Life-safety Systems

Continuing Education from Plumbing Systems & Design

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INTRODUCTION

A threat to personnel safety often present in pharmaceutical facilities is accidental exposure and possible contact with toxic gases, liquids, and solids. This chapter describes water-based emergency drench equipment and systems commonly used as a first-aid measure to mitigate the effects of such an accident. Also described are the breathing-air systems that supply air to personnel for escape and protection when they are exposed to either a toxic environment resulting from an accident or normal working conditions that make breathing the ambient air hazardous.

EMERGENCY DRENCH-EQUIPMENT SYSTEMS

GENERAL

When toxic or corrosive chemicals come in contact with the eyes, face, and body, flushing with water for 15 min with the clothing removed is the most recommended first-aid action that can be taken by nonmedical personnel prior to medical treatment. Emergency drench equipment is intended to provide a sufficient volume of water to effectively reach any area of the body exposed to or has come into direct contact with any injurious material. Within facilities, specially designed emergency drench equipment, such as showers, drench hoses, and eye and face washes, are located adjacent to all such hazards. Although the need to protect personnel is the same for any facility, specific requirements differ widely because of architectural, aesthetic, location, and space constraints necessary for various industrial and laboratory installations.

SYSTEM CLASSIFICATIONS

Drench equipment is classified into two general types of system based on the source of water. These are plumbed systems, which are connected to a permanent water supply, and self-contained or portable equipment, which contains its own water supply. Self-contained systems can be either gravity feed or pressurized.

One type of self-contained eyewash unit is available that does not meet code requirements for storage or delivery flow rate. This is called the personnel eyewash station and is selected only to supplement, not replace, a standard eyewash unit. It consists of a solution-filled bottle(s) in a small cabinet. This cabinet is small enough to be installed immediately adjacent to a high hazard. If an accident occurs, the bottle containing the solution is removed and used without delay to flush the eyes while waiting for the arrival of trained personnel and during travel to a code-approved eyewash or first-aid station.

CODES AND STANDARDS

1. ANSI Z-358.1, Emergency Shower and Eyewash Equipment.
2. OSHA has various regulations for specific industries pertaining to the location and other criteria for emergency eyewashes and showers.
3. The Safety Equipment Institute (SEI) certifies that equipment meets ANSI standards.
4. Applicable plumbing codes. For the purposes of the discussion in this section on drench equipment, the word "code" shall refer to ANSI Z-358.1.

TYPES OF DRENCH EQUIPMENT

Emergency drench equipment consists of showers, eyewash units, face-wash units, and drench hoses, along with interconnecting piping and alarms if required. All of these units are available either singly or in combination with each other. Ancillary components include thermostatic mixing systems, freeze protection systems and enclosures. Each piece of equipment is designed to perform a specific function. One piece is not intended to be a substitute for another, but rather, to complement the others by providing additional availability of water to specific areas of the body as required.

Emergency Eyewashes

Self-Contained Eyewash

Emergency eyewashes are specifically designed to irrigate and flush both eyes simultaneously with dual streams of water. The unit consists of dual heads in the shape of a "U," each specifically designed to deliver a narrow stream of water, and a valve usually controlled by a large push plate. Code requires the eyewash to be capable of delivering a minimum of 0.4 gpm (1.5 L/min). Many eyewashes of recent manufacture deliver approximately 3 gpm (11.4 L/min). Once started, the flow must be continuous and designed to operate without the use of the hands, which shall be free to hold open the eyelids. The flow of water must be soft to avoid additional injury to sensitive tissue. To protect against airborne contaminants, each dual stream head must be protected with a cover that is automatically discarded when the unit
is activated. The head covers shall be attached to the heads by a chain to keep them from being lost. The eyewash can be mounted on a counter or wall, or as a free stranding unit attached to the floor. The eyewash could be provided with a bowl. The bowl does not increase the efficiency or usefulness of the unit but aids in identification by personnel. It is common practice to mount a swivel type eyewash on a laboratory sink faucet, installed so it can be swung out of the way during normal use of the sink but can be swung over the sink bowl in order to be operated in an emergency.

The code recommends (but does not require) the use of a buffered saline solution to wash the eyes. This could be accomplished with a separate dispenser filled with concentrate that will introduce the proper solution into the water supply prior to reaching the device head. A commonly used device is a wall-mounted, 5 to 6-gal (20 to 24-L) capacity solution tank connected to the water inlet dispenses a measured amount of solution when flow to the eyewash is activated. A backflow device shall be installed on the water supply.

Self-Contained Eyewash
A typical self-contained eyewash has a storage tank with a minimum 15-min water supply. The mounting height and spray pattern requirements are the same as those for a plumbed eyewash.

Emergency Face Wash
The face wash is an enhanced version of the eyewash. It has the same design requirements and configuration, except the spray heads are specifically designed to deliver a larger water pattern and volume will flush the whole face and not just the eyes. The face wash should deliver approximately 8 gpm (55 L/min). The stream configuration is illustrated in Figure 8-2. Very often, the face wash is chosen for combination units. In general, the face wash is more desirable than the eyewash because it is very likely an accident will affect more than just the eyes. All dimensions and requirements of the free-standing face wash are similar to those for the eyewash.

