FIRE AND FIRE EXTINGUISHMENT

A BRIEF GUIDE TO FIRE CHEMISTRY AND EXTINGUISHMENT THEORY FOR FIRE EQUIPMENT SERVICE TECHNICIANS

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INTRODUCTION

The professional service technician, who selects, installs, maintains, recharges and otherwise performs service work on portable fire extinguishers, pre-engineered and engineered fire suppression systems should have a basic knowledge of fire chemistry, theory of extinguishment, classification of fires and properties of different fuels. This base knowledge will allow the professional technician to better understand the fire hazards that they may encounter, how various fire extinguishing agents, in theory, suppress fire and therefore have a better understanding of the equipment that they are entrusted to install and maintain.

This document is not intended to make the reader an expert on the subjects discussed, rather, it is intended to give a base knowledge and provide references for more in-depth study.

FIRE RESPONSE

Response to any fire scenario, regardless of the form of the response, should have these three basic priorities listed by importance:

1. **Life Safety and Personal Protection**. The most important thing to accomplish in any fire incident is to protect life and avoid injury. Property, product, processes and material can be replaced and rebuilt. Human life and health is most precious and cannot be replaced. If nothing else is accomplished in a fire incident other than the complete safety of all persons involved, then the first and the most important goal in a response to fire has been accomplished.

2. **Incident Stabilization**. Once the first priority has been accomplished, the second goal is to stabilize the incident – keep it from growing or getting worse. By stabilizing the incident and not allowing it to change, grow in intensity or grow in size, the incident cannot threaten more lives and property, even if the area or property involved becomes a total loss.

3. **Property conservation.** Only after item 1 and item 2 have been established, the focus may turn to extinguishing the fire quickly with the least amount of damage to the property involved.

The role of portable extinguishers and pre-engineered systems in response to a fire incident has the same priorities listed above. Together with a fire plan, alarm notification, evacuation, quick and safe response, portable extinguishers and pre-engineered systems may be key factors in the outcome of any fire incident.

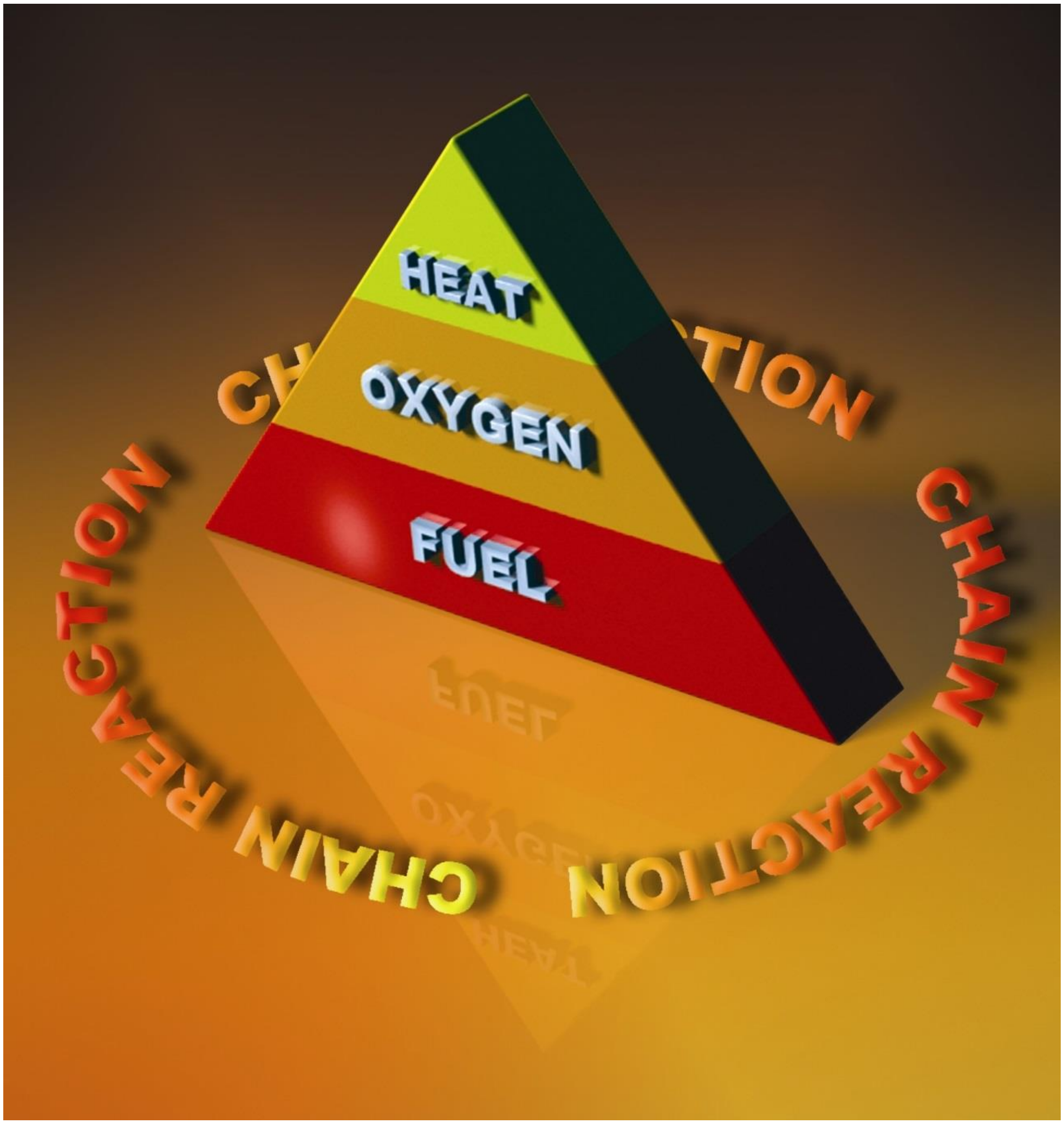
SAFETY TRIANGLE CONCEPT

The successful use of any type of fire equipment - fire extinguishers, fire suppression systems, hose lines, nozzles or even apparatus - depends upon three elements being in place at the same time: Equipment – Maintenance – Training

If these three elements are considered sides of a triangle, then if any one element is missing or incomplete, the triangle – and the chances of successful use – either fails to exist or is incomplete.

Having the correct equipment and proper maintenance without effective training on proper use of the equipment is inadequate. Effective equipment in the hands of trained personnel will not be effective if the equipment has not been maintained and either fails or performs poorly in an incident. Trained personnel using well maintained equipment will not be successful if the equipment was not the proper type for the hazard or the anticipated type of incident. It should be the goal of the salesperson, the installer, the maintenance technician and the end-user – working together – to put a complete triangle together and maintain the triangle concept for as long as the hazard exists.

Every proposal, every installation and all maintenance performed on every fire extinguisher or fire extinguishing system should strive to complete and maintain this triangle concept. It cannot be known which extinguisher or which system will be depended upon to operate in a fire incident. A fire incident is the ultimate test of the triangle concept.


HEAT
OXYGEN
FUEL
CHAIN REACTION
CHAIN REACTION

BASIC ELEMENTS OF FIRE

Four elements must be present in order for fire to exist. These elements are **HEAT**, **FUEL**, **OXYGEN** and **CHAIN REACTION**. While not everything is known about the combustion process, it is generally accepted that fire is a chemical reaction. This reaction is dependent upon a material rapidly oxidizing, or uniting with oxygen so rapidly that it produces heat and flame. Until the advent of newer fire extinguishing agents, fire was thought of as a triangle with the three sides represented by heat, fuel, and oxygen. If any one of the three sides were to be taken away, the fire would cease to exist. Studies of modern fire extinguishing agents have revealed a fourth element - a self propagating chain reaction in the combustion process. As a result, the basic elements of fire are represented by the fire tetrahedron - **HEAT, FUEL, OXYGEN** and **CHAIN REACTION**. The theory of fire extinguishment is based on removing any one or more of the four elements in the fire tetrahedron to suppress the fire.

