PDHonline Course M110A (4 PDH)

Introduction to Fire Protection Systems

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MODULE - 4
NON-WATER BASED AND SPECIALIZED FIRE PROTECTION SYSTEMS

This module will introduce the student to the following:

- Dry and Wet Chemical Fire Protection Systems
- Carbon Dioxide Fire Protection Systems
- Halon and Clean Agent Fire Protection Systems
- Water Mist Systems
- Fire Protection Foam Systems
- Explosion Protection Systems

Following successful completion of this module, the student should be able to:

- Define a basic description of the systems covered in this module.
- List the main fire extinguishment mechanism associated with each type of system.
- Describe a "Clean Agent"
- Describe the differences between the major classifications of fire fighting foams.
- Describe the similarities and differences between sprinkler and water mist fire extinguishing systems.
- Describe the (3) basic methods of explosion suppression.

DRY CHEMICAL FIRE EXTINGUISHING SYSTEMS

Dry chemical extinguishing systems are used to protect a variety of fire hazards such as electrical transformers, flammable liquids, restaurant equipment, and fuel truck loading racks. It is electrically non-conductive and primarily suited for surface fires and is not effective on deep-seated fires, and is compatible with some fire fighting foams. Our discussion in this module will focus on dry chemical pre-engineered systems used to protect restaurant-cooking equipment.

Dry chemical fire extinguishing systems for commercial restaurant equipment were introduced in the early 1960's in response to an alarming rise in restaurant fires. Soon, most insurers required these fixed systems to be installed in restaurants.

Dry chemical fire extinguishing agent generally consists of a chemical powder mixture with particle sizes ranging from less than 10 microns to 75 microns. (1 micron = 0.000039 inch). There are a variety of powders ranging from potassium bicarbonate base, monoammonium phosphate (used in type ABC fire extinguishers), to urea-potassium bicarbonate, which provides the greatest extinguishment effectiveness of the dry chemical agents.

Generally, the dry chemical powder is fluidized with an expellant gas (usually carbon dioxide) and discharged directly to the fire through a carefully configured piping system and well placed nozzles.

Activation of the extinguishing system can be either automatic or manual. In the automatic mode, a fusible link element, located in the exhaust hood or duct, melts in response to a fire, thereby activating the dry chemical system. The dry chemical, in the fluidized state, is distributed through a piping system to nozzles placed throughout the hood and ductwork. A pull station is also provided to permit manual activation of the system. Additionally, the kitchen hood dry chemical system operation is interlocked with a gas valve or electric power supply to automatically shut-off the flow of gas or electricity to cooking equipment. The kitchen exhaust fan continues to run in order to disperse the dry chemical agent throughout the system.

Once activated, the systems were usually effective in suppressing the fire. However, due to the consistency of the dry chemical, extensive clean up is required. Additionally, some dry chemicals, when exposed to high temperatures, can breakdown in corrosive compounds and can attack metal if not properly cleaned up.

Although generally non-toxic, localized discharge of a dry chemical agent may cause respiratory irritation as well as reduced visibility in the area of discharge. Therefore, it is best to avoid inhalation of dry chemical powder.

Although some dry chemical systems are in use, the prevalent method of kitchen equipment fire protection is with wet chemical extinguishing agents.

Dry chemical fire extinguishing systems are covered under NFPA standard 17. Standard NFPA 96 addresses ventilation control and fire protection of kitchen equipment.

Smothering, cooling, and heat transfer shielding contribute to the fire extinguishment characteristics of dry chemical agent. ***However, studies indicate that the greatest fire extinguishment mechanism is through a break down of the combustion chain reaction.*** It is believed that the dry chemical agent prevents the reactive particles in the flame from coming in contact with one another, thus breaking the chain reaction and extinguishing the fire.

WET CHEMICAL FIRE EXTINGUISHING SYSTEMS

Wet chemical extinguishing systems were introduced in the early 1980's as an enhancement to restaurant equipment fire protection.

Generally, wet chemical extinguishing agents consist of a mixture of organic and inorganic salts in solution. A separate expellant gas tank is mounted next to the agent solution tank (usually in a wall-mounted cabinet adjacent to the protected equipment). Once the system is automatically or manually actuated, the wet chemical solution is released and mixed with the expellant gas and distributed from nozzles within the ductwork and hood. As in the case of a conventional dry chemical system, gas flow/electricity to the kitchen equipment is automatically shutoff with system activation.

Wet chemical fire extinguishing systems are covered under NFPA standard 17A. NFPA Standard 96 covers ventilation control and fire protection of kitchen equipment.

