HAZARDS IN PROCESSING LIGHT HYDROCARBONS

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SYNOPSIS

Techniques of design and operation of plant for handling and processing light hydrocarbons are discussed in relation to the fire and explosion hazards inherent in these operations.

A brief description of the Olefine Works of Imperial Chemical Industries Ltd. Heavy Organic Chemicals Division is given since this is the works which will be used to illustrate most of the points discussed.

The works can be split into three main sections:

(i) The storage area where liquid feedstock is pumped from ocean-going tankers and where it is stored ready for processing.

(ii) The pyrolysis section which converts feedstock into a mixture of gas and crude motor spirit and where temperatures reaching 2000°F are encountered. From here the products go to a quench device where the reaction is stopped.

(iii) The product purification and gas separation section which is the most costly and difficult stage. This section includes a compression section handling the process gas and the refrigeration gases for the low temperature, medium pressure distillation of low molecular weight hydrocarbons.

Introduction

Within the sections of the Olefine Works of Imperial Chemistry Industries Ltd. a wide variety of hazards are encountered and, for the main part, the paper discusses these in detail. It is however stressed that there are many more general aspects of safety which will seem to have scant attention paid to them.

Pre-production studies are carefully carried out. Within ICI there are hazards experts whose job it is to advise plant designers and operators on how to keep a process safe and when a new plant is to be designed with a novel process these specialists will be consulted and after their experiments data will be given on such features as the maximum permissible concentration of oxygen in recycle gas, *etc.* This paper however is not concerned with a novel process.

The measures which are taken in the engineering departments to arrive at sound equipment are also taken for granted. Specifications are carefully prepared, all equipment is designed with substantial safety factors and it is inspected regularly to see that it remains safe. Preventative maintenance schemes include any equipment which could harm either production or employees.

The maintaining of a comprehensive system of permanent instructions is a most important aspect of safety. Management sees that workers wear the correct protective clothing, the proper use of tools is emphasised, and a plant clearance system is operated with rewarding results.

These and many other features are carefully controlled by line management with the assistance of a safety officer but the sections which follow will concentrate on safety aspects which have to do with the process itself.

The Olefine Works of Heavy Organic Chemicals Division

The Olefine Works of Heavy Organic Chemicals Division is typical of the many petro-chemical plants which are operating in the United Kingdom and a brief description will show how the various parts of the plant fit into the overall picture. The flow-diagram is given in Fig. 1. This shows that an olefine plant can be divided into three main sections.

(1) The feedstock area where the low flash-point feedstock is stored.

(2) The pyrolysis area where the feedstock is cracked into a mixture of crude petrol and gas. Cracking occurs mainly in the soaker line where hot hydrocarbons are mixed with even hotter steam. After cracking the mixture goes forward to the quench boiler where the cracking is stopped and then the pre-fractionator separates off first the heavy polymeric oil, which is burned on the furnaces, and finally, petrol is taken off to be sold back to the oil companies.

(3) The gas goes on to the gas separation area. First hydrogen sulphide and then acetylene is removed and then butenes and butadiene are removed, in a warm fractionator system. Then the gases go to a train of distillation columns working at low temperatures and medium pressures and the low molecular weight hydrocarbons are separated. This area includes the process gas compressors and the refrigeration gas compressors, for propylene and ethylene refrigeration systems are necessary for the final distillation of the low molecular weight hydrocarbons.

This description will suffice to show the kind of plant we have to deal with and now a word about some of the measures taken:

Site Layout

Much thought goes into deciding the best plant layout. On the one hand the designer is asked to separate the hazardous materials from the hazards, and on the other hand it is known that a compact site is the most economical. Careful thought is necessary to arrive at a proper balance between safety and economy. Models are a boon to the design engineer during the early considerations which decide not only the general arrangement of plant items, but also fire precautions and the classification of areas. They give a much more composite view of what actual conditions will be like and the process operators find them

