

FIRE RISK OF HALOGEN-FREE ELECTRICAL CABLE

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Abstract

This paper deals with the fire risk of a selected halogen-free electrical cable. The research was objected to a three-core power electric cable for a fixed installation CHKE J3x1.5 (cross section of each copper core was 1.5 mm²) with a declared class of reaction to fire B2_{ca}, s1, d1, a1. The electrical cable was manufactured and supplied by VUKI, a. s., Slovakia. The fire risk of the electric cable was evaluated based on the heat release rate, total heat release, smoke release rate, total smoke release and effective heat of combustion. These parameters were measured using a cone calorimeter at 50 kW m⁻² (specimens and cone emitter were placed horizontally during the test). The measured electrical cable showed a maximum heat release rate of nearly 150 kW m⁻², a maximum average heat emission rate of almost 100 kW m⁻², a total heat release of almost 130 MJ m⁻², a maximum smoke release rate of almost 2.5 s⁻¹, a total smoke release of more than 800 m² m⁻², an effective heat of combustion (cable as a whole) of nearly 9 MJ kg⁻¹ and an effective heat of emission (polymeric parts of the cable) of 26.5 MJ kg⁻¹.

Key words

Cone calorimeter, electrical cables, fire risk, halogen-free, reaction to fire class

INTRODUCTION

Electrical cables are classified according to EN 13501-6:2018 based on test results according to EN ISO 1716:2018, EN 60332-1-2:2004, EN 50399:2011, EN 61034-2:2005 and EN 50267-2-3:1998, which has been replaced in its entirety by a technical standard EN 60754-2:2014 into seven classes of reaction to fire A_{ca}, B1_{ca}, B2_{ca}, C_{ca}, D_{ca}, E_{ca} a F_{ca}, four additional smoke classification classes s1, s1a, s1b a s2, three additional classifications for burning droplets d0, d1 a d2 and three additional classifications on the acidity of combustion products a1, a2 a a3. The additional classification is determined only for electrical cables with reaction class to fire from B1_{ca} to D_{ca}. The contribution of a cable to fire development increases from

the reaction to fire class from A_{ca} (no or negligible contribution to the development of the fire) to F_{ca} (maximum contribution to fire development). Likewise, the formation of smoke, flaming droplets and the acidity of the combustion products (trapped in distilled or demineralized water) increases with the increasing number of supplementary classification.

For the classification of the electrical cable in the reaction to fire class, it is necessary to measure combustion heat according to EN ISO 1716:2018 (reaction class to fire A_{ca}), the total heat release, maximum heat release rate, parameter FIGRA (Fire Growth Rate Index) and vertical flame spread according to EN 50399:2011 (reaction classes to fire from $B1_{ca}$ to D_{ca} ; for the class D_{ca} it is not necessary to measure vertical flame spread) and vertical flame spread according to EN 61034-2:2005 (reaction classes to fire from $B1_{ca}$ to E_{ca}). For the classification of the electrical cable in the additional smoke classification, it is necessary to measure the total smoke release, the maximum smoke release rate according to EN 50399:2011 and the light transmission (through combustion products) according to EN 61034-2:2005. To classify the electrical cable into the additional classification for burning droplets, it is necessary to measure the burning droplets according to EN 50399:2011. To classify the electrical cable in the additional classification for the acidity of the combustion products, the pH and conductivity of the distilled or demineralized water to which the combustion products are retained according to EN 60754-2:2014 need to be measured.

The reaction to fire of other construction products and building elements (other than electrical cables) is in more detail described in the paper by Mitterova et al. (2004).

In compartments with high fire risk for persons (especially escape routes), STN 92 0203:2013 requires to use cables with a reaction-to-fire class $B2_{ca}$, s1, a1, s1. The cable with the mentioned fire reaction class is therefore considered to be the standard for fire hazard areas in the Slovak Republic but also in some other European Union Member States.

Although the cables are classified in the fire reaction classes, it is necessary to know, in particular, the heat release rate, the total heat release, the heat of combustion, the rate of smoke release and the total smoke release determined under conditions comparable to those of the other solid materials. The aim of this scientific paper is therefore to determine the heat release rate, the total heat release, effective heat of combustion, the rate of smoke release, and the total smoke release from the selected non-halogen electrical cable with the fire reaction class of $B2_{ca}$, s1, a1, s1 using a cone calorimeter.

