

3. HYDROCARBON INDUSTRY EXPLOSIVE ATMOSPHERE

3.1 OVERVIEW

This chapter briefly defines the hydrocarbon industry wherein mixture of gaseous or dust substances creates an explosive / flammable atmosphere. Fire safety of plants and equipment is the paramount importance in an oil and gas industrial environment.

Occupational Safety and Health Administration (OSHA) of the Department of Labor in the US has defined various standards to be applied in the design of a (OSHA, 2012) that, Hazardous locations are areas, where flammable liquids, gases or vapours or combustible dusts exist in sufficient quantities to produce an explosion or fire. In hazardous locations, specially designed equipment and special installation techniques must be used to protect against the explosive and flammable potential of these substances.

3.2 FIRE BASICS

Fire as well as burning, releases heat and light energy when a substance is rapidly oxidising. When the rate of rapid oxidation is very high, it causes an explosion releasing high pressure and sound waves. Essentially the oxidation is a chemical reaction of a compound or element with oxygen that produces heat energy; this is an exothermic reaction. Magnitude of energy released depends on the oxidising compounds. Highest heat energy releases when oxygen combines with carbon and hydrogen, prevailing in a hydrocarbon industry.

There are three factors necessary for a fire, first a combustible material,

Secondly, presence of oxygen or oxidising agent and thirdly, enough heat to raise the temperature of the combustible material to start the ignition.

There are two types of fire, first smoldering fire which can be explained through a well-known fire triangle filled with factors of fire. Secondly the flaming combustion type which can be explained through the fire tetrahedron which is depicted in Figure.3.1.

A fire can become self-supporting with ample fuel and oxygen. This continuous chemical reaction produces more heat. The increase in heat raises more fuel to its ignition temperature, as the need for more oxygen arises to support combustion; it is drawn into the fire zone. The oxygen, in turn, increases the heat and more fuel becomes involved. Combustion will continue as long as the factors from the three sides of the fire triangle are present.

While oxidation is speeding up to the combustion stage, another process is occurring that helps combustion. A chemical decomposition process occurs when a substance is exposed to heat. As chemical decomposition takes place, the substance emits vapors and gases that can form flammable mixtures with air at certain temperatures (pyrolysis).

The fire chain reaction continues until the fuel present, oxygen is completely used or the heat source is dissipated and hence the temperature reduces below ignition temperature of the fuel.

3.3 SOURCES OF HEAT

Molecular motion in a material is measured as heat, because the molecules are constantly moving all the matter having heat, even in very low temperature. The rate of change of moving molecules increases when the substance is heated.

