The project class B2ca

How formulations can influence the PVC cables fire behavior

PVC FORUM ITALIA: CABLES GROUP

How formulations can influence the PVC cables fire behavior

- Cables Group Italy
- The project class B2ca
- Fire performances of old and new cables
- Focus on smoke acidity
- The importance of R&D
- Conclusions

Cables Group Italy

- The group was born in 2013 with the aim to develop new formulations for cables with better performances in term of flame retardancy, smoke suppressant properties and smoke acidity

- The project was called B2Ca

B2ca PROJECT

- The project is divided in 3 steps

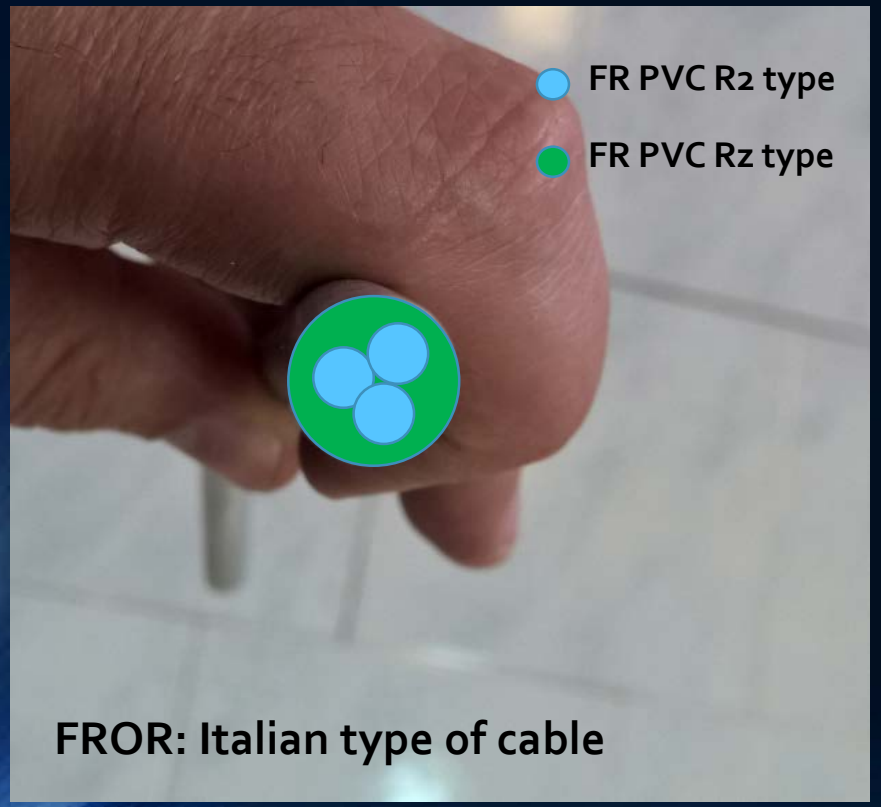
1) Evaluation of the cables on the market before CPR
2) R&D for getting improvements on compounds on lab scale tests
3) Evaluation of the new cables on CPR basis