MATERIALS AND METHODOLOGY OF EXPERIMENT

The research was objected to a three-core power electric (halogen-free) cable for a fixed installation designated as CHKE J3x1.5. The cable was manufactured and supplied by VUKI, a. s., Slovak Republic. The investigated electrical cable consisted of three insulated copper wires and other sheath. The space between the insulated conductors and the sheath was filled with bedding. The copper wires were wrapped under the insulation with mica tape. The copper conductors were 1.5 mm² thick in cross-section. Insulated copper conductors and electrical cable sheathing were made of ethylene-based polymer. The bedding between the insulated electric conductors and the sheath was made of an ethylene-based polymer with a high content of inorganic fillers (metal hydroxides and chalk). The diameter of the insulated electric conductors constituting the electrical cable was 3 mm thick and the diameter of the electrical cable was 9 mm thick. The manufacturer declared the fire reaction class of the investigated electrical cable to be $B2_{ca}$, s1, d1, a1. The cross section of the examined electric cable is shown in Fig. 1.

The samples were tested by a cone calorimeter according to the ISO 5660-1:2015 technical standard. The test procedure was also set up according to the ISO 5660-1:2015 standard. Orientation of the samples to the cone emitter was horizontal. The samples were thermally

loaded by a heat flux of 50 kW m^{-2} during the test. The duration of the test was 30 minutes in accordance with the ISO 5660-1:2015. ARHE (Average Rate of Heat Emission) was calculated from data measured by cone calorimeter (heat release rate) by the method of Zhang (2008). The Maximum Average Rate of Heat Emission (MARHE) was set as the maximum value of ARHE.

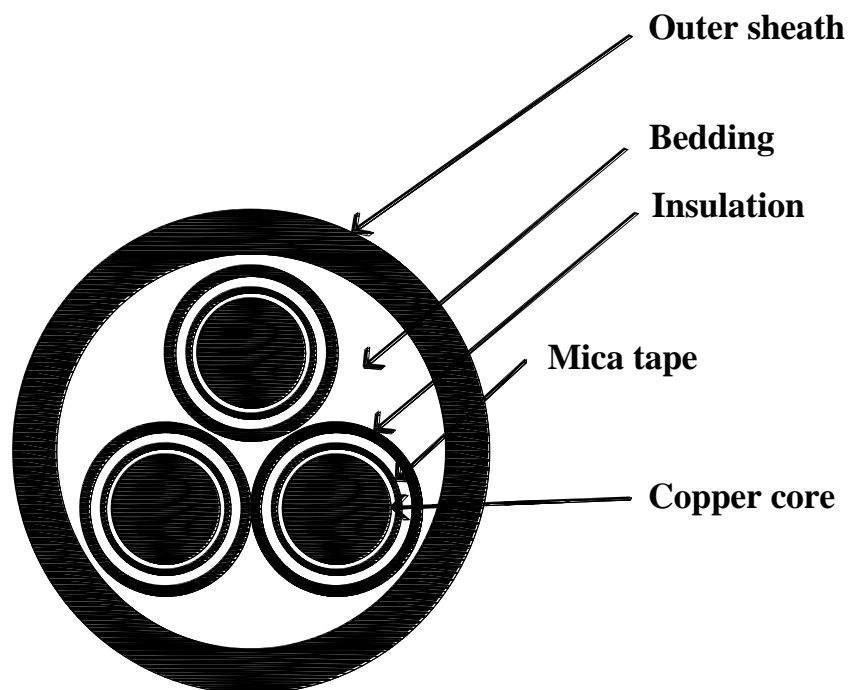


Fig. 1 The cross section of the investigated CHKE-V J3x1.5 electrical cable

RESULTS AND DISCUSSION

The heat release rate and the total heat release from the measured cable are shown in Fig. 2. In Fig. 2, two approximately the same local maxima were identified. The first local maximum corresponded approximately to the moment of initiation, while the second local maximum was recorded just before the complete burnout of the polymeric components of the investigated electrical cable. The cause of the second local maximum was probably overheating of the samples. This conclusion is consistent with the results of scientific work by Scharrel et al. (2005) and Carvel (2011).