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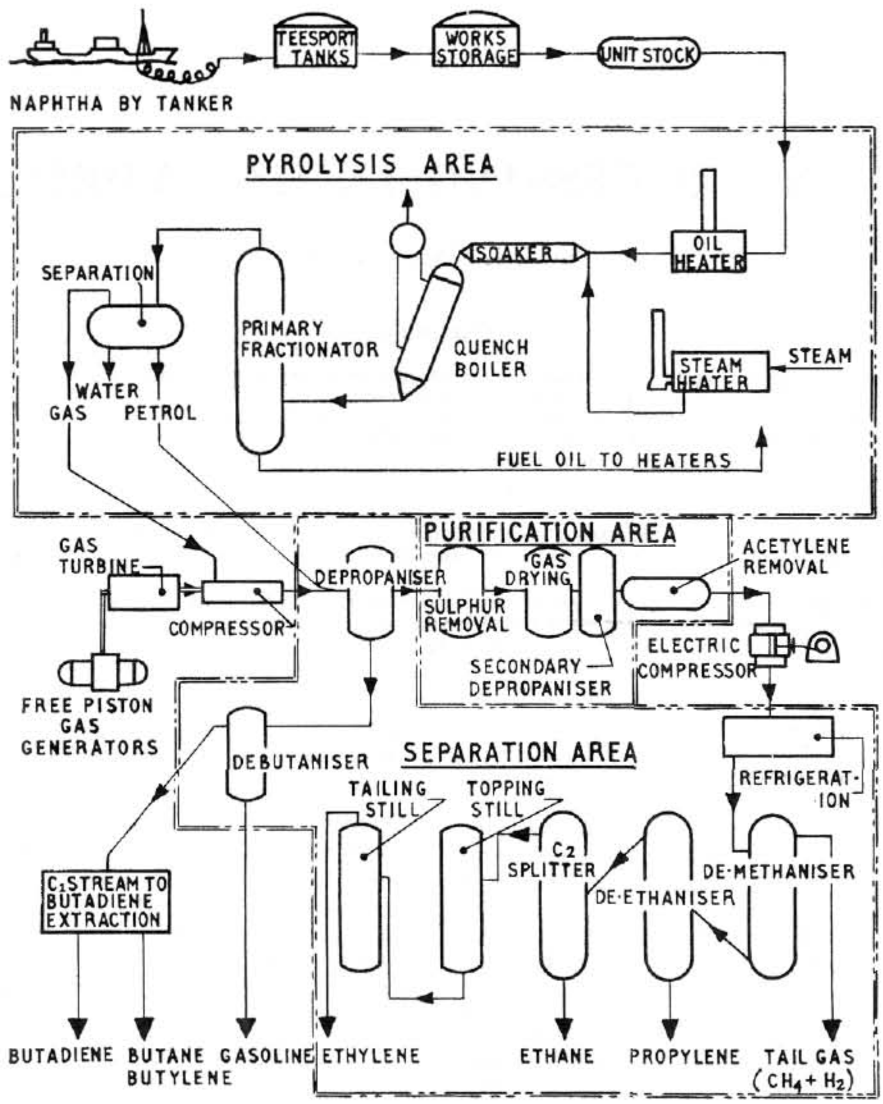

Fig. 1.—*Diagrammatic flow-diagram of the olefine plant*

easier to understand than drawings. During the early meetings at which the matters are discussed everyone is asked to think hard about all possible sources of hazard.

The Importation and Storage of Feedstock

The 100 000 ton/year unit demands a feedstock storage unit similar to an oil company's bunkering depot. Feedstock for ethylene has flammability limits similar to those of petrol but it has lower vapour pressure and three 12 000 m^3 floating-roof tanks are provided for its storage. Other hydrocarbons are bunkered in smaller fixed-roof tanks which can be nitrogen-blanketted to keep the atmosphere safe. The whole storage compound is designed as a self-contained unit and some salient features of its design and operation are given:

(i) Each storage tank is bunded separately to contain all its contents, care being taken to ensure that pipes breaking the bund walls do so without destroying the seal.

(ii) Floating-roof tanks collect a considerable amount of rain water and though a water bottom is required for dipping purposes the water level has to be adjusted by drainage. All such tank, process lines, and bund drainages are taken to an oil-and-water separator to prevent oil entering the river.

(iii) Cast-steel valves and fittings are used throughout the installation to avoid their cracking in fires, and all first isolation drain valves are carefully protected from freezing.

(iv) A diesel-driven fire pump system which includes fixed water sprays and foam-making equipment is installed, tested weekly, and full-scale fire practices are arranged.

Off-loading operations on the jetty are carefully controlled and the following notes indicate the type of precaution taken:

(i) The coupling and uncoupling operations are done to a rigid procedure which is designed to avoid the smallest spillage of hydrocarbon.

(ii) The hoses, which are the most vulnerable part of the equipment, are pressure tested at regular intervals, and during the actual off-loading operations they are supported on special slings which are constantly adjusted to prevent any chance of strain.

(iii) To avoid static charges very low pumping rates are used initially because of the possible presence of water. Low rates are also used whenever the tanks are off-float.

When these two conditions are passed the rates are increased to the maximum for the material being pumped.

