive hearing loss occurs when sound pressure cannot reach the inner ear. Conductive hearing loss is rarely the result of workplace exposures, but may be caused by extremely high peak noise levels such as an explosion or a traumatic injury to the ear. Sensorineural hearing loss is the inability of the ear to convert pressure variations into nervous impulses that the brain can interpret as sound. The most important workplace-related cause for sensorineural hearing loss is exposure to high levels of sound. Sound-induced hearing loss can happen gradually over a period of years, which makes the hearing loss difficult to detect. Another reason that this type of hearing loss is difficult to detect is that excessive sound usually causes hearing loss at some frequencies more than others. The person suffering from sensorineural hearing loss may be able to hear sounds such as speech, but may not be able to understand what is being said.

OSHA regulations require that employers implement a hearing conservation program for employees exposed to high levels of sound. This program includes sound measurements, training, record-keeping, and audiometric testing.

The minimum standard for noise protection and hearing conservation is the OSHA regulation for noise, 29 CFR 1910.95.[3] Sound intensity is measured on the decibel (dB) (A) scale [dBA]. The dB(A) scale measures sound intensity over the whole range of audible frequencies (different pitches), and then it uses a weighing scheme which accounts for the fact that the human ear has a sensitivity to each different sound frequency. For further information on sound intensity scales, see the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) *Handbook of Fundamentals*, Chapter 7, "Sound and Vibration" 2001.[4] Code of Federal Regulations, 29 CFR 1910.95,[3] requirements allow exposures to noise of 90 dBA for 8 hours and halves the permissible exposure time for every 5-dBA increase in noise level. Some hearing conservation programs are based upon allowing exposures to 85 dBA for 8 hours and halving the permissible exposure time for every 3-dBA increase in noise level, as specified in the TLV for noise. Noise levels are often given in dBA units. The definition of a dB of sound pressure ("noise") level is such that noise intensity is reduced 10-fold for every 20 dB reduction of noise level.

Excessive sound is best reduced with engineering controls such as vibration isolation and selection of quieter equipment. However, those who work with ventilation systems may need to use administrative controls and personal protective equipment (PPE). Administrative controls may involve changing work schedules to reduce the length of exposure and/or the number of workers exposed. This may include rotating employees' duties or work locations so that no employee receives a significant exposure. Another administrative control is scheduling sound-producing work during hours when fewer workers are around.

If engineering and administrative controls cannot completely reduce the sound to acceptable levels, then workers must use hearing protective devices to provide additional control. The ability of such devices to reduce sound levels is expressed as the Noise Reduction Rating (NRR). The U.S. Environmental Protection Agency (EPA) defines the NRR as, "A single number noise reduction factor in decibels, determined by an empirically derived technique which takes into account performance variation of protectors in noise reducing effectiveness." According to EPA regulations, the NRR must be shown on the hearing protector package. In general, those devices with a higher NRR are better at reducing sound levels. However, NRR values are determined under ideal laboratory conditions and do not indicate exact sound level reduction under actual workplace conditions. Adjustments of the NRR are described in OSHA Standard 29 CFR 1910.95, Appendix B.[3] Selection of the specific adjustment method is dependent upon the employer's noise measuring instruments. Specific devices should be selected based on several factors such as the NRR, comfort, and interference with other personal protective devices such as respirators. There are three common types of hearing protective devices: aural inserts, superaural protectors, and earmuffs. Aural insert protectors are commonly referred to as earplugs. They come in many shapes and sizes and are made from a variety of materials. Superaural protectors seal the opening of the ear canal. A light band holds a soft material in the opening of the ear canal. These devices are generally easier to insert and remove than earplugs and are easier to reuse. However, some workers may find such devices uncomfortable, and they may not provide as much sound reduction as earplugs. Earmuffs consist of two cup-shaped devices that fit over the entire external ear and seal against the side of the head. A spring-loaded headband holds the cups in place. Earmuffs are generally more durable than earplugs and are easy to use. However, to be effective, earmuffs must form a complete seal to the side of the head. Anything that interferes with the seal (e.g., temples of glasses, hair, respirators) may significantly reduce the effectiveness of the muffs. A relatively new kind of earmuff uses electronic devices to cancel the incoming sound. These muffs are quite expensive, but may be useful in some situations.

11.1.3 Shock-Sensitive Materials

Laboratory personnel commonly use perchloric acid to prepare organic and inorganic materials for analysis. Perchloric acid is a strong oxidizing agent and reacts with many materials to form chemical compounds that are susceptible to detonation by heat, friction, or impact. Other shock-sensitive or reactive materials such as nitrates may also collect in ventilation systems. The accumulation of such compounds in hoods, fans, and ducts presents a potentially hazardous situation for maintenance personnel and others who may be exposed to ventilation systems. There are numerous examples of the accumulation of shock-sensitive compounds at U.S. Department of Energy (DOE) facilities, including the Chemical Metallurgical Research Building at Los Alamos National Laboratory in New Mexico.

There have been several explosions and fires at DOE facilities caused by contact with perchlorates. The most serious occurrence (1962) killed one worker and injured two others during routine maintenance work.[5] On several occasions at DOE sites, workers have had to stop activities when they found perchlorates in unexpected locations or at higher-than-expected levels.

