

FIRE PROTECTION ARRANGEMENT FOR CABLES

Object of the Invention.

The object of the present invention is a hydrocarbon fire protection arrangement for
5 cables, which consists of a layer of extruded ceramifiable coating over a cable core, a tape with
high resistance to temperature and an outer cover for the mechanical protection of the entire
assembly.

Another object of the present invention is a low-voltage or medium-voltage electrical
instrumentation cable, which comprises said arrangement.

State of the art.

Traditionally, the cables used in installations critical for security do not incorporate fire
protection. In consequence, it was necessary to add protection against possible fires after the
cable has been installed, for example by application of an intumescent paint or fireproof tapes.
15 This trend has changed in recent years, and it is now possible to find high-security cables that
already incorporate fire protection in their design, with protection after installation being
unnecessary.

There are solutions to protect cables against HCF (hydrocarbon fire) in the market,
mainly in the "OGP" (oil, gas and petroleum) market, and therefore, they can be considered as
20 part of the state of the art. They are basically composed of the use of a ceramifiable compound
which is extruded with large cavities in the interior, allowing, in the case of fire, the expansion of
the material when it is transformed into a ceramic material. An orifice-free fibre glass tape is
used with this solution, coating the ceramifiable compound.

However, this type of solutions have the drawback that it allows the migration of gases
25 and/or liquids in the cable through said conduits, all of which makes said protections inadequate
for certain cable applications.

These and other drawbacks are overcome with the present invention, so that it achieves
improving the fire protection of electrical cables making them resist the fire actively for longer,
and additionally, they have an easily manufactured fire protection comprising a simpler process
30 of extrusion when disposed over the cable.

Purpose of the Invention.

The invention is applied to low-voltage or medium-voltage electrical cables, of those
used in instrumentation, and comprises a fire protection arrangement disposed over a cable
35 core, which consists of a layer of ceramifiable coating, a tape with high resistance to

temperature and an outer cover for the mechanical protection of the entire assembly. Said arrangement allows the cable to be used safely in fixed installations, for instrumentation, communication, control systems, power cables, emergency and alarm systems, where said installations are located in areas where the resistance to fire generated by hydrocarbons is vital, such as refineries, petrochemical industry and in production or drilling platforms.

Description of the Invention.

The invention essentially consists of a fire protection arrangement for a cable based on the novel use of a halogen-free fireproof compound, which is continuously extruded over the cable it aims to protect. The compound is characterized in that it has a polymer matrix with a fireproof filling material, which when subjected to fire, transforms into a ceramic material that protects the inner part of the cable.

During this transformation into a ceramic material, the material increases in volume by up to 200%, it almost does not emit any type of smoke and does not emit corrosive gases.

Additionally, over the compound a fibre glass tape is applied with orifices that acts as a fire barrier. The function of this tape is to avoid that the ceramic material falls off during exposure to fire (which would represent the loss of fire protection) and, at the same time allow the ceramifiable compound to expand through the orifices. This point is of vital importance in the invention, since if expansion of the ceramic material is not permitted, the tape will eventually break, with the subsequent loss of protection of the cable.

Finally, to complete the arrangement, the cable is mechanically protected by means of a fireproof cover.

This invention improves the current state of the art due to the following advantages:

- a) Greater fire protection, i.e. greater time of resistance to fire during a fire with HCF conditions (hydrocarbon fire).
- b) A greater ease of extrusion of the ceramifiable layer. It is much easier to extrude a continuous and solid layer of material than with a form of profile comprising orifices or cavities.
- c) The problems related to migration of gases and/or liquids through the cable as the ceramifiable layer is extruded in a continuous solid layer.

More specifically, the fire protection arrangement of the present invention comprises a combination of three layers applied to a low-voltage or medium-voltage electrical instrumentation cable, as described below:

- a) The first layer is a solid layer of constant thickness, which is extruded on a core of cylindrical cable, the thermoplastic cable has the following properties:

- Halogen-free compound.

- Contains inorganic filling materials in a binding agent formed by an ethylene copolymer (which is transformed from thermoplastic to ceramic in the case of a fire).

- The expansion of the material starts at a temperature of 190°C and may reach 200% in volume in the ceramic state; self-repair effect.

5 - Good thermal conductivity in virgin state. This is because when the compound is extruded over a cable the heat does not accumulate inside the cable which it is protecting. Said accumulation is avoided since the compound allows the heat to be transported through it towards the open air, therefore, the compound used is a poor thermal insulator up to peaks of 170°C in comparison with passive fire protections.

