Application

UltraCarb in fire retardant PVC cable compounds

Technical paper

A review of the important fire retardant performance criteria of UltraCarb in fl exible PVC compounds used for cable sheathing and insulation compounds.

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Performance criteria

The table below shows a very typical set of performance parameters for a fire retardant PVC cable insulation compound. This insulation compound would meet the IEC 60502, BS 5467 or BS 6346 standards and the IEC 60332-3 flame test requirements. Additional parameters may also be specified to meet requirements for anti-termite, anti-rodent, sunlight or oil resistance, extremely low temperature bending and hot water aging.

Property	Value	Test method
Tensile strength	Min. 12 N/mm^2	IEC 60811-1-1
Elongation at break	Min. 150 %	IEC 60811-1-1
Density at 23 °C	1.52 (+/- 2 %) g/cm^3	IEC 60811-1-3
Hardness (Shore A)	86 +/- 3	DIN 53505
HCL emission	Max. 18 %	IEC 754-1
Oxygen index	Min. 29 %	ASTM 2863
Flame propagation test	Pass	IEC 60332-3

An exemplary fire retardant formulation, which would meet these requirements, would contain:

- PVC – with a K-value of 70 is the most common type for wire & cable
- A primary plasticiser - typically a phthalate type
- A secondary plasticiser or extender (optional) - either a chlorinated paraffin or phosphate ester type
- Calcium carbonate (optional)
- Stabiliser - Calcium/zinc mostly, some tin based (mainly USA) and sometimes lead based in developing regions
- Fire retardant filler (aluminium hydroxide (ATH) or UltraCarb (HMH))
- Fire retardant synergist (antimony trioxide, zinc borate or zinc hydroxystannate)

Classic fire retardant

UltraCarb is compatible with a wide range of polymer types and provides the final product with fire retardancy and smoke suppression. When you expose the UltraCarb filled polymer to fire, it will reduce further combustion and flame spread.

Flammability and the influence of plasticisers on PVC flammability

The number one parameter to be fulfilled for a fire retardant PVC cable is the oxygen index. This is also known as the limiting oxygen index or LOI and is a measure of flammability. It is the only reason to add fire retardant components to PVC.
Sometimes, the temperature index (TI) of a PVC compound is also evaluated, which is measured by reversing the LOI test principle.

Basic unmodified PVC is rigid at room temperature, does not burn easily and has an LOI of 50%. Plasticiser is added to PVC to make it flexible but these are flammable and reduce the LOI to below 25 %. 29 % is a common specified minimum value for LOI. Most customers aim at a value greater than 30 % and an LOI of 32 % is often cited to provide a comfortable safety margin.

Two notable exceptions to this general guideline requiring LOI values above 40 % are the Russian GOST cable standard and the American NFPA standard for plenum cable.

Formulation options

The PVC formulator has several possible options to improve the fire behaviour of the compound. There are three performance criteria, which need to be considered depending on the level of fire retardant performance being targeted.

1. Reaction to fire
2. Reduction in smoke emission
3. Reduction of smoke acidity

Formulation option 1: Improve reaction to fire

Addition of a fire retardant filler and a fire retardant additive. A typical formulation for a fire retardant PVC compound is shown in the table below.

Component	phr
PVC, K = 70	100
Plasticiser (phthalate)	50
Stabiliser	5
FR filler 75	75
FR additive 5	5

The properties of this type of formulation are:

- Tensile strength > 12 Mpa
- Elongation at break > 200 %
- Hardness (Shore A) 87 – 89
- LOI > 32 %

The addition of 100 phr (ca. 50 %) of fire retardant filler such as UltraCarb or ATH will increase the LOI to around 35 % and reduce the cost of this formulation. Unfortunately with nearly 50 % of filler, the compound is typically too stiff.