Drench Hoses
A drench hose is a single-head unit connected to a water supply with a flexible hose. The head is generally the same size as a single head found on an eye/face wash. Code requires the drench hose be capable of delivering a minimum of 0.4 gpm (1.5 L/min). It is controlled either by a squeeze handle near the head or a push-plate ball valve located at the connection to the water source. It is used as a supplement to showers and eye/face washes to irrigate specific areas of the body. Drench hoses are selected for the following reasons:

1. To spot drench a specific area of the body when the large volume of water delivered by a shower is not called for.
2. To allow irrigation of an unconscious person or a victim who is unable to stand.
3. To irrigate under clothing prior to the clothing’s removal.

Combination Equipment
Combination equipment consists of multiple-use units with a common water supply and supporting frame. Combinations are available that consist of a shower, eye/face wash, and drench hose in any configuration. The reason for the use of combination equipment is usually economy, but the selection should be made considering the type of irrigation appropriate for the potential injuries at a specific location. For combination units, the water supply must be larger, capable of delivering the flow rate of water required to satisfy two devices concurrently rather than only a single device. The most often-used combination is the drench shower and face wash. Figure 8-2 illustrates a combination shower, eye/face wash and drench hose complete with mounting heights.

DRENCH EQUIPMENT COMPONENTS

Controls
Often referred to as “activation devices,” controls cause water to flow at an individual device. Stay-open valves are required by code in order to leave the hands free for the removal of clothing or for holding eyelids
has a much greater flow than the device at the end. During operation, the higher pressure could cause the flow rate to be as much as 50 gpm (L/min). If no floor drain is provided, the higher flow for 15 min at the higher pressure could produce a much greater amount of water that must be cleaned up and disposed of afterwards. Drench hoses and eye and face washes are not affected because of their lower flow rates and their flow head designs.

Where pressure-reducing devices are required for an entire system, they should be set to provide approximately 50 psig (345 kPa).

SYSTEM DESIGN

General
It is a requirement that a plumbed system be connected to a potable water supply as the sole source of water. This system is therefore subject to filing with a plumbing or other code official for approval and inspection of the completed facility, as are standard plumbing systems.

An adequately sized pipe with sufficient pressure must be provided from the water supply to meet system and device operating-pressure requirements for satisfactory functioning. One maintenance requirement is that the water in the piping system be flushed to avoid bacterial growth.

It is common practice to add antibacterial and saline products to a self-contained eyewash unit and an antibacterial additive to an emergency shower. Water is also commonly used if it can be changed every week. It is well established that no preservative will inhibit bacterial growth for an extended period of time. Self-contained equipment must be checked regularly to determine if the quality of the stored water has deteriorated to a point where it is not effective or safe to use.

If valves are placed in the piping network for maintenance purposes, they should be made for unauthorized shut-off.

Water-Supply Pressure and Flow Rates
Emergency showers require between 20 and 30 gpm (76 to 111 L/min), with 30 gpm recommended. The minimum pressure required is 30 psig (4.5 kPa) at the farthest unit, with a generally accepted maximum pressure of 70 psi (485 kPa). Code mentions a high pressure of 90 psig (612 kPa), which is generally considered to be excessive.

Most plumbing codes do not permit water pressures as high as 90 psig. Generally accepted practice limits the high water pressure to between 70 and 80 psig (480 and 620 kPa). Most eyewash units require a minimum operating pressure of 15 psig (105 kPa) with a flow rate minimum of 3 gpm (12 L/min) at the farthest unit. Maximum pressure is similar to that for showers. Face washes and drench hoses require a minimum operating pressure of 15 psig (105 kPa) with a minimum flow rate of 8 gpm (30 L/min) at the farthest unit.

System Selection

Plumbed System
The advantages of a plumbed system include:
1. Permanent connection to a fresh supply of water, requiring no maintenance and only minimum testing of the devices to ensure proper operation.
2. It provides an unlimited supply of water often at larger volumes than self-contained units.

Disadvantages include:
1. Higher first cost than a self-contained system.
2. Maintenance is intensive. Such systems require weekly flushing, often into a bucket, to remove stagnant water in the piping system and replace it with fresh water.

Self-Contained System
Advantages of the self-contained system include:
1. Lower first cost compared to a plumbed system.
2. Can be filled with a buffered, saline solution, which is recommended for washing eyes.
3. Available with a container to catch waste water.
owners have specific regulations for its need and location.

necessary in the selection and location of equipment. Very often, facility

CFR, and other regulations for specific occupations. Judgment is nec-

sion and by the use of common sense in conformance with OSHA,

analysis of the hazard by design professionals or health or safety per-

The need to provide emergency drench equipment is determined by an

treatment?

But this means that it is located adjacent to electrical equipment. Location on normal access and egress

paths in the work area will reinforce the location to personnel, who will see it each time they pass.

There are no requirements in any code pertaining to the location of

any drench equipment in terms of specific, definitive dimensions. ANSI code Z-358.1 requires emergency showers be located a maximum distance of either 10 seconds travel time by an individual or no more than 75 ft (22.5 m) from the potential protected hazard, whichever is shorter. If strong acid or caustic is used, the equipment should be located within 10 ft (3 m) of the potential source of the hazard. The path to the unit from the hazard shall be clear and unobstructed, so

INSTALLATION REQUIREMENTS FOR DRENCH EQUIPMENT

The need to provide emergency drench equipment is determined by an

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essary in the selection and location of equipment. Very often, facility

owners have specific regulations for its need and location.