10 - Good thermal insulation above 200°C.

- Good mechanical stability in its cellular form. When the compound reaches a temperature between 750-800°C, pyrolysis occurs of the polymer binders, which generates a "solid" layer of microporous ceramic which has good mechanical stability.

- It acts as a flame barrier.

15 - Low smoke emission during combustion. The reading of the clear light beam measured according to ASTM E662 (Standard test method for the specific optical density of the smoke generated by solid materials) is of 70% and 94% for irradiation and open flame, respectively. There is no residues or particles in the smoke generated, and no black smoke are generated. Furthermore, no toxicity in the smoke is observed. The marginal smoke production from
20 combustion of the compound occurs in the preliminary phase of the two-stage reaction process. Once the compound has reached its ceramic phase, the compound is incombustible and is completely "dead". According to the DEF STAN-713 standards, the toxicity index of the compound is of 1.6 (in a scale of 1 to 30), which is extremely low.

- It does not produce corrosive gases over burning.

25 It is known that certain polymer materials may be endothermal, i.e. the material as such is subjected to a temperature above a given threshold value experiencing a chemical reaction that results in an effect of decreasing the temperature (cooling). Furthermore, it is known that some polymer materials such as those exposed to a temperature above a given threshold value expand, i.e. they have a swelling effect. It is also known that some polymer materials show both
30 effects simultaneously, i.e. when they are exposed to a temperature above a given threshold value the material expands and ceramifies, whilst a chemical reaction also occurs in the material that consumes energy, so that the material in itself, and indirectly the environment, cools. These properties make this type of endothermal material suitable for its use in a variety of insulation applications to prevent the penetration of heat in relation to various fire scenarios.

35 The inventors of the present invention have found that if a layer of said ceramifiable

expandable endothermal material is combined with a layer of a fibre glass net structure, the characteristics of the combined material are improved to withstand greater fire requirements. The results show that a synergic effect is obtained by the combination of said endothermal material with a fibre glass mesh with texture.

It is not known what mechanism underlies this synergy effect, but it is possible that the improved fire resistance properties, such as expansion, take place with a certain resistance made by the traction of the network structure. On the other hand, the mesh that retains the compound probably plays a role in maintaining the ceramifiable expandable endothermal material in its place during the fire, passing from a solid state to a ceramic state when the second endothermal reaction occurs. This combined effect is achieved with the combination of a ceramifiable endothermal material with a traction material, i.e. on the one hand resistance to the expansion of the ceramifiable material, providing a better thermal insulation, and on the other, that the ceramified material retained remains mounted on the cable, so that it maintains the insulation effect, i.e. that this combined effect is important for the reaction template of the material used.

b) The second layer consists of one of the following options placed on the upper part of the aforementioned layer:

- fibre glass tape, with a mesh size less than 16 mm^2 , placed helicoidally over the ceramifiable material, with a superimposition or overlapping of between 5% and 30%, or
- fibre glass or metal braid (aluminium or steel), with a mesh size less than 16 mm^2 , placed in the cable with a coating level determined by the mesh size, or
- fibre glass or metal wire (aluminium or steel), with a minimum diameter of 0.5 mm placed helicoidally over the ceramifiable material, with a separation of between 0.5 and 5 mm.

Preferably, the fibre glass mesh used will have a service temperature of up to 1100°C , a resistance to traction value of 700 min(N/5cm) (warp) and 600 min(N/5cm) (weft), and a SiO_2 content between 94% and 96%, and of Al_2O_3 between 3% and 4%.

c) The third layer is a solid layer of plastic material, which is extruded over the aforementioned layers, with a thickness in accordance with international standards such as NEK TS 606, which are known in the state of the art. This is the last layer of the cable and gives the cable suitable mechanical protection. In addition to this mechanical protection, this extruded layer is acting as a fire barrier and must undergo IEC flame and fire propagation tests, but it should not actively protect in the fire resistance tests, such as the hydrocarbon fire tests.

The material of this solid layer has the following properties:

- Good abrasion and resistance to scratching.
- High mechanical resistance and tenacity.

- Good water permeability.
- Excellent resistance to cracking due to environmental stress.
- Resistencia to UV rays.
- Low smoke emission.

5 Despite preferably being a compound with low smoke emission and halogen-free, a halogen compound can be used in this layer.

Other details and characteristics shall be revealed in the course of the description made below, wherein reference is made to the drawings attached to same, and wherein its shows an illustrative but not limiting embodiment of the invention.

