Firefighting and Fire Prevention

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Purpose

The operation and maintenance personnel around a powerplant, pumping plant, or other Reclamation establishment are not presumed to be firefighters, but occasionally their duties may make it necessary for them to fight fires. The purpose of this volume is to supply them with fundamental facts which may prove valuable in such an emergency and acquaint them will the use, care, and testing of firefighting equipment.

It is assumed that operation and maintenance personnel are familiar with the common safety practices in connection with fire prevention and general safety around electrical equipment. This volume is designed to help improve work along these lines.

The data in this volume are intended to supplement Subpart L, Fire Protection, part 1910 of Title 29 of the Code of Federal Regulations, Department of Labor, OSHA (Occupational Safety and Health Administration), Occupational Safety and Health Standards, and to provide a quick reference for answers to most firefighting problems.

I. Chemistry of Fire

1.1. MECHANICS OF COMBUSTION.- From casual observation of a simple wood fire, it seems that the wood itself is burning. Actually, only the vapors given off by it supply the fuel that feeds the flames. Nearly all combustible materials, whether in a liquid or solid state, give off vapors when heated. Even paper, which is not ordinarily regarded as vapor producing, when heated gives off vapors which can be burned at some distance from the paper itself. Most solids must first be converted into a liquid state before vaporization takes place - paraffin, for example, as in the case of a candle burning. The ignited wick melts the paraffin into a liquid, and the liquid flows into the wick and gives off vapor to feed the flame.

1.2. FLASHPOINT.- Almost all oils must be heated until a vapor is given off before burning can take place. The temperature at which an oil begins to give off vapors that can be ignited is known as the flashpoint. Most lubricating oils must be heated to over 149 EC (300 EF) before they will flash. However, more highly volatile liquids such as gasoline, alcohol, naphtha, etc., have flashpoints so low they can be ignited readily at room temperature. The fire hazards that these liquids present are due to the fact that even at low temperatures they are constantly giving off highly flammable vapors.

The flashpoint of gasoline is -43 EC (-45 EF), and while the ever-present vapors are not visible to the naked eye, they may be observed by means of a shadow image produced by a powerful light. The flashpoint of a liquid, however, should not be confused with the temperature necessary to ignite the vapors, for unless a source of heat considerably hotter than the flashpoint of the fuel comes into direct contact with the vapors, the fuel will merely continue to give off vapors without burning.

1.3. OXYGEN REQUIRED FOR COMBUSTION.- The second essential factor in the process of combustion is oxygen. Without oxygen, even the most flammable vapors will not burn. Under normal conditions, a flame draws the amount of oxygen necessary to sustain combustion from the air. When the oxygen content of the air falls from normal 21 percent to below 15 percent, there is immediate extinguishment of practically all flames.

The part that oxygen plays in supporting combustion is illustrated in a cutting torch. When only the acetylene gas is used, there is no cutting effect on the metal, but when the oxygen valve is opened the torch readily cuts through the metal on which it is being used. Under normal conditions, the oxygen in the air combines with the combustible vapor in the direct proportion to sustain combustion. With the regulated flow of vapor in an open space, the ready mixture of the two elements is evidenced. The greater the flow of vapor, the greater the mixture with oxygen and the larger the flame. This action is caused by the heat of the flame. The hot-air currents rising from the flame create a draft suction that draws a steady flow of oxygen into the flame area.

With fuel at its flashpoint and vapors combining readily with air, the mixture may be regarded as in a state of readiness. Combustion, however, cannot occur until further heat is applied. An electric spark in some cases, or the heat of an open flame in others may furnish this needed heat.

1.4. IGNITION TEMPERATURE.- There is a wide temperature difference between the flashpoint of a fuel and the ignition temperature; for example, the flashpoint (vapor given off) of gasoline is -43 EC (-45 EF), and the ignition temperature (heat necessary to ignite the mixture) is 257 EC (495 EF). A small flame can be thrown Into lube oil which is at average room temperature and it will not burn, but with the addition of burning gasoline, vapors soon rise and burn to raise the temperature of the surrounding oil to the flashpoint. The rate of burning Is governed by the surface area; i.e., only the fuel coming into contact with the air is consumed. The greater the surface area, the more readily oxygen reaches the vapors. The surface area of a material in proportion to its volume affects the readiness with which it will ignite. For example, if you cut two identical blocks of wood from the same piece of timber and reduce one of them to a pile of shavings, this greatly increases the surface area of the material; when a lighted match is placed against the solid block, it merely chars and absorbs the heat, while the same flame readily ignites the shavings.

1.5. Fire Triangle.- The starting of a fire involves three elements - fuel, oxygen, and ignition temperatures. These elements may be compared to the three legs of a triangle (fig. 1), for fire cannot occur until all three are brought together.

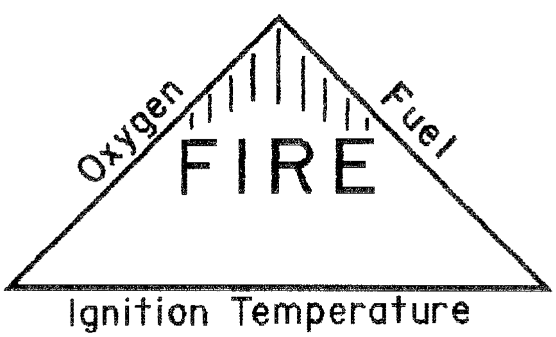

Figure 1. - Fire triangle

The following is a common cause of fires in terms of the fire triangle. A cigarette is carelessly discarded and comes to rest on a scrap of paper. The heat of the glowing cigarette is sufficient to cause the fuel - in this case, the paper (with a low ignition temperature)- to give off vapor. Oxygen is present, and when the vapors are given off in sufficient quantity the mixture ignites, the cigarette being hot enough to supply the ignition temperature. Because of the relatively large surface area, the fire spreads rapidly and grows in intensity, building up higher temperatures, causing more and more vapors to be given off. The heat of the flame causes the hot air to rise, drawing in additional oxygen to combine with the vapors and feed the flames.

Referring to the fire triangle, to extinguish a fire, it is necessary to break up the triangle by taking away any one if its sides. This may be accomplished in various ways, as will be pointed out in the following sections.

II. Classification of Fires

2.1. Definition and Types.- Classification of fires is the systematic arrangement in classes of the various substances that as fuels produce heat by combustion, as follows:

2.1.1. Class A: Ordinary combustible materials such as wood, cloth, paper, and some rubber and plastic materials.

2.1.2. Class B: Flammable liquids, gases, greases, and some rubber and plastic materials.

Flammable or inflammable (identical in meaning) liquids do not themselves burn or explode, but, as pointed out previously, the gases or vapors formed when they are heated and evaporated explode; that is, the change of state from liquid to gas must first occur. As long as they are in a liquid state with no vapors being given off, there is little or no hazard. For the more volatile liquids, such as gasoline, storage in a closed container is a necessity. In order for any vapor to explode, it must have the correct vapor-air ratio, just as in the carburetor of a car. When the engine is flooded with gas, the mixture is too rich and fails to ignite. The same holds true in gasoline storage. The danger is when the gases being poured from one container to another, thus giving the vapors the change to mix with the correct amount of air to form an explosive moisture. The same circumstances hold true with all flammable oils when enough heat is present to release vapors from the liquid.

Keeping in mind that a flammable liquid is not hazardous as long as It is not hot enough to give off vapors which can mix with the oxygen in air and burn, two things can be done: (a) The liquid can be cooled down to the point where no vapors are given off; and (b) the supply of oxygen can be blanketed out. Some flammable liquids give off vapors at temperatures ordinarily considered cold. For example, gasoline vaporizes at -43 EC (-45 EF) or lower.

2.1.3. Class C: Live electrical equipment.

When equipment is deenergized, extinguishers for class A or B fires could be used safely; however, in fighting an electrical fire there are two important things to be taken into consideration: namely (a) damage to the equipment far beyond what the fire could do, and (b) danger to the Individuals fighting the fire. To avoid these two possibilities, deenergize the circuit and use only the types of extinguishment recommended for class C fires.

2.1.4. Class D: Combustible metals such as magnesium, titanium, sodium, potassium, lithium, and zirconium.

III. PORTABLE FIRE EXTINGUISHERS

3.1. Types and Usage.- All extinguishers of a portable type act as a "first-aid" appliance for extinguishing fires in their incipient stage, and they cannot be expected to be effective after a fire has spread to involve a large amount of combustible material. The action of all extinguishers is by cooling the burning substance below its ignition temperature and by excluding the air supply (blanketing out the oxygen), or by a combination of these methods. Also, some types tend to inhibit oxidation by chemical action.