Pipe Sizing and Material

In order to supply the required flow rate to a shower, a minimum

pipe size of 1 in. (25 mm) is required by code, with 1¼ in. (30 mm) recommended. If the device is a combination unit, a 1½-in. size should be considered as minimum. An emergency eye/face wash requires a minimum ½ in. (13 mm) pipe size.

Except in rare cases where multiple units are intended to be

used at once, the piping system size should be based on only one unit operating. The entire piping system is usually a single size pipe based on the requirements of the most remote fixture. Appropriate pressure loss calculations should be made to ensure the hydraulically most remote unit is supplied with adequate pressure with the size selected. Adjust sizes accordingly to meet friction loss requirements.

The pipe material should be copper to minimize clogging the

heads of the units in time with the inevitable corrosion products released by steel pipe. Plastic pipe (PVC) should be considered where excessive heat and the use of closely located supports will not permit the pipe to creep in time.

Emergency drench equipment shall be sized based on the

single highest flow rate, usually 30 gpm (115 L/min) for an emer-

gency shower. Piping is usually a 1¼-in. header of copper pipe for

the entire length of a plumbed system.

Flushing Water Disposal

Water from emergency drench equipment is mainly discharged

onto the floor. Individual eye/face washes mounted on sinks discharge most of the water into the adjacent sink. Combination units have an attached eye/face wash also discharge water on the floor. There are different methods of disposing of the water resulting from an emergency device depending on the facility. The basic consideration is whether to provide a floor drain adjacent to a device to route that water from the floor to a drainage system.

It is accepted practice not to provide a floor drain at an emergency

shower. Experience has shown in most cases, particularly in schools and laboratories, it is easier to mop up water from the floor in the rare instances emergency devices are used rather than add the extra cost of a floor drain, piping and a trap primer. Considerations include:

1. If the drain is not in an area where frequent cleaning is done, the trap may dry out, allowing odors to be emitted.
2. Is there an available drainage line in the area of the device?
3. Can the chemical, even in a diluted state, be released into the sanitary sewer system or must it be routed to a chemical waste system for treatment?
4. Must purification equipment be specially purchased for this purpose?

Figure 8-4 Wheelchair-Accessible Shower and Eyewash Equipment

Dimensional Requirements

The mounting height of all equipment, as illustrated in ANSI Z-358.1, is shown in Figure 8-2. If the shower head is free-standing, the generally accepted dimension for the mounting height is 7 ft 0 in. (2.17 m) above the floor. Generally accepted clearance around showers and eye/face washes is illustrated in Figure 8-3. A wheelchair- accessible, free-standing, combination unit is illustrated in Figure 8-4.

Equipment Location

The location of the emergency drench equipment is crucial to the

immediate and successful first-aid treatment of an accident victim. It should be located as close to the potential hazard as is practical without being affected by the hazard itself or potential accidental conditions, such as a large release or spray of chemicals resulting from an explosion or a pipe and tank rupture. Another location problem is placement adjacent to electrical equipment. Location on normal access and egress paths in the work area will reinforce the location to personnel, who will see it each time they pass.
impaired sight or panic will not prevent clear identification and access. There is no regulation as to what distance could be covered by an individual in 10 seconds. There are also no specific provisions for the physically challenged.

Since there are no specific code requirements for locating drench equipment, good judgment is required. Accepted practice is to have the equipment accessible from three sides. Anything less generally creates a “tunnel” effect that makes it more difficult for the victim to reach the equipment. It should be located on the same level as the potential hazard when possible. Traveling through rooms that may have locked doors to reach equipment shall be avoided, except placing emergency showers in a common corridor, such as outside individual laboratory rooms, is accepted practice. Care should be taken to avoid locating the shower in the path of the swinging door to the protected room to prevent personnel coming to the aid of the victims from knocking them over.

Emergency eye/face washes should be located close to the potential source of hazard. In laboratories, accepted practice is to have 1 sink in a room fitted with an eyelash on the counter adjacent to the sink. The sink cold-water supply provides water to the unit. The eyewash could be designed to swing out of the way of the sink if desired.

VISIBILITY OF DEVICES
High visibility must be considered in the selection of any device. The recognition methods usually selected are high-visibility signs mounted at or on the device; having the surrounding floors and walls painted a contrasting, bright color; and having the device in a bright, well lit area on the plant floor to help a victim identify the area and help in first-aid activities.

NUMBER OF STATIONS
The number of drench-equipment devices provided in a facility is a function of the number of people in rooms and areas with potential exposure to any particular hazard at any one time, based on a worst-case scenario. It is rare for more than one combination unit to be installed. It is important to consider if a group of individuals has potential exposure to a specific hazard, more than one drench unit may be required. Consulting with the end user and the safety officer will provide a good basis for the selection of the type and number of equipment.

Generally, one shower can be provided between an adjacent pair of laboratories, with emergency eye/face washes located inside each individual laboratory. In open areas, it is common practice to locate emergency equipment adjacent to columns for support.

WATER TEMPERATURE
Code now requires tempered water of approximately 85°F be supplied to equipment. A comfortable range of 60 to 95°F (15 to 35°C) is mentioned in the code. For most indoor applications, this temperature range is achieved because the interior of a facility is heated in the winter and cooled in the summer to approximately 70°F (20°C). Since the water in the emergency drench system is stagnant, it assumes the temperature of the ambient air. A generally accepted temperature of between 80 and 85°F (27 and 30°C) has been established as a “comfort zone” and is now the recommended water temperature.

