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OIL AND GAS INDUSTRY: REVIEW ON FIRE HAZARDS AND PROTECTIVE TEXTILES

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ABSTRACT

Oil and Gas industry is one of the riskiest industries when it comes to health and safety of employees. Inherent flash fire hazards are associated with oil and gas well drilling, servicing, refining and production-related operations. A flash fire requires oxygen, an ignition source, and a fuel source such as hydrocarbon or an atmosphere containing combustible. During the production of oil and gas, risk of fire is very high. Catching of fire can affect the clothes and the skin of the workers. As the fire and heat related accidents are very common in this industry, it is required to have proper work-wear which can protect workers from fire and heat related health hazard, especially injuries and death. Keeping this aspect in mind, an attempt has been made in this paper to focus the areas, where there is a potential hazard for petrol/diesel catching fire present and to discuss various types of fibers being used to develop protective work-wear for oil and gas workers.

Keywords: FR fibers, fire hazards, protective textile, oil and gas industry

I. INTRODUCTION

The Oil and Gas industry plays a major role in the economic and political scenario of the world. It is the most important sector in any economy since it caters to a wide range of industries including petrochemicals, fertilizers, automobiles etc. It is one of the highly regulated sectors in India. It has very significant forward linkages with the entire economy.

Oil and Gas industry is one of the riskiest industries when it comes to health and safety of employees. Inherent flash fire hazards are associated with oil and gas well drilling, servicing, refining and production-related operations. A flash fire requires oxygen, an ignition source and a fuel source such as hydrocarbon or an atmosphere containing combustible. It finely divided particles with a concentration greater than the lower explosive limit of the chemical. Exposure to flash fires can result in devastating burns and death – 16 per cent of fatalities in the oil fields result from fire and explosions.

It is estimated that unsafe work conditions is one of the leading causes of death and disability among India’s working population. These deaths are needless and preventable. It is estimated that around 500,000 workers are employed in Oil and Gas industries in India. The workplace environment can be a hazardous place to work. Workers are exposed to numerous potential hazards including physical such as fire, fluctuating temperature, flying sparks, electrical, moving objects or sharp edges. They also suffered health hazard problems caused by

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exposure to radiant heat, loud noise, harmful dusts, chemicals or viruses. These hazards are responsible for wide range of injuries and illness starting from a simple headache to severe burns and respiratory diseases.

Even though it has been worked and put efforts by oil and gas industries to reduce the risk of flash fire incidents, these could not eliminate the flash fires occurrence and thus the burn injuries and fatalities. The use of Fire-Resistant (FR) Clothing greatly improves the chances of a worker to survive and regain quality of life after a flash fire. (www.osha.gov, 2016).

Conventional clothing fabrics made from natural fibers, polyester fibers and nylon fibers can ignite and continue to burn on the body because of its flammable properties (www.nascoinc.com, 2016). Fire-resistant clothing can significantly reduce the extent and severity of burn injuries as well as provide time to the wearer to get away from burning environment.

II. HAZARDS IN OIL AND GAS REFINERY

Petroleum refining begins with the distillation, or fractionation, of crude oils into separate hydrocarbon groups. The resultant products are directly related to the characteristics of the crude processed. Most distillation products are further converted into more usable products by changing the size and structure of the hydrocarbon molecules through cracking, reforming, and other conversion processes. These converted products are then subjected to various treatment and separation processes such as extraction, hydro treating, and sweetening to remove undesirable constituents and improve product quality. Integrated refineries incorporate fractionation, conversion, treatment, and blending operations and may also include petrochemical processing.

Modern technological developments have brought with them a vast increase in the kinds of hazards to which workers are exposed. The dangers are frequently so specialized that no single type of clothing will be adequate for works outside the normal routine. Some of the hazards to which workers are subjected to:

1. Physical hazards - Extreme heat/ fire, noise, vibration, various forms of radiation.
2. Chemical hazards - Harmful chemicals and gases (toxic, corrosive, irritant and sensitizing substances and possible carcinogens).
3. Biological hazards - Bacterial/ viral environment.
4. Contamination.
5. Radiation hazards etc.
6. Psychosocial hazards associated with either the work (Isolation, hours of work, tours, shifts, work load and content/ fatigue, etc all of which can contribute to psychological stress.

III. SAFETY AND HEALTH CONSIDERATIONS

1. Because refinery processes are closed processes, there is little potential for exposure to crude oil unless a leak or release occurs. The potential exists for a fire due to a leak or release of crude from heaters in the crude refining unit. Low boiling point components of crude may also be released if a leak occurs.
2. Inadequate desalting can cause fouling of heater tubes and heat exchangers throughout the refinery. Fouling restricts product flow and heat transfer and leads to failures due to increased pressures and temperatures.

