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Spin–off Company of
Italian National Research Council (CNR)

Flame-Retardant Formulations for PVC Cables: Performance, Stability, Sustainability

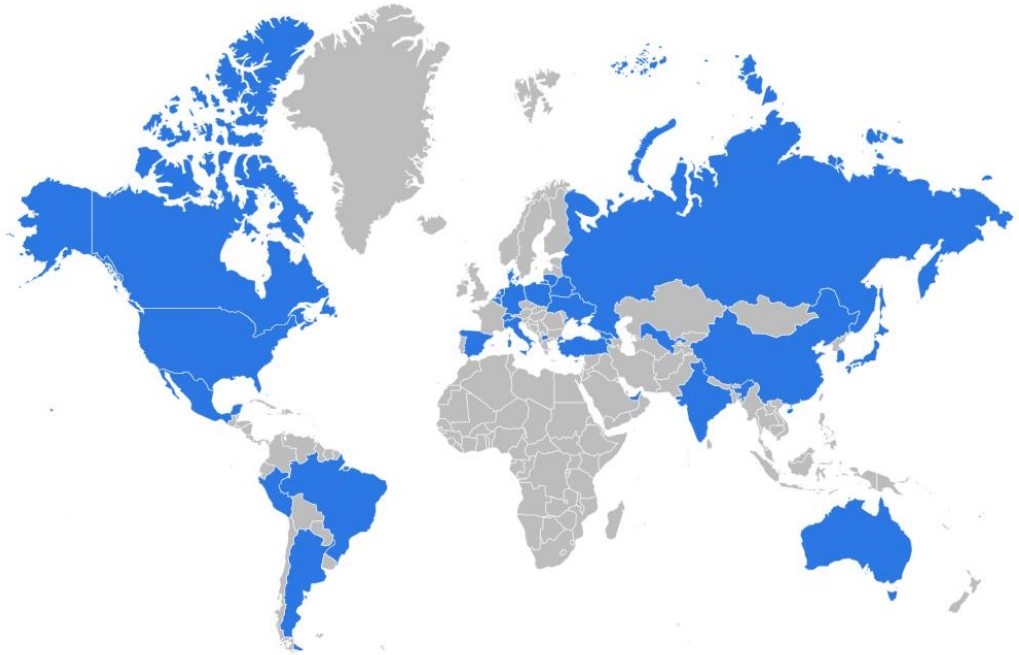
FUTURE OF PVC 2026
11-12 March 2026 Mainz, Germany

https://www.ipoolsrl.com/materiali
materiali@i-pool.it

IPOOL's Company profile

IPOOL is specialized in:

- **Cable technology** and other materials such as **ACP composite panels**, **TPO/PVC/bitumen roofing membranes**, **pipes**, and **rubbers**
- **Formulation expertise** in polymers, fillers, and additives for PVC and HFFR compounds
- **Processing equipment**, including twin-screw extruders, single-screw extruders, and BUSS co-kneader
- **Laboratory solutions** for R&D and quality control
- **Strategic support** for product marketing and additive development

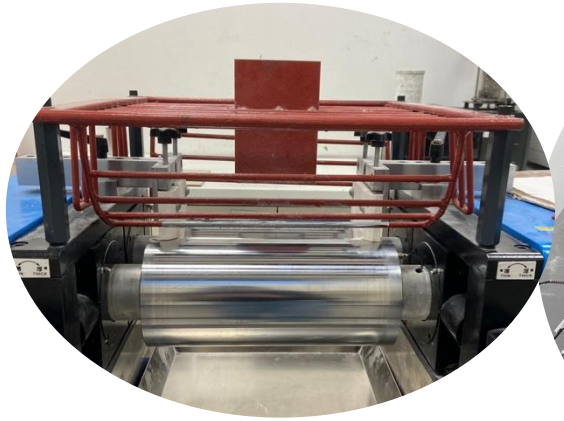


10 YEARS ANNIVERSARY
JULY 2012-2022

SYSTEM CERTIFICATION STANDARD SGS

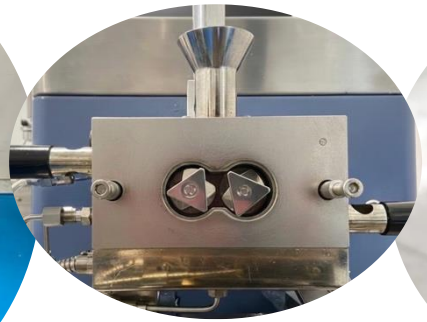
R&D – Technology company, Spin-Off company of Italian National Council of Research institute (CNR), established on July 2011 in Pisa (ITALY).

