
CHAPTER 17

LIFE SAFETY SYSTEMS

GENERAL

An often present threat to personnel safety in 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, and breathing air systems that supply air to personnel for escape and protection when exposed to either a toxic environment resulting from an accident or normal working conditions that make breathing the ambient air hazardous.

EMERGENCY DRENCH EQUIPMENT

GENERAL

When toxic or corrosive chemicals come in contact with the eyes, face, and body, flushing with water for 15 min with 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 volume of water sufficient to effectively reach any area of the body that has been exposed to or has come into direct contact with any injurious material. Within facilities, this is accomplished by means of specially designed emergency drench equipment, such as showers, drench hoses, and eye and face washes located adjacent to all such hazards. Although the need to protect personnel is the same for any facility, specific requirements will differ widely because of architectural, aesthetic, location, and space constraints necessary for various industrial and laboratory installations.

SYSTEM COMPONENTS

Emergency drench equipment consists of showers, eyewash units, facewash units, and drench hoses along with interconnecting piping and alarms if required. Each of these units is available either singly or in combination with each other.

SYSTEM CLASSIFICATIONS

Drench equipment is classified into two general kinds of systems based on the source of water. They 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 fed* or *air pressurized*.

Another type of self-contained eyewash unit is available that does not meet code requirements for storage or delivery flow rate. These units are called *personnel eyewash stations* and are selected only to supplement, not replace, standard eyewash units. They consist of 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: Various regulations for specific industries pertaining to location and other criteria for emergency eyewashes and showers

3. SEI: Safety Equipment Institute certified equipment that meets ANSI standards
4. Applicable plumbing codes.
5. Code of Federal Regulations (CFR), Chapter 29.

In future discussions in this section, the reference to “code” on drench equipment refers to ANSI Z-358.1.

TYPES OF DRENCH EQUIPMENT

Each piece of equipment is designed to perform a specific function. Each piece is not intended to be a substitute for another but rather, to complement the other pieces to provide additional availability of water to specific areas of the body where required.

Emergency Showers

Plumbed Showers. Plumbed emergency showers are permanently connected to the potable water piping and designed to supply enough water continuously to drench the entire body. The unit consists of a large-diameter showerhead intended to distribute water over a large area. The most commonly used type has a control valve with a handle extending down from the valve on a double chain or single rod that is used to turn water manually off to on in 1 second. Code requires that the shower be capable of delivering a minimum of 20 gpm (75.7 Lpm) of evenly dispersed water at a velocity low enough so as not to be injurious to the user. The minimum spray pattern shall have a diameter of 20 in (50.8 cm) diameter, measured at 60 in (152.4 cm) above the surface upon which the user stands. This requires a minimum pressure of 30 psi (4.47 kPa). Emergency showers can be ceiling mounted, wall mounted, or floor mounted on a pipe stand, with the center of the spray at least 16 in (40.6 cm) from any obstruction. Showers should be chosen for the following reasons:

1. When large volumes of potentially dangerous materials are present
2. Where a small volume of material could result in large affected areas, such as in laboratories and schools
3. Where an accident involving corrosive material may result in full body exposure
4. It shall be located within 10 seconds or 100 ft (33 m) of the hazard.

A typical emergency showerhead is mounted in a hung ceiling is illustrated in Fig. 17.1. Since free-standing emergency showers only are rarely installed, a free-standing combination showerhead and eye-face wash is illustrated in Fig. 17.2.

Self-Contained Showers. A self-contained emergency shower has a storage tank for water. Often this water is heated. The shower shall be capable of delivering a minimum of 20 gpm (75.5 Lpm) for 15 min. The mounting height and spray pattern requirements are the same as for plumbed showers.

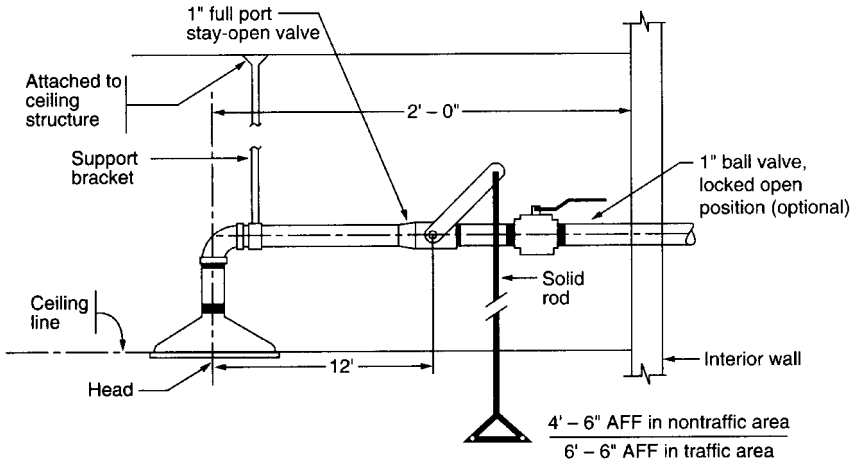


FIGURE 17.1 Detail of typical emergency shower.

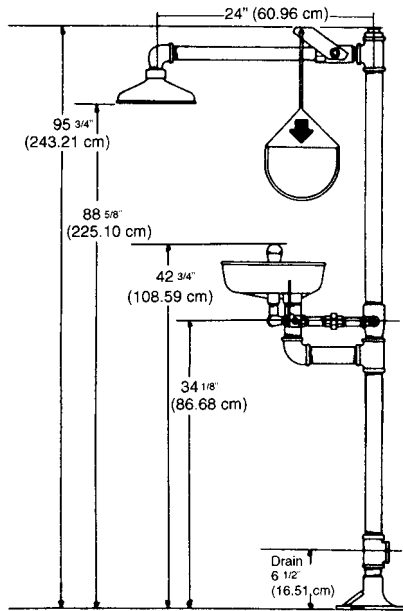


FIGURE 17.2 Detail of typical combination shower, eyewash, and drench shower.

Emergency Eyewash

Plumbed Eyewash. Emergency eyewashes are specifically designed to irrigate and flush both eyes simultaneously with a dual stream of water. The unit consists of dual heads in the shape of a U specifically designed to deliver a narrow stream of water, and a stay-open valve usually controlled by a large push plate. The stream configuration is illustrated in Fig. 17.3. Code requires that the eyewash be capable of delivering a minimum of 0.4 gpm (1.5 Lpm). Many eyewashes of recent manufacture deliver approximately 3 gpm (11.4 Lpm). 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. The eyewash can be mounted on a counter, on a wall, or as a free-standing unit secured to the floor. The eyewash could be provided with a bowl. The bowl does not increase efficiency or usefulness of the unit but aids in identification by personnel and provides a drain path to the floor.

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 that dispenses a measured amount of solution when flow to the eyewash is activated. A backflow device shall be installed on the water supply. A typical free-standing eyewash is illustrated in Fig. 17.4.

