MEDIUM VOLTAGE HYDROCARBON FIRE RESISTANT CABLE FOR OIL & GAS APPLICATION

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1. ABSTRACT

A medium voltage fire resistant cable has been developed and tested exceeding existing fire performance requirements.
The main purpose of this study is to describe the need for an improved fire resistant cable solution/design to demonstrate the fire properties of a novel cable design.
The study gives an overview of existing international fire test requirements and a description of the technology behind the cable development.
Finally it concludes in safety contribution and cost reduction for the Oil & Gas industry.

2. KEYWORDS

Passive fire protection, fire resistant cable, hydrocarbon fire

3. INTRODUCTION

The Oil & Gas is traditionally an industry that drives technical innovation in order to reach more and more challenging solutions in a wide range of areas. Health and Safety is one of the major areas where this industry has developed new products to ensure human and equipment safety. One of the most important hazards of this industry is the fire risk. When a fire occurs at a refinery, offshore facility or petrochemical plant, the electrical systems that serve critical circuits such as process equipment, ventilation, fire extinction systems, alarms and other emergency systems must remain operational. Otherwise safety would not be guaranteed.

In recent years a great deal of research has taken place internationally to ascertain the types of fire which could occur in a petrochemical installation. This research has taken place in both real, by simulation and laboratory conditions. As a conclusion of this research, three different type of fire scenarios have been defined; cellulosic fire, hydrocarbon fire and jet fire. However, classification societies define hazardous zones only taking into account cellulosic fire. Otherwise a specific risk assessment is required.

In a Hydrocarbon Fire (HCF) risk zone all cables must be protected by external passive fire protection system. The passive fire protection system insulates the electrical installation and prevents it from collapsing when subjected to the effects of fire. This ensures the integrity of the electrical system during evacuation time.

The new developed medium voltage cable incorporates the required passive fire protection (PFP) into its design in order to keep electrical integrity during a HCF scenario.

4. DEFINITIONS

FIRE SCENARIOS:

Cellulosic fire – Intended to simulate natural carbonaceous-type materials such as wood and paper, these fires have relatively slow heat rise and peak temperatures of 950 °C.
Scenario in which is based IEC standard (IEC 60331-21).

Hydrocarbon fire – Although the Cellulosic curve has been in use for many years it's certain that the burning

rates for certain materials e.g. petrol gas, chemicals etc., were well in excess of the rate at which for instance, timber would burn. As such, there was a need for an alternative fire exposure conditions intended to represent fires fuelled by oil spills or gas clouds, characterized by higher heat fluxes and faster time to a maximum temperature of 1100 °C.
After the Piper Alpha Platform fire in 1988, protection against hydrocarbon-fuelled fires has become the norm for the offshore industry.
Such scenarios are defined by EN 1363-2:1999 and ISO-834-3, with heat flux of 200 kW/m^2.

Jet fire – A unique type of hydrocarbon fire caused by pressurized gases or fuels that are released through a leakage and then ignited. A jet fire has even higher heat fluxes, where peak temperatures can exceed 1200 °C and recognized by highly erosive forces.
Scenario in which are based on ISO 22899-1 with heat flux greater than 200 kW/m^2.

HAZARDOUS AREAS:

Oil & Gas facilities are frequently equipped with storage, drilling and production equipment and, consequently, the presence of hydrocarbons. On those Oil & Gas facilities not intended to perform these type of operations, the presence of hydrocarbons may be temporarily. Any zone where hydrocarbon vapours are present during the operation is classified as a hazardous area.

Hazardous areas are defined by the classification societies and IEC standards, such areas where a flammable atmosphere may be expected to exist continuously or intermittently, are defined as a hazardous area. Thus, flammable atmospheres may arise from storage, leakage, or any other source that that can release flammable liquids and gases on the installation.

Classification societies does not recommend to install electrical equipment in hazardous areas unless essential for operational purposes [1]. Where the installation of electrical equipment in a hazardous area is necessary, the selection and installation of appropriate equipment and cables has to be in accordance with IEC 61892 or other recognized standards [2].

IEC 61892-4 does not provide a cable selection guide other than for a simple CF scenario. Consequently, it does not include or consider a much more harsh fire scenario as that of a HCF. However, guidance about how to test under HCF condition is given as a non-normative note [2].