10 **Description of the figures.**

Figure no. 1 is a cross-section of an embodiment of the cable of the invention, where the cable has a single multi-filament conductor.

15 Figure no. 2 is a cross-section of another embodiment of the cable of the invention, where the cable has three multi-filament conductors.

Figure no. 3 is an elevational view of an embodiment of the cable of the invention, where the different layers forming the cable's fire protection are shown.

Figure no. 4 is an elevational view of an embodiment of the cable of the invention, showing the second layer of the fire protection formed by a meshed tape.

20 Figure no. 5 is an elevational view of an embodiment of the cable of the invention, showing the second layer of the fire protection formed by a braid.

Figure no. 6 is an elevational view of an embodiment of the cable of the invention, showing the second layer of the fire protection formed by wire.

25 Figure no. 7 is sectional view representation of the cable of the invention, illustrating the cable and its fire protection at three different times when exposed to a hydrocarbon fire.

Figure no. 8 corresponds to a detail of figure number 7.

Figure no. 9 illustrates the standard HCF curve according to standard NS-EN 1363-2:1999, followed in hydrocarbon fire testing.

30 **Description of an embodiment of the invention.**

The invention, as illustrated in figure no. 1, consists of a fire protection arrangement (20) for a cable, comprising a combination of three layers applied to a core (10) of an electrical low-voltage or medium-voltage instrumentation cable.

35 The arrangement (20) comprises a first solid layer (21), of a halogen-free thermoplastic material, containing inorganic filling materials in a binding agent formed by an ethylene

copolymer which is transformed from thermoplastic to ceramic in the case of a fire, isolating and protecting the inner part of the cable. Said first layer (21) has a constant thickness, and is extruded over the core (10) of the cylindrical cable.

Additionally, a second layer (22) is disposed over the first layer (21) which acts as a fire barrier, and its function is to avoid that, once the cable is exposed to the hydrocarbon fire, the ceramified material of the first layer (21) falls off during exposure to fire and the fire protection is lost, but at the same time, said second layer (22) should allow the ceramifiable compound to expand therethrough towards the outside.

For this purpose, as shown in figures 4, 5 and 6, three variants of embodiment of the second layer (22) have been developed in the present invention, adapted to efficiently allow the expansion and securing of said first ceramifiable layer (21). In this regard, in a first variant of embodiment, figure no. 4 illustrates the second layer (22) formed by a fibreglass mesh tape, with orifice size (25) suitable for allowing expansion of the ceramifiable material. Preferably, as illustrated in figure no. 4, the tape is disposed helicoidally over the first layer (21) with an overlapping that varies between 5% and 30%.

Figure no. 5 illustrates the second layer (22) formed by a braid which may be of fibre glass or metal, the metal preferably being aluminium or steel, said braid preferably has a mesh orifice size less than 16 mm².

The third variant of embodiment of the second layer (22) is illustrated in figure no. 6, in said figure, the second layer (22) is formed by a fibre glass or metal wire, with a minimum diameter of 0.5 mm, the metal preferably being aluminium or steel. Said wire, as illustrated in figure no. 6, is placed helicoidally with a separation between the wires which may vary between 0.5 and 5 mm.

As previously mentioned, the second layer (22) is of vital importance in the invention, since if the suitable expansion of the ceramic material is not permitted this will eventually break said layer with the consequent loss of protection of the cable.

Finally, forming part of the arrangement (20), a third layer (23) is extruded over the layer (22), said third layer (23) being composed of a plastic material with a thickness in accordance with international standards known in the state of the art. Said third layer (23) is the last layer of the cable and gives the cable suitable mechanical protection, also acting as a fire barrier. However, to achieve the correct functioning of this arrangement (20), said layer (23) should not actively protect in the event of a hydrocarbon fire.

The material of this third layer (23) is preferably a compound with low smoke emission and halogen-free, but a halogen compound can be used.

The cable core (10) may be formed by one or more conductors: figure no. 1 shows an

embodiment of the invention with a conductor, and in figures nos. 2 to 7 illustrate the embodiments with three conductors. Additionally, the core (10) may comprise elements such as conductor insulations, e.g. Mica tape, inner covers comprising flame-retardant compounds, and reinforcement frames or screens, in addition to other elements that allow the adaptation of the cable to the functions it has been designed for.

