THE SELECTION OP FIXED PROTECTION IN CHEMICAL PROCESS PLANTS

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This paper examines the methods by which an engineer may select and design a fixed protective system to control accidental fires in specific chemical process plant risks.

INTRODUCTION

The engineer engaged in the protection of chemical process plant against accidental fires is likely to be faced with a variety of different risks, hut will have at his disposal a number of alternative fixed protective systems which will give him a fairly wide choice of characteristics. It is the function of this paper to clarify as far as possible, the process of selection and design of system to meet the requirements of the risk.

The first prerequisite must be a systematic study of the risk to determine its salient features, since these will determine the type of system to be used. Once the decision is taken, the engineer must proceed to a design study of the problem in order to produce an adequate quantitative solution. This selection and design process is largely based on experience and empiricism, although a 'decision tree' method of analysis is being developed in order to rationalise the choices available.

ANALYSIS OF POTENTIAL FIRE SITUATION

In order to determine the likely characteristics of the fire situation, the following salient points should be considered:

a) What type of combustibles will be involved? Are they likely to give rise to deep-seated combustion, thus needing a cooling agent, or will they be surface fires, for example, on flammable liquids, where an inerting or inhibiting agent may be sufficient? Are there any special features which rule out certain extinguishing agents, or make others preferable?

b) Is speed of detection vital, highly important, or just important? (see also (c) below).

c) Is there a life risk? If so, to what extent is toxicity of combustion or agent decomposition products significant? How does this interact with (b)?

d) Is the fire indoors or outdoors? If outdoors, what will be the effect of wind on rate of burning, involvement of other combustibles, exposure of nearby hazards, difficulties of extinction of fire? If indoors, is there a case for a local application system or for a total flooding system?

e) What is the likelihood of fire spread beyond the initial fire area? What steps should be taken to combat this?

f) Should the selected system be designed to give detection and control, or detection and extinction? The existence of back–up forces must be considered here.

g) Could quicker or surer results be obtained by a dual-agent system than by a single-agent system, for example, water spray and carbon dioxide, or use of a foam-sprinkler system to blanket a flammable liquid fire at floor level, in conjunction with dry powder applicators to cover potential running-fuel fires from leaking valves etc.

h) Is there an explosion risk either inherent in the fire situation or due to the use of a specific agent, for example, static discharge from carbon dioxide into flammable vapour zone, or use of water spray on metal fires.

j) Are there any other special features which will affect the choice of system.

REQUIREMENTS FOR A SATISFACTORY INSTALLED SYSTEM.

An installed extinguishing system consists essentially of the agent itself together with any additional propellant gases which may be required, storages for the agent, pumping system (where required), metering system (where required), piping and discharge nozzles. In addition, there must be a detection mechanism which will activate the system automatically on responding to a fire, and/ or a manual system for actuation by personnel. The whole must, to be satisfactory, conform with specific requirements as follows:

a) The detection system must be adequately sensitive to respond rapidly to a fire situation, but must not be subject to false operation which might release the agent unnecessarily. In this respect, a dual detection system is sometimes desirable, and sometimes, automatic lock-cffs are necessary to protect personnel.

b) The system, once operated, must be capable of controlling and extinguishing the expected fire situation without recourse to outside assistance, unless this has been catered for in the planned procedures. The effectiveness of the system can be established quantitatively from available laboratory and research data giving design concentrations and durations of agents, from which the required application rates, discharge times and quantities may be assessed on the basis of a planned spacing of discharge nozzles to cover all areas of the risk.

c) The system must be reliable and its construction must take into account any features of the environment which may be detrimental to its operation, for example, corrosive atmospheres, dust, cotton fly, fluff, tar or other heavy vapour deposits.

d) The possible toxicity of the agent or its breakdown products on the expected fuels, must be determined, since this knowledge will be essential in making the choice of system, and in determining what safety measures must be applied, particularly in the case of total—flooding systems.

e) The cost and weight of the system must be determined, both for initial capital investment and cost of maintenance and recharging.

f) The selected agent must be compatible, both with the process itself and with any other agents. The system must be compatible with any other installed system/s.

g) The effect of the agent discharge on visibility in the fire zone must be considered if manual fire—fighting may also be undertaken.

REVIEW OF THE CHARACTERISTICS OF PROTECTIVE SYSTEMS

It is not intended to give a detailed description of all the protective systems available, but rather to outline the essentials necessary to correct selection and design. The systems available are as follows:

Water-dispensing systems

Water is used in situations where its high specific and latent heats may be used to advantage in cooling combustibles. On conversion to steam, it can also be used to provide an inerting atmosphere.

