



The dynamics of leather combustion

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Leather is a combustible material and must be treated with appropriate flame-retardant products to pass fire-prevention testing. This is part one of a two-part article on this subject from Ikem. With more than 40 years' experience of offering beamhouse, tanning, retanning and finishing products to the global leather industry, Ikem became part of the GSC group at the start of 2019.

Fireproof leather offers the obvious advantage of always having an element available that can reduce the speed of fire propagation so that the flames do not touch other combustible materials. This increases the time allowed for any evacuation before a fire spreads.

Slowing the spread of a fire means having a low participation in combustion but also a rapid cooling time so as not to contribute to the overheating of the environment. The level of passive safety can also include minimal formation of dense and toxic fumes to aid visibility and breathability.

Fire regulation and reaction tests

Each country has fire regulations and tests that must be respected. For leather to meet regulatory requirements, flame retardants must be selected at testing stage in accordance with these.

A good example is the UNI EN 91/75 standard for the 1IM classification and the BS 5852 - source 1- standard. These are very similar, but only the UNI EN 91/75 provides an initial wash of the specimen, which aims to remove any deposited treatments and anything not fixed. It follows that the use of flame retardants that can be washed out prejudices the result of the test according to Italian law.

How fire reacts to leather

Let us now try to highlight what contributes to the behaviour of fire on leather. Depending on the application and the environment in which the leather is to be used, the tolerance of measured parameters can vary greatly (for example, in aircraft and trains, the build-up of smoke must be taken into account but in the former case tolerance is much lower).



In *Figure 1* we have broken down the course of combustion into four phases. We can now consider which parameters to keep under observation during combustion of generic finished leather and the factors that influence them.

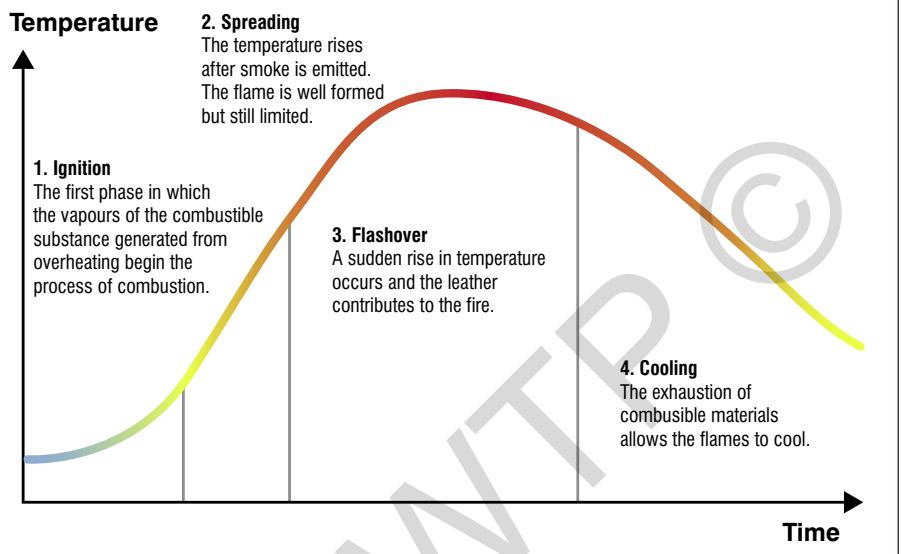
Fire resistance

Fatliquors, particularly those with mineral oils, provide the greatest amount of fuel vapour. In order for the fireproof system to work, it must be balanced: the flame retardants used must be available in the immediate vicinity of the flame and must degrade at or near the temperature at which combustion takes place. An example of an unbalanced system is one in which the flame is far from the fireproofing agents; this can occur if there is a high presence of mineral oils and a very thick finishing layer. Overheating generates gases on the flesh side, which is more permeable than the finished side. In the case of a vertical test conducted on leather, the flame remains distant from the flame retardants. Reduced post-combustion time and reduced destruction of the material may occur. The flame mainly feeds on the back of the sample leather, expelling gases. The flame has less contact with the leather on the other side, but manages to carbonise it without giving rise to a high enough level of combustion to degrade the flame retardants.

An example of an unbalanced system in which the combustion temperature is too low to degrade the flame retardants is observed when a small flame that brings little destruction but is very persistent is fed over the oil that oozes from the surface of the leather. It is a candle effect by which the wick burns with slow destruction fed by the vapours of the overheated wax. In both cases, flame retardants fail to intervene correctly and risk not complying with the standard performance requirements.

In the case of applications for furniture leather, according to UNI EN 91/75 and BS 5852, the use of padding is foreseen. This adds a variable and complicates things. The filling foam, even if it is fire-retardant, releases combustible gases. If the fire-retardant leather is damaged only a little it helps to keep the gases imprisoned and this condition maintains the flame inside the cushion. The latter is consumed more quickly and, once its thickness is consumed, it does not satisfy one of the requirements required by law. The leather must be consumed

Figure 1: Phases of combustion



to the extent that it allows the outflow and dilution of the gases to the outside; this will prevent the excessive consumption of the padding.