REMOVING THE HEAT

In order to remove the heat, something must be applied to the fire to absorb the heat or act as a heat exchanger. Water is not the only agent used to accomplish this, but it is the most common. A more detailed discussion of how to apply water on a fire and some theories regarding its use as an extinguishing agent will be covered in a later section.

REMOVING THE FUEL

Under many circumstances, it is not practical to attempt to remove the fuel from the fire. When dealing with flammable liquid fires, valves can be shut off and storage vessels pumped to safe areas to help eliminate the supply of fuel to the fire. Flammable gas fires are completely extinguished by shutting off the fuel supply.

REMOVE THE OXYGEN

Oxygen as it exists in our atmosphere (21%) is sufficient to support combustion in most fire situations. Removal of the air or oxygen can be accomplished by separating it from the fuel source or by displacing it with an inert gas. Examples of separation would be foam on a flammable liquid fire, a wet blanket on a trash fire, or a tight fitting lid on a skillet fire. Agents such as CO_2, nitrogen, and steam are often used to displace the oxygen.

INTERRUPT THE CHAIN REACTION

Modern extinguishing agents, such as dry chemical and halons, have proven to be effective on various fires even though these agents do not remove heat, fuel, or oxygen. Dry chemical and halogenated agents are thought to suspend or bond with “free radicals” that are created in the combustion process and thus prevent them from continuing the chain reaction. A more detailed study of this phenomenon is available from the NFPA Fire Protection Handbook and various manufacturers of special fire extinguishing agents.

COMBUSTION

Generally speaking, for any material to burn, it must be heated to the point that it releases vapors that may be ignited. The temperature at which a material (solid, liquid or gas) will be capable of being ignited varies greatly from one material to another. Another factor to be considered, particularly in the case of solids, is the physical size and shape of the material. The more surface area subjected to heat and resulting vaporization, the more easily ignitable it becomes. As an example – it is very difficult to light a large log in a fireplace with a single match, but very small pieces of wood, having more combined surface area exposed to heat, can be easily ignited.

HEAT TRANSFER

Heat may be transferred from one object to another or one material to another by any one of three methods.

Conductive heat - the transfer of heat through a solid – as an example, a pan on an electric burner is heated by direct contact with the hot burner.

Convective heat - transfer of heat through a circulating fluid or gas (such as air), as an example, the hot coils of a heater will warm the air that contacts it causing the air to rise and circulate and then heating (or warming) other objects in the room.

Radiant heat - transfer of heat without direct contact or heating a fluid or air between the objects – as an example, the sun heats the earth without direct contact with the earth and without heating the space between the earth and the sun.

CLASSIFICATION OF FIRES

CLASS “A” FIRES

A class “A” fire can involve any material that has a burning ember or leaves an ash. Common examples of class “A” fires would be wood, paper, or pulp. The preferred method for extinguishing class “A” fires is to remove the heat. Water is the most common agent, but others such as dry chemical, halon, halogenated agents and foam can be used effectively.

CLASS “B” FIRES

A class “B” fire involves flammable liquid or gas. Familiar examples would be gasoline, oil, propane, and natural gas. A variety of fire extinguishing agents are used on flammable liquid fires employing all theories of fire extinguishment. Which agent is best to use is dependent upon the circumstances involved. Flammable liquids do not ignite in their liquid state; rather it is the vapors being generated by these liquids that ignite. The mixture of oxygen and flammable vapors in proper proportion needs only an ignition source to start the combustion process.

CLASS “C” FIRES

Class “C” fires involve live electrical equipment and require the use of an extinguishing agent and/or extinguisher that will not conduct electricity back to the fire fighter(s). Electricity is an energy source and an ignition source, but by itself will not burn. Instead, the live electrical equipment may serve as a source of ignition for a class “A “fire such as insulation or packing, or a class “B” fire.

CLASS “D” FIRES

Class “D” fires involve exotic metals such as titanium, zirconium, magnesium, and sodium. These fires require special agents such as dry powders and special application techniques. The extinguishing agents and techniques used on “A”, “B”, or “C” fires will not work on class “D” fires, nor will the agents and techniques used for class “D” fires work on any other classification of fire. Many common agents like water will actually react to burning metals and increase the intensity of the fire in a violent manner.

CLASS “K” FIRES

Class “K” fires involve cooking media. These can be any animal or vegetable based fats or oils. These fires require special agents such as wet chemical extinguishers and systems that are alkaline in nature and have superior cooling capabilities. The entire mass of the cooking medium in a deep fat fryer must be secured and cooled below its auto ignition point in order to achieve complete extinguishment. Prior to the 1998 edition of NFPA 10 these fires were considered to be Class “B” fires. After extensive testing it was decided that they are unique in nature and are totally different than Class “B” fires.

COMMON TERMS - FLAMMABLE LIQUIDS

Flash Point is the lowest temperature at which a liquid will generate enough vapor to form a flammable mixture in the air.

Auto-Ignition Temperature is the temperature at which the air/vapor mixture will ignite without an extraneous source of ignition such as a flame or spark. Ignition temperature is an important factor when flammable liquids are exposed to hot metal surfaces.

Vapor Density is the ratio of the weight of a substance to an equal volume of dry air. Vapor with a number greater than one is heavier than air; vapor with a number less than one is lighter than air.

Specific Gravity is the ratio of the weight of a substance (liquids) to an equal volume of water. A liquid with a specific gravity of less than one will float on water; a specific gravity of more than one will sink.

Additional Information: NFPA Fire Protection Handbook, NFPA 30

FLAMMABLE LIQUIDS

Two different groups are identified in order to select the appropriate extinguishing agent:

Hydrocarbons - will generally not mix with water

Polar Solvents - water miscible fuels or flammable liquids that will mix readily with water

NFPA 30 Flammable and Combustible Liquids code 2008 Edition:

“4.3 Classification of Liquids
Any liquid within the scope of this code and subject to the requirements of this code shall be classified in accordance with this section.
4.3.1 Flammable liquids, as defined in 3.3.30.2 and 4.2.3, shall be classified as Class I liquids and shall be further sub-classified in accordance with the following:
(1) Class IA Liquid — Any liquid that has a flash point below 73°F (22.8°C) and a boiling point below 100°F (37.8°C)
(2) Class IB Liquid — Any liquid that has a flash point below 73°F (22.8°C) and a boiling point at or above 100°F (37.8°C)
(3) Class IC Liquid — Any liquid that has a flash point at or above 73°F (22.8°C), but below 100°F (37.8°C)
4.3.2 Combustible liquids, as defined in 3.3.30.1 and 4.2.2, shall be classified in accordance with the following:
(1) Class II Liquid — Any liquid that has a flash point at or above 100°F (37.8°C) and below 140°F (60°C)
(2) Class III Liquid — Any liquid that has a flash point at or above 140°F (60°C)
(a) Class IIIA Liquid — Any liquid that has a flash point at or above 140°F (60°C), but below 200°F (93°C)
(b) Class IIIB Liquid — Any liquid that has a flash point at or above 200°F (93°C)”

EXAMPLES:	**FLASH POINT**	**AUTO-IGNITION**
Lubricating Oil	300ºF	783ºF
Fuel Oil #6	150ºF to 270ºF	765ºF
Diesel	100ºF	494ºF
Kerosene	100ºF to 130ºF	410ºF
Gasoline	-36ºF to -45ºF	536ºF to 853ºF

Higher viscosity fuels pose special fire extinguishment problems such as frothing and boiling, therefore, extra care must be exercised to identify the hazard properly.