Sprinkler systems. These are suitable mainly for Class 'A' risks such as offices, storages, finished product protection, for example polyurethane blocks, boxed products, high stacked or high racked storages, rolled paper, carpets etc. Also for living and sleeping accommodation, canteens, rest rooms etc. The main design features and categories of risk are listed in Fire Offices' Committee Rules (latest edition). Discharge densities range from 2.25 to 30 mm/min, and specified minimum areas of coverage at design density from 72 to 300 m^2. Detection is by sprinklers, each of which has a heat-sensitive element. Systems may be wet, dry, alternate, pre-action, cycling etc, according to need. This is a reliable and reasonably sensitive system for solid-fuel risks, with a great deal of 'inbuilt safety factor'. (l dm^3Vm^2min = 1 mm/min.)

Water spray systems. These are essentially used for risks involving flammable liquids, with or without solid-fuel risks also. Systems may be an adjunct to an existing sprinkler, for example where a flammable liquid risk exists within a predominantly solid-fuel risk, or may be independent systems. Their main usage is against fires in non-water-miscible liquids with fire points above 45°C, for example kerosine, gas oil, transformer oil etc, where a 'high velocity' system can project the spray into the burning liquid for extinction by direct cooling. A mass median drop size between 0.4 and C.8 mm is necessary with an application rate above a critical value which depends upon the type of liquid, the burning time before spray application, and other factors. Water spray is not suitable for use against fires in flammable liquids which form a 'hot zone' with a temperature above about 100°C. Water sprays with a mass median drop size of 0.3 mm or below can be used against low fire point liquids (45°C), or against water-miscible liquids of all fire points up to 10C°C. In the first case, they extinguish by direct cooling of the flames, and in the second by forming a high fire point solution of the liquid in water. Neither process is very satisfactory, however, although some advantage may be gained by cooling of the surroundings to prevent reflash, while another agent (dry powder, carbon dioxide, halon) is used to complete the extinction. For these applications, 'medium velocity' spray nozzles are used. Water spray systems may also be used to extinguish 'mixed' fires of flammable liquids and heated solids, such as oil-filled transformers. The salient features for success, particularly in outdoor applications,are a speedy detection of fire and an adequate application of water spray over the risk in such a way that all areas, including hidden pockets, may be cooled. The distribution density required will be in the range 10-70 l/m^2 min, where the area is the 'envelope area' that will just enclose the risk. The actual figure selected in this range will depend upon speed of detection, intricacy of the installation and likely wind speed. Water spray systems may also be used for large flammable liquid risks such as aircraft maintenance hangars and similar process areas. The design criteria given in NFPA No. 409 are usually followed. Large water spray installations may be used to protect exposures such as tank farms, LPG and LNG tanks etc, against heat radiation from adjacent fires, the design density normally being given as 10 l/m^2 min. For very large tanks, this figure may involve a very high water requirement, and it is usual to reduce this as far as possible by only applying the design figure to the high points of the risk, particularly adjacent to any ullage space, and allowing the lower parts to be cooled by drainage of water from above. Water sprays should not be used on flammable metal fires, and not on high—voltage electrical equipment.

Foam-dispensing systems

Foam is made by aerating a solution of a foaming agent in water and 'working' it into a bubble structure, the volume of which bears a relation (the 'expansion') to the volume of the solution from which it was made.

'Low-expansion' foams (expansion usually 8-10 units). These foams are suitable for the extinction of fires in non-water-miscible flammable liquids of fire points below 100°C. The foam liquid used may be protein, fluoroprotein or fluorochemical, in a 4 to 6 per cent concentration. Specially fortified protein ('general purpose*) foams are necessary for water-miscible liquids such as alcohols etc. The application of foams to flammable liquids is characterised by a 'critical rate' below which the fire canrot be extinguished. This is normally of the order of 1 $1/m^2$ min of foaming solution, related to the free surface area of the fire, but may be more in the case cf alcohol-resistant foams on certain 'difficult' solvents. The mcst economical application rate is usually some 3 to 5 times the critical rate, and the system should be designed to give a gentle application of foam to the flammable liquid surface, particularly where alcohols etc are involved. A laboratory assessment of a foam on the flammable liquid to be protected is to be recommended in any case of doubt.

Foam systems consist essentially of a water supply into which the foam liquid is first 'proportioned' to form the solution, which may then be converted to foam in an in-line generator from which it is pumped to plain open nozzles. Alternatively, the foam solution may be pumped to a series of aspirating nozzles, which project the made foam on to the risk. Foams are not suitable for use on flammable metal or any material which may react with water, nor should they be used on high-voltage electrical equipment. Otherwise they present no hazard in themselves to the personnel present.

Their most usual application is in engine rooms, boiler rooms, oil-rig modules, chemical plant etc, where flammable liquids are involved.

'Medium expansion' foams. These foams are made from solutions of a synthetic foaming agent in a concentration of 1-3 per cent in water. They may be used on fires in flammable liquids, or in solids, where the drainage cf water from the foam gives some cooling effect. Systems at present in use are relatively small and protect special risks such as gas-turbine driven electric generating sets. Prudence suggests that the current supply should be cut off before application. The expansion is usually in the range 100-250 units, and the foam can be used indoors or outdoors.

