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Jozef Martinka

Fire Hazards of Electrical Cables

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Preface

Electrical cables are among key components in practically all structures, means of transport and technologies. Electrical cables may pose a considerable fire hazard if they are incorrectly chosen, or if they are wrongly sized or installed. Electrical cables can be a source of fire, spread flame over their surfaces and contribute to the fire loading of a fire compartment. Nevertheless, this issue receives little attention.

The work presented is a comprehensive survey of the fire hazards of electrical cables. The work is divided into four chapters. Chapter 1 deals with the different types of electrical cables, the description of their basic parameters and construction (an emphasis is put on the qualities fundamental to the assessment of fire hazards). It also details the properties of materials used in the production of electrical cables, conductors, insulation, bedding, sheath and other components. This chapter aslo presents the hazards related to electrical cables and outlines their fire hazards. This chapter includes the definition of the difference between the fire hazards of different electrical cables, substances, materials and products. Chapter 2 focuses on effects associated with the transmission of electrical power using cables (skin effect, proximity effect, voltage drop and Joule heating effect) and fault scenarios (short circuit, overload, increased contact resistance and electric arc) as possible sources of fire. Chapter 3 describes the traditional approach to the assessment of the fire hazards of electrical cables. This traditional approach assesses the reaction to fire class (and its additional classification), flame spread and maintenance of circuit integrity under fire conditions. Chapter 4 offers a totally new approach to the assessment of the fire hazards of electrical cables. This new approach is predominantly applicable to further research (especially in the fields of the fire hazards of electrical cables, fire safety science, fire engineering, the fire safety of structures, electrical engineering and fire investigation), but may also be applied in engineering practice (especially in the design of electrical installations, the design of the fire safety of structures and investigation of occupational injuries caused by the electrical current). This new approach is based on the assessment of the ignition characteristics of electrical cables and the impact of their fire on the surrounding area (mainly their impact on the health and lives of occupants, animals, the environment and property). The assessment of ignition characteristics includes the key ignition mechanisms (ignition by an external heat source or ignition by heat generated inside an electrical cable, or at the point of contact between a conductor and a connected device, for example, within a terminal box) and the key ignition characteristics (critical heat flux, ignition temperature and critical electrical current). The impact of a cable fire on the surrounding area is quantified by the heat effects (heat release rate and total heat release), the toxicity of the combustion products (amount of carbon monoxide, hydrogen cyanide, halogen hydrogens and carbon dioxide released and also the oxygen consumption) and the reduction of the visibility in a fire affected space (the amount of smoke released). The impact of fire on electrical cables that are required to function during fire conditions (e.g. an emergency lift power cable) is expressed by the circuit integrity time. This chapter also includes an assessment of the fire risk of selected power cables through a newly designed method. The conclusion provides an overview of the outcomes achieved using the proposed method and its contribution to the assessment of the fire hazards of electrical cables. One of the key conclusions is that the reaction to fire class (or maintenance of circuit integrity) has almost no informative value in some applications related to fire engineering. This may be due to the classification of electrical cables as reaction to fire class F_{ca} without testing, or the installation of an electrical cable with a declared circuit integrity on a cable management system which does not maintain its functionality in fire (under such conditions, the electrical cable may behave significantly differently than is indicated by its classification). The conclusion also provides a comprehensive summary of the outcomes and contributions of the monograph.

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Summary

Electrical cables are key components of practically all structures, means of transport as well as technologies. The operation of electrical cables may lead to several hazards. The greatest hazards include fire, as practically every electrical cable could be a source of ignition, allow the spread of flame over the surface of the cable, and release heat into the fire compartment (thus contributing to the development of the fire).

The fire hazards of electrical cables are currently only assessed using the reaction to fire class (or additional classification) and in addition, for selected cables (powering critical devices), through circuit integrity. The reaction to fire class provides certain information on the contribution of an electrical cable to the development of the fire. However, such information (reaction to fire class, additional classification and circuit integrity) is not sufficient to allow a comprehensive assessment of the fire hazards from electrical cables within fire engineering. The presented monograph offers an original method for the comprehensive assessment of the fire hazards of electrical cables so that the data obtained is directly applicable within fire engineering. This method assesses the ignition parameters of electrical cables and the impact of their combustion on the surrounding area. The main ignition parameters of electrical cables are the critical heat flux, ignition temperature and critical electrical current. The main parameters that quantify the impact of the fire of electrical cables to the surrounding area are the heat released (heat release rate and total heat release) and the toxicity of combustion products (the amount of carbon monoxide, carbon dioxide, hydrogen cyanide and hydrogen halides released and the amount of oxygen consumed). The results obtained by this method can be directly applied in research into fire science and fire engineering. This method was used to assess the fire hazards of selected power cables.