With respect to the operation of the arrangement (20), as illustrated in figures nos. 7 and 8, when the cable is exposed to hydrocarbon fire, where temperature values of approximately 1100°C are reached, a deterioration occurs in the third layer (23) and a change in the state of the ceramifiable compound of the first layer (21) transforming into a ceramic material which isolates and protects the inner part of the cable. During this transformation, as illustrated in figure no. 8, the ceramifiable material that forms the layer (21) increases in volume by up to 200%, causing its exit through the orifices (25) or spaces present in the second layer (22) which is disposed over said layer (21). In this way, the second layer (22) allows, thanks to its arrangement and manufacturing, both the expansion of the ceramifiable material during its expansion and its retention over the core (10) once it has ceramified.

Fire resistance tests

With the aim of studying the degree of fire protection offered by the protection arrangement of the present invention to the cable core, several tests were performing, including:

- a) Hydrocarbon fire test.
- b) Fire resistance tests.

a) Hydrocarbon fire test:

The test consists of a fire resistance test, with the nominal voltage of the cable applied during the tests, based on standard NEK TS 606:2009.

During the test, the voltage operation is monitored and the time of rupture or failure when the cable stops functioning is determined; this value is the survival time of the cable.

Fire exposure is performed according to the HCF curve of standard NS-EN 1363-2:1999:

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

Where:

t is the time from the start of the test in minutes

T is the average temperature of the furnace required in °C.

To measure temperature in the furnace, thermocouples for furnaces were used according to paragraph 7.3 of the IMO 2010 FTP Code part 3.

Figure no. 9 illustrates the standard HFC curve according to standard NS-EN 1363-

2:1999, which is followed during the test.

The furnace described in standard NEK TS 606:2009 is significantly smaller than the furnace used for the test execution, however, with a larger furnace the temperature measurement and control of the furnace temperature, in addition to pressure, are much easier to control.

The test sample length is 900 mm. The cable is fastened by both ends outside of the furnace and there is no further support within the furnace.

The failure in the test occurs when there is a short-circuit between one of the conductors and the screen around the phases, or between the conductors and the braid.

Example no. 1:

Following the previous test, three variants of RFOU-HCF cables were compared (hydrocarbon fire resistant, flame retardant, medium-voltage cable), with the characteristics stated in table no. 1.

Table no. 1.

Description	Cable A	Cable B	Cable C
Core	RFOU-HCF 3x70 mm ² 8.7/15 kV	RFOU-HCF 3x70 mm ² 8.7/15 kV	RFOU-HCF 3x70 mm ² 8.7/15 kV
Ceramifiable material	Layer of 11 mm of thickness with orifices	Layer of 11 mm of solid thickness (no orifices)	Layer of 11 mm of solid thickness (no orifices)
Fibre glass tape	No orifices	No orifices	With orifices
Cover	Thermoplastic LSOH	Thermoplastic LSOH	Thermoplastic LSOH
Result (survival time)	35 minutes	37 minutes	65 minutes

From the results shown in table no. 1, it is observed that the best survival time results, understanding this to be the total time the cable was operational during the test, were obtained with cable "C", where it combined the solid ceramifiable material with no orifices with the fibre glass tape with orifices, obtaining a survival time value of 65 minutes at temperatures of 1100°C, from which it is gathered that the tape with orifices is fundamental for achieving an increase in survival time of the cable in the Hydrocarbon Fire Test (based on standard NEK TS 606:2009).

Cable "A" coincides with the typical arrangements mentioned in the state of the art, so that the test performed makes it possible to demonstrate that the arrangement of the present

invention has a greater hydrocarbon fire resistance than those arrangements known in the state of the art.

b) Fire resistance tests:

5 This test was performed according to standard IEC 60331-21, and were carried out in the General Cable Manlleu Laboratory, Spain.

In the test, the cable is subjected to the action of a burner at a minimum attack temperature of the flame of 750°C, during a period of 90 minutes.

10 The aim of the test is to verify the capacity of a cable to maintain circuit integrity during a fire.

The test conditions were as follows:

- Flame temperature: 750°C.
- Test voltage: nominal voltage of the cable (for these tests, 250 V).
- Test assembly: cable tightened on panel.

15 The criteria to determine the failure point (survival time) was as follows:

Voltage is not maintained, indicated by the failure of the fuse or by short-circuit interruption.

A conductor is broken during the test time, indicated when a pilot lamp switches off.

20 **Example no. 2:**

Two BFOU-HCF cables were compared (halogen-free, flame retardant, instrumentation cables with hydrocarbon fire resistance protection), using the ceramifiable material of the invention. In the case of cable 1, a fibre glass tape was used without orifices, coating the ceramifiable material, and in the case of cable 2, a fibre glass tape was used in the form of mesh with orifices according to the hydrocarbon fire protection arrangement of the invention.