Self-Contained Eyewash. A typical self-contained eyewash has a storage tank with a minimum 15-min water supply and is illustrated in Fig. 17.5. The mounting height and spray pattern requirements are the same as for plumbed eyewashes.



FIGURE 17.3 Stream from typical eyewash.

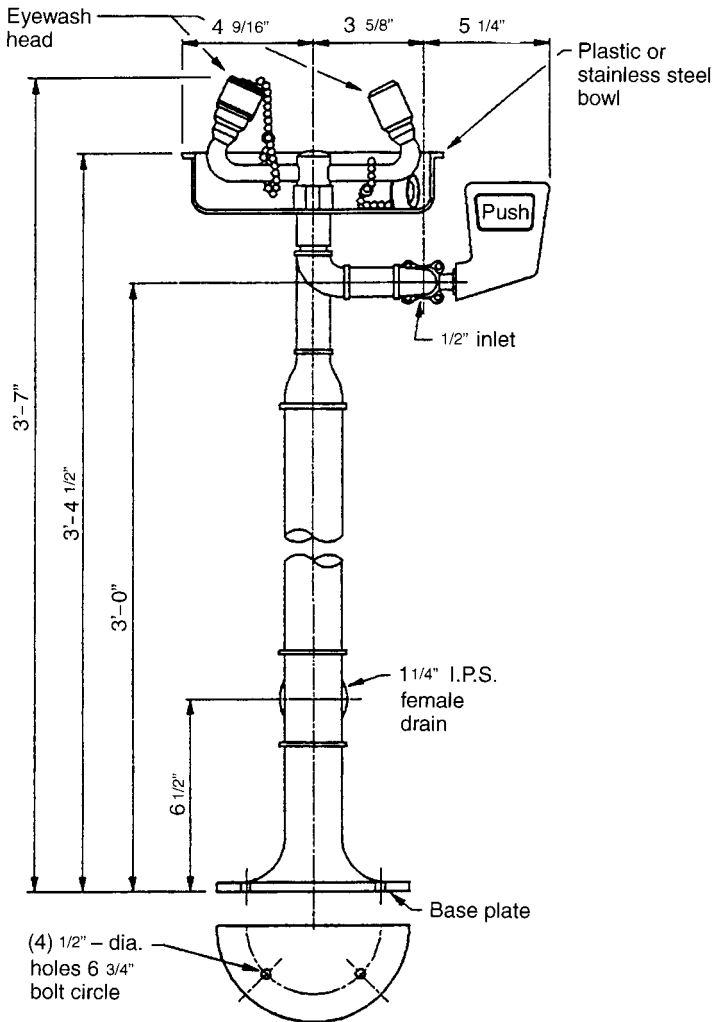


FIGURE 17.4 Detail of free-standing eye or face wash.

Emergency Facewash

The facewash is an enhanced version of the eyewash. It has the same design requirements and configuration except that the spray heads are specifically designed to deliver a larger water pattern and volume that will flush the whole face and not just the eyes. The facewash should deliver approximately 5–8 gpm (36–55 Lpm). The stream configuration is illustrated in Fig. 17.6. Very often, the facewash is chosen for combination units. In general, the facewash is more desirable than the eyewash because it is very likely that an accident will affect more than just the eyes. All dimensions and requirements of the free-standing facewash are similar to the eyewash, illustrated in Fig. 17.4.



FIGURE 17.5 Portable eyewash.



FIGURE 17.6 Stream from typical face-wash.

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 similar to that found on a eye-face wash. Code requires that the drench hose be capable of delivering a minimum of 0.4 gpm (1.5 Lpm). 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 a shower and eye-face wash to irrigate specific areas of the body. Drench hoses are selected for the following purposes:

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 having the clothing removed while simultaneously using the emergency shower

A drench hose is not considered as a substitute for any emergency equipment.

Combination Equipment

Combination equipment consists of multiple-use units with a common water supply and supporting frame. Combinations are available that consist of shower, eye-face wash, or drench hose in any configuration. The reason for the use of combination equipment is usually economy, but the selection should consider the type of irrigation potential for injuries that might occur at a specific location. For combination units, the water supply must be larger and 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 facewash. Figure 17.7 illustrates a combination shower, eye-face wash, and drench hose.

INSTALLATION REQUIREMENTS FOR DRENCH EQUIPMENT

The need to provide emergency drench equipment is determined by an analysis of the hazard by design professionals, health or safety personnel, and the use of common sense in conformance to OSHA, CFR, and other regulations for specific occupations. Judgment is necessary in the selection of equipment and its location. Very often, facility owners have specific regulations for their need and location.

Dimensional Requirements

The standard range of mounting heights as illustrated in ANSI Z-358.1 are shown in Fig. 17.8. If the showerhead is free-standing, the generally accepted dimension for the mounting height is 7 ft, 0 in (2.17 m) above the floor. Figure 17.13 illustrates a wheelchair-accessible, free-standing combination unit. Generally accepted clearance around showers and eye-face washes is illustrated in Fig. 17.9.

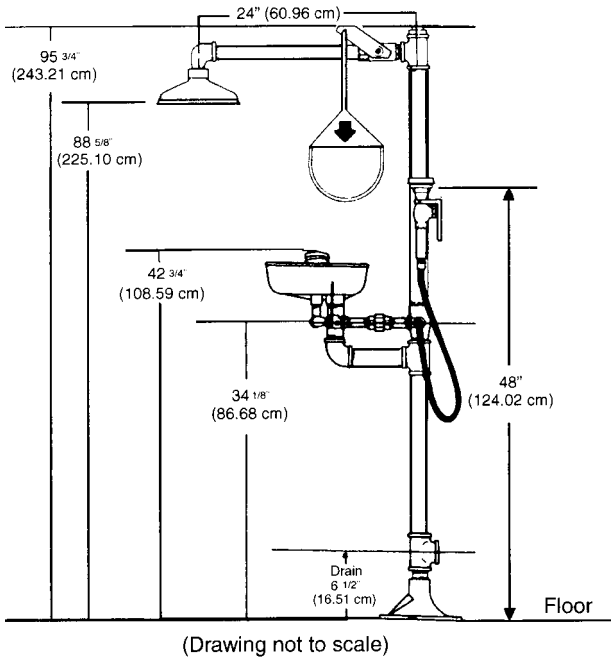


FIGURE 17.7 Detail of combination emergency shower, eye-face wash, and drench hose.

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 hazard as practical without being affected by the hazard itself or by potential accidental conditions such as a large release or spray of chemicals resulting from an explosion or a pipe and tank rupture. In addition, drench equipment must not be placed adjacent to electrical equipment. Location along normal access and egress paths in the work area will reinforce the location to personnel as they see it each time they pass it.

