VÉDELEM TUDOMÁNY
KATASZTRÓFAVÉDELMI ONLINE TUDOMÁNYOS FOLYÓIRAT

Katalin Kopecskó, Zsuzsanna Kerekes, Éva Lublóy, Gyula Vass, Ágoston Restás

EFFECT OF THERMAL BEHAVIOUR ON BURNING OF PLASTIC COATING FOR ELECTRIC CABLES

Abstract

Cable is in the first place amongst the cause of fire. Fires are always triggered by unsafe and non-standard conditions, so, we can approach safety if we know the properties of cables we want to use. Cable fires may have two starting points: one is the heat reaching the plastic insulation of cables, due to the fire created by burning, the other one may be due to the fire generated by the overvoltage in the inappropriately sized cables when the outer plastic coating begins to burn. The basic condition of fire retardant is that wire breaks or short circuits may not occur in a cable system. During this research, both effects are tested on fire retardant cables.

On the one hand, we exposed wires of various plastic sheaths to flame and to heat, as well as tested at which actual oxygen content they start combustion and flame propagation.

Each combustion starts with thermal decomposition, so it is of particular importance in the thermal behavior of plastic coatings and the expected burns. The selected samples were examined by thermoanalytical method (DTA, TG, TDG). The most important parameters are the weight loss and the initial temperature of the decomposition, which also indicate the expected ignition point of the plastics.

Keywords: fire-resistant cable, electric fires, cable fires, thermal decomposition and pyrolysis of plastics, cable fires

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HŐSZIGETELÉS HATÁSA A MŰANYAG BEVONAT ÉGÉSEKOR ELEKTROMOS KÁBELEK ESETÉN

Absztrakt

Az elektromos vezetékek tűz okozói is lehetnek, fokozzák a tűz továbbterjedését, nagyobb károk bekövetkezéséhez járulnak hozzá. Az elektromosság, mint tűzkeletkezési ok a leggyakrabban visszatérő probléma, általánosságban világviszonylatban az összes tűzeset felében, beleértve a fejlett országokat is. Az elektromos vezetékek-tűzvédelmi rendszerek részét képzik, és a tűz okozói között első helyen vannak. Különböző műanyag burkolatú vezetékeket vetettük alá hőhatásnak. A kábelek hő, láng hatására termikus átalakuuláson mennek át, amelyek folyamtát derivatográfos vizsgálatokkal is követtük, abból a célból, hogy milyen hőbomlási és pirolízis folyamatok vezetnek a kábelek égéséhez.

Minden égés termikus bomlással indul, így különös fontossága van a műanyag burkolatok termikus viselkedésének. A kiválasztott mintákat termoanalitikai módszerrel (DTA, TG, TDG) vizsgátuk. Leglényegesebb paraméterek a tömegveszteség és a bolmás kezdeti hőmérséklete, amely utalnak a műanyagok várható gyulladáspontjára is

Kulcsszavak: tűzálló-kábel, elektromos tüzek, kábel tüzek műanyagok hőbomlása és pirolízise, derivatogramm

1. INTRODUCTION

Electric cables have a dual role from a fire protection aspect:

1) they are part of fire protection systems and assist in escaping and rescue,

2) they may be the cause of fires, increase the propagation of fire and contribute to greater damages.

Electric current is the commonest cause of fire; worldwide, half of all the fires, causing injuries, death, material damage, failures, and very often, the complete destruction of devices [1]. In

Hungary as well, electric fires have also been increasing in recent years and are the second commonest cause of fires [2].

The amount of temperature required for ignition is primarily defined by the kind and condition of the insulating material used in electrical conduit systems. The ignition of plastics occurs at 300-400 °C, which results from a complex sequence of events, whose last phase immediately before ignition is

- the formation of electric arc, or
- excess heat developing due to operation.