FIRE FIGHTING AGENTS:

In this section we will discuss various fire extinguishing agents except water. The use of water on fires is discussed in a separate section along with corresponding application techniques and industrial hose handling procedures.

Foam:

Chemical Foam:

Fire fighting foams have been grouped into two main types: Chemical Foams and Mechanical Foams. Chemical Foams are rarely found still in use and have been replaced for the most part by different types of Mechanical Foams. Chemical Foams relied on a chemical reaction between two materials to produce a foam layer that blankets the flammable liquid surface and secures the vapors. A familiar example of chemical foam would be the old foam fire extinguishers that were constructed the same as soda-acid fire extinguishers. An outer chamber containing a solution of sodium bicarbonate and foam stabilizers would mix with an inner chamber containing a solution of aluminum sulfate when the extinguisher was inverted. The mixing of these two solutions would cause a chemical reaction that would create pressure expelling the agent and expanding the solution into foam. This foam was very stable but had no film forming capabilities and was unable to move easily across a fuel surface. For the most part, extinguishers using these types of foams have been considered obsolete for some time and are required to be removed per NFPA 10.

Mechanical Foams:

Mechanical Foams refer to foam solutions that require a mechanical injection of air to expand and form bubbles. Some examples of mechanical foams are: Protein Foam, Fluoroprotein Foam, Aqueous Film Forming Foam (AFFF), Film Forming Fluoroprotein Foam (FFFP), Alcohol Type AFFF, Alcohol Type FFFP, Mid Expansion Foam and High Expansion Foam. All of these foams are sold in concentration, proportioned by different means into a foam concentrate/water solution and delivered to the fire as an expanded or finished foam. Foam concentrates are identified by percentages, 6%, 3%, 3-6% 1%. This percentage refers to the required amount of foam that must be mixed (proportioned) with water to make foam solution.

Protein Foam (available in 3% or 6% concentrates is made of foam stabilizers and hydrolyzed protein meal. It has been in use since the 1940s, offers excellent burn back resistance, will seal against hot metal surfaces and is a very stable foam. Some of the drawbacks of protein form are its inability to shed hydrocarbons when submerged below a flammable liquid surface, its ineffectiveness on polar solvent (water miscible) fuels like alcohol and polar solvent/hydrocarbon mixtures and its inability to move easily across a liquid surface.

Fluoroprotein Foams are made of the same base as protein foams with a fluorochemical surfactant to give it better hydrocarbon shedding characteristics and better movement across a fuel surface.

Aqueous Film Forming Foams (AFFF) lack the stability of protein based foams, have no protein base, and are made mostly of fluorochemical surfactants. As the foam bubbles break, drain out and lose their water, they form a film on the surface of the fuel that moves easily across the fuel surface and excludes vapors from escaping.

Alcohol Type AFFF's are similar in base to AFFF with the addition of a copolymer. The copolymer reacts with water miscible fuels (polar solvents and hydrocarbon/polar solvent mixtures containing 10% or more polar solvents) and will react with the polar solvents to create a polymeric membrane. This membrane creates a physical barrier between the fuel and the vapor/air mixture above it, securing the fire. Foam created by Alcohol type AFFF's will generally be more stable and have greater burn back resistance than standard AFFF's. Alcohol type concentrates are either a "3 X 6" (meaning 3% concentration for hydrocarbon fires and 6% concentration for polar solvent fires) or a "3 X 3" concentrate.

Film Forming Fluoroprotein Foam (FFFP) is a protein based foam that will form a film over a flammable liquid surface much like AFFF's.

Medium Expansion Foam is made of surfactants without fluorocarbons that are expanded with special devices to achieve more bubbles. These foams do not usually have film forming capabilities and are more susceptible to thermal columns and winds when being applied to a fire
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High Expansion Foams are similar to low expansion foams but use different devices for their expansion. These foams have been used on class A and structural fires where water sources are scarce and have been applied using a total flooding application.

THEORY OF EXTINGUISHMENT

All mechanical foams extinguish fires through physical means. The foam blanket or film secures vapors coming off of the fuel surface, the foam concentrate is mixed with water prior to being expanded and therefore has excellent cooling characteristics additionally mechanical foams will separate the fuel from air. Foam agents are the only agents that may be applied to a flammable liquid to prevent ignition by suppressing the release of vapors from the fuel surface. Mechanical foams used by themselves are ineffective on gaseous fires, flammable liquids under pressure, three dimensional fires and fires involving liquids in motion. On class A fires, the surfactants that are added to the water solution tend to reduce the surface tension of the water, allowing better penetration, less run-off and more efficient cooling. In order for mechanical foams to work properly, they must be mixed or proportioned correctly with water, injected with air to achieve expansion (form bubbles) and be applied correctly to the fire surface.

Foam proportioning involves mixing foam concentrate with water to form foam solution. A 6% foam concentrate must be mixed in a ratio of 6 parts foam concentrate to 94 parts water. A 3% solution would be a mixture of 3 parts concentrate to 97 parts water and a 1% solution would be a mixture of 1 part concentrate to 99 parts water. Mixing a 6% concentrate in a ratio of 3 gallons of concentrate with 97 gallons of water would make a weak solution and mixing a 3% concentrate in a ratio of 6 gallons of concentrate to 94 gallons of water would result in a rich solution.

There are many methods of proportioning foam including in line educators, bladder tanks, around the pump proportioning and pre-mix solutions. Hand portable and wheeled foam fire extinguishers use a pre-mix method of proportioning where the foam concentrate and water are measured and mixed in fixed amounts inside a vessel.

Foam expansion is achieved by injecting air into the foam solution as it is discharged onto the fire. Expansion is usually stated in ratios: low expansion foam (Protein, Fluoroprotein, AFFF, FFFP) 10:1, Medium expansion 20-100:1, High expansion 100-1000:1. Low expansion foams may be listed or approved for use with both air aspirating and non-air aspirating nozzles. Medium expansion foams use special air aspirating nozzles with several screens and a wider deflection to generate greater expansion. High expansion foams will use water or air driven foam generators to achieve even higher expansion ratios. All foam Hand Portable and Wheeled Fire Extinguishers use an air aspirating nozzle. These nozzles consist of a tip with holes in the sides to pull air into the stream (much like a venturi) and small screens on the tip to mildly expand the solution.

Halogenated Agents:

Halogenated agents have been used for fire fighting since the early 1900's. Of the ten halogenated agents that have been used two have been the most common since the early 1970's - halon 1211 and halon 1301. To have a better understanding of the chemical properties of these agents, the US Army Corps of Engineers developed a numerical system for halogenated agents:

Agent Name	C (Carbon)	FL (Fluorine)	CL (Chlorine)	BR (Bromine)	I (Iodine)
BROMOTRIFLUOROMETHANE	1	3	0	1	0
BROMOCHLORODIFLUOROMETHANE	1	2	1	1	0
BROMOCHLOROMETHANE	1	0	1	1	0
CARBON TETRACHLORIDE	1	0	4	0	0
DIBROMOTETRAFLUOROETHANE	2	4	0	2	0
DIBROMODIFLUOROETHANE	1	2	0	2	0
METHYL BROMIDE	1	0	0	1	0

This numbering system is based upon the number of atoms of each chemical component that the agent has. If the last digit(s) have no atoms of that chemical the number is dropped as in halon 1301, halon 1211, etc...

