PVC 4 CABLES

PVC CABLES STANDARDS IN EUROPE AND BEYOND

Camillo Cardelli
Senior Researcher &
Co-Founder, iPOOL

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www.ipoolsrl.com

an ecvm platform

PVC CABLES

ABOUT IPOOL

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

IPOOL, working in international projects from Europe to Middle East, from Russia to Asia, from Northern to Southern America, is technical specialist in **cables**, **ACP composite panels**, **TPO/PVC/bitumen roofing** membranes, **pipes** and **rubbers**.

- Flame retardant fillers for PVC and halogen free compounds
- Design and testing of new additives for compounds
- Cost and performances optimisation of PVC and HFFR compounds.
- Equipment for compounding: twin screw extruders, co-kneaders, internal mixers, …
- Optimization of extrusion of insulation and sheathing compounds
- Laboratory testing equipment for R&D and QC
- Selection and training of technical people for R&D activities (experimental thesis)
- Design of marketing strategy for new products and new additives

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DYNAMISM OF THE MATERIALS FOR CABLES

- HFFR are constantly evolving and are the subject of R&D projects by hundreds of companies worldwide, involving also academic centers.
- The development of new PVC formulas has been carried out by only a few people and associations (PVC4Cables)
- PVC evolution mostly/only driven by “cost saving” target
- Perception of PVC as mature, almost “obsolete” material
- European cable manufacturers are more or less resigned to the decline of PVC (and this feeling is also spreading outside the European borders….)

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NORMS OF CABLES

	Europe	USA	India	Middle East	Russia
Standards	EN 50399 (Common test methods for cables under fire conditions), IEC 60332 (Tests on electric and optical fiber cables under fire conditions).	NFPA 70 (National Electrical Code), NFPA 262 (Plenum cables)	IS 10810 (Methods of Test for Cables), IS 1554 (PVC Cables), IS 7098 (XLPE Cables).	Similar to European standards (IEC 60332, EN 50399)	GOST R 53315 (Fire Safety of Cables), GOST 31565-2012 (Fire Safety Requirements).
Tests	EN 50265/IEC 60332-1-2 (Test for vertical flame propagation), EN 50399 (Heat release and smoke production).	UL 1666 (Riser cables. Standard for Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts) UL 1685 (Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables).		Local regulations may incorporate or adapt European standards like BS EN 50200 (integrity under fire conditions), BS 6387 for fire performance (circuit integrity).	Tests: like European IEC standards, including flame propagation and smoke release tests. GOST IEC 60332-1-2 GOST IEC 60332-3-22 (Tests on electric and optical fiber cables under fire conditions, Cat A).
		UL 1581 (Test for vertical and horizontal flame propagation of a single cable).	IS 10810-53 (Vertical flame propagation of a single cable), IS 10810-62 Temperature Index Test of cable materials		Toxicity of the cable is calculated by combining the toxicity of each material.
Cables Used	Predominantly HFFR cables, especially in public and high-risk buildings, due to stringent fire and smoke emission standards.	Both PVC and HFFR (Halogen-Free Flame Retardant) cables are used	PVC is more common due to cost considerations, but there is an increasing use of HFFR cables	Both PVC and HFFR, with HFFR becoming more common in newer constructions	PVC is prevalent, HFFR is used in applications where higher fire safety is required.

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SAFETY OF CABLES

- Flame propagation through the cable ⇒ **crucial for HF**
- Heat Release ⇒ **crucial for HFFR**
- Dripping of flaming material ⇒ **crucial for HFFR**
- Smoke density ⇒ **crucial for PVC**
- HCl / acid / corrosive gases emission ⇒ **Irrelevant, misleading**
- Emission of toxic and asphyxiant gases ⇒ **Next battleground**

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FIRE TESTS ON FINAL CABLES: COMPARISON

	NFPA 262 (Plenum Cables)	UL 1666 (Riser Cables)	UL 1685 Vertical Tray Test	EN 50399 (CPR)	IEC 60332-3 ("Bundle Test")
Way of mounting	Horizontal	Vertical	vertical	vertical	vertical
Sample length, m	7.3	5.33	2.44	3.5	3.5
Way of mounting	One layer covering the width of the tray (286 mm)	One layer covering the width of the tray (305 mm) (generally 3 cables)	One layer spaced 0.5 cable diameter apart (300 mm)	One layer with a gap	One or several layers, depending on required fuel mass. Cat A: 7 l/m - Cat C:1.5 l/m
Gap between cables	No	No	Yes	Yes	Both
Flame application time, min	20	30	20	20	40 (Cat A) - 20 (Cat C)
Flame spread, m	< 1.52	< 3.66	< 2.44	< 1.75 (cat B1ca) < 1.5 (cat B2ca) < 2 (cat Cca)	< 2.5
Burner	Methane burner	Propane ribbon burner	Propane ribbon burner	Propane ribbon burner	Propane ribbon burner
Burner power, kW	86	154.5	20.6	30 (cat B1) 20.5 (cat. B2, C, D)	20.5+-0.5
Airflow, m3/min	0.17 m/s	3.5 m/s	0.65	1.0	5
Additional parameters	Smoke Density (Average SD ≤0.15, peak SRR≤0.5)		Smoke density SD, peak SRR (TSR ≤95 m2, peak SRR 0.25 m2/s)	Heat and Smoke Release (THR, peak THR, FIGRA, TSP, peak SPR) Dripping, Acidity (on materials)	-
Cable types	Data communication cables (PVC only, the majority of Cat 5 or Cat 6)	Data communication cables (PVC)	All building cables, HFFR and PVC	Building wires, Solar cables	All building cables, HFFR and PVC

