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Further to your enquiry regarding the following Libraries Australia ID 405679 holding, I have pleasure in attaching the following information and the two scanned documents from Section 9 of the document:-

1. Module 15 – Dry Chemical Fire Suppression Systems.
2. Module 16 – Explosion Suppression Systems.

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Fire technology studies

Volume 1 of Self-paced Fire Technology Studies: Distance Learning Studies,

School of Mines and Industries Ballarat, Australian Committee on TAFE Curriculum

Contents

1. Infectious & bioactive hazards - Malcolm Forsyth
2. Fire fighting equipment and its application - Graham Healy
3. Fire mechanics 1 & 2 - Bruce Marshall
4. Detection systems / Russell Cooper
5. Fire safety management - Tony Truett
6. Material science 1 - Peter Johnson
7. Fire chemistry 1 - Ronald White
8. Principles of fire behaviour - Kevin Maynes
9. **Suppression systems - Richard Foster**

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Sincerely

J Button

Janice Button – Records Officer

Suppression Systems

Module 15 - Dry Chemical Fire Suppression Systems.

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THE SCHOOL OF MINES & INDUSTRIES BALLARAT LIMITED.

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SS/15

DRY CHEMICAL FIRE SUPPRESSION SYSTEMS

OBJECTIVE

In order to successfully complete this module, the student will be expected to:

* state the main components of dry chemical systems;
* describe the principles of operation;
* list the advantages/disadvantages of the various agents;
* list typical applications.

RATIONALE

These skills are required to enable the student to assess the possibility of using dry chemical as a fire suppression agent in a qualitative manner, as opposed to other fire suppression agents.

CONTENT

1. INTRODUCTION

Dry chemical has been used in portable fire extinguishers for many years, but its adaptation to fixed extinguishing systems is recent. The number of dry-chemical systems presently approved by recognised testing laboratories is limited, and detailed installation standards are not covered in this module. For guidance, one must rely upon the general characteristics of dry-chemical systems as discussed here and on the specific characteristics as reported by the testing laboratories.

A dry-chemical extinguishing system consists primarily of a container of dry chemical and another of expellant gas which, when released by automatic or manual means, will carry the dry chemical through a special system of piping to fixed nozzles at the hazard area.

2. TYPES OF SYSTEM

Two general types of system are available: total flooding and local application.

2.1 Total flooding systems

Total flooding systems have fixed piping and nozzles arranged to discharge the chemical into an enclosed space.

2.2 Local application systems

Local application systems have piping and nozzles arranged to discharge the dry chemical directly onto the hazard without the aid of an enclosure to confine the chemical.

(More detail about system types is given in Section 6).

3. TYPES OF DRY CHEMICAL AGENTS

Dry chemical agents chemically inhibit fire. There are a number of inorganic solids among which are $NaHCO_3$, $KHCO_3$, $NH_4H_2PO_4$, $(NH_4)_2HPO_4$, $(NH_4)_2SO_4$, KCl, K_2SO_4 and $KC_2N_2H_3O_3$. These materials generally have a particle distribution of 5-105 microns (millionth of a metre) with a median particle size of approximately 20 microns. Since most of these materials are *hygroscopic* (absorbing/attracting moisture from the air), various additives and surface treatments are usually employed by the manufacturers.

Dry chemical extinguishing agents are comprised of a finely-divided powdered material that has been specifically treated to be water repellent and capable of being fluidized and free-flowing when under expellent gas pressure. There are several types of dry chemical extinguishing agents available, each having its own distinct capabilities. Dry chemicals are available for all classes of fires:

* ordinary combustibles such as wood, paper cloth and upholstery;
* flammable liquids such as gasoline, oil or grease; or
* live electrical equipment.

Some of the more common dry chemicals currently in use may be described briefly as follows:

3.1 Sodium Bicarbonate ($NaHCO_3$) Based Dry Chemical

This agent consists primarily of sodium bicarbonate and is suitable for use on all types of flammable liquid and gas fires and also for fires involving energized electrical equipment.

Its effect on fires in common cooking oils and fats is particularly good, as in combination with these materials the sodium bicarbonate based agent reacts to form a type of soap (*saponification*), which floats on the liquid surface, such as in deep fat fryers, and effectively prevents reignition of the grease.

Sodium bicarbonate base dry chemical is not generally recommended for the extinguishment of fires in ordinary combustibles, although it may have a transitory effect in extinguishing surface flaming of such materials.

3.2 Dry Chemicals Based on the Salts of Potassium

Commercially available agents are essentially potassium bicarbonate ($KHCO_3$), potassium chloride (KCl), and urea based potassium bicarbonate ($KC_2N_2H_3O_3$). All three agents are suitable for use on all types of flammable liquid and gas fires and also for fires involving energized electrical equipment.

It is generally recognised that salts of potassium are more effective in terms of chemical extinguishing mechanisms than sodium salts in extinguishing flammable liquid and gas fires and that they afford an improvement over sodium bicarbonate in retarding reignition of the fuel.

Dry chemicals based on the salts of potassium are not generally recommended for the extinguishement of fires in ordinary combustibles, although they may have a transitory effect in extinguishing surface flaming of such materials.

3.3 Multi-purpose Dry Chemicals

This agent has as its base monoammonium phosphate ($NH_4H_2PO_4$) and is similar in its effect on flammable liquid and gas fires to the other dry chemicals. However, it does not possess a saponification characteristic and unlike the other dry chemicals, it does have a considerable extinguishing effect on ordinary combustibles. The agent, when heated, decomposes to form a molten residue which will adhere to heated surfaces. On combustible solid surfaces this characteristic excludes the oxygen necessary to propagation of the fire.

4. PRINCIPLE OF SUPPRESSION

The almost instantaneous quenching of flames by dry chemicals can only be accounted for on the basis of *chemical inhibition.* The kinetics of a typical hydrocarbon fire can be described by a series of sequential chemical reactions. Within the chain reaction sequence are a number of atomic and molecular fragments called *free radicals.* These radicals appear both as reactants and as products in the chain reaction sequence, with the salts of the alkali metals, the Na or K or their oxides or hydroxides, act as a precursor of these free radicals; effectively removing them and thereby causing the chain reaction sequence to terminate. The dry chemical can also act to provide an active surface upon which the free radicals can recombine, effectively terminating the chain reaction sequence.

4.1 In general, the Na and K salts are effective only on flammable liquid and gas fires. The ammonium salts of phosphoric acid are unique in that they are effective on multi-purpose agents. These agents form a polyphosphate glass on the surface of cellulosic fuels, effectively sealing off the surface. Their behaviour on flammable liquid and gasses is that of providing active surface for radicals recombustion to occur on. While dry chemicals are excellent flame extinguishants, they provide no securing action.

4.2 A recently developed agent is based upon the phenomenon of *decrepitation*[1] that has been observed with $K_2C_2O_4$, which breaks up into small particles of K_2CO_3 on exposure to flame. The compound is a reaction product of urea and $KHCO_3$, having the empirical formula $KC_2N_2H_3O_3$. It is likely that other materials, particularly the salts of dicarboxylic acids, will undergo the same change.

4.3 Combustible metal fires represent a slightly different problem in that they tend to burn at much higher temperatures than ordinary combustibles, flammable liquid or gasses. The conventional approach has been to apply inorganic solids to the surface of the burning material in a thickness such that oxygen is excluded from the hot metal surface and significant cooling of the metal is produced.. There is only one agent which is listed and approved for use on liquid sodium potassium, sodium alloy, potassium and magnesium. This agent is a sodium chloride based agent and contains a thermoplastic resin which acts to bind the sodium chloride into a continuous mass on the metal surface. This is desirable because of the density difference between the moten metals (i.e. liquid sodium, potassium etc.) and sodium chloride. The largest potential hazard in this area is, of course, that associated with liquid metal cooled nuclear reactors. For this reason, a low chloride based agent known as NA-X (also blended with a thermoplastic resin), has been developed and approved for use on sodium, potassium and sodium potassium alloy.

NOTE: The extinguishing effect of dry-chemical systems is transitory; any lingering ignition source may cause reignition almost immediately after extinguishment. Use of these systems should be limited to hazards where complete extinguishment may be expected.