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 that emergency showers be located a maximum distance of either 10 seconds' travel time by an individual or no more than 100 ft (30.5 m) from the protected hazard, whichever is shorter. It is recommended that a distance of 75 ft (21 m) be used. If strong acid or caustic is used, the equipment should be located within 10 ft (3 m) from the source of the hazard. The path to the unit from the hazard shall be clear and unobstructed, so that 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 s. There is also no specific provisions for the handicapped.

Since there are no specific code requirements for locating drench equipment, good judgment is required. Accepted practice is to have the equipment accessible

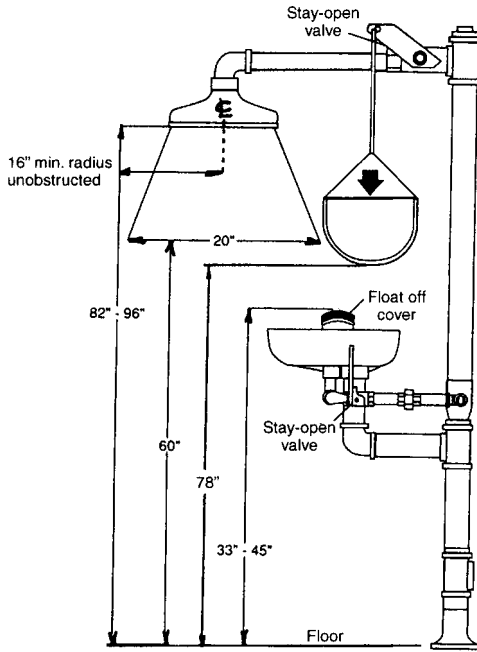


FIGURE 17.8 Code dimensions for wheelchair-accessible shower and eyewash mounting height.

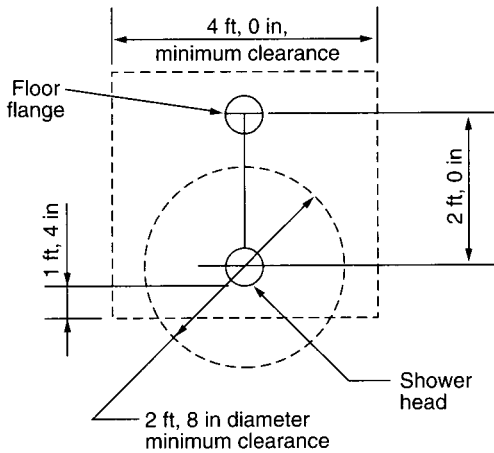


FIGURE 17.9 Clearance dimensions in plan for shower and eye-face wash.

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 hazard when possible. Traveling through rooms that may have locked doors to reach equipment shall be avoided, except that placing emergency showers in a common corridor, such as outside individual laboratory rooms, is accepted practice. Care should be taken not to locate the shower in the path of the swinging door to the protected room to avoid personnel who are coming to the aid of the victim from knocking the victim over.

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

Number of Stations

The number of drench equipment devices provided in a facility is a function of the type of hazard and number of people in rooms and areas exposed to any particular hazard at any one time, using a worst-case scenario. It is rare that more than one combination unit will be installed. It is important to consider that if a group of individuals may be exposed to a specific hazard, more than one drench unit may be required. Consulting with the end user and safety personnel 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 mandates the temperature of water supplied to equipment shall be “tempered.” A range of 60 to 95°F (15 to 35°C) is suggested. Medical authorities recommend irrigation of chemical burns with 78 to 92°F (26 to 33°C) water. For a dedicated indoor system, this temperature range is achieved because the interior of a facility may be 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 (29°C) has been established as a “comfort zone” and is the most desirable water temperature.

The body will attempt to generate body heat lost if the drenching fluid is below the comfort zone. The common effect is shivering and increased heart rate. In fact, most individuals are uncomfortable taking a shower with water below 60°F (15°C). With the trauma induced by the 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 to prevent pores from opening 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 stagnant water supplying the showers may become too cold and must be tem-

pered. Manufacturers offer a variety of tempering methods, including water temperature maintenance cable similar to that used for domestic hot water, fail-safe blending systems, and heat exchangers. In remote locations, complete self-contained units are available with tanks storing and maintaining heated water. OSHA reserves the right to cite in cases where individuals run away from drench water streams due to cold water temperatures.

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 electric heating cable and providing insulation around the entire water supply pipe and the unit itself. Recommended water temperature should be maintained at 75°F (24°C). Refer to Chap. 5 for the design of the freeze protection system.

For exterior showers located where freezing is possible, the water supply shall be installed below the frost line and a frost-proof shower installed. This type of shower has a method for draining the water above the frost line when the water to the drench equipment is turned off. A typical frost-proof emergency shower and eyewash is illustrated in Fig. 17.10.

When a number of drench equipment devices are located where low temperature is common, a circulating tempered water supply should be considered (Fig. 17.11). This uses a hot water heater and a circulating pump to supply the drench equipment. The heater shall be capable of generating 30 gpm (or more if more than one shower could operate simultaneously) of water from 40 to 85°F (4 to 29°C) with a low temperature of 78°F (26°C).

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

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 to remove clothing or hold eyelids open. The valves most often used are ball valves with handles modified to provide for the attachment of chains, rods, and push plates. In very limited situations, such as in schools, valves that automatically close (quick closing) are permitted if acceptable to the facility and authorities having jurisdiction.

Valves are operated by different means to suit the specific hazard, location, durability, and visibility requirements. Operators for valves are handles attached to pull rods, push plates, and foot-operated treadle plates and triangles. A solid pull rod is often installed on concealed showers in order to push the valve closed after operation. Another method could be to have two handles attached to chains that extend below the hung ceiling, one to turn the valve on and another handle to turn it off. This is illustrated in Fig. 17.12. Chains are used if the handle might be accidentally struck, enabling the handle to move freely and not injure the individual striking the hanging operator.

Operating handles for a handicapped-accessible unit are mounted lower than for a standard unit. In many cases, this will require that operating handles be placed