IPOOL's Equipment and instruments



Twin Roll Mixer

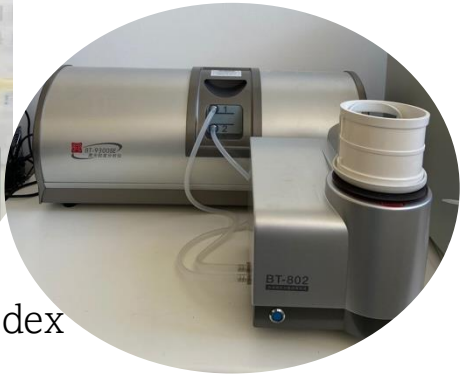
BUSS co-kneader extruder



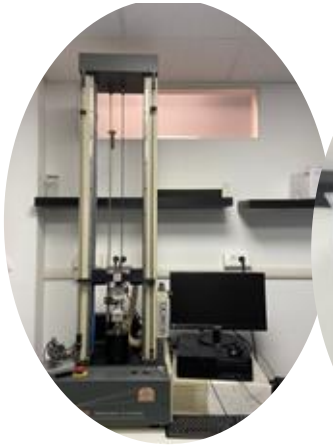
Plastograph

Single screw extruder

Limiting Oxygen Index



Particle Size Distribution



Dynamometer

FT-IR

DSC

TGA

Melt Flow Index

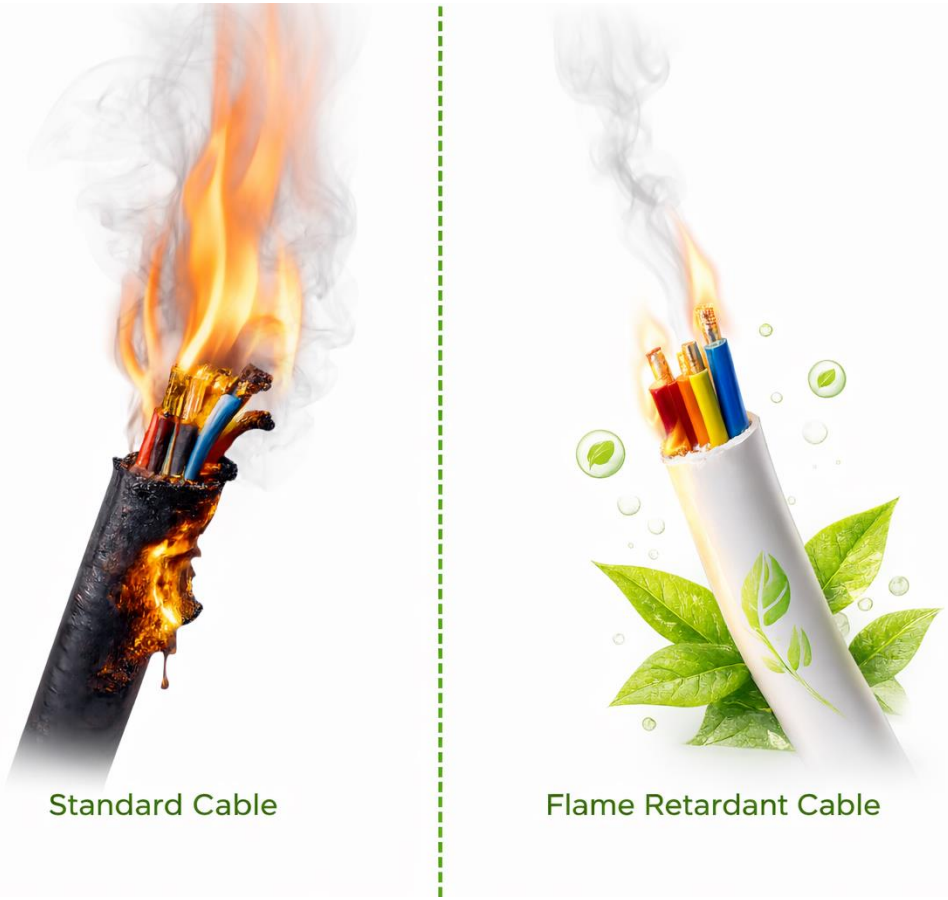
IZOD impact test

Hardness Shore A and D

Hot press

Content

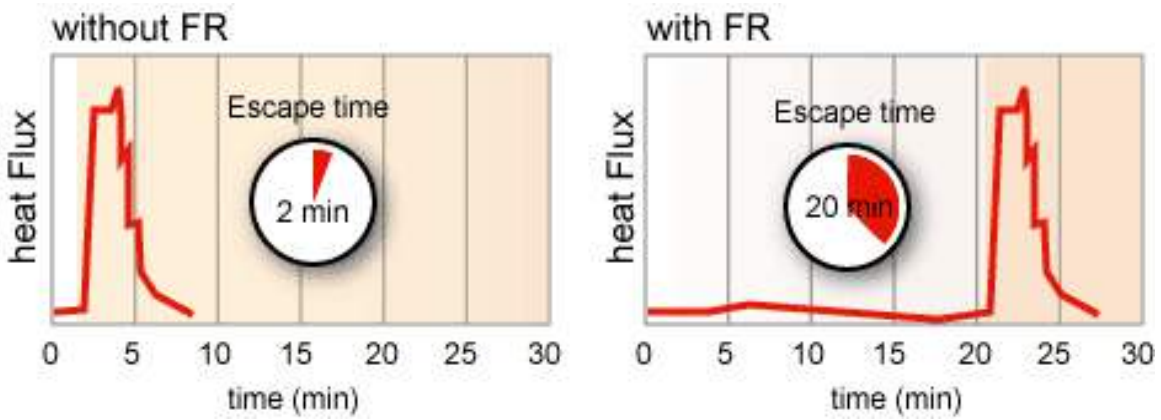
- Flame retardant plasticised PVC formulation
- Actions for Smoke suppressions
- New class of bio-plasticizers
- Essechlor 70 as additive
- CPVC a new resin?
- Compounding with BUSS MX-30
- Red P MB, an alternative to ATO?