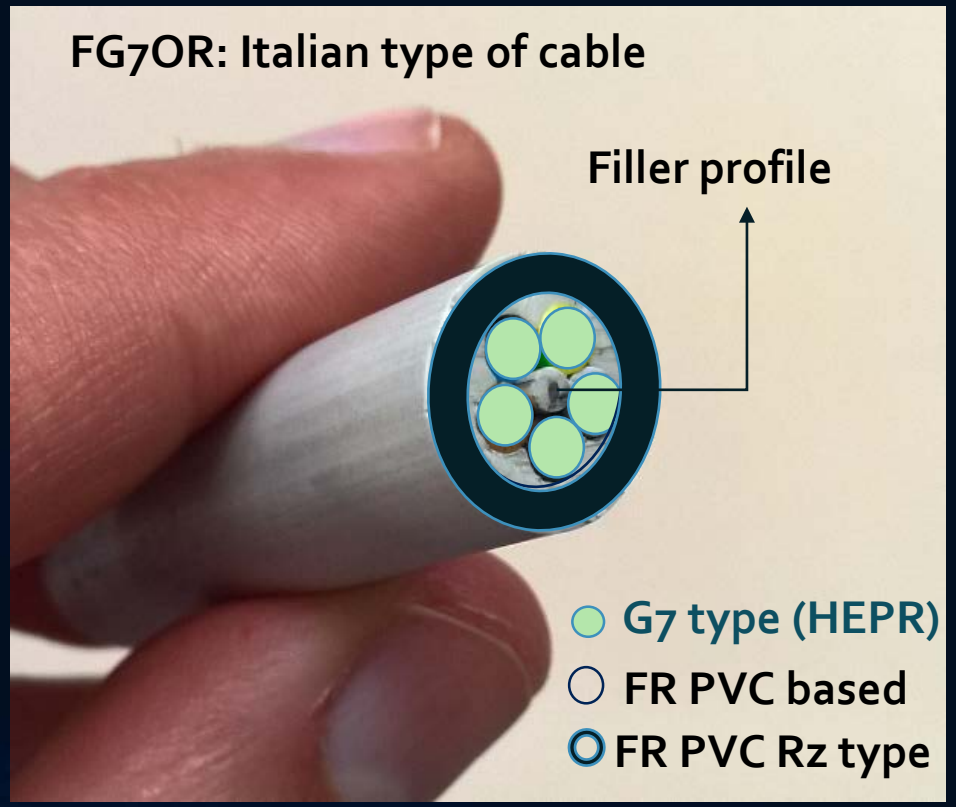
- The target?

Classification B2ca and the best possible on subclasses

1) Evaluation of the cables on the market before CPR

Several kinds of cables have been tested with new CPR rules





1) Evaluation of the cables on the market before CPR

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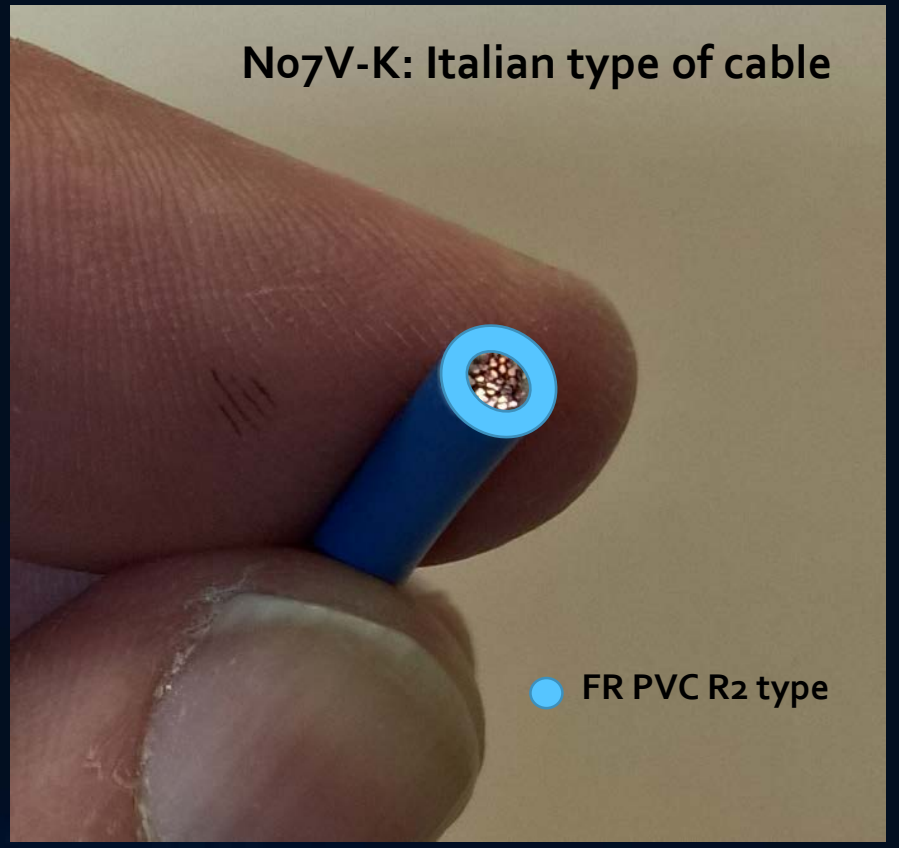