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FIRE TESTS ON COMPOUNDS FOR CABLES

	Europe	USA	India	Middle East	Russia
Flame Retardancy	LOI, UL-94 ISO5660 (Cone Calorimeter)	UL 94: Standard for Safety of Flammability of Plastic Materials for Parts in Devices and Appliances.	IS 694: General requirements for PVC+HFFR materials for cables: LOI IS 10810-58 and Temperature Index Test IS 10810-62	LOI, UL-94	GOST R 12.1.044-89: LOI, V-rating
Smoke Release	**ASTM E662: Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials.**	**ASTM E662: Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials.**	**ASTM D2863**		**GOST R 12.1.044-89: Method of determination of Smoke Release of solid materials**
	ISO5660 (Cone Calorimeter)	**NFPA 258: Smoke Generation of Solids**			
Smoke Acidity	EN 50267: Methods of test for corrosive gases in smoke.	UL 2556: Wire and Cable Test Methods, including acidity tests as part of material analysis.	IS 10810-61 (Determination of corrosivity of combustion gases from cables).	EN 50267: Typically follows European standards.	GOST IEC 60754: Evolved halogen acid gas from combustion of cables.
	IEC 60754: halogen acid content in smoke.	ASTM E2074: Method for Smoke Acidity.			
	Low Acidity: Polymer materials must emit minimal acidic gases during combustion to prevent corrosion and harm to occupants.	Acidity Testing: Focuses on the corrosive effects of smoke produced by burning polymer materials on human health and surrounding materials.	Acidity Testing: Ensures that the polymer materials used in cables do not produce corrosive gases.	Low Acidity: Required for polymer materials used in critical or enclosed environments.	Acidity Limits: Ensures that polymer materials produce minimal acidic gases, reducing corrosion risks.
Smoke Toxicity	EN 50305: Railway applications, specifies smoke toxicity limits. p.9.2 (Apparatus - EN 50267-1) NES 713 for naval ships cables	NFPA 270: Test Method for Smoke Toxicity) ASTM E1678: Test Method for Measuring Smoke Toxicity for fire scenarios (involves animals)	IS 10810-60: Toxicity Index by analysis of emitted gases: CO, HCl, HCN, NH3, SO2, NOx,…)	EN 50305: Typically follows European standards.	GOST R 12.1.044-89: Toxicity tests for fire hazard.
	Method: calculative	Calculative and it could also involve animals	Method: calculative	Method: calculative	Conducted on animals
	Low Toxicity: Polymer materials must release minimal toxic gases, particularly for use in enclosed or public spaces.	Toxicity Testing: Assesses the levels of harmful gases like carbon monoxide (CO), hydrogen cyanide (HCN), and others released by burning polymer materials.	Toxicity Testing: Ensures that polymer materials used in cables do not release excessive toxic gases during combustion.	Low Toxicity: materials must meet strict toxicity limits, particularly in high-risk or public areas.	Toxicity Limits: Polymer materials must release minimal toxic gases during combustion.