TEST YOURSELF

1. What type of dry chemical would be selected for use in a dry chemical powder suppression system which is protecting the cooking surfaces and exhaust hoods/ducting in a commercial kitchen?

2. Name two dry chemical agents which are least effective on ordinary combustibles?

3. Which dry chemical agent should be selected if the expected fire load consisted of ordinary combustibles together with flammable liquids?

Answers appear on page 15

5. SYSTEM APPLICATION AND SELECTION CRITERIA

The following applications for dry chemical systems include where they may be used to advantage.

1. decrepitation - bursting or cracking of *crystals* of certain substances on heating, mainly due to expansion of water within the crystals.

5.1 Unmanned Hazards (Fig. 1)

All the hand held equipment in the world can't put a fire out unless people are available to operate it. Automatic fire suppression systems guard against fire even when people are not present.

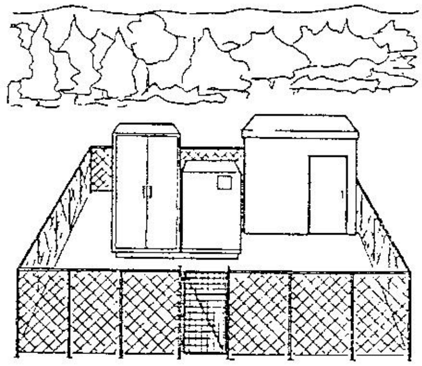

Fig. 1
Transformer Yard

5.2 Limited Manpower (Fig. 2)

An automatic or manually actuated system can be used to greatly increase the extinguishing effectiveness of limited manpower. It is used when a hazard is too large, complex or inaccessible to be extinguished by hand held equipment.

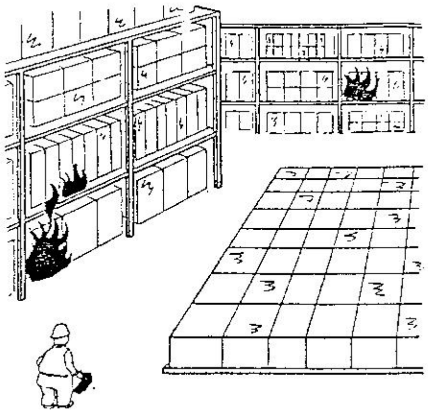

Fig. 2
Warehouse

5.3 Dangerous Hazards (Fig. 3)

Systems are recommended protection when human safety could be jeopardized by an approach with hand held equipment.

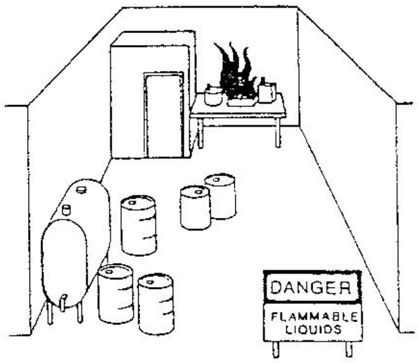

Fig. 3
Flammable Liquid Storage Area

5.4 Inaccessible Hazards (Fig. 4)

Fixed nozzles fit in places personnel can't. Systems can be used when a hazard is either obstructed or inaccessible to attack by hand held equipment.

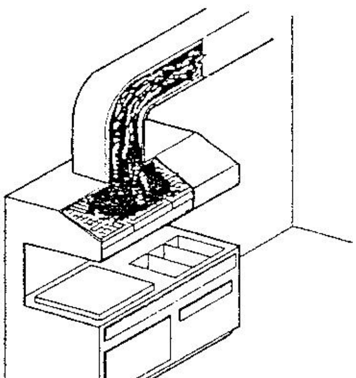

Fig. 4
Restaurant Hood and Duct

5.5 Quick Reaction (Fig. 5)

Automatic or manual systems are engineered to eliminate human error or delay. These systems are recommended when involvement of an entire hazard is likely upon ignition and immediate control is critical.

Fig. 5
Rapid Fire Spread

6. SYSTEM DETAILS

Fixed nozzle systems may be broadly categorized into two types, either TOTAL FLOODING or LOCAL APPLICATION. These may then be further divided into two further groups: indicating whether they are PRE-ENGINEERED or ENGINEERED.

6.1 Total Flooding Systems

A *total flooding system* is arranged to discharge dry chemical powder into an enclosure where there is a permanent enclosure adequate to enable an adequate concentration to be built up. A limited number of unclosable openings may be permitted which, dependant on size and location, may require an increased supply of agent to compensate for leakage.

6.2 Local Application Systems

A *local applicaiton system* is arranged to discharge dry chemical powder directly on to the fire where the hazard is limited in size and does not have a permanent enclosure.

6.3 Pre-engineered Systems

These have a predetermined size of agent storage container (which often may be used in multiples), limited and pre-sized distribution piping (and configuration of piping) and pre-calculated nozzle types and flow rates. Thus the flow rate, discharge time and agent distribution conforms to the specification and performance criteria determined by the manufacturer in conjunction with a testing laboratory.

Pre-engineered systems can protect a wide variety of hazards in industry. The following are some of the current applications:

- Armature Dipping Operations;
- Asphalt Saturators;
- Buffing Equipment;
- Coating Machines;
- Combines;
- Compressors;
- Corn Pickers;
- Cotton Gins;
- Cotton Pickers;
- Diesel Engines;
- Dry Cleaning Process Equipment;

* Dust Collectors;
* Electric Motors and Engines;
* Forest Harvesting Machines;
* Glove Boxes;
* Heat Transfer Units;
* Hydraulic Equipment;
* Junction Boxes;
* Laboratory Hoods and Ducts;
* Laundry Lint Traps;
* Mining Machines;
* Mobile Equipment (trucks, bulldozers, etc.);
* Oil Cellars;
* Oil Fired Furnaces;
* Paint Lockers;
* Spray Booths;
* Printing Machines;
* Public Transportation Vehicles;
* Quench Tanks;
* Restaurant Hoods and Ducts;
* Solvent Cleaning Tanks;
* Test Cells;
* Textile Processing Equipment;
* Transformer Rooms.

6.4 Engineered Systems

These require individual calculation and design to determine the flow rates, nozzle pressures, pipe sizes, area or volume protected by each nozzle, quantities and type of dry chemical and the number and types of nozzles and their placement in a specific system.

Engineered dry chemical systems are available in a wide range of sizes and can be effective on all types of fires depending on the extinguishing agent used. All systems are self-contained and are operated with an expellent gas stored in large cylinders.

Engineered dry chemical systems have been used to protect the following hazards in industrial operations:

* Asphalt Flow Coaters;
* Dip Tanks (Fig. 6);
* Drag Lines;
* Drain Boards;
* Drumming Stations;
* Fabric Dipping Operations;
* Fabric Processing Equipment;
* Foil Rolling Mills;
* Fuel Pumps;
* Fuel Storage Areas;
* Generators;
* Glass Forming Machines;
* Jet Test Cells;
* Lacquer Mixers;
* Large Off-Road Vehicles;
* Liquid Pumps;
* Loading Racks (Fig. 7);
* Motors - Electrical;
* Motors - Reciprocating;
* Oil Bath Filters;
* Oil Wells;
* Oil Storage Areas;
* Ovens;

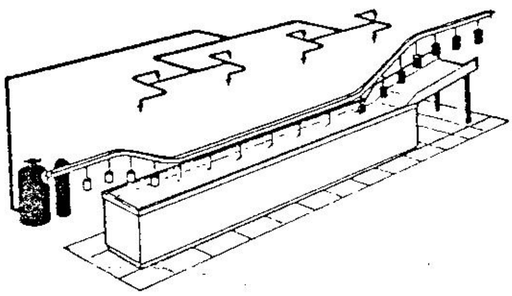

Fig. 6
Typical Dip Tank Application

* Pipe Wrappers;
* Pistons;
* Pump Motors;
* Quench Tanks;
* Reactor Rooms;
* Resin Melters;
* Solvent Tanks;
* Spray Booths;
* Switch Gear;
* Test Cells;
* Transformers;
* Turbine Bearings;
* Turbines - Steam;
* Valves;
* Wax Coaters.