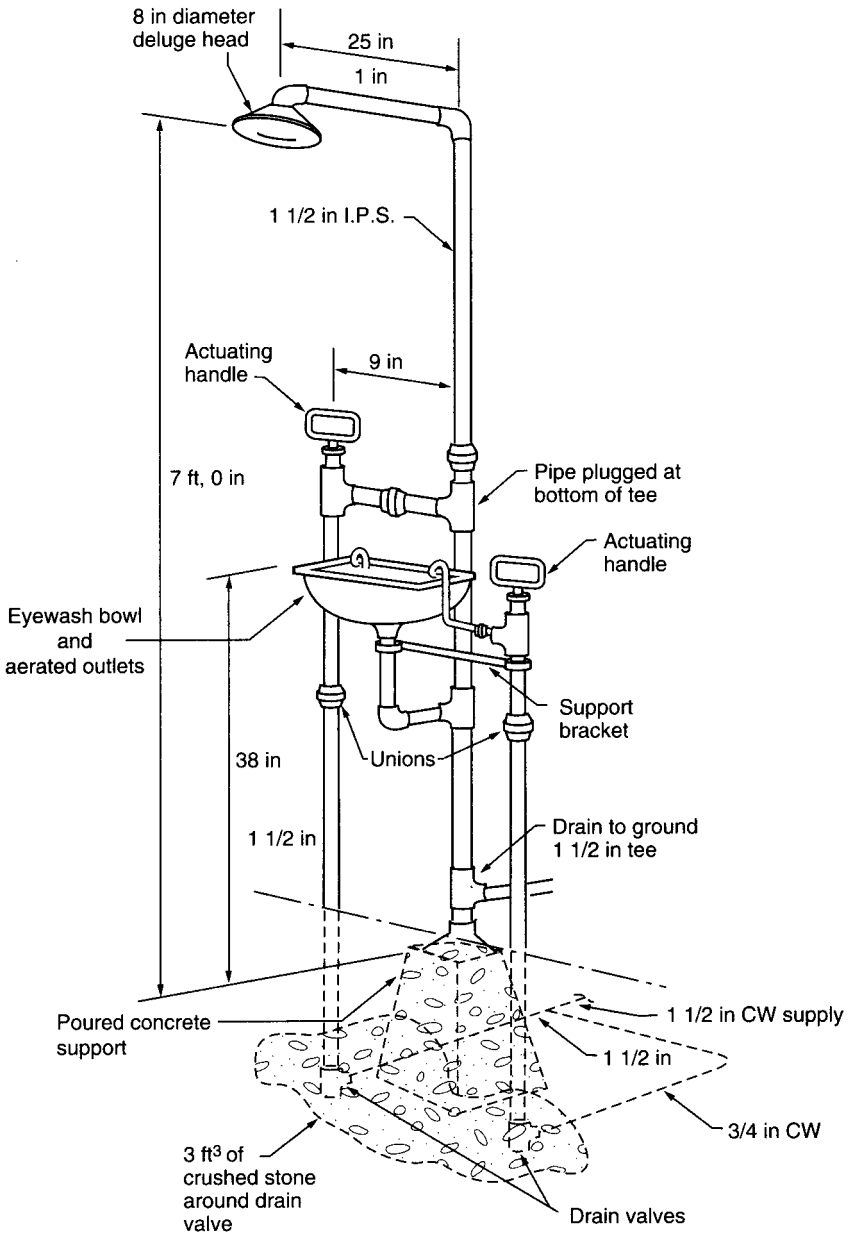


FIGURE 17.10 Typical frost-proof emergency shower and eyewash. *Note:* Provide shutoff valve in supply line in adjacent building. Where there is no building nearby, provide valve in supply line underground with curb box.

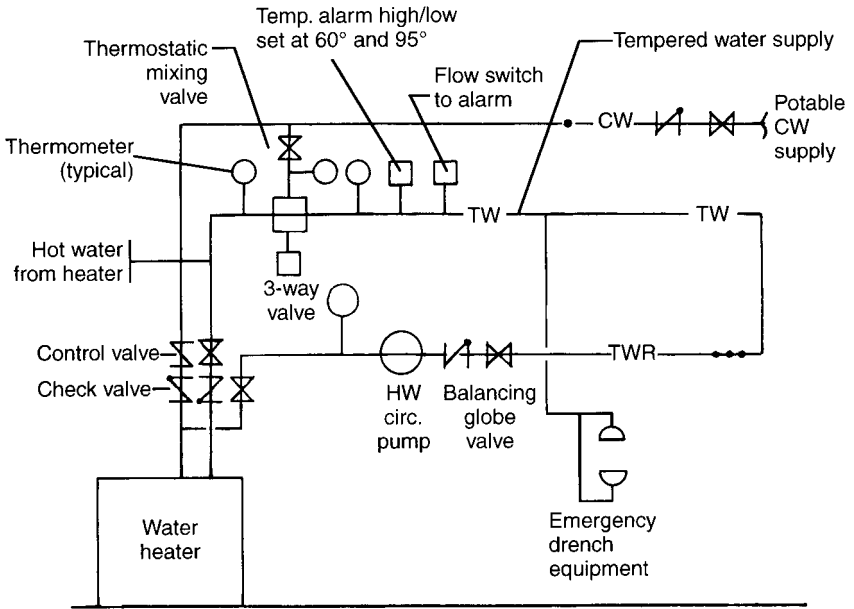


FIGURE 17.11 Schematic detail of central tempered water emergency shower supply. Note that one alarm could be a horn or light in occupied area. Normal temperature is 70°F (18°C). High temperature is 95°F (38°C). Low temperature is 60°F (15°C).

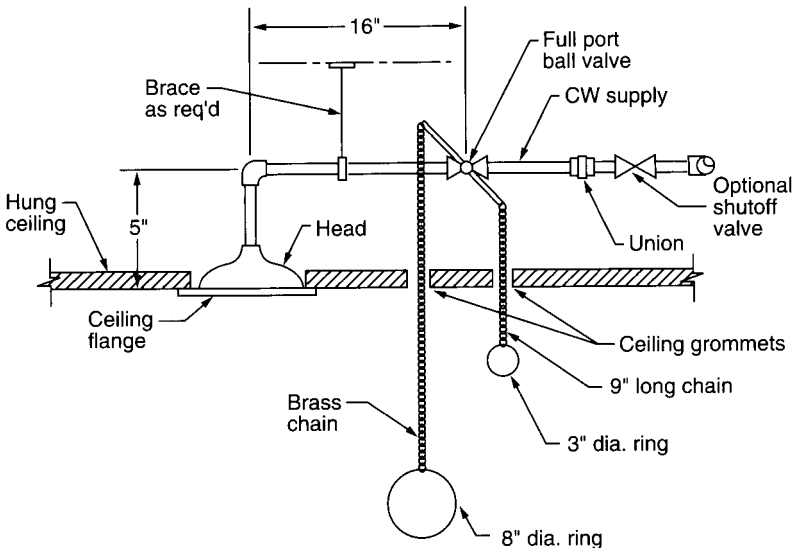


FIGURE 17.12 Typical emergency shower with two control rods in hung ceiling.

near walls to keep them out of traffic patterns where they would be an obstruction to able-bodied people passing under them. A free-standing, handicapped-accessible combination shower and eyewash using handles hung from the ceiling is illustrated in Fig. 17.13. The handle must be located close enough to the center of the shower to be easily reached, which is about 2 ft, 0 in from the center of the shower. Another method using a wall attached chain is illustrated in Fig. 17.14.