The body will attempt to generate body heat lost if the drenching fluid is at a temperature below the comfort zone. The common effect is shivering and increased heart rate. In fact, most individuals are uncomfortable taking a shower with water at about 60°F (15°C). With the trauma induced by an accident, the effect is escalated.

Another consideration is the potential chemical reaction and/or acceleration of reaction with flushing water or water at a particular temperature. Where the hazard is a solid, such as radioactive particles, that can enter the body through the pores, a cold-water shower shall be used in spite of its being uncomfortable. It is necessary to obtain the opinions of medical and hygiene personnel where any doubt exists about the correct use of water or water temperature in specific facilities.

Where showers are installed outdoors, or indoors where heating is not provided, the water supplying the showers must be tempered if the air temperature is low. Manufacturers offer a variety of tempering methods, including water-temperature maintenance control similar to that used for domestic hot-water systems for this purpose and mixing valves with hot and cold-water connections. In remote locations, complete self-contained units are available with storage tanks holding and maintaining heated water.

PROTECTION AGAINST TEMPERATURE EXTREMES
In areas where freezing is possible and water drench equipment is connected to an above-ground, plumbed water supply, freeze protection is required. This is most often accomplished by using electric heating cable and providing insulation around the entire water-supply pipe and the unit itself. It is recommended the water temperature be maintained at 85°F (20°C).

For exterior showers located where freezing is possible, the water supply shall be installed below the frost line and a freeze-proof shower shall be installed. This type of shower has a method of draining the water above the frost line when the water to the drench equipment is turned off.

When a number of drench-equipment devices are located where low temperature is common, a circulating tempered-water supply should be considered. This uses a water heater and a circulating pump to supply the drench equipment. The heater shall be capable of generating water from 40 to 80°F at a rate of 30 gpm (or more if more than one shower could operate simultaneously).

In areas where the temperature may get too high, it is accepted practice to insulate the water-supply piping.

BREATHING-AIR SYSTEMS

GENERAL
Breathing-air systems supply air of a specific minimum purity to personnel for purposes of escape and protection after exposure to a toxic environment resulting from an accident or during normal work where conditions make breathing the ambient air dangerous. As defined by 30 CFR 10, a toxic environment has air that “may produce physical discomfort immediately, chronic poisoning after repeated exposure, or acute adverse physiological symptoms after prolonged exposure.”

This section discusses the production, purification, and distribution of a low-pressure breathing air and individual breathing devices used to provide personnel protection only when used with supplied air systems. Low pressure for breathing air refers to compressed air pressures up to 250 psig (1725 kPa) delivered to the respirator. The most common operating range for systems is between 90 and 110 psig (620 and 760 kPa).

Much of the equipment used in the generation, treatment, and distribution of compressed air for breathing-air systems is common to that for medical/surgical air discussed in the “Compressed-Gas Systems” chapter.

CODES AND STANDARDS
2. CGA: commodity specifications G-7 and G-7.1.
3. Canadian Standards Association (CSA).
5. Mine Safety and Health Act (MSHA).
7. DOD (Department of Defense): Where applicable.

BREATHING-AIR PURITY
Air for breathing purposes supplied from a compressor or a pressurized tank must comply, as a minimum, with quality verification level grade D in CGA G-7.1 (ANSIZ-86.1), Table 8-1, from ANSI/GA G-7.1, lists the maximum contaminant levels for various grades of air.
For grade D quality air, individual limits exist for condensed hydrocarbons, carbon monoxide, and carbon dioxide. Particulates and water vapor, whose allowable quantities have not been established, must also be controlled because of the effects they may have on different devices of the purification system, on the piping system, and on the end user of the equipment.

**Contaminants**

**Condensed Hydrocarbons** Oil is a major contaminant in breathing air. It causes breathing discomfort, nausea, and, in extreme cases, pneumonia. It can also create an unpleasant taste and odor and interfere with an individual’s desire to work. In addition, the oxidation of oil in overheated compressors can produce carbon monoxide. A limit of 5 ppm has been established.

Some types of reciprocating and rotary-screw compressors put oil into the airstream as a result of their operating characteristics. Accepted practice is to use only oil-free air compressors in order to eliminate the possibility of introducing oil into the airstream.

**Carbon Monoxide** Carbon monoxide is the most toxic of the common contaminants. It enters the breathing-air system through the compressor intake or is produced by the oxidation of heated oil in the compressor. Carbon monoxide easily combines with the hemoglobin in red blood cells, replacing oxygen. The lack of oxygen causes dizziness, loss of motor control, and loss of consciousness. A limit of 10 ppm in the airstream has been established based on NIOSH standards.

**Carbon Dioxide** Carbon dioxide is not considered one of the more dangerous contaminants. Although the lungs have a concentration of approximately 50,000 ppm, a limit of 1,000 ppm has been established for the breathing airstream.

**Water and Water Vapor** Water vapor enters the piping system through the air compressor intake. Since no upper or lower limits have been established by code, the allowable concentration is governed by specific operating requirements of the most demanding device in the system, which is usually the CO converter, or the requirement of being 10°F lower than the lowest possible temperature the piping may experience.

After compression, water vapor is detrimental to the media used to remove CO. The dew point of the airstream must be greatly lowered at this point in order to provide the highest efficiency possible for this device. Water vapor is removed to such a low level that breathing air with this level of humidity will prove uncomfortable to users.

After purification, too much humidity will fog the faceplate of a full face mask. It will also cause freeze-up in the pipeline if the moisture content of the airstream in the pipe has a dew point that is higher than the ambient temperature of the area where the compressed-air line is installed.