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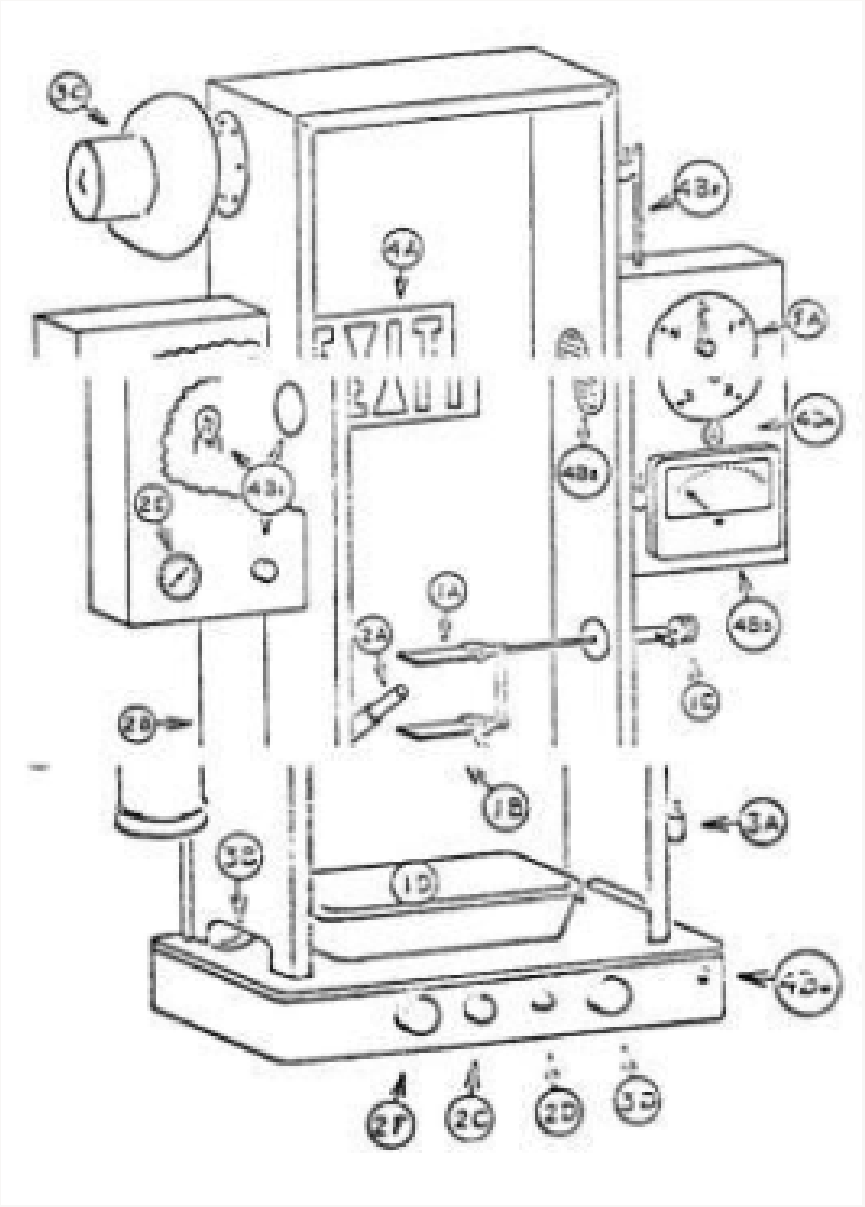
INDIA

- **Cable Type**: **PVC cables** are widely used due to their cost-effectiveness, although there is growing interest in **HFFR cables** for environments where fire safety is critical (e.g., metro projects, public buildings).
- Limitation of HCl emission is just <18%, not so stringent
- Fire safety of PVC cables is increased by adopting FR LS (= Flame-Retardant Low-Smoke) PVC with specific **LOI value >29** (measured collecting material from cable) and limitation into emission of smokes: **<60% smoke density as per ASTM D 2843**



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FIRE SAFETY OF PVC AND HFFR CABLES (2022-2023)

CPR
EN 50399

Sheathing type	Std FR PVC	FRLS PVC	FRLS PVC4Cables	Std HFFR	Special HFFR
Cable	**FG160R16 5G1.5**	**N2XH-0 5*1.5**	**FG16OR16 5*1,5**	**N2XH-0 5*1.5**	**N2XH-0 5*1.5**
FS, m	**1,06**	**1,07**	**1,00**	**1,95**	**0,77**
Burning droplets	none	none	none	none	none
Peak HRR, kW	**27,6**	**29,8**	**29,9**	**42,3**	**22,6**
THR 1200s, MJ	10,7	10,1	6,6	26	10,5
Peak SPR, m^2/sec	0,85	0,26	0,12	0,08	0,05
TSP 1200s, m^2	278,4	75,2	37,3	43,7	22,7
FIGRA, W/s	80,3	139,7	92,9	97,3	45,7
Classification	**$B2_{ca}$ d_0 s_2**	**$B2_{ca}$ d_0 s_2**	**$B2_{ca}$ d_0 s_1**	**C_{ca} d_0 s_1**	**$B2_{ca}$ d_0 s_1**

PVC4CABLES

CONCLUSION OF PREVIOUS WORK

- Innovative PVC4cables compounds gave an excellent final cable in terms of low smokes ($\mathbf{B_{ca}}$ $\mathbf{d_0}$ $\mathbf{s_{1b}}$) and also emission of the killer gas CO. Reduction of smoke density is closely correlated with low CO production. In other words: **Low smokes = Low CO emission = Low Toxicity.**
- Emission of CO from FRLS PVC cables during burning is fast and immediate, and almost zero after in the 2nd half of test; on the opposite, HFFR cables release CO more gradually, almost linearly during the fire test with higher release at the end of the test.
- Very good cables in terms of safety (=low smokes, low HRR, low CO emission, no dripping, low flame spread) are the result of competition between **special PVC compounds** ($\mathbf{B2_{ca}}$ $\mathbf{d_0}$ $\mathbf{s_{1b}}$ $\mathbf{a_3}$) and **special HFFR compounds** ($\mathbf{B2_{ca}}$ $\mathbf{d_0}$ $\mathbf{s_{1a}}$ $\mathbf{a_1}$).
- Letter “a” is not related to toxicity or safety of the cable, but just to differentiate HF from PVC.