Alarms

Alarms are often installed to alert security or other rescue personnel that emergency drench equipment has been operated and to guide them rapidly to the scene of the accident. Commonly used alarms are audible and visual devices, such as flashing or rotating lights on top of, or adjacent to, a shower or eyewash and electronic alarms wired to a remote security panel. Remote areas of a plant are particularly at risk if personnel often work alone. Alarms are most often operated by a flow

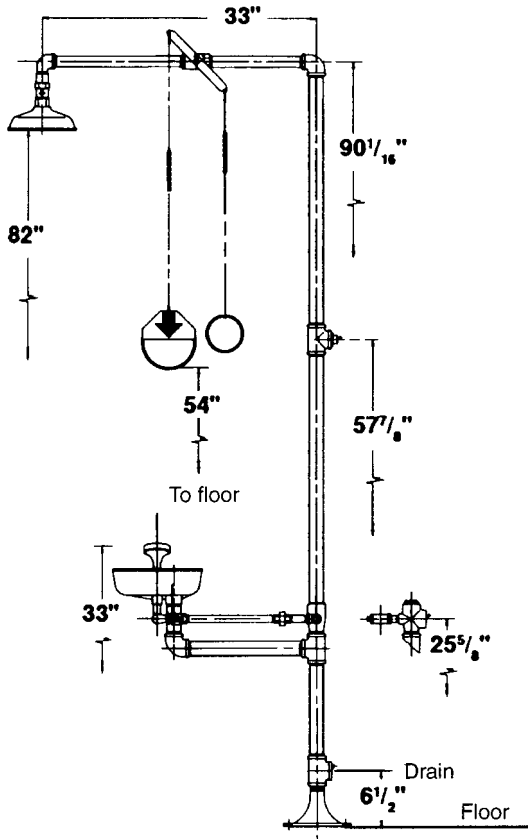


FIGURE 17.13 Handicapped-accessible free-standing combination emergency shower and eyewash.

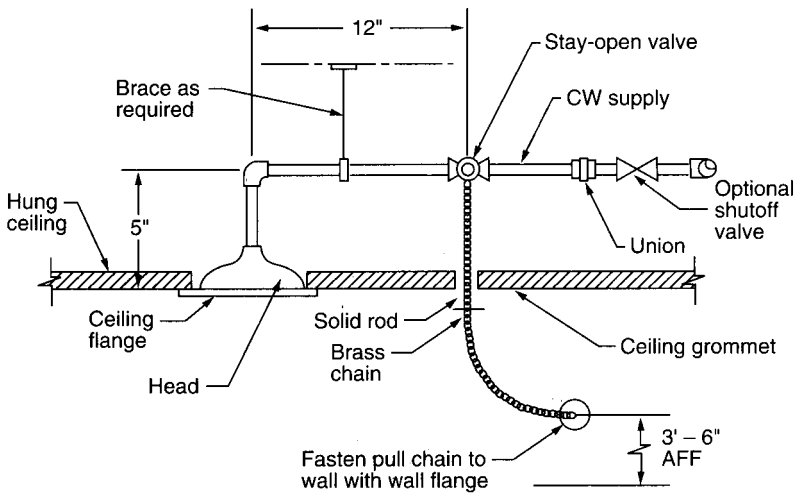


FIGURE 17.14 Detail of combination emergency shower in hung ceiling with wall attached chain operator.

switch activated by the flow of water when a piece of equipment is used, proximity switches, switches mounted on push plates, and on shower pull chains or rods. When tempered water systems are used to supply drench equipment, a low water temperature of 60°F shall cause an alarm annunciation.

Flow Control

If water pressure exceeds 80 psig (550 kPa) or if the difference in water pressure between the first and last shower head is more than 20 psig (140 kPa), it is recommended that a self-adjusting flow control device be installed in the water supply pipe. The purpose of this device is to limit the flow to just above the minimum required by the specific manufacturer to function properly. Flow control devices are considered important because a shower installed at the beginning of a long run will have 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 (189 Lpm). If there is no floor drain provided, the higher flow for 15 mm at the higher pressure could produce a much greater amount of water that must be cleaned up and disposed of afterward. Drench hoses and eye- and face-washes are not affected because of their lower flow rates and flow head design.

Where a pressure-reducing device is required for an entire system, it should be set to provide approximately 50 psig (345 kPa) at the most remote shower.

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 that have an attached eye-face wash will also discharge that water onto 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 that in most cases, particularly in schools and laboratories, it is easier to mop up water from the floor in the rare instances that emergency devices are used. Considerations are:

1. Is the drain in an area where frequent cleaning is done, so that the trap will not 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?

VISIBILITY OF DEVICES

High visibility must be considered in the selection of any device. Usually selected recognition methods are high-visibility signs mounted at or on the device, surrounding floors and walls painted a contrasting, bright color, specifically colored indicator lights, and a bright, well-lit area on a plant floor to help a victim identify the area and help in first aid activities. Color blindness should also be considered in color selection.

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 required for standard plumbing systems.

The water supply must provide an adequate size pipe and sufficient pressure to overcome system and device operating pressure requirements in order to function satisfactorily. One maintenance requirement is to regularly flush the water in the piping system to avoid bacterial growth.

It is common practice to add antibacterial and saline products into 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 locked open to prevent unauthorized shutoff.

Water Supply Pressure and Flow Rates

Emergency showers require a minimum of 20 gpm (76 Lpm), 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 minimum flow rate of 3 gpm (12 Lpm) at the furthest unit. Maximum pressure is similar to that for showers. Facewash and drench hoses require a minimum operating pressure of 30 psig (210 kPa) with a minimum flow rate of between 5–8 gpm (36–55 Lpm) at the farthest unit.

System Selection

Plumbed System. The advantages of the plumbed systems are:

1. The systems are permanently connected to a supply of water, and minimum testing of the devices is needed to assure proper operation.
2. The systems provide an unlimited supply of water, often at larger volumes compared to self-contained units.

Disadvantages are:

1. The first cost is higher than for a self-contained system.
2. These systems are maintenance intensive. They require flushing, often into a bucket, to remove stagnant water in the piping system, which is replaced with fresh water.

Self-Contained System. Advantages of the self-contained system:

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 wastewater.
4. Units are portable and can be moved to areas of greatest hazard with little difficulty.
5. Gravity eyewash is more reliable. The water supply can be installed where there is room above the unit. If not, a pressurized unit mounted remotely should be selected.

Disadvantages:

1. Only a limited supply of water at a lesser flow rate is available.
2. Stored liquid must be changed on a regular basis to maintain purity.

The plumbed system is the most often selected type of system because of the unlimited water supply.

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 (32 DN) recommended. If the device is a combination unit, 1½-in (40 DN) size should be considered as minimum. Emergency eye-face wash requires a minimum ¾-in (20 DN) 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 assure that the hydraulically most remote unit is supplied with adequate pressure with the size selected. Adjust sizes accordingly to meet friction loss requirements. PRVs shall be installed if required.

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, which is 20 gpm (75 Lpm) for an emergency shower. Piping is usually a 1½ or 2 in (40 or 50 DN) header of copper pipe, for the entire length of a plumbed system.