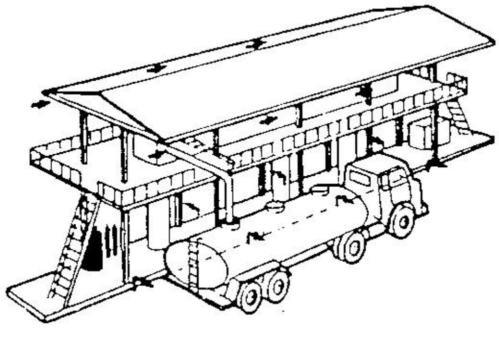

Fig. 7
Typical Loading Rack Application.

TEST YOURSELF

4. What type of system would you use to protect a totally enclosed flammable liquid store?

5. What type of system would you use to protect the predominately open engine bay of a large mining truck?

6. What type of system would you use to protect a road tanker loading facility?

Answers appear on Page 17

7. INSTALLATION ENGINEERING

7.1 General

The extinguishment of fire by a dry-chemical system is a function of the quantity of dry chemical, rate of discharge and method of application. The flow of dry chemical through piping does not follow the general hydraulic principles that pertain to liquids and gases, and much of the design data are being determined empirically, in the absence of exact knowledge.

7.1.1 The flow characteristics of a dry-chemical system including the pressure drop in pipe and fittings, nozzle discharge patterns, nozzle spacing and placement, the required flow rate, and the quantity of dry chemical for various sizes of hazard are dependent upon the design of the system and the physical characteristics of the dry chemical. Requirements based on one manufacturer's system and dry chemical may not be applicable to those of another manufacturer.

7.1.2 The flow of dry chemical in a gaseous carrier requires specially designed piping arrangements to prevent the chemical from settling out of the gas stream and to prevent separation of the two elbows and tees. Settling within the piping and separation at changes of direction will produce improper flow characteristics and non-uniform distribution of the dry chemical.

Since dry-chemical distribution within an enclosure is determined primarily by the design and placement of nozzles rather than by the diffusion or convection characteristics of gaseous extinguishing agents, interference with the nozzle discharge by large objects must be avoided to ensure proper dispersion of the chemical.

7.2 Piping Arrangements

Because, as stated previously, the flow of fluidised dry-chemical in piping requires special consideration, tests have shown that the piping configuration must provide even splitting of the flow at tees (resulting in "T" or "H" pattern nozzle placement). Also necessary are equal equivalent piping lengths to nozzles and minimum upstream pipe lengths before flow splitting at tees, to ensure even splitting.

The illustrations below (Figs. 8.1 - 8.4) show acceptable methods of connecting piping:

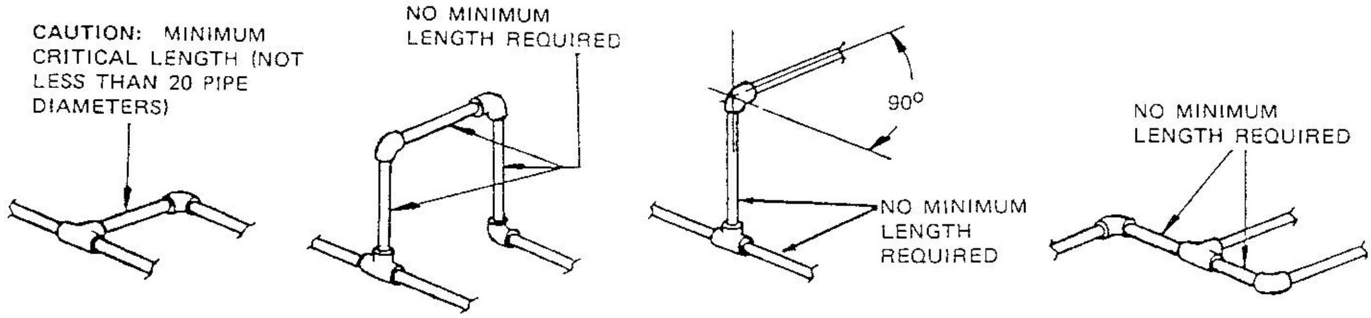

Fig. 8.1 **Fig. 8.2** **Fig. 8.3** **Fig. 8.4**

Fig 8: Piping methods for dry-chemical systems.

Illustrations below (Figs. 9.1, 9.2) show acceptable and unacceptable methods of splitting tees.

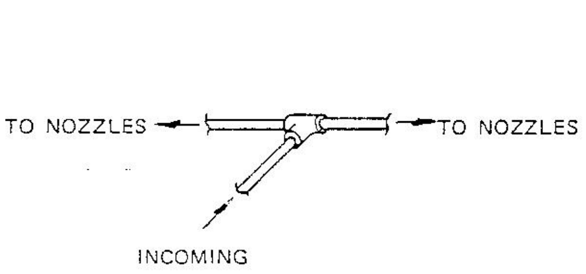

Fig 9.1
Acceptable splitting of tees

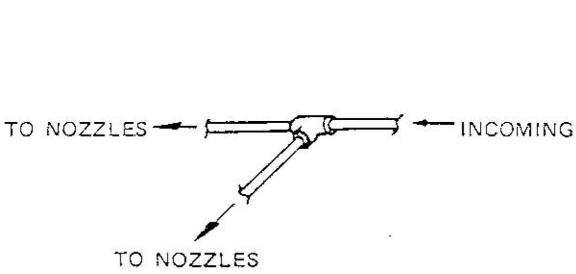

Fig 9.2
Unacceptable splitting of tees

7.3 Total Flooding Example

The illustration below (Fig. 10) shows a typical method of laying out the dry chemical nozzles and piping in an engineered total flooding system within a flammable liquid store:

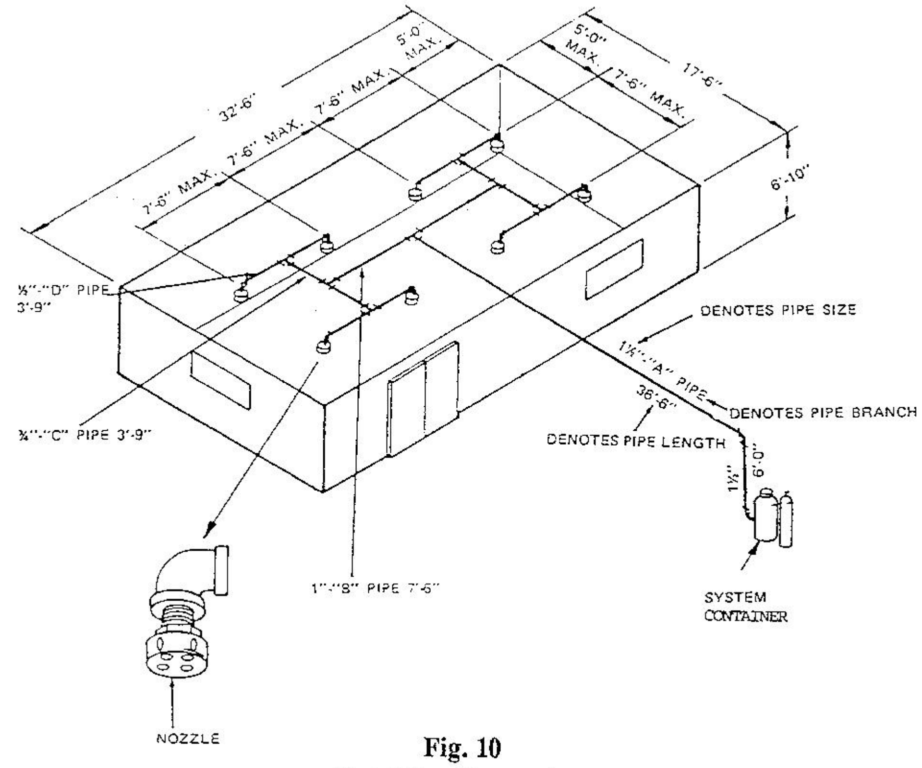

Fig. 10
Total flooding system

7.4 Local Application Example

The illustrations below (see Figs. 11.1 - 11.3) show a typical method of laying out the dry chemical nozzles and piping in a pre-engineered local application system for a dip tank:

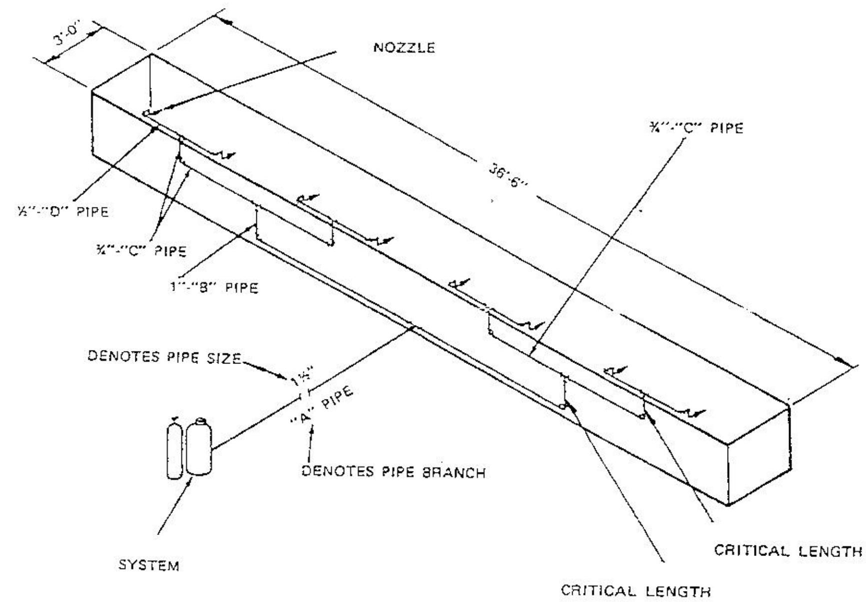

Fig. 11.1
Local Application System: Piping Pattern

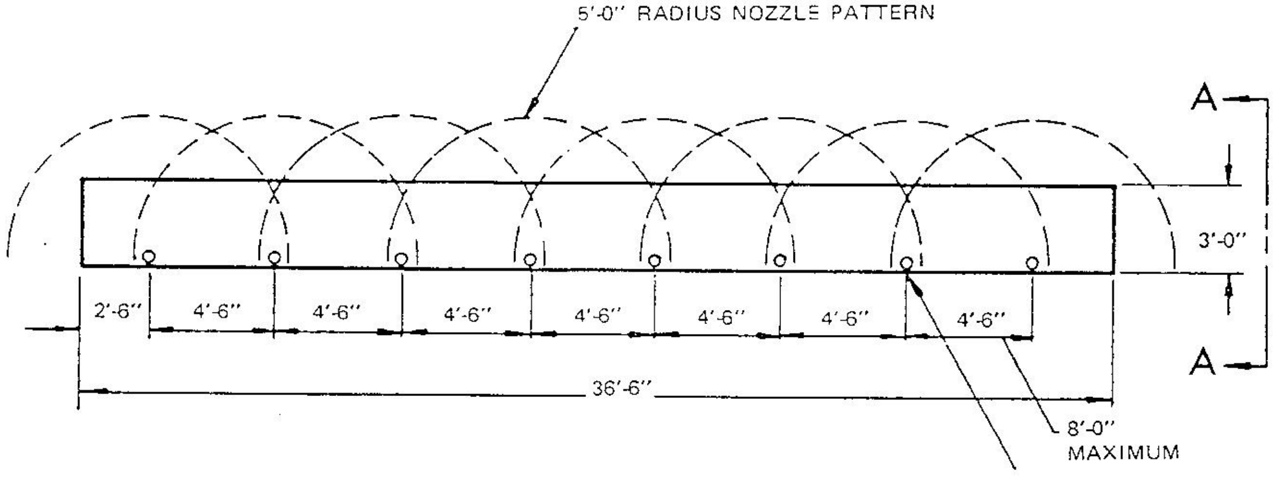

Fig. 11.2
Local Application System: Nozzle Pattern

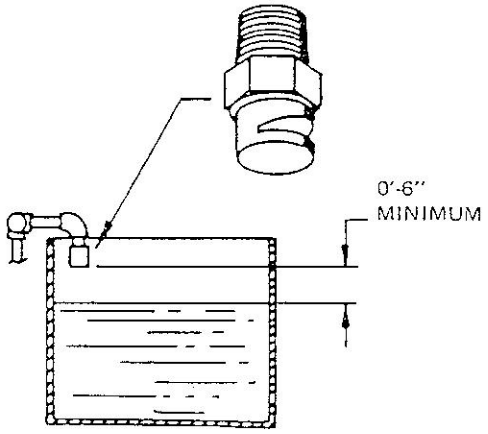

Fig. 11.3
Section 'A A' through dip tank.

[Figs. 11.1 - 11.3 are reprinted with the kind permission of Ansul Fire Protection. All rights reserved.]

8. SYSTEM COMPONENTS

All dry chemical powder systems utilise components for storage, pressurisation and discharge of the agent which are often common to all types of systems.

Total flooding and local application systems generally consist of:

* a container of dry chemcial;
* a container of expellant gas;
* actuation equipment;
* piping and/or hose;
* selector valves;
* nozzles;
* alarms;
* shutdown devices.

The system may be actuated automatically or manually by pneumatic, electrical or mechanical means. It may be designed to protect single or multiple hazards, separately or simultaneously.

Nozzles are of various types, each best suited to a particular situation. Different nozzles are used for total flooding, tankside local applications and over-head local application.

8.1 Storage Container

The storage container is usually a vertical cylindrical container which, dependant on size, may be either forged steel or fabricated from rolled steel plate with torrespherical[2] (semi-elliptical) top and bottom. As pressure is required to discharge the agent, it must be designed and constructed in accordance with legislated design codes such as AS 1210 or AS 2030.1.

8.2 Pressurisation

In order to discharge the agent, the container is pressurised with either dry nitrogen (N_2) or carbon dioxide (CO_2) as the expellant gas. The container may be either permanently pressurised or, more usually, the pressure source is contained in another cylinder; the N_2 or CO_2 gas being released into the agent storage container on system actuation. The latter is more usual because as the dry chemical flow characteristics are improved by fluidisation by the expellent gas, fluidisation can be improved by the expellent being discharged into the body of the dry chemical agent by a perforated tube. The quantity of expellent gas is a function of the quantity and the type of dry chemical, the required discharge time and flow rate and the required nozzle pressure for effective distribution.

8.3 Distribution

Agent distribution is normally effected using steel pipe and fittings conforming to either AS 1835 or AS 1836 with pipe joints using fittings to BS 1740.

8.4 Discharge

Many different types of discharge nozzles are available to achieve either total flooding or local application. The techniques for achieving the required distribution pattern vary widely between manufacturers. The nozzle type selection depends on the hazard to be protected and the application concept to be used. *Total flooding nozzles* produce a widely diffused soft pattern. *Local application nozzles* produce a higher velocity directional discharge designed to discharge dry chemical directly on a hazard. The nozzle size selection depends on the dry chemical flow rate desired.

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2. **torus** (phys.) A 'doughnut' or anchor-ring shaped *solid* of circular or elliptical cross-section. If the cross-section is a circle of radius a, and the ring has a radius b, the volume of the torus is $2\pi^2a^2b$.

Typical nozzles from one manufacturer Ansul Fire Protection are depicted below:

8.4.1 Total Flooding Nozzles

"D" type nozzles (Fig 12) are used for total flooding applications. The nozzle is a hollow ball shape with a plurality of small discharge openings which create a widely dispersed and diffused discharge pattern. This discharge pattern is used for total flooding of enclosed volumes.

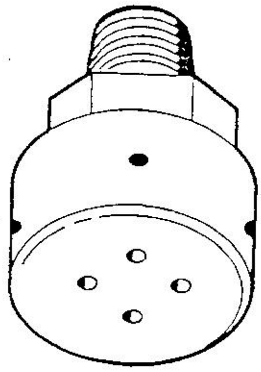

Fig. 12
"D" Nozzle

8.4.2 Local Application Nozzles

The "F" type nozzle (Fig. 13) has been designed to provide a flat area of discharge.

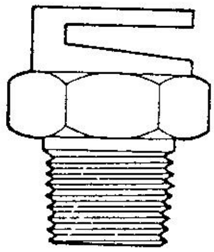

Fig. 13
"F" Nozzle"

The "C" nozzle (Fig. 14) has been designed to provide a conical area of discharge from overhead.