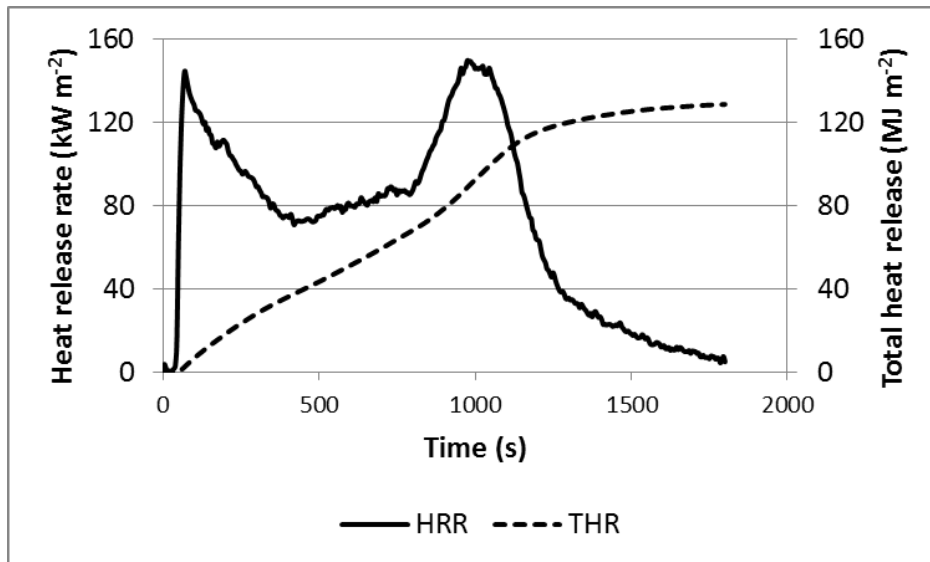


Fig. 2 Heat release rate and total heat release of halogen-free electrical cable CHKE-V thermally loaded by heat flux of 50 kW m^{-2}

The maximum heat release rate (approximately 150 kW m^{-2} in Fig. 2) is roughly consistent with the results published by Witkowski et al. (2012), according to which ethylene-vinyl acetate filled with metal hydroxides (a material used for the manufacture of halogen-free electrical cables) shows a maximum heat release rate of approximately 170 kW m^{-2} (under conditions identical to those used in this scientific work).

Significant decrease in the heat release rate in Fig. 2 (during a time interval of 1,000 to 1,500 s) was caused by the complete burnout of the polymer components of the tested electric cable. This conclusion was confirmed also by Fig. 3, which clearly demonstrates that the mass of the measured electric cable drops very slowly in the time interval from 1,500 s to 1,800 s (end of test). The residual mass of the examined cable represents the mass of copper wires and inorganic fillers (mainly used in the filler).