Two articles in *Applied Occupational and Environmental Hygiene*[6, 7] describe activities conducted at Oak Ridge National Laboratory (ORNL) to address potential perchlorate contamination of ventilation systems. A team of laboratory personnel, including chemists, industrial hygienists, and fire protection engineers implemented a program with the following objectives:

- Identify ventilation systems where laboratory personnel have or are now using perchlorates.
- Develop sampling and analysis protocols.
- Develop procedures for estimating the amount of perchlorate present in the samples.
- Determine the threshold for what constitutes serious contamination.
- Generate a plan for decontamination of ventilation systems contaminated with perchlorates.

Identification of perchlorate contaminated ventilation systems may be difficult because some systems have been in use for many years, laboratory personnel have used the systems for a variety of purposes, and former users may be difficult to contact. Laboratory personnel may use questionnaires to identify locations where perchlorates have been used. Questionnaires should be supplemented with visits to known current and former users. Laboratory records can also be useful in identifying perchloric acid usage.

The *Applied Occupational and Environmental Hygiene* articles[6,7] describe a step-by-step process for decontaminating perchlorate-contaminated ventilation systems. The first step is containment of the contamination. Personnel should take precautions during sampling and dismantling operations to prevent the spread of contamination. This includes removing or protecting any equipment or furnishings which may be contaminated by a leak or spill. This is especially important when the ventilation system is radiologically contaminated. The second step is wetting. ORNL personnel used continuous wetting during aggressive penetration of a system such as sawing, drilling, or separation of rusted parts. The next step is testing. Safety and Health personnel should sample all ventilation systems with known usage of perchloric acid, as well as a portion of systems without known usage. Industrial hygienists should select specific sampling locations within each ventilation system based on a determination of the likely point of accumulation and the feasibility of accessing the sampling location. ORNL personnel determined that, for most systems, samples should be taken at points in each system as close as possible to where air enters the duct work, within the fan housing, and at or near the exit from the stack. Due to the possibility of detonating perchlorates, sampling within a ventilation system may present a risk of injury to personnel (staff sample for perchlorates by swabbing about two square feet of surface with wetted gauze pads). Staff should minimize the number of samples, but should take enough to form a representative picture of perchlorate contamination. Maintenance personnel can provide valuable information on means of entry.

During the ORNL study, staff wore personal protective equipment such as ballistic-rated body shields to perform sampling activities. After examining the results of initial sampling, ORNL staff determined that perchlorate salts often accumulated at the entrance to filter housings. Staff sampled fan housings by cutting a small incision in the fabric acoustical coupling between the duct and the fan, then sprayed the internal surfaces of the fan housing and fan blades with measured quantities of deionized water. They then collected the rinsate from the fan housing by suction.

The two articles cited above also describe methods for analyzing perchlorates. Analytical methods vary considerably regarding sensitivity and possible interferences. The articles state that a ventilation system is positive for perchlorates if rinsate is found to contain more than 750 milligram (mg) of perchlorate per liter, or if swab samples indicate a perchlorate level of greater than 70 mg/m^2.

The next step is removal of contaminated equipment, if feasible. Disassembly may make decontamination easier. The inside and outside of the ductwork should be wetted by spraying or misting. This wetting may wash some contamination from the system, but is done for safety rather than decontamination. ORNL personnel used nonsparking tools when sawing or cutting on ventilation systems. During drilling, they used a continuous flow of water over the drill bit. [Note: When planning work involving spaying or misting, criticality safety issues must be considered.]

Workers decontaminate ventilation system parts by soaking, if possible, followed by wet scrubbing. After washing, workers should test the parts for remaining contamination and further decontaminate as necessary. When decontamination is complete, the ventilation system parts may be repaired, replaced, or disposed of (ORNL staff caution that perchlorate contamination may be found outside as well as inside ventilation systems).[6, 7]

11.1.4 Heat Stress

Workers may have to change or test filters without the aid of mechanical handling devices, and this work can be done in locations with little, if any, heat or air conditioning. In addition, the workers might be required to wear personnel protective devices that increase the potential risk of heat stress.

The human body has a remarkable ability to regulate internal temperature within a narrow range, even when exposed to large fluctuations in environmental conditions. Normal metabolic processes produce heat, and the amount of heat produced is related to the level of physical activity. The body can also exchange heat with the environment by convection, radiation, or direct contact. The direction and magnitude of the exchange depend on the relative differences in temperature. The principal method of losing body heat is by sweat evaporation. The rate of evaporation depends on air temperature, air movement, and relative humidity (RH).

Heat stress can cause several problems. The first is simple discomfort, which is highly subjective and depends on factors such as type and amount of clothing worn, age, previous experience, and/or degree of acclimatization to heat. In addition to water, sweat contains sodium and other minerals. If a person loses too much sodium, they may suffer from painful muscle spasms (heat cramps). Excessive loss of water may also cause dehydration, which can lead to a condition known as heat exhaustion. A person suffering from heat exhaustion can maintain their body temperature within a reasonable range, but may become fatigued, faint, or suffer from other symptoms. A person suffers heat stroke when the temperature regulation system is overwhelmed and the body temperature rises. The skin of someone suffering heat stroke is hot and dry. Heat stroke is a life-threatening condition, and the victim must get medical attention quickly. If allowed to continue, elevated body temperature may have serious consequences such as brain damage or death.