Each halogenated agent has unique physical properties such as vapor pressure, boiling point, specific gravity and the like. All halogenated agents decompose when exposed to flame or temperatures above 900 deg. F.

THEORY OF EXTINGUISHMENT Halogenated agents suppress fire by interrupting the chemical chain reaction in the combustion process, working in the fire chemically instead of physically. Exactly how this "chain breaking" process works is not completely understood. It is generally agreed that bromine is released from the agent as it decomposes in the fire carrying away the "free radicals" that cause the combustion and releasing more bromine to continue the "chain breaking" process.

Many of these halogenated agents, halon 1301and 1211 specifically, are identified as ozone-depleting agents and are subject to control under the Montreal Protocol and other Federal requirements. NFPA 10 and 12A have specific requirements for reclaiming these agents and preventing their release into the atmosphere under non-fire conditions. For more information on how to accomplish this consult the manufacturer’s service, maintenance and recharge manual for the equipment and agent involved.
The primary advantage of halogenated agents has been the lack of clean up required after using the agent. In some environments (such as electronics, data processing, jet engines and high tech optical equipment), discharging other extinguishing agents such as dry chemical or water could cause more property damage than the fire itself. Pound for pound, halogenated agents as used in hand portable extinguishers were never as effective as more common agents on typical class B and class A fires.

Halon Alternatives:
Since the ratification of the Montreal Protocol, alternatives to Halon 1301 and Halon 1211 have been sought. Various proprietary blends of gases are available on the market. For “streaming agents” (those used in portable fire extinguishers), there are three popular agents in use at this time - FE-36, Halotron I and NOVEC 1230. All of these agents extinguish fires primarily through cooling. For “flooding agents” (those used in total flood systems) there are a variety of agents used at this time. See NFPA 2001 for more information on the available “flooding” agents, their names and physical properties.

Wet Chemical:
Wet Chemical agents are solutions of water mixed with potassium acetate, potassium carbonate, potassium citrate or combinations thereof. They are specifically designed for Class “K” fires but they have demonstrated superior effectiveness (gallon for gallon) on Class “A” fires when compared with plain water. These agents are used in both hand portable extinguishers and pre-engineered fixed systems.

THEORY OF EXTINGUISHMENT Wet Chemical extinguishers work on Class “K” fires through two methods. The solution is alkaline in nature and therefore reacts with the free fatty acids in the cooking medium to form a soapy foam on top of the burning material. This secures the vapors and cools the cooking medium as the foam drains out and converts to steam. This reaction is called saponification. In addition to saponification, the agent is discharged as a fine mist. This mist does not submerge below the surface of the cooking medium (preventing a steam explosion) but rather it converts to steam on the surface pulling heat out of the material. Cooking media fires must be cooled below their auto ignition point in order to successfully extinguish the fire. The requirement for cooling the cooking media below its auto-ignition temperature stresses the importance of automatic shut off of heat sources to appliances when preengineered systems activate. Without removal of the heat source to the appliance, the fire will reflash.

On Class “A” fires, the Wet Chemical works much like water only more efficiently. The fine mist spray cools the Class “A” fire more efficiently and the addition of the chemical breaks down the surface tension of the water for better penetration and less “run-off”. See NFPA 10 for more information on class K extinguishers and NFPA 17A for more information on Pre-engineered wet chemical systems. NFPA 96 and the IFC (International Fire Code) have specific requirements for the use and placement of Class K extinguishers as well.

Water Mist:
The Water Mist extinguisher uses de-ionized water that is discharged as a fine spray onto the burning material. It is designed as an alternative to halon in areas where contamination must be kept to a minimum without the expense of halon substitutes. The nozzle uses a wide spray pattern with fine droplets to give a soft and controlled discharge pattern. This extinguisher has passed the UL test for electrical conductivity, and water agent must have a conductivity rating of 1 microseimen or less as required by NFPA 10, allowing it to be listed for Class “C” applications.

Dry Chemical:
Dry Chemical agents have unique properties for fire extinguishing applications. On class B fires they demonstrate superior "flame knock-down" over other available agents. Pound for pound they are unequaled in effectiveness when used properly on class B fires. Monoammonium phosphate has similar capabilities on class B fires plus the ability to effectively suppress class A fires.

Dry Chemical extinguishing agents have been used since the early 1900's. Early in the development of dry chemical agents, sodium bicarbonate was found to have greater effectiveness on flammable liquid fires compared with other chemicals being used at the time and is still widely used today. In the 1960's major developments in dry chemical agents led to the introduction of potassium bicarbonate (Purple-K), siliconized dry chemical manufacturing processes (to allow for use with protein foam), monoammonium phosphate for use on class A B & C fires, potassium chloride (Super-K) and urea-potassium based dry chemical (Monnex). Potassium chloride and urea-potassium based dry chemicals are less common in the U.S. markets and will not be discussed in depth in this primer.

Extinguishment Theory for Dry Chemicals:
For class B fires, all dry chemicals rely on particle size and decomposition to accomplish extinguishment. Theoretically, the smaller the particle size, the more effective the chemical will be as an extinguishing agent. Particle sizes on the average of 20 to 25 microns are said to be best, however, smaller particles pack too easily and are not practical for use in a hand portable. Dry Chemicals can be found with particle sizes ranging from 10 to 75 microns. The relationship of particle size to extinguishing effectiveness implies that the surface area of Dry Chemical agents plays a key role in extinguishing a fire.

Some "smothering" action occurs when Dry Chemical is decomposed in a flame front and produces CO2. It is generally recognized that while CO2 is formed during the extinguishment process, however, the quantity of CO2 being generated is so small as to be insignificant in comparison with other factors.

Cooling also takes place as the Dry Chemical decomposes. Water vapor is formed as a product of decomposition and the solid particles act as a barrier between the fuel surface and the radiant heat formed by the flames in the vapor space above the liquid fuel. This barrier prevents the radiant heat from returning to the fuel surface and continuing ignition. As with the "smothering" action, while some cooling is taking place through the formation of water vapor and the creation of a particle barrier, this cooling action alone is not considered significant enough to extinguish the fire.

Similar in theory to halogenated agents, the primary mechanism through which Dry Chemicals extinguish a class B fire is a "chain breaking" action. Application of Dry Chemical is considered to prevent the "free radicals" (formed in the combustion process) from linking up to sustain the reaction. It is presumed that the decomposition of the Dry Chemical forms new species that react with the "free radicals" and terminate the generation of new "free radicals" breaking the chain reaction. It has been asserted that in some instances the surface area of the chemical particles allow the free radicals to link up and be carried out of the chain reaction sequence.

"Flame Flare-Up" Phenomenon
Another unique property of Dry Chemical is the "Flame Flare-Up" that occurs when Dry Chemical is applied to a flammable liquid fire. The extinguisher operator will notice a tremendous increase in flame and heat in front of the chemical discharge. This is caused by a combination of two events. The Dry Chemical stream, consisting of solid particles, pushes air in front of the discharge into the fire causing the flames to push to one side and flare up. Air is also injected into the dry chemical stream through a venturilike process, causing the vapor mixture to achieve more complete combustion resulting in a larger "fire-ball". This "flame flare-up" is short in duration and is usually of little consequence to the fire fighter since it occurs opposite the Dry Chemical flow and will burn itself out quickly. In some instances such as fire fighting within structures or limited spaces (such as mine shafts), the extinguisher operator must be aware of

combustibles that may be ignited from the "flare-up" or having the flames impinge back to the operator.

"Heat Shield"
Since the Dry Chemical discharge consists of finely divided solid particles, it may serve as a barrier to radiant heat being generated by the fire. Instructions for application of Dry Chemical generally state to stay back from the fire, only advance after discharge has begun in order to take advantage of this barrier and provide better comfort and safety for the operator.