⇒ PVC and HFFR cables offer the same safety in case of fire

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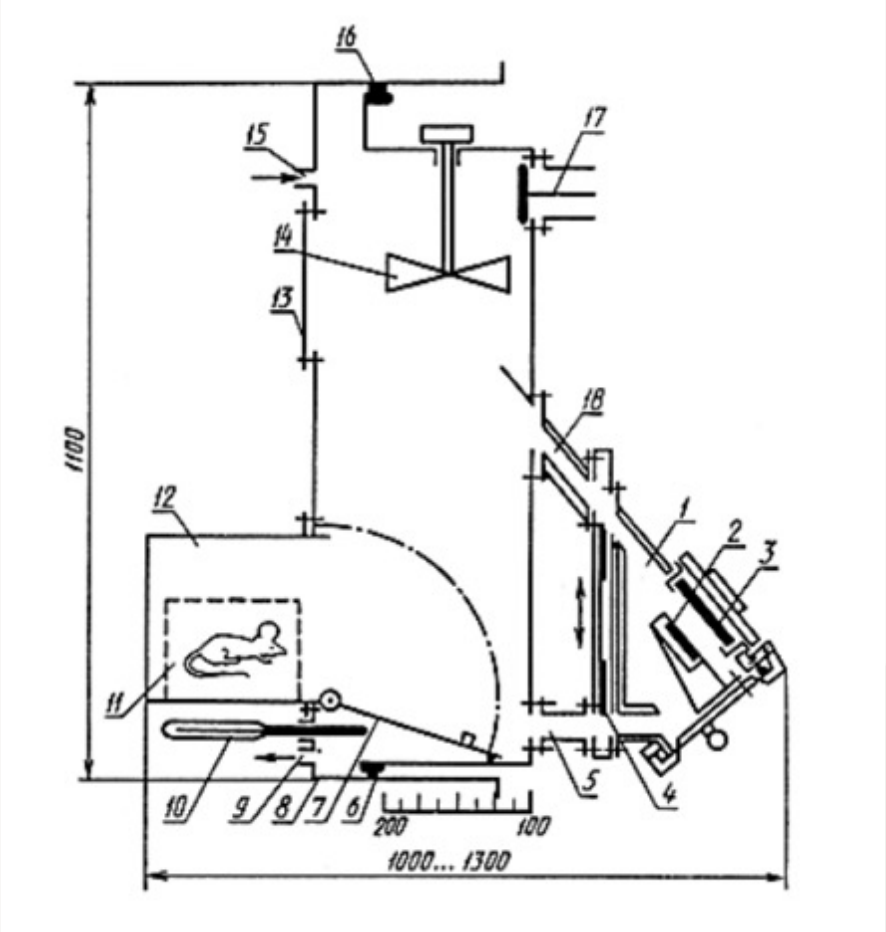
TOXICITY TEST GOST 12.1.044-89 (RUSSIA)



1-combustion chamber; 2-sample holder; 3-electric heating emitter; 4-dampers; 5,18-transition sleeves; 6-stationary section of the exposure chamber; 7-pre-chamber door; 8-movable section of the exposure chamber; 9,15-fittings; 10-thermometer; 11-cage for animals; 12-pre-chamber; 13-safety membrane; 14-fan; 16-rubber gasket; 17-purge valve

GOST 12.1.044-89: Close to real fire conditions, it shows real impact on animals.

The toxicity index of combustion products is the ratio of the amount of material to a volume of the chamber in which the gaseous products formed cause the death of 50% of the experimental animals. Toxicity classes:

T1	>120	Low toxic
T2	40 to 120	Moderately toxic
T3	13 to 40	Highly toxic
T4	up to 13	Extremely toxic

Maximum toxicity obtained at 450°C under smouldering mode of burning. Lower toxicity at 750°C, under flaming mode of burning