Portable fans, coolers, or other equipment may be helpful in removing heat from the work environment and supplementing the body's ability to lose heat through sweat evaporation. Control of heat stress greatly depends on replenishing body water. Workers can lose several kilograms of water during a workday, and they should be provided with and encouraged to drink water. Salted water or "sport drinks" may be useful in some situations (it is best to consult an occupational physician in such cases). Workers may be required to wear PPE such as special clothing or respirators that can increase the chance of dehydration because workers are reluctant to leave a controlled area and doff the equipment to drink water. Placement of fans and water intake in contaminated areas need to be well thought out. Administrative controls may be used to reduce the risk of heat stress. The ACGIH (2001 Threshold Limit Values for Chemical Substances and Physical Agents)[8] recommends a work-rest cycle to reduce the effects of heat stress. The relative proportions of work and rest depend on the level of physical activity and environmental conditions. Workers and supervisors should also consider clothing and the need for fluid intake as factors in determining a work-rest cycle. PPE, such as ice vests and suites or hoods with vortex coolers are available for use in hot environments. However, this equipment requires additional resources such as air for the coolers and may also increase the workers' effort and interfere with their movements. The OSHA Technical Manual, Section III, Chapter 4, "Heat Stress," also contains useful information and an extensive bibliography on this topic.[9]

11.1.5 Confined Spaces

Filter maintenance and testing sometimes requires work in confined spaces. Confined spaces may expose workers to additional hazards and may require special training and planning before work is conducted. Numerous work-related deaths and serious injuries have occurred in confined spaces. OSHA regulations require identification and posting of confined spaces, however, workers should be alert to unposted spaces.

A confined space is an area that meets the following three criteria:

- A person can bodily enter the space and perform assigned work.
- The space has limited or restricted means for entry and exit.
- The space is not designed for continuous human occupancy.

According to OSHA Standard 29 CFR 1910.146,[10] some confined spaces are called "permit-required confined spaces." In addition to the above three criteria, permit-required confined spaces meet one or more of the following criteria:

- The space contains or has the potential to contain a hazardous atmosphere (this could include airborne toxic materials, flammable or explosive materials, or oxygen deficiency).

- The space contains a material with the potential for engulfment of an entrant.
- The space has a configuration, such as a sloping floor, which could trap an entrant.
- The space contains any other recognized serious safety or health hazard.

Workers should be aware that their work activities could introduce a hazard into a confined space, thereby redefining the space as a permit-required confined space. OSHA requires employers to implement a comprehensive confined space program including a permit process for controlling entry into confined spaces. It is important to note that “entry” into a confined space happens when a worker places any part of their body into the space. The permit identifies hazards present in the confined space, documents atmospheric testing, and lists who may enter the space and who is responsible for activities such as atmospheric testing and rescue.

Before workers enter into and during work in a confined space, qualified personnel using properly calibrated and maintained equipment must conduct atmospheric testing. OSHA standards require testing for three types of airborne hazards before entry into a confined space.

- Oxygen content,
- Concentration of flammable gases and vapors, and
- Concentration of toxic materials.

Monitoring should also be conducted for the duration of the confined space entry. If testing identifies atmospheric hazards, employers must institute controls such as ventilation or respiratory protection before allowing entry. Planning for a confined space entry must include planning for emergencies. This is very important because a large portion of workers killed or injured in confined spaces are would-be rescuers. An emergency plan must include:

- Potential rescue methods,
- Available rescue personnel,
- Available and appropriate rescue equipment for the specific confined space, and
- Methods of summoning rescuers.

During a confined space entry, at least one person (the attendant) must remain outside the space. This person may perform other duties such as air monitoring and providing assistance in handling materials and tools, but must maintain continuous communication with entrants and must not leave the area without obtaining a qualified replacement. Depending on the complexity of the work to be done, the number of entrants and other factors, additional attendants may be required. Supervisors authorizing entry should consult with an industrial hygienist to determine protective measures.

Eliminating inputs of hazardous materials, such as inert gasses, toxic solids/liquids/gasses, and even water, as well as hazardous energy, (e.g., inadvertent startup of motors and fans), is an essential part of confined space safety. Vigorous application of lockout/tag-out is normally required (see Section 11.3.3). Hazardous materials are often blocked by “double block and bleed”, in which two valves (one valve just is not enough) are closed between the material source and the confined space while a third valve between them that dumps to an unoccupied and safe location is opened. Segmented pipes can be rendered safe by removing a segment and securely placing a flange on the opened ends and/or by misaligning the ends so flow from the source cannot hit the end leading to the confined space.

11.1.6 Biological Hazards

Biological hazards consist of bacteria, viruses, fungi, and, to a lesser degree, rickettsia and parasites. Pathogenic organisms can also gain access via these same entrances, but may also gain access by puncture through intact skin and by contact with the mucosa (the moist tissue, of the eyes, nose, and mouth). Some of these organisms may cause infections, and some may produce allergic reactions in susceptible persons. Ventilation systems may provide an environment that promotes the growth of fungi and bacteria (such as legionella). Workers should be on the lookout for signs of such environments (e.g., visibly moist areas or standing water, unusual odors). It is important to look for such signs during routine maintenance and surveillance as well as during filter testing and replacement. Filters, low spots in the duct work, duct lining and internal structures such as vanes can be locations for growth of bacteria and fungi. Respirators, protective clothing, and good sanitary practices such as washing, are effective means of reducing exposure to biological agents. Biological hazards may also include rodents, reptiles, insects, and arachnids. Animals and their droppings may be a source of plague, hanta virus, histoplasmosis and other diseases.