Sodium Bicarbonate
Sodium bicarbonate dry chemical is also called "regular dry chemical". In addition to effectiveness on class B and C fires, it will have some effect on the flaming stages of a class A fire but no effect on the ember or deep seated stages of a class A fire. When used with common cooking greases it will react with the hot grease to form a thick foam through a process known as "saponification". The foam created by saponification will act much like other fire fighting foams but does not have the cooling effect of wet chemical and is no longer considered effective for use on Class K fires. Sodium bicarbonate dry chemical is alkaline in nature and will not cause corrosion during normal use.

Potassium Bicarbonate - "Purple-K"
Potassium bicarbonate or "purple-K" dry chemical was developed by the U.S. Naval Research Lab, precluding the use of the term "Purple-K" as a Trade Name. It was discovered that the salts of potassium were far more effective on flammable liquid fires compared with the salts of sodium. Claims of the effectiveness of potassium bicarbonate agents range from 50% to 100% more effective on flammable liquid fires when compared to sodium bicarbonate. Potassium bicarbonate is also alkaline in nature, has similar abilities to saponify when used on hot cooking grease, but like sodium bicarbonate, it lacks the cooling capability of wet chemical and is no longer the agent of choice for Class K fires. Purple -K will not cause corrosion under most uses.

Monoammonium Phosphate
Monoammonium Phosphate or "ABC" or "Multi-Purpose" Dry Chemical differs from potassium bicarbonate or sodium bicarbonate in that it is acidic in nature. In addition to similar effectiveness on class B and C fires when compared to sodium bicarbonate, monoammonium phosphate has unique effectiveness on class A fires. When it contacts the burning surface of an ordinary combustible, a molten residue (metaphosphoric acid) is formed. This residue coats the burning ember and excludes oxygen. Monoammonium phosphate will not saponify when used on hot cooking grease and will cause corrosion if not thoroughly removed from most surfaces.

Dry Powders for Use on Class D Fires
Combustible metal fires represent a special hazard that is not like class A, B and C fires. Extinguishing agents used on all other classes of fires have no success when used on class D fires. In fact some agents, such as water, will react violently with the

burning metal.

Most agents used in extinguishers for these fires are proprietary in nature and are classified according to the manufacturer of the dry powder or the brand name of the agent. Each agent has different limitations regarding the type of metal (magnesium, zirconium, titanium, lithium etc.) that it may be used on and the form the metal is in (molten, casting, turnings or fines). Data sheets from the agent extinguisher manufacturer should be consulted to determine which agent is appropriate for a particular situation. The following NFPA codes standards and recommended practices should also be consulted: NFPA 484 – Combustible Metals

Most class D agents are applied generously to the material burning, often requiring up to 15 lbs. of agent per pound of burning material. The extinguishing agent will usually exclude oxygen and perform as a "heat" sink to absorb the thermal energy, cooling the material down. Caution must always be used when applying special agents to combustible metal fires since these fires will react with any moisture to be found in the ground or surrounding materials.

Graphite-based Powder is a finely divided graphite (carbon) powder which may be applied from a bulk container with a scoop or shovel and is also available in a portable extinguisher. This powder will conduct heat away from the material reducing its temperature below the point that combustion may be sustained.

Salt-based Dry Powder is a Sodium Chloride based powder and is available in a 30 lb. hand portable or a wheeled unit as well as in bulk form for delivery via scoop or shovel. Sodium chloride - based dry powder will form a crust on the burning material, excluding oxygen. It will also help to dissipate heat from the burning material.

Copper-based Dry Powder is a pure copper powder, and was specifically developed for use on lithium fires. It is available either in a 30 lb. hand portable or a wheeled fire extinguisher. Argon is used as the expelling gas for these extinguishers because lithium will react with nitrogen to form other combustible alloys.

Other Class D Agents are available for specific Class D fuels and/or environments. As always, proper identification of the hazard and careful selection of the appropriate extinguishing agent must be performed. It is best to consult with the manufacturer of these special agents to determine if they are applicable to the hazard being protected.

Definitions:
There are some basic terms that a fire extinguisher or pre-engineered systems technician should be familiar with:

AFFF - Aqueous Film Forming Foam, a synthetic foam capable of producing a water solution film on the surface of many flammable liquids which excludes air and reduces fuel vaporization.

Ambient - Surrounding (as in ambient temperature, atmosphere, or conditions).

Auto ignition - Ignition of a material without the presence of an extraneous source of ignition.

BTU - British Thermal Unit – while no longer considered an SI (Standard International) unit; it is still used in cooking appliance specifications and in calculating air movement for hood and duct systems in commercial cooking operations

CGA – Compressed Gas Association

Combustible - Likely to catch fire.

Contain - To restrain within limits, enclose or cease spreading.

Control - To exercise restraining or direct influence over.

Disperse - To break up or scatter (as in - to disperse a flammable gas or vapor cloud).

Effective - Producing decided, decisive, or desired effect.

Extinguish - To put out (as in fire) to bring to an end the process of combustion.

FFFP - Film Forming Fluoro Protein foam, a protein based foam with fluorocarbon surfactants added and said to have the same film forming capabilities of AFFF.

Flammable - Easily ignited.

Flash Point - The lowest temperature at which enough vapor is generated from a flammable liquid to form a mixture in the air capable of being ignited.

Fluoroprotein Foam - A protein based foam with fluorochemical surfactants added to achieve hydrocarbon shedding properties.

Foam Concentrate - Concentrated foam agent.

Foam Solution - Mixture of foam concentrate and water at proper proportions.

Foam - Foam solution that has been air-aspirated to form expanded foam.

Frothing - Bubbles formed in or on high flash point combustible liquids.

Fuel - A substance used to produce heat or combustion.

GPM - Gallons Per Minute.

Gas - The physical state of a substance composed of molecules in constant motion that has no shape or volume, but will assume the shape and volume of an enclosure. A fluid that tends to expand indefinitely.

Heat - A form of energy that causes a body to rise in temperature, to fuse and to evaporate.

ICC – International Code Council

Inhibit - To hold in check, restrain or repress.

IFC – International Fire Code

IMC – International Mechanical Code

Miscible - Capable of being mixed.

NFPA - National Fire Protection Association
.
Nozzle - A device used to direct the flow, change velocity of the flow, change the pattern of the flow, or change the volume of the flow of any agent.

Nozzle Reaction - The rearward thrust caused by the flow of water or other agent through the nozzle.

OSHA – Occupational Health and Safety Administration

Oxidize - To chemically combine with Oxygen.

Oxygen - A colorless, odorless, gaseous chemical element that is found in the air and is essential to life, and when combined with fuel vapors will produce heat and light when ignited.

Perimeter inches – calculated for an exhaust duct as 2 X side “A” + 2 X side “B” = perimeter inches or the sum of all sides of the duct = perimeter inches.

PSI - Pounds per Square Inch

Proportion - To adjust in size relative to other parts as in mixing foam concentrate with water to specific ratios.

Pyrophoric - Any chemical (gas, solid or liquid) that will spontaneously ignite in air at or below a temperature of 130 deg. F.

Quenching - The application of water spray to cool the fuel down below its flash point.

Saponification – The formation of a soapy foam on burning cooking fats or oils through the application of an alkaline based fire extinguishing agent such as wet chemical, sodium bicarbonate or potassium bicarbonate based dry chemical. The foam is a reaction of the alkaline with the free fatty acids in the cooking medium.

Vapor - A substance in the gaseous state.

Viscous - The property of resistance to flow in a fluid or semifluid – example, glue is thick and resists flow.