3.1.1. Extinguishers for Class A Fires.-

Multipurpose dry chemical
Foam extinguishers
Loaded stream extinguishers

3.1.2. Extinguishers for Class B Fires.-

Multipurpose dry chemical
Foam
Carbon dioxide (CO_2)
Dry chemicals
Loaded stream extinguishers
Bromotrifluoromethane - Halon 1301

3.1.3. Extinguishers for Class C Fires.-

Multipurpose dry chemical
Bromotrifluoromethane - Halon 1301
Carbon dioxide (CO_2)
Dry chemicals

3.1.4. Extinguishers for Class D Fires.-Extinguishers or extinguishing agents for class D fires shall be types approved for use on the specific combustible metal.

3.2. OPERATION.- This volume does not attempt to explain the complete operation of each individual fire extinguisher, as the directions for operation will be found on the equipment. All persons who may have to use an extinguisher should carefully read and adhere to the instructions placed on the extinguisher by the manufacturer. Upon initial assignment and at least annually thereafter, all employees designated to use fire extinguishers will be provided training in the use of such equipment. All other employees will be educated in the general principles of fire-extinguisher use and the hazards with incipient-stage firefighting at least annually.

3.3. INSPECTION AND MAINTENANCE.-

3.3.1. General.- Portable extinguishers shall be maintained in a fully charged and operable condition, and kept in their designated placed at all times when they are not being used. Each extinguisher shall be equipped with a tag for registering inspection date. Aluminum tags on which the date can be punched are preferred for a lasting record.

3.3.2. Inspection.- Inspection is a quick check that an extinguisher is available and will operate. Extinguishers shall be inspected monthly, and the following items shall be checked:

(1) The extinguisher shall be in its designated place.

(2) Access to, or visibility of, the extinguisher shall not be obstructed.

(3) The operation instructions on the extinguisher nameplate shall be legible and face outward.

(4) Any seals or tamper indicators that are broken or missing shall be replaced.

(5) For water types without gauges, their fullness shall be determined by "hefting."

(6) Any obvious physical damage, corrosion, leakage, or clogged nozzles shall be noted.

(7) Pressure-gauge readings when not in the operable range shall be noted.

The date the inspection was performed and the initials of the person performing the inspection shall be recorded. When an inspection reveals that tampering has occurred, or that the extinguisher is damaged, impaired, leaking, under- or overcharged, or has obvious corrosion, the extinguisher shall be subjected to applicable maintenance procedures.

3.3.3. Maintenance.- Maintenance is a "thorough check" of the extinguisher intended to give maximum assurance that an extinguisher will operate effectively and safely. It includes a thorough examination and any necessary repair or replacement. Maintenance shall be performed at regular intervals, not more than 1 year apart or when specifically indicated by an inspection. Any extinguishers removed from the premises to be recharged shall be replaced by spare extinguishers during the period they are gone. Refill all extinguishers as soon as they are used.

Stored pressure-dry chemical extinguishers that require a 12-year hydrostatic test will be emptied and subjected to applicable maintenance procedures every 6 years. Dry chemical extinguishers having non-refillable, disposable containers are exempt from this requirement.

3.3.4. Hydrostatic Tests.- If, at anytime, an extinguisher shows evidence of corrosion or mechanical injury, it should be subjected to hydrostatic pressure tests or replaced. In addition, the hydrostatic test intervals for extinguishers listed below should be followed. (See NFPA No. 10 for test methods.) Extinguishers requiring discharge for hydrostatic testing or refueling should be utilized for demonstration purposes, giving each employee an opportunity to handle an extinguisher and apply the extinguishing agent to a fire.

Extinguisher type	Hydrostatic test interval (years)
Storage-pressure water and/or antifreeze.	5
Wetting agent.	5
Foam.	5
Loaded stream.	5
Dry chemical extinguishers with stainless steel shells, or soldered-brass shells.	5
Carbon dioxide.	5
Dry chemical, stored pressure, with mild steel shells, brazed-brass shells, or aluminum shells.	12
Dry chemical, cartridge operated with mild steel shells.	12
Bromotrifluoromethane - Halon 1301.	12
Bromochlorodifluoromethane - Halon 1211.	12
Dry power, cartridge operated, with mild steel shells.	12

IV. Application of Firefighting Equipment (Portable and Fixed)

4.1. Water Extinguishing Systems.- Water was man's first means of fighting fire and is still one of the best all-around weapons. However, it should be borne in mind that water can be damaging to insulated conductors and windings, such as in motors and generators, and to switchboard wiring. The damage to the insulation from soaking may require extensive drying out or rewiring operations, and the damage from water may be as much or more than the damage caused by the fire itself. For this reason, water should be used on a fire of this type only as a last resort. Water may also be undesirable from the standpoint that it is sometimes difficult to deenergize all circuits with which the water might come in contact. Since water's effectiveness depends on the speed with which it is applied to the fire after the fire is first discovered, the firefighting force must function as a well-organized team in laying the hoses in order to get the water on the fire.

4.1.1. Handling of Fire Hose.- The hose must be unrolled so that male and female ends are in the correct position for coupling. All couplings must be made tightly to guard against leakage and loss of pressure. The hose must be spread out or laid so that it will not kink or tangle when the line is advanced toward the fire. Unless all these tasks are performed quickly and efficiently, valuable time will be lost that may mean the difference between a fire being quickly extinguished and a fire getting out of control. Hose, when coiled as illustrated in figure 2, can be run out without tangling or kinking.

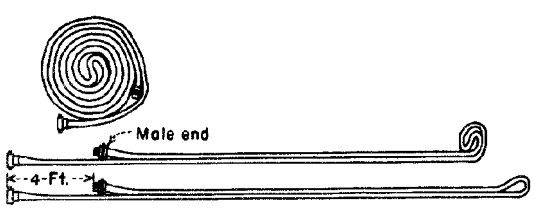

Figure 2. Coiling fire hose.

The male end is always run in the direction of the fire. This is done because all nozzles and fittings are equipped with female couplings. By having the female end on the outside of the coil, the correct end is always at the correct place for coupling, and the threads on the male end are protected against abrasion or damage. To unroll the hose, the foot Is placed on the female end, the male end is snapped up sharply and run toward the fire. To roll the hose in a coil, the length is first laid straight, then doubled over, placing the male end on the top about 1.2 m (4 ft) from the female end. Grasped at the fold, the hose is rolled tightly as slack is taken up. Care should be taken to obtain an even, compact roll. Coiled in this manner, the ends are in the correct position, the male end always on the inside.

Connecting hose is usually a two-person operation (fig. 3). One person holds the male

Figure 3. Two men connecting fire hose.

end firmly, the second person engages the threads of the female swivel. The swivel is given a half turn back to align the thread. This prevents the threads from fouling and speeds up the coupling operation. When the connection is made by one person, the male end is held in position with the foot, leaving both hands free to engage the swivel (fig. 4). In making all couplings, the person handling the female end should make sure the rubber gasket is in place. Without it, the connection

Figure 4. One man connecting fire hose.

will leak and pressure will be lost.

4.1.2. Fog Nozzles for Electrical Installations.- The form in which water is used is determined by the type of fire to be extinguished. Flammable- liquid fires can be extinguished with water only in the form of a fine spray or fog. (The terms "fog" and "spray" are used interchangeably.) Fog is also used to protect the firefighter in approaching a fire. Fires involving materials other than liquids require a balanced stream to break up or penetrate the burning material.

Water fog has two characteristics that render it more suitable than solid streams to most firefighting applications with which electric power personnel are concerned: (a) Water fog is more effective on fires of combustible liquids such as oil fires, and (b) the spray is essentially nonconductive to electricity at distances over 5 m (15 ft). **SINCE BOTH OF THESE CHARACTERISTICS ARE NEEDED AROUND ELECTRICAL EQUIPMENT, SUCH INSTALLATIONS SHOULD BE EQUIPPED ONLY WITH FOG NOZZLES WHICH CANNOT PRODUCE A SOLID STREAM.** There are two suitable types, the fixed-fog nozzle and the adjustable nozzle. The latter may produce a cone of spray from a 30-degree cone to a nearly flat curtain, and shut off. (This adjustable nozzle is not to be confused with the all- purpose type which, with the handle in one position, will produce a solid stream.)

While there will seldom be occasion to deliberately direct a spray on electrical conductors, the liberty and limitations within which this can be done should be understood by anyone who may have occasion to fight fires in or near electrical apparatus. To withhold use of water fog until all electrical circuits have been deenergized might occasion lengthy and disastrous delay.

4.1.3, Instructions for Fog-Nozzle Use.- Breaking the water stream up into small droplets so increases the electrical resistance of the stream that dangerous electrical currents cannot flow if reasonable distances are kept. General instructions and limitations for use of fog nozzles are summarized as follows:

Allow air and scale to clear from system before directing near energized conductors. See that fog, not solid stream, is produced. Allow clearance of over 5 m (15 ft) from energized conductors for 15 to 230 kV and allow at least 1 m (3 ft) on conductors up to 16 kV. All systems should be flushed periodically.