Main compounded materials for cables

Flame retardant features:

- ✓ Self-extinguish behaviour
- ✓ Delay of ignition
- ✓ Smoke suppression
- ✓ Fire spread prevention



Polymers	Insulation	Bedding	Sheathing
XLPE/X-EPR	X		
PVC	X	X	X
HFFR	X	X	X
XL-HFFR	X		X
CPE			X

Increasing demand of flame-retardant materials ⇨ Global <u>competition</u> between **halogenated** and **halogen-free materials**

Comparative behaviour of main base polymers in fire

Polymer	Description	Self-ignition T (°C)	Heat of combustion (MJ/g)	LOI (%)	Flame spread	Tendency to drip	Smoke release
EVA	Poly(ethylene-vinyl acetate)	320	38-42	<20	High	Medium	Medium
EPR/EPDM	Ethylene-Propylene rubber	350	44	<20	High	Medium	Medium
PE/POE/PP	Polyethylene, Polypropylene and related plastomers	350	44	<20	High	High	Medium
CPE	Chlorinated polyethylene	400	30-35	22-24	Low	No	High
u-PVC	Polyvinyl chloride	450	<20	42	Low	No	High
p-PVC	Plasticised Polyvinyl chloride	250-300	25-30	23	Low	No	High
c-PVC	Chlorinated Polyvinyl chloride	480	15-17	60	Low	No	Low

Strengths of PVC

- ✓ Cost effective
- ✓ High flame retardancy properties (LOI)
- ✓ No dripping (CPR "d_0")
- ✓ Very low tendency to spread flame in case of fire

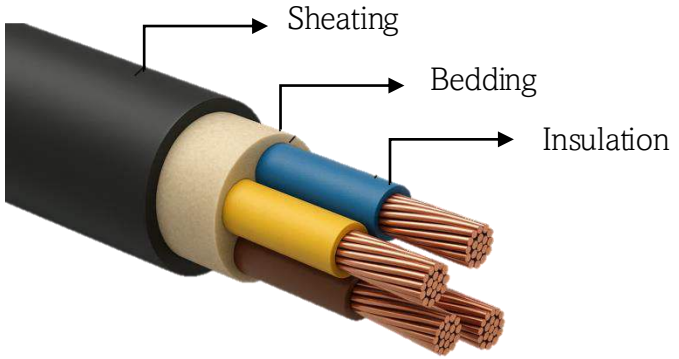
Weak points of PVC

- X Dense smokes released
- X Flammability of the plasticizer

Strategies for a safe PVC cable

Demands of material properties in case of fire:

1. Low flammability and flame spread.
2. Low smoke emission and smoke's toxicity.
3. Low acidity/corrosivity of emitted gas.
4. Char-forming and antidripping



PVC formulation for cable	phr
PVC resin	
Plasticizer	
Fillers	0-160
FR Additives (ATO)	3-10
Stabilizer	5

Sb_2O_3 under pressure for shortage, price and safety (suspected of causing cancer)

Multiple actions necessary:

- Removal of traditional ingredients producing s Sb_2O_3 - ATO)
- ses of plasticisers with less flame retardancy
- Increase content of minerals acting as flame retardant, HCl scavenger, smoke suppressant, char forming and antidripping
- **Use of alternatives to "dangerous" ingredients**

…but without losing the traditional advantages of PVC:

✓ High speed of production
✓ Low formulation cost

Content

IPOOL also collaborates with **PVC4Cables**, the ECVM platform dedicated to the PVC cable value chain.

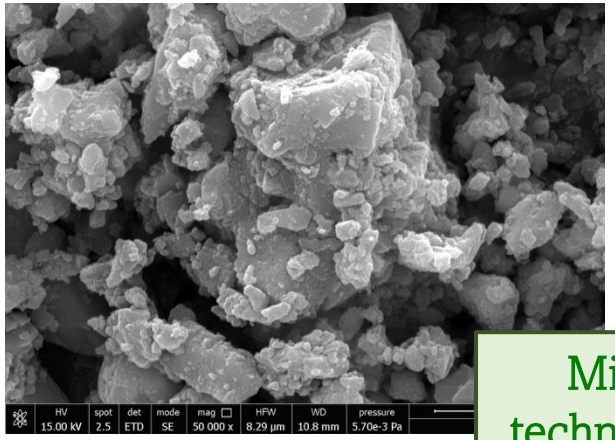
Replacement of Antimony Trioxide (Sb_2O_3) in PVC Formulations

Actions for a safer cable:

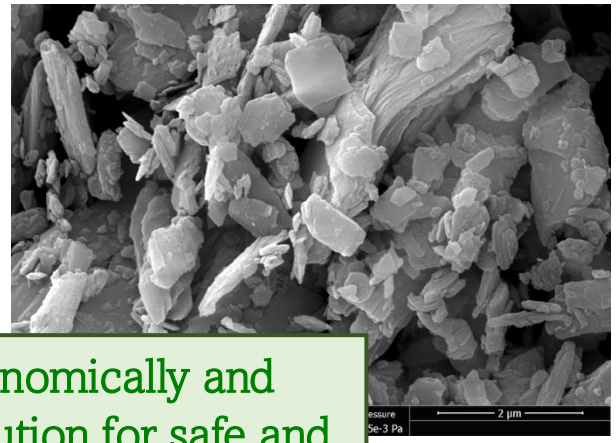
- Use of natural minerals
- New class of bio-plasticizers
- Use of alternative additives