1) Evaluation of the cables on the market before CPR

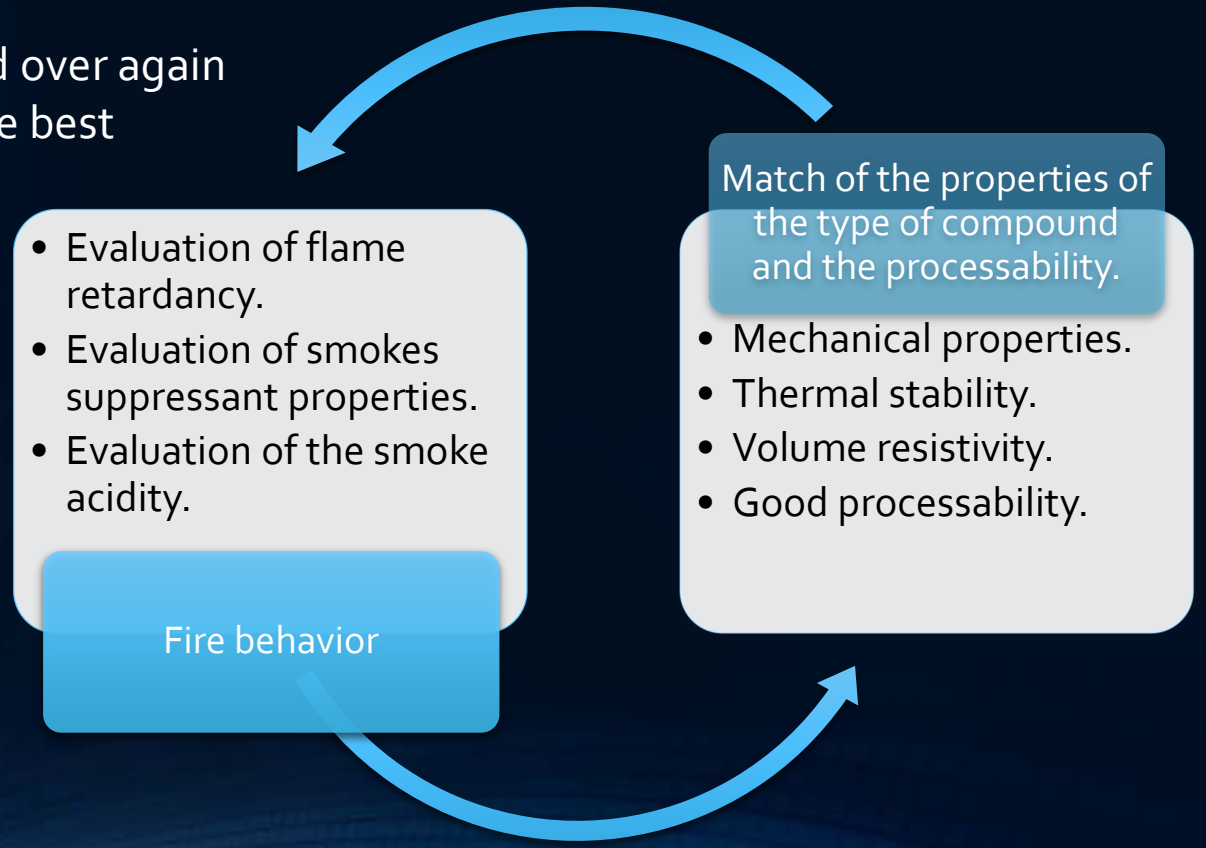
Classes and subclasses according to CPR

Type	Class	Smoke	Droplets	Acidity
FG7OR	Dca	S2	d1	a3
FROR	Cca	S2	do	a3
No7V-K	Dca	S2	do	a3

2) Lab scale tests

R&D for getting improvements on lab scale tests on specific types of compounds

We loop over and over again until we reach the best compromise



More than 70 compounds have been tested according to the following technical standards

2) Lab scale tests:

Technical standards performed

Fire behavior

Cone calorimetry (ISO 5660 – 1a)

Oxygen index (ASTM D 2863)

Smoke Density Rate % (ASTM D 2843)

Smoke acidity (EN 60754 part 1 and 2)

Type of compound

Tensile strength & Elongation @ break before and after aging

Water absorption

Insulation properties

Etc….

a.t. specific technical standard of type of compound

2) Lab scale tests:

Comparison of some critical physical properties

OLD COMPOUNDS

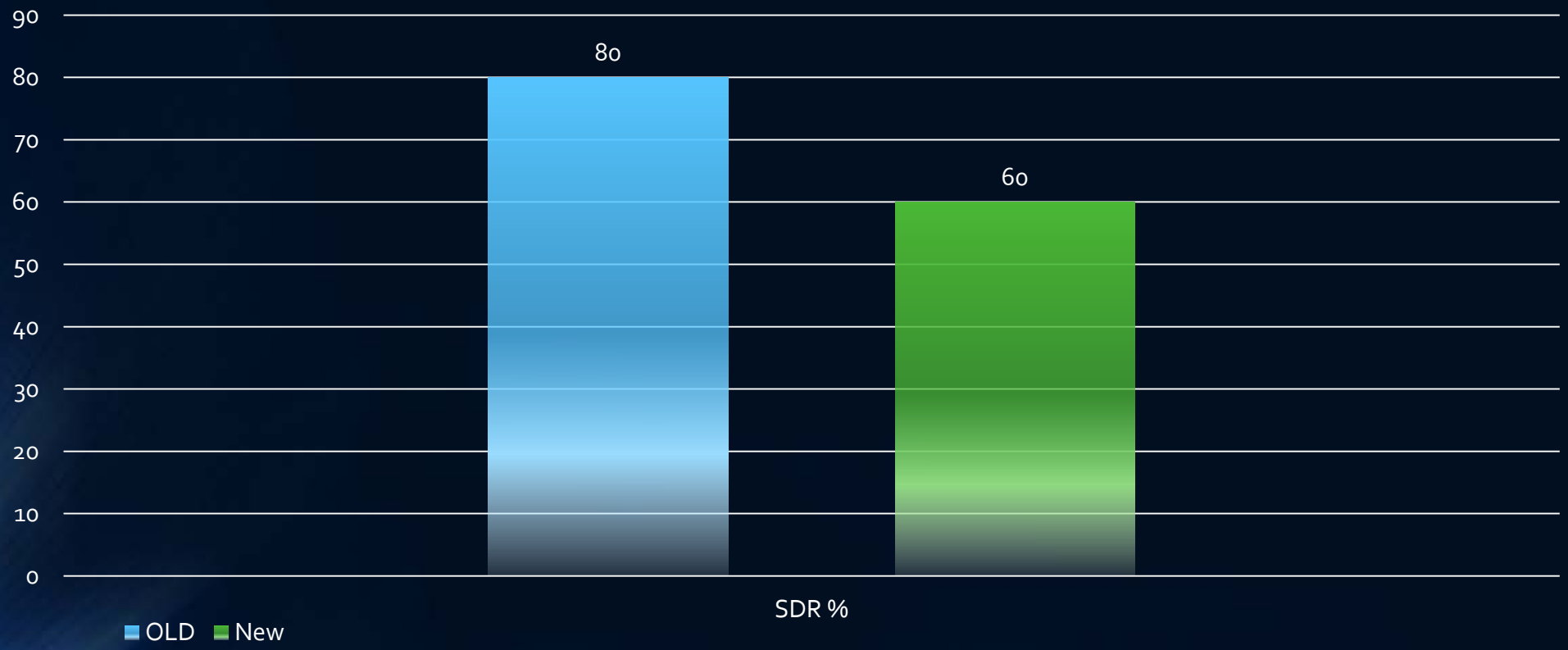
- SDR % : [75 – 85] %
- pH: [2,50 – 2,80]
- Conductivity: [100 – 220]µS/mm