This information has been printed on 216- by 280-mm (8-1/2- by 11 -in.) cards to be posted at manual fog nozzle installations near electrical apparatus. This card, designated form PO&M-173 (12-81), figure 5, is obtainable from the Chief, Supply and Services Division, Attn: Code D-7923, Denver Office.

4.1.4. Class C Fire Precautions.- Oil switches, oil-filled transformers, and other electrical equipment containing oil of a relatively high flashpoint may be heated and ignited by excessive current or an electric arc. As mentioned before, when a fire breaks out, deenerglze the circuit and proceed on the oil fire with CO_2, dry chemical, or water (fog nozzle).

PRECAUTIONS FOR USE ON EQUIPMENT 15 KV* AND ABOVE

1. ALLOW AIR AND SCALE TO CLEAR FROM SYSTEM BEFORE DIRECTING NEAR ENERGIZED CONDUCTORS
2. SEE THAT FOG, NOT SOLID STREAM, IS PRODUCED
3. MAINTAIN AT LEAST 5 METER (15 FEET) OF DISTANCE FROM ENERGIZED CONDUCTORS (UP TO 230 KV)
4. HAND-HELD NOZZLES SHALL NOT BE USED ON OR NEAR ENERGIZED CONDUCTORS OR EQUIPMENT RATED ABOVE 230 KV PHASE-TO-PHASE

MAINTENANCE
FLUSH SYSTEM PERIODICALLY

***NOTE: IN NO EVENT SHALL NOZZLE BE HELD CLOSER THAN I METER (3 FEET) FROM AN ENERGIZED CONDUCTOR**

Figure 5. Fire-protection water fog nozzles.

There is ordinarily no danger from playing hose streams on low-voltage circuits; however, for safety, always use a fog or fine spray. Electrical equipment should always be approached carefully during a fire, due to the possibility of some electrical breakdown causing electrical shock. The greatest danger lies primarily in accidental physical contact with live wires or equipment. However, under certain conditions, enough current can flow through a hose stream to injure the man holding the nozzle. With this in mind, if you must fight a fire on live electrical equipment, be sure that the fog nozzle is operated at its designed pressure to produce a fine spray before using it on the live electrical equipment and maintain distance in excess of 5 m (15 ft) from live conductors.

4.1.5. Solid-Stream Nozzles Prohibited.- The use of solid-stream nozzles in electric power installations is prohibited because of the hazards involved in applying a stream of water with possible high electrical conductivity.

4.1.6. General Use of Fog Nozzles.- In situations involving liquid fires, low-velocity fog should be used, produced by a fog head at the end of an applicator. An applicator is an extension pipe 1.2 to 3.6 m (4 to 12 ft) in length with the end bent at an angle. The applicator head provides a greater spread and finer diffusion of the water. This increases the rate of cooling, and since the entire area must be cooled below the ignition temperature of the fuel before the fire can be extinguished, the applicator should be used whenever possible on liquid fires. Another advantage of the applicator is the ease with which it can be manipulated at the seat of the fire. Applied close to the burning surface, the finely diffused water particles form a steam blanket that aids in extinguishing. Metal applicators should not be used in switchyards and substations because of the danger of making contact with energized circuits.

High-velocity fog extinguishes fires in flammable liquids by a complete coverage of the burning surface with a fine spray which cools the surface, dilutes the flammable vapors, or emulsifies the flammable liquid, while the extinguishing action of low-velocity fog, as previously mentioned, depends on cooling and dilution. Both types of fog nozzles have their limitations; for example, burning gasoline flowing over a large area on the ground could be extinguished by a fog nozzle, but it would be more difficult than if the same gasoline were in an open tank.

4.2. FOAM EXTINGUISHING SYSTEMS.-

4.2.1. General.- Firefighting foam is a mass of gas-filled bubbles which is lighter than flammable liquids. The foam can float on all flammable liquids and produces an air-excluding, cooling, continuous layer of vapor-sealing, water-bearing material for purposes of halting or preventing combustion. Two main types of foam are available. These are low- and high-expansion foam as discussed below. The following general rules apply to the application and use of ordinary air foams:

(1) Most foams are adversely affected by contact with vaporizing liquid extinguishing agents and by many dry chemical agents. These materials should not be used simultaneously with air foams. Gases from decomposing plastic materials have a similar breakdown effect on foams.

(2) Foam solutions are not recommended for use on electrical fires as the foam is conductive.

(3) High-expansion foam can seem to completely submerge and apparently extinguish fires, while the fire continues to burn quietly beneath it, This can occur when burning vapors beneath the foam support the foam blanket on heated air.

4.2.2. Low-Expansion Foam.- The normal expansion ratios for low-expansion foam range from 4:1 to 12:1. The expansion ratio is the volume of foam generated, divided by the volume of solution used. The primary method of extinguishment with low-expansion foam is smothering, although cooling is a factor. The minimum foam depth for extinguishing a fire is about 6 mm (1/4 in) with an average depth of 76 mm (3 in) or more.

4.2.3. High-Expansion Foam.- The normal expansion ratios for high- expansion foam range from 100:1 up to 1000:1. The primary method of extinguishment is the smothering and cooling effect of water. High-expansion foam is particularly suited as a flooding agent for use in confined spaces, for transporting wet foam masses to inaccessible places, and for volumetric displacement of vapor, heat, and smoke.

4.2.4. Limitations of Foam.- Foams are primarily used for control and extinguishment of fires involving flammable or combustible liquids, and the following criteria must usually be met for the foam to be effective:

(1) The liquid must be below its boiling point at the ambient condition of temperature and pressure.

(2) If foam is applied to liquids with a bulk temperature higher than 100 EC (212 EF), the foam forms an emulsion of steam, air, and fuel. This may produce a fourfold increase in volume.

(3) The foam must not be highly soluble in the liquid to be protected, and the liquid must not be unduly destructive to the foam.

(4) The liquid must not be water reactive.

(5) The fire must be a horizontal surface fire as falling fuel fires cannot be extinguished by foam unless the fuel has a relatively high flashpoint and can be cooled to extinguishment by the water in the foam. However, some foams are capable of following a flowing fuel fire.

4.3. CARBON DIOXIDE EXTINGUISHING SYSTEMS.-

4.3.1. Principle.- The use of CO_2 as an extinguishing agent is based on the principle of using an inert gas to reduce and displace the oxygen content of the air. Most fires where there are no flowing embers to maintain a high degree of heat for reignition can be extinguished by a reduction of the oxygen content from the normal 21 percent to 15 percent. Since CO_2 is heavier than air, it has the ability to penetrate into loose material and confined spaces where water or foam might not. The rapid expansion of the gas on discharging produces a refrigerating effect, as indicated by the CO_2 snow, which has a temperature of minus 79 EC (-110 EF). This snow turns into gas and in the process absorbs heat from the surrounding atmosphere.

4.3.2. Uses.- CO_2 may be used on a large variety of fires, such as: flammable liquids in practically any type container, all types of electrical machinery and apparatus, and any situation where water would be damaging to the material after the fire is extinguished. CO_2 is not suitable for use on pyroxylin plastics (photographic film).

4.3.3. Precautions in Using CO_2.- The characteristics of carbon dioxide are such that certain precautionary measures are necessary. So far as safety to life is concerned, CO_2, if not breathed in excessive amounts, is not dangerous; however, a concentrated atmosphere inhaled for several minutes will produce suffocation, as illustrated in the following tabulation:

CO_2 concentration	Increase in lung activity
2 percent.	50 percent.
3 percent.	100 percent.
5 percent.	300 percent.
9 percent.	Can be tolerated only a few minutes.

Breathing a higher concentration than 9 percent CO_2 can render a person helpless almost immediately. As CO_2 design concentrations for fire extinguishing generally exceed 25 percent, it Is potentially dangerous for personnel to be in an area protected by a CO_2 system. Also, the release of carbon dioxide into an enclosure causes a blinding storm of small crystals and builds up CO_2 concentration so rapidly that escape becomes nearly Impossible. All employees entering such areas must obtain clearance on the stationary extinguishing system and make it inoperative by mechanical and/or electrical means. A test release of a bank of CO_2 concentrations from atmospheric normal to above 45 percent in less than 10 seconds. It also increased CO_2 concentrations in turbine pits to 15 percent, and hazardous concentrations in both locations remained for approximately 1 hour.