Cable design, insulation and sheathing materials together determine the efficiency of cables against flame ignition and propagation [3]. Fire-resistant cables, so-called low-fire-hazard cables (LFHCs), have been developed to satisfy the requirements of low flame propagation and heat release together with very low emission of smoke and hazardous gases [4,5] and should be used in such situations. Polyvinyl chloride (PVC) is one of the most widely used polymers in the field of electrical and control cables. When considering flammability in general, PVC is essentially considered to be self-extinguishing. However PVC is able to support flame propagation along its length. Passive fire protection are coatings and firestops, and the use of inherently flame-retardant materials [6]. The propagation of fire along PVC sheathed electrical cables may be diminished by using either flame-retardant smoke-suppressant (FRSS) additives, AND/OR by applying fire-retardant intumescent coatings to the surface of the cable sheath.

Fire-proof functionality is made by using organic or inorganic flame retardants as cable compounds, to reducing flammability, delaying combustion or inhibiting fire spread. Large quantities (60–70%) [7,8] of inorganic filler materials such as metal hydroxides (aluminum trihydroxide, $Al(OH)_3$, or magnesium hydroxide, $Mg(OH)_2$) are widely used. Their interaction with fire has previously been described by many authors [9,10,11,12] and can be briefly summarized as follows:

- retardants slow the thermal decomposition of the overall material by releasing a significant amount of water in an endothermic reaction and so absorb the energy from the combustion zone, and
- retardants produce char and a metal oxide coating that can act as a protective layer during combustion.

Together with the aforementioned retardants, the fire-proof functionality of cables can be further improved by incorporating a special fire-protective layer (fire barrier) within the cables (such as glass tape, mica glass tape or ceramifiable silicon rubber).

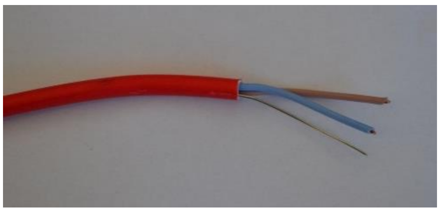
The polymer structure of plastics changes due to persistent or repeatedly high temperatures (200-300° C). Their insulating capacity, due to the semiconductor capability of the carbon generated, can deteriorate to such an extent that it can lead to the formation of arcing short circuit. Plastics have a different risk of carbonizing. PVC is the most common insulating material, however, in this respect, it belongs to the worst-performing plastics.

2. CABLE SPECIMENS FOR TESTING

We have selected the test specimen in a way that they be preferably of different types and classifications, e.g., PH30, 90, 120, 180. [13], [14] .

We have selected 5 cables with different fire retardance for testing. The material of the conduits was always copper. We specify the characteristics of the cables in Table 1. The unspecified external coating is usually PVC, only specimen 3 is polyolefin.

Table 1- Features of cable specimens. Created by the Authors.

Specimen type[13], [14]		Main features
1 PH 30	C 	With fire resistant ceramic silicone conduit insulation. Sheath with low smoke emission, preventing flame propagation, halogen-free, with 2x1.9 mm^2 solid conduits. 1.0 mm^2 cross-section, conduit made of Cu, halogen-free coating (sheath)

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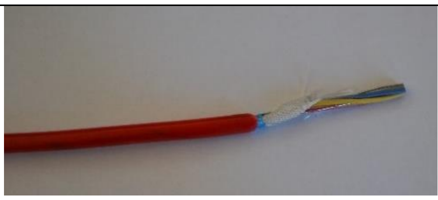
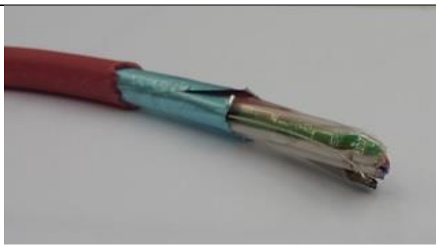
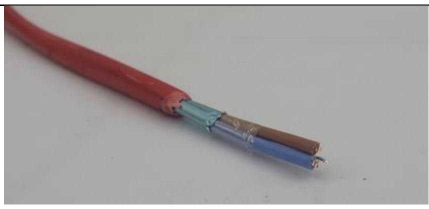
2 FE180, E90		Halogen-free, flame resistant, safety technology cable. Structure: solid copper conduit, halogen-free conduit insulation, aluminum foil-shielded, mounted on plastic, fire retardant external sheath made of halogen-free material. Cu conduit, halogen-free coating (sheath)
3 PH 120		Fire retardant cable with solid copper conduit, halogen-free polyolefin insulation and external sheath. 0.5 mm^2 cross-section conduit made of Cu, halogen-free coating (sheath)
4 No PH marking		Assumably, with non- fire retardant PVC sheath, a 4-conduit fire alarm cable.
5. PH 180, E90		Fire resistant cable, 3-hour fire retardance, shielded, EN54. Aluminated, synthetic foil, red flame retardant PVC sheath. 1.0 mm^2 cross-section conduit made of Cu, halogen-free coating (sheath)