NEW COMPOUNDS

- SDR %: [55 – 65] %
- pH: [3,50 – 3,90]
- Conductivity: [10 – 28] µS/mm

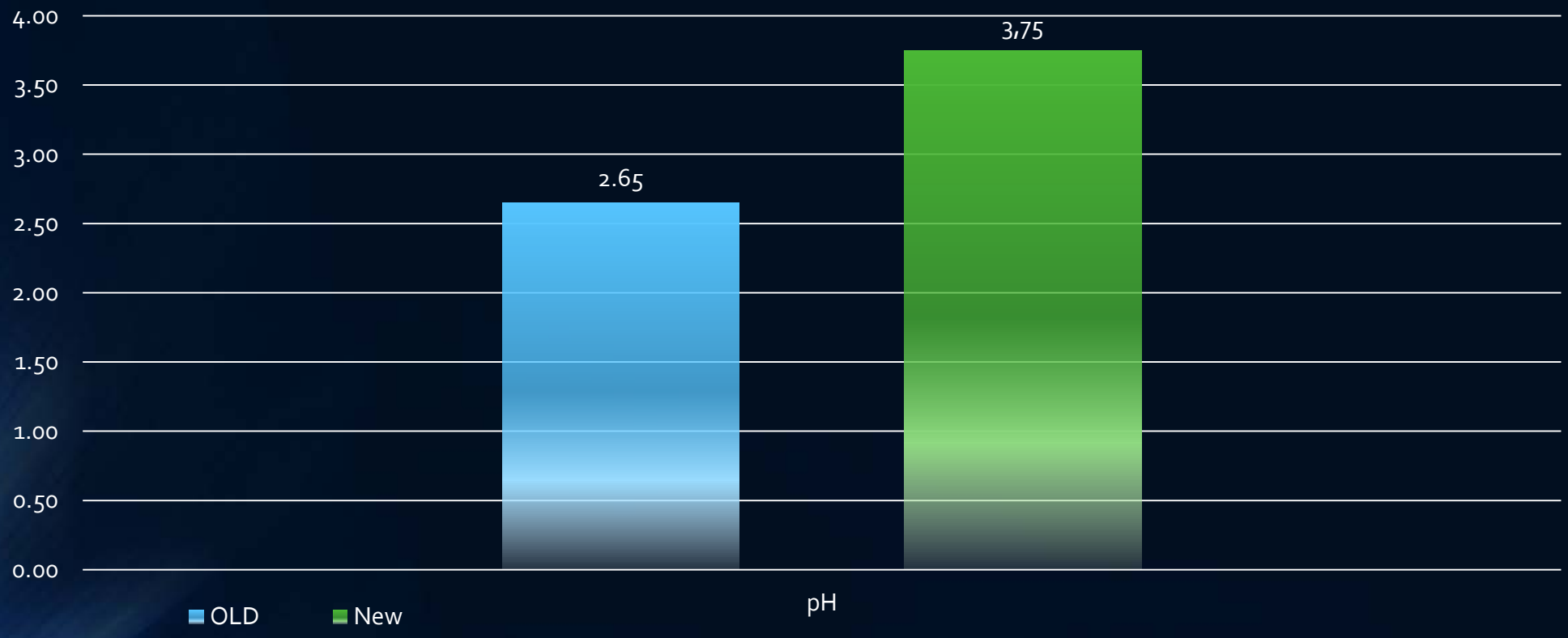
2) Lab scale tests:

Comparison of some critical physical properties : SDR % mean values



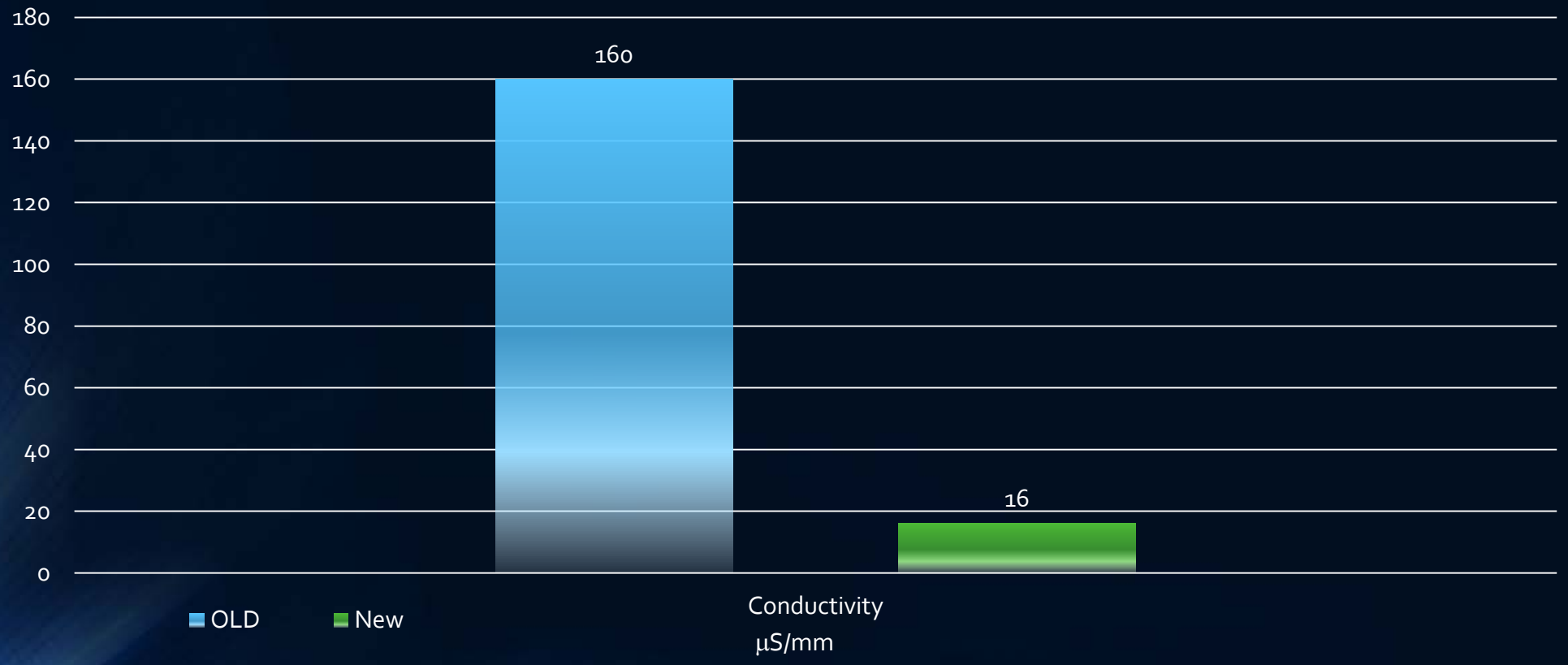
2) Lab scale tests:

Comparison of some critical physical properties : pH mean values



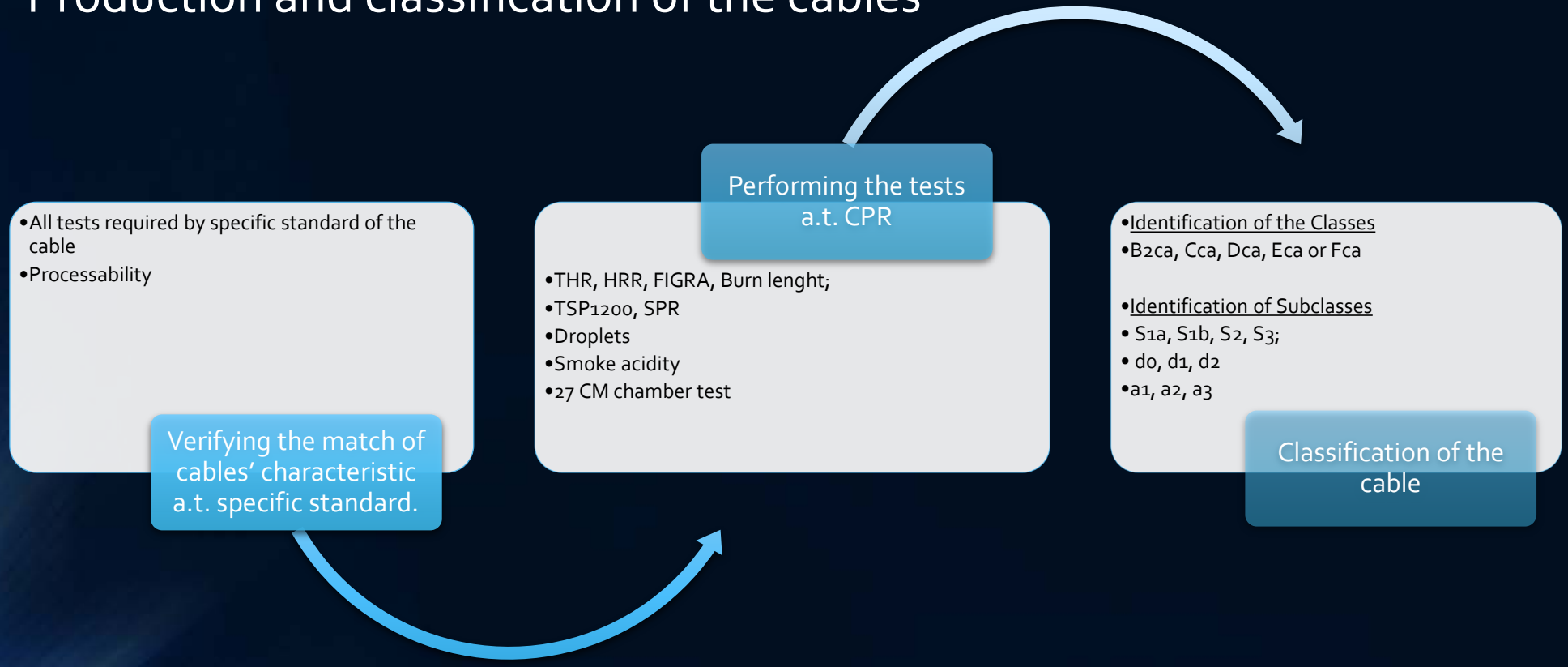
2) Lab scale tests:

Comparison of some critical physical properties : conductivity mean values



3) Tests on cables

Production and classification of the cables



3) Tests on cables

Evaluation of fire performances a.t. CPR: standard performed

- EN 60332-1-2 (Vertical flame propagation on single cable)
- EN 50399 (Vertical flame propagation on bunched cables)
- EN 61034-2 (smoke density in 27 m^3 chamber)
- EN 60754-2 (Test on gases evolved during combustion of materials from cables – Part 2: Determination of acidity (by pH measurement and conductivity)

FIRE PERFORMANCES:OLD AND NEW CABLES

Comparison b/w old and new cables

New Cables	Class	Smoke	Droplets	Acidity
FG16OR16 New code of FG7OR	Cca	S2	do	a3
FROR	B2ca	S2	do	a3
FS17 New code of NO7V-K	Cca	S1	do	a3

Old Cables	Class	Smoke	Droplet	Acidity
FG7OR	Dca	S2	d1	a3
FROR	Cca	S2	do	a3
No7V-K	Dca	S2	do	a3

FIRE PERFORMANCES:OLD AND NEW CABLES

We improved the flame retardancy reaching the class B2ca for some kinds of cables

We verified a quite better performance in term of dripping in comparison to the Halogen Free systems

But we have to get better values in terms of smoke density and smoke acidity

So other sets of lab scale tests are scheduled to reach the new targets

The most difficult task is the reduction of smoke acidity

FOCUS ON SMOKE ACIDITY

Technical standards a.t. CPR

- EN 60754-2
- Tubolar Oven at fixed temperature ranging b/w 935°C up to 960°C
- Determination of pH and conductivity

The method used 4 PVC before CPR

- EN 60754-1
- Tubolar Oven at temperature ranging b/w 790°C up to 810°C
- Determination of mg of halogens in 1 g of compound
- Temperature ramp

To understand the differences b/w the two standards we need to introduce the theory of acid scavenging for the reduction of smoke acidity

ACID SCAVENGING THEORY

°C

23 50 77 104 131 158 185 212 239 266 293 320 347 374 401 428 455 482 509 536 563 590 617 644 671 698 725 752 790 800 810 837 864 891 935 948 960 975

Acid scavengers active until PVC is still alive

Stable reaction products with HCl: 810°C for EN 60754-1

Single step RXN

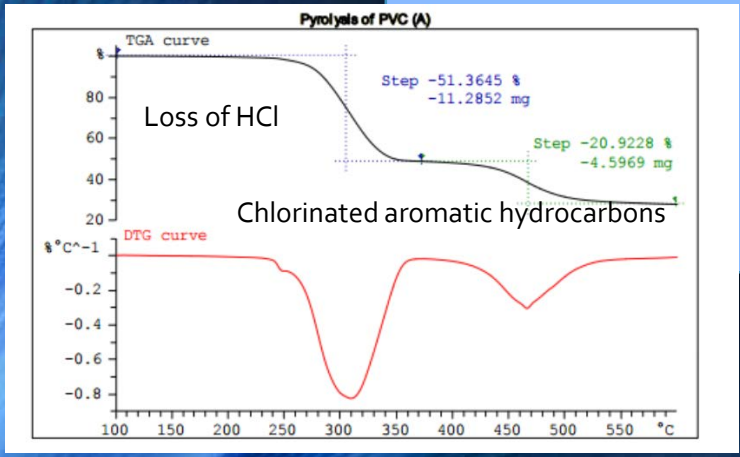
Multiple steps RXN

Stabilization zone

Pyrolysis Massive release of HCl [1,2]