Volatile - Readily becoming a vapor at low temperatures; easily erupting into violent action.

Volume – calculated for an enclosure as Height X Width X Length = total volume of an enclosure

Water Mist – Water dispersed in a finely divided form using droplet sizes of 200 microns or less.

Wet Chemical – A solution of water and potassium acetate, potassium carbonate, potassium citrate or combinations thereof.

USING WATER AS AN EXTINGUISHING AGENT

A. Advantages of water as an extinguishing agent

1. Water is relatively inexpensive when compared to other extinguishing agents such as dry chemical, CO2, halons and foam.
2. Water is readily available in adequate quantities under most circumstances. However, sources of supply should not be assumed to be free of failure or infinite in quantity.
3. With proper planning and forethought, water can be easily, safely and effectively used as a fire extinguishing agent.

B. Disadvantages of water as an extinguishing agent

1. Water by itself will not extinguish flammable liquid fires under most circumstances.
2. Water can spread flammable liquid fires.
3. Use of water may increase the amount of hazardous materials requiring disposal.
4. Water may react with some materials creating excessive heat and toxic vapors.
5. In addition to spreading flammable liquids, when water is applied to a high flash point, high viscosity liquid (such as asphalt), “frothing’ or “slop-over” may result.
6. Because of surface tension, water by itself has difficulty penetrating some dense, deep seated class A fires, causing excessive run off and decreasing fire fighting effectiveness.
7. Water can conduct electricity and may pose a safety hazard to fire fighting personnel if proper, listed nozzles or other devices and precautions are not used.
8. 2 ½ gallon portable fire extinguishers weigh considerably more than similarly rated

extinguishers using other agents, weight may therefore be a factor for the personnel using these extinguishers.
9. If water is used in conjunction with foam application it can disturb or destroy the foam blanket, allow flammable vapors to be released.

C. Heat absorption and expansion characteristics of water
1. Unlike other extinguishing agents such as dry chemical, CO_2 and halons, water has both large accessible quantities and excellent heat absorption qualities
2. It takes 1150 BTU of thermal energy to convert one pound of water at 32 deg. F to steam at 212 deg. F.
3. When water converts to steam it expands at a ratio of 1750 to 1.
4. When water is finely divided into small droplets, the heat transfer process becomes more efficient.

Application of water on class A fires.
1. Effective streams are important when fighting class A fires.
2. Fuel for class A fires will not float on the surface of water like flammable liquids but care should be taken in order to avoid damaging equipment or spreading dust by using the
wrong stream pattern.
3. Overhaul techniques must be used in order to confirm that the fire is extinguished.
4. Some class A fires (tires, bales, rolled craft paper, wood chip piles) can be difficult to penetrate.

APPLICATION TECHNIQUES

The most important aspect of any fire extinguisher application technique is operator safety. Techniques that needlessly jeopardize the safety of the operator are unnecessary and should never be taught or demonstrated.

It is advisable that all fires should be fought from the upwind side, to stay out of the smoke, flames and radiant heat. While this is preferable, it is not always practical. regardless of wind direction, fires should only be fought from a side that allows a clear path of escape. Never place yourself on the opposite side of a fire from the path of escape in order to take advantage of the wind direction.

The priorities discussed at the beginning of this primer should be kept in mind during any fire incident:
First priority – Save lives and protect physical wellbeing, fires are only to be fought with extinguishers if it is safe to do so, an alarm has been turned in and occupants are evacuating
Second priority – After the first priority is accomplished, Stabilize the incident, keep the fire from spreading if possible and if it is safe to do so
Third priority – After the first two priorities have been accomplished, Limit property damage by using the right agent – the agent and extinguisher that will be most effective on the fire and cause the least amount of property damage.

Foam Application Techniques

When applying foam to a fire, it is important to stay back during the initial attack. Unlike Dry Chemical or water fog patterns, Foam streams do not give good protection against radiant heat. Once control of the fire starts to be established, the operator can safely move closer.

Care should always be taken to be sure that the foam is not submerged into the fuel and is applied gently with minimal disturbance to the fuel surface. Some ways of doing this is to deflect the stream off of a vertical surface near the fire allowing the foam to run down onto the fuel surface and spread out over the fuel with minimum disturbance to the surface. Another technique would be to discharge the foam at the ground in front of the fire, allowing the foam to roll over the front edge of the fire and onto the fuel with minimal disturbance to the fuel surface. Foam may also, in the case of hydrocarbons, be discharged directly over the surface, allowing the foam to gently "rain" down on the fuel causing some disturbance. Faster extinguishment can be accomplished if the stream is moved about the surface rather than holding at one application point and waiting for the foam to move across the fuel surface. Once control has been established, shut down the nozzle and see if the foam will seal up, completing extinguishment. As long as the stream is disturbing the fuel surface, the foam cannot seal across the surface and complete extinguishment.

If water-miscible (polar solvent) fuels are involved, even in a small percentage, an “alcohol type” foam must be used. When using an alcohol type foam it is important that the fuel surface not be disturbed so that the polymeric membrane can form on the surface. No firefighting foam will secure a fuel surface indefinitely. Re-application is necessary over a period of time to prevent re-ignition. The bubbles in the foam will eventually break and drain down. Drain down times are specific to each type of foam and each foam manufacturer through fire testing and are usually listed in the manufacturer’s literature or product specification. Fire fighters should never drag hoses through a foam blanket or step into a fuel source with a foam blanket on it without having specific equipment and protection to do so. Water streams should not be applied to surfaces covered with foam as the streams will disturb or even destroy the foam blanket. Water miscible (polar solvent) fuels such as alcohol are particularly dangerous since they burn so cleanly that flames may not be visible.

Dry Chemical Application

Unlike foam on a class B fire, Dry Chemical has no securement capabilities. All of the fire must be extinguished or none of it will be extinguished. Since Dry Chemical uses a "chain breaking" action to extinguish a class B fire, no physical properties of the fire are being affected. Oxygen is not being displaced, very little cooling is being accomplished and the fuel is not being removed. Depending upon the type of materials that are exposed to the fire (such as steel, gravel, combustibles), the chance for a reflash is usually present. The operator(s) should anticipate the possibility of a reflash and never turn their back on a fire. **THERE IS NEVER A REASON TO STEP INTO A FLAMMABLE LIQUID SOURCE WHEN USING ONLY FIRE EXTINGUISHERS**. With the exception of fighting fires inside structures or underground mining operations, the operator should remain upright to have the best and safest mobility. Bending over or running may cause the operator to trip.

Always start the approach at a safe distance, humans were made to walk forward very well but running backwards is never done safely.

Be aware of what is on the opposite side of the fire from where the operator will be discharging. The "flare-up" phenomenon can catch other fuels or combustibles on fire at a great distance from the dry chemical discharge. In addition to looking for fuels on the opposite side of the discharge, the operator must also be aware of any personnel in that area that may be exposed to the “flare-up”.

Whether one operator is involved or several, keep your heads alert, communicate loudly and always have an escape route open in case you are not successful.

Fuel in Depth

Class B fires involving fuel in depth present unique problems for the application of Dry Chemical. Fuel in depth implies that the flammable liquid is contained to a certain area either by a vessel, berm or a dike. Only the surface is of concern, it does not make a difference from an application stand point whether the surface area has 5 gallons or 500 gallons of fuel. Since the fuel is contained to a specific surface area, it is important that the operator does not get too close and splash fuel, causing the area to increase. Ideally this fire would be fought from upwind, but if the upwind approach would cut off a safe escape route, it can be fought with a crosswind or diagonal wind. It is important for the operator to start discharging the extinguisher from a comfortable distance, using the dry chemical stream to "lay down" the fire and push it back before stepping closer. If the fire surface is in a rectangular shape, a slow, deliberate cut across the leading edge will get chemical into the freeboard area between the lip of the containment and the fuel surface. This is best accomplished by splitting the stream of dry chemical on the leading edge. Generally, the stream should be placed at least six inches in front of the leading edge and the sweep or cut should begin at least six inches beyond the side of the fire and continue past six inches beyond the other side of the fire.

