

## STUDY PROCESSES OF INTUMESCENCE IN FIRE-PROTECTING COATINGS

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**ABSTRACT:** Flame retard of polymers was studied for prevention from burning by various additives stimulated the char formation during heating and thermal degradation of polymer materials. Forming char have high porosity, low thermal conductivity and act as thermal shield for heat transmission from the flame to the polymer and oxygen towards the polymer. The results showed that various additives may regulate the processes of intumescence. The efficient fire protective intumescent char was result of processes of melting, gas evolution, cross-linking, carbonization etc.

### INTRODUCTION

The researches in field of flame retard of polymers in the last 30 years show that one of the most promising methods for its prevention from burning is development various additives stimulated the char formation during heating and thermal degradation of polymer materials. Indeed the forming char have high porosity, low thermal conductivity and act as thermal shield for heat transmission from the flame to the polymer and as a physical barrier hindering diffusion of volatiles towards the flame and oxygen towards the polymer [1, 2].

Special and very important aspect regarding to char-forming polymers is investigation and development of "intumescent" systems. In this case the processes of both charring and foaming take place under action of fire. In result the blown protective char having microcellular structure being produced and its sizes, as usual, tens times more than the sizes of initial material. This approach is used for development fire-protecting coatings designed for protecting of wood or metal structures from the effect of fire.

Although process of intumescent char formation on the whole seems obvious really it is complicated. The phenomenon of intumescence includes chemical and physical processes occurring in condensed phase for relatively short-time interval. Mains of these processes are following:

- Melting of polymer composition due partial degradation to unsaturated oligomeric products.
- Swelling (foaming) of melted viscous layer due to internal gas evolution. As sources of gaseous products usually used certain additives such as ammonium polyphosphate (APP), diammonium dihydrophosphate (ADP), ammonium pyrophosphate (APP<sub>h</sub>), diammonium pentaborate (APB) and similar that easy dissolve at moderated temperatures.
- Formation of char in consequence of further degradation of polymer and cross-linking of unsaturated oligomers. The structure of formed char is represented mainly macromolecular polyaromatic stacks bridged by polymer links and phosphate groups [5]. Thus above mentioned phosphorus containing compounds play a part of special "catalyst" of carbonization [3,4].
- Oxidation of char. The oxidation rate becomes significant at temperatures exceeding 800-900°C. This process is especially important in case of fire-protecting coatings that should to protect wood or metal structures from the fire during long time (one hour and more).

The fire protective efficiency of intumescent char depends from its physical and mechanical properties. The essentially characteristics of char are following [3,4,6,7]: thickness of char layer, high carbon content, low penetrability, sufficient mechanical strength and integrity, homogeneous small pores, high thermal and oxidative stability.

### EXPERIMENTAL

The experiments carried out on the polymer composition consisting from carbamide-formaldehyde and perchlorvinyl resins in a mixture of organic solvents (acetone, toluene, ксилол, and butylacetate). The ammonium polyphosphate (APP) and diammonium dehydrophosphate (ADP) were used as the foaming agents.

The prepared low viscous mixture was overcoated to a steel plates 200x200x3 mm by air-brush. Overage thickness of coating was 1,6-2,2 mm. The samples were dried before testing during 5 day at room temperature. The experimental setup is shown in Figure 1.

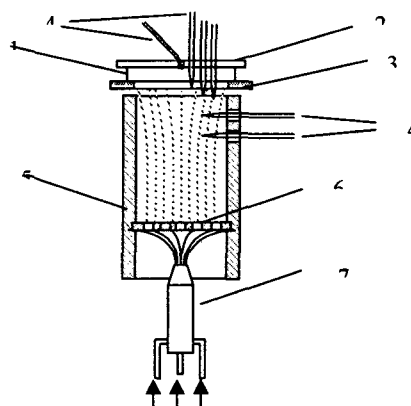


Figure 1. The experimental setup for determination of fire protective efficiency of intumescent coatings. 1 - tested coating, 2 - steel plate, 3 - heat-insulating holder, 4 - thermocouples; 5 - chamber with internal refractory facing, 6 - flame spreader, 7 - propane-air burner.

During testing the char thickness, the temperature of a gas flow and temperature inside of steel plate were registered. The temperature of external gas flow was measured near of surface of coating and changed from 25°C up 1000°C according standard curve GOST 30247.94 (Russia) and ST RK 615-2001 (Kazakhstan) approximating the condition of an average fire.