'High expansion' foams. These foams are made in the same way as medium expansion foams hut their higher expansions (500-1000) demand some form of forced induction for the air supply. This is usually a fan driven by a hydraulic or electric motor. High expansion foams are used mostly to fill volumes in which solid or flammable liquid fires may exist. They cannot he used outdoors owing to their rapid dispersal by wind. While they are effective in "blanketing fires and preventing ingress of air for further combustion, they are not immediately successful on deep-seated fires and the foam level may have to be maintained sufficiently long to ensure cooling by water drainage.

Both medium and high-expansion foams, hy their physical nature, are difficult to use with other agents, and in particular, dry powders break them down rapidly by impact. Their rates of application are measured in terms of metres3/min, or in a volume, in terms of the depth cf foam/min ahove the floor level. Either must he sufficient to enahle the foam to build up and 'envelop' the fire.

Dry powder systems

These are similar in principle to other systems in that they consist of a powder container, pressurising gas, actuating valve, discharge piping and nozzles. The powders used may he suitahle for flammahle liquids and gases (EC powders), or solids, flammahle liquids and gases (ABC powders). Alternatively, there are special powders for use on flammahle metals. The charging gas is usually dry carbon dioxide. 'Packaged' systems are available in the range 1½-15 kg of powder, usually as single-point discharge systems. 'Ergineered' systems range up to 100C kg in size, and have multi-point discharge, the arrangement of nozzles being that to give the most effective coverage. The rate of discharge is usually at least twice that deemed satisfactory by tests, and in this respect dry powder also has a 'critical rate' of application, and a 'most economical' rate. It should be remembered that dry powders are only effective while they are being applied, and even in enclosed volumes will 'settle out' rapidly. It is essential for this reason alone that the rate of discharge is adequate to extinguish a fire completely. Dry powders are suitable for flammable liquid and solid fires (ABC), and are particularly valuable for dealing economically with running fuel or gaseous fires from a jet. They can also be used effectively in conjunction with water sprays and inerting gases, but may cause some breakdown of low—expansion foams unless they are specifically designed to be foam compatible. They are likely to cause considerable breakdown of medium and high—expansion foams. They may be used either indoors or outdoors, but in the latter case, may suffer from the effects of strong winds.

Carbon dioxide systems

The most effective use of carbon dioxide is indoors, either as a local application or total-flooding system. Outdoors it is likely to disperse and be ineffective almost immediately after application ceases. As a relatively inert, non-corrosive and non-conductive gas, it is particularly useful where it is essential to cause the least possible damage to the materials at risk. It can be used effectively on flammable liquids, solids and gases, but not on materials which contain their own oxygen, or which are capable of reducing the carbon dioxide to carbon and burning in its oxygen, for example magnesium. While the design concentration of carbon dioxide is usually not much greater than the theoretical concentration for those materials which burn at the surface, for example petrol has a design concentration of 34 per cent by volume as compared with 28 per cent theoretical, for deep-seated fires the design concentration may be very high, for example 65 per cent by volume for paper storages. This shows two major difficulties. First, the necessary volume of carbon, dioxide has to be introduced very carefully into a building to avoid excessive pressure rise, and air must be vented to ensure this is so. Second, the concentration of carbon dioxide dangerous to humans is only some 5 to 10 per cent, so that a positive •lock-off system roust be arranged to ensure that discharge does not occur until all personnel have left the building for a place of safety. Systems may be 'high' or 'low' pressure, single-shot or multi-shot. Carbon dioxide may be used in conjunction with water sprays, foams, dry powders or halons without mutual ill effect.

Halon systems

Like carbon dioxide, the halons (1211 and 1301) act as inerting gases, with the additional advantage that they have a strong inhibiting effect on the combustion reaction. HALON 1211 is a liquefiable gas boiling at -4°C, and HALOK 1301 is a liquefiable gas boiling at -58°C, at NTP. Both are colourless and odourless and electrically non-conductive. Both are effective on a wide range of combustibles. They may be used from fixed systems for local or total flooding applications. Their best use is on flammable liquids, or on solid fires which have not become too deeply involved. Discharge on to a deep-seated solid fire may produce a high degree of breakdown into acid gases with an unacceptable increase in toxic products. Under normal circumstances, however, their extinguishing concentrations are both of the order of 5 per cent by volume, and in this case they offer a considerably lesser hazard than does carbon dioxide for total flooding applications. Nevertheless, the situation is being recognised as one in which a 'lock-off' system should be employed in order to make quite sure that personnel are not placed at risk.

Halon systems are similar in principle to carbon dioxide systems, except that an additional propellant gas is usually used in solution to ensure adequate discharge characteristics. This gas may be nitrogen or carbon dioxide. Halons may be used in conjunction with water sprays, foams, dry powders, or carbon dioxide without ill effects.

CONCLUSIONS

This paper has shown the processes by which a suitable fixed protective system may be selected and designed to suit any specific risk in a chemical process plant. It illustrates the wide range of systems available, and their salient advantages and disadvantages.

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