If, after the initial cut has been made, fire is seen raising immediately on the lead edge right after the dry chemical stream moves away, the aim is too high, or in the case of a deep freeboard area, the angle is too flat. If fire immediately reappears on one side or the other, the cut or sweep is not being extended far enough to that side.

If the fire surface is in the shape of a circle, as in a round pan, start the discharge at the closest point, splitting the stream on the lead edge, hold for a count of 1 - 2 and then begin sweeping side to side. As with a rectangular pan, each sweep must extend beyond the edges on both sides.

Once the fire is moving backwards, the operator can take slow steps forward, sweeping side to side until the fire is completely out. During these sweeps side to side, each sweep must extend at least six inches past each side. Unless it is necessary because of nozzle range, it is advisable to always stay back away from the fuel source as far as possible. Should a sudden wind shift occur, the attempt at extinguishment fail, or a new source of ignition be introduced, the entire surface area of fuel will quickly ignite.
If for any reason it is necessary to be close to the fuel source, the speed of the sweep action must be increased in order to keep from splashing fuel.

Do not chase the "flare-up", keep the stream down on the surface of the fuel, the "flare-up" will burn out quickly. Once extinguishment has been accomplished, stand by waiting for re-flash and then back carefully away towards the escape route.

Spill Fires
Spill fires by themselves are most likely the easiest of all flammable liquid fires to extinguish with dry chemical. There is no "lead edge" or freeboard area to conceal burning vapors. The same basic technique that is used for fuel in depth is used for spill fires with one extra caution. With a lot of dry chemical flying about, the exact spill area may be hard to define, so it is important that the operator stay back as far as possible to avoid inadvertently stepping into the fuel source.

Three Dimensional Fire (Gravity Fed) (requires extinguishers with high flow rates per NFPA 10 – 2013 Edition)
This type of fire involves flammable liquids in motion, usually running from a source through several levels and pooling on the ground and other areas. Often obstacles are involved and at the least, areas where fuel will flow around structures. For these reasons, more than one extinguisher operator should be used at the same time.
Initial approach and application are the same as for a spill fire. The operator(s) should open up the stream(s) at a safe distance, keep a clear path of exit and then, once the fire is moving, move forward taking care so stay out of the fuel spill. Application must begin with the ground fire and then systematically continue extinguishment up to the source. Everywhere that fuel is flowing over hot metal surfaces, or wrapping around an obstacle, the Dry Chemical stream should be held briefly to allow chemical to build up at that spot before continuing. If the low level fire re-ignites at any point during the application, the Dry Chemical stream must be brought back to the ground fire in order to be successful.

Applications with More than One Operator
Using extinguishers in teams can be the safest and most successful way of extinguishing fires in their incipient or early stages. Communication is the key to having a safe, coordinated effort. All other basic rules apply regarding safe exit, distance, staying clear of the fuel source and individual application technique. Each operator must speak loudly and clearly to each other. Dry Chemical streams must be opened at the same time (effectively doubling the flow rate of the agent) and each operator should know what the other is going to do prior to the attack.

At no time should the operators be at direct opposite sides of the fire, this will obscure vision, spray fuel and dry chemical on each other. Each operator should be able to see the other at all times and know where each team member is at.

If one operator runs out of dry chemical before the other, that person should state loudly and clearly **"I'm out"** and then back away to safety along the predetermined path. This will let the other operator know that it is time to back away and cover both of their exits by discharging dry chemical between them and the fire and creating a heat barrier.

If one operator spots fire that is being missed by the other operator, that person must point it out immediately to the other. While each person may have a specific task to do, or a specific part of the fire to handle, it is important for each person to keep looking at all aspects of the fire. Other operators may not be able to see fire lingering in a small area because their vision is obscured by the dry chemical discharge.

If the fire is successfully extinguished, one of the operators must call the fire out. Both operators should then stop discharging, stand by and look for a re-flash and then back away to safety following the same route used to advance on the fire.

Spill or Fuel in Depth with an Obstacle (requires multiple operators and/or extinguishers with high flow rates per NFPA 10 – 2013 Edition
An obstacle inside a fuel in depth or spill fire will shield the Dry Chemical stream from covering the entire liquid surface. At least two operators must be used when obstacles are present.

First a plan of attack must be agreed to by the operators, (who goes which way and covers what part). Standing side by side, start discharging dry chemical together, each covering two thirds of the surface area. Once the fire is moving they then advance and split to each side until they can reach the back of the obstacle from an approximate 45º angle. When the fire is out behind the obstacle they then sweep the rest of the surface fire out. Once extinguishment is accomplished, they stand by looking for re-flash and then back away along the same path used to advance.

Fires with Flammable Liquids Under Pressure (requires extinguishers with high flow rates per NFPA 10 – 2013 Edition)
Generally the best way to extinguish flammable liquids under pressure is to shut off the source of supply. This is not always practical and Dry Chemical can be very effective on these types of fires. Usually it is necessary to place the Dry Chemical stream right at the point of escape and hold at that spot until the fire goes out, and then continue to put out any ground fire that is burning. Fast flow equipment with high flow rates must be used on this type of fire since the dry chemical flow rate must match the flow of fuel escaping.

Using Dry Chemical with Water Lines
Dry Chemical can be applied to fires from behind fog patterns with great success. The fog pattern protects the fire fighters and aids in cooling the fire. The Dry Chemical can be directed from behind through the pattern without allowing fire to come back on the

operator. When using this technique it is still necessary to apply the Dry Chemical using the same application techniques that are used without a fog pattern. Common mistakes with a combined water/Dry Chemical attack involve just directing the Dry Chemical into the water stream (this will have little effect on the fire) or sticking the Dry Chemical nozzle into the fog pattern (thus breaking the pattern and allowing flame to come back onto the hose team).

Using Dry Chemical with Foam

Dry chemical used in combination with foam can be more effective than either agent by itself. The classic “twinned-agent” equipment employing separate tanks for foam and dry chemical along with separate hoses and nozzles has been used successfully for decades on spills and fuel in depth fires. It is important when using dry chemical and foam together to use each agent’s properties to the best advantage. The dry chemical should be discharged initially to use the superior flame knock down to push the fire back off of the surface. Foam then is applied behind the dry chemical to secure the vapors and prevent re-flash.

Dry Powder on Class D Fires

Applying Dry Powder to class D fires generally involves a soft discharge pattern that will completely cover the burning material under a mound of Dry Powder. The operator should be careful that no moisture is present in the surrounding area that may contact the burning metal. Once the material is completely covered, the operator should stand by and watch for "hot spots": that start to burn through the powder and re-apply as necessary. It should never be assumed that the fire is out and extra care must be taken when attempting to move the material that has been burning. Manufacturers of Class D extinguishers and agents have established ratios of agent to burning material, based upon testing. These ratios may be as high as 15 lbs. of agent per lb. of burning Class D material and are given on a label affixed to the extinguisher.