## RESULTS AND DISCUSSION

Results of testing of the polymer compositions have shown that at its heating from 25°C up to 1000°C take place the processes of intensive char formation. The required amount of additives (APP and ADP) in this case is 10-12%. Essential features of formed char are the high porosity and the low thermal conductivity. The degree of intumescence i.e. ratio between the maximal thickness of char to initial thickness of a coating is 35-40. On the whole the processes of intumescence are completed during first 25-30 minutes and then growth of char is finished. The visual swelling of investigated compositions is shown in Photograph 1.

Figure 2 shows a temperature curve in steel plate with polymer coating. By comparison of the temperature in the metal with the temperature of a gas flow, it is obviously that formed char possesses high heat-insulating properties.

The form of temperature curves 1, 2 allows three basic stages of chemical and physical transformations in these coatings to be determined. In stage I practically linear rise of temperature is observed at slight intumescence. The coating in this stage transforms to viscous state. As the temperature of polymer composition in this time interval is low for intensive evolution of gaseous products the foaming is not yet occurs. The primary processes of foaming and charring take place in stage II. Although temperature of an external gas flow rise the temperature in metal substrate almost does not change. At this stage thickness of char reaches the maximal value (70-80mm). In stage III processes of char oxidation begin to prevail. The structure of char is destroyed and thus the temperature inside metal again began to rise.

From temperature profiles 1 and 2 (Figure 3) it may be concluded that addition APP of lead to increase of temperatures of melting, foaming and charring (stages I and II) compare with ADP. At the same time APP lead to intermolecular cross-linking in polymer system [8]. As a result of increase of cross-linking the thermal stability insulating properties of char enlarge that confirm with temperature profiles 1 and 2 in stage III.

These results show that various additives may regulate the processes of intumescence. The efficient fire protective intumescent char is result of processes of melting, gas evolution, cross-linking, carbonization etc. The rates of these processes should be mutual corresponding in wide time and temperature interval.

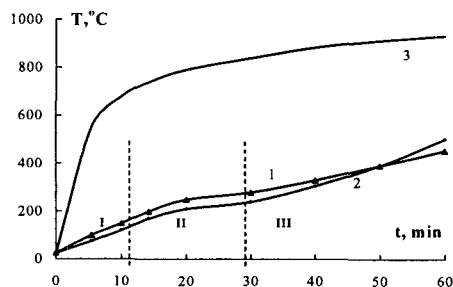
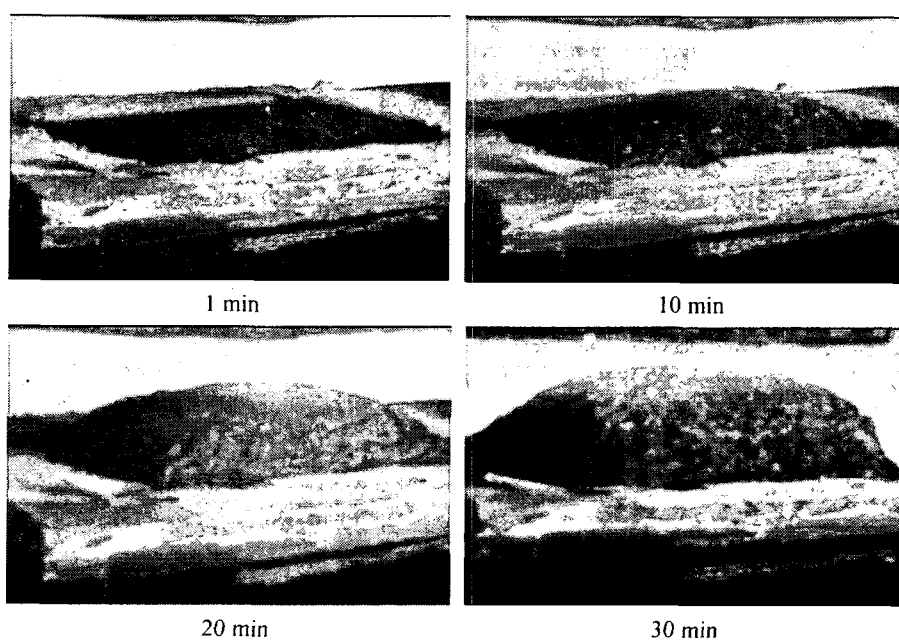


Figure 2. The temperature inside metal plate (1,2) as function of time during heating of intumescent coatings. 1 - 12% APP, 2 - 12% - ADP, 3 - temperature of external gas flow.

### References

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Photograph 1. The formation of char at various time interval during testing of intumescent polymer compositions.