The results obtained demonstrated that if an electrical cable is classified within a significantly lower reaction to fire class, it does not necessarily mean that the cable will have a significantly higher contribution to fire development, as an electrical cable may be classified in reaction to fire class F_{ca} (product with the largest contribution to fire development) without any testing. The data obtained further demonstrated that upon ignition, a power cable (three core with core cross-section area 1.5 mm^2)

behaves as a thermally thin material, or as a material at the interface between thermally thin and thermally intermediate. The results obtained showed that the average critical heat flux of the mentioned power cable is 15 kW m^{-2}, the average ignition temperature is 410 °C, and the average critical electrical current is 52 A. The total heat release is in the range of 1 to 1.5 MJ m^{-1}, the total carbon monoxide release is in the range of 1 to 1.7 g m^{-1}, and the smoke extinction area is from 6.4 to 7.6 m^2 m^{-1}. The main difference between electrical cables and other products is in the expression of their fire characteristics. For most products, fire characteristics calculated per unit area have the most informative value, while for electrical cables, values calculated per unit length are more informative.

Introduction

An electrical cable is a relatively simple product intended for the transmission of electricity. Optical cables that transmit signals as electromagnetic radiation (most frequently in the infra-red spectrum) are a specific group. In spite of the relatively simple construction, the operation of electrical cables may lead to a large number of different hazards. The greatest hazards include fire, electric shock and the interruption of the supply of electrical power. The interruption of electrical power transmission is especially hazardous when an electrical cable powers a device whose failure may result in a risk to the lives or health of people (e.g. an evacuation lift during a fire) or to substantial financial losses (e.g. a device that would be very energy intensive to restore to working condition after a shutdown).

Of the most significant hazards, fire represents a special category. This is consequence of the temperatures that are applied to a cable during a fire which typically cause thermal degradation of the polymer components (insulation, bedding and sheath), which may lead to an electric shock and/or the interruption of electrical power transmission. An electric shock may be, in particular, caused by the transmission of electrical voltage from a thermally degraded cable to metal objects in contact with the cable. The interruption of electrical power transmission may primarily result from a short circuit (contact between conductors at different potentials or between a phase conductor and ground) or from melting of metal conductors (melting is more likely for aluminium conductors (melting point 660 °C) than for copper conductors (melting point 1085 °C). Melting of copper conductors is unlikely (with regard to the high melting point). This therefore implies that the combustion of electrical cables (or a fire in their immediate proximity) may pose other significant hazards associated with their operation.

The majority of substances, materials and products may only be ignited by an external heat source, for example, thermal radiation or a flame, etc. (substances that tend to self-ignite are an exception). In comparison with such materials and products, electrical cables may be ignited by both an external heat source and the heat generated during their operation (Joule heating). The incorrect operation of electrical cables may thus cause a fire, and during the fire, the cables may contribute to its development (flame propagation and heat release).

Another difference between electrical cables and the majority of other materials and products is the fact that cables often pass through different areas and fire compartments. Electrical cables therefore enable the spread of flame, along their surface, between different areas, and, when the passage through two fire compartments is insufficiently well sealed, also between these fire compartments.

The aforesaid implies that the assessment of the fire hazards of electrical cables requires a different approach than that taken for the majority of materials and products.

The risk that an electrical cable may become an ignition source or the cause of a fire is greater for electrical power cables, in comparison with signal cables (data, communication and control cables). This is due to significantly higher power, and thus electrical current, which causes (or may cause for wrongly sized cables, poor installations or overload) them to generate (excessive) heat.

The objective of this monograph is to design a method for the comprehensive assessment of the fire hazard of electrical cables. This method is based on available knowledge and is enriched and supplemented by knowledge, which is basically new, in the area of the assessment of the fire hazard of electrical cables. This method is applicable to virtually all types of electrical cables. The presented monograph offers an application of this method to the assessment of electrical cables with an emphasis on those electrical cables that pose the greatest fire hazard (mainly electrical power cables).

The presented knowledge may be used in the further examination of the fire hazard of electrical cables as well as in the field of fire science, fire engineering, the fire safety of structures, electronic engineering and fire investigation. It may further be used in engineering practice (especially in the sizing of electrical cables, the performance of design work for the fire safety of structures and investigations into occupational injuries caused by electricity).