3. TEST METHOD: DERIVATOGRAPHY

Changes in phases were followed by TG/DTG/DTA serves using MOM Derivatograph-Q 1500 D TG/DTA instrument. During the measurements, the reference material was alumina (Al_2O_3), the mass of samples were ca. 300 mg, and the samples were heated at 10 °C min^{-1} heating rate up to ~1000 °C, in air atmosphere (in static condition). Before the investigations, the specimens were ground in an agate mortar, and directly after that they were measured in the TG/DTA device avoiding samples from carbonation due to the airborne CO_2. The thermoanalytical test results were evaluated by Winder (Version 4.4.) software [15]

During the thermal analysis test, we subjected the components of each cables (coverage, foil, cellophane) to a separate derivatograph test.

4. RESULTS AND THEIR ASSESSMENT

4.1 External coverage

In Table 2 we show the derivatography views of the external coverage of the cables which are the basis of combustion.

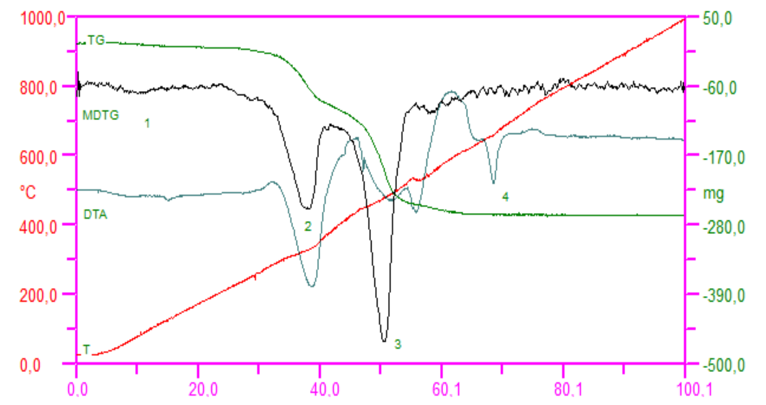
In case of the 4 th marked non- fire retardant PVC sheath is clearly visible the effect of the lack of the additive flame retardant: At about 240 ° C the thermal decomposition begins, and it means the half of the total mass of the material. The released decay products continuously provide the exothermic peaks 2,3,4 and 5. Table 2 shows the most typical thermodynamic values of the external coverage of the cables, which are the basis of combustion.

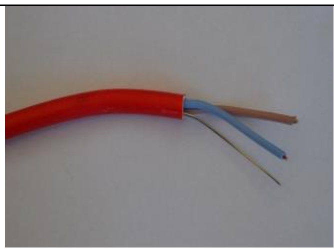
Table 2 - The most typical thermodynamic values of the of the external coverage of the cables. Created by the Authors.