11.1.7 Respiratory Protection

Engineering controls and administrative controls are preferred over PPE, and respirator use is normally discouraged unless engineering controls or containment devices are not available or are not completely effective in minimizing airborne radioactivity or protecting workers from chemical hazards.

Respiratory hazards fall into one of the following classes: oxygen deficiency, gases and vapors, and particulates. The choice of a specific respirator depends on the specific hazard to the workers. An atmosphere containing less than 19.5 percent oxygen is considered oxygen-deficient. Gases and vapors include a great variety of substances with a variety of toxic effects and chemical characteristics. Particulates include dusts, fumes, mists, and sprays that also have a wide range of characteristics.

There are two general types of respirators: air-supplying and air-purifying. Air-supplying respirators provide the wearer with breathing air from a tank carried by the wearer, air from a chemical reaction, or air from a hose connected to a stationary tank or compressor. Air-purifying respirators use adsorbents and/or filters to trap unwanted materials before the air can reach the wearer. There is no respirator available that is designed to remove all unwanted materials from the air. Selection of air-purifying respirators, therefore, must be based on the specifics of the hazardous materials involved.

If there is a possibility for generating airborne radioactivity, as may be the case in removing high-efficiency particulate air (HEPA) filters, then full protective clothing, including respiratory protection, should be worn. Respirators come in a variety of types (such as respirators fitted with particulate cartridges or gas filtering cartridges and respirators with supplied air or self-contained breathing equipment) to complete supplied-air hoods or full body suits. Actual use of any respirator should be chosen based on the protection factor it affords and on the airborne radioactivity or chemical concentrations in which it will be used. Degree of protection is not the only factor in selecting a respirator. Air line respirators provide a long-term air supply, but there is risk the air hose will become tangled or pinched shut. Self-contained breathing apparatus provide additional freedom of movement, but have a limited air supply and may interfere with access in tight spaces. Respirators may affect a worker's vision. If the worker requires corrective lenses, special glasses that fit inside the respirator must be provided, because normal glasses can interfere with the seal.

DOE requires its respiratory protection program to be conducted in accordance with DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*,[11] which endorses the most restrictive requirements of the American National Standards Institute (ANSI) Z88.2, *Practices for Respiratory Protection*,[12] or 29 CFR 1910.134, *Respiratory Protection*.[13] Individuals should be aware of the following basic requirements governing the use of respirators.

Personnel must:

- Have a medical examination certifying them as fit to perform their jobs while wearing protective respiratory equipment;
- Be trained in the proper use of respirators;
- Be fit-tested to ensure the respirator is properly sealed on the face and that only the respirator for which the individual is tested will be worn;
- Be clean-shaven in the area where the respirator fits onto the face; and,
- Be aware of any adverse conditions or stress resulting from respirator use, and leave the work area if necessary.

Employees who are required to wear respirators must participate in an established respiratory protection program. A complete respiratory protection program consists of the following elements:

- The program must be the responsibility of a qualified administrator.
- The program must be based on workplace-specific procedures.
- Respirator selection must be based on hazard assessments.
- Respirator wearers must participate in a program of medical evaluation.
- Respirator wearers must be fitted for the specific type and model of respirator to be worn.
- The program must include procedures for cleaning and maintaining respirators.
- Respirator wearers must receive training.
- Employees must use only respirators approved by the National Institute for Occupational Safety and Health.
- Management must periodically evaluate the effectiveness of the respiratory protection program.

Respirator wearers are responsible for protecting their assigned respirator from damage, inspecting the respirator before and after each use, and promptly reporting any suspected damage or malfunction. Wearers may clean and sanitize their respirators if given that responsibility by the respiratory protection program. Wearers must not modify their respirators in any way.

11.2 Radiation Protection

This section is concerned with radioactive waste materials contained in the process airstreams that potentially could be released to the environment, radiologically safe removal and replacement of HEPA filters used to minimize potential releases, and contamination of local work areas where workers could be exposed. [Note: HEPA filters are usually supplemented by other filters such as the roughing filters that form part of the basic engineering design features of the air handling systems of a facility.]

Radiation protection organizations are responsible for administering radiation safety programs that promote the use of radiation and radioactive materials in a manner that protects workers, the public, and the environment. Health physics programs cover a wide spectrum of activities across not only the DOE complex, but other areas as well. Humans are subjected to radiation every day because of natural radioactivity in the environment. Radiation is found in air, soil, water, foods, materials used to build homes, and even in the human body. Radiation and radioactive materials also are used in many ways that benefit humankind, including many diagnostic and therapeutic medical procedures, electricity production, in smoke detectors, and food preservation, to name just a few. Radioactive waste products are generated as a result of these beneficial uses of radioactive materials. These waste products can be in the form of solids, liquids, and gases, and disposing of them efficiently and effectively presents a challenge.

Radiation safety is the responsibility of both the radiation protection program and the individuals onsite. The steps and actions required to maintain occupational exposures at levels that are as low as reasonably achievable (ALARA) are described below. It is incumbent upon each individual working in a controlled area to understand these basic requirements and ensure they are considered when performing work that can result in exposure to radiation. For example, each individual must know and understand the meaning of radiological postings, the radiation levels in the areas where they work, and the importance of following procedures and abiding by the instructions in the procedures and in the Radiological Work Permit (RWP). Workers must also be provided with the training required to work in specific areas.