The maximum workable level is usually around 75 phr (ca. 30 %), which yields an LOI of 29-30 %. To get the additional safety margin in fire performance, 4-5 phr (ca. 3 %) of a fire retardant additive is added. Antimony trioxide is the most effective additive while zinc borate is less effective but cheaper.

A combination of zinc borate and antimony trioxide is therefore very often used as an effective method of boosting LOI.

Substitution of all or part of the phthalate type plasticiser for a "fire retardant" plasticiser

Special plasticisers based on phosphate esters can be used as substitutes for phthalate plasticisers.

Phosphorus compounds generally work in the condensed phase causing char to form. The purpose of these types of plasticisers is to reduce smoke and flame spread while maintaining or increasing LOI.

Unfortunately, they are not so effective in low temperature environments, can affect ageing and aremore expensive.

Sometimes, the effectiveness of phosphate ester plasticisers incombina-tion with other fire retardants can be less than expected - at best additive and not synergistic.

Phosphate ester plasticisers are not universally used in cable compounds except in plenum type formulations used in the USA. In some regions of the world they are not readily available or not imported at all. It is worth noting, that in the majority of cases when customers give negative feedback other than on smoke/flame retardance, the choice of plasticiser is the cause.

Polymer Knowledge is key

At LKAB Minerals, we have an in-depth understanding of the incorporation of UltraCarb and ATH into the polymer matrix to receive the best results possible. In cooperation with partners from the wire and cable industry, we continuously develop our products to make dispersion within the polymer successful.

Please get in touch with your local sales manager to help find the best solution for your wire and cable product.

Formulation option 2: Reduce smoke emission

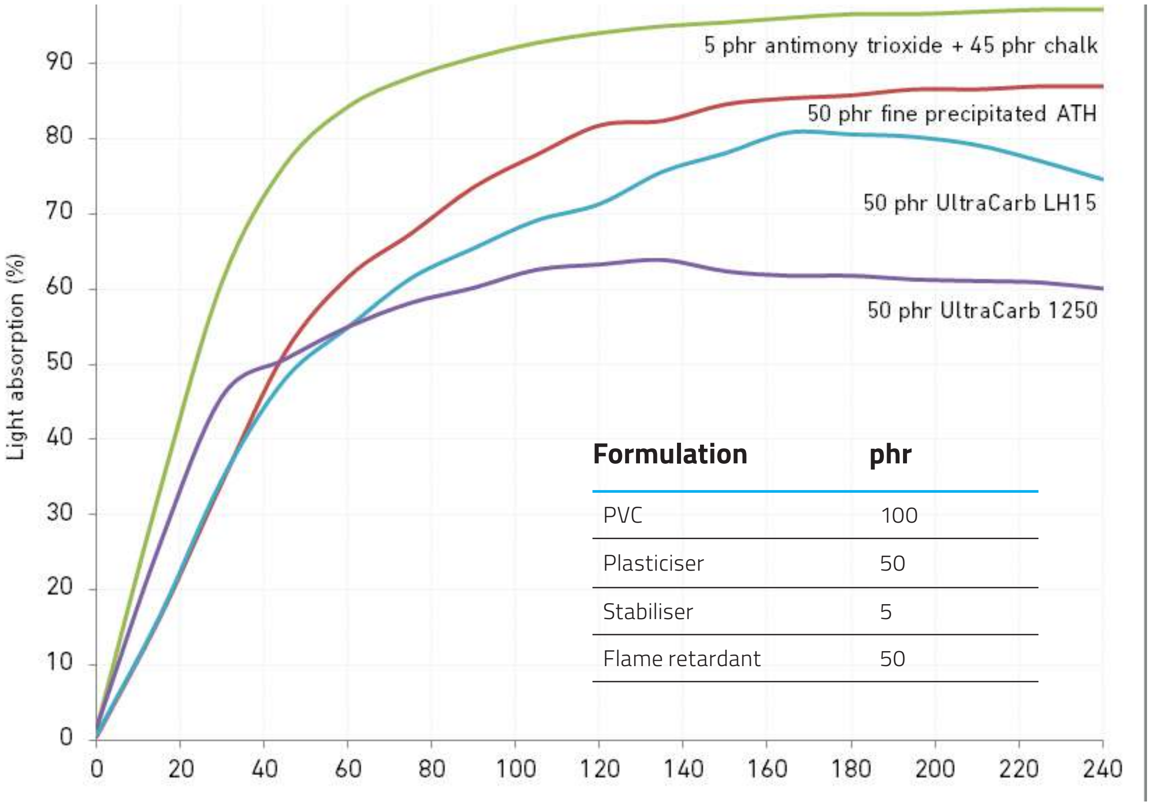
Smoke is most effectively reduced by using fillers and synergists which promote char formation and the adsorption of soot particles. The absolute level of smoke reduction achievable is primarily dependent on the choice of plasticiser and other readily combustible components in the formulation.