Smothering, cooling, and radiation shielding contribute to the fire extinguishment characteristics of dry chemical agent with ***cooling being the main extinguishment mechanism. However, unlike dry chemical, the wet chemical agent will develop a temporary foam layer on the surface of hot grease, which permits the grease to cool below the ignition temperature.***

The blanket also serves to prevent air from coming in contact with the grease (fuel) thus removing oxygen from the process. However, if the foam blanket should breakdown or is disturbed before the grease has had an opportunity to cool below the ignition point, re-ignition could occur.

KITCHEN EQUIPMENT FIRE EXTINGUISHMENT TRENDS

Within the last several years, a hybrid wet chemical system has been introduced into the market that addresses the protection of the deep fat fryer, arguably the most difficult piece of kitchen equipment to protect. The fire protection difficulty lies in the quantity of fuel (grease) that deep fat fryers equipment can hold (Some fryers can hold up to 80 pounds of grease).

The activated hybrid systems function initially as a wet chemical system, however immediately upon fire extinguishment, a water spray is discharged through the wet chemical piping system to cool the fuel and prevent re-ignition.

CARBON DIOXIDE FIRE EXTINGUISHING SYSTEMS

Carbon dioxide fire extinguishing systems have been in use for many years, and are used for the extinguishment of flammable liquids, gas fires, and fires involving electrically energized equipment, and some ordinary combustibles.

Typical applications include printing presses, vaults, dip tanks, spray booths, engine rooms, and flammable gas or liquids storage.

Under normal conditions, carbon dioxide is a gas. However, in fire suppression systems, carbon dioxide is stored in high-pressure tanks (high-pressure systems) by compressing and cooling or in low pressure refrigerated containers (low-pressure systems).

Liquid carbon dioxide, when discharged, has a white cloudy appearance due to fine dry ice particles and flash vapor in the discharge stream.

Additionally, some atmospheric water vapor will condense in the area adding to the fog effect.

Although only mildly toxic, discharged carbon dioxide vapor can be deadly due to the vapor density that is significantly heavier than air. Total flood systems discharging into confined spaces will displace oxygen with high concentrations of carbon dioxide necessary for fire extinguishment (typically 35- 70% by volume based on the material) and will extinguish the fire. It is for this reason that carbon dioxide total flood systems should not be used in areas that can be occupied unless complete evacuation of personnel can be assured. Additionally, due to its high vapor density, carbon dioxide gas can leak from the area of discharge into lower occupied spaces and affect personnel.

Typically there are two methods of application of carbon dioxide agent. One method is to discharge a sufficient amount into an enclosure and create an extinguishment atmosphere (total flood system), or local application (nozzles, hose lines, etc.). Total flood systems utilize a piping distribution system from a central source (high-pressure manifold tanks or central refrigerated bulk tank). Local applications involve using a mobile tank supply of CO2 to be applied to the fire by trained personnel.

NFPA Standard 12 covers carbon dioxide fire extinguishing systems.

HALON/CLEAN AGENT FIRE EXTINGUISHING SYSTEMS

Halogenated fire extinguishing agents consist of hydrocarbons in which one or more atoms from the halogen series hydrogen atoms have been replaced by: fluorine, chlorine, bromine, or iodine. This molecular replacement provides a nonflammable fire-extinguishing agent that was in use for many years.

Originally, Halon fire extinguishing agents were developed and used by the military for the protection of aircraft, ships, etc. in the 1930's. There were a number of Halon fire extinguishing agents tested in the late 1940's, however, the most effective and least toxic was Halon-1301 (bromotrifluoromethane). For years this agent was used in portable fire extinguishers and total flood applications due to its low toxicity, non-conductivity, and low agent concentration necessary for fire suppression (5-

7% by volume). Halon 1301 could be discharged into an occupied area without adverse health effects and still provide fire extinguishment. Halon 1301 was the preferred choice for protection of sensitive electronic equipment for over 30 years. However, in the mid 1980's it was recognized that some halogenated chemicals (CFC's) discharged into the atmosphere interacted with and environmentally damaged the ozone layer. By 1994, production and importation of new halon was halted. The only Halon in use today has either been recycled or produced prior to 1994.

Various chemical companies began research and development of an alternative fire suppressant to Halon-1301 that provided similar low-toxicity and fire extinguishment characteristics. Ultimately, a number of chemical companies have introduced ozone friendly "clean agents" on the market that provide excellent fire extinguishment, and offer low-toxicity. Some agents utilize mixtures of common gaseous elements while others use chemically altered formulas.