4.3.4. Entering Enclosures After CO_2 Discharge.- Concentrations for the proportions listed in paragraph 4.3.3 are not likely to be encountered when portable CO_2 equipment is being used to fight fires in an open area; however, they will be obtained when CO_2 is used to smother a fire in an enclosure such as a generator housing on oil storage or oil purifier room. It is desired to maintain a minimum concentration of at least 25 percent for a period of time to extinguish fires in enclosures of this kind. Therefore, the following precautionary measures for personnel safety are required. In entering a generator housing after CO_2 has been discharged, proper clearance of the generator should be obtained and enough time should elapse so that the CO_2 application has served its intended purpose in extinguishing the fire. This period should be determined by a CO_2 concentration test. Two employees equipped with self-contained breathing apparatus will open generator housing door and vents to permit the CO_2 and smoke to escape by natural draft and to determine if all fire has been extinguished. Fans can also be used to clear the unit of smoke and CO_2. After this has been accomplished and atmospheric tests for carbon dioxide and carbon monoxide concentrations are found to be below safe limits, other personnel may enter the housing. In the case of the oil storage and oil purifier rooms, proper airing out of the area should also be obtained before personnel are allowed to enter.

CO_2 is stored in a liquid state under very high pressure; and when discharged, the rapid expansion produces a refrigerating effect to the extent that one may obtain a "burn," or frostbite from coming in contact with a metal part through which the gas has passed. The CO_2 nozzles in generator housings should not direct the gas directly against the windings as the chilling effect may damage the insulation. The effective discharge period of the CO_2 extinguishers varies from 1 to 2 minutes, depending upon the size and design of the units.

4.4. CARBON TETRACHLORIDE, CHLOROBROMOMETHANE AND INVERTING-TYPE EXTINGUISHERS.- The use of carbon tetrachloride and chlorobromomethane extinguishers is not allowed in any form at Reclamation installations because of their toxic and corrosive effects and possible damage to some electrical insulations. Inverting-type fire extinguishers, such as self-generating soda acid, self-generating foam, or gas-cartridge, water-type, portable fire extinguishers which operate by inverting the unit to initiate an uncontrolled pressure generating chemical reaction to expel the agent, are prohibited at Reclamation facilities because their shells are subject to metal fatigue and creep at the seams of construction which can cause failure of the units and may injure the operator.

4.5. DRY-CHEMICAL EXTINGUISHERS.-

4.5.1. Principle and Uses.- Dry-chemical extinguishers expel a finely powdered dry chemical which, on striking flame, releases many times its volume in nontoxic fire-extinguishing gases similar to CO_2. The powder consists principally of bicarbonate of soda which has been chemically processed to make it free-flowing. The extinguishers contain a cartridge of CO_2 or nitrogen (depending on size) to expel the dry chemical. These extinguishers can be used for electrical fires, both in rotating machinery and other equipment, since the powder is nonconducting and, in some types, nonabrasive. However, the powder remaining after the fire is extinguished is difficult to clean from motor or generator windings. These extinguishers are effective on fires of flammable liquids in vats and pools, spilled fires on floors, or in any situation where the compound stream can be swept across the burning surface.

4.5.2. Wheeled Units.- Dry-chemical-compound wheeled units are available in capacities of 45 to 159 kg (100 to 350 lb) with operating pressure furnished by nitrogen gas. Extinguishing characteristics are similar to those of portable extinguishers. An effective discharge of dry chemical is obtained for a period of approximately 1 minute 45 seconds in smaller size, and about 3 minutes 30 seconds in the 159-kg (350-!b) size. Effective range of the compound stream is from 10.7 to 13.7 m (35 to 45 ft).

4.5.3. Safety Requirements.- Where there is a possibility that personnel may be exposed to a dry-chemical discharge, suitable safeguards shall be provided to ensure prompt evacuation of such locations, and also to provide means for prompt rescue of any trapped personnel.

V. Emergency Action Plan and Cause, and Prevention of Fires

5.1. EMERGENCY ACTION PLAN.- The most important factors to consider in providing adequate employee safety in a fire situation are the availability of proper exit facilities to assure ready access to safe areas and proper education of employees as to the actions to be taken in a fire emergency.

For each workplace, an emergency action plan will be established in writing and shall cover those actions necessary to ensure employee safety from fire and other emergencies.

The following elements, at a minimum, will be included in the plan:

(1) Emergency escape procedures and emergency escape route assignments;

(2) Procedures to be followed by employees who remain to operate critical point operations before they evacuate;

(3) Procedures to account for all employees after emergency evacuation has been completed;

(4) Rescue and medical duties for those employees who are to perform them;

(5) The preferred means of reporting fires and other emergencies; and

(6) Names or regular job titles or persons or departments who can be contacted for further information or explanation of duties under the plan.

An alarm system which complies with OSHA (29 CFR 1910.165) will be established for alerting employees and/or fire-brigade members.

Before implementing the emergency action plan, each plant will designate and train a sufficient number of persons to assist in the safe and orderly emergency evacuation of employees.

The emergency action plan will be reviewed with each employee covered by the plan at the following times:

(1) Initially when the plan is developed,

(2) Whenever the employee's responsibilities or designated actions under the plan change, and

(3) Whenever the plan is changed.

5.2. FIRE PREVENTION.- Many fires start as a result of poor housekeeping, not only in the home but in many supposedly fireproof structures. Many building fires can be traced to oily rags and other materials (subject to spontaneous ignition) discarded or inadvertently dropped onto inaccessible places, such as an oily rag falling onto heating system pipes. The temperature of the pipes starts the process of vaporization, and heated vapor entrapped in the rag accumulates and builds up a higher temperature. In time, the ignition temperature of the oil rag is reached and a fire is under way.

A high standard of cleanliness and order is perhaps the most important single element in fire prevention. Simple daily tasks such as regular disposal of wastepaper and other combustible waste are of utmost importance. Waste cans should be metal containers with lids. Also, oily mops, dust rags, etc., should be kept in fire-resistive storage enclosures since they are subject to spontaneous ignition.

Good housekeeping is as essential outdoors as it is within structures. Rubbish and waste should not be allowed to accumulate where it can serve to aid in the spread of fire. Dry weeds or grass around buildings present a fire hazard.

Another likely place for a fire to start is in a locker room where men have left oily clothes or clothes smeared with paint. Matches left carelessly laying around, particularly where there are mice or rats, constitute a fire hazard.

Other items to watch for as a possible source of fire are hot bearings, exposed light bulbs near flammable material, sparks flying from grinding wheels, dust and lint collecting oil in blower and ventilating systems, and careless disposal of cigarettes and matches.

Gasoline fires or explosions are often caused by static electricity, particularly during loading or fueling operations around service stations or on tank cars and trucks. The electric charge is generated by friction of the flowing liquid. When the nozzle is grounded by contact with the tank, the electric charge drains off to the ground; but when the nozzle is not in contact and no grounding exists, static charge is likely to build up and eventually discharge to ground through the shortest path. Since the mouth of the tank is the nearest metal conductor, a spark hot enough to ignite a vapor-oxygen mixture will span the gap between the nozzle and the tank.

5.3. COMMON CAUSE OF ELECTRICAL FIRES.- The more frequent causes of electrical fires are arcs, sparks, overheating, and over-loading a circuit. When a current-carrying circuit is interrupted, intentionally or otherwise, an arc is produced such as that formed when a knife switch carrying load is opened. Such arcs have temperatures high enough to ignite any combustible material that may be in the vicinity, as well as through hot metal from the fused conductor. The amount of heat generated in a conductor is in direct proportion to the resistance of the conductor and to the square of the current. For this reason, conductors used to carry power to electrical equipment should be large enough (of low resistance) to carry the load without overheating. Metals such as copper and aluminum are used for this purpose. In many instances, electrical fires are caused by temporary or inadequate wiring jobs which are in violation of the National Electrical Code, which limits the current a conductor shall carry and the type of insulating covering.

Some of the major causes of electrical fires are:

(1) Use of fuses too large for the circuit they are protecting, or a circuit breaker with too high a setting.

(2) Adjustable-type circuit breakers with a blocked tripping element.

(3) Pennies inserted behind plug fuses.

(4) Nails or bolts substituted in place of cartridge fuses.

(5) Refillable fuses in which additional strips have been placed.

(6) Corrosion of fuses, circuit breakers, or conductors.

(7) Insulation of conductors deteriorated from age or mechanical injury and exposure to heat, moisture, or vapors.

(8) Joints not properly soldered and taped.

(9) Burned and pitted contacts.

(10) Overheating due to poor contact or overload.

VI. Care and Inspection of Firefighting Equipment

6.1. Training.- Fire protection, regardless of how good the equipment may be, is entirely nullified if equipment is not kept in operative condition at all times. Therefore, the importance of proper care of equipment and routine inspection to make sure the equipment is kept in perfect working order for instant use cannot be overemphasized.