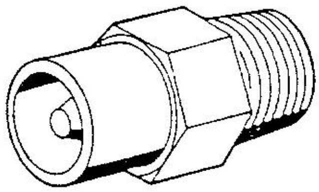

Fig. 14
"C Nozzle"

The "S" nozzle (Fig. 15) consists of a cylindrical body with a straight unobstructed centre bore. This nozzle produces a long range circular discharge pattern.

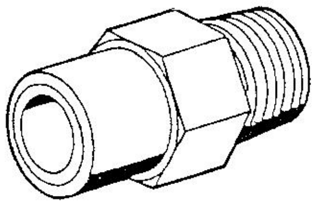

Fig. 15
"S" Nozzle"

The "T" nozzle (Fig. 16) has a slotted discharge opening parallel to the inlet axis of the nozzles and is designed to give a flat fan shaped discharge.

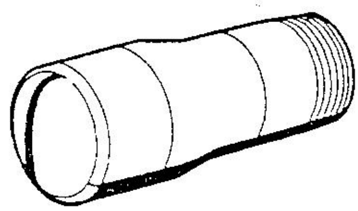

Fig. 16
"T Nozzle"

9. DESIGN CALCULATIONS

Designing a dry chemical powder fire suppression system is a complex process dependant very much on the research and testing carried out by the individual manufacturers. The code, *NFPA17 - Dry Chemical Extinguishing Systems,* provides further background on the design and installation of such systems but unlike other American, British and Australian design codes for other fire suppression systems, gives no specific quantitative design criteria, so reliance for design quantities and discharge times are threfore dependant on manufacturers' data.

The following two graphs, however, indicate the results of test data from two major manufacturers:

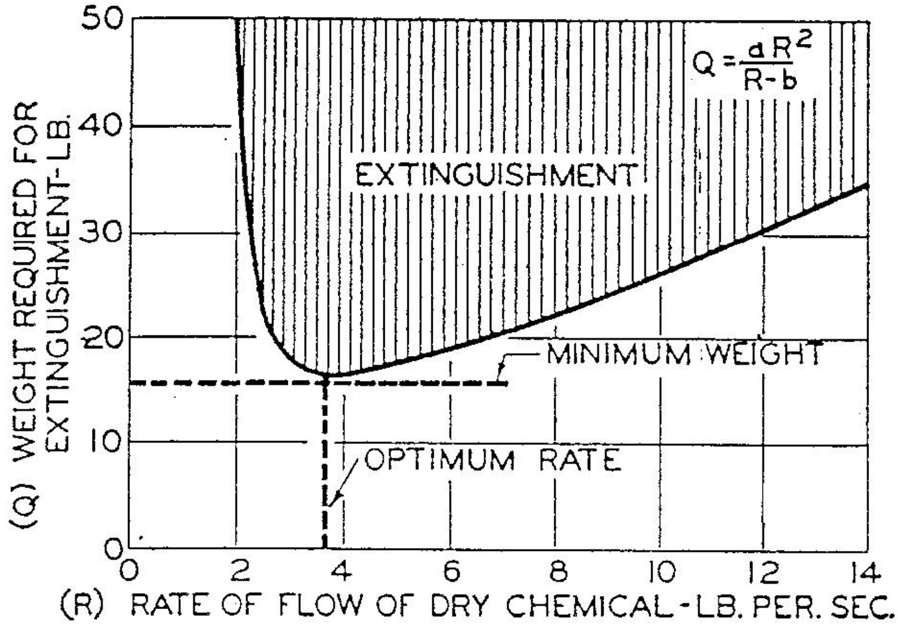

Fig. 17

Variations of the quantity of dry chemical required to extinguish a 50 sq. ft. test fire with variations of the rate of flow.

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The graph shows that for a given set of test calculations there is an optimum rate of flow at which a minimum quantity of dry chemical will be required for extinguishment.

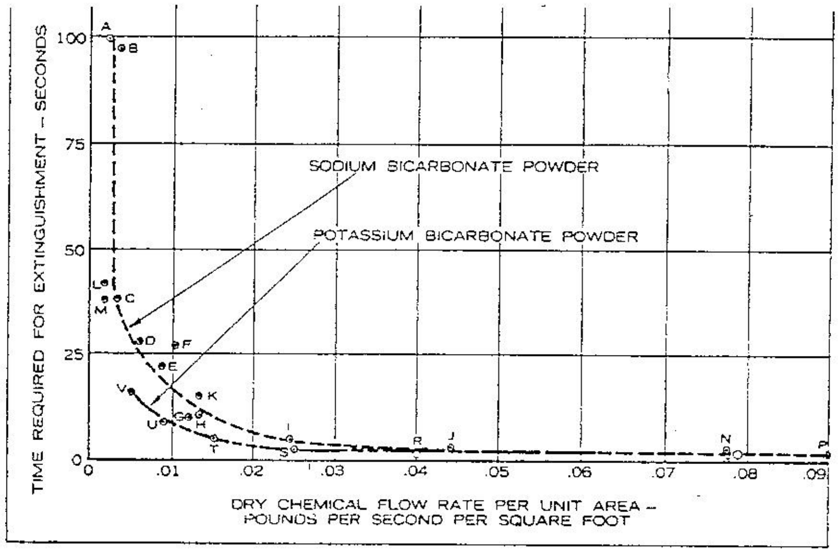

Fig. 18
Correlation of test data on dry chemical flow rate requirements for extinguishing fires.

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NOTE: A-V indicates data from various tests.

REFERENCES

Ansul Fire Protection. *Ansul Fire Training Manual.* Wormald. Wisconsin, USA

Australian Standards Association. *Unfired Pressure Vessels.* AS 1210.

Australian Standards Association. *S.A.A. Gas Cylinders Code.* AS 2030.1.

Australian Standards Association. *Tubes for pressure purposes - seamless.* AS 1835.

Australian Standards Association. *Tubes for pressure purposes - welded.* AS 1836.

British Standards Association. *Steel Pipe Fittings.* BS 1740.

National Fire Protection Association. *Code 17 - Dry Chemical Extinguishing Systems.* NFPA 17. (USA).

FURTHER READING

Linville, J. (ed). *Fire Protection Handbook, 16th ed.* National Fire Protection Association. Quincy, MA. USA. 1985

ASSESSMENT

[Work to be completed and returned to Tutor for correction and comment]

1. List the advantages and disadvantages of a dry chemical system.

   [35 marks]

2. What is the principal extinguishing effect of dry chemicals in general?

   [10 marks]

3. How does sodium bicarbonate prevent re-ignition of cooking oil fires?

   [5 marks]

4. Which dry chemical would you use for local application system on a turbocharged diesel engine on a bulldozer and why?

   [15 marks]

5. Of the nine hazards listed below, categorize them into three groups under the headings, "Total Flooding", "Local Application", "Combined Total Flooding and Local Application".

   a) Dust Collector
   b) Electric Motor
   c) Laboratory Hood and Duct
   d) Paint Locker
   e) Printing Machine
   f) Restaurant Hood and Duct
   g) Spray Booth
   h) Transformer Room
   i) Quench Tank

   [15 marks]

6. In selecting either a Total Flooding or Local Application system, what is the primary consideration?

   [10 marks]

7. Which of an engineered or a pre-engineered system would be the easiest to judge in terms of design, performance and approval and why?

   [5 marks]

8. Which elements of a system may be subject to control by legislated design codes and why?

   [5 marks]

Total = 100 marks

Answers to Test Yourself Questions

1. Sodium bicarbonate (Na HCO_3)
2. Sodium bicarbonate (Na HCO_3) and Potassium bicarbonate (KH CO_3)
3. Monoammonium Phosphate ($NH_4H_2PO_4$)
4. Total Flood - either engineered or pre-engineered.
5. Local Application - either engineered or pre-engineered.
6. Local Application - engineered.

Suppression Systems

Module 16 - Explosion Suppression Systems.

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SS/16

EXPLOSION SUPPRESSION SYSTEMS

OBJECTIVES

In order to successfully complete this module, the student will be expected to:

* state the main components of explosion suppression systems;
* describe the principles of operation;
* list typical applications.