Strategies for a safe PVC cable – *FILLERS*

- Increase content of minerals acting as flame retardant, HCl scavenger and smoke suppressant

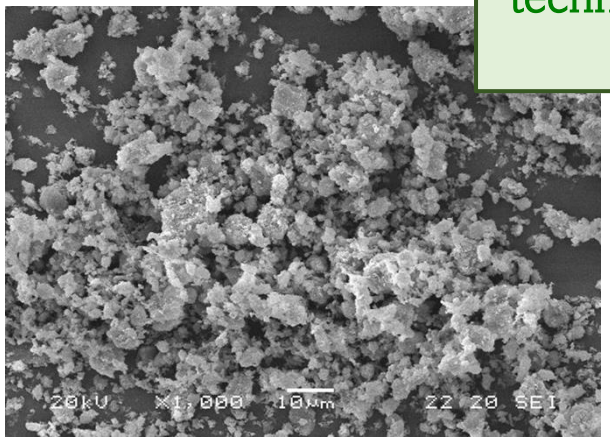


Ground $CaCO_3$ (GCC)



Natural $Mg(OH)_2$ (MDH)

Mineral fillers are the economically and technically most suitable solution for safe and green materials.



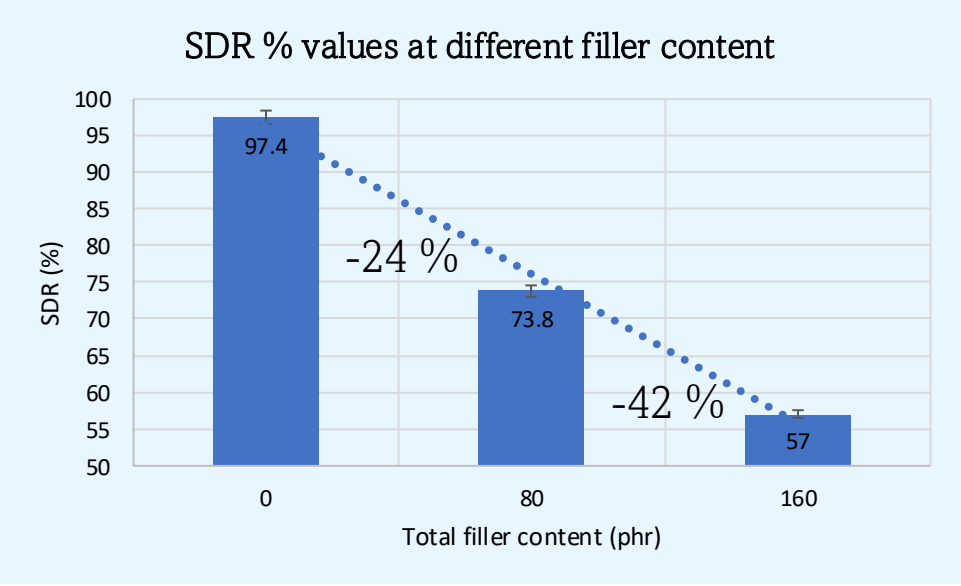
$MgCO_3$

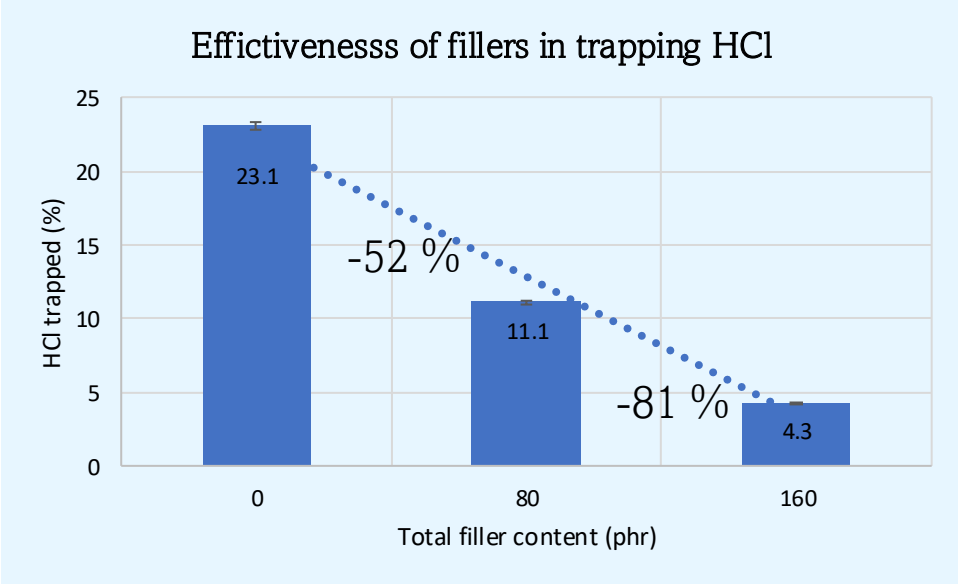
$Al(OH)_3$ (ATH)

Smoke density and acidity reductions

ASTM-D2843	*0 phr fillers*	*80 (40-40) phr fillers*	*160 (80-80) phr fillers*
Smokes Density (%SDR)	97,4	73,8	57