Foremen and other employees should be instructed in the use of all fire equipment so that they will not only be able to bring it quickly into action in the event of fire, but also so that they will realize the importance of its being accessible and unobstructed at all times. Trained employees will not allow firehose or extinguishers to become obstructed by piles of construction materials, supplies, or permanent equipment, or allow fire doors to become blocked open. Theywill see that aisles are kept clear so that there will be less chance of accidents occurring. Foremen and employees who are instructed in the dangers of poor housekeeping and defective electrical equipment will see to it that clean conditions are maintained, oily rags properly disposed of, and defective wiring, etc., repaired at once.

6.2. INSPECTIONS OF EQUIPMENT.- Periodic inspections should be made by capable personnel, preferably two or more, who should alternate in making the inspections. Portable extinguishers shall be inspected as required by section 3.3. Automatic foam or CO_2 systems should be checked to see that they are ready for operation in event of fire.

6.2.1. Fire Doors and Shutters.- All fire doors and shutters and their hardware, including fusible links, should be in good condition. The action of automatic sliding doors should be checked by raising the counterweight by hand. The guides of rolling steel doors should be checked. Any paint on fusible links should be scraped off. Rolling doors should be given an occasional operating test by disconnecting the fusible link. When checking over the fire doors, note if there are any openings in firewalls not properly protected by the fire doors or shutters.

6.2.2. Floor Drains.- Floor drains are provided in some instances to drain the floors of water promptly in event of fire or sprinkler leakage. They should be kept clear at all times.

6.3. CARE OF EQUIPMENT.-

6.3.1. Antifreeze Pump-Tank Extinguishers.- Antifreeze pump-tank extinguishers should be frequently inspected, kept full at all times, and refilled immediately after use. In recharging, it is desirable that all parts be washed thoroughly with water and the water drained through the hose. It is essential to draw all water from the hose to prevent freezing or clogging of the nozzle. It is recommended that after recharging and during inspections, the pump be operated several times, discharging the liquid back into the tank. Where an antifreeze solution is used, the specific gravity of the solution should be determined periodically with a hydrometer so as to ensure against freezing at the lowest temperature that may be encountered. Liquid which has evaporated or is used must be replaced. Pump tanks should be kept tightly covered so as to retard evaporation.

This type of extinguisher should be examined as to condition of operating parts at least once yearly, and during this examination, a drop of oil should be put on the piston-rod packing. Manufacturers of this type of extinguisher are now marketing a special antifreeze charge for these devices. Common salt or chemicals other than those specified must not be used in these extinguishers for any purpose; they cause corrosion.

6.3.2. Carbon Dioxide Extinguishers.- Carbon dioxide extinguishers should be weighed at least once every 6 months to detect leakage or accidental release and must be recharged immediately after use, even though only partially discharged. CO_2 cylinders should not be lifted by the neck or cap of the cylinder during weighing or handling procedures as the cylinders are not structurally designed to be supported by the neck. If an extinguisher shows a loss of weight of less than 10 percent of the rated capacity stamped on it, it need not be discharged or refilled; the contents do not deteriorate with age. The extinguisher should be sent to the manufacturer or his authorized agent for recharging. A close check on the condition of rubber and composition hoses should be made, especially where they are exposed to the sun, as in outdoor installations.

6.3.3. Dry-Chemical Extinguishers.- Dry-chemical extinguishers are filled with a compound consisting principally of bicarbonate of soda which has been chemically processed to make it waterproof, noncorrosive, nonconducting, and free flowing. The extinguisher contains a cartridge of carbon dioxide or nitrogen used to expel the dry compound. The carbon dioxide or nitrogen cartridge should be removed and weighed every 6 months. It should be replaced if it shows loss of weight. It is not necessary to removed to make sure it is full and there is no caking or moisture present. Compound and cartridges other than those furnished by the manufacturer should not be used, and recharging instructions should be carefully followed. A quantity of dry compound and spare cartridges should be kept on hand for immediate recharging after use. Care should be exercised that the extra compound is not contaminated by foreign materials.

6.3.4. Wheeled-Type Units.- Large wheeled-type units of carbon dioxide are available, and the common size for these devices are 23, 24, and 45 kg (50, 75, and 100 lb). The procedure for recharging and maintaining these devices is similar to the procedure on the small devices. Care must be taken in considering these devices to see that the doorways are wide enough to permit passage of the extinguisher from one room or section to another. In switchyards and any other type of structure on which protection is necessary, there should be concrete runways for the large-wheeled units where they are equipped with steel wheels. Where the large-wheeled units come equipped with pneumatic tires, a check should be maintained to see that these tires are properly inflated. Where it is necessary to store these large units outdoors, a small three-sided shed should be provided to keep the units out of the sun and weather to prevent deterioration of the rubber hose and tires.

Dry-compound extinguishers of the 45- to 159-kg (100- to 350-1b) size must be inspected every 6 months to ensure that the nitrogen pressure Is available. This is done by pressure gauges forming a part of the extinguisher, similar to those found on an acetylene welding unit. This extinguisher must be recharged and hose cleaned out by blowing out compound when used or partly used, and the nitrogen cylinder replaced by one fully charged when the pressure gauge shows less than 454 kg (1,000 lb). Compound furnished by other than the manufacturer should not be used. The recharging instructions should be carefully followed. A quantity of dry compound and a spare nitrogen cylinder should be kept on hand for Immediate recharging after use.

6.3.5. Hose.- Successful firefighting depends upon adequate fire streams. The fire-hose is a connecting link between the water supply and the fire, and of all firefighting equipment, it is the most essential. The life of firehose may be as short as 3 years or as long as 15 years. Under average fire conditions and with proper care, hose should be serviceable for a period of at least 7 years. Hoses requiring replacement should be replaced with lined hose.

The principal sources of damage to hoses are mechanical Injury, heat, mildew and mold, acid, gasoline, and oil. Tears, snags, and abrasions from dragging hose over ground or rough surfaces account for much damage to hose. Hose on racks, reels, or on firetrucks should be reloaded from time to time. This is to change the hose and prevent kinks which may damage the hose. A satisfactory method of storing hose, not in actual use, is in rolls stored horizontally. All hoses on racks and reels in powerplants or warehouses should be completely unrolled or unfolded at least annually. All racked hoses will be reracked using a different folding pattern. If drying facilities are available, they should be used.

6.3.6. Handling Hose at Fires.- The wear and tear on a hose may be reduced to a minimum by proper care and handling. Hose lines should not be dragged unnecessarily over pavements. Needless traffic should not be permitted to pass over hose, and it should be protected against unavailable traffic by the use of hose bridges and guards. Hose rollers should be used in hoisting hose onto roofs and into windows. Hose wet at fires and drills should be replaced by dry hose upon return to quarters. Hose couplings should not be dropped or dragged as this may result in mashed threads, jammed swivels, and other damage. After the hose has been used, all the dirt should be thoroughly brushed off. If the dirt cannot be removed by brushing, the hose should be washed with plain water and scrubbed. When the hose has been exposed to oil, the oil may be removed by washing the hose with soap and an mild alkali, and then properly rinsing. The hose should then be hung up or placed on a rack to dry. A hose-drying rack is recommended when a hose-drying tower is not available. The rack should be of such design that the hose is supported throughout its length and does not hang in loops or any other manner in which the water can become pocketed. If a hose appears to be in doubtful condition, it should be tested hydrostatically and replaced if necessary. The test pressure should be about 350 kPa (50 lb/in$^{2)}$ in excess of the working pressure at fires. For powerplant Installations where fire-main pressure should normally run between 700 and 1,050 kPa (100 and 150 lb/in2), 1,200 or 1,400 kPa (175 or 200 lb/in$^{2)}$ test pressure will be sufficient.

6.3.7. Hose Couplings.- Couplings should be kept in good order; and after hose is used, the threads should be examined and any injured or defective couplings should be repaired. They should be so adjusted that they can be easily screwed up by hand. Do not use oil or grease on any hose coupling as oil on couplings is likely to result in damage to the hose, as previously mentioned. If dirty, they should be spun in a pail of soapy water. The rubber coupling washers should be renewed as needed. Care should be taken also that the rubber washers do not project into the waterway, particularly at the nozzle, as this will frequently cause a ragged stream.

6.4. CHECKING EQUIPMENT.-

6.4.1. Automatic Sprinkler Systems.- In the majority of Reclamation plants, the oil storage and oil purifier rooms have been provided with an automatic water sprinkler system. These sprinkler systems are provided with a valved blow-off line. These blow-off lines should be opened at monthly or more frequently intervals in order to keep scale and rust from plugging up the sprinkler headers.

6.4.2. Transformer Spray Systems.-Some Reclamation powerplants and switchyards have fog-nozzle-type, water-spray systems for transformer bank fire protection. An initial test should be made on each system with the transformers deenergized to see that the fog coverage is adequate. Subsequently, the waterlines should be flushed out annually to remove rust and scale and ensure proper functioning of the system. For these tests, the nozzles may be removed or wrapped in burlap to prevent the spray from contacting transformers if they cannot be deenergized for the test. Automatic controls by thermostats or fusible links should be tested annually.