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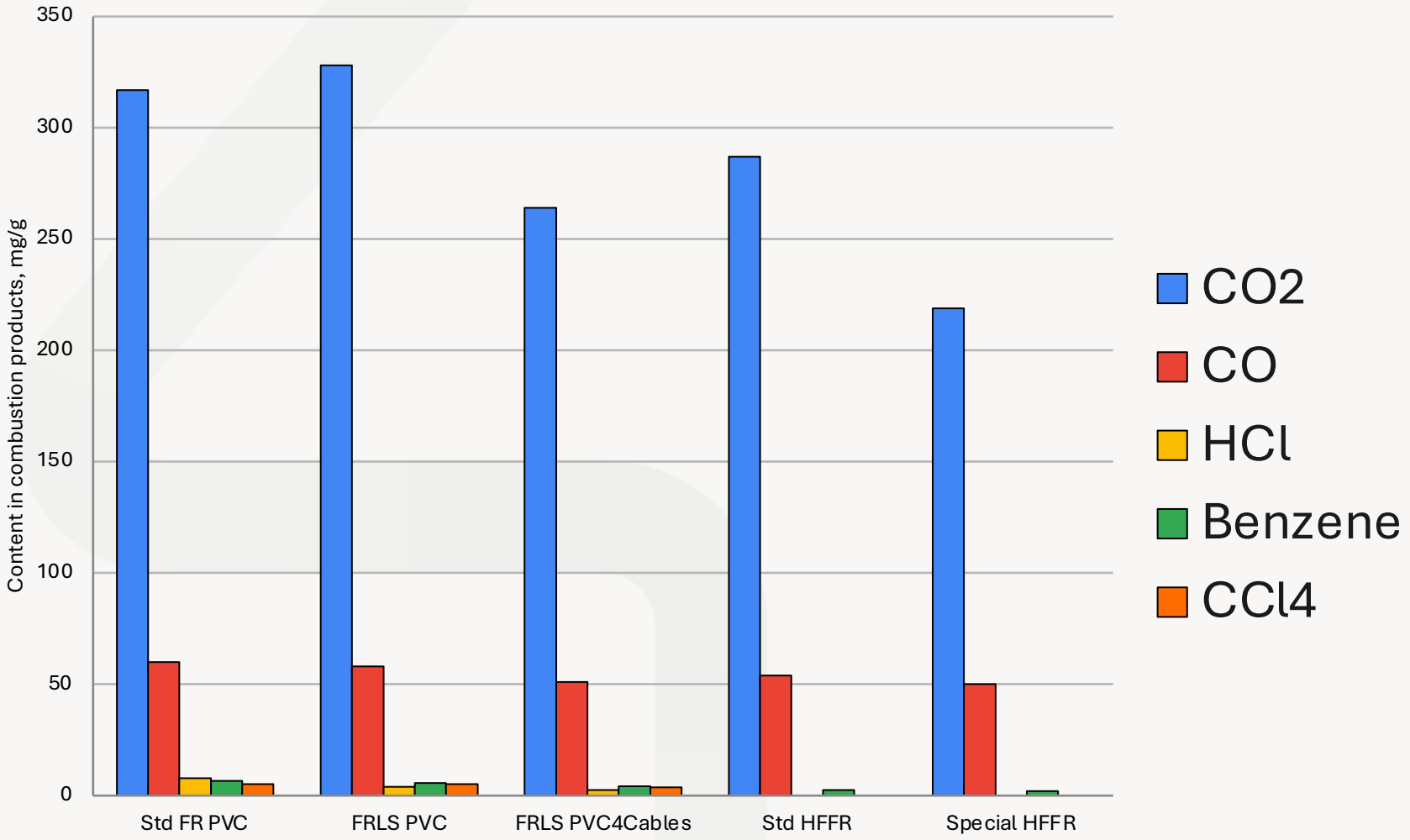
GOST 12.1.044-89 : TOXICITY PVC VS HFFR COMPOUNDS

Sheathing type	Std FR PVC	FRLS PVC	FRLS PVC4Cables	Std HFFR	Special HFFR
Cable	**FG160R16 5G1.5**	**N2XH-0 5*1.5**	**FG16OR16 5*1,5**	**N2XH-0 5*1.5**	**N2XH-0 5*1.5**
Toxicity index, g/m3	112 ± 10	122 ±11	136 ± 11	138 ± 11	146 ± 13
Toxicity class	T2	T1	T1	T1	T1
Toxicity level	moderate	low toxic	low toxic	low toxic	low toxic
HbCO %	56 ± 3	58 ± 3	59 ± 3	64 ± 3	65 ± 3
Cause of death	CO and other	CO and other	CO and other	CO	CO