The fire retardant filler is the baseline for smoke reduction because it is the largest non-combustible component in the formulation. If necessary, char promoting synergists can also be used to further enhance smoke reduction. Zinc borate, ammonium octamolybdate, zinc hydroxystannate are effective char promoting synergists.

The graph below shows a comparison of smoke suppressant performance of a plasticised PVC formulation filled either with UltraCarb; fine precipitated ATH or a combination of chalk and antimony trioxide. UltraCarb products with a high proportion of fine huntite particles are especially effective in reducing smoke emission when compared to the other systems.

The results show that smoke output is reduced by 25 % compared to an ATH filled PVC if UltraCarb 1250 is used.

The VW-1 cable fire test is a further good example of the effective char promoting performance of UltraCarb. The test specifies five applications of a flame to a vertically mounted sample. In general, for a reasonable chance of passing this test, the optimal situation is that after the second application of the flame, no fresh polymer is ignited because a stable layer of char has started to form.



Formulation	phr
PVC	100
Plasticiser	50
Stabiliser	5
Flame retardant	50

The combination is the difference

UltraCarb is a unique halogen-free fire retardant as it acts differently to traditional fire retardants, which release water in a single action phase. Upon decomposition, UltraCarb provides classical endothermic fire retardant functionality, it releases carbon dioxide and it provides char stabilisation.

We call this the three-stage fire retardant mechanism. This multi-process fire retardancy offered by UltraCarb.

Formulation option 3: Reduce acid gas (HCl) emission

A basic (high pH) filler is used to reduce acidic gas fumes by neutralizing the hydrochloric acid (HCl), which is released as one of the combustion products of PVC. The most effective filler for reducing acidic gas emission is fine precipitated calcium carbonate.

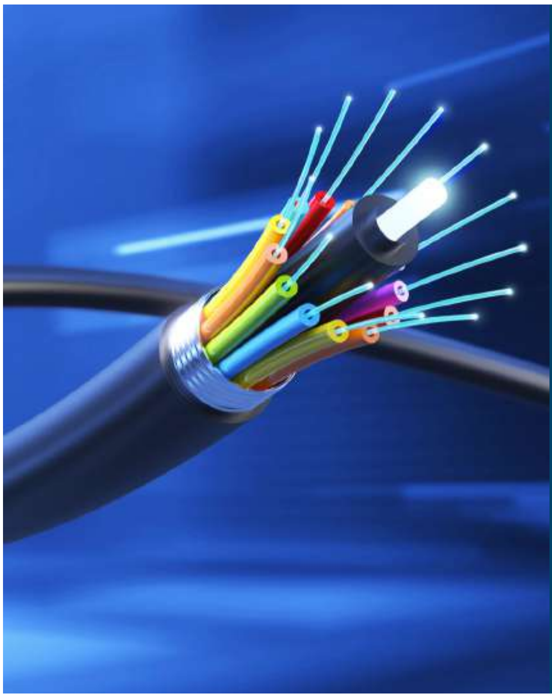
Unfortunately, removing the acidic gas also decreases the LOI because HCl is no longer available to inhibit flame propagation.