**Solid Particles** Solid particles known as “particulates” can enter the system through the intake. They are released from non-lubricated compressors as a result of friction from carbon and Teflon material used in place of lube oils. No limits on particulates have been established by code.

**Odor** There is no standard for odor measurement. A generally accepted requirement is that there be no detectable odor in the breathing air delivered to the user. This requirement is subjective and will vary with individual users.

### TYPES OF SYSTEM

There are three basic types of breathing-air system: constant flow, demand flow, and pressure demand.

**Constant-Flow System**

Also known as a “continuous-flow system,” the constant-flow system provides a continuous flow of purified air through personnel respirators to minimize the leakage of contaminants into the respirator and to ventilate the respirator with cool or warm air depending on conditions.

This system could be used in a wide variety of areas, ranging from least harmful to most toxic, depending on the type of respirator selected.

**Demand-Flow System**

Also known as a “continuous-flow system,” the constant-flow system provides a continuous flow of purified air through personnel respirators to minimize the leakage of contaminants into the respirator and to ventilate the respirator with cool or warm air depending on conditions.

This system requires tight-fitting respirators. Its application is generally limited to less harmful areas because the negative pressure in the respirator during inhalation may permit leakage of external contaminants. This system is designed for economy of air use during relatively short-duration tasks and is usually supplied from cylinders.

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### Table 8-1 Maximum Contaminant Levels for Various Grades of Air

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<th>Limiting Characteristics</th>
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<td>Percent O₂ balance predominantly N₂</td>
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<td>atm/</td>
<td>19.5</td>
<td>23.5</td>
<td>atm/</td>
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<td>atm/</td>
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<td>23.5</td>
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<td>Dew point, °F</td>
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<td>Carbon monoxide</td>
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<td>Acetylene</td>
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Source: ANSI/CSA G 7-1 ANS 1 7-81, Table 1.

Note: The 1973 edition of CSA G 7-1 listed nine quality verification levels of gaseous air, lettered A to J, and two quality verification levels of liquid air, lettered A and B. Some of those letter designations were dropped from the 1988 edition, since they no longer represent major volume usage by industry. New letter designations, K, L, M, and N, have been added to reflect current specifications. To get a listing of quality verification levels dropped, see CSA G 7-1-1973 or contact the Compressed Gas Association.

a The term atmospheric (atm) denotes the oxygen content normally present in atmospheric air; the numerical values denote the oxygen limits for synthesized air.

b The water content of compressed air required for any particular quality verification level may vary with the intended use from saturated to very dry. For breathing air used in conjunction with a self-contained breathing apparatus in extremely cold where moisture can condense and freeze, causing the breathing apparatus to malfunction, a dew point not to exceed -50°F (63 ppm v/v), or 10°F lower than the coldest temperature expected in the area, is required. If a specific water limit is required, it should be specified as a limiting concentration in ppm (v/v) or dew point. Dew point is expressed in °F at 1 atmosphere pressure absolute, 101 kPa abs. (760 mm Hg).

c Not required for synthesized air whose oxygen and nitrogen components are produced by air liquefaction.

d Includes water.

e Not required for synthesized air when the nitrogen component was previously analyzed and meets National Formulary (NF) specification.

f Not required for synthesized air when the oxygen component was produced by air liquefaction and meets United States Pharmacopoeia (USP) specification.

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DECEMBER 2011  Plumbing Systems & Design 7
Pressure-Demand System

A pressure-demand system delivers purified air continuously through personnel respirators with increased air flow during inhalation. By continuously providing a flow of air above atmospheric pressure, leakage of external contaminants is minimized. This system also uses tight-fitting respirators, but the positive pressure aspect allows them to be used in more toxic applications.

SYSTEM COMPONENTS

The breathing-air system consists of a compressed-air source, purification devices and filters to remove unwanted contaminants from the source airstream, humidifiers to introduce water vapor into the breathing air, the piping distribution network, respirator outlet manifolds, respirator hose, and the individual respirators used by personnel. Alarms are needed to monitor the quantity of contaminants and other parameters of the system as a whole and to notify personnel if necessary.

Compressed-Air Source

The source of air for the breathing-air system is an air compressor and/ or high-pressure air stored in cylinders. Cylinders use ambient air, which is purified to reduce or eliminate impurities to the required level, and compress it to the desired pressure. A typical schematic detail is shown in Figure 8-5.

Air Compressor

The standard for air compressors used to supply breathing air shall comply with the requirement for oil-free medical gas discussed in the “Compressed-Gas Systems” chapter. Medical-gas type compressors are used because these systems as a whole generate far fewer contaminants than other types of system. When a liquid-ring compressor is used, it has the advantage of keeping the temperature of the air leaving the unit low. It is also possible to use any type of compressor for this service, provided the purification system is capable of producing air meeting all the requirements of code.

The air-compressor assembly consists of the intake assembly (including the inlet filter), the compressor and receiver, the aftercooler, and the interconnecting water seal supply and the other ancillary piping. All of these components are discussed in the “Specialty Gases for Laboratories” section.

Air compressors have a high first cost and are selected if the use of air for breathing is constant and continuous, making the use of cylinders either too costly or too maintenance intensive because of the frequent changing of cylinders.