6.4.3. Automatic Generator CO_2 Systems.- A fixed CO_2 fire-protection system is provided at most Reclamation powerplants for extinguishing fires within the generator housing and in some other areas within the generator housing and in some other areas such as oil storage rooms. This equipment may remain dormant for years without being called upon for an operation, and without proper periodic checking may not be in operating condition when needed, resulting in a disastrous fire. It is, therefore, important that periodic checking be done to ensure that the equipment is always in operating condition.

Periodic checks as follows should be made:

(1) Weigh all CO_2 cylinders at intervals of not more than 6 months and replace cylinders in which the CO_2 content weighs less than 90 percent of the weight marked on the cylinder by the supplier. A record of the weights should be kept.

(2) Check the electrical control features at intervals of not more than 1 month by means of the test devices where these are provided. This checks the continuity of the electrical control circuits should the detonators and other devices in the circuits.

(3) Open and close the routing valves by hand at least once a year and after painting or other repair work is done to assure that the valves are not stuck.

(4) At annual intervals, make an overall CO_2 system check by disconnecting the detonators of all except those CO_2 cylinders that are under test [see (5) below] and operate the actuating contacts by hand, releasing CO_2 into the generator or other protected area. Observe for proper operation and leaks in the system and generator housing. CO_2 cylinders being removed because of loss of weight may be used for this purpose. Check for energization of the detonators by each of the other actuating contacts without discharging CO_2.

(5) All CO_2 cylinders shall be discharged and then hydrostatically checked by qualified suppliers every 12 years. Any cylinder that has been discharged that has not been hydrostatically tested within 5 years must be hydrostatic tested prior to being refilled.

VII. Fire Brigades

7.1. FIRE-BRIGADE DEFINITION.- For purposes of this manual, a fire brigade is an organized group of employees who are knowledgeable, trained, and skilled in at least basic firefighting operations. Even employees engaged only in incipient-stage firefighting will be considered a fire brigade if they are organized in that manner.

7.2. ORGANIZATION.- Each plant or facility that decides to maintain a fire brigade will pre- pare a written statement of policy establishing the existence of a fire brigade; the organiza- tional structure; the type, amount, and frequency of training to be provided to fire-brigade members; the expected number of members in the fire brigade; and the functions that the brigade is to perform in the workplace.

7.3. PHYSICAL REQUIREMENTS.- Employees who are expected to do interior structural fire-fighting must be physically capable of performing duties which may be assigned to them during emergencies. No employee with known heart disease, epilepsy, or emphysema may participate in fire-brigade emergency ac- tivities unless a physician's certificate is provided stating the employee's fitness to par- ticipate in such activities. Fire-brigade members will be provided an annual physical examination as is specified for firefighters, GS-081, in Reclamation Supplement to FPM R339.2.

7.4. TRAINING.- All fire-brigade members will be provided training and education commen- surate with those duties and functions that fire- brigade members are expected to perform. Such training and education shall be provided to fire-brigade members before they perform fire- brigade emergency activities. Fire-brigade leaders and training instructors shall be provided with training and education which is more comprehensive than that provided to the general membership of the fire brigade. It is recommended that fire-brigade leaders and fire- brigade instructors receive more formalized training and education on a continuing basis by attending classes provided by such training sources as universities and university fire extension services. The publications of the International Fire Service Training Association (Fire Protection Publications, Oklahoma State University, Stillwater, Oklahoma 74078) are recommended training manuals.

All fire-brigade members shall be provided with hands-on training at least annually and with education sessions or training at least quarterly. The quality of the training and education program for fire-brigade members shall be similar to those conducted by such fire training schools as the Maryland Fire and Rescue Institute; Iowa Fire Service Extension; West Virginia Fire Service Extension; Georgia Fire Academy, New York State Department, Fire Prevention and Control; Louisiana State University Firemen Training Program; or Washington State's Fire Service Training Commission for Vocational Education.

All fire-brigade members will be informed about special hazards in the workplace such as the storage of flammable liquids or gases, toxic chemicals, water-reactive substances, and energized electrical equipment to which they may be exposed during fire or other emergencies. Written procedures that describe the actions to be taken in situations involving the special hazards will be included in the training and education programs.

7.5. PROTECTIVE CLOTHING.- All fire-brigade members will be provided with protective clothing that protects the head, body, and extremities, and consists of at least the following components: Foot and leg protection, hand protection, body protection, eye, face, and head protection.

All fire-brigade members will wear protective clothing meeting the requirements of OSHA (29 CFR 1910.156) and summarized below:

(1) Foot and leg protection. Foot and leg protection will be achieved by either of the following methods:

(a) Fully extended boots which provide protection for the legs; or

(b) Protective shoes or boots worn in combination with protective trousers.

(2) Body protection.- Body protection will be coordinated with foot and leg protection to ensure full-body protection for the wearer. This may be achieved by one of the following methods:

(a) Wearing of a fire-resistive coat in combination with fully extended boots; or

(b) Wearing of a fire-resistive coat in combination with protective trousers.

(3) Hand protection.- Hand protection will consist of protective gloves or glove system which will provide protection against cut, puncture, and heat penetration. (4) Head, eye, and face protection.- Head protection shall consist of a protective head device with earflaps and chinstrap. Protective eye and face devices will be used by fire-brigade members when performing operations where the hazards of flying or falling materials which may cause eye and face injuries are present.

7.6. RESPIRATORY PROTECTION DEVICES.- Approved, self-contained breathing apparatus with full face piece, or with approved helmet or hood configuration, shall be provided to and worn by fire-brigade members while working inside buildings or confined spaces where toxic products of combustion or an oxygen deficiency may be present. Such apparatus shall also be worn during emergency situations involving toxic substances.

Self-contained breathing apparatus will have a minimum service-life rating of 30 minutes in accordance with the methods and requirements of the MSHA (Mine Safety and Health Administration) and NIOSH (National Institute for Occupational Safety and Health); except for ESCBA (escape self-contained breathing apparatus) used only for emergency escape purposes.

Self-contained breathing apparatus will be provided with an indicator which automatically sounds an audible alarm when the remaining service life of the apparatus is reduced to within a range of 20 to 25 percent of its rated service time.

Self-contained breathing apparatus for use by fire-brigade members performing interior structural firefighting operations will be the pressure-demand or other positive-pressure type.

Employees wearing self-contained breathing apparatus .will not enter alone into an area immediately hazardous to life. A team of two or more members, each wearing self-contained breathing apparatus may be used to enter hazardous atmospheres.

Employees instructed to use self-contained breathing apparatus should receive a minimum of 4 hours of training on the equipment with a 2-hour annual refresher course.

Employees required to operate resuscitation equipment must be given a 4-hour training course, followed by annual 1-hour refresher training sessions.

VIII. Instructions for Making Generator CO_2 Concentration Test

8.1. PURPOSE OF TEST.- A CO_2 concentration test should be made on at least one unit of each powerplant or large pumping plant, which is provided with a CO_2 fire-protection system, about the time the plant is to be placed in service; or, if not then, as soon thereafter as is practicable and when air-housing modifications dictate additional tests. These instructions are intended to provide the necessary details on how this test should be made.

The purpose of the CO_2 concentration test is to determine the adequacy of the CO_2 system, and at what time intervals delayed-action cylinders should be discharged to maintain at least the minimum 34 percent CO_2 concentration required. The system will be considered adequate if the minimum 34 percent CO_2 concentration can be held for 30 minutes, or until the unit comes to rest, whichever is the longer. The rate of unit declaration and the generator-housing pressure should also be observed.

8.2. TEST EQUIPMENT REQUIRED.- The apparatus required for making the test is as follows:

(1) Ranarex CO_2 recorder.

(2) Four stopwatches or watches with second hands.

(3) Graph paper, computation paper, carbon paper, curves, and pencils.

(4) Four clipboards.

(5) Generator-housing connections consisting of pipe or hose as required to connect between the 9.5-mm (3/8-in) sampling connections and outer generator housing (see A, fig. 6).

If sampling connections are not provided on the generator, they should be installed as shown in section B-B of figure 7. This is a typical installation, and all dimensions given can normally be adhered to except the distance from the center of the unit. The test sampling connections should be located approximately over the stator-winding end turns.

(6) U-tube manometer made of 9.5-mm-(3/8-in-) or larger inside-diameter clear Saran plastic tubing or glass.

The manometer should be mounted on a board with a suitable scale in the center. The U-tube legs should be at least 1 meter (3 ft) long and filled to 0.5 meter (18 in) with water (see B, fig. 6).

(7) Ranarex recorder and manometer connections consisting of hoses and fittings as required to provide supply and return lines between the Ranarex recorder sampling connections and the generator sampling connections (see C, fig. 6).