11.2.1 Radiation Protection Considerations for HEPA Filter Removal and Replacement

DOE regulation (10 CFR 835)[14] and DOE Order 5400.5, *Radiation Protection for the Public and Environment*,[15] specify the basic requirements for ensuring that radiation doses to workers and the public are kept below specified limits and maintained at ALARA levels. In addition to DOE regulations, the EPA, as promulgated in 40 CFR Part 61,[16] also limits exposure of the public via the air pathways from DOE facilities. In addition, there are standards and guidance documents[17-25] that aid in interpretation and implementation of the regulations in 10 CFR 835,[14] from which much of the information in this section is derived. Some background material and some of the basic elements involved in radiation safety programs are discussed in the following sections. Although these elements are applicable to most tasks involving radiation and/or radioactive materials, the focus in this Handbook is on radiologically safe removal and replacement of HEPA filters.

11.2.1.1 ALARA

The regulations contained in 10 CFR 835[14] that govern workers in the DOE complex mandate the documentation of a DOE-approved radiation protection program (RPP). The content of the RPP is to be commensurate with the nature of the activities performed, but must include formal plans and provisions for applying the ALARA process. Giving due consideration to the economics of various activities, this means that all activities involving radiation or radioactive materials must be performed using a process that maintains exposure to radiation at the lowest level reasonably achievable. The formal plans for maintaining exposures at ALARA levels should include provisions for and descriptions of the following elements:

- A formal written, high-level management policy statement invoking management's commitment to the ALARA process;

- An ALARA Committee consisting of members of various disciplines that advises management on improving progress toward minimizing radiation dose and radiological releases;
- An organization specifically designed to implement the ALARA program;
- A formal ALARA training program;
- ALARA design reviews of new processes and equipment;
- Internal assessments and audits to evaluate the ALARA program;
- Pre- and post-job review and analysis;
- Individual and collective dose estimation; and
- In some cases, mock-ups or dry runs.

Newer air handling systems have generally incorporated the ALARA philosophy in the initial design, which is the primary means that should be used for minimizing exposures. However, older air handling systems may not have benefited from these concepts. As such, existing ALARA programmatic requirements (e.g., administrative controls, procedures, etc.) must serve to minimize personnel exposure. These requirements are discussed below. A maintenance and surveillance plan such as required by ASME N510,[26] can be a valuable component of an ALARA program. Practice on mock-up filter installations can help worker's complete tasks more quickly, shortening the duration of radiological exposure.

11.2.1.2 Training Requirements

All individuals must receive training in accordance with the requirements of 10 CFR 835[14] before being allowed unescorted access to controlled areas and before receiving any occupational dose of radiation. Specific topics listed in the regulations must be covered in the training program. In addition, various levels of training, commensurate with the positions of the individuals, should be provided in accordance with DOE-STD-1098-99, *Radiological Control Standard*.[18] Radiation workers receive detailed training in understanding the nature and hazards of radiation and understanding their responsibilities for implementing ALARA principles. Personnel most affected include technical support personnel, personnel responsible for developing work plans for working in controlled areas, and personnel responsible for implementing radiological control measures. Training includes the basics of the ALARA concepts and techniques used to minimize their exposures such as shielding, containment devices, the use of special tools, and the importance of careful planning prior to conducting the work.

In addition, on-the-job training is critical for tasks performed in areas where radiation levels can be high. It is important to be familiar with the task and to be prepared with all tools required on the job to minimize the time spent in an area and to eliminate the need for stopping the job and leaving the area to acquire tools. This may also consist of conducting dry runs before attempting any job in a high radiation area. In some air handling systems that use HEPA filters, the filters can have very high radiation levels. Although there are different procedures for changing these filters, personnel must be trained in each procedure as necessary. A dry run is recommended for personnel who may use a bag-in/bag-out system for the first time.

11.2.1.3 Radiation Surveys

HEPA filters are designed to collect particles down to 0.3 micrometer (μm) with an efficiency of 99.97 percent. The airstreams in which the HEPA filters are used can contain highly radioactive particles. As such, the filters become contaminated and can sometimes have significant radiation levels when they are due for replacement. The filter housings and the filters themselves should be surveyed prior to filter removal and replacement, and personnel should be familiar with these radiation levels. In addition, surveys for radioactive contamination should be performed periodically during this process to monitor the location of surface contamination, and surveys of airborne radioactive material should be performed. The radiation surveys are usually discussed as part of the pre-job review. In most situations, a member from the RPP must be present to perform the radiation surveys. However, in some instances where maintenance personnel or work groups have been trained and qualified, surveys may be performed by the individuals in the group. Such instances may be site-specific, and self-surveys should be discussed with health physics personnel.

11.2.1.4 Internal Dosimetry

The internal dosimetry program generally consists of the two elements listed below, each of which is designed to either minimize the intake of radioactive materials, evaluate actual or suspected intakes, or calculate potential doses resulting from these intakes.

- An individual monitoring program, (if bioassay is unavailable, inadequate, or not as accurate as air monitoring data).

- A dose evaluation program to evaluate air sampling and bioassay data to determine the individual doses.

Health physics personnel provide these services and usually determine who will participate in the bioassay program based on regulatory and programmatic requirements.

