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NOTE

Effect of Deposited Urea on the Flame Retardancy Imparted to Cotton Fabric

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The effect of urea as a non-durable finish on the flammability of 100% cotton fabric, plain construction, weighing 168 g/m^2 has been of interest in this study. The laundered, oven-dried, weighed fabrics were impregnated with suitable concentrations of aqueous urea solutions by means of squeeze rolls and dried at 110°C for 30 min. Afterwards, they were cooled in a desiccator, weighed with analytical precision and kept under ordinary conditions before the accomplishment of the vertical flame test. The optimum add-on value to impart flame retardancy expresed in g anhydrous urea per 100 g fabric was about 25%. The results obtained with the impartation of urea into the cotton fabric is in favour of gas theory and also condensed phase retardation.

Key Words: Urea, Flammability, Flame retardancy, Gas theory, Condensed phase retardation.

A flame retardant is a component or mixture of compounds that when added or incorporated chemically into a polymer serves to show up to hinder the ignition or growth of fire[1,2]. It is mentionable that the flame retarding component is intended to prevent a small fire from rapidly developing into a major disaster[3]. However, a flame retarded substance is believed to be combustible in the intense ignition circumstances.

There are different ways in which flame-retardants may act. As a rule, a flame retardant interferes with one or more of the three factors essential to the combustion process, *i.e.*, it interrupts the *fire triangle* (combination of oxygen, fuel and heat). In practice, flame retardants are designed according to the specific properties of the flammable material and to the common causes of fire in the material's environment. The most important groups of chemicals used in the world as flame retardants are:

1. Organic halogen compounds, especially bromine and chlorine compounds, often in combination with antimony oxides.
2. Phosphorus compounds, such as phosphate esters (about 20%).
3. Metal compounds such as alumina trihydrate, $Al_2O_3 \cdot 3H_2O$ and magnesium hydroxide, $Mg(OH)_2$ (another 20%)[3].

The aim of this study is to investigate the effect of deposited urea as a non-durable finish on the flame retardancy imparted to cotton fabric.

All fabrics were a plain construction, weighing 168 g/m^2, unfinished 100% cotton, laundered and dried. They were 22 by 8 cm strips cut along the warp

direction and pre-washed in hot distilled water. The specimens were dried at 110°C for 30 min in an oven, cooled in a desiccator and weighed with analytical precision.

Bath treatment: With the exception of the first bunch, all other samples were impregnated with suitable concentrations of urea at 20°C. Afterwards, they were squeeze rolled and dried horizontally in an oven at 110°C for 30 min, then they were cooled in a desiccator and re-weighed with an analytical balance so that the suitable add-ons presented into the specimens were obtained.

Flammability test: The vertical flame test, also described in the previous investigations[4–5], has been employed. It is similar to the procedure described in DOC FF 3–71[6]. The conditions of the fabrics and environment in average temperature ranged between 20° and 22°C and the average of relative humidity (RH) ranged between 65 and 67%. According to the aforementioned test, an aluminium frame with the following specification was used: two strips of 3 mm aluminium double-sheet, 22.5 by 1.5 cm were cut, perforated and welded at right angles to a shorter 9 cm strip.

The samples were pinned tightly to the frame and held vertically in a retort stand by clamps with the lower edge 1.9 cm above the top of a Bunsen burner with a 3 cm yellow flame and an ignition time of 3 s. This procedure was conducted in order to avoid the harsh circumstances of ignition. Then the burning time at the nearest 0.1 s was measured with a stop-watch.

Repeatability of burning time was ±5% for untreated samples. This figure was lower for urea treated specimens. In fact the pad squeeze process caused a certain amount of variability.

TABLE-1
EFFECT OF DEPOSITED UREA ON THE FLAME-RETARDANCY IMPARTED TO COTTON FABRIC (PLAIN 168 g/m^2)

Bunch No.*	Treating solution (molarity)	Per cent (add-on) drying at 110°C and weighing	Burning time (s)	Burning rate (cm/s)	State of the fabric†
1	Untreated fabric	—	31	0.709	CB
2	2.5	19.48	32.3	0.681	CB
3	2.75	24.42	—	—	FR
4‡	3	25.93	—	—	FR

*Average of 5 tests for each bunch.
†CB stands for completely burned and FR stands for flame-retarded.
‡Confirmatory tests applying excessive quantities of urea.

It can be deduced from the aforesaid experimental results (Table-1) that a range of 24.47–25.93% urea is sufficient to impart flame retardancy to the cotton fabric.

Although urea has a high nitrogen content (46.7%)[7], but showed only a tendency towards flame retardancy effect. It is noticeable that the mode of action of nitrogen-containing flame retardants is still not well understood in scientific literature[8]. However, there are some explanations concerning their application. Nitrogen-based flame retardants such as melamine and melamine derivatives act

by intumescence. These flame retardants are most often applied in conjunction with other flame retardants. Gases generated from the compounds make the material swell and form an insulating char on the surface. It seems that the main factor to play some crucial role in the above mentioned experiments is the release of ammonia and carbon dioxide in the vicinity of the thermal degradation zone of cellulose. The reaction seems to be accomplished *via* the following equation:

$$H_2N—CO—NH_2 + H_2O \longrightarrow 2NH_3 + CO_2$$

The required water for the sustenance of the afore-mentioned reaction can plausibly be supplied by the humidity regain subject to the fabric's conditioning process. Hence, it can be attributed that the action of urea in the conditioned cotton fabric to impart flame-retardancy, though not a spectacular performance, is *via* gas theory.

According to this theory, the action of some flame retardants is because of the liberation of inert or not easily oxidizable gases such as NH_3, CO_2, H_2O, SO_2, etc. These gases may be generated in the vicinity of the inflamed specimen so that the adjacent atmosphere will be modified either to dilute the flammable gases liberated during the combustion process or to play the role of a blanket, which hinders or makes the access of air or oxygen very difficult.

On the other hand, condensed phase retardation seems to play some role in the above mentioned tests[9, 10], *i.e.*, the deposited urea as a nitrogen based compound generates ammonia and carbon dioxide in the combustion zone of the treated fabric and acts by intumescence. Hence, the thermo-degraded specimens swell and form the insulating carbonaceous char. This causes a dehydration process, shown below:

$$(C_6H_{10}O_5)_x \longrightarrow 6xC + 5xH_2O$$

The generated water may sustain the moisture required for urea to supply NH_3 and CO_2 as mentioned recently.

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