Uncharted Zone

Stable reaction products with HCl: 960°C for EN 60754-2

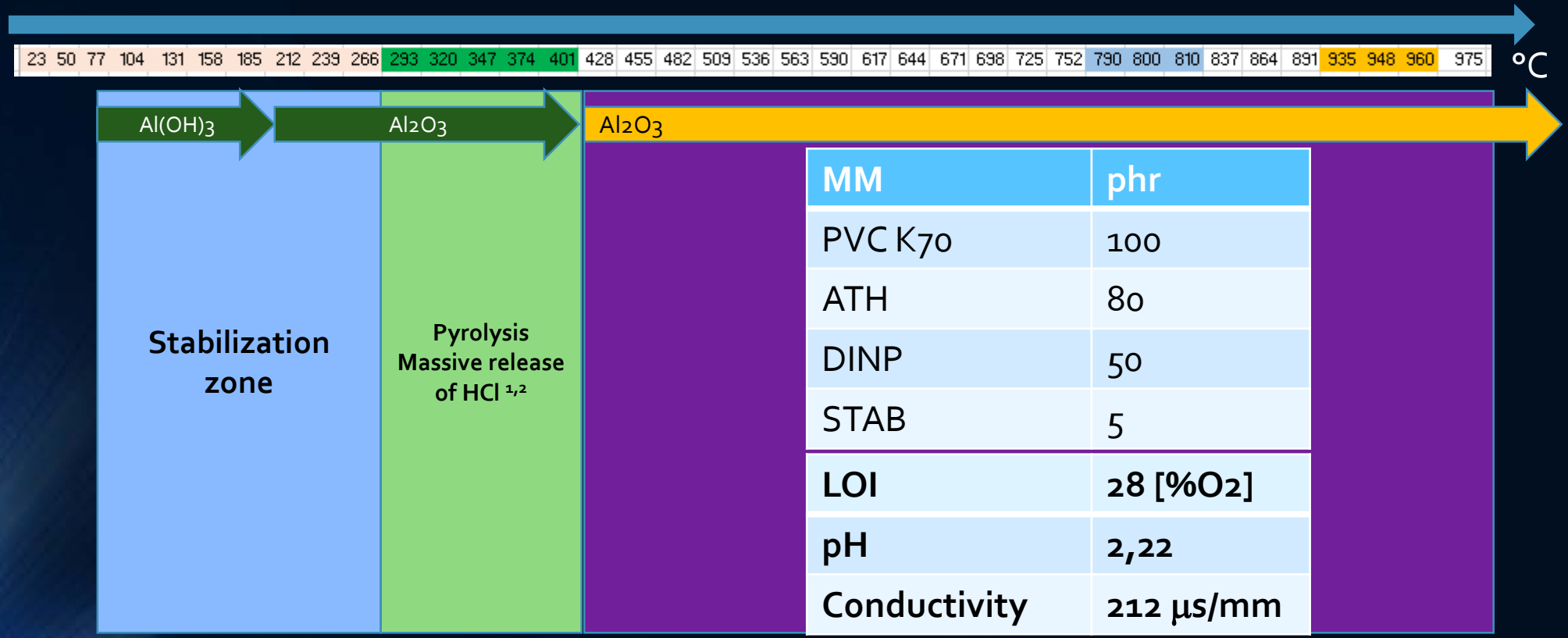


FOCUS ON SMOKE ACIDITY

Acid scavenging theory: inert substance

ATH starts the decompositions b/w 180°C and 200°C, releasing water. It acts as heat sink, dilutes the flame, dilutes the polymer and plasticizers, creates a char of Al_2O_3 [3].

From a AS point of view ATH is ineffective due to the chemical inertia of Al_2O_3.

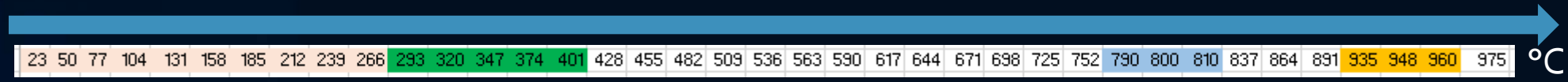