Radiological workers are required to participate in an internal dosimetry program, including routine bioassays if, under normal conditions, they are likely to receive a committed effective dose equivalent of 1 mSv (100 mrem) or more from all occupational radionuclide intakes in a year [10 CFR 835.402(c)].[14] For typical HEPA filter removal without the use of bag-out systems and for personnel who rely more on the use of respiratory devices, participation in a routine bioassay program will likely be required.

11.2.1.5 Posting and Labeling

Radiation protection staff should determine the appropriate access controls and warning signs for the replacement of HEPA filters. A bag-in/bag-out system is preferred. However, in some circumstances, it is not possible to use a bag-in/bag-out system for changing HEPA filters. In these situations, compensatory precautions must be taken. If the filter housing is contained within a room, the door to the room can be posted with the appropriate radiation and/or contamination area sign(s) and access can be restricted. In the event the area around the filter housing is an open area, physical barriers such as ropes and stanchions can be placed so that access into the area is controlled by the barriers or by personnel. Entrance to areas that are barricaded must be posted with appropriate radiation and/or contamination area signs to inform personnel of the potential hazard in the area.

After the HEPA filters are removed from the system, they must be surveyed and labeled with radiation and/or contamination labels that identify their magnitudes. Other materials such as contaminated tools and used protective clothing must be bagged, surveyed, and labeled appropriately before they are removed from the area.

11.2.1.6 External Dosimetry

Personnel who work in controlled areas where they are likely to receive doses at or above those specified in 10 CFR 835.402[14] are required to wear dosimeters for monitoring their effective dose equivalent. Film badges, track-etch dosimeters, thermoluminescent dosimeters, or other radiation-sensitive devices specified by radiation protection personnel could be used to measure the external dose. Dosimeters are typically used to monitor dose to the whole body. In some circumstances, additional dosimeters may be required and would be specified on the RWP. Such dosimeters may be used to monitor the extremities if remote handling of the radioactive sources is not feasible, or for monitoring the lens of the eyes depending on the specific job and the nature of the radiation fields. Extremity dosimetry is especially important for filters with unusually high levels of radiological contamination. This is another reason planning is important. The location of the extremity dosimeters will be specified by health physics personnel. Care must be taken to avoid contamination of the dosimeters.

11.2.2 Work Requirements

In addition to the requirements mentioned above, there are a number of prerequisites before approval is granted for individuals to perform work in radiological areas. These prerequisites begin with the work group initiating an RWP that contains information about the work to be done and submitting it to the health physics staff. Based on the information provided, health physics personnel will make the necessary radiation and contamination surveys and establish a radiological control area around the work site. Health physics personnel will also establish and specify on the RWP those additional requirements to be followed before, during, and after completion of the work. Some of the information that should be included on the RWP is described in the following section.

11.2.2.1 Radiological Work Permit (RWP)

The RWP is an administrative mechanism used to establish controls for the work to be accomplished. The RWP contains information that informs workers of the radiological conditions in an area and prescribes basic requirements for conducting the work in a safe and expeditious manner. The RWP generally includes the following information (DOE-STD-1098-99).[18]

Description of the work:

- Radiological conditions in the area,
- Dosimetry requirements,
- Pre-job briefing requirements,
- Training requirements for entry,
- Protective clothing and respiratory protection requirements,
- Radiological control coverage and stay-time controls, as applicable,
- Limiting radiological conditions that may void the RWP,
- Special dose or contamination reduction considerations,
- Special personnel frisking considerations,
- Technical work document number, as applicable,
- Unique identifying number,

- Issue and expiration dates, and
- Authorizing signatures.

The RWP should be integrated with other work authorizations that address health and safety issues, such as those for industrial safety and hygiene. The RWP also serves the purpose of relating doses received with specific jobs to support the ALARA program.

A typical RWP for the removal and replacement of contaminated or radioactive HEPA filters would specify the applicable items listed above, as well as some special instructions. These special instructions may include ensuring a radiation survey is conducted before each filter is removed or replaced; using continuous air monitors (CAMs) during the process; stopping work if there is a breach in any containment system such as the bag-in/bag-out system or any sleeving material that may be used; ensuring the work crew has participated in a whole body count or *in vitro* bioassay (e.g., urinalysis) if respirators are to be worn; specifying the maximum allowable exposure for each individual conducting the work; and/or requiring a post-job briefing. All conditions specified on the RWP must be thoroughly understood and implemented.

11.2.2.2 Pre-job Review and Briefing

HEPA filter removal and replacement is not a simple task. It is performed infrequently, so it should be carefully planned (as should all work in radiological areas). A pre-job review and briefing should be conducted to ensure all personnel are familiar with the task and the radiological requirements that may be imposed. The briefing should include the following items:

- A review of the RWP to ensure all conditions and requirements are understood and met;
- A review of the instructions regarding hold points;
- A review of the radiation survey that normally accompanies the RWP, taking particular note of the areas of highest and lowest radiation levels;
- The scope of the work to be conducted (i.e., how many filters will be replaced, what technique will be used, what location is the system in, etc.);
- Information concerning whether the area around the system is to be barricaded and step-off pads used, or if a bag-in/bag-out system is to be used;
- Coordination with operations personnel to ensure the system to be worked on is not needed and is tagged out;
- Established conditions for stopping work (e.g., unexpected radiation levels, contamination due to system breach, dropped filter, etc.);
- Established plans for cleanup and restoring the area;
- Identification of the tools and equipment needed and assurance of their availability;
- Scheduling of the work at a convenient time to avoid delays in the work process (i.e., not near break time or lunch);

- Ensuring that preparation for disposal of filters is coordinated with the waste management group;
- Minimizing the material to be taken into the area to limit waste generation;
- Reviewing the individual and collective doses estimated for the job; and
- Establishing the number of personnel required for the job.