Specimen type		2. Peak	3. Peak	exothermic Peak maximum	**Total loss of weight %**		LOI
1	beginning of the degradation T (C)	231,1	379,1				
	end of the degradation	379,1	614,1				
	loss of weight of the peaks	17,52	**33,12**		**53**		33,7

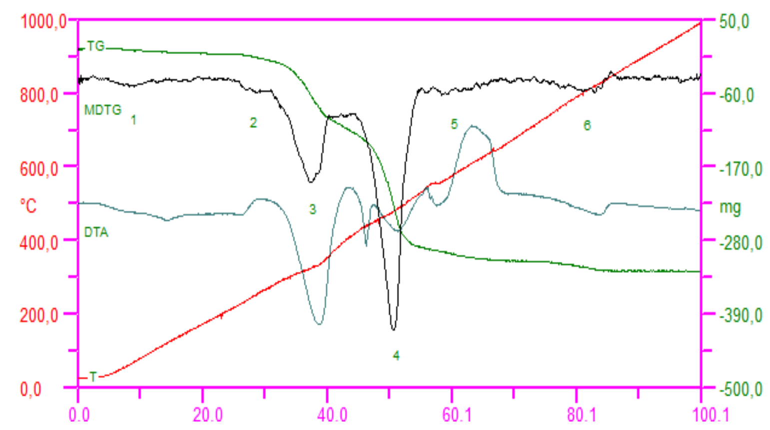
				400-550			
2	beginning of the degradation	276,6	396,8				
	beginning of the degradation	396,8	530				
	loss of weight of the peaks	18,63	**34,15**		**63**		**33,4**
				550			
3	beginning of the degradation	205,1	398,3	550			
	beginning of the degradation	398,3	548,5				
	loss of weight of the peaks	22,26	**34,66**		**61**		**37,7**
4	beginning of the degradation	242		continuous pyrolysis			
	beginning of the degradation	371					
	loss of weight of the peaks	**46,51**			**76**		**<36**

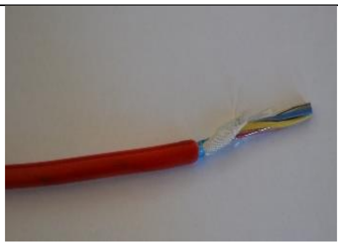
Figure 1- Derivatography recording of the external coverage of the cables. Created by the Authors.