RATIONALE

This skill is required to enable the student to assess the possibility of utilising explosion suppression techniques in industrial applications which give rise to an explosion hazard, due to the nature of the materials and operations, in either processing or storage.

CONTENT

1. INTRODUCTION

1.1 What is an explosion?

An explosion is defined as a *violent and rapid increase in pressure* (usually in a confined space). It may be caused by an external source of energy (eg. heat) or by an internal exothermic chemical reaction in which relatively large volumes of gases are produced. (N.F.P.A. 69)

An explosion can occur wherever there is a flammable mixture and a source of ignition together with oxygen usually in the form of air. Sources of ignition can include such items as hot bearings, sparks caused by foreign bodies entering a grinder or high speed machinery, static electrical discharges and smouldering material. Explosive mixtures can be formed in association with air by many substances such as petrol vapour, white spirit, town or tail gas and finely divided dusty materials such as sugar, dextrine, plastics, cereals, cork, wood, flour and others.

An explosion is not an instantaneous occurrence but requires a definite and measurable time from the instant of ignition to the development of maximum pressure. For a single point source of ignition, say in the approximate centre of a vessel, the flame commences as a small sphere and grows as a sphere whose radius is expanding at a constant rate and follows a cube law. The pressure at any instant is thus proportional to its volume. When the flame has filled the vessel all the mixture will have been burnt and the pressure can rise no higher. It follows that the larger the vessel the longer the time taken to reach a given pressure. The final pressure depends on the initial pressure in the vessel; an ideal hexane/air mixture commencing at 100 kPa absolute develops 750 kPa gauge. However, at 200 kPa absolute the final pressure would be about 1500 kPa gauge. In turbulent conditions the rate of rise of pressure is increased although the maximum pressure is unaffected.

1.2 In general, any dust or gaseous explosive mixture which, when ignited in a confined space, reaches its maximum pressure in not less than 40 milliseconds, can be brought under control by suppression.

2. COPING WITH EXPLOSIONS

2.1 Explosion Prevention

Although not an objective of this module, the methods of explosion prevention should be examined as the application of these prevention techniques may be useful.

The aim of *preventive measures* against explosions is to avoid the occurrence of an explosion. This can be done in two different ways, which each have in common the fact that they exclude one of the conditions necessary for an explosion to occur:

* avoidance of ignition sources;
* avoidance of explosive concentrations of the material to be handled.

However, for a number of production process conditions, these preventive measures often cannot be applied with sufficient reliability.

2.2 Explosion Protection

When everything possible has been done to eliminate sources of ignition, the possibility of explosions must still be guarded against. There are four basic methods of preventing plants from being ruptured by explosive pressure, these being:

2.2.1 <u>Design the plant to withstand the maximum explosive pressure.</u>

However, this is usually too expensive and only in small vessels is this solution ever encountered.

2.2.2 <u>Continuously inert the plant to keep the oxygen content below that required to support combustion.</u>

Again, this is an expensive method, especially when one is considering continuously running plant; although in some instances, a supply of inert gas (like carbon dioxide o nitrogen) may be readily available at no charge as a by-product of other plant processes. However, the use of inert gases for certain industrial processes does not give effective safety, as danger sometimes exists during start-up conditions, unless very strict precautions are taken to ensure that the system is inerted beforehand.

2.2.3 Isolate the plant.

Contain the plant within adequate blast walls or locate the plant where damage would not be detrimental to safety of operatives, i.e. on the roof of the building or in a secure area.

2.2.4 Provide venting or explosion relief.

This form of protection really needs no explanation as it is the most commonly used method and under normal circumstances is very satisfactory, providing the plant is located so that the relief vents can operate direct to atmosphere (assuming the vents are large enough and properly designed). If the plant is under suction, venting is a very simple and reliable method; since the vents can operate at low pressures they can be considered as virtually open vents and the strength of the plant kept low.

If a location is vented but the vent is insufficient to deal with the explosion and with the combination of a low strength construction, the vessel will, of course, burst. In bursting, flame will be emitted which may spread widely throughout the workspace, and will travel with considerable velocity, impelled by the pressure within the bursting vessel.

2.3 Explosion Suppression

2.3.1 An *explosion suppression system* is designed to detect and suppress an incipient explosion before the pressure rises to the enclosure damage threshold. Suppression is achieved by the rapid discharge of an extinguishing agent from pressurized containers mounted on the protected enclosure. A pressure or flame radiation detector senses the incipient explosion while only a small fraction of the flammable gas or dust has burned. The sensor triggers the discharge of a liquefied gas or powdered agent into the enclosure. When the agent reaches the expanding flame front, it quenches the flame and thereby suppresses the explosion.

Explosions involving most flammable vapors, gases and dusts are slow enough so that pressure can be limited as shown in Fig. 1 below:

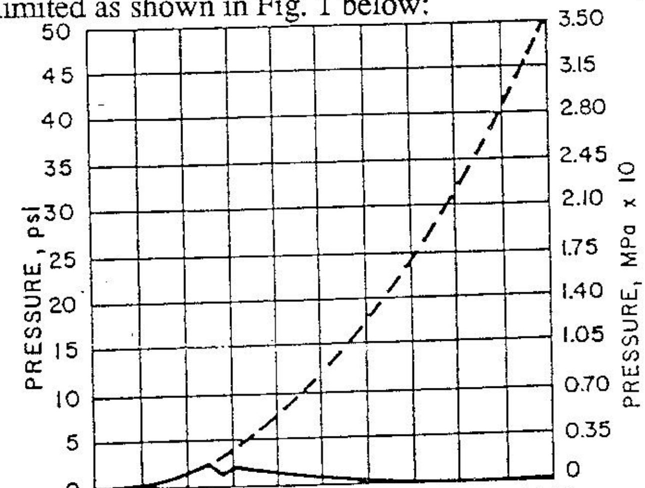


Fig. 1

Typical limitation of explosion pressures by an explosion suppression system is shown by the solid line. The dashed line represents an unsuppressed explosion.

2.3.2 One important advantage of explosion suppression systems versus explosion venting is that there is no discharge of flame or fuel. Thus, suppression systems can often be used more readily on indoor equipment and on equipment containing toxic materials. One major disadvantage of the system is the high cost associated with both the installation of a complex system and the refilling and resetting of the system after a discharge.

3. SUPPRESSION TECHNIQUES

The most effective method of extinguishing an explosion flame is by *chemical inhibition*; normally one of the halogenated agents is chosen such as Halon 1301 - Bromotrifluoromethane. Liquid agents are used because of the ease with which they can be distributed at the high speed necessary when broken down into finely divided droplet form. The mechanics of explosion suppression are twofold:

* the finely divided droplets act as a flame trap to the advancing flame, cooling and extinguishing the flame;

* the oxygen content is reduced through the extinguishant's inert properties.

The following diagrams are representative of an explosion showing the sequence of ignition, pressure rise, detection and suppression.

Fig 2.1: Ignition commencing.
Time 0 ms. Pressure 0 kPa
(ms = milliseconds)

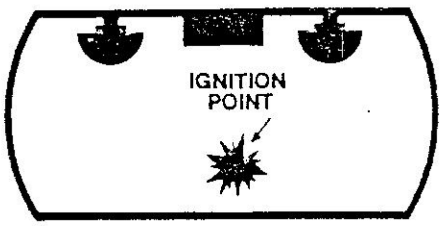


Fig 2.2: Detector operates
Time 35 ms. Pressure 1.4 kPa

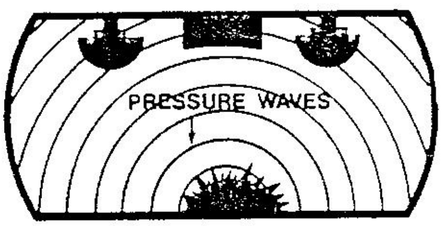


Fig 2.3: Suppression commences
Time 40 ms. Pressure 3.8 kPa

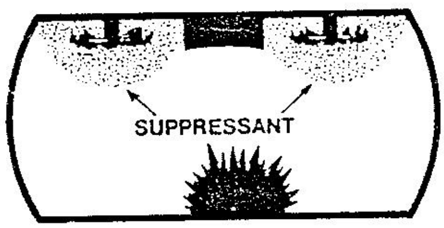


Fig 2.4: **Suppression occurring**
Time 55 ms. Pressure 11.4 kPa

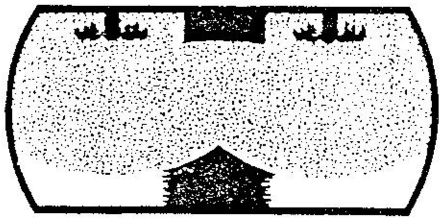
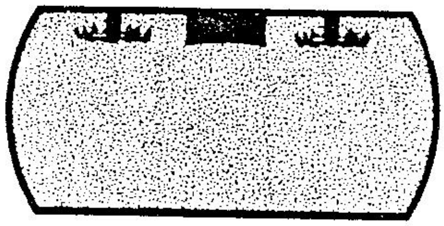


Fig 2.5: **Suppression complete**
Time 60 ms. Pressure 14 kPa



[Figs 2.1-2.5 reprinted with the kind permission of Kidde-Graviner Ltd. UK.