This review should be conducted with all personnel who will be involved in the job and with operations personnel who have control over the system where the work will take place.

11.2.2.3 Hold Points

Hold points may be predetermined for operational reasons or may result from unusual conditions that occur during performance of the task. Predetermined hold points should be specified in the procedure/technical work document or on the RWP (as indicated above). These hold points would exist in situations such as a breach in any control system or an increase in radiation on the HEPA filter beyond expected levels (based on the original survey). Obvious stop-work conditions would exist if personnel felt discomfort due to use of respiratory equipment, heat stress, or fatigue for any reason.

11.2.2.4 Air Monitoring

Air monitoring is required by 10 CFR 835.403(a)(2)[14] to characterize the airborne radioactivity hazard where respiratory protective devices for protection against airborne radionuclides have been prescribed. The use of containment devices is often not amenable for removal and replacement of some HEPA filters. In such situations, respiratory protection equipment could be prescribed and air monitoring would then be required. Care must be taken to locate the air monitoring equipment to ensure the sample represents the concentrations of airborne radioactive material that workers would breathe if respirators were not worn or to warn workers of the release of airborne radioactive material. The potential intake of radioactive material can be determined using these measured concentrations and the protection factor for the particular respirator used. Health physics personnel would designate the type of monitoring and the location of the monitors. They also would collect the data from the air monitoring devices and make any required calculations.

11.2.3 Technical Work Document

The technical work document/procedure provides guidance to the personnel who will perform the task. A procedure is required for removal and replacement of HEPA filters. This procedure must be written for the specific method to be used and must include step-by-step instructions. Typical procedures for removal of HEPA filters with and without a bag-out system are described briefly below.

11.2.3.1 Use of a Bag-Out-System

A bag-out system is a good example of implementation of the ALARA process. It minimizes the possibility of creating an airborne radioactivity area, in some cases may eliminate the need for respiratory equipment, and may minimize the need for followup bioassays on the work crew. This system should be used whenever possible, as recommended in a Lessons Learned Communication[23] reported by Brookhaven National Laboratory describing the use of a glovebag system to remove a large HEPA filter**.** Planning is essential. For example, having the right tools available will minimize interruptions and waste produced.

11.2.3.2 Filter Removal without a Bag-Out System

If use of a bag-out system is not possible, the steps taken for opening the housing and removing and replacing the HEPA filter would be essentially the same as described above. The used filter would require careful handling to avoid spreading contamination and would have to be wrapped in some suitable material such as plastic. However, additional health physics measures would be required, including barricading the area around the filter housing, ensuring the area is posted to warn personnel of the radiological conditions, performing air monitoring, placing a step-off pad at the entrance to the area, and providing a frisker for personnel to survey themselves for contamination after completion of the job. All personnel should wear full protective clothing, including respirators, and frisk themselves for contamination before leaving the area. The personnel may also be required to submit to a whole body count or bioassay as required by local programs.

11.2.3.3 Filter Removal from Man-Entry Housings

If a man-entry housing is required, two teams of two persons each are required to enter the filter housing. One team will enter upstream of the filter stage; the other will enter downstream of the filter stage. Similar health physics/radiation protection measures will be required as used in the "removal without bag-out systems." The filters are changed while the filter system is operating. One team blanks off the side of the filter mounting frame opposite the filter. The other team will replace the damaged/used filter. The filter will be placed in a plastic bag. The mounting surface will be cleaned. A new filter will be installed. The blank will be removed. The filter will be removed from the housing and the two teams will exit the housing. All workers, and the used filter, will be monitored by the health physics/radiation personnel.

11.2.4 Post-Job Requirements

To obtain some lessons learned, provide additional training, and assist in supporting the ALARA program, a post-job review should be held. This review should focus on the manner in which the work was conducted to provide an opportunity for personnel to learn from their success or failure, as the case may be, in performing the work. Such post-job reviews and discussions also aid in ensuring the safety of personnel who will perform the task in the future, and are normally conducted in an expeditious manner.

11.2.4.1 Whole Body Counts

Whole body counts or in vitro bioassays (e.g., urinalysis) are not normally provided for all radiological workers unless they are required to wear respirators. However, depending on the procedure used for removal and replacement of the HEPA filters (e.g., whether respirators were worn), whole body counts or bioassays may be required upon completion of the job. In addition, whole body counts would be required if there were an unexpected release of airborne radioactive materials, if contamination were detected on an individual's face, or if there were a failure in the protective clothing or control devices. Whole body counts are not suitable for detection of all radionuclides and are only one part of the bioassay program for the detection of internal contamination. Health physics personnel should be consulted to ensure the appropriate method is used for evaluation of any potential internal contamination.