HbCO: is the concentration of carboxy-emoglobine into blood of dead mice

GAS EMITTED BY BURNING PVC VS HFFR CABLES /1



In the test chamber of **GOST 12.1.044-89 at 450°C**

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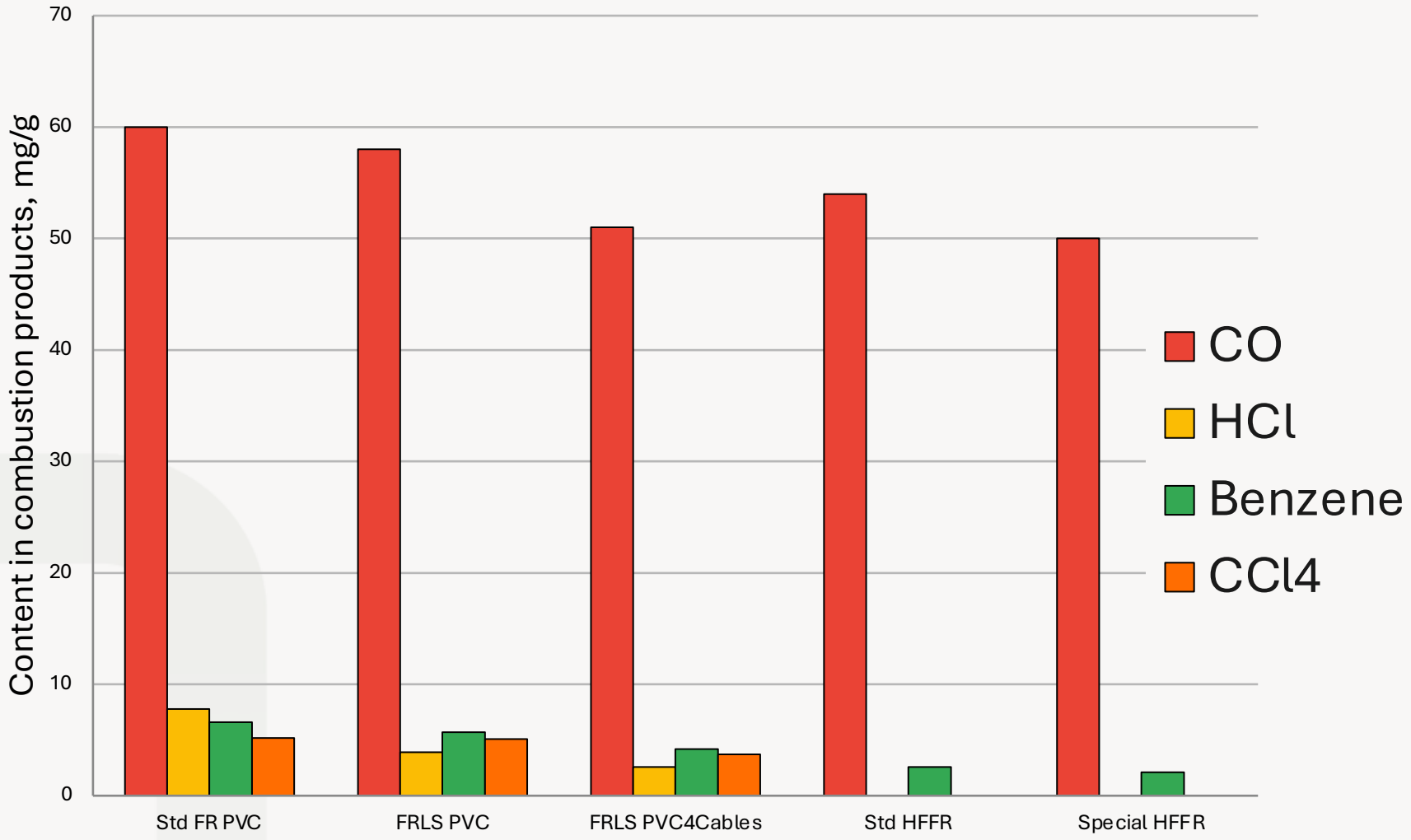
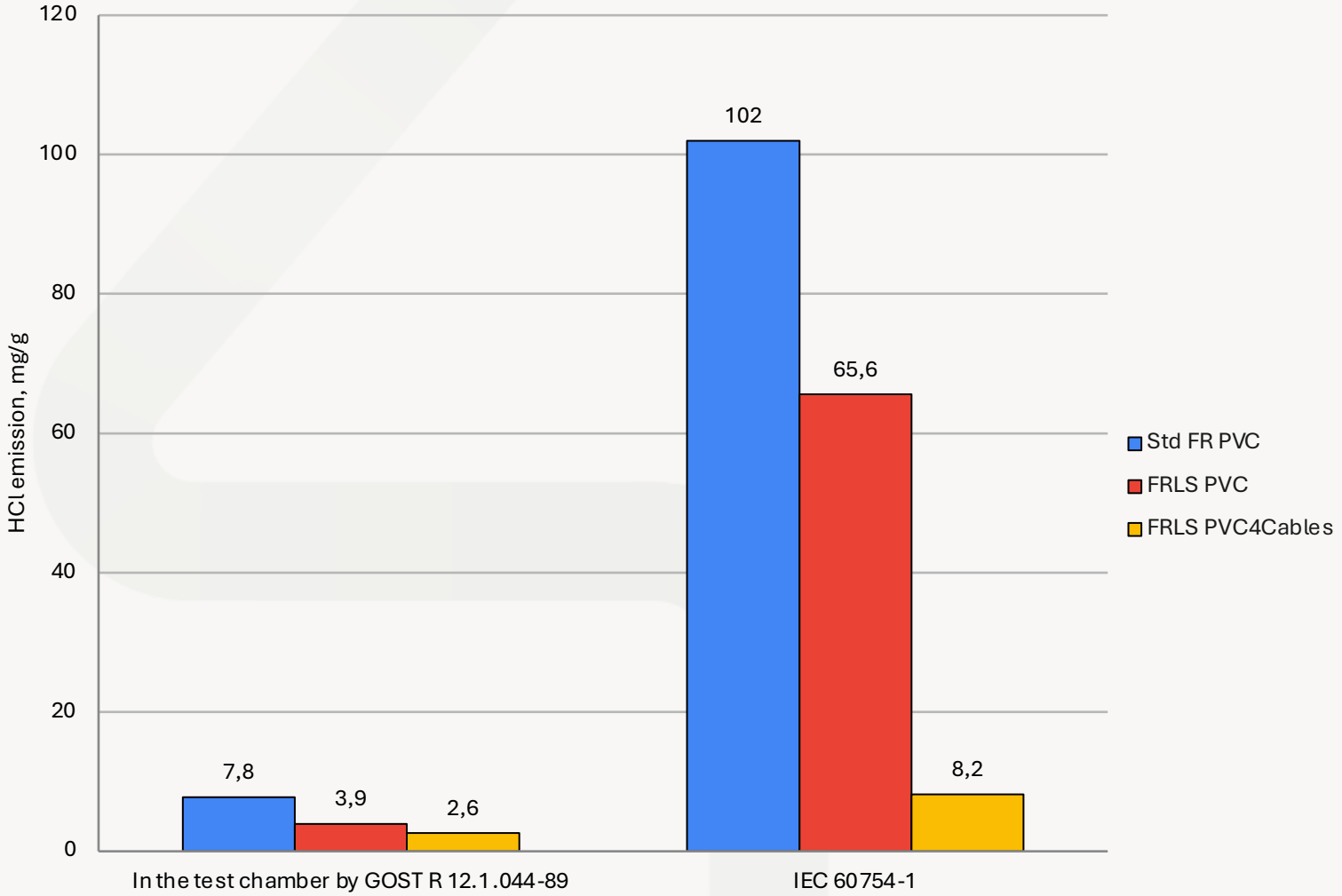
GAS (-CO2) EMITTED BY BURNING PVC VS HFFR CABLES /2