(iv) After the ship's cargo has been off-loaded the lines are emptied by means of a small pump-out pump so that no material of low flash-point remains between the storage compound and the jetty.

The Furnace Area

To ensure that the furnaces never feed their own flames, dangerous conditions inside the furnace tubes are prevented by ensuring that all air is excluded, or when this is not possible, by carefully controlling the air/hydrocarbon mixture.

Dangerous conditions arising *outside* the tubes are forestalled by various practical measures:

(i) Leaking furnace tubes are obviated by choosing materials of construction which are satisfactory for the temperatures encountered and joints are omitted wherever possible by using fully welded-up systems.

(ii) Safe operating conditions are never exceeded by the alarm and trip systems which are fitted. These will give warning of temperature rises or flow failures.

(iii) Explosive conditions are precluded from arising from the combustion chambers by the use of flame-failure switches which prevent the burners being relit before steps have been taken to ensure a safe atmosphere.

Additional to all these steps, there is a good supply of fire-fighting appliances available, particularly snuffing steam, for extinguishing any small fires which may evade subjugation.

The Flare-stack and Blow-down System

Normally, but not always, the flare-stack and blow-down system is in the furnace area and it is thus convenient to describe this equipment next.

Flammable vapours are required to be vented either voluntarily, through purges, or involuntarily by relief valves, and these purges have to be disposed of safely. Before going to a closed blow-down system, it is usual practice to give consideration to venting directly to atmosphere, but before doing this one must satisfy oneself that it can be done safely.

A vapour stream emitted from a stack, which is sufficiently high above the surrounding buildings and with enough velocity to avoid down-draughts, spreads out so that it resembles a cone, having its apex at the top of the stack. At some point down-wind the edge of the cone reaches the ground and it is about this point that the maximum concentration occurs. In an earlier paper, Dr. Long has shown that there are formulae for calculating maximum concentrations and distances and, providing certain conditions apply, this system of venting is worth considering.* The most important conditions are that:

Hydrocarbon vapours of molecular weight greater than 60 should not be vented directly to atmosphere.

If a vent-stack is used it should be at least 100 feet above ground level to avoid effects of atmospheric inversion.

The vapours should be relased at the maximum possible velocity, and velocities of the order of 500 ft/s are sometimes required to combat the effect of atmospheric inversion.

Often, however, it is necessary to use a closed blow-down system which can cater for hot and cold, light and heavy hydrocarbons. Light hydrocarbons discharge into a separate

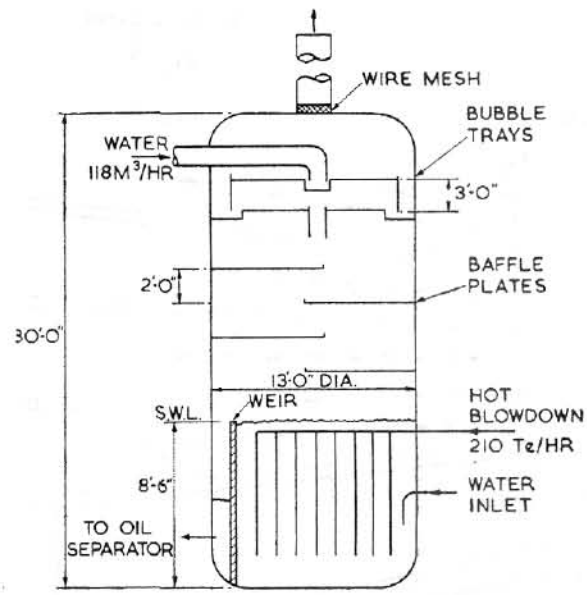

Fig. 2.—*Direct contact condenser for hot blow-down system*

closed system direct to a blow-down drum which is vented to the stack. Hot, heavy hydrocarbons are vented to a direct-contact condenser where the heavy fractions are condensed and the non-condensibles flow upwards through the stack. At the top of the stack the gases are ignited by a pilot flame which must be reliable and fitted with a sure-fire ignition system controllable from a safe distance. Such a hot blow-down system is shown in Fig. 2.

The Gas Separation Area

Within the gas separation area there is concentrated an assortment of complicated process equipments all handling low flash-point hydrocarbons, many of them liquefied at the temperatures and pressures and clamouring to escape and cause a fire. The three elements necessary for fire are fuel, oxygen, and a means of ignition, and all three have to be carefully watched.

(i) The fuel/oxygen mixture within the equipment is carefully controlled so that the mixture is always beyond the nose of the flammability curve and we do this on our process by simply excluding oxygen altogether.

