Learning Objectives

2.07.01 Explain the purpose of respiratory protection standards and regulations.

2.07.02 Identify the OSHA, ANSI, and DOE respiratory protection program requirements.

2.07.03 Identify the respiratory protection standards.

2.07.04 Describe the advantages and disadvantages (limitations) of each of the following respirators:
   a. Air-purifying, particulate-removing filter respirators
   b. Air-purifying, Chemical-Cartridge and Canister respirators for Gases and Vapors
   c. Full-face, air-line supplied-air respirator
   d. Self-contained breathing apparatus (SCBA)
   e. Supplied Air Respirator with Escape (SAR-E) and combination SAR/SCBA.
   f. Supplied-air suits (bubble suits).

2.07.05 Define the term protection factor (PF).

2.07.06 State the difference between a qualitative and quantitative fit test.

2.07.07 State the recommended physical functions the subject must perform during a respirator fit test.

2.07.08 Describe how the PF and DAC apply to the selection of respirators.

2.07.09 State the considerations for the nature of the hazard when selecting the proper respiratory protection equipment.

2.07.10 Identify the requirements for the use of respirators at LANL.

2.07.11 Identify the quality specifications breathing air must meet.

References

ESH-1-08-01 Respiratory Protection Procedure
2.07.01. INTRODUCTION

Good radiological control practices require the use of engineering controls to prevent the internal deposition of radioactive and nonradiological contaminants. However, when engineering controls are not available or feasible, respiratory protection may be necessary. The Radiological Control Technician should know and apply the considerations used to determine the respiratory protection equipment that is most appropriate for the job. Inappropriate use of the respiratory protection equipment may result in undesirable health effects.

The potential hazards in specific operations mandate the careful and informed selection of respiratory protective equipment. Each type of respirator has its limitations, areas of application, and operational/maintenance requirements. It is most important that the correct respirator be selected for a particular operation. Using the wrong respirator may be worse than using no respirator at all.

The DOE Radiological Control Manual (section 531) and DOE Order 5480.4 mandate the requirements for a respiratory protection program contained in ANSI Z88.2 and 29 CFR 1910.134.

The purpose of respiratory protections standards and regulations is to provide reasonable measures to protect the safety and health of workers, and to specify the minimum acceptable respiratory protection program.

2.07.02. OSHA, ANSI AND DOE REQUIREMENTS

DOE 5480.4 mandates the requirements contained in ANSI Z88.2 and 29 CFR 1910.134 for implementation of the Respiratory Protection Program and associated training of personnel.

The OSHA regulations, 29 CFR, Part 1910.134, specify that the minimal acceptable respiratory protection program must contain or address the following:

- Respirators shall be selected on the basis of hazards to which the worker is exposed.
- The user shall be instructed and trained in the proper use of respirators and their limitations.
- Where practicable, the respirators should be assigned to individual workers for their exclusive use.
- Respirators shall be monitored, decontaminated, cleaned and disinfected.
- Respirators for emergency use such as SCBAs shall be thoroughly inspected at least once a month and after each use.
2.07 - RESPIRATORY PROTECTION

• DOE 5480.4 mandates that breathing air meet the specifications of ANSI Z86.1 and CGA G-7.1 Grade D breathing air as specified in 29 CFR 1910.134. Compressed air supplied to respirators shall be tested quarterly. Special attention shall be focused on the location of compressor air supply intakes and on cross-connections to other compressed gas systems to prevent contamination.

• Area conditions and worker stress shall be monitored.

• Persons should not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment.

ANSI Z88.2-1980 further specifies the minimal acceptable program for industries involved in the use of radioactive material.

2.07.03. RESPIRATORY PROTECTION STANDARDS

If allowance for the use of respiratory protection equipment in estimating exposures is made, then the following must be observed:

• The average concentration actually inhaled on any one day must be less than the DAC.

• Evaluate actual exposures with surveys and bioassays.

• Prior to initial use, and annually, a physical examination must determine the user’s physical capability to wear a respirator.

• Written policy statements must be issued on:
  use of engineering controls instead of respirators;
  periods of respirator use and relief from respirator use.

• Each user must be advised that they can leave the work area upon failure of equipment, physical distress, or deterioration of operating conditions.

• Communication devices are to be issued when needed.