Hazardous zones are classified in three different classes: zone 0, zone 1 and zone 2 [1], [3]:

Zone 0: ignitable concentration of flammable gases or vapours are continuously present or present for long periods.

Zone 1: ignitable concentration of flammable gases or vapours are likely to occur in normal operating conditions.

Zone 2: ignitable concentration of flammable gases or vapours are not likely to occur, and if it occurs, it will exist for a short time.

Resulting from this zone classification, cables are generally not to be installed in hazardous areas. In zone 0 cable must be associated to a necessary circuit if it is essential for operational purpose.
In zone 1 cables must be armoured, metallic sheathed, mineral insulated or installed in a metallic conduit. Cables also need to be sheathed with impervious jacket and armoured to prevent gas migration and mechanical damage.

5. TEST PROCEDURES

HCF test set-up

The test furnace was a gas heated horizontal furnace with a total of 16 propane burners. At the top of the furnace, there was made an annex to reach 900 mm exposure length of the cables according to NEK TS 606:2016 [4]. The furnace lining consists of materials with an approximate density of 550 kg/m^3. See Figure 1 for further description of the furnace.

The furnace thermocouples were designed according to IMO – FTP Code (Fire Test Procedures Code), part 3 paragraphs 7.3 [6]. There were a total of 4 thermocouples poisoned in the same level and direction as the cables, with the face towards the furnace burning chamber, see Figure 1. The reason to put the thermocouples in the same level, and in the same direction/angle as the cables, is to measure the temperature in exact the same position as the cables (the temperature will vary inside the furnace depending on the position and level).

The pressure inside the furnace was measured by T-shaped sensors according to IMO – FTP Code, part 3 paragraphs 7.4 [6].

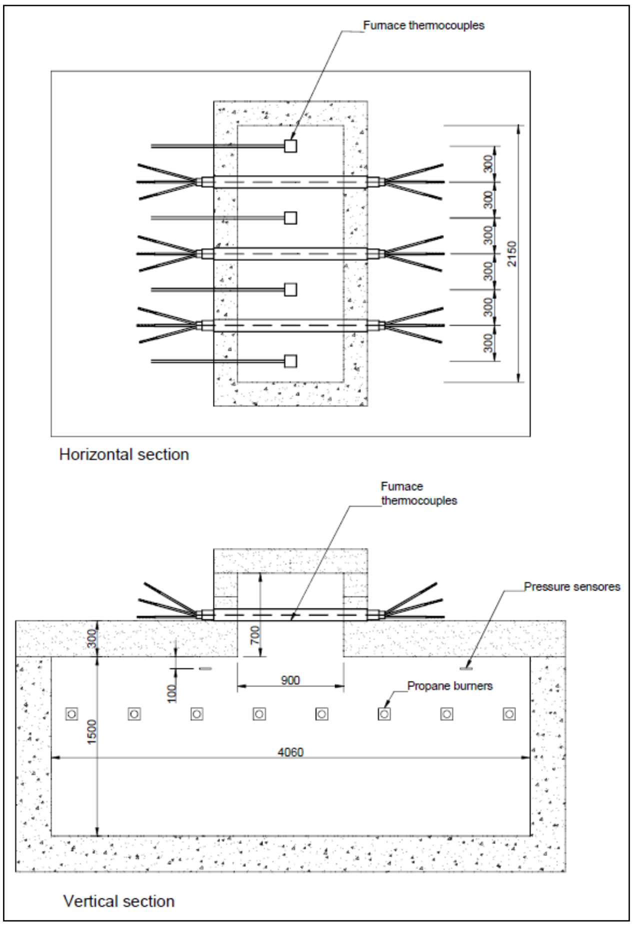

Figure 1 – Furnace setup

Test conditions

The furnace temperature was measured with an accuracy of ±15K, and the tolerances were based on EN 1363-2:1999 [5]. See Figure 2 for average furnace temperature during the test. The temperature inside the furnace during the test was given by mean of the four thermocouples described above.

Heating curve was the Hydrocarbon fire curve in accordance to EN 1363-2:1999 [5], which is in accordance with the newly adopted NEK-TS-606:2016 [4]:

$$T = 1080\,[1 - 0{,}325e^{-0{,}167t} - 0{,}675e^{-2{,}5t}] + 20$$

t is the time from start of the test in minutes

T is the average required furnace temperature in °C

The intended pressure during the test was +20 Pa (compared with the atmosphere pressure outside the furnace). The sensors were positioned at the level 400 mm below the cables; see Figure 1.