11.2.4.2 Contamination Surveys

Contamination control is an important and necessary part of any health physics program. Contamination should be limited through engineering controls and proper work practices. However, it is not always possible to prevent contaminating surfaces when opening contaminated systems or working on contaminated equipment (e.g., changing HEPA filters). Since contamination is easily transferred from one area to another via either air movement or transport on shoes or protective clothing, it is necessary to establish controls at the work area. To ensure contamination is not spread outside of the work area, health physics personnel should establish a contamination control zone. A rope barrier usually designates this control zone along with appropriate postings specifying the levels of contamination and/or radiation in the area. Entrance to these areas should require the individual to wear appropriate protective clothing (sometimes multiple layers, depending on the levels of contamination). A step-off pad is usually placed at the entrance and exit from the contamination areas where personnel remove their contaminated clothing prior to leaving the area. Upon completion of the task in the contamination zone, the following steps must be taken to restrict the contamination from being spread by personnel and equipment:

- **Personnel Surveys.** Personnel exiting the contamination area may be required to remove their protective clothing at the control point. Personnel must frisk themselves with a radiation-monitoring device that is maintained at the step-off pad. Existing procedures should be followed to ensure personnel use the proper techniques for removing protective clothing and performing a whole body frisk if portable monitoring devices are used. Care must be taken to ensure the frisking is performed in a slow, methodical manner to ensure the detection capability of the instrument is not compromised. Personnel should also frisk any personal items brought into the area such as pencils, papers, jewelry, badges, etc.

- **Equipment Surveys.** A trained individual, normally from the health physics program, must monitor the equipment leaving the work area. However, for HEPA filter removal and replacement, it is unlikely that equipment other than the hand tools necessary to change the filter will be brought into the area. Some of these tools may be designated radiological tools because they have fixed contamination and may be maintained separately from uncontaminated tools. Health physics personnel should determine whether the tools have been contaminated with removable contamination by performing smear surveys. The HEPA filter itself must be enclosed in some containment device such as plastic, treated as radioactive, surveyed for contamination and radiation, and appropriately labeled. It should then be held or transported for disposition possible incineration, or direct disposal as radioactive waste.

- **Area Surveys.** Upon completion of the task (i.e., removing the HEPA filter(s) and securing the system housing) the area must be surveyed for radiation and contamination. If contamination is found, the area must be decontaminated and resurveyed until removable contamination no longer exists. A radiation survey must be performed in the area to ensure that the conditions that existed prior to the work did not change and the area is appropriately posted as necessary.

11.2.4.3 Waste Disposal

The final step upon completion of the work is to perform housekeeping in the area while the area is being cleared for general use by health physics. Some of these housekeeping chores involve gathering all the protective clothing for transport to the laundry or shipping to an offsite laundry service and ensuring that all waste materials are packaged and labeled appropriately for disposition as waste. These materials include the step-off pads, the containers in which the used HEPA filters are placed, and any miscellaneous materials used in performing the work.

11.3 Occupational Safety

11.3.1 Electrical Safety

Electrical potentials in excess of 200 volts are common around ventilation systems. Therefore, employees performing filter testing must be aware of electrical hazards. OSHA regulations and prudent practice limit electrical work to qualified personnel. Only a qualified person may perform any repair, installation, or testing of electrical equipment. Workers need to be aware of exposed energized parts in the vicinity of the work. Electrical circuits must be considered energized until opened and locked out according to established procedures and must be tested to verify that the circuit is de-energized. If it is necessary to de-energize electrical circuits to conduct work, the circuits must be de-energized and locked out by qualified personnel. A significant factor in preventing electrical accidents is awareness of possible electrical hazards. Workers should point out hazards to qualified persons. A good housekeeping program can significantly reduce electrical hazards.

Personnel should examine electrically powered equipment and tools for problems. Personnel must not use equipment with frayed or damaged cords or with missing ground pins from the plug (including extension cords). If testing equipment is custom-built, has not been tested by a nationally recognized testing laboratory, or has been modified, the workers should consult qualified electrical safety personnel before using the equipment. Workers should not assume that low voltage controller circuits are free of hazards. Even relatively low voltage may cause injury or startle the worker and cause a fall. Some controller circuits contain higher voltages.

11.3.2 Machine Guarding

Ventilation systems contain rotating shafts, moving belts, gears, and other moving equipment that may present hazards to workers. Such hazards have resulted in serious injuries and even death. Any mechanical device that may cause injury must be guarded. Even a relatively small, unguarded portion on a mechanical device may be enough to cause serious injury. For example, in the past a small portion of a rotating shaft snagged a jacket worn by a worker, causing serious injury. Besides illustrating the danger of even a small exposed moving part, this incident illustrates the danger of wearing loose-fitting clothing while working around moving parts.

Workers should be concerned with three specific types of mechanical hazards: the point of operation where work is performed (e.g., a fan); power transmission equipment including components such as drive belts and pulleys; and other moving parts such as shafts, couplings, and gears.

Workers should not remove guards unless absolutely necessary, and only after all energy sources are shut off and locked out.

11.3.3 Lockout/Tag-out

Work on ventilation systems may expose workers to energy sources or toxic materials that may cause serious injury or death. All potentially hazardous energy sources must be secured, relieved, disconnected, and, if possible, reduced to a zero energy state before personnel start work. Energy sources may include high pressure, heat, electric current, and mechanical energy. Workers should also isolate sources of toxic materials that may present a hazard. Hazard sources must be locked out in accordance with the employer's Lockout/Tag-out program. Simply shutting off a switch or closing a valve is insufficient to control energy or toxic materials. Sources must be locked in such a manner that only those workers potentially exposed to the hazards may remove the lock, and workers will not be exposed to hazards due to someone opening a valve or flipping a switch.

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