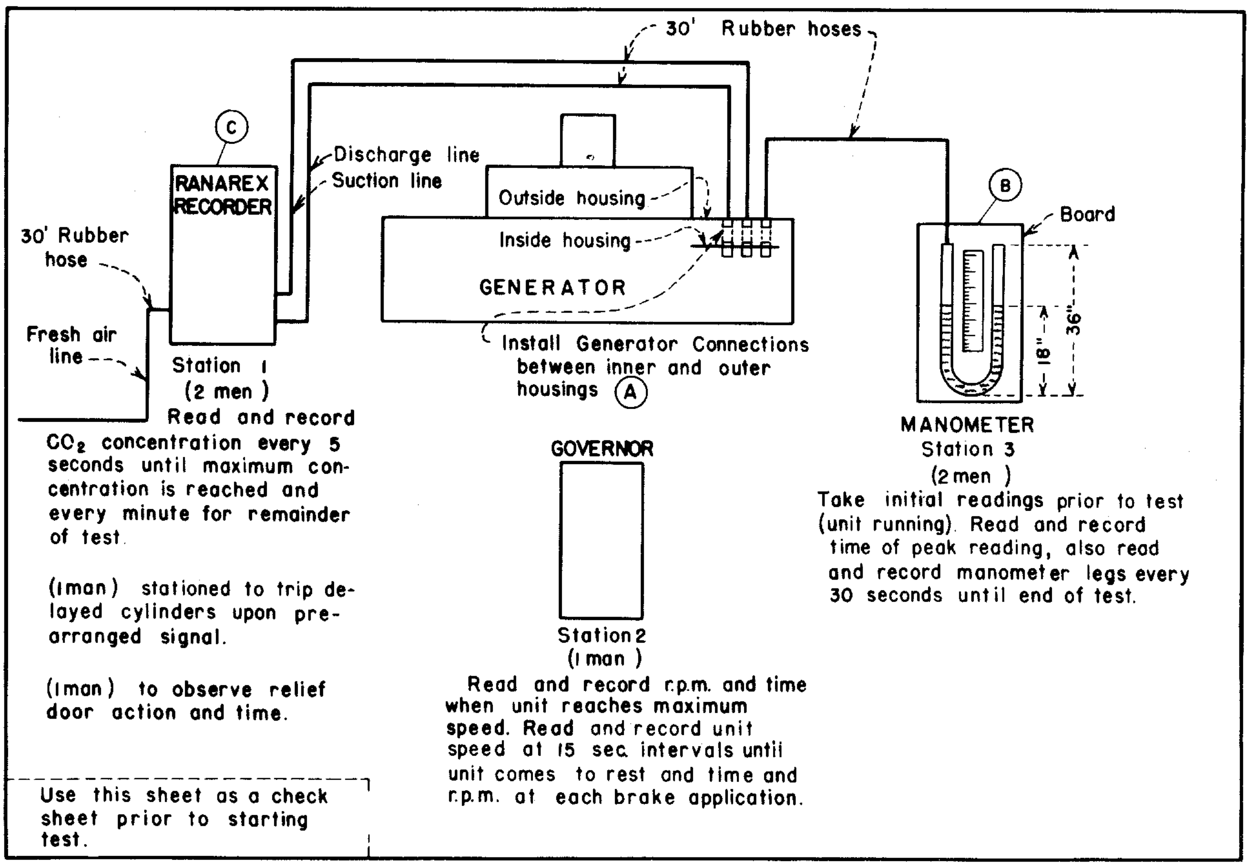

Figure 6. Checksheet for making generator CO_2 concentration test.

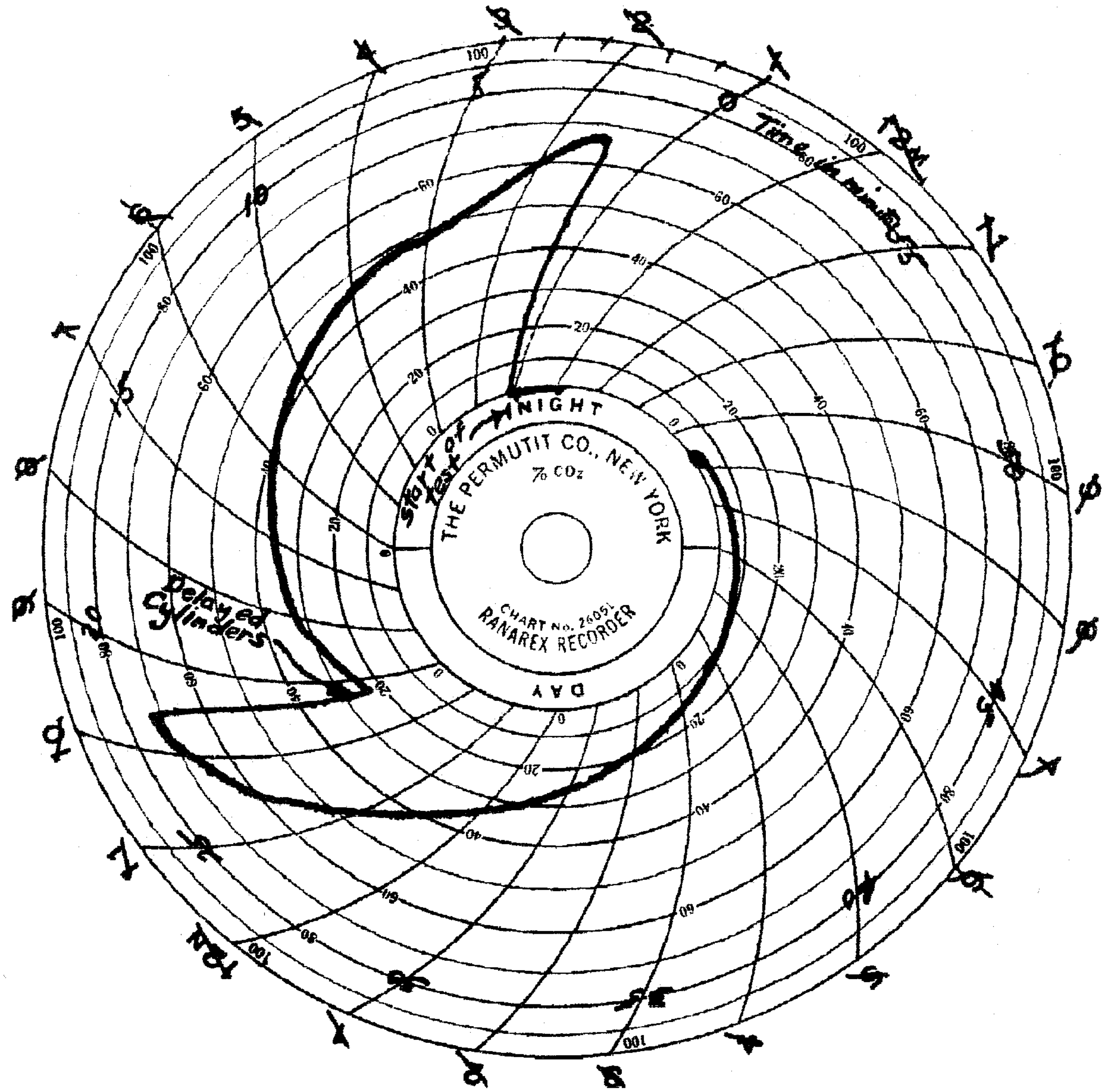

Figure 7. Ranarex recorder chart.

8.3. PRETEST INSPECTION AND PREPARATION.-

(1) Install necessary pipe and hose connections to generator housing as required for test.

(2) Inspect pipe fittings and valves for generator CO_2 system.

(3) Check CO_2 electrical control connections.

(4) Mount Ranarex recorder on a wood frame if desired and connect to 120-volt circuit. Check the operation of the Ranarex recorder and make a check of the zero point. The zero-point test should be made with the humidifiers filled, instrument warmed up, and the instrument operating in air with all external hose connections attached to the instrument, but with the opposite end of the hoses in atmospheric air. If the zero-point adjustment is required, follow the procedure in the Ranarex instruction book. After the

zero-point test has been made, connect generator end of Ranarex recorder hoses to generator and see that the open end of the fresh-air hose Is far enough away from the generator so that escaping $C0_2$ will not enter It. Check operation of Ranarex chart recording mechanism. If the disk of the recording mechanism is geared to make one revolution per hour and the charts furnished are marked for a 24-hour period per revolution, a time correction will have to be marked on the charts as shown on the sample chart, figure 7.

(5) Locate the U-tube and connect to generator housing.

(6) Inspect generator housing for tightness and proper operation of dampers if any are used. Close all access openings.

(7) Check floor drains within generator housing for adequate seal.