BREATHING AIR

GENERAL

Breathing air systems supply air of specific minimum purity to personnel for purposes of escape and protection when exposed 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 will discuss 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 of 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 the breathing air system is common to that for medical-surgical air discussed in Chap. 14, “Compressed Gases.”

CODES AND STANDARDS

1. OSHA, 29 CFR 1910
2. CGA, Commodity Specification G-7 and G-7.1
3. CSA, Canadian Standards Association
4. NIOSH, National Institute of Occupational Safety and Health
5. MSHA, Mine Safety and Health Act
6. NFiPA, NFPA-99 Medical Compressed Air
7. DOD, Where applicable
8. ANSI, Z-88.2 Standard for Respiratory Protection
9. CFR, Code of Federal Regulations

SYSTEM COMPONENTS

The supplied air category of respirators uses compressed air cylinder(s) or an air compressor, air purifying equipment at the source, and central piping system. Respirators are connected to the cylinder or distribution piping system.

TYPES OF SYSTEMS

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

Constant Flow

Also known as *continuous flow*, constant flow systems provide an uninterrupted flow of purified air through personal respirators to minimize 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 wide variety of areas ranging from least harmful to most toxic depending on the type of respirator selected.

Demand Flow

The demand flow system provides an interrupted supply of purified air to respirators during inhalation. Upon exhalation, the flow of air is shut off until the next breath. Demand flow systems automatically adjust to an individual's breathing rate. This system requires tight-fitting respirators. Their application is generally limited to less harmful areas because the negative pressure in the respirator during inhalation may permit leakage of external contaminants. These systems are designed for economy of air use during relatively short duration tasks and are usually supplied from cylinders.

Pressure Demand

A pressure demand system delivers purified air continuously through personal respirators with increased airflow 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.

TYPES OF PERSONAL RESPIRATORS

There two general categories of respirators used for individual protection: air purifying and supplied air. The air purifying category of respirator is portable and has self-contained filters that purify the ambient air on a demand basis. The advantages to their use are that they are less restrictive to movements and they are light in weight. Disadvantages are that they must not be used where gas or vapor contamination cannot be detected by odor or taste or where the atmosphere is oxygen deficient. This type of respirator is outside the scope of this book, and is mentioned only because of its availability.

The type of respirator selected depends on the expected breathing hazards. When choosing a respirator, the highest expected degree of hazard, applicable codes and standards, manufacturer recommendations, suitability for the intended task, and comfort of the user are all important considerations.

The EPA Office of Emergency and Remedial Response has identified four levels of hazards at cleanup sites involving hazardous materials and lists guidelines for the selection of protective equipment:

1. Level A calls for maximum available protection requiring a positive pressure, self-contained suit, generally with a self-contained breathing apparatus worn inside the protective suit.

2. Level B protection is required when the highest level of respiratory protection is needed but a lower level of skin protection is acceptable.
3. Level C uses full facepiece, air-purifying respiratory protection with chemical-resistant, disposable garments. This is required when the contaminant is known and the level is relatively constant. Typical of the uses are asbestos removal projects.
4. Level D protection is used where special respiratory or skin protection is not required but a rapid increase of contaminant level or degradation of ambient oxygen content is possible.

If the hazard cannot be identified, it must be considered an immediate danger to life and health (IDLH). This condition exists when the oxygen content of the air falls below 12.5 percent (95 ppm O₂) or where the air pressure is less than 8.6 psi (450 mm Hg), which is the equivalent of 14,000 ft (4270 m).

There are five general types of respirators available as follows.

Mouthpiece Respirators

Used only with demand-type systems, mouthpiece respirators are designed only to deliver breathable air. They offer no protection to the skin, eyes, or face. Their use is limited to only those areas where there is insufficient oxygen and no other contaminants that could affect the eyes and skin. A mouthpiece respirator is illustrated in Fig. 17.15.

Half Facepiece Respirators

Half facepiece respirators cover the nose and mouth and are designed primarily for demand and pressure systems. They are usually tight-fitting and provide protection for extended periods of time in atmospheres not harmful to eyes and skin. Often worn with goggles, these respirators are limited to areas of relatively low toxicity. A half facepiece respirator is illustrated in Fig. 17.16.

Full Facepiece Respirators

Full facepiece respirators cover the entire face and are designed for use with constant flow and pressure demand systems. They are tight-fitting and suitable for

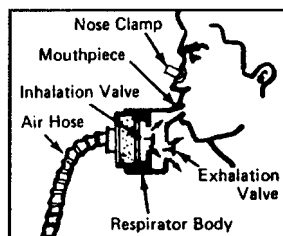


FIGURE 17.15 Illustration of mouthpiece respirator.

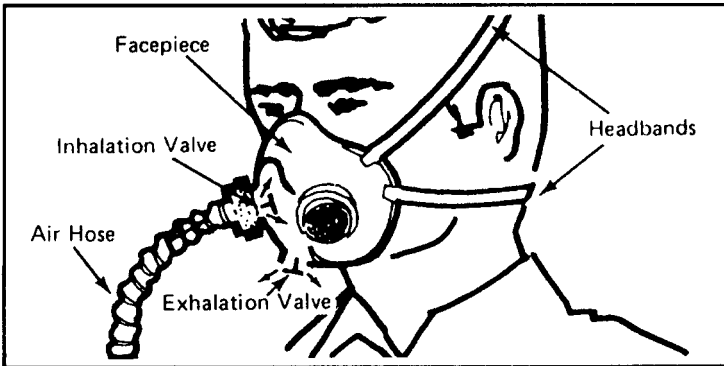


FIGURE 17.16 Illustration of half facepiece respirator.

atmospheres of moderate and high toxicity. They are usually used in conjunction with full protective clothing for such tasks as chemical tank cleaning where corrosive and toxic gas, mist, and liquids may be present. Since the face mask provides protection to the face and eyes, they are also suitable for other tasks such as welding and inspection of tanks and vessels where there is an oxygen-deficient atmosphere. A full facepiece respirator is illustrated in Fig. 17.17.

Hood and Helmet Respirators

Hood and helmet respirators cover the entire head and are normally used with a constant flow system. They are loose-fitting and suitable only for protection against contaminants such as dust, sand, powders, and grit. Constant flow is necessary to ventilate the headpiece and to provide sufficient air pressure to prevent contaminants from entering the headpiece. A hood and helmet respirator is illustrated in Fig. 17.18.

Full Pressure Suits

Full pressure suits range in design from loose-fitting, body protective clothing to completely sealed, astronautlike suits that provide total environmental life support.

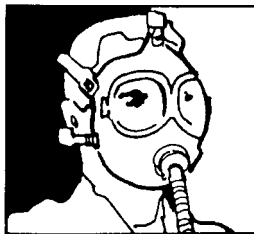


FIGURE 17.17 Illustration of full facepiece respirator.