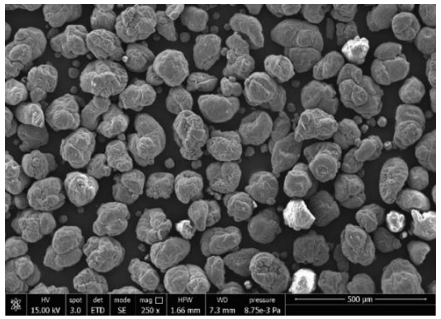
IEC-60754-1	0 phr *fillers*	80 (40-40) phr *fillers*	160 (80-80) *phr fillers*
HCl released (%wt/wt)	23,1	11,1	4,3

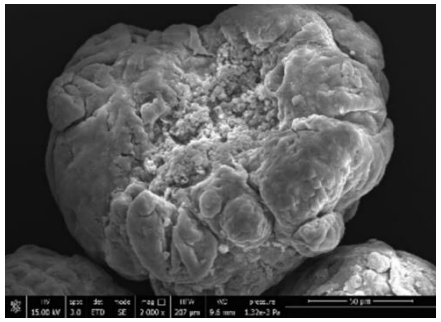




Strategies for a safe PVC cable – *PLASTICIZERS*

PVC RESIN

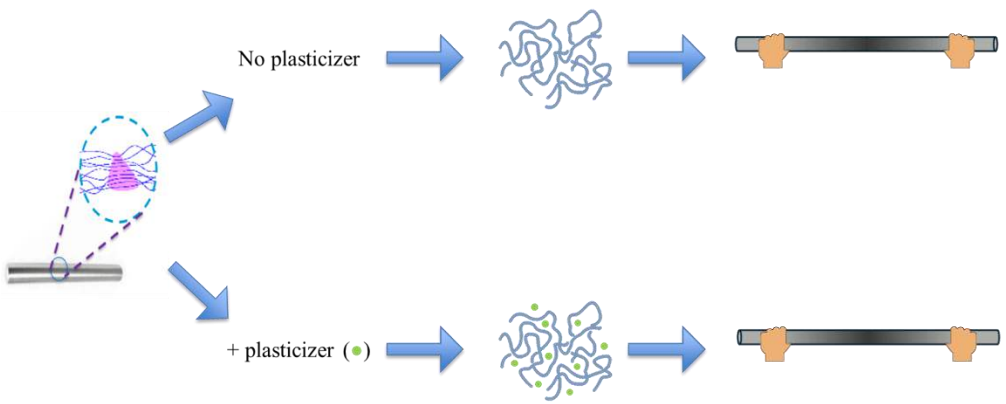




PRIMARY PLASTICIZER:

Main plasticizer, lowering Tg

Flexibility to the final cable



SECONDARY PLASTICIZER:

Use of non burnable plasticizers: FR

Chlorinated paraffins (CP52)
Brominated plasticizers
Phosphorous plasticizers

Alternative from BIO-ORIGIN
ESSEBIOCHLOR HV

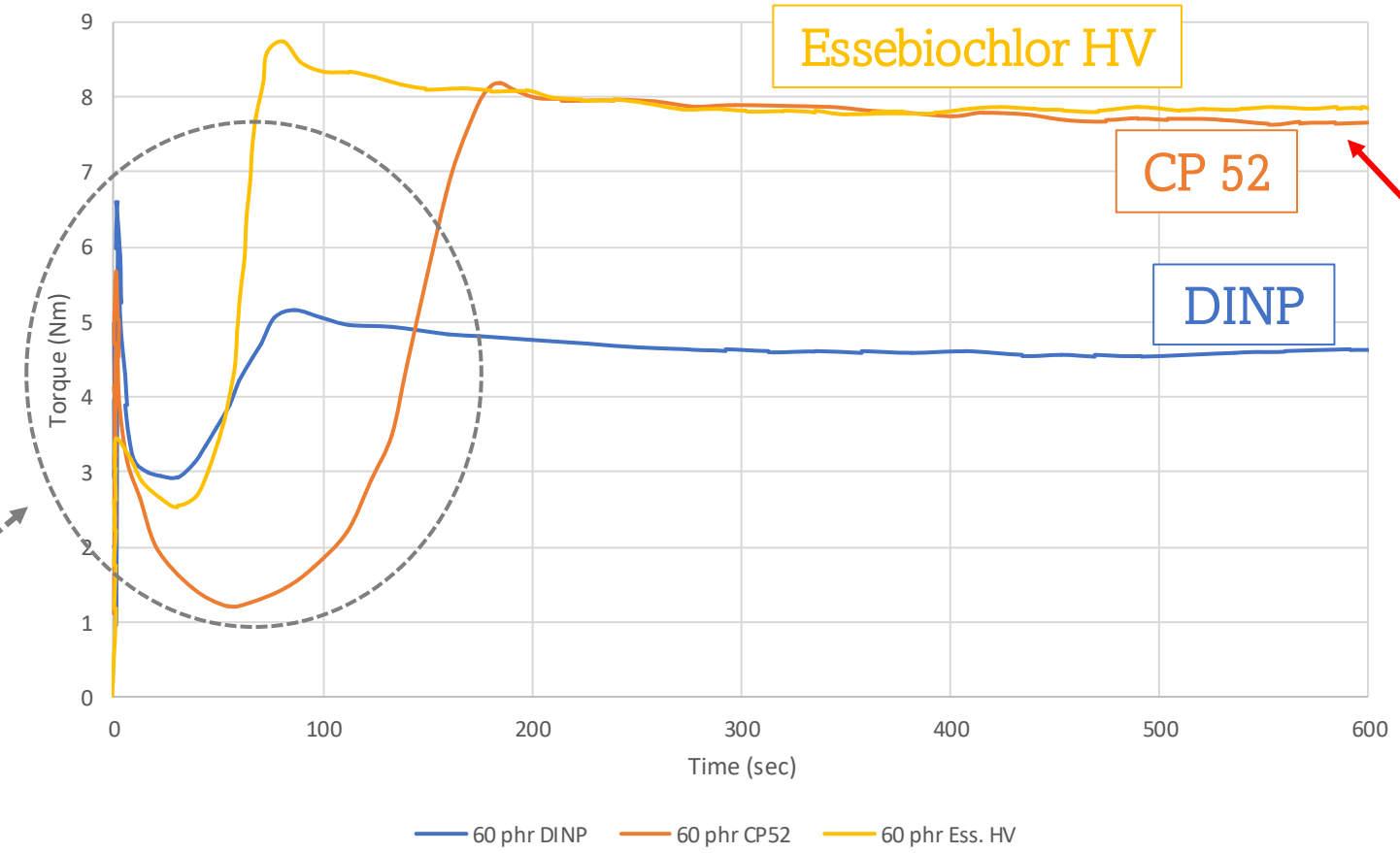
ALTAIR CHEMICAL

Essebiochlor HV

- It is NOT chlorinated paraffin
- It is chlorinated ester of bio-origin
- It has plasticizing efficiency as traditional chlorinated paraffin
- It is more compatible than CP with PVC
- There is low risk of migration in combination with primary plasticizers
- Much less volatile than CP in plasticized PVC compounds
- It is flame retardant
- Its thermal stability is similar to CP52 (but slightly lower)
- It is REACH registered and accepted in any standard
- It is sustainable and cost competitive

Plasticizer efficiency – Rheological measurments

Brabender plastograph conditions:
T=150 °C and 30 rpm.



Higher dosage of chlorine content gives higher **torque** and viscosity

The Essebiochlor gives **faster fusion** in comparison to CP52

ATO replacement with Essebiochlor HV

	A	B	C	D
PVC k70	100	100	100	100
DINP plasticizer	50	50	30	30
Essebiochlor HV from Altair			20	20
Antimony trioxide (ATO)		5	1	
Coated natural Magnesium Di Hydroxide (MDH)	40	40	40	40
Stearic coated Calcium Carbonate ($CaCO_3$)	40	40	40	40
Zinc Borate (ZB)	4	4	4	4
Ca/Zn stabilizer	5	5	5	5
Total	*240*	*244*	*240*	*239*
Properties				
Density (g/cm^3)[a] ± 0,001	1,511	1,526	1,566	1,544
LOI ($\%O_2$)[b] ± 0,5	26	33	33	30
Thermal stability (min)[c] ± 3	52	55	45	36

[a]ASTM D792; [b]ASTM D2863; [c]ISO 182-1

✓ Very good flame retardancy

✗ Lower thermal stability

Not easy to achieve the same results of ATO

Alternatives are under study

Chlorinated solid paraffin wax (CP70)
Zinc salts (ZHS, ZnO etc)
Red Phosphorous
Nanoadditives
And others……

Strategies for a safe PVC cable – *RESIN*

Total or partial substitution of PVC K70

- PVC K80
- PVC K90
- PVC K100

↓

Higher K value
↓
higher filler dosage

- Solid Chlorinated Paraffin (CP70)
- Chlorinated PVC (C-PVC)
- Chlorinated PE (CPE)

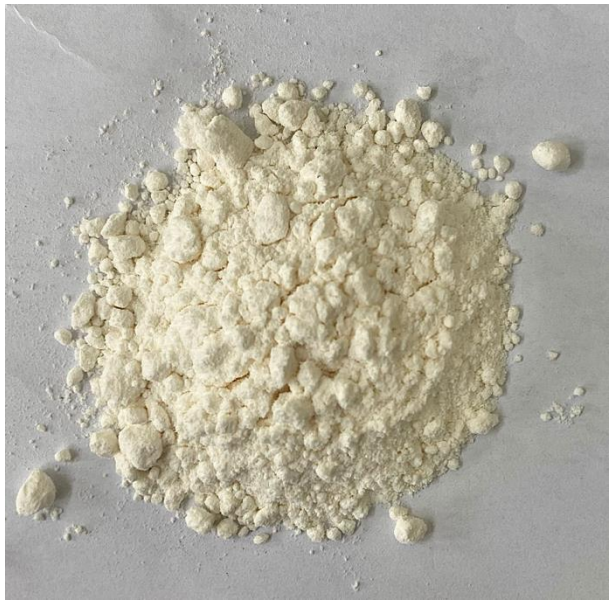
↓

Cl content > 56%
↓
Less smokes during combustion

Essechlor 70

Is a solid chlorinated paraffin wax (C_{22}-C_{30}) distributed by ALTAIR CHEMICAL:

- chlorine content is usually around 70% by weight
- Insoluble in water, glycerine, lower alcohols
- soluble in mineral oil, aromatics, chlorinated alkanes, and esters
- Low volatility
- Softening point > 80°C
- white or light yellow powder (or particle)
- Odorless
- Good chemical stability (decomposition occurs >250°C)