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Corrosion, which occurs due to the presence of hydrogen sulphide, hydrogen chloride, naphthenic (organic) acids, and other contaminants in the crude oil, also causes equipment failure.

3. Neutralized salts (ammonium chlorides and sulphides), when moistened by condensed water, can cause corrosion. Over pressuring the unit is another potential hazard that causes failures.
4. An excursion in pressure, temperature, or liquid levels may occur if automatic control devices fail. Where sour crudes are processed, severe corrosion can occur in furnace tubing and in both atmospheric and vacuum towers where metal temperatures exceed 450° F. Wet H2S also will cause cracks in steel.
5. There is a potential for exposure to extraction solvents such as phenol, furfural, glycols, methyl ethyl ketone, amines, and other process chemicals.
6. At hydro-cracking unit, there is a potential for exposure to hydrocarbon gas and vapour emissions, hydrogen and hydrogen sulphide gas due to high-pressure leaks. Large quantities of carbon monoxide may be released during catalyst regeneration and changeover.
7. If the feedstock is not completely dried and desulfurized, the potential exists for acid formation leading to catalyst poisoning and metal corrosion.
8. Corrosion may also occur in piping manifolds, reboilers, exchangers, and other locations where acid may settle out.
9. Sulphuric acid and hydrofluoric acid are potentially hazardous chemicals. Loss of coolant water, which is needed to maintain process temperatures, could result in an upset.

IV. REQUIREMENTS OF PROTECTIVE TEXTILE FOR OIL AND GAS REFINERY

Fire-Resistant clothing is made from fabrics that do not ignite and will not continue to burn when the flame/thermal source is removed. It also provides a barrier from the flame and insulates the wearer from some of the heat (1 & 2). Typical non-FR work clothes can ignite and burn. It has been demonstrated that more severe burns are actually caused by clothing ignition rather than the original flame exposure (3). In fact, clothed areas can be burned more severely than bare skin. In sum, Fire-Resistant clothing provides three basic benefits:

1. It reduces the amount and severity of the burn injuries.
2. It provides the wearer some time to escape the fire area.
3. It increases the wearer’s chances of survival (4 & 5).

All protective clothing should conform to the requirements of relevant, recognized standards. The regular working clothing in the petrochemical industry should be taken into consideration as part of the risk assessment process. The protective textiles must meet following requirements:-

1. Fibre used in the fabric or composite should be non-melting and flame-resistant. Toxic gases should not be emitted at high temperature.
2. A high level of flame resistance – fabric should not ignite easily when exposed to a flame or continue to burn after the flame is removed.
3. Fabric should have electrostatic property.
4. The fibre should resist shrinkage and maintain strength and flexibility at a high temperature. Low thermal conductivity is needed to reduce heat transfer to underlying skin.

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5. Fabric should not break or split open when exposed to flames.
6. Ease of maintenance and proper fit must be considered. One of the most important functions for protective garment is to limit the amount of heat stress to the wearer and not hinder normal work.
7. Dimensional stability, colour fastness should be considered.
8. It must maintain integrity during the heat exposure, and be liquid repellent (6).

4.1 Flame-resistant fabrics suitable for protective clothing

The flame retardant protective fabric is mostly developed by the following two processes:

- Treating with FR Finish
- Using Inherently FR fibers

4.1.1 Treating with FR finish

Flame retardant behavior in the fabric can be incorporated by applying FR finish on the fabric. Mostly FR finishing is applied on fabric made out of fibers like cotton, viscose, silk , polyester and their blends. To make the fabric flame retardant, it is treated with chemical finishes. Although there are phosphorus and halogenated (bromine) based finishes available worldwide. In India mostly phosphorus based finishes are used for the manufacture of FR finish fabric. These finishes are applied on fabric using any of the following routes:

- Spraying
- Dipping
- Pad application

4.1.2 Fire-resistant fabrics using inherent flame-retardant fiber

Fabrics composed of these type of fibers, made from polymers are not necessarily thermally stable but their monomers are also not combustible. Fibers have undergone changes in their synthesis, which make intrinsically resistant to flame by the incorporation of flame-resistant copolymers (Marina Textiles, 2016). Wool, Modacrylic, FR Viscose, FR Polyester, Aramid, polybenzimidazole (PBI) and nylon 6, 6 etc. are common types of fibers used for flame-resistant fabrics (4 & 9).

Merino Wool: It is a flame-resistant fiber which does not stick to the skin and melt, when the source of flame is removed. It extinguishes by itself. It provides natural barrier to UV rays. These fibers are extremely fine, give a soft feel and luxuriously gentle next to the skin. It beautifully drapes to the body also.

Merino wool fibers have a natural protective outer layer that prevents stains from being absorbed. It attracts less dust and lint (www.merino.com, 2015). Merino wool regulates the body temperature naturally and keeps the body cool in summer by wicking away the sweat as it is a natural breathable fiber. Hence, provides a great level of comfort (www.decathlon.co, 2015).