• Emergency use equipment must be specifically certified by NIOSH/MSHA (National Institute for Occupational Safety and Health / Mine Safety and Health Administration)

Equipment must be certified by NIOSH/MSHA or specifically authorized by DOE. Approvals for respiratory devices are authorized in accordance with 30 CFR 11 and the device, type and certification number are listed in NIOSH Publication No. 76-45.
DOE RADCON Manual Respiratory Protection Program Guidance (section 531):

1. Use of respiratory protection shall be reduced to the minimum practicable by implementing engineering controls and work practices to contain radioactivity at the source.

2. Respirators shall be issued only to personnel who are trained, fitted and medically qualified to wear the specific type of respirator. Training and qualification testing shall be performed annually.

3. Engineering controls should be designed to control radioactive materials at the source, so that the need for respiratory protection can be reduced.

2.07.04. RESPIRATORY PROTECTION EQUIPMENT

a. Air-Purifying, Particulate-Removing Filter Respirators

These are generally called "dust" respirators, and by a filtering action remove particulates before they can be inhaled.

Air-purifying respirators generally operate in the negative pressure (NP) mode; that is, a negative pressure is created in the face mask during inhalation.

**Class Discussion**: RCT lesson 2.06 implied that negative pressure was desirable in a Contamination Area. Is negative pressure desirable inside a respirator face mask?

**Half-face** respirators extend from below the chin to the bridge of the nose, whereas full-face respirators cover the eyes, extending up to the forehead. The current revision of 10 CFR 20 (January 1, 1994) states that half-face respirators are not satisfactory for use where it might be possible for the ambient airborne concentrations to reach instantaneous values greater than 10 times the DAC values. Half-face respirators are undesirable because the seal over the nose is more likely to fail than with a full-face respirator, particularly during heavy work. Half-face respirators are not permitted for routine radiological work at LANL.

Limitations:

- Air purifying respirators do not provide oxygen, so they must NEVER be worn in oxygen-deficient atmospheres.

- Particulate-removing filter respirators offer no protection against atmospheres containing contaminant gases or vapors.

- Particulate-removing filter respirators may not be used in atmospheres that are immediately dangerous to life or health (IDLH).
b. Air Purifying, Chemical Cartridge and Canister Respirators for Gases and Vapors

Description:

Vapor and gas-removing respirators use cartridges or canisters containing chemicals (i.e., sorbents) to trap or react with specific vapors and gases and remove them from the air breathed. The basic difference between a cartridge and a canister is the volume of the sorbent.

ESH-5 determines the correct canister to be used for a specific operation from at least 12 types of respirator canisters available. Because canister sorbents and filters are effective only for specific contaminants, and because they might not remove other toxic contaminants, it is extremely important to use only the canister selected by ESH-5.

Limitations:

• These respirators do not provide oxygen, so they must NEVER be worn in oxygen deficient atmospheres.

• Unless specifically approved by DOE, no credit may be taken for the use of sorbent cartridges or canisters for protection against radioactive gases and vapors.

c. Atmosphere Supplying Respirators - Supplied Air

Supplied air respirators use a central source of breathing air that is delivered to the wearer through an air supply line or hose. The respirator type is either a tight-fitting face mask (half face or full) or loose-fitting hood/suit.

Supplied air respirators may operate in one of three modes:

• demand: negative pressure
• pressure-demand: positive pressure
• continuous-flow: positive pressure.

In the demand mode, air enters the face mask only on "demand" of the wearer, i.e., when the person inhales. During inhalation, there is a negative pressure in the mask, so if there is leakage, contaminated air may enter the mask and be inhaled by the wearer.

The pressure-demand device has a regulator and valve design such that there is a continuous flow (until a fixed pressure is attained) of air into the face mask at all times, regardless of the "demand" of the user. The airflow into the mask creates a positive pressure outward.
The \textit{continuous-flow} air line respirator maintains a constant airflow at all times and does not use a regulator, but uses an airflow control valve or orifice which regulates the flow of air. The continuous-flow device creates a \textit{positive pressure} in the face mask. At power reactors, virtually all supplied air operations use the continuous-flow mode.

\textbf{Limitations:}

- Since the air line respirator provides no protection if the air supply fails, they are not approved for use in atmospheres "immediately dangerous to life or health" (IDLH) or for emergency escape or rescue.
- The trailing air supply hose severely limits mobility so it may be unsuitable if frequent movement among separated work stations is required.
- Control of the air quality is essential to avoid introduction of hazardous respiratory agents to the wearers breathing zone.

Requirements for use of respirators in "dangerous" atmospheres is specified in 29 CFR 1910.134(e)(3) as follows:

"(3) Written procedures shall be prepared covering safe use of respirators in dangerous atmospheres that might be encountered in normal operations or in emergencies. Personnel shall be familiar with these procedures and the available respirators.