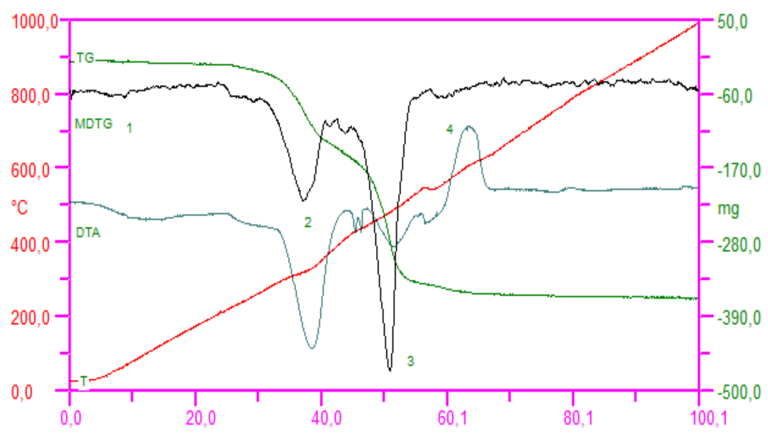


1 st marked cable

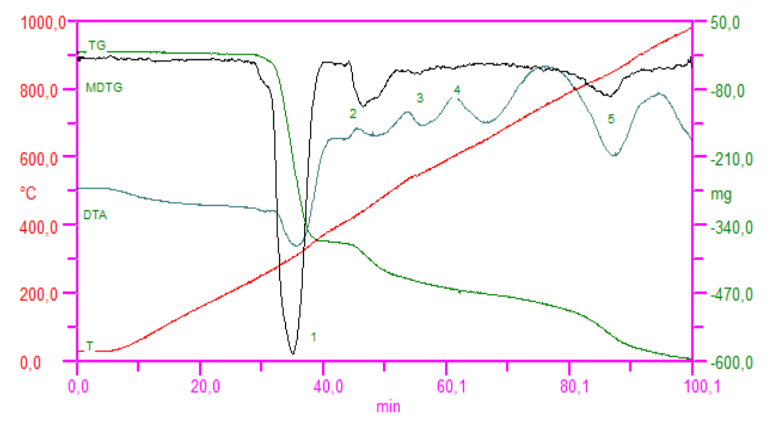


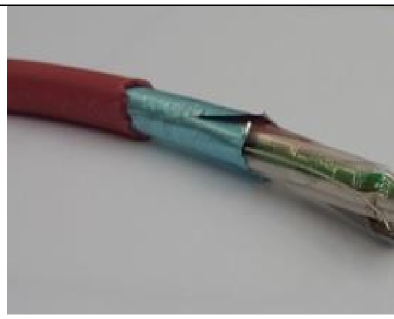


2 nd marked cable



3 rd marked cable

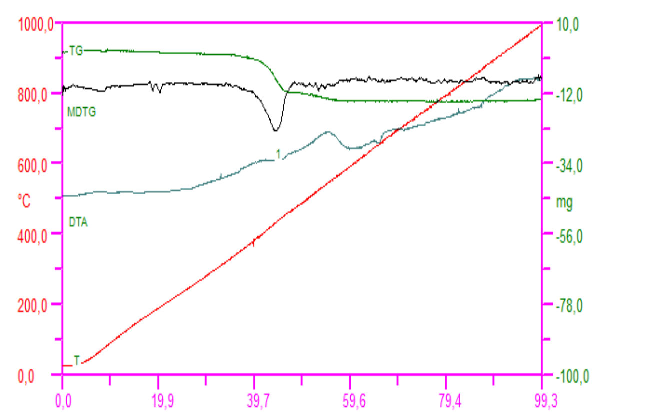




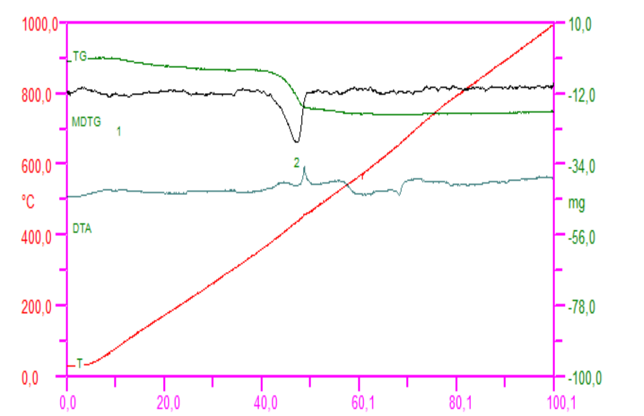
4 th marked cable

4.2 Effects of the blue foils

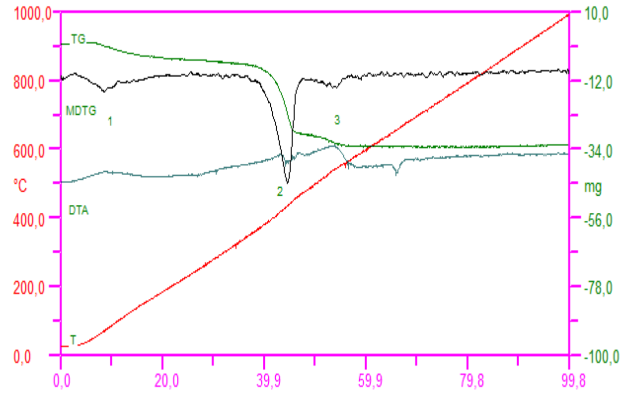
Samples 2 and 3 blue foils did not have exothermic effects in interior coverage, they are even more stable than external red coverage. The thermal degradation of the 4 foils is stronger. Blue foils do not affect the burning of the cover (Figur 2).