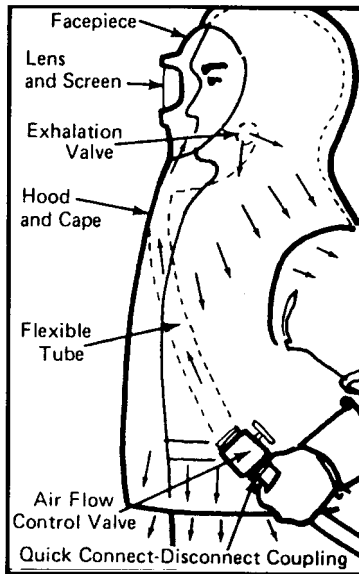


FIGURE 17.18 Hood and helmet respirator.

They are designed to be used only with constant flow systems and are suitable for the most toxic and dangerous environments and atmospheres.

BREATHING AIR PURITY

Air for breathing purposes supplied from compressors or from a pressurized tank must comply as a minimum with quality verification level grade D in CGA G-7. 1 (ANSI Z-86.1). Table 1 from ANSI/CGA G-7.1 is reproduced here as Table 17.1 and 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 effect they may have on different devices of the purification system, in the piping system, and by 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, oxidation of oil in overheated compressors could 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

TABLE 17.1 Listing of the Maximum Contaminant Level for Various Grades of Air
(Units in ppm (mole/mole) unless shown otherwise)

Limiting characteristics	A	K	L	D	E	G	J	M	N
Percent O ₂ balance predominantly N ₂ (Note 2)	atm/ 19.5–23.5	atm/ 19.5–23.5	atm/ 19.5–23.5	atm/ 19.5–23.5	atm/ 20–22	atm/ 19.5–23.5	atm/ 19.5–23.5	atm/ 19.5–23.5	atm/ 19.5–23.5
Water, ppm (v/v) (Note 3)		200	50				1	3	
Dew point, °F (Note 3)		–33	–54				–104	–92	
Oil (condensed) (mg/m ³ at NTP)				5/(4)	5/(4)				None*
Carbon monoxide				10/(5×6)	10	5	1	1	10
Odor									None
Carbon dioxide				1000/(6)	500	500	0.5	1	500
Total hydrocarbon content (as methane)		25			25	15	0.5	1	
Nitrogen dioxide						2.5	0.1 } 0.5		2.5
Nitric oxide									
Sulfur dioxide						2.5	0.1		5
Halogenated solvents						10	0.1		
Acetylene							0.05		
Nitrous oxide							0.1		
USP									Yes

*Includes water.

1. The last edition of CGA G-7.1-1973 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 have been dropped from this edition (1989) since they no longer represent major volume usage by industry. Four 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 CGA-7.1-1973 or contact the Compressed Gas Association.
2. The term "atm" (atmospheric) denotes the oxygen content normally present in atmospheric air; the numerical values denote the oxygen limits for synthesized air.
3. 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 extreme 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 degrees 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 one atmosphere pressure absolute, 101 kPa abs. (760 mm Hg).
4. Not required for synthesized air whose oxygen and nitrogen components are produced by air liquefaction.
5. Not required for synthesized air when nitrogen component was previously analyzed and meets *National Formulary* (NF) specification.
6. Not required for synthesized air when oxygen component was produced by air liquefaction and meets *United States Pharmacopeia* (USP) specification.

Source: ANSI/CGA G-7.1, ANSI 2-86.1, Table 1.

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 oxidation of heated oil in the compressor. Carbon monoxide easily combines with the hemoglobin in red blood cells and replaces 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 1000 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 by the most demanding device in the system, which is usually the CO converter or the requirement of having the dew point 10°F lower than the lowest temperature where piping is installed.

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 higher dew point than the ambient temperature of the area where the compressed air line is installed.

Solid Particles. Known as *particulates*, solid particles can enter the system through the intake and are released from nonlubricated compressors as a result of friction from carbon and Teflon material used in place of lube oils. No limits 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.

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, and 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.

Generation and Storage of Breathing Air

The source of air for the breathing air system is an air compressor and/or high-pressure air stored in cylinders. The air in cylinders uses ambient air which is purified to reduce or eliminate impurities to the required level and compresses it to the desired pressure. A typical schematic detail is shown in Fig. 17.19.

Air Compressor. The required standard for air compressors used to supply breathing air shall comply with the oil-free medical gas discussed in Chap. 14, "Compressed Gases." Medical gas compressor systems are used because, as a whole, they generate far fewer contaminants than other types. When a liquid ring

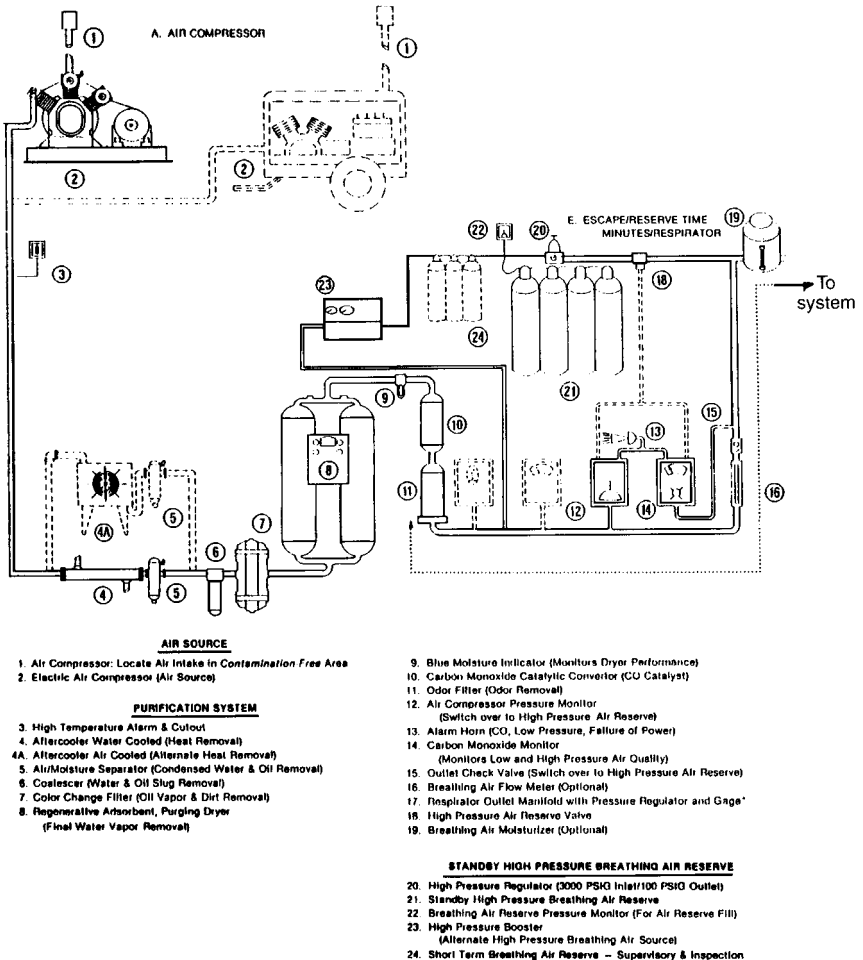


FIGURE 17.19 System with standby high-pressure breathing air reserve. (Courtesy Nominox.)