"(i) In areas where the wearer, with failure of the respirator, could be overcome by a toxic or oxygen-deficient atmosphere, at least one additional man shall be present. Communications (visual, voice, or signal line) shall bemaintained between both or all individuals present. Planning shall be such that one individual will be unaffected by any likely incident and have the proper rescue equipment to be able to assist the other(s) in case of emergency.

"(ii) When self-contained breathing apparatus or hose masks with supplied air lines are used in atmospheres immediately dangerous to life or health, standby men must be present with suitable rescue equipment.

"(iii) Persons using air line respirators in atmospheres immediately hazardous to life or health shall be equipped with safety harnesses and safety lines for lifting or removing persons from hazardous atmospheres or other equivalent provisions for the rescue of persons from hazardous atmospheres shall be used. A standby man or men with suitable self-contained breathing apparatus shall be at the nearest fresh air base for emergency rescue."

d. \textbf{Self-Contained Breathing Apparatus (SCBA)}

The self-contained breathing apparatus (SCBA) allows the user to carry a respirable breathing supply and does not need a stationary air source such as a
compressor to provide breathable air. The air supply may last from 3 minutes to 4 hours depending on the nature of the device.
There are two groups of SCBAs: the closed-circuit and the open-circuit. Another name for closed circuit SCBAs is "rebreathing" device. The air is rebreathed after the exhaled carbon dioxide has been removed and the oxygen content restored by a compressed oxygen source or an oxygen-generating solid. These devices are designed primarily for 1-4 hours use in toxic atmospheres. An open circuit SCBA exhausts the exhaled air to the atmosphere instead of recirculating it. A tank of compressed air carried on the back, supplies air via a regulator to the face mask. Because there is no recirculation of air, the service life of the open circuit SCBA is shorter than the closed circuit system (usually 30 or 60 minutes).

In a demand SCBA, air flows into the face mask only on demand of the wearer, i.e., when the person inhales. During inhalation, there is a negative pressure in the mask so if there is leakage, contaminated air can enter the mask and be breathed by the user. A demand-type SCBA does not provide any higher degree of protection against airborne contaminants than an air-purifying respirator with the same face mask, but it does provide protection against oxygen deficiency. These types of respirators should not be used for emergency use or for escaping from dangerous environments according to existing guidance (NUREG 0041).

The pressure-demand SCBA has a regulator and a valve design which maintains a positive pressure in the face mask at all times regardless of the "demand" of the user. Because of the high degree of protection provided by the pressure-demand SCBA, this type of unit is used for emergencies, escape and rescue.

Limitations of the Pressure-Demand SCBA.

The air supply is limited to the amount in the cylinder and therefore the respirator cannot be used for extended periods without recharging or replacing cylinders. (45 ft³ in a full cylinder at 2216 psig delivers approximately 30 minutes of service, and 85 to 90 ft³ in a full cylinder at 4500 psig delivers approximately 60 minutes of service.)

Because these respirators are bulky and heavy, they are often unsuitable for strenuous work or use in confined spaces (the weight of the unit ranges up to 35 lb.).

Special Considerations of the Pressure-Demand SCBA.

As specified in Section 5.5 of NUREG 0041, only the pressure-demand type SCBA should be selected for emergency use, rescue, and re-entry into a contaminated area to perform emergency shutdown or maintenance of equipment.
This type of respirator is the only one authorized for emergency response at LANL and shall be used only by employees trained and authorized by ESH-5.

Supplied-air suits, equipped with auxiliary SCBA units for escape, may be acceptable in some concentrations of toxic or hazardous materials up to 1000 times the occupational exposure.

e. Supplied-air respirator with escape (SAR-E) and SAR/SCBA combinations

There also exist combination atmosphere supplying respirators which combine supplied air and an SCBA. The apparatus serves as a long duration work device and as an escape device as well. It is approved for respiratory protection for entry into, for extended periods of work in, and for escape from IDLH atmospheres.

The Dual-Purpose Breathing Apparatus combines the capabilities of a self-contained breathing apparatus and a supplied-air respirator in one unit. The apparatus is approved by the NIOSH and MSHA for use in oxygen deficient atmospheres or where dangerous concentrations of toxic gases or vapors are present.

f. Supplied-air suits (bubble suits)

In an atmosphere containing tritium, half the internal exposure results from absorption of tritium through the skin, so an SCBA will reduce the dose by only half. When working with high concentrations of tritium, a supplied-air suit (bubble suit) is required. These suits can also increase worker comfort and reduce heat stress.