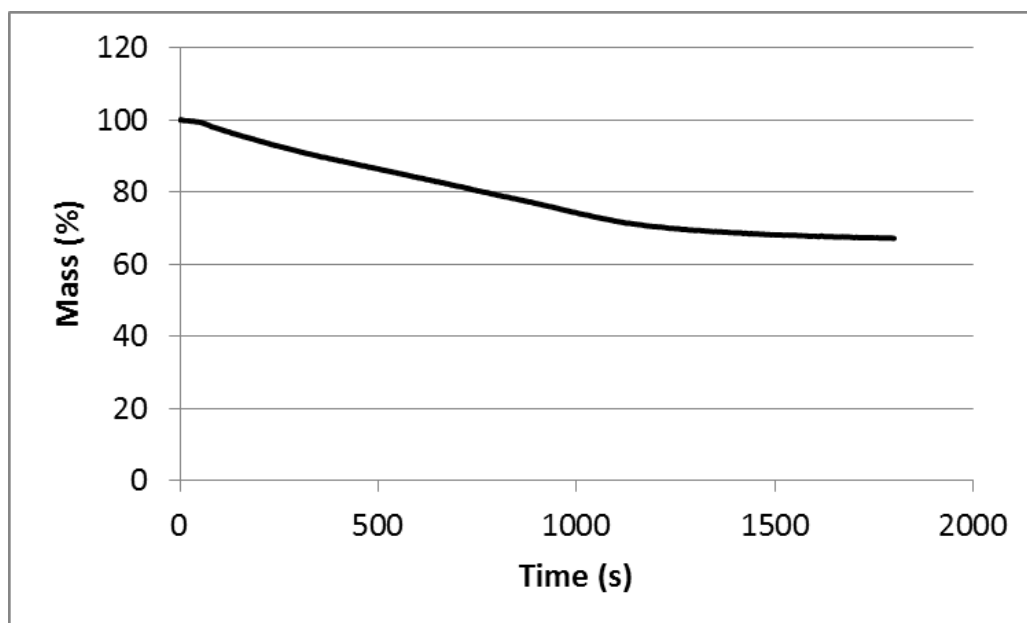


Fig. 3 The time dependence of mass of halogen-free electrical cable CHKE-V thermally loaded by heat flux of 50 kW m^{-2}

From the obtained data of total heat release, initial sample mass and sample mass loss, the effective heat of combustion of the electrical cable as a whole and the effective heat of combustion of the polymeric parts of the electric cable were calculated. The effective heat of combustion of the electrical cable as a whole (8.9 MJ kg^{-1}) was calculated from the released heat and from the initial mass of the sample. The application of this effective heat of combustion is mainly in the calculation of fire load; because it is sufficient to know the origin of mass of cables (it is not necessary to know the mass ratio of inorganic and organic components of the electric cable). The effective heat of combustion of polymeric parts of the electrical cable (26.5 MJ kg^{-1}) was calculated from the released heat and from the mass loss of the sample. The application of this effective heat of combustion is primarily in modelling fires.

Reference material in the fire safety of structures is considered to be wood. According to Gunther et al. (2012) an effective heat of combustion of wood is $17.41 \pm 0.67 \text{ MJ kg}^{-1}$ and according to Martinka et al. (2018) it is $17.84 \pm 0.17 \text{ MJ kg}^{-1}$. The measured electrical cable (as a whole) therefore shows lower effective heat of combustion than the reference material in the field of fire safety of structures.

The average rate of heat emission (ARHE) from the measured cable is shown in Fig. 4. Although ARHE (Fig. 4) had a more uniform course than the rate of heat release (Fig. 2), it was still possible to identify two local maxima in time dependence. The maximum average rate of heat emission (MARHE) of the measured cable was nearly 100 kW m^{-2} (Fig. 4). This value was lower than MARHE of wood and wood-based materials in the scientific work of Carosio et al. (2016).

The specific smoke production rate and the total smoke release are shown in Fig. 5. The specific smoke production rate was that of a unit $\text{m}^2 \text{ m}^{-2} \text{ s}^{-1}$. This unit simply quantifies the area of the light beam (in m^2) which overshadows the amount of released smoke from the area of one square meter (measured cable) per second. The total smoke release was that of a unit $\text{m}^2 \text{ m}^{-2}$. This unit simply quantifies the area of the light beam (in m^2) which overshadows the amount of released smoke from one m^2 area (measured cable) from the start of the test. Similar ideas are expressed, for example, by Ostman (2009).