Storage Cylinder

When high-pressure cylinders are used either as a source or as an emergency supply of breathing air, they shall be filled with air conforming to breathing-air standards. The regulator should be set to about 50 psi (340 kPa) depending on the pressure required to meet system demands and losses.

The cylinders have a low initial cost and are not practical to use if there is continuous demand. Cylinders are best suited to intermittent use for short periods of time or as an emergency escape backup for a compressor.

Aftercooler

Some components of the purification system require a specific temperature in order to function properly. Depending on the type of compressor selected and the type of purification necessary, the temperature of the air leaving the compressor may have to be reduced. This is done with an aftercooler.

Aftercoolers can be supplied with cooling water or use air as the cooling medium. Water, if recirculated, is the preferred method. The manufacturer of both the compressor and purification system should be consulted as to the criteria used and the recommended size of the unit.
**Purification Devices**

The contaminants that are problematic for breathing-air systems must be removed. This can be done with separate devices used to remove individual contaminants or with a prepped assembly of all the necessary purification devices, commonly referred to as a “purification system,” which requires only an inlet and outlet air connection. For breathing-air systems it is commonly done with a purification system.

The individual purification methods used to remove specific contaminants are the same as those discussed in the “Compressed-Gas Systems” chapter. For breathing-air, oil and particulates are removed by coalescing and other filters, water is removed by desiccant or refrigerated dryers, and carbon monoxide is removed by chemical conversion to carbon dioxide using a catalytic converter.

**Carbon Monoxide Converter** The purpose of the converter is to oxidize carbon monoxide and convert it into carbon dioxide, which is tolerable in much greater quantities. This is typically accomplished by the use of a catalyst usually consisting of manganese dioxide, copper oxide, cobalt, and silver oxide in various combinations and placed inside a single cartridge. The material is not consumed but does become contaminated. The conversion rate greatly decreases if any oil or moisture is present in the airstream. Therefore, moisture must be removed before air enters the converter. Catalyst replacement is recommended generally once a year since it is not possible to completely control all contaminants that contribute to decreased conversion.

**Moisture Separator** Water and water vapor are removed by two methods, desiccant and refrigerated dryers. The most common desiccant drying medium is activated alumina. For a discussion of air-drying methods, refer to the “Compressed-Gas Systems” systems.

**Odor Remover** Activated, granular charcoal in cartridges is used for the removal of odors.

**Particulates Remover** Particulates are removed by means of in-line filters. Generally accepted practice eliminates particulates 1 μ and larger from the piping system.

**Humidifier** When water is removed from the compressed airstream prior to catalytic conversion, the dryer produces very dry air. If the breathing-air system is intended to be used for long periods of time, very low humidity will dry the mucous membranes of the eyes and mouth. Therefore, moisture must be added to the airstream to maintain recommended levels. Humidifiers, often called “moisturizers,” are devices that inject the proper level of water vapor into an airstream. Some require a water connection.

A recommended level of moisture is 50% relative humidity in the compressed airstream. Care must be taken not to route the air-distribution piping through areas capable of having temperatures low enough to cause condensation. If the routing is impossible to change, a worker will have shorter periods of time on the respirator.

**Combination Respirator Manifold and Pressure Reducer** This is a single component with multiple quick-disconnect outlets providing a convenient place both to reduce the pressure of the distribution network and to serve as a connection point for several hoses. A pressure gauge should be installed on the manifold to ensure the outlet pressure is within the limits required by the respirator.

**Respirator Hose**

The respirator hose is flexible and is used to connect the respirator worn by an individual to the central-distribution piping system. Code allows a maximum hose length of 300 ft (93 m)

**Personnel Respirators**

There are two general categories of respirator used for individual protection: air purifying and supplied air.

The air-purifying type of respirator is portable and has self-contained filters that purify the ambient air on a demand basis. The advantages to its use are that it is less restrictive to movements and is light in weight. Disadvantages are that it must not be used where gas or vapor contami-
tors intended to be used simultaneously and the minimum pressure required by the purification system.

The following general flow rates are provided as a preliminary estimate for various types of respirator. Since there is a wide variation in the pressure and flow rates required for various types of respirator, the actual figures used to size the system must be based on the manufacturer’s recommendations for the specific respirators selected.

1. 4 scfm (113 L/min) for pressure-demand respirators.
2. 6 scfm (170 L/min) for constant-flow respirators.
3. Up to 16 scfm (453 L/min) for flooded-hood respirators.
4. Up to 35 scfm (990 L/min) for flooded suits.
5. Add 15 scfm (425 L/min) of air for suit cooling if used.

**High-Pressure Storage Cylinder** High pressure cylinders are used either to supply air for normal operation to a limited number of personnel for short periods of time or as an emergency supply to provide a means of escape from a hazardous area if the air compressor fails. The main advantage to using cylinders is the air in the cylinders is prepurified, and no further purification of the air is necessary. The number of cylinders is based on the simultaneous use of respirators, the cfm (L/min) of each and the duration, in min, the respirators are expected to be used, plus a 10% safety factor. The total amount of compressed air in the cylinders should not be allowed to decrease too low. A low-pressure alarm should sound when pressure falls to 500 psig (3450 kPa) in a cylinder normally pressurized to 2400 psig (16 500 kPa) when filled to capacity.

Example 9-1 Establish the number of cylinders required for an emergency supply of air for 8 people using constant-flow respirators require 15 min to escape the area.