TEST YOURSELF

1. What is the principal phenomena (effect) of an explosion?
2. What three elements are required to cause an explosion?
3. What is the general time limit in which an explosion can be brought under control by suppression?
4. Name two gases that could be used for inerting?
5. Which types of agent provides the most effective explosion suppression?

Answers appear on Page 12

4. COMPONENTS OF AN EXPLOSION SUPPRESSION SYSTEM

4.1 Detectors

4.1.1 Pressure detectors

The most common detector in an explosion suppression system is a highly sensitive, low inertia, diaphragm-type *pressure detector*. It is adjustable from 1.7 to 34.5 kPa. A pressure at, or in excess of, the setting will move the stainless steel diaphragm and close the detector electrical contacts. The detector may be mounted off the equipment and connected with a flexible hose to isolate the diaphragm from vibration or from erosion by particles.

4.1.2 Ultraviolet radiation detectors

The other detector commonly used is an *ultraviolet radiation detector*. Pressure detectors are preferable and most common, but ultraviolet detection is used in the following situations:

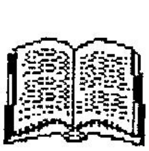
* where there is a flash fire potential and a pressure increase is unlikely;
* in a low strength enclosure (in the range of 0.7 to 1.4 kPa);
* where pressure detector operation would be too slow.

Ultraviolet sensors involve more maintenance and are normally less reliable. They are subject to actuation by flames, electrical or mechanical sparks, glowing material, induced electrical currents, cosmic rays and radioactive sources. If the viewing port (viewing aperture) is coated with hydrocarbon fuels or organic residues, the coating may be opaque to ultraviolet and the detector may be desensitized. The coating may be so thin as to be invisible. If this can be a problem, the port must be regularly cleaned.

4.2 Control Equipment

An Electrical Power Unit (EPU) provides central control, continuous monitoring of external circuits and includes automatic plant shut-down and battery stand-by facilities.

4.3 Suppression Agents



Agents for explosion suppression include chlorobromomethane (Halon 1301), bromochlorodifluoromethane (Halon 1211), dibromotetrafluoroethane (Halon 2402), water (with calcium chloride or ethylene glycol for freezing depression), wetted waters, dry chemicals, and combinations. (Refer to Module SS/13 for a discussion of halons used in Gas Flooding systems).

4.3.1 Selection

Selection of an agent can depend on its effectiveness as determined by experience or tests. Halon 1011 has been the usual choice for flammable vapors and gases; all agents have been used for combustible dusts. Clean-up is often a factor in a preference of Halon 1301 over Halon 1011. For example, Halon 1011 forms a mastic mess with styrene dust creating a clean-up problem. Halon 1301 is commonly used where foods are involved.

The nature of the ignition source can affect the selection of the agent. If it is persistent, such as an overheated bearing, an inert condition should be maintained after suppression to prevent reignition. A heavy volatile agent will persist for a greater period of time; Halon 1011 is the most persistent.

4.4 Agent Containers and Discharge Apparatus

The selected agent is stored in one or more steel pressure vessels fitted with electrically operated, high discharge rate valves or explosively actuated, frangible discs. The agent containers are usually connected directly to the enclosure being protected, to reduce to a minimum agent discharge and transit time.

One leading manufacturer (GRAVINER) offers both types which are described below, being either the *hemispherical suppressor* (Fig. 3.1, 3.2) or the *high rate discharge bottle* (Fig. 3.3, 3.4).

4.4.1 The *hemispherical suppressor* consists of a nickel plated, copper hemisphere mounted to a robust, steel backplate. When the hemisphere operates, the relatively thin, copper section ruptures along scored lines in a petal-like fashion, releasing the stored extinguishant. Hemispheres are designed for mounting within the vessel and on operation rapidly distribute suppressant as an expanding hemisphere of fine droplets.

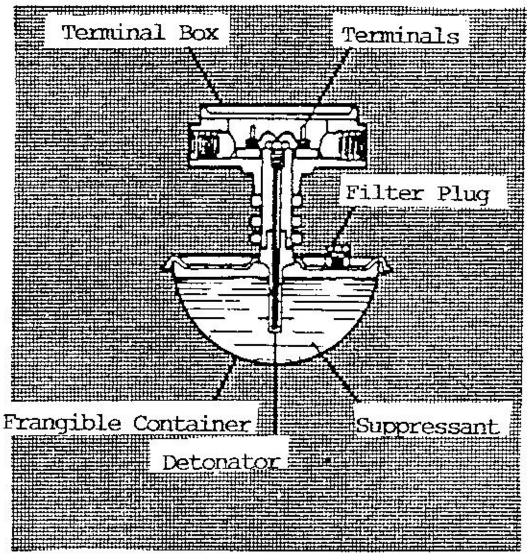


Fig. 3.1
Hemispherical suppressor: cutaway view

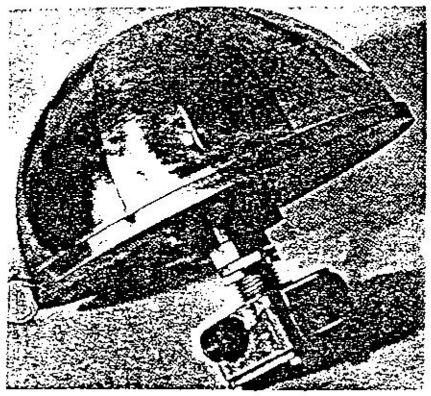


Fig. 3.2
Hemispherical suppressor: external view

4.4.2 The *high rate discharge bottle* is used as a suppressor where plant conditions dictate that suppressors cannot be located within the volume to be protected, either because of high temperatures, or due to interference with the efficient operation of the plant. These are normally mounted external to the vessel. On operation, the suppressant is discharged through a spreader assembly to distribute it evenly into the vessel in very fine droplets.

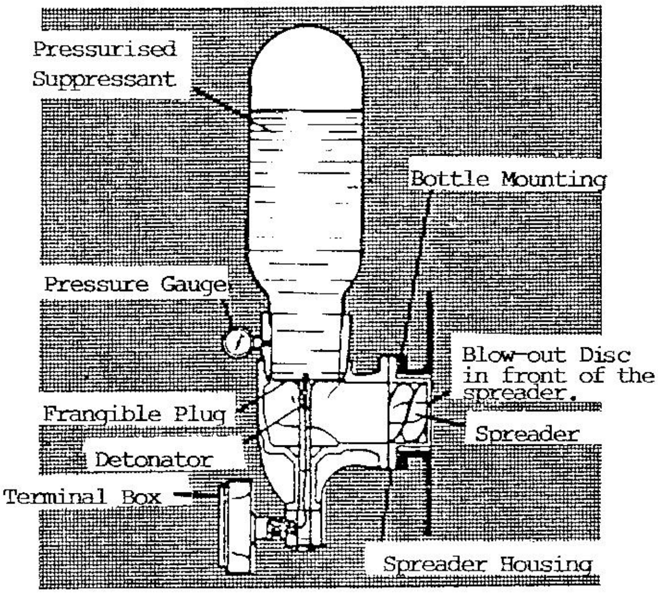


Fig. 3.3
High-rate discharge bottle:
cutaway view

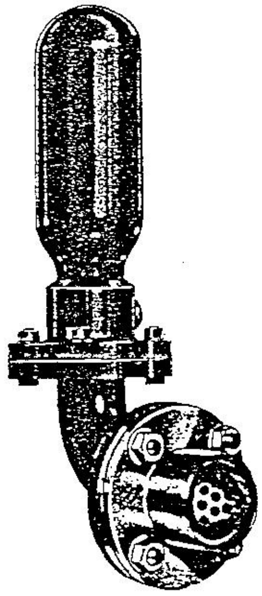


Fig. 3.4
High-rate discharge bottle:
external view

4.4.3 Both types of suppressors are explosively operated by means of an electrical detonator, but with the high rate discharge bottle the container is pressurised with 2000 kPa of nitrogen to assist the distribution of the suppressant, whereas in the hemispherical suppressor the only pressure would be the vapour pressure of the suppressant, and the energy from the detonator to distribute the suppressant.