Table no. 2. Fire resistance test results

Description	Cable 1	Cable 2
Core	BFOU-HCF(i) 150/250 V 1x2x0.5 mm ²	BFOU-HCF(i) 150/250 V 1x2x0.5 mm ²
Ceramifiable material	Layer of 11 mm of solid thickness (no orifices)	Layer of 11 mm of solid thickness (no orifices)
Fibre glass tape	No orifices	With orifices
Cover	Thermoplastic LSOH	Thermoplastic LSOH
Result (survival)	123 minutes	180 minutes

time)		
Observations	The ceramifiable material does not expand through the tape, since it does not have orifices, and eventually breaks the tape.	The ceramifiable material expands through the tape orifices, allowing a significantly longer test duration than the previous one.

The ceramifiable material does not expand through the tape, since it does not have orifices, and eventually breaks the tape. The ceramifiable material expands through the tape orifices, allowing a significantly longer test duration than the previous one.

From the results shown in table no. 2, it is gathered that the effect of the orifices is vital for achieving an increase in survival time in the fire resistance tests. Expansion of the material through the orifices is the key to guaranteeing good functioning of the present system.

Having sufficiently described the present invention, in correspondence with the attached figures, it is easy to understand that any modifications of details deemed convenient can be introduced therein, provided that it does not alter the essence of the invention which is summarized in the following claims.

CLAIMS

1. Fire protection arrangement (20) for low-voltage or medium-voltage instrumentation cables disposed over a core (10) of a cable, characterized in that it comprises a first solid layer
5 (21) of a ceramifiable fireproof thermoplastic compound which is extruded with a constant thickness over the cable core (10), a second layer (22) disposed over the first layer (21) that acts as a fire barrier, and which is adapted to allow the expansion of the ceramifiable compound and retaining same on the cable core (10), wherein the second layer (22) is selected from: a
10 fibre glass mesh tape, with mesh size less than 16 mm² disposed helicoidally over the first layer (21) with a superimposition or overlapping that varies between 5% and 30%, or a fibre glass or metal wire, with minimum diameter of 0.5 mm placed helicoidally with a separation between the wires of between 0.5 and 5 mm, and a third solid layer (23) of plastic material which is extruded over the second layer (22) which is adapted to give mechanical protection to the cable and act as fire barrier without actively protecting against fire generated by hydrocarbons, so that with
15 said arrangement (20) the cable is adapted to resist in active operation a period of at least 60 minutes at temperatures of 1100°C.
2. Fire protection arrangement (20) according to claim 1, wherein the ceramifiable compound has a polymer matrix of an ethylene copolymer, with inorganic filling materials.
20
3. Fire protection arrangement (20) according to any claims 1 or 2, wherein the expansion of the ceramifiable compound starts at a temperature of 190°C and may reach 200% of its volume in ceramic state.
- 25 4. Fire protection arrangement (20) according to any claims 1 to 3, wherein the ceramifiable compound has low smoke emission during combustion and does not produce corrosive gases during burning.
5. Fire protection arrangement (20) according to claim 1, wherein the second layer (22) is
30 an aluminium or steel wire, with a minimum diameter of 0.5mm, placed helicoidally with a separation between the wires of between 0.5 and 5 mm.
6. Fire protection arrangement (20) according to claim 1, wherein the material of the third layer (23) is a compound with low smoke emission and halogen-free.
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7. Fire protection arrangement (20) according to claim 1, wherein the material of the third

layer (23) is a halogen compound.

8. Fire protection arrangement (20) according to claim 1, wherein said arrangement is adapted so that, when the cable is exposed to fire by hydrocarbons reaching temperature values over 1100°C, the third layer (23) deteriorates, and the fireproof compound that forms the first layer (21) changes state transforming into a ceramic material, increasing its volume by up to 200%, causing during said transformation its exit through a plurality of orifices (25) present in the second layer (22), with the ceramified compound being retained over the core (10) so that it insulates and protects said core (10) from fire.

9. Low-voltage or medium-voltage instrumentation cable, comprising a fire protection arrangement defined in any of claims 1 to 8.

10. Use of a cable defined according to claim 9, in installations for instrumentation, communication, control systems, power systems, emergency and alarm systems, where said installations are located in areas where resistance to fire generated by hydrocarbons is vital.