The cable was installed in the furnace with supporting outside the burning chamber, on both ends of the cable. There was no support of the cable along the exposed length.

The average ambient temperature inside the test hall was 19°C during the test.

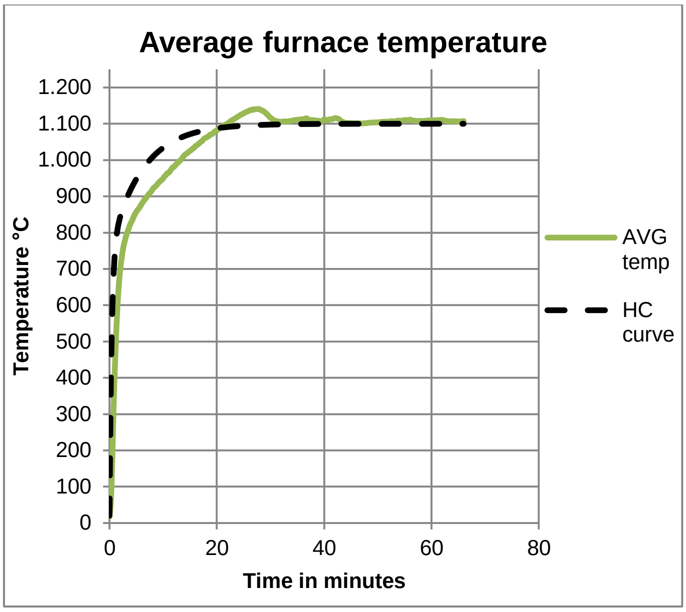

Figure 2 – Average furnace temperature

Test specimen

The tested cable was in full scale, and produced by General Cable. The cable was transported to SP Fire Research AS for fire testing. The cable was stored in the test hall prior to the fire test for conditioning until ambient temperature was reached inside the whole cable.

Figure 3 – Cable design

SP Fire Research AS controlled the cable, and found it to be in accordance with the description given by the client (General Cable). The cable was installed in the furnace by technical staff from SP Fire Research AS prior to the fire test. The exposed length of the cable was 900 mm based on NEK TS 606:2016 [4]. There was no support of the cable along the exposed length, in order to replicate a worst-case scenario. The cable was supported on both ends, outside the burning chamber. The cable was orientated horizontally.

Electrical circuit

IEC 60331 "Tests for electric cables under fire conditions – circuit integrity" states that the test voltage between conductors shall equal the rated voltage between conductors, and the test voltage from conductor to ground shall equal the rated voltage from conductor to earth. In this case the test object is a 15 kV, three-phase cable with individual metallic earth screen on each phase and a common fire-protected outer sheath. The design indicates that a conductor to earth-failure must occur prior to a conductor to conductor failure, thus the power supply was designed for a voltage of 8.7 kV applied between conductor and ground. The three conductors were connected in parallel and all individual earth screens were interconnected and grounded.

Electrical field grading terminations were assembled on each of the six cable ends and the test object was verified partial discharge-free at 10 kV (conductor to ground) prior to the fire test. This was performed in order to ensure that any cable damage during the test was related to the HCF curve exposure and not electrical issues outside of the heat oven.

IEC 60331 comprises low voltage cables up to and including 0,6/1 kV and the test acceptance criterion for such cables is no breaking of a 2 A fuse during the test period. For higher voltages, slow fault development is not relevant and the acceptance criterion for the 15 kV cable was based on no collapse of the supply voltage (total cable breakdown) during the test period.

The layout of the electrical circuit was designed to fulfill the technical requirements described. In addition HSE requirements for high voltages were considered. The electrical equipment was built into an insulated cabinet to avoid contact electricity. Red flashing lamps were installed at selected locations to visualize supply power switched on. A voltage indicator lamp was installed at the primary side of the high voltage transformer to visualize power on the test object. A high voltage probe was used for the operator of the electrical equipment to monitor the applied voltage and adjust it to correct level during the test. A logger signal was transmitted to the HCF control room for continuous monitoring of the electrical integrity of the test object. A sketch of the electrical circuit is shown in Figure 4.