Post incandescence

The persistence of embers in the leather as a result of combustion is a parameter that is not considered in the aviation sector but is instead very important in the public spaces sector.

It is well known that embers are a problem if fire-retardant leathers are produced from mineral tanned hides, while organic tanning agents do not present this phenomenon. This is due to the absence of metals. With the presence of metals, combustion results in a more solid residue, which is compacted by absorbing more heat and offering more resistance to destruction. In the absence of metals, organic substances have better combustion and are destroyed more quickly with the advantage of dispersing heat more quickly. However, it must be taken into account that a wet white leather must be more lubricated than a wet blue leather.

Dripping

During combustion, some portions of molten material can become detached, with the risk of spreading the fire. This phenomenon does not usually occur with leather, unless it is treated with oils or waxes to produce burnished and pull-up articles. Waxes, particularly, melt and burn, and therefore may migrate in liquid form before being consumed. In this type of leather, it is very difficult to

reconcile the aesthetically pleasing effect obtained with oils and waxes with the performance requirements imposed by fire regulations. Even a cigarette resting on an armchair covered with this material could constitute a fire risk. On the other hand, being treated with a flame retardant would compromise the essential characteristics of these pleasantly natural articles.

To date, the only solution to offer an acceptable compromise between aesthetics and performance is a bonded-resin and wax finish applied to a fireproof crust. This type of finish is also suitable for non-fireproof leathers in the case of minor cigarette-induced ignition, but in more severe cases it would not contribute to combustion and would not disrupt the effect of flame retardants used during the retanning process.

Deciding to undergo a test for fireproof leather is certainly helpful in understanding the dynamics of combustion. We have reported some experiments that will be implemented in the future in order to form a more complete overview and to choose the type of processing best adapted to the purpose.

Smoke toxicity

Smoke is a collection of tiny particles in solid, liquid and gaseous form, not sufficiently destroyed by the thermal reaction. According to statistics, its inhalation is the main cause of death in fires.

Although it may contain a large number of chemicals that contribute to continuous reactions, only a limited number of the main products



of combustion are included in the tests conducted in the aviation and railway sectors. Some test variations can be specifically requested by the manufacturers of aircraft and trains, as well as the non-use of certain substances upstream. Typically, these are:

- **Carbon dioxide:** the better the system's combustion, the greater the presence of CO_2 in fumes; it is present in far greater quantities than other gases
- **Carbon monoxide:** it forms due to the incomplete combustion of hydrocarbons
- **Hydrogen sulfide:** this forms through the combustion of sulfur; it is a constituent part of leather, but may also be present as a residue of dehairing
- **Sulfur dioxide:** it forms in the presence of sulfur when more oxygen is available for combustion
- **Hydrogen cyanide:** formed, for example, by acrylic resins, following combustion with poor aeration
- **Hydrochloric acid:** formed by the chlorine contained in retanning or fireproofing products
- **Hydrobromic acid:** formed by the bromine generally contained in fire retardants
- **Nitrogen oxides:** formed by the nitrogen contained, for example, in melamine resins as well as by the nitrogen present in the air.

The way in which combustion occurs determines the final composition of the fumes. The variables involved are temperature, the type of fuel (the leather and all the products it contains) and the percentage of oxygen available.

In general, for the aviation and railway sectors, the toxicity of leather's combustion fumes is not considered a worrying obstacle. The empirical values detected are widely below the limits in place.

Fume density

The ability to emit low-density fumes is the most complex feature to impart to leather, due to the fact that it is always linked to other flame-resistance requirements such as low destruction or low heat development.

We know that the warmer the flame, the faster pyrolysis takes place, and that the better the combustion, the lower the smoke density.



Leather samples and finished products undergoing flame-retardant testing.

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Complete combustion forms water vapour and carbon dioxide, the products of maximum oxidation, with a much more transparent gaseous phase. The material that does not sublime remains in the ashes, which are therefore composed of the residual minerals and carbon. In the case of wet blue, there is usually more material in the solid carbonised portion than in wet white. In the final phase of the combustion reaction, carbon dioxide is still released. Since it cannot be further degraded, it does not give rise to fire, but it can keep the embers incandescent if a high temperature is maintained and there is contact with oxygen.

In the combustion chamber where the leather specimen is tested, the

amount of air available is fixed. Combustion proceeds in different ways with a higher or lower than stoichiometric air-fuel ratio. In the former case, we have partial combustion with less heat, more unburnt particles released, and a long, yellow, smoky flame. In the second case, with lower fuel than air, we have better combustion, with a short, bluish flame. 🔥

The second part of this paper will be published in the December 2019-January 2020 issue of World Leather. It will examine a series of parameters to consider in attempting to achieve a compromise between leather's resistance and its reaction to fire.