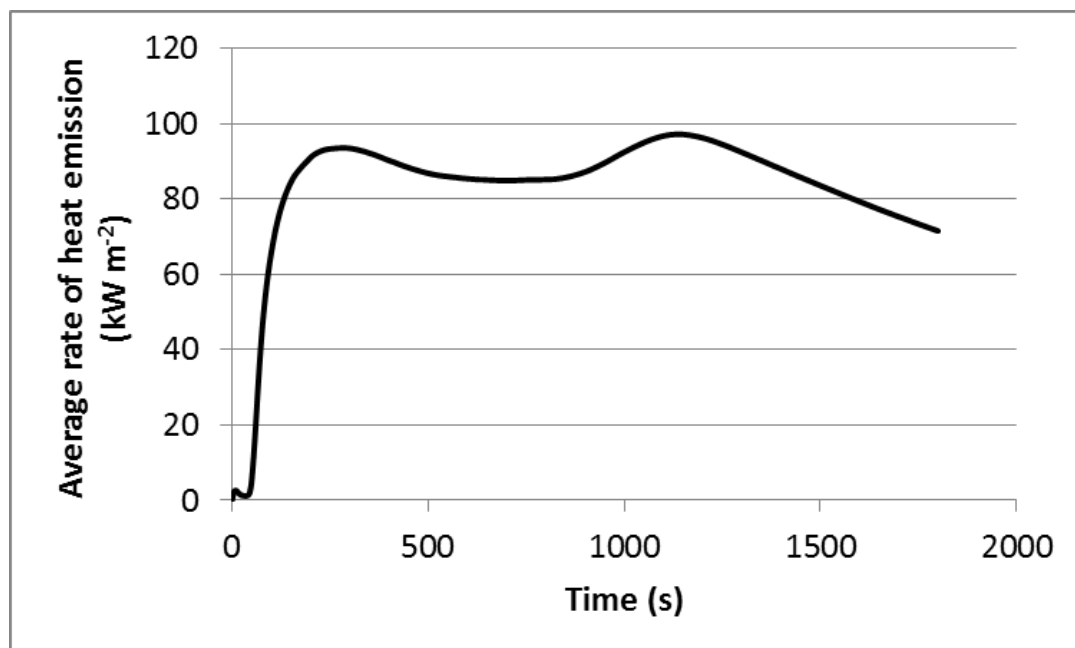


Fig. 4 Average rate of heat emission of CHKE-V cable thermally loaded by a 50 kW m^{-2}

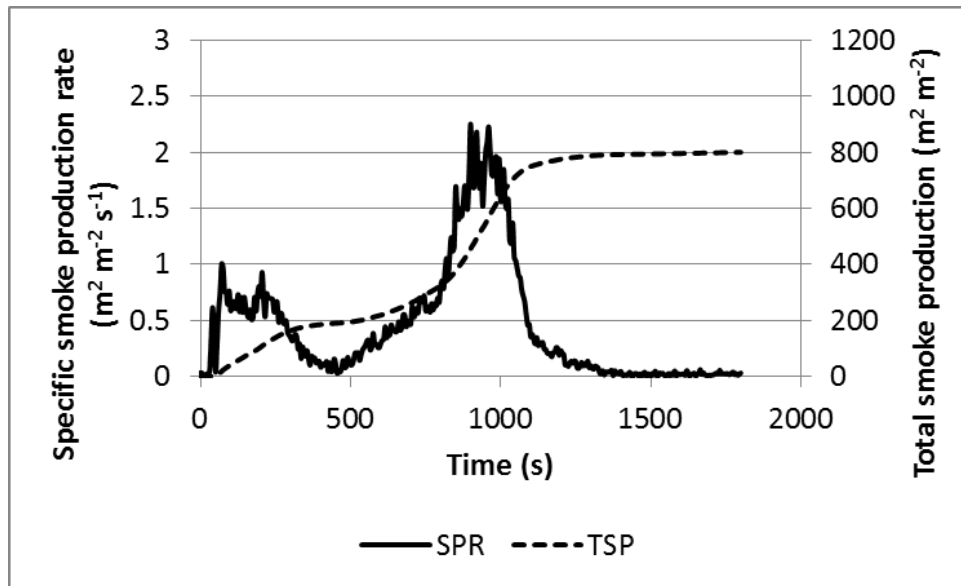


Fig. 5 Specific smoke release rate and total smoke production of CHKE-V cable loaded by 50 kW m^{-2}

Comparison of the total smoke production (Fig. 5) with the Martinka's (2017) research shows that the investigated electrical cable exhibits a higher total smoke production than lignocellulosic materials.

CONCLUSION

In the scientific research, the fire risk of a halogen-free electric cable with the reaction to fire class B2_{ca}, s1, d1, a1 (which according to valid technical regulations can be used in the Slovak Republic in areas with the highest threat to persons - especially escape routes) was investigated. The fire risk was evaluated based on the heat release rate, effective heat of combustion and specific smoke production rate. The obtained data showed that the investigated halogen-free electrical cable showed a lower maximum heat release rate, lower effective heat of combustion (electrical cable as a whole), and a higher specific smoke release rate as a reference material in the fire safety of constructions (wood).

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