2.07.05. PROTECTION FACTORS

The overall protection afforded by a given respirator design is defined in terms of its protection factor (PF). The PF is defined as the ratio of the concentration of contaminant in the atmosphere to the concentration inside the face mask or hood under conditions of use.

Protection Factors may not be appropriate where chemical or other respiratory hazards exist in addition to radioactive hazards or where the mode of entry is through the skin and not through inhalation. For example, 50% of the intake from exposure to tritiated oxide is through skin absorption. In this case, the use of atmosphere supplying respirators will only provide a PF of 2. Also, regulations specifically prohibit the use of PFs for canister sorbents as protection against radiiodine, although these do provide some small measure of protection.

- The protection factor for the device selected must be greater than the ratio of the peak exposure concentration and the associated DAC.
Application of PF's is relatively straightforward. The work area airborne radioactivity concentration is divided by the PF to estimate the inhaled concentration. For example, a worker performing steam generator eddy current testing with a full-face continuous-air-flow air-line respirator and in an atmosphere of $1 \times 10^{-6}$ $\mu$Ci/cc Co-60 would be estimated to inhale a concentration of $5 \times 10^{-10}$ $\mu$Ci/cc Co-60. From another perspective, if one wanted to maintain the estimated inhalation concentration at $1 \times 10^{-9}$ $\mu$Ci/cc for an atmosphere of $1 \times 10^{-6}$ $\mu$Ci/cc then the worker must use a respiratory device with a PF of at least 1000.

### 2.07.06. QUANTITATIVE AND QUALITATIVE FIT TESTS

**Definitions:**

**Qualitative fit test:** Test to determine if there is any mask leakage, usually using irritant smoke ("Go/no-go" test).

**Quantitative fit test:** Test to determine quantity of mask leakage and assign a "fit factor." Corn oil is the typical challenge atmosphere used. (Measures concentration in mask due to leakage against concentration in atmosphere).

It is impractical to perform a quantitative fit test prior to each entry requiring respiratory protection. Therefore, qualitative tests are performed to ensure an adequate fit for the user. Qualitative tests can use challenge atmospheres such as Isoamyl Acetate (banana oil) or irritant smoke (e.g., stannic chloride) or as a negative or positive pressure test. The irritant smoke test is the most effective since the wearer's obvious discomfort from the smoke will show leakage through the respirator face seal. However, the test produces noxious odors for not only the wearer but those in the test area.

The use of "banana oil" requires a subjective evaluation by the wearer and more often than not a user will not admit that in-leakage has occurred. One reactor respiratory program was faithfully utilizing the banana oil to perform the fit test and virtually all wearers indicated no in-leakage through the face mask. Unfortunately, the respirator only contained a particulate filter cartridge rather than an organic vapor cartridge. Since most reactors use respirators at many different locations, challenge atmosphere tests are difficult to perform and therefore the "immediately prior-to-use" qualitative test normally selected is to perform a negative pressure test.

### 2.07.07 FIT TEST

The subject performs the following functions during fit testing:

1) Normal breathing
2) Deep breathing
3) Moving head from side to side
4) Moving head up and down
5) Grimace  
6) Talking  
7) Running in place  

2.07.08. SELECTION

In protecting against radiological airborne contaminants the most critical factor will be meeting the provisions of DOE Order 5480.11 which requires the protection factor for the respirator device used to be greater than the ratio of the work area concentration to the associated DAC.

This implies that the concentration of contaminants inside the face-mask (the air actually breathed) must be less than 1 DAC.

In addition, selection of the proper respirator for any given situation requires consideration of the following:

- The location of the hazardous area with respect to a safe area having respirable air. How would the workers escape in an emergency?
- The period of time for which respiratory protection may be provided. SCBAs last for 30 or 60 minutes.
- The activity of the workers in the hazardous area. Consider worker comfort and stress.
- The physical characteristics, functional capabilities, and limitations of respirators of various types. SCBAs are heavy and bulky.
- The respirator-protection factors, respirator fit factor, and the DAC should be considered as follows.

\[
\text{air in the face mask (actually breathed) must be < 1 DAC} \\
\text{PF > number of DACs} \\
\text{< 0.1 DAC: respirator not required} \\
\text{< 100 DAC of solid particulates, non-IDLH: air-purifying filter} \\
\text{< 1000 DAC, non-IDLH: air-line supplied-air} \\
\text{< 10000 DAC: SCBA} \\
\text{tritium: supplied-air suit} \\
\text{chemicals or gases: SCBA or consult ESH-5} \\
\text{low oxygen or IDLH atmosphere: consult ESH-5}
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2.07.09. HAZARDS