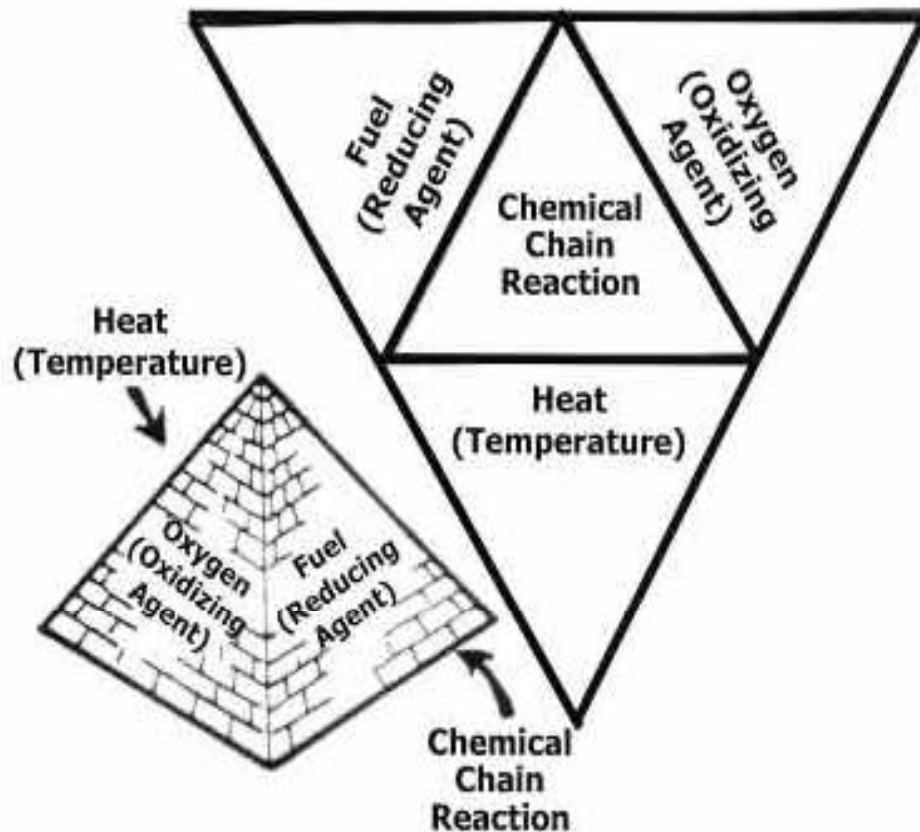


Figure 3.1 Fire Tetrahedron (Courtesy: Mine Emergency Response Program Mine Rescue Manual [21])

There are many sources of heat energy to ignite a fire chemical reaction in the hydrocarbon industry. The focus of this research is the high surface temperature of the equipment and devices installed in a plant.

Heat is generated when there is resistance to electron flow in an electrical circuit. The partial shading /irradiation level imbalance/ material imperfection / fabrication flaws / damages in a PV module gives resistance to electron flow when it is illuminated and thus producing heat on its surface.

Number of laws in physics explains the transmission of heat and its flow which can travel by one of the three methods defined as conduction / convection and (Saskatchewan, Mine Emergency Response Program - Mine Rescue Manual, 2001). The surface temperature raise in a PV module due to faults can

travel through either one or combination of two or three methods.

3.4 FLAMMABLE VAPOUR

The fuels can be found in solid, liquid and gaseous states, but only gases can catch fire or burn. The liquid or solid fuel requires its conversion to a gaseous state by heating. Fuel gases are evolved from pyrolysis for solid fuels and vaporization for liquids through heat.

Generally, the vaporization process of liquid fuels requires less heat than does the pyrolysis, for solid fuels.

All liquids give off vapors to some degree in the form of simple evaporation. Liquids that give off large quantities of flammable or combustible vapors are dangerous because they may be easily ignited.

Gaseous fuels can be the most dangerous because they are already in the natural state required for ignition. Gaseous fuel fires are also the most difficult to contain. Vapor density is the density of gas or vapor in relation to air. Vapor density is of concern with volatile liquids and gaseous fuels. Gases tend to assume the shape of their container, but have no specific volume. If a vapour is less dense than air (air has a vapour density of one), it will rise and tend to dissipate. If a gas or vapour is denser than air, it will tend to hug the ground and travel, as directed, by terrain and wind.

Every hydrocarbon except the lightest one, methane, has a vapour density greater than one and will sink and hug the ground, flowing into low lying areas. For this reason, Hydrocarbons are very dangerous. Common gases such as ethane, propane and butane are examples of hydrocarbons that are heavier than air.

Once a fuel has been converted to a gaseous state, it must mix with an oxidizer to burn, usually oxygen. The mixture of the fuel vapour and the oxidizer must be within the flammable limits for the fuel. That is, there must be enough, but

not too much, fuel vapour for the amount of oxidizer. If there is too much fuel vapour, the mixture is too rich to burn. If there is not enough, it is too lean to burn.

The flammable limits of how rich or lean a fuel vapour mixture can be and still burn, are recorded in handbooks and are usually reported for temperatures of 21°C. These are referred to as the lower explosive limit (LEL) and the upper explosive limit (UEL). These limits change slightly with temperature.

Auto Ignition Temperature (AIT) of a flammable vapour is defined as hot surface ignition, once started will propagate throughout the flammable
(API 2216 Ed 3, 2003)

with temperature classification, for designing the apparatus, so that it shall not become source of ignition in the hydrocarbon field. Table-3.1 indicates sample of various temperature class of flammable material for hydrocarbon vapor/gas.

Essentially, the surface temperature of any equipment and devices under fault
(Garside, 1997) (IEC-60079-14, 2007)

(Heinrich Groh, 2004) in a hydrocarbon vapour environment.

3.5 FLAMMABLE DUST

Solid fuels have a definite shape and size that significantly affects how efficiently they catch fire. Of primary consideration, is the surface-to-mass ratio, that is, the ratio of the surface area of the fuel to the mass of the fuel (A. Di Benedetto, 2010). As this ratio increases, the fuel particles become smaller and more finely divided (i.e., sawdust as opposed to logs), and the ease of ignition increases tremendously. As the surface area increases, heat transfer and vaporization of the small particles is easier and the material heats more rapidly, thus speeding pyrolysis. No pyrolysis or vaporization is needed for combustion.

Minimum Ignition Temperature (MIT) of a flammable dust is defined as the lowest surface temperature at which ignition occurred. MIT of flammable materials are well defined with temperature classification, so as it shall not become source of ignition in the hydrocarbon field.

Table 3.1 Auto Ignition Temperature (AIT) of Hydrocarbon Vapour / Gas

Hydrocarbon Gas / Vapour	Auto Ignition Temperature	T - Class		Remarks / Notes
	°C	IEC 60079	North America NEC 500-5(d)	
Carbon Disulphide	102	T5	T5	1. The maximum Ambient Temperature is taken as being 40°C.
Acetaldehyde	140	T4	T4	
Benzaldehyde	190	T4	T3A	
Dibutyl Ether	185	T4	T3A	2. IEC 60079 Classifies the surface temperature as source of ignition in °C as T1≥450, T2 ≥300, T3 ≥200, T4 ≥135, T5 ≥100, T6 ≥85
Decane	205	T3	T3	
Cyclohexane	259	T3	T2C	
Ethanethiol	295	T3	T2A	3. North America Classifies the surface temperature as source of ignition in °C as T1≥450, T2≥300, T2A≥280, T2B≥260, T2C≥230, T2D≥215, T3≥200, T3A≥180, T3B≥165, T3C≥160, T4≥135, T4A≥120, T5≥100, T6≥85
Di-isobutylene	305	T2	T2	
Ethelenediamine	385	T2	T2	
Methanol	455	T1	T1	

Table 3.2 Minimum Ignition Temperature (MIT) of a flammable dust

Flammable Dust / Fibre Layer	Minimum Ignition Temperature	Remarks / Notes
	°C	
Coal Dust	230	1. Source BIA (1987) for Minimum Ignition Temperature (MIT) by Godbert – Greenwald furnace
Methyl Cellulose	320	
Grain Dust	300	2. Ignitability and Explosability of dust depends on particle size distribution.
Starch	435	
Aluminium	> 450	3. DIN / VDI method of evaluating ignition temperature varies based on glow temperature and test methods.
Soot	570	

Table-3.2 indicates sample of various temperature class of dust materials. Essentially, the surface temperature of any equipment and devices under fault (K.Eckhoff, 2005) (ASTM-E1491-06, 2006) which can ignite a flammable dust layer. In mines application the surface temperature above 100°C is considered as source of ignition of an explosive (Saskatchewan, Occupational Health and Safety Division - Mine Rescue Manual, 2001) . MIT of the dust layer is directly linked to the particle (K.Eckhoff, 2005) (K.Eckhoff R. , 1997) (Hadden, 2011). The objective of this work is to investigate the surface temperature rise of PV modules due to hotspot phenomena and to evaluate fire hazard of applying it as a power supply source in hydrocarbon field.

3.6 SUMMARY

This chapter has briefly described the fire basics, sources of heat, flammable vapour and dust prevailing in a hydrocarbon industry. Technical aspects described in this chapter are detailed in voluminous books and only excerpts are presented for this research premise.

Hydrocarbon facilities always demand application specific devices specially (Heinrich Groh, 2004), flame proof enclosures and intrinsic safe mobile phones and spark arrestor in automobiles. Inherent safety approach is to select PV cell materials / design which exhibit lowest surface temperature at any fault level.