In the test chamber of **GOST 12.1.044-89 at 450°C**



HCL EMITTED BY BURNING PVC VS HFFR COMPOUND



In the test chamber of **GOST 12.1.044-89 at 450°C** standard (close to real fire conditions), the emission of HCl is definitively much lower than the emission from IEC 60754-1

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TOXICITY OF PVC VS HFFR COMPOUND NES 713

Test No. 1 Test Mass: 1.032g

GAS	ANALYSIS METHOD	LIMIT OF DETECTION *(ppm)*	CONCENTRATION OBSERVED ppm (Background)	Co	Cf	Co/ Cf
Carbon Dioxide	CIT	2.0	2000 (1500.00)	48449.61	100000	0.4845
Carbon Monoxide	CIT	1.0	5 (0.00)	484.4961	4000	0.1211

Toxicity Index of Special HFFR = 0,61

Toxicity Index of FRLS PVC = 1,31

LIMIT FOR TOXICITY = 2 (NES 713)

Test No. 1 Test Mass: 1.032g

GAS	ANALYSIS METHOD	LIMIT OF DETECTION *(ppm)*	CONCENTRATION OBSERVED ppm (Background)	Co	Cf	Co/ Cf
Carbon Dioxide	CIT	2.0	2000 (1500.00)	48449.61	100000	0.4845
Carbon Monoxide	CIT	1.0	10 (0.00)	968.9922	4000	0.2422
Phenol	CIT	5.0	0	0	250	0
Ammonia	CIT	1.0	0	0	750	0
Hydrogen Sulphide	CIT	0.5	0	0	750	0
Sulphur Dioxide	CIT	0.1	0	0	400	0
Formaldehyde	CIT	0.2	0	0	500	0
Hydrogen Chloride	CIT	0.2	3	290.6977	500	0.5814

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USA – *PLENUM CABLES*

Plenum cables are electrical cables that are laid in the plenum spaces of buildings, regulated under the NFPA 90A: Standard for the Installation of Air Conditioning and Ventilating Systems.
In case of fire event, cables must not propagate fire inside to ventilated pipes, as well as there must not be any gas release to avoid spread of gas all around the plenum spaces.
Plenum Cables are the application where halogen free compounds are not yet able to work as PVC in terms of low propagation of fire and low emission of smokes in order to guarantee the maximum safety in case of fire.
Plenum cable is jacketed with a fire-retardant plastic jacket of either a **special low-smoke PVC** or a fluorinated ethylene polymer (FEP).