Not hazourds and not banned because it's solid not like MCCP (C_{14}-C_{17}) or LCCP (C_{18}-C_{28})

Essechlor 70

	E	F
PVC k70	100	100
Essechlor 70 from Altair		**15**
DINP plasticizer	30	30
Essebiochlor HV from Altair	20	20
Coated natural Magnesium Di Hydroxide(MDH)	40	40
Stearic coated Calcium Carbonate ($CaCO_3$)	40	40
Zinc Borate (ZB)	4	4
Ca/Zn stabilizer	5	5
Total	*239*	*239*
% Cl	26,5	27
Density (g/cm^3)[a]	1,544	1,583
LOI ($\%O_2$)[b]	**30**	32
Tensile Strength (MPa)	15,5	12,4
Elongation at break (%)	164	166
SDR (%)[c]	74	74
Thermal stability (min)[d]	36	39

[a]ASTM D792; [b]ASTM D2863; [c]ASTM D2843; [d]ISO 182-1

Introduction of Essechlor 70 at only 15 phr allows you to get 2 point of LOI without bad effects on smokes' density

Next steps:
Increase Essechlor 70 content being careful in avoiding migration problems

Strategies for a safe PVC cable – *RESIN*

Total or partial substitution of PVC K70

- PVC K80
- PVC K90
- PVC K100

↓

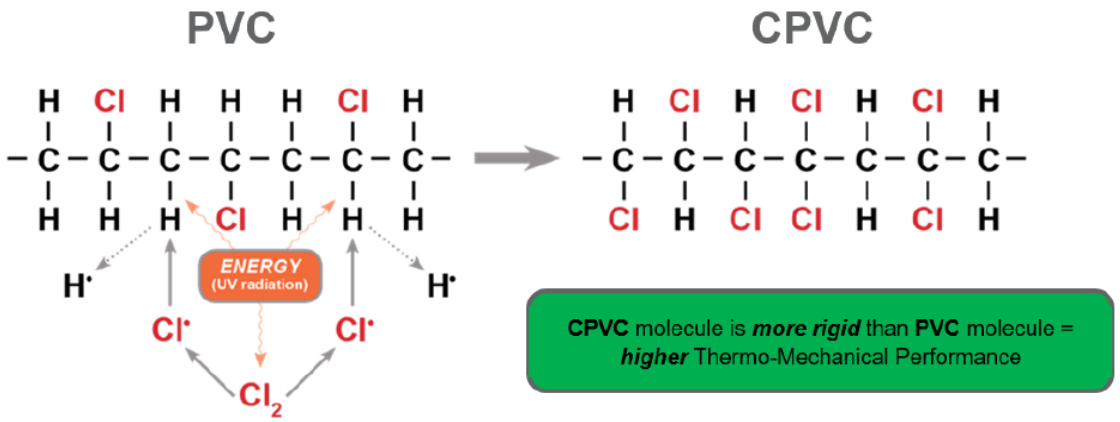
Higher K value
↓
higher filler dosage

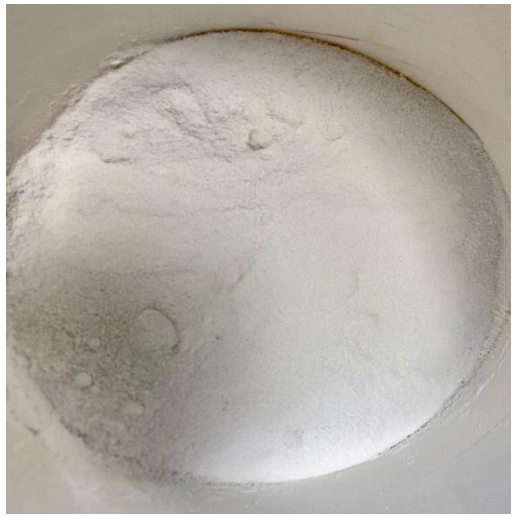
- Solid Chlorinated Paraffin (CP70)
- Chlorinated PVC (C-PVC)
- Chlorinated PE (CPE)

↓

Higher Cl content
↓
Less smokes during combustion

CPVC resin





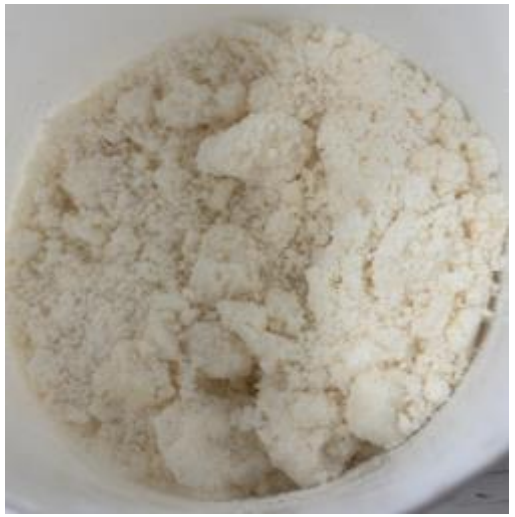
PVC

PVC: 56% of Cl

C-PVC: 65-67% of Cl

More content of chlorine

Resin difficult to plasticize by dry blending



CPVC

*Thanks to Lubrizol Advanced Materials for the info showed: https://www.lubrizol.com/