Modacrylic: These are inherently flame resistant acrylonitrile fibres. They have properties that are similar to acrylic fibres. They are produced by polymerizing the components. Their co-polymers dissolve in acetone and the solution is pumped into the column of warm air (dry-spun), they are then stretched while hot. These are produced in creamy or white color. However, modacrylics are flame retardant and do not combust. The fibers are difficult to ignite and will self-extinguish. In addition to modacrylic's flame retardant properties these fibers

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are highly durables as compared to wool. Modacrylic fibers have a moderate resistance to abrasion and a very low tenacity.

Modacrylics are poor conductors of heat. The fabrics are soft, warm and resilient but are prone to pilling and matting. Modacrylics display high performance when it comes to appearance retention. The fibers have property of good wrinkle resistance, great dimensional stability and high elastic recovery, which gives them the ability to hold their shape..

Aramid: Aramid fibers are produced by DuPont. These fibers come in the category of heat-resistant and strong synthetic fibers and can be used in petrochemical, aerospace and military applications. These are generally prepared by reacting an amine group and a carboxylic acid halide group. After production of the polymer aramid fiber is produced by spinning and solid fibers are produced by solved polymer from a liquid chemical blend Polymer solvent for spinning (p-phenylene terephtalamides, PPTA) which is a generally 100% anhydrous (water free) sulfuric acid (H_2SO_4). Two types of fibers i.e. Para- aramid and meta- aramid are produced by Dupont.

Meta-aramid, are best known for their combination of heat-resistance and strength. The polymer is produced by condensation reaction from the monomers m-phenylenediamine and isophthaloyl chloride. In addition, meta-aramids do not ignite, melt or drip. These aramids offer better long-term retention of mechanical properties at elevated temperature. Meta aramids have a relatively soft hand and tend to process very similarly to conventional fibers. These are available in a variety of forms, anti-static, conductive, in blends with other high performance fibers etc.

Para-aramid, synthesized in solution from the monomers 1,4-phenylene-diamine (*para*-phenylenediamine) and terephthaloyl chloride in a condensation reaction yielding hydrochloric acid as a byproduct. Due to their highly oriented rigid molecular structure, para-aramid fibers have high tenacity, high tensile modulas and high heat resistance. Para-aramids have similar operating temperatures to meta-aramid fibers, but have 3 to 7 times higher strength and modulus, making them ideal for reinforcement and protective type applications.

FR Polyester- Fire-retardant qualities are incorporated into polyester fibers by adding to the polymer, prior to spinning process thereof into filament, not more than about 20 percent. An organic phosphorous compound is incorporated in its polymer to impart flame retardancy. Highly polymeric polyester is prepared by the condensation of terephthlate and a polymethylene glycol containing from about 2 to 10 carbon atoms and particularly ethylene glycol. These fibers are relatively insoluble, chemically inactive and hydrophobic in nature. The flame resistant effect of incorporating this copolymer into a fiber results from two physical properties. First, incorporation of the copolymer makes it difficult for combustion to take place because the incorporated copolymer gives the polyester fabric a lower melting point than regular polyester. Thus, the polyester, which is a thermoplastic material, melts and shrinks away from flames. Second, if any burning does take place during the shrinkage from the flame, the phosphorous component prevents the melting drips from burning by influencing the composition of the pyrolisis gases (7).

A wide variety of techniques have been employed to produce flame retardancy in polyesters, including the co-polymerization and transesterification of monomers which contain halogen and phosphorus and these elements are incorporated into the polymer by means of additives or carriers. In melt phase when a phosphorus or halogen- containing compound is added to its polymer system, the compound, or the fire resisting elements thereof more likely remain in fiber, even when exposed to subsequent washing or dry cleaning operations.

FR Viscose- The flame retardant viscose fiber is made by adding a high performance flame retardant mainly composed of nitrogen series compounds. During burning of this fiber the flame point produce a lot of nitrous oxide, which effectively isolates the fiber flame point from oxygen, thereby showing a fire-retardant effect. This fiber has advantages such as environmental protection and no combustion, no smoldering combustion, instant extinction without fire source, low smoke concentration. This can easily dye for its natural white color. The flame retardant performance is stable and permanent. The flame retardant viscose fiber content of the finished product is 18 percent and it is wash-resistant, alkali and acid erosion resistant and sunshine resistant. This fiber provides special protection when blended with polyester fiber. It shows small thermal shrinkage which avoids second burn injury.