1. 8 x 6 x 15 = 720 scfm + 72 (10%) = 792 scfm total required
2. Next, find the actual capacity of a single cylinder at the selected high pressure, generally 2400 psi (16 500 kPa), and divide the capacity of each cylinder into the total scfm required to find the number of cylinders required.
3. If I cylinder has 225 scf, 792 ÷ 225 = 3.5. Use 4 cylinders.

**Purification Components**
The air used to fill breathing-air cylinders is purified before being compressed. Breathing air produced by air compressors requires purification to meet minimum code standards for breathing air.

Prior to the selection of the purification equipment, several samples of the air where the compressor intake is to be located should be taken so specific contaminants and their amounts can be identified. The ideal situation is to have the tests taken at different times of the year and different times of the day. These tests quantify the type and amount of contaminants present at the intake. With this information known, the purification systems needed to meet code criteria can be chosen. The other requirement is the highest flow rate that can be expected. With these criteria, the appropriate size and types of purifier can be selected.

The most commonly used method of purification is an assembly of devices called a “purification system” specifically chosen and based on the previously selected criteria. Manufacturers’ recommendations are commonly followed in the selection and sizing of the assembly.

**Carbon-Monoxide Converter** The requirement for installation of a carbonmonoxide converter is rare. The need for a converter is based on tests of the air at the proposed location of the compressor intake. Another source of information is the EPA, which has conducted tests in many urban areas throughout the country. Another indication that installation may be necessary is the use of a non-oil-free compressor. Good practice requires the installation of a converter if there is an outside chance the level of carbon monoxide may rise above the 10 ppm limit set by code.

The converter is sized based on the flow rate of the system.

**Coalescing Filter/Seperator** The coalescing filter/separator is a single unit that removes large oil and water drops and particulates from the airstream before the air enters the rest of the system. It is selected on the basis of maximum system pressure, flow rate, and the expected level of contaminants leaving the air compressor, using manufacturer’s recommendations. If an oil-free compressor is used, a simple particulate filter could be substituted for the coalescing filter.

**Dryers (Moisture Separators)**

**Desiccant Dryers** — The two types of desiccant media dryer most commonly used are the single-bed dryer, which is a disposable cartridge, and the continuous-duty, two-bed dryer.

When two-bed dryers are used, a portion of the air from the compressor is used for drying one bed while the other is in service. The compressor must be capable of producing enough air for both the system and dryer use.

The single-bed dryer has a lower first cost but a higher operating cost. The disposable cartridge often is combined with other purification devices into a single, prepiped unit. An indicator is often added to the media so the need for replacement is indicated by a color change.

Disposable units are best suited for short durations or occasional use, such as for replacement of a main unit during periods of routine service. Because of their generally small size, only a limited number of respirators can be supplied from a single unit. Other considerations are that these disposable units have a limited capacity, in total cfm, they can process. Manufacturers’ recommendations must be used in the selection of the size and number of replacement cartridges required for any application.

The two-bed unit, commonly called a “heatless dryer,” is similar in principle to that discussed in the “Compressed-Gas Systems” chapter. Such units are used for continuous duty.

The two factors contributing to the breakdown of media are fast-drying cycles and high air velocity. If a desiccant dryer is selected, the velocity of air through the unit shall conform to manufacturer’s recommendations. Velocity should be as low as is practical to avoid fluidizing the bed. High velocity requires more cycles for drying, which means wasting more air. If the size of the dryer is a concern, more drying cycles mean smaller dryer beds. Longer drying cycles reduce component wear.

**Refrigerated Dryers** — Refrigerated dryers are used if there is no requirement for a nitrous oxide converter and if the 35–39°F dew point produced is 10°F below the lowest ambient air temperature where any pipe will be installed. The refrigerated dryer is less efficient than the desiccant dryer. Its advantages are that all the air produced by the compressor is available to the system and it has a lower pressure loss.

When refrigerated dryers are preferred, several purification devices are often combined into a single unit, including the refrigeration unit, filter/separator for oil and water, and a charcoal filter for odor removal. This unit produces air that is lower in temperature than the inlet air. If the breathing-air distribution piping is to be routed through an area of lower temperature, the pressure dew point of the air must be reduced to 10°F lower than the lowest temperature expected.

**Odor Remover** Odors are not usually a problem, but their removal is provided for as a safeguard. The activated charcoal cartridges remove odors are selected using manufacturers’ recommendations based on the maximum calculated flow rate of the breathing-air system. The cartridges must be replaced periodically.

**Humidifiers**

Often called a “moisturizer,” a humidifier is required to increase the relative humidity of the breathing air to approximately 50% if required. The unit is selected using the increase in moisture required for the airstream and the flow rate of air. Caution must be used so as not to increase the dew point of the compressed air above a temperature 10°F lower than the lowest temperature in any part of the facility the pipe is routed through.

**Respirator Hose**
The respirator hose most often used to connect the respirator worn by an individual to the central-distribution piping system is 38 in. (10
mm) in size. Code allows a maximum hose length of 300 ft (93 m). The most common lengths are between 25 and 50 ft (7.75 and 15.5 m).

**System Sizing Criteria**

**System Pressure** The outlet pressure of the compressor shall be within the range required by the purification system. Typically, the pressure is approximately 100 psi (70.3 kg/cm²). The precise range of pressure and flow rate shall be obtained from the purification system manufacturer selected for the project.

The pressure in the distribution system should be as high as possible to reduce the size of the distribution-piping network. Code requires the pressure be kept below 125 psi (88 kg/cm²). The distribution-piping pressure range is usually 90 to 110 psig (620 to 760 kPa) available in the system after the purifier.