Compounding line: BUSS MX-30

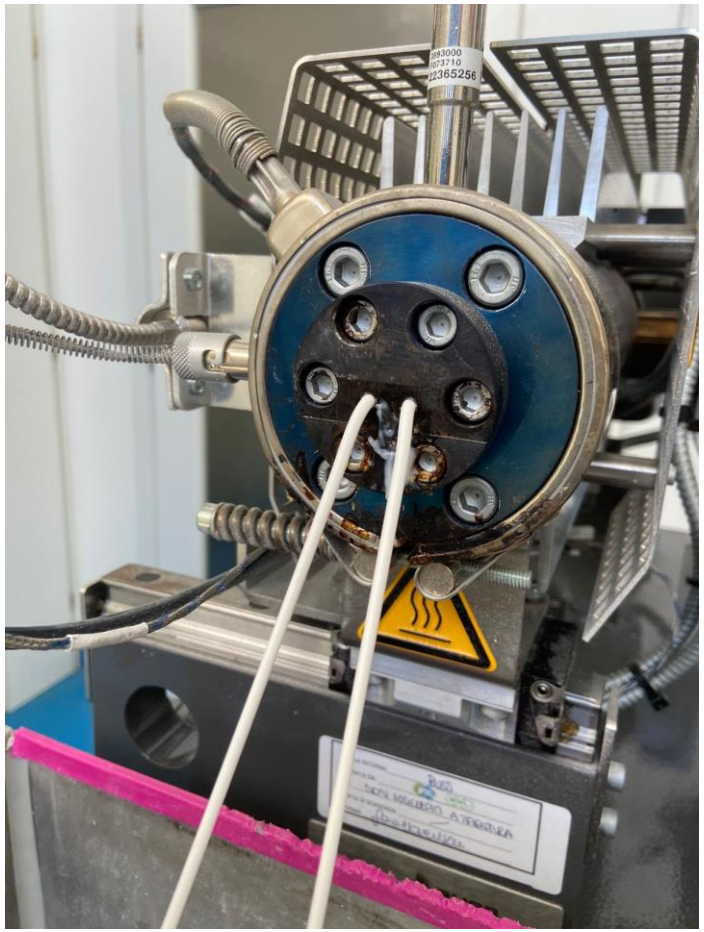
NEW BUSS Laboratory Kneader MX 30 is a compact small-scale compounding line for

- research and development,
- process optimization,
- customer sampling.

It is especially suitable for the **development of highly filled** and **heat/shear-sensitive compounds**.

- laboratory-scale throughput rates from 5 to 25 kg/h.

Thanks to the modular processing zone of the MX 30, all production process conditions can be precisely emulated. The split barrel design enables not only optimal access to all process parts, but also visual assessment of all individual steps along the processing zone.



CPVC compound ATO FREE

Properties	PVC+ ATO COMPOUND	CPVC COMPOUND	NON FR-PVC COMPOUND
Density (g/cm^3)[a]	1,568	1,515	1,534
LOI (O_2%) [b]	32	31	25
Hardness ShA[c]	89	85	88
Hardness ShD[c]	39	37	39
Smoke density (%) [d]	>75	<40	65
Thermal stability (min) [e]	85	>90	78
Tensile Strength (MPa)	13,4	15,3	13,6
Elongation at break (%)	166	168	170

CPVC has:
- Same performances of PVC formulation + ATO in terms of flame retardancy
- Exhibits by far the lowest dense smoke values
- Higher thermal stability

[a]ASTM D792; [b]ASTM D2863; [c]ASTM D2240; [d]ASTM D2843; [e]ISO 182-1

Strategies for a safe PVC cable – *MB Red P*

	L	M	N
PVC resin	100	100	100
DINP (plasticizer)	50	50	35
Essebiochlor HV			15
Ecopiren 3.5C (n-MDH)	40	40	40
Coated $CaCO_3$	40	40	40
Antimony Trioxide (ATO)	5		
Masteret 40460 by Italmatch		12	12
Stab. Ca/Zn	5	5	5
TOTAL	*238*	*247*	*247*
Properties			
Density (g/cm^3)[a]	1,514	1,503	1,524
LOI (O_2%) [b]	30	29	31
Hardness ShA[c]	89	88	89
Tensile Strength (MPa)	13,4	12,3	12,6
Elongation at break (%)	166	167	147
Thermal stability (min) [e]	60	53	35

Red P MB:

- Same performances of 5 phr of ATO
- When there is also the FR secondary plasticizer Essebiochlor HV the LOI is even higher!

Italmatch Chemicals

Summing up

- We developed PVC formulations for electrical cables with low smoke and acidity emissions. As the content of natural milled MDH or ATH increases, better results in terms of flame retardancy such as smoke emissions and limited oxygen index (LOI) are obtained. As the filler content increases, lower acidity of the smokes and a lower smoke density are obtained.
- The use of innovative chlorinated bio-ester as secondary plasticizer contributed to increase LOI values without dramatic increases of smoke release, by providing a sustainable and green alternative to chlorinated paraffins.
- The addition of CP70 gives benefits in terms of flame retardancy and smoke suppression
- By using a CPVC-based resin at laboratory level, we have got nice LOI values without using any ATO, and extremely low smoke emissions: this is an incentive for future developments in terms of low-smoke flame-retardant cable compounds.
- The use of MB of Red P gives very promising results with the aim of removing ATO from formulations

Spin–off Company of
Italian National Research Council (CNR)

Thanks for your attention

FUTURE OF PVC 2026
11-12 March 2026 Mainz, Germany

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