5. DESIGN CALCULATIONS

Designing an explosion suppression system is a complex process dependant very much on the research and testing carried out by the individual manufacturers. *NFPA 69 - Explosion Prevention Systems* - provides further background on the design and installation of such systems but unlike other American, British and Australian design codes for fire suppression systems, gives no specific quantitative design criteria, so reliance for design quantities are therefore dependant on manufacturers' data.

6. APPLICATIONS

Explosion suppressant systems may be used as an alternative to damage limiting construction for rooms or equipment. However, they are seldom used to protect rooms because of limitations of wall strength, personnel safety and room size.

Explosion suppression systems are most commonly used in enclosed equipment. In the few milliseconds required for detection and suppression, some buildup of pressure must be expected. This is due to the incipient explosion and to the suppressing medium discharged into the enclosure. In most cases, this should not exceed 20 kPa for 50 to 75 milliseconds. The enclosure should have the structural integrity to withstand this pressure.

Explosion suppression has been applied to the following areas:

6.1 Storage tanks

Explosion suppression originated in aircraft fuel tanks; it can be applied to flammable liquid storage tanks.

6.2 Dryers

Explosion suppression has been applied to spray dryers, rotary dryers (discharge end and hoods), tray dryers, etc.

6.3 Scrap and refuse shredders and automotive fragmentizers

Explosion suppression equipment is designed to protect the shredders or fragmentizers and associated shrouds and dust collection equipment.

6.4 Feed, grain and flour handling

Explosion suppression systems are used mainly in dust collection equipment, pulverizing equipment and in finished flour handling. Recent research has shown that suppression equipment is effective on bucket elevators.

6.5 Wood processing

Explosion suppression systems are provided in dust collectors, particularly where there are potential ignition sources, such as from sanders. They are used on equipment, downstream from particle dryers at particle board plants, including chippers, particle classifiers and lay-up machines.

6.6 Plastic grinding and blending

Explosion suppression systems have been used on plastic resin grinders, blenders, and associated dust collection equipment.

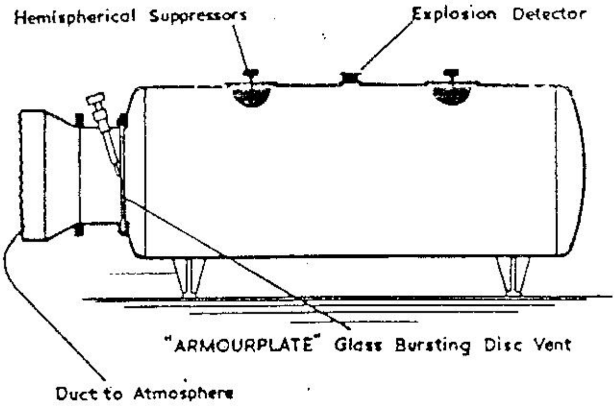


Fig. 4
Typical Explosion Suppression System For A Storage Tank Using Hemispherical Suppressor

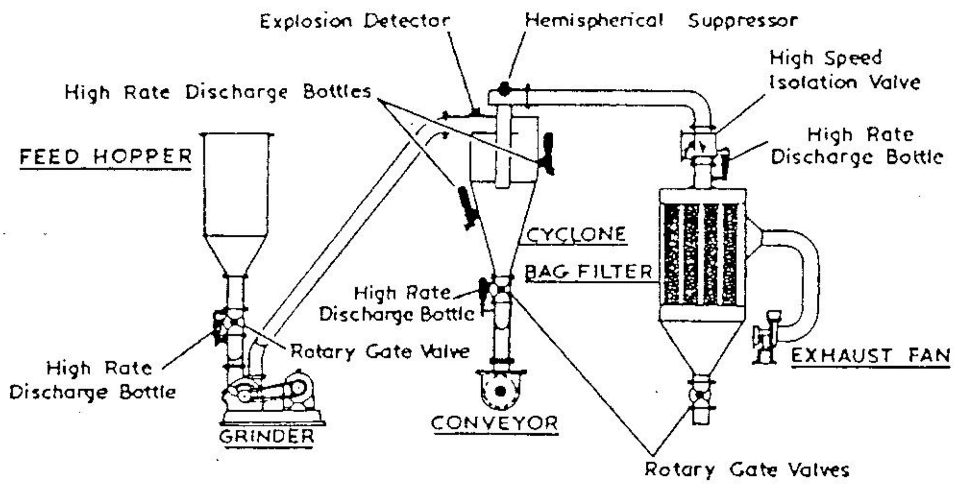


Fig. 5
Typical Explosion Suppression System For A Grinding Plant Using High Discharge Rate Bottles

[Figs 4 and 5 reprinted with the kind permission of Kidde-Graviner Ltd. UK.

7. LIMITATIONS

7.1 Combustion explosions having a very high flame speed are difficult to control with an explosion suppression system because the pressure buildup may be too rapid and exceed the strength of the container. Materials having high flame speeds include metal dusts, hydrogen and acetylene. High flame speeds also occur in oxygen enriched atmospheres. Explosions in the liquid or solid phase (condensed phase) tend to be extremely fast. Substances that react with water, halon, or both, cannot be protected by these materials.

7.2 Explosion suppression is difficult and expensive for very large enclosures or rooms. If the volume is over 570 cubic metres, protection might not be practical.

7.3 If the strength of the enclosure is below 20 kPa, the explosion suppression might not prevent failure of the enclosure.

7.4 Careful application of the system and selection of extinguishing agent must be observed for protection of rooms or enclosures in which personnel may be present. Normally, before any room or equipment is entered for whatever reason, the room or equipment should be cleared of the hazard and the explosion suppression systems should be deactivated.

REFERENCES

National Fire Protection Association. *Code 69 - Explosion Prevention Systems.* NFPA 69. (USA).

FURTHER READING

Linville, J. (ed.) *Fire Protection Handbook. 16th Ed.* National Fire Protection Association. Quincy, MA, USA. 1985.

ASSESSMENT

[*Work to be completed and returned to Tutor for correction and comment*]

1. Name the two causes of explosions.

   [5 marks]

2. List the two preventative measures which can avoid the occurrence of an explosion.

   [10 marks]

3. Of the four measures available to protect against explosion, which two are usually considered too expensive?

   [10 marks]

4. At 100 milliseconds (ms) what are the generally accepted pressures (in kPa) for:

   a) an unsuppressed explosion?
   b) a suppressed explosion?

   [10 marks]

5. Name the two principal detectors used in explosion suppression systems.

   [10 marks]

6. Which suppression agent would be most suitable for a flour grinding mill and why?

   [20 marks]

7. What is the most common device for rapidly opening the suppressant discharge device?

   [5 marks]

8. List three materials or applications where the effectiveness of an explosion suppression system may have limited, or no, effectiveness.

   [30 marks]

Total = 100 marks

Answers to Test Yourself Questions.

1. A rapid and violent increase in pressure.

2.
a) source of ignition
b) flammable substance
c) oxygen (in air)

3. 40 ms (milliseconds)

4.
a) nitrogen
b) carbon dioxide

5. Halogenated agents - such as Halon 1301 - Bromotrifluoromethane.