# Determination of fire behavior of polymer halogen-free cable materials and mathematical modeling of highly-filled compound burning

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## ABSTRACT

*A comparative study of the fire parameters was carried out on a number of halogen-free materials that are used in fire performance cable constructions intended for various applications.*

*A mathematical model was developed for the physical and chemical processes going on in a non-charing halogen-free polymer material under exposure to flame. The model makes allowance for the transient heating of the material and the thermal decomposition of its basic components which is accompanied by a reduction of mass of the specimen.*

## KEYWORDS

Mathematical model, burning, pyrolysis, halogen-free polymer compound, flame retardant, mass loss, cone calorimeter, thermal analysis, DSC, TGA, DTA, heat release, smoke release.

## INTRODUCTION

Due to adverse combination of combustible polymer materials and ignition sources occurring under emergency operation conditions the cables become fire-hazardous objects. Moreover, taking into consideration that branched cable grids are not only bearers of fire risks but also channels along which fire can propagate in buildings and constructions, the improvement of cable fire performance characteristics is an important problem at present.

## TEST DATA AND THEIR ANALYSIS

The required level of fire safety of cable products is achieved mainly by using special highly-filled polymer materials. The behavior of a cable exposed to fire is determined by the material characteristics which have to be measured under controlled conditions simulating the effect of external thermal flow and flame and similar to the conditions of cable burning in fire. Such conditions are simulated while testing materials in a cone calorimeter which is used to perform tests in accordance with the international standard [1]. This device allows the critical fire hazard properties of the materials to be measured in common.

The heat release rate and the mass loss rate are the key parameters required for the fire hazard assessment of materials and products as they determine quantitatively the scope and the rate of fire development.

The tests of polymer compounds carried out with the use of a cone calorimeter under different test conditions (exposure to heat fluxes of 10 to 100 kW/m$^2$) make it possible to evaluate the dynamics of the combustion process. Based on the obtained results one may estimate the fire performance of the materials both at the stage of their development and at the stage of cable designing for various applications.

The comparative tests were performed on the polymer compounds of three manufacturers that are most widely used in the halogen-free cable production in the Russian Federation (see **Table 1**).

**Table 1. Types of halogen-free compounds**

| Manufacturer | Material | Application |
|---|---|---|
| a | I1 | Insulation |
| | S1 | Outer sheath |
| | F1 | Inner sheath |
| в | F2 | Inner sheath |
| | S2 | Outer sheath |
| c | S3 | Outer sheath |
| | S4 | Outer sheath |
| | I2 | Insulation |
| | I3 | Insulation |

The tests were carried out according to [1] under the exposure to heat flux of 35 kW/m$^2$ on material specimens in the form of 100x100x3 mm plates. The specimens were fixed horizontally using an edge frame and a wire grid.

The heat release rate curves for the outer sheath materials are shown as an example in **Fig.1.**

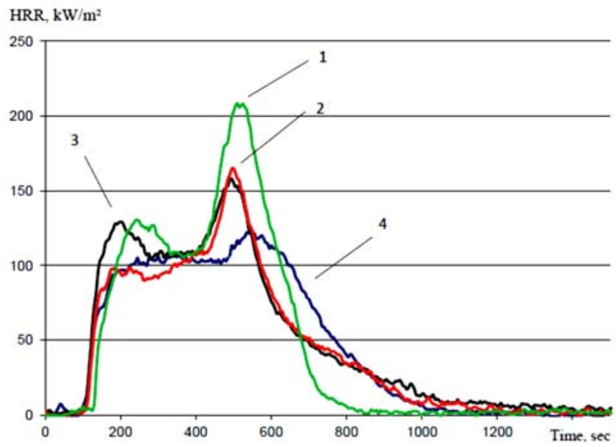


**Fig. 1: Dependence of heat release rate (HRR) during burning of halogen-free sheathing compounds of types: 1 – S3, 2 – S2; 3 – S4; 4 – S1**

The results of comparative tests of halogen-free insulating and sheathing compounds for flame retardant cables are given in **Table 2** where for reference purposes also data on XLPE widely used as cable insulation are given.

To choose polymer compounds for fire performance cable designs in addition to direct comparison of the characteristics obtained in the cone calorimeter tests one may use the Fire Growth Rate (FIGRA) which is calculated by dividing the peak value of the heat release rate by the time required to reach this value, i.e. it represents the heat release rate in fire [2]. This indicator