ANSI (American National Standards Institute)/UL (Underwriters Laboratories) STANDARD 711 FIRE EXTINGUISHING RATING SYSTEM

The numerical portion of Class A ratings of extinguishers is developed on the basis of comparative fire tests using various sizes of wood-crib and wood-panel fires. The numerical portion of Class B ratings of extinguishers is developed on the basis of fire tests using square steel pans in specific size increments and a flammable liquid test fuel similar to unleaded gasoline. The fire extinguisher classification is equivalent to 40 percent of the area of fire extinguished twice by an expert operator. ***This 40% relationship should not be construed – as it commonly is – that the extinguisher will successfully extinguish, in an incident, 40%, in square foot area, of the size fire successfully extinguished under UL testing. There are too many factors – operator effectiveness, wind conditions, nature of the fire and the fuel – to even suggest that this would be true in any given incident.***

All fire tests are conducted by experienced personnel. The operator of the extinguisher must be protected against the heat of the fire. A fire fighter’s helmet and face shield, personal protective gear (fireman’s “turn-outs”) or a long coat and gloves of aluminized insulated cloth and self-contained breathing apparatus is required.

CLASS A FIRE TESTS

For ratings Class 1A through 6A the extinguisher shall be tested on the appropriate wood-panel and wood-crib fires. For a 10A rating, the extinguisher shall successfully extinguish the 6A wood-panel fire plus the appropriate 10A wood-crib fire test. For a 20A rating or higher, only the appropriate size wood-crib fire is required. The minimum allowable discharge time for extinguishers rated 2A and higher is 13 seconds. During the fire tests the extinguisher must be in the full open position under continuous discharge.

A pan containing commercial grade Heptane is placed beneath the wood-crib and is used to ignite the wood members. The Heptane is allowed to burn until it fully consumed. The crib is allowed to continue burning until it has lost 45% of its original weight for fires up to 10A ratings, which may be an additional 8-10 minutes. After the pre-burn period, the operator attacks the fire from the front at a distance of not less than six feet. The operator may then shorten the distance and attack the fire from all sides except from the back of the crib.

For wood-panel test fires, the panel is first placed in a horizontal position and a predetermined volume of No. 2 fuel oil is applied to the panel which is then mounted vertically on a steel frame. A row of excelsior is placed at the base of the panel. Three additional rows of excelsior are placed at the base of the panel. Three additional rows of excelsior are strategically spaced on the floor of the test room. Using Heptane, the first row of excelsior at the foot of the panel is ignited. At 45 second intervals, the three remaining rows are pushed to the base of the panel. At three minutes and 20 seconds after ignition, all remaining excelsior is cleared from the base of the panel. The fire then will be allowed to burn vigorously for 4-5 minutes, at which time the horizontal furring strips located between 6 and 30 inches above the floor, will burn through and begin to fall away from the panel. Within 5 seconds from this observation the initial attack with the fire extinguisher is made from not less than 10 feet from the face of panel. The operator must attack this fire using two horizontal sweeps across the bottom of the panel and then may use the technique of his choice provided the extinguisher remains under continuous discharge in the full open position until emptied.

After August 14, 2002, the 6th Edition of ANSI/UL 711 was published. This new Edition eliminated the excelsior fires, increased the size of the crib fires by approximately 40% and retained the panel fire test requirement.

CLASS B FIRE TESTS

Class B fire tests are conducted using a square steel pan not less than 8 inches in depth. The test fuel is to consist of not less than a two inch layer of Heptane, the surface of which is to be located six inches below the top edge of the pan. Water may be added to establish the required 6 inches freeboard.

For B ratings up to and including 20B, the fire test is conducted indoors in a large volume draft free room. For B ratings in excess of 20B, outdoor fire tests are conducted under conditions of essentially still air - steady between 3-8 miles per hour with gusts not greater than 10 miles per hour and no precipitation. After a one minute pre-burn, the operator then attacks the fire, but is only permitted to do so from one side only. The operator is prohibited from extending any part of his person past the edge of the test pan while fighting the fire.

CLASS K FIRE TESTS

For Class K fire tests, a commercially available gas deep fat fryer, with a capacity of 80 Lbs. of shortening is used. The fryer must meet a criteria for minimum heat rate and maximum cooling rate. New vegetable oil or shortening is used in the fryer and is heated to auto-ignition. Auto-ignition cannot occur below 685 deg F. Once ignited, the fryer is allowed to burn freely for a period of one minute, at which time the extinguisher is discharged with the nozzle fully open and the heat source to the fryer remaining on. No burning shortening can be ejected from the fryer during discharge. At the end of the discharge, the heat source to the fryer is turned off and the fryer fire must remain extinguished for a period of twenty minutes. The extinguisher must successfully extinguish the fryer test fire three times to achieve a Class K rating.

CLASS A FIRES
(used for fire testing after Aug. 14, 2002)
Ordinary Combustible
Wood - Paper - Textiles
NUMERICAL RATING WOOD-PANEL FIRE TEST WOOD-CRIB FIRE TEST
Overall Dimension-Quantity & Size

• **1-A = 72 members 2"x 2"x20"**	**12 layers of 6**
• **2-A = 112 members 2"x 2"x25"**	**16 layers of 7**
• **3-A = 144 members 2"x 2"x29"**	**18 layers of 8**
• **4-A = 180 members 2”x 2”x32”**	**20 layers of 9**
• **6-A = 230 members 2”x 2”x36”**	**23 layers of 10**
• **10-A = 324 members 2"x 2"x 43"**	**27 layers of 12**
• **20-A = 256 members 2”x 4”x 55”**	**16 layers of 16 on edge**
• **30-A = 324 members 2”x 4”x 64”**	**18 layers of 18 on edge**
40-A = 400 members 2”x 4”x 69”	**20 layers of 20 on edge**

FIRE TEST WOOD-PANEL FIRE TEST
WOOD-CRIB FIRE TEST

1A	8’ x 8’
2A	10’ x 10’
3A	12’ x 12’
4A	14’ x 14’
6A	17’ x 17’
10A	N/A
20A	N/A
30A	N/A
40A	N/A

CLASS B FIRES Flammable Liquids Oils - Greases - Paints

FLAMMABLE LIQUIDS & GAS

Rating (indoor tests)	Minimum effective discharge time	Square foot pan size	Gallons of heptane used
1B	8 seconds	2 ½ square feet	3 1/4
2B	8 seconds	5 square feet	6 ¼
5B	8seconds	12 ½ square feet	15 ½
10B	8 seconds	25 square feet	31
20B	8 seconds	50 square feet	65
Outdoor tests			
30B	11 seconds	75 square feet	95
40B	13 seconds	100 square feet	125
60B	17 seconds	150 square feet	190
80B	20 seconds	200 square feet	250
120B	26 seconds	300 square feet	375
160B	31 seconds	400 square feet	500
240B	40 seconds	600 square feet	750
320B	48 seconds	800 square feet	1000
480B	63 seconds	1200 square feet	1500
640B	75 seconds	1600 square feet	2000

CLASS C FIRES Electrical Equipment NO FIRE TEST

Extinguishing agent is tested for electrical non-conductivity. Extinguisher is discharged onto a copper target charged with 100,000 volts AC across an air gap of ten inches between the target and the discharge nozzle. No measurable current can be detected at the nozzle in order to pass the test. Water based agents must have a conductivity of 1 microseimen or less. If acceptable, “C” Symbol is added.

Documents used in preparing this material:

NFPA Fire Protection Handbook 20th Edition

NFPA 10 – Standard for Portable Fire Extinguishers – 2013 Edition

NFPA 34 – Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids – 2011 Edition

“Selection and Application of Special Extinguishing Agents in Industrial Hazards” – John F. Riley, June 1980, Institute of Gas Technology

Standard for Fire Extinguishers, Rating and Fire Testing of, UL 711 Fifth Edition, 1995

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