The pressure required at the respirator ranges from approximately 15 psig for pressure-demand respirators to 80 psig for full-flooded suits that require cooling. The actual requirements can be obtained only from the manufacturer of the proposed equipment because of the wide variations possible. Pressure-regulating valves shall be installed to reduce the pressure to the range acceptable to the respirator used. Often, this reduction is done at the respirator manifold, if one is used, or, if a single respirator type with a single pressure is used throughout the facility, a single regulator can be installed to reduce the pressure centrally.

**Pipe Sizing and Materials** The most commonly used pipe is type L copper tubing, with wrought copper fittings and brazed joints.

For pipe sizing, follow the sizing procedure discussed in the “Compressed-Gas Systems” chapter. The number of simultaneous users must be obtained from the facility. No diversity factor should be used.

**Alarms and Monitors**

The following alarms and monitors are often provided:

**CO Monitor** Usually included as a built-in component, this monitor measures the CO content of the airstream and sounds an alarm when the level reaches a predetermined high set point.

**Oxygen-Deficiency Monitor** Used as a precautionary measure in an area where respirators are not normally required, the oxygen monitor measures the oxygen content of the air in a room or other enclosed area and sounds an alarm to alert personnel when the level falls below a predetermined level. Usually, several alarm points are annunciated prior to reaching a level low enough to require the use of respirators.

**Low-Air-Pressure Monitor** The low-air-pressure monitor must sound an alarm when the pressure in the system reaches a predetermined low point. This set point allows the users of the breathing-air system to leave the area immediately while still being able to breathe from the system. For cylinder storage, this set point is about 500 psig in the cylinders. For a compressor system, the alarm should sound when the pressure falls to a point 10 psig below the pressure set to start the compressor. This should also switch over to the emergency backup supply if one is used. If no backup is used, the pressure set point shall be 5 psig higher than the minimum required by the respirators being used.

**Dew-Point Monitor** A dew-point monitor is used to measure the dew point and sound an alarm if it falls to a low point, set by a health officer, that might prove harmful to the users. It is required to alarm if the dew point reaches a point high enough to freeze in some parts of the system.

**High-Temperature Air Monitor** Some purifiers or purifier components will not function properly if the inlet air temperature is too high. The set point is commonly 120° F but will vary among different manufacturers and components.

**Failure-to-Shift Monitor** This monitor is placed on desiccant dryers to initiate an alarm if the unit fails to shift from the saturated dryer bed to the dry bed when regeneration is required.
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**CE Questions — “Life-safety Systems” (PSD 183)**

1. Which of the following is a type of emergency drench equipment?
   a. face wash
   b. eyewash
   c. drench hose
   d. all of the above

2. The spray pattern of an emergency shower shall be ________ minimum in diameter.
   a. 16 inches
   b. 20 inches
   c. 30 inches
   d. 60 inches

3. ________ are the most-often-used type of activation device on drench equipment.
   a. ball valves
   b. disc valves
   c. gate valves
   d. none of the above

4. Drench hoses require a minimum operating pressure of ________.
   a. 15 psig
   b. 30 psig
   c. 105 kPa
   d. both a and c

5. The minimum pipe size for a combination unit is ________.
   a. ½ inch
   b. 1 inch
   c. 1¼ inches
   d. 2 inches

6. For a wheelchair-accessible combination unit, the handle for the shower valve shall be located ________ from the floor.
   a. 33 inches
   b. 45 inches
   c. 48 inches
   d. 60 inches

7. The most common operating range for breathing-air systems is ________.
   a. 90–110 kPa
   b. 250 psig
   c. 90–110 psig
   d. 1,725 kPa

8. What is the most toxic contaminant of a breathing-air system?
   a. carbon dioxide
   b. carbon monoxide
   c. oil
   d. water

9. Which of the following is a type of breathing-air system?
   a. constant flow
   b. demand flow
   c. pressure demand
   d. all of the above

10. Which of the following is included in a breathing-air system?
    a. humidifiers
    b. respirators
    c. purification devices
    d. all of the above

11. A ________ is used to reduce the temperature of the air leaving an air compressor.
    a. humidifier
    b. aftercooler
    c. cooling tower
    d. none of the above

12. What is the maximum length of a respirator hose?
    a. 100 feet
    b. 200 feet
    c. 300 feet
    d. 400 feet
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### Life-safety Systems (PSD 183)

**Questions appear on page 12. Circle the answer to each question.**

- **Q 1.** A B C D
- **Q 2.** A B C D
- **Q 3.** A B C D
- **Q 4.** A B C D
- **Q 5.** A B C D
- **Q 6.** A B C D
- **Q 7.** A B C D
- **Q 8.** A B C D
- **Q 9.** A B C D
- **Q 10.** A B C D
- **Q 11.** A B C D
- **Q 12.** A B C D

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### Appraisal Questions

**Life-safety Systems (PSD 183)**

1. Was the material new information for you? [ ] Yes [ ] No
2. Was the material presented clearly? [ ] Yes [ ] No
3. Was the material adequately covered? [ ] Yes [ ] No
4. Did the content help you achieve the stated objectives? [ ] Yes [ ] No
5. Did the CE questions help you identify specific ways to use ideas presented in the article? [ ] Yes [ ] No
6. How much time did you need to complete the CE offering (i.e., to read the article and answer the post-test questions?)