(ii) The fuel/oxygen mixture outside the equipment is controlled by seeing that no fuel escapes or if it does, by seeing that it is whisked away before it can form an explosive mixture.

(iii) Means of ignition are excluded.

The prevention of hydrocarbon leaks from equipment is probably the aspect which has been most successful on olefine plants over the past few years and since this absence of leaks allows standard electrical equipment to be used, it is the basis of many design economies.

The methods used to avoid leaks are not novel, but by careful attention to details one can be certain of avoiding dangerous concentrations of hydrocarbons in areas where a few years ago one was much less sure.

(i) Flanges are avoided wherever possible and whole reboiler and overhead condenser systems on some stills are welded up.

(ii) Glandless pumps and mechanical seals on pumps and rotary compressors are used; and if necessary double seals flush with a compatible flushing medium are installed.

* See page 6

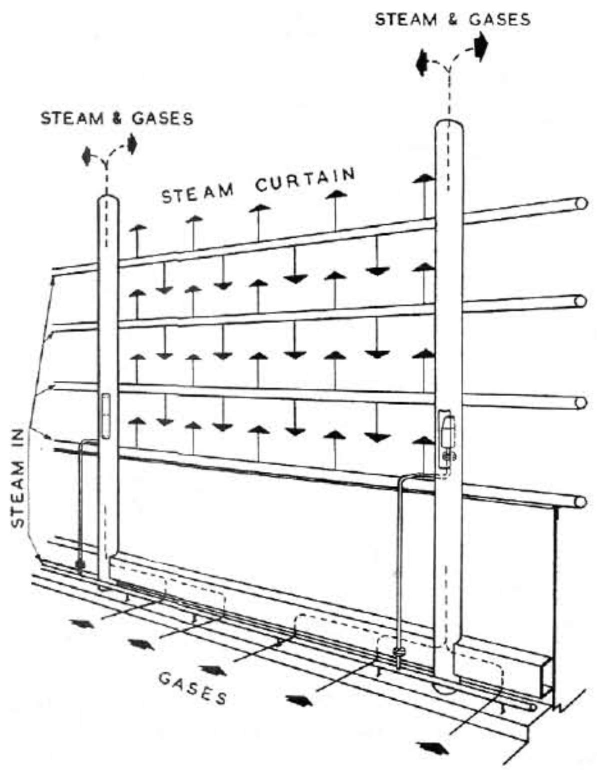

Fig. 3.—*A fire-wall barrier*

(iii) By careful choice of materials and by the judicious use of insulation to avoid thermal shocks, failures due to chilling have been avoided.

Sometimes however, despite all these precautions, the presence of hydrocarbon vapours cannot be ruled out in some areas and when this happens facilities for localising and dispersing these must be provided—very often segregation and fesh air can be relied on to do this.

Compressors are erected in the open or in well-ventilated buildings, and gland leaks, if they are not collected and vented back to an acceptable part of the process, are dissipated by the ventilation (pits and sumps where heavy hydrocarbons can collect are avoided).

The fire-wall barrier is also a device for separating a danger area and disposing of any gross hydrocarbon leakage (Fig. 3). At one time the whole low temperature distillation train was enclosed by a fire-wall barrier. Nowadays, because of improvements and our ability to contain leakage, the need for large-scale steam curtains is disappearing, but there are occasions when smaller areas need to be curtained off in a hurry.

The Classification of Areas

Considerable care is taken to ensure that, as far as possible, equipment is incapable of leaking and, being in the open, is also incapable of being surrounded by a hazardous atmosphere. Furthermore there exists a standard type of electrical equipment which is unlikely to cause ignition. It is justifiable therefore and economically essential that, when these circumstances coincide, they should be recognised, for it is in these areas that the risks do not warrant the use of fully flame-proof equipment.

In ICI the classification of areas has been done in the following way:

Class " *A* " *Areas*—these are where no flammable materials exist and standard electrical equipment can be used.

Class " *B* " *Areas*—are where the flammable material is well under control so that its liability to constitute a hazard may be considered remote and non-sparking equipment is specified.

Class " *C* " *Areas*—where a flammable material is handled under conditions where its presence cannot be considered unlikely and under these conditions fully flame-proof equipment is required.

The method used for defining the areas within a plant commences with the identification of all sources of hazard. Which class of hazard an item forms depends upon its likelihood of producing a hazardous vapour in its vicinity. Having established sources of hazard, distances are taken from the sources to locate the boundaries of the classified area. No fixed rules are applied for these distances and each case is considered on its merits, but it is rare that a boundary is less than 50 feet away from a Class " B " or " C " source of hazard.

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