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 that 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, aftercooler, and interconnecting water seal supply and the other ancillary piping. All of these components are discussed in Chap. 14, in the subsection called "Medical Gases."

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 in the frequent changing of cylinders.

Cylinder Storage. 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 if it should fail.

Aftercoolers

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 installed on an air compressor by the manufacturer. 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 recommended size of the unit.

Purification Methods

The contaminants of concern to breathing air systems must be removed. This can be done by separate devices to remove individual contaminants or with a prepiped assembly of all necessary purification devices, requiring only an inlet and outlet air connection. For breathing air systems, this is commonly done with a purifier system.

The individual purification methods used to remove specific contaminants are the same as discussed in Chap. 14, "Compressed Air." 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. Very often all of the required purification devices are combined into a single prepiped assembly commonly referred to as a *purification system*.

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 combina-

tions and placed inside a single cartridge. The material is not consumed, but it 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 Chap. 14.

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

Particulates. Particulates are removed by means of in-line filters. Generally accepted practice eliminates particulates in the piping system 1 μm and larger. Refer to Chap. 14 for a discussion of filter types.

Humidifiers

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 percent 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 this routing is impossible to change, a worker will have shorter periods of time on the respirator.

Respirator Manifold and Pressure Reducer

This is a combination device used to provide a single component that has multiple quick disconnect outlets, providing a convenient place to both reduce the pressure of the distribution network and a connection point for several hoses. A pressure gauge should be installed on the manifold to assure that the outlet pressure is within 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). A quick disconnect is the most common method of connecting a hose to the supply piping.

COMPONENT SELECTION AND SIZING

Source of Breathing Air

Air Compressor. The air compressor size is based on the highest flow rate in cfm (Lpm) required by the number and type of respirators 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 respirators. Since there is a wide variation in the pressure and flow rates required for various types of respirators, 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 Lpm) for pressure demand respirators
2. 6 scfm (170 Lpm) for constant flow regulators
3. Up to 16 scfm (453 Lpm) for flooded hood respirators
4. Up to 35 scfm (990 Lpm) for flooded suits
5. Add 15 scfm (425 Lpm) of air for suit cooling if used

High-Pressure Cylinder Storage. 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 that 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 (Lpm) of each, and the duration, in minutes, that the respirators are expected to be used, plus a 10 percent safety factor. The total amount of compressed air in the cylinders should not be allowed to decrease too low. This requires that a low-pressure alarm be activated when the pressure falls to 500 psig (3450 kPa) in a cylinder normally pressurized to 2400 psig (16,500 kPa) when refilled to capacity.

As an example, establish the number of cylinders required for an emergency supply of air for eight people using constant flow respirators that require 15 min to escape the area:

1. $8 \times 6 \times 15 = 720$ scfm + 72 (10 percent) = 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. Refer to Eq. (14.4) for the cylinder capacity.
3. If 1 cylinder has a capacity of 225 cf of air, 792 divided by $225 = 3.5$. Use 4 cylinders.

Selection of 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 that specific con-

taminants and their amounts can be identified. Ideally, the tests are taken at different times of the year and at different times of the day. These tests will quantify the type and amount of contaminants present at the intake. Knowing this, the purification systems needed to meet code criteria can be chosen. The other requirement is the highest flow rate that could be expected. With these two criteria, the appropriate size and types of purifiers can be selected.

The most commonly used method of purification is by an assembly of devices called a *purification system* specifically chosen and based on the previously selected criteria. The manufacturer's recommendations are commonly followed in the selection and sizing of the assembly.

Carbon Monoxide Converter. Based on experience, the requirement for installation of a carbon monoxide converter in rural areas is rare. The need for a converter is based on tests of the intake 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 for installation of a converter is the use of a non-oil-free compressor. Good practice requires the installation of a converter if there is a possibility that the level of carbon monoxide may rise above the 10 ppm limit required by code. The converter is sized on the flow rate of the system.

Coalescing Filter-Separator. The coalescing filter-separator is a single unit that removes large-size oil, water, and other 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 the 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 medium dryers most commonly used are the single-bed dryer, which is a disposable cartridge, or a 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 has a lower first cost but has 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 that the need for replacement is indicated by a color change.

Disposable units are best suited for short durations or occasional use such as replacement for 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 that it 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 operating principle to that discussed in Chap. 14. These units are used for continuous duty.

The two factors contributing to the breakdown of the medium are fast-drying cycles and high air velocity. In selecting the desiccant dryer, the velocity of air through the unit shall conform to manufacturers' recommendations. Velocity should be as low as practical to avoid fluidizing the bed. High velocity requires more

cycles for drying, which means more air is wasted. If the size of the dryer is a concern, the 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 to 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. The advantages of the refrigerated dryer is that all of 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, combining 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 that of 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 that could be expected.

Odor Removal

Odor is not usually a problem, but its removal is provided for as a safeguard. The activated charcoal cartridges that remove odors are selected by 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 percent 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 below a temperature 10°F higher than the lowest temperature in any part of the facility the pipe is routed through.

Respirator Hose

The respirator hose size most often used to connect the respirator worn by an individual to the central distribution piping system is $\frac{3}{8}$ in (10 mm) in size. Code allows a maximum hose length of 300 ft (93 m). The most common lengths are between 25 ft (7.75 m) and 50 ft (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 that 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 to 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 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 could be installed to centrally reduce the pressure.

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 Chap. 14, "Compressed Gas," in the medical air subsection, and Table 14.15 to 14.18 for the proper size pipe. The number of simultaneous users must be obtained from the facility. Use no diversity factor.

Alarms and Monitors

The following alarms and monitors are often provided.

CO Monitor. Usually included as a built-in component, this monitor will measure the CO content of the airstream and sound 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 will sound an alarm to alert personnel when the level falls below a predetermined level. Usually, there are several alarm points that are annunciated prior to reaching a level low enough to require the use of respirators.

Low Air Pressure. The low air pressure monitor must sound an alarm when the pressure in the cylinder supply reaches a predetermined low point. This set point will allow the users of the breathing air system to immediately leave the area while still being able to breathe from the system. For cylinder storage, this set point is about 500 psig (3450 Lpm) in the cylinders. For a compressor system, the alarm should sound when the pressure falls to a point 10 psig (70 kPa) 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 approximately 5 psig (35 Lpm) 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 as previously set by a health officer as potentially harmful to the users. The alarm is required to be activated 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 set at 120°F (49°C) and will vary between different manufacturers and components.

Failure to Shift. This monitor is placed on desiccant dryers to alarm the users if the unit fails to shift from the saturated dryer bed to the dry bed when regeneration is required.

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