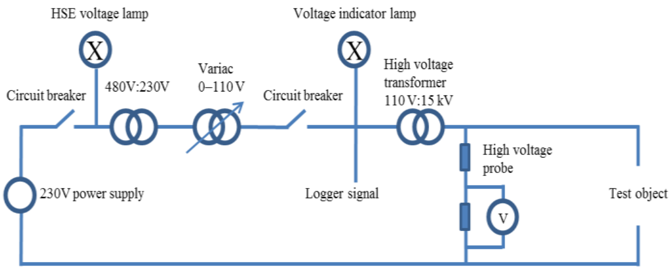

Figure 4 – Electrical circuit

The area of the furnace and electrical equipment was visually fenced with marking bands and high voltage signs. During the HCF test the operator of the electrical equipment was responsible for avoiding persons entering beyond the marked "danger area".

6. HCF CABLE SOLUTION TECHNOLOGY

The cable design to pass the HCF fire test is based on the use of specific ceramifiable compound as a fire barrier.

The base-polymer for the Favuseal HCF technology is found in the Ethylene Vinyl Acetate (EVA) family of products. This foundation gives excellent processing capabilities via injection molding, vacuum forming, compression molding, and ultimately, extrusion processability. This type of polymer is also found to be a good carrier of the extreme technology found inherently in the Favuseal compound.

The Favuseal HCF material is designed and engineered to exploit two inherently strong endothermic reaction processes ignited at two separate temperature intervals on the HC fire curve. The first endothermic reaction process, recognized by the release of “trapped water”, has the added benefit of swelling effect of the Favuseal HCF technology. Consequently, a robust thermal barrier is created reducing the heat penetration thru the Favuseal HCF material inwards towards the MV cable core. The first endothermic reaction process is actually so strong in nature that it cools of the surface of the object it is protecting. The second endothermic reaction happens at a higher temperature. Although not as endothermically strong as the first reaction, it further helps to cool down whatever object the Favuseal HCF compound protects.

The “cooling” effect is a result of the pyrolysis of the polymeric binders in the material, resulting in a transformation away from a polymer into a solid micro-porous ceramic state. This end-result is a stable ceramic layer that is able to withstand in excess of temperatures of 1.500 degrees Celsius, well within the defined temperature of the HCF curve.

How Favuseal Technology contributes to reach Hydrocarbon Fire performance in General Cable solution for MV cables

The OD of a cable is very small in terms of traditional fire protection meaning that the ability of the object to absorb applied heat is extremely low compared to traditional objects protected under a HCF scenario. In addition, a cable is flexible making the use of traditional PFP products redundant. The “in situ” application of fire protection via spraying or construction of fire boxes on the cable trays is an old an outdated way of providing passive fire protection of a cable design.

The Favuseal material represents a flexible, low cost, and easily applied technology in order to have PFP to cables via the use of existing extrusion machines readily available in a cable factory. Expensive on-site application of passive fire protection products is, consequently, a thing of the past and not feasible from a total cost of ownership point of view. In addition, the internal rate of return of doing an initial investment into a Favuseal “powered” cable is extremely high when compared to the traditional way of providing PFP to a cable design. Once the extreme Favuseal compound is extruded onto the cable in a solid layer, it gives continuous 24/7 active passive fire protection for the life of the installation. The ide of providing inherent protection to the cable at factory-level is completely new, and represents truly amazing cost savings to the end customers of and users of such cables.

In conclusion, it is the two strongly energy consuming endothermic reaction processes, resulting in a very low lambda value ceramic state, that makes the cable survive the temperature curve defined by ISO-834-3, 200 kW/m^2. In addition, the solid ceramic micro porous state of Favuseal makes an excellent thermal barrier, and yields added mechanical protection, for the exposure time of the testing in mention.

7. TEST RESULTS

Failure occurs when there becomes a short circuit between one of the conductors and the screen around the actual phases, or between the conductors and the braid armour. The cable was tested with operating voltage to the conductors during the test. See chapter “Electrical circuit” above for further description regarding to the electrical setup.

Test duration was 66 minutes, and the time to breakdown was 65 minutes and 30 seconds. There were a total of three cables in the same test. This paper and the given test results describes one cable only. The three cables were connected to an independent power supply and did not influence to each other during the fire test.

The applied voltage and the time to breakdown were given by the logger signal during the test. Se Figure 5 for graphical presentation.