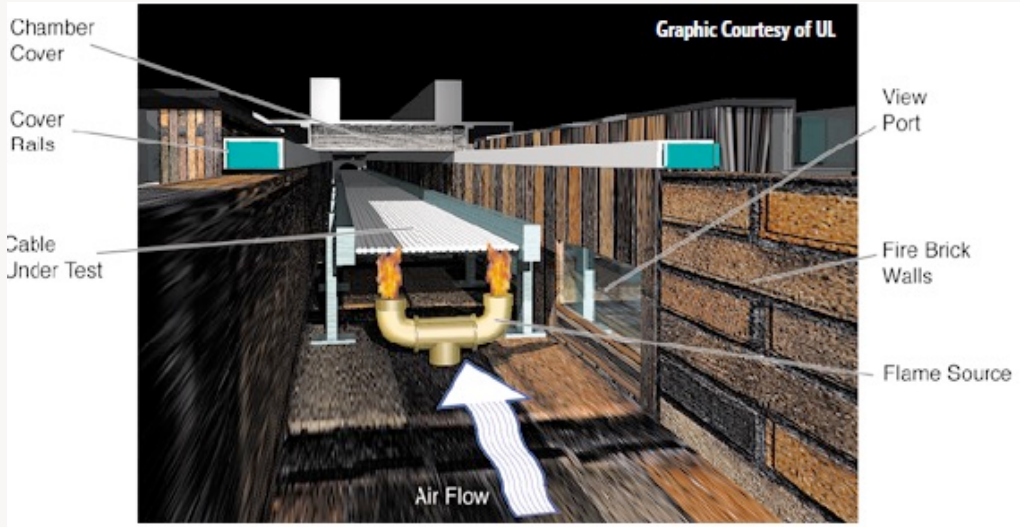
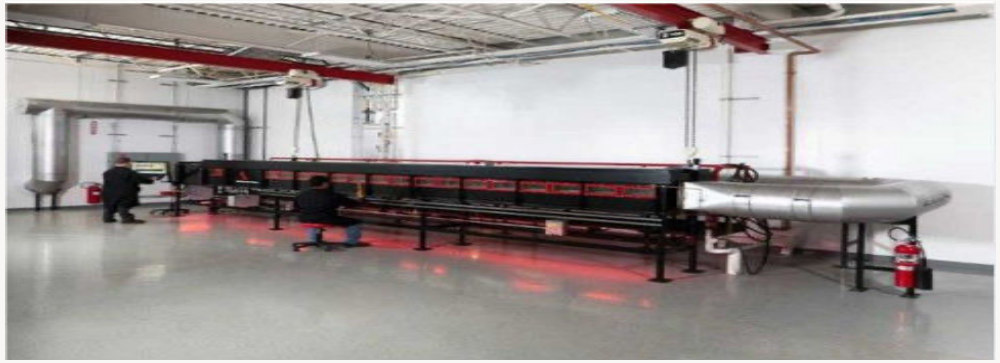


Figure 7: NFPA 262 (UL 910 Steiner Tunnel) test setup



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TO DO LIST

Aligning Test Methodologies and Adopting a Common Set of Fire Safety Criteria: Fire resistance, flame spread, smoke release, toxicity, and corrosivity of smoke. A globally accepted set of minimum fire safety benchmarks would help bridge these gaps.

Promoting International Collaboration: Harmonization will require collaboration between regulatory bodies, industry associations, and standardization organizations like CENELEC (Europe), UL (USA), and BIS (India). Forums like the International Electrotechnical Commission (IEC) and ISO could help create pathways for dialogue between regions, encouraging the adoption of cross-recognized standards.

In the above activities, the **scientific research** must provide the technical bases to improve PVC applications and to avoid the discrimination of PVC, and the PVC industry (including suppliers of resin, plasticizers, additives, flame retardants,…) must actively cooperate.

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WE ARE ALREADY AT WORK

TECHNOLOGY COMPANY iPOOL DESIGN MATERIAL


Marco Diciotti


Marco Badalassi


Sara Haveriku


Cosimo Micheletti


Michele Benvenuti


Carola Bianca


Vanessa Matteucci


Antonio Cardelli


Gian Pietro Vianelli


Ginevra Vongher


Luigi Minnella


Filippo Gabbani

www.ipoolsrl.com

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THANK YOU

www.pvc4cables.org

pvc4cables@pvc4cables.org

www.ipoolsrl.com