2 nd marked cable



3 rd marked cable

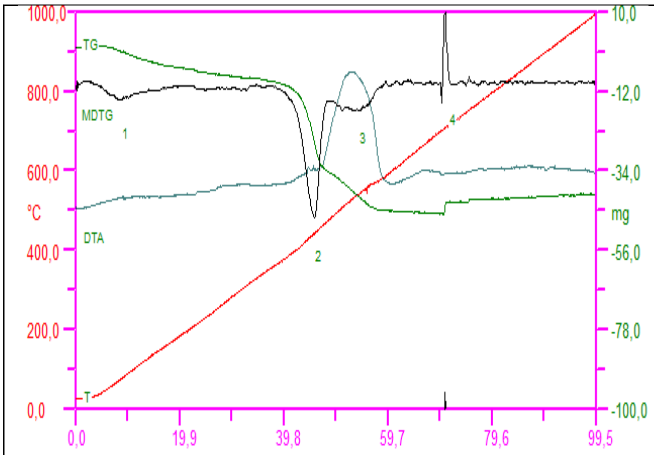


4 th marked cable

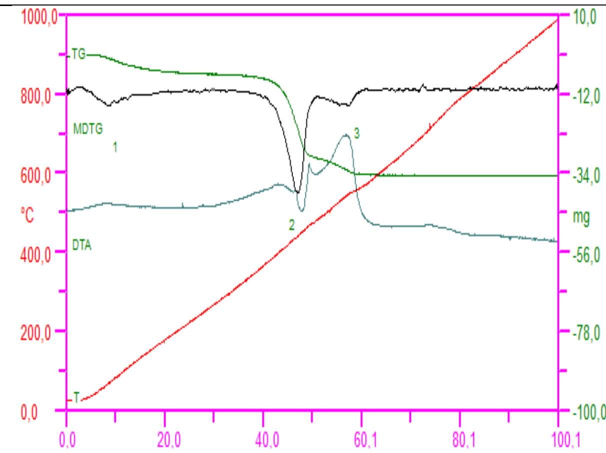
Figure 2- Derivatogramphs of the blue foils. Created by the Authors.

4.3 Effects of the cellophanes

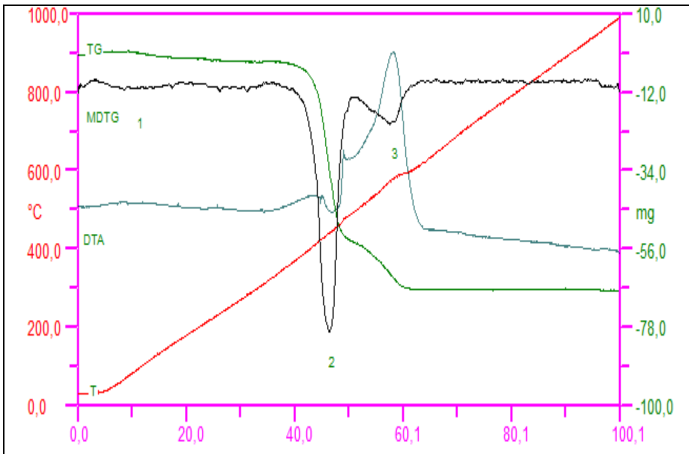
The blue cellophanes are thermodynamically unstable, even above 500 ° C, they show an exothermic process. They will further help the existing combustions. In case of 4 cellophanes, a high degree of thermal degradation starts at 320 ° C, but from 500 ° C exothermic pyrolysis can be observed (Figure 3).



2 nd marked cable



3 rd marked cable



4 th marked cable

Figure 3 - Derivatogramphs of the blue foils. Created by the Authors

5. SUMMARY

The behavior of fire retardant cables versus fire is a very important issue since they are used and built in into flammable environments. As we can see, all the specimens have fire retardance classification, but our measurements show that chemical properties are significant differences. All of these discrepancies are based on the impact on plastics by fire, which are not shown in normal use. But unfortunately, fires are always triggered by unsafe and non-normal conditions

The structure of the polymer may change spontaneously, so, the combustion-retardant substances lose their efficiency, which also negatively affects fire resistance The main thermal degradation (from which the combustion occurs) is above 450 ° C. The 4 red coverage lose about half of their weight at 270 ° C, and pyrolysis can be easily to start. The difference between the two sample groups is between the initial value of the degradation, (200 ° C), which can be regarded as very significant. In general, the combustion phenomena of the cables can be trace back to their thermodynamic stability. Overall, thermal insulation will continue to be important in the design of building protection [16] [17].

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