Therefore, combinations of fire retardant filler and precipitated calcium carbonate are used.

The formulation below is an example of how the acidic fumes can be reduced below 18 % by using a combination of UltraCarb and precipitated calcium carbonate.

- LOI > 30 %
- Acid gas (HCl) emission < 14 %.

Component	phr
PVC, K = 70	100
Plasticiser (phthalate)	58
Stabiliser	5
UltraCarb 1291	75
Precipitated calcium carbonate	25
Antimony trioxide	5



Conclusion

UltraCarb is widely used around the world as a fire retardant filler in flexible PVC compound applications. The design of an effective and economic compound relies on careful selection of components to achieve the correct balance of reaction to fire and smoke emission.

UltraCarb is particularly beneficial in fire retardant low smoke formulations.

Appendix

PVC and PVC plasticisers used in cable compounds

Component	Options	Comments
PVC	K- value. Lower = easier processing, higher = better mechanical properties.	K = 70 is the most common type for wire & cable. Good compromise between easy processing and mechanical properties.
Primary plasticiser	DOP (di-octyl-phthalate) (also known as DEHP (3-6 carbon low molecular weight plasticiser, also in the sale group one can find DIBP, BBP, DBP, DEP).	Low molecular weight, cheapest orthophthalate option but under suspicion by REACH as potential carcinogen and will be phased out in the EU by February 2015 <http://www.plasticisers.org/plasticisers/low-phthalates>
	DINP (di-iso-nonyl-phthalate) or DIDP (dioso-decyl-pthalate) (7-13 carbon high m.w. plasticiser, also in the same group one can find DPHP, DIDC, DIUP).	High molecular weight and less volatile than DOP and the most common replacement for DOP. But, DINP and DIDP are sometimes not allowed in food packaging and children's toys. However the EU published in Feb 2014 "DINP and DIDP are safe in all current consumer applications" <http://www.plasticisers.org/media/90/58/DINP-and-DIDP-are-safe-in-all-currentconsumer-applications> (Generally give better heat resistance and are suitable for higher temperature applications).
	TOTM (Tris (2-Ethylexyl) Trimellitate).	Used in applications where extremely low volatility of the plasticiser is of supreme importance. e.g. some wire & cable applications and automotive interiors. Good ageing properties. Their higher viscosity and poorer fusion compared to high phthalates make them more difficult to dry-blend (compounding) and process.
Secondary plasticiser (also known as extenders)	Chlorinated paraffin (ca. 40 - 50% Cl), e.g Cereclor S52 (also soyabean oil, epoxidised linseed oil ELO. They act as lubricants as well).	Price optimization. Good electrical properties, less flammable, works well with antimony trioxide. Negative effect on thermal and photo-stability and cold resistance.
	Phosphate esters e.g. Santicizer 148 (better smoke/low temperature/compatibility performance than phthalates).	Sometimes referred to as a fire retardant plasticiser. More expensive, but work well with antimony trioxide. Can be used as oneto-one replacement for DOP or DINP or in combination.
	CPE (chlorinated PE), EVA.	Better resistance to oil.
	Brominated phthalate (e.g. tetrabromophthalate ester) DP45 from Great Lakes.	Can also be used as a secondary or primary plasticiser and works well in combinartion with antimony trioxide.
	Specialty plasticisers.	Sebacates/adipates/azelates like DOS, DOZ, DIDS. Good low temperature performance.

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We develop sustainable mineral solutions in partnership with our customers, supplying natural minerals engineered for functionality and usability.

LKAB Minerals is part of the Swedish company LKAB, one of the world's leading producers of highly upgraded iron ore products and other related mining services and products.

Value-driven
We are proud and passionate about what we do – this is reflected in our values Committed, Innovative and Responsible.

Learn more at lkabminerals.com

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