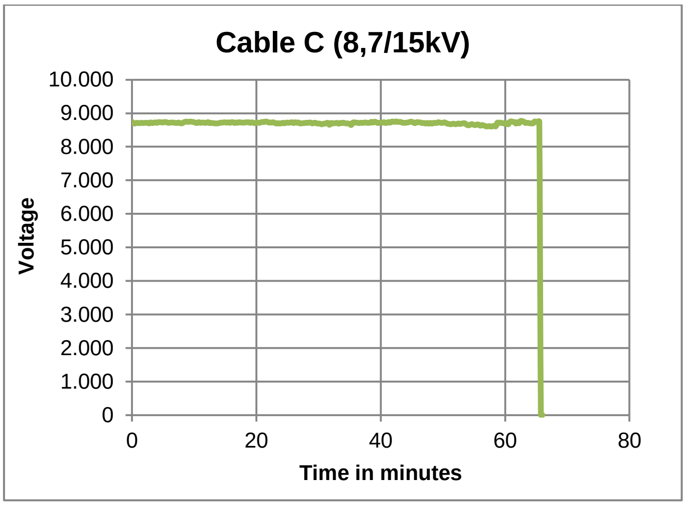

Figure 5 – Test results and time to breakdown

8. CONCLUSION

A fire accident is an immense disaster and gives images that will always remain in our minds. Recent catastrophes have been published in the most important information media and the consequences of such accidents are huge. Human lives but also enormous financial consequences arise after a fire accident. Oil platforms and refineries have been out of order for months after an accident. Direct repair cost, but also the cost related to lost business, replacement of infrastructure, materials brings the direct and indirect financial loss to the millions.

Protecting power supplies contributes to keep active protection systems, such as smoke extraction systems, fire escape signs, detection systems, and the total integrity of technical installation intact, so that light and communications remains available allowing for a proper and safe evacuation to be executed.

It goes without saying that adopting to a HCF resistant cable contributes to an overall safer industry, dramatically reduces the risk of failure during a fire scenario , and, ultimately, significantly impacts the financial burden in case of a fire in a positive way.

During new build FEED phase, there are several advantages of using HCF cables instead of plain fire resistant cables. Engineers will be able to route the cables through HCF classified zones without any additional engineering to protect electrical and instrumentation circuits via use of external PFP products, thus, reducing the overall cost significantly for the end-client. In addition, finding a complex cable route to skip HCF classified zones are also a thing of the past, as is the problem regarding possible space constraints. Additionally, the need for cable tray wrappings or protection do not need to be considered in order to reach HCF compliancy. The cable itself has inherently full fire protection if subjected to a HCF scenario for the entire life of the installation.

More importantly, a certified HCF cable is not in need of any de-rating, which is the case if one adopts to applying external thermal barrier products onto the cable, or cable tray, which is commonly used in the industry. The uncertainty of ampacity de-rating will not be an issue any more because the values given in the cable data sheets can be used without need of any additional calculation.

There are also a plethora of advantages during maintenance and possible repair/inspection operations. The cable is directly installed in a cable tray without any additional wrapping or protection. Huge amount of hours, but also the uncertainty of introducing 3rd party products that may, or may not, inflict the operations of the cable, is greatly reduced.

In conclusion, the introduction of a fully certified HCF cable represents a paradigm shift in the on- and offshore industry. The savings, in both time and money, when adopting to a ready-made HCF cable are great, especially from the view-point of the asset owner.

By using HCF cables including PFP in its design, estimated space saving on boxing and wrapping cables is estimated to be in the range of 10kg/m^2.

9. REFERENCES

[1] ABS “Rules for Building and Classing Mobile Offshore Drilling Units” (Part 4, Chapter 3, Section 3.9)

[2] IEC 61892-4 – Mobile and fixed offshore units – Electrical installations – Part 4: Cables

[3] IEC 61892-7 – Mobile and fixed offshore units – Electrical installations – Part 7: Hazardous areas

[4] NEK TS 606:2016 – Cables for Offshore Installations – halogen free low smoke flame-retardant / fire-resistant (HFFR-LS)

[5] EN 1363-2 – Fire Resistance Tests. Part 2: Alternative and additional procedures

[6] IMO (International Maritime Organization) – FTP Code (International Code for Application of Fire Test Procedures)