One of the agents on the market today is under the trade name "Intergen" that is marketed by the Ansul Inc. Intergen is a mixture of three naturally occurring gases: nitrogen (52%), argon (40%), and carbon dioxide (8%). The mixture is slightly heavier than air (vapor density=1.1), and does not provide a visible discharge. Normal atmospheric air contains 21% oxygen and less than 1% carbon dioxide. The inerting properties of Intergen lowers the ambient oxygen content to approximately 12.5% while increasing the carbon dioxide level to about 3%. Since most normal combustibles will not burn in atmospheres with less than 15% oxygen, extinguishment is attained. The increase in carbon dioxide concentration increases respiration, which compensates for the lower oxygen concentration level.

Additional clean agents include industrial grade Argon, FM-200, and FE-227.

Argon gas suppresses a fire similar to Intergen by lowering the oxygen content to about 12.5% which is below the 15% level for ordinary combustibles to burn and above the 10% level required by the EPA for human safety. Argon is suitable for class A, B, and C fires; is colorless and odorless and is electrically non-conductive.

The clean agents that use the trade names "FM-200" and "FE-227" are chemically known as heptafluoropropane which are compounds of carbon, fluorine, and hydrogen that are effective on class A, B, and C fires. They extinguish the fire by cooling at the molecular level and are the same class of compounds used in refrigerants. These agents are odorless, colorless, and electrically non-conductive and are considered safe for total flood applications.

Generally, the clean agent system configurations are similar to the obsolete Halon-1301 systems in the configuration and delivery of agent to the room. Essentially, heat and/or smoke detectors are placed throughout the protected area. Once heat and/or smoke is detected, an alarm signal is sent to a main control panel. Usually, pre-discharge notification with a reasonable delay is given audibly and visually to permit occupants to either abort the discharge or evacuate the room. Once the system is set to discharge, air-moving equipment is shut down to prevent unnecessary leakage from the space. The clean agent is released from manifold high-pressure cylinders into a piping system and discharged through specially designed nozzles.

NFPA Standard 2001 covers the design, and installation of clean agent fire extinguishing systems.

WATER MIST FIRE EXTINGUISHING SYSTEMS

Water has long been the preferred fire extinguishment agent, and water spray systems have been applied for many years. However, with the phase out of Halon-1301, renewed interest has sparked research in the application of a properly applied water spray system as an effective and economical means of fire extinguishment.

Water spray systems are essentially scaled down versions of limited area or local application sprinkler systems that rely on the fire extinguishment properties of finely atomized water droplets (less than 1000 microns). Some manufacturers list pre-engineered system droplet sizes produced in the 100-150 micron range. The small size of these water droplets provides a large surface area for heat transfer permitting much of the water mist to be vaporized into steam and providing the cooling effect necessary for fire extinguishment.

Water mist systems are characterized similar to conventional sprinkler systems as wet pipe, dry pipe, pre action, and deluge. However, unlike a conventional sprinkler system, water mist systems are used for local application (nozzle located at the potential ignition source), compartment application (similar to CO_2 or Clean Agent total flood system), or zoned application (a water mist system protecting a portion of an enclosure). Conventional sprinkler systems rely on a network of piping to provide complete or extensive building fire suppression from (usually) ceiling mounted sprinkler heads.

Water mist systems are designated as either high or low-pressure systems. High-pressure systems are defined as those that operate at or above 500 psig. Low-pressure systems are defined as those systems that operate between 175 to less than 500 psig.

Water mist systems are designated as either single or twin fluid systems. In single fluid systems, water is the only medium used for system operation. Generally, a mechanical pump is used in a single fluid system to provide the necessary pressurization for proper system operation. In twin fluid systems, compressed air is used in conjunction with the water to provide proper pressurization and atomization of the water necessary for proper operation.

Spray nozzle activation is similar to a conventional sprinkler system with either thermally actuated nozzles or open (deluge) nozzles. Nozzles must be carefully selected to provide the required flow and distribution pattern.

Hydraulic analysis for a low-pressure single fluid system is similar to a conventional sprinkler system by utilization of the Hazen-William calculation method for pressure loss (under certain pipe size and velocity limitations as defined in NFPA-750). The recommended calculation method is through use of the Darcy-Weisbach equation with an appropriate determination of the Fanning friction factor through the use of the Moody diagram and determination of Reynolds number. Most data, tables, and charts to compute friction loss in single fluid systems are contained within NFPA 750.

Hydraulic analysis for twin fluid systems is a bit more involved since compressed air and water are involved, however NFPA 750 offers guidance in the analysis of these systems.

Water mist systems are being applied to protection of electrical switchgear, transformers, cooling protection for tanks, dilution of flammable and combustible gas and liquid air-fuel mixtures. Water mist systems are commonly applied to gas turbines, spray booths, switchgear rooms, welding areas, and bulk conveyors.