(8) Check generator relief doors for free swing and proper adjustment. Doors should be set to open when the housing pressure reaches 1.4 kPa (0.2 lb/in2).

(9) Assign and instruct personnel regarding the test and how to fill out the data sheets for their station (see figs. 8, 9, 10, and 11).

8.4. PERSONNEL REQUIRED FOR TEST.-

Duty station	Personnel required
Ranarex recorder	2
U-tube manometer	2
Governor tachometer	1
Relief door observer	1
Person to discharge delayed cylinders on prearranged signal	1
Control room operator on duty and two extra persons	3

8.5. TEST PROCEDURE AND DATA REQUIRED.-

(1) Take initial readings at all stations and be sure that Ranarex recorder is warmed up.

(2) With the test generator under full load at normal speed, trip the differential relay and take readings from the Ranarex recorder at 5-second Intervals until maximum concentration is reached and take readings at 1-minute intervals from zero test time until end of test. Discharge delayed cylinders as required to maintain 25 percent $C0_2$ concentration. (See Ranarex station sample data sheet, fig. 8.)

(3) Obtain the static reading on the housing pressure manometer. This reading should be taken with both legs of the manometer open to atmospheric pressure. Then, take the initial reading of the manometer with one leg connected to the generator air housing with the generator running. This will be called the initial reading. The water-column height on the legs under this condition will no longer be the same as the static readingbecause of the pressure in the generator housing caused by the rotation. Record this initial reading. Throughout the actual test after the $C0_2$ has been discharged, read both manometer legs every 3 seconds until the end of the test. In a few seconds after the discharge of the $C0_2$, the manometer reading will be at a maximum. Read this peak and time of peak. (See manometer station sample data sheet, fig. 9).

(4) Read the revolutions per minute by the governor tachometer. Record the maximum unit overspeed (peak r/min) and time, in seconds, that it occurred after zero test time. Read and record unit speed at 15-second intervals until the unit comes to rest. Also, note time and r/min at all brake applications. (See governor station sample data sheet, fig. 10.)

(5) Note the time of opening and closing of generator housing pressure relief doors. (See generator relief door sample data sheet, fig. 11 .)

8.6. Test Results.- From the data obtained, plot curves as shown on the typical curve example enclosed (fig. 12).

Date ______________________

Powerplant ____________________________ Unit No. ______________________________

Time at start of test ______________________ Recorded by ___________________________

Read by ______________________________

Time of delayed cylinder discharges ____

Time sec	CO_2 %	Time sec	CO_2 %	Time sec	CO_2 %
0		45		30	
5		50		35	
10		55		40	
15		60		45	
20		5		50	
25		10		55	
30		15		60	
35		20		Etc.-Might take	
40		25		5 min to reach	
				maximum	

Time sec	CO_2 %
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
Etc. to end of test	

Sample of Data Sheet

(The purpose of this sample data sheet is to show what readings are required at this station and is not complete as to length of time test will actually last.)

Figure 8. CO_2 concentration test data sheet - Ranarex station.

Date ____________________________

Powerplant ________________________________ Unit No. ___________________________________

Time at start of test ________________________ Recorded by ________________________________

Read by ___________________________________

Manometer static reading (inches H_2O) Right leg ____________ Left leg ______________

Manometer initial reading (inches H_2O) Right leg ____________ Left leg ______________

Manometer peak reading (inches H_2O) Right leg ____________ Left leg ______________

Time of peak reading ___________________

Remarks

Time sec	Right leg	Left leg
0		
30		
60		
30		
60		
30		
60		
30		
60		
Etc. to end of test		

Sample of Data Sheet

(The purpose of this sample data sheet is to show what readings are required at this station and is not complete as to length of time test will actually last.)

Figure 9. CO_2 concentration test data sheet - manometer station.

Date ______________________

Powerplant __________________________ Unit No. ____________________________

Time at start of test ____________________ Recorded by _________________________

Normal rpm of unit _____________________

Peak rpm during test ___________________ Time of peak rpm _____________________

1st brake application rpm ________________ Time of 1st application __________________

2nd brake application rpm ________________ Time of 2nd application __________________

3rd brake application rpm ________________ Time of 3rd application __________________

etc.

Remarks

Time sec	Rpm
0	
15	
30	
60	
Etc. to unit stops	

Sample of Data Sheet

(The purpose of this sample data sheet is to show what readings are required at this station and is not complete as to length of time test will actually last.)

Figure 10. CO_2 concentration test data sheet - governor station.

Date ___________________________

Powerplant _______________________________ Unit No. __________________________________

Time at start of test ________________________ Recorded by _______________________________

On initial discharge

Time relief door opens _________________ Time relief door closes _____________________

On delayed discharges

Time relief door opens _________________ Time relief door closes _____________________

Remarks

Figure 11. CO_2 concentration test data sheet - generator relief door.

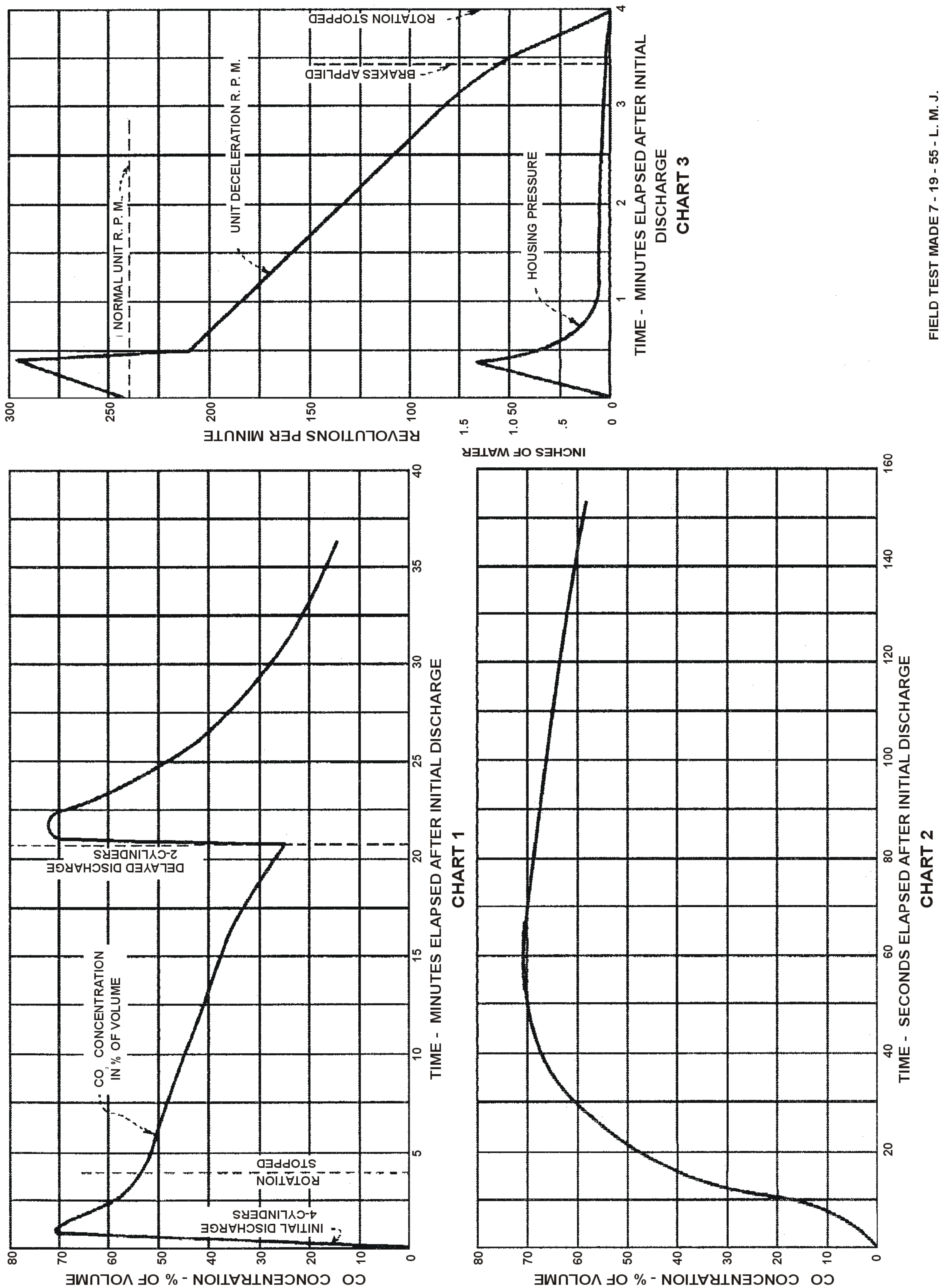

Figure 12. Kortes Powerplant - Generator carbon dioxide fire extinguishing system test - Unit 1.