RadCon section 316.3 recommends that respiratory protection should be considered for:

- a) Airborne Radioactivity Areas (> 10% of the DAC)
- b) Breach of contaminated systems or components
- c) High Contamination Areas
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d) When there is the potential for airborne radioactivity
The following factors concerning the nature of the hazard requiring the use of respirators shall be considered in respirator selection:

- The type of hazards
  - Oxygen deficiency
  - IDLH
  - confined space

- The physical properties
  - solid particulates: use an air purifying filter
  - liquid, vapor or gas: consult ESH-5

- The chemical properties
  - consult ESH-5

- The physiological effects on the body
  - heat stress, the weight of the equipment

SORBENTS AND PROTECTION AGAINST RADIO-IODINES

The regulations specifically prohibit the use of PFs for canister sorbents as protection against radioiodine atmospheres. However, the charcoal canisters provided by most manufacturers do provide a measure of protection against radioiodine atmospheres. The efficiency of the charcoal canister is dependent upon the chemical form of the radioiodine, humidity of the atmosphere, and breathing rate of the user. Approval can be obtained from the NRC to use PF's for sorbent cartridges. The criteria for testing and certifying the charcoal cartridges is contained in NUREG/CR-3403: "Criteria and Test Methods for Certifying Air-Purifying Respirator Cartridges and Canisters Against Radioiodine."

2.07.10. RESPIRATORS AT LANL

The use of protective equipment is required in Laboratory work areas in which hazards are (1) not effectively controlled by other means (such as engineering or administrative controls), (2) unknown (such as site characterizations at solid waste management units, or (3) controlled but require additional protection. Various types of personal protective equipment provide specialized protection for the respiratory system, eyes, face, feet, head, as well as the entire body.

Procedures for the safe and effective use of personal protective equipment at LANL are listed in ESH-1-08-01 "Respiratory Protection Procedure".

Standard Operating Procedures and Special Work Permits

Operations requiring the use of respirators require an SOP or an RWP.
Medical Approval

Employees MUST have medical approval from ESH-2 before they use any respirators or fully encapsulating, hazardous materials (HAZMAT), Level A suits. Employees must submit a completed questionnaire, Form 1465 (ESH Form 12-1A), "Request for Respiratory Protection Evaluation and Medical Approval for Personal Protective Equipment", to ESH-2 for scheduling of the required medical surveillance exam. The form is available from ESH-5. Employees must be approved by ESH-2 and must renew this medical approval annually. Employees must notify ESH-2 immediately if there is a change in their health status that may affect their ability to use respirators or fully encapsulating Level A suits.

Respirator authorization cards

When ESH-5 training is complete, participants are issued respirator authorization cards, which must be updated at least annually. Respirator authorization cards must be current and available for inspection, and should be worn behind the employees' security badges.

2.07.11 AIR QUALITY

Compressed air cylinders used for breathing air (SCBA and supplied air systems) shall be refilled or recharged only by ESH-5. RCTs should ensure that cylinders have been monitored and are free from contamination before transporting them to ESH-5 for refilling.

An air quality testing program for all sources of respirable air is required. Compressed breathing air shall meet at least the quality specification for Grade D breathing air as described in Compressed Gas Association Commodity Specification G-7.1-1973 (also ANSI Z86.1-1973). ESH-5 uses grade E air.

The atmosphere consists of approximately 80% nitrogen, 20% oxygen, and small amounts of water vapor, carbon dioxide, and other gases. Air that contains less than 19.5% oxygen is considered oxygen deficient.

Our bodies warn us when carbon-dioxide levels are higher than usual, e.g. by making us yawn in a stuffy room, but do not necessarily warn us if the oxygen is replaced by an inert gas. In low oxygen atmospheres, a person usually loses consciousness before realizing that anything is wrong. At the IBF at LANL, a worker without a supplied-air respirator, entered the tank while it was full of an inert gas, and quickly lost consciousness. A second worker entered the tank to rescue him, and also lost consciousness. Both workers died a few minutes later.
SUMMARY

Many types of respiratory protection equipment are available at LANL. In routine jobs with known hazards and low levels of particulate activity, an RCT may specify the use of respirators on the RWP. In unfamiliar situations, an RCT should consult ESH-5.