The activation of a water mist system in a fire situation (especially in localized applications), results in rapid-fire extinguishment with a fraction of the water that would be used in a conventional sprinkler system.

Pre-engineered systems are available from several manufacturers. In all cases, the application of a water mist fire extinguishing system must be performed in close consultation with the manufacturer of the equipment.

NFPA Standard 750 covers the design and installation of fire extinguishing water mist systems.

FOAM FIRE EXTINGUISHING SYSTEMS

Foam fire extinguishing systems have been in use for many years protecting a variety of hazards. Foam extinguishing systems have been successfully utilized for flammable and combustible liquid fires, storage tanks, marine tankers, fuel loading areas, and fuel spills as the result of aircraft and automobile crashes.

Fire extinguishing foam is generally defined as a stable aggregation of small bubbles (filled with air or other gas), that has a specific gravity less than the fluid it is being applied to, and forms an air-excluding blanket over the liquid to prevent the mitigation of volatile vapors and access to air. The foam should also have resilience to wind, heat, and flame attack, and should be capable of resealing in the event of blanket rupture.

All foam systems, regardless of size, contain four (4) essential components:

- A supply of foam concentrate
- A water supply
- A proportioning device to mix the water and foam concentrate in correct quantities.

- A foam maker. (air entraining device)

There are a variety of foams produced for the specific characteristics of the fire hazard it is intended to protect. Unfortunately, it is not practical to discuss every specific type of foam in production. Therefore we will concentrate on the broad classifications of foam.

- Protein Foam Concentrates: Intended for use on non-polar hydrocarbon fuels. This foam is economical, and has excellent heat resistance, burnback, and drainage characteristics. However, fire knockdown characteristics are somewhat slow.

- Fluoroprotein Foam Concentrates: Similar to protein foam with the addition of fluorochemical surfactants to improve fast fire knockdown, and dry chemical compatibility.

- Synthetic Foam Concentrates: are divided into aqueous film forming foams (AFFF) and alcohol resistant aqueous film forming foams (AR-AFFF). The AFFF foam is a combination of the fluoroprotein foams with the addition of synthetic foaming agents. The AFFF foam quickly drains the foam solution from the foam bubble to provide a film layer that spreads across the fuel to provide rapid-fire knockdown and separation of the fuel surface from air. The AFFF foams are most effective on hydrocarbon fuels with high surface tension such as kerosene, diesel fuel, and jet fuels. AFFF is intended for use on non-polar fuels. AR-AFFF foam is similar to the AFFF foam with the addition of synthetic stabilizers and polymers that are resistant to solvents that tend to breakdown the foam blanket and extract water (polar solvents) from the foam. The addition of the polymers in the form prevents breakdown of the foam blanket in contact with the polar solvent. AR-AFFF foams are suitable for use on hydrocarbon fuels and polar solvents.

- High Expansion Foam concentrates: are synthetic detergent foams used with air aspirating foam equipment to provide foam expansions from 100:1 to 1000:1. High expansion foams are "total flood systems" and are generally used on class A combustibles in areas such as basements, mine shafts, attics, and other hard to reach or inaccessible places.

EXPLOSION PROTECTION SYSTEMS

As discussed in Module 1, an explosion involves a rapid increase in pressure that produces a shock wave followed by a flame front. Most explosion protection systems are designed to operate within 100 milliseconds of detecting either a pressure increase and/or the presence of optical radiation associated with flaming combustion. (See Module-5 for a discussion of optical flame detectors).

The concept of explosion protection basically involves one of three methods:

- Venting
- Suppression
- Isolation

Venting is usually the most economical method of explosion protection and is designed to provide a pressure relief device (disk, etc.) that ruptures at a predetermined pressure and channels the explosive fireball and pressure to vent to a safe location. Common application of this type of protection would be an explosion relief panel on a piece of process machinery located outside. Extreme care must be taken to assure that personnel do not occupy the area designated for explosion venting. Typically, venting is used in conjunction with isolation method (discussed below).

Suppression involves the use of high speed pressure detectors that responds to a pressure increase (usually within milliseconds of ignition) and discharges a flame suppressant to the explosive flame front before destructive pressure can build up. The suppressant works chemically by interfering with the explosion reaction and thermally to removing the heat from the flame front and preventing further ignition. Generally, suppressants such as carbon dioxide, and gaseous fire suppressants are used.

Isolation involves the use of either mechanical or chemical methods to detect an incipient explosion and prevent the shock wave/ flame front from propagating into other areas. One method of isolation employed is the detection of an incipient explosion and the release of a physical barrier to stop the shock wave and flame front. The isolation method is normally used in conjunction with venting (see above). A typical application is connecting piping between process equipment that has the potential for an explosion.