This flame-retardant viscose fiber is an organic compound with polysilicic acid manufactured by nano modified spinning technique. It is a new fiber applicable to the flame retardant and heat resistance fields with high flame retardant performance and low smoke. The product adopts the fiber spin-dying method; the flame retardant viscose fiber and the flame retardant paste are infused before the spinning, so the flame retardant performance is permanent. The feel of the flame retardant viscose fiber is very soft and has the water absorption and sweat conduction function of the traditional viscose fiber.

Polybenzimidazole (PBI)- It is a synthetic fiber with a very high melting point and also does not readily ignite. It possesses a unique combination of thermal and chemical stability. PBI is prepared by step-growth polymerization from 3, 3’, 4, 4’-tetraaminobiphenyl and diphenylisophthalate (an ester of Isophthalic acid and phenol). The resulting polymer is processed into a solution using dimethyl acetamide, then fibered via a dry spinning process. It provides highest level of comfort, durability, and protection. It is a most flexible and supple fiber. It has low heat transfer and low tenacity. This fiber produces little or no smoke on burning. This has excellent chemical resistance property. It decomposes at temperature ≥ 1300º F (8).

Nylon 6, 6- It is a polymer as polyamide- semi-crystalline, known as nylon. The polymer is made of hexamethylenediamine and adipic acid, which give nylon 6,6 a total of 12 carbon atoms in each repeating unit. This fiber is synthesized by condensation polymerization of hexamethylenediamine and adipic acid. Condensation polymerization is the formation of a polymer involving the loss of a small molecule. In this case, molecule is water. Its polymer units are mixed with water. In the process nylon salts are produced and sent to evaporator where excess water is removed and in reaction vessel polymerization process takes place. This chemical process makes nylon 6, 6. After this process nylon 6, 6 are extruded to spinneret.

Its melting point is 268ºC, which is high for synthetic fibers. This property makes it heat and friction resistance. Its chemical stability enables it not to be affected by solvents such as water, alcohol and alkali etc. Its amorphous structures accounts for its elastic property. It has high tensile and flexural strength. It also exhibits high abrasion resistance and self-lubricating properties. It has high thermal stability, fire resistance, draw ability, good appearance and good processability. Nylon 6, 6 has a tighter molecular structure than nylon 6 due to a higher level of hydrogen bonding and maximum alignment between molecular chains, creating a tighter structure that better resists crushing, matting and stain penetration. It is 100% elastic under 8% of extension (www.chemsystems.com).

Designing of Flame-Resistant Fabric

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Depending upon the area of application the design of a flame resistant fabric is drawn; as the higher degree of fire threat demands multilayer protection. The thermal resistance is approximately directly proportional to the thickness.

Fire-resistance protective clothing should consist of an overall (or coats and pants), helmet, boots, gloves If the threat is more severe then undergarment should also have non-melting characteristics. Appropriate neck, face, head, hand and foot covering should be flame resistance. The outer garment should be flame resistance to avoid heat generation at the surface of undergarments causing heat transfer to the body of the wearer. Sleeve and shirt should be fully buttoned.

In addition to fire resistance, these require a good cut and puncture resistance as air entrapped within the fabric layers provides insulation, thus air- gap is more essential for a fabric to be flame resistant. Fire resistant garment should also have mobility, water proofness and durability. It should also provide good functional fit for protection and comfort. Loose fitting clothing provides additional thermal protection due to increased air spaces. In case of these garments fabric weight is essential for insulation purpose.

Mostly oil and gas industry used FR overall made out of one layer of fabric. If the fire accident threat is very high, the garment may contain following three layers:

1. **The outer layer-** This layer should be heat and flame resistance. It must be suitable for wet, dry and hot environments. The most commonly used material in this layer is being meta-aramid blended with para-aramid or Polybenzimidazole (PBI), uncoated or coated with neoprene.
2. **The moisture barrier layer-** The main purpose of this layer is to keep the fire fighter dry. It also protects the wearer from toxic fumes and harmful chemicals. Therefore woven, knitted or non-woven substrates coated or laminated with neoprene or PTFE are commonly used for this layer.
3. **The thermal barrier layer-** Although the first two layers are flame resistant, the inner layer provides the main protection against heat. This layer comprises non-woven battings or a layer quilted to the face cloth for stability and strength. In this layer various high temperature resistant fibres can be used to provide unique insulation characteristic.

V. CONCLUSION

In the Oil and Gas industry the threat of flash fire is a daily concern. While technological innovations have greatly decreased their occurrence, the threat is still very real. In refinery most of processes are closed processes, in spite of this, heaters and exchangers in the atmospheric and vacuum distillation units could provide a source of ignition, and the potential for a fire exists. The potential for fire is present in most of the operations due to vapour or product leaks. Workers within the oil and gas industries have a fundamental need to wear clothing that is resistant to heat and flames. India is a developing country and the Oil and Gas Industry is one of the prime industries with ample work force, there is as need to provide a suitable work-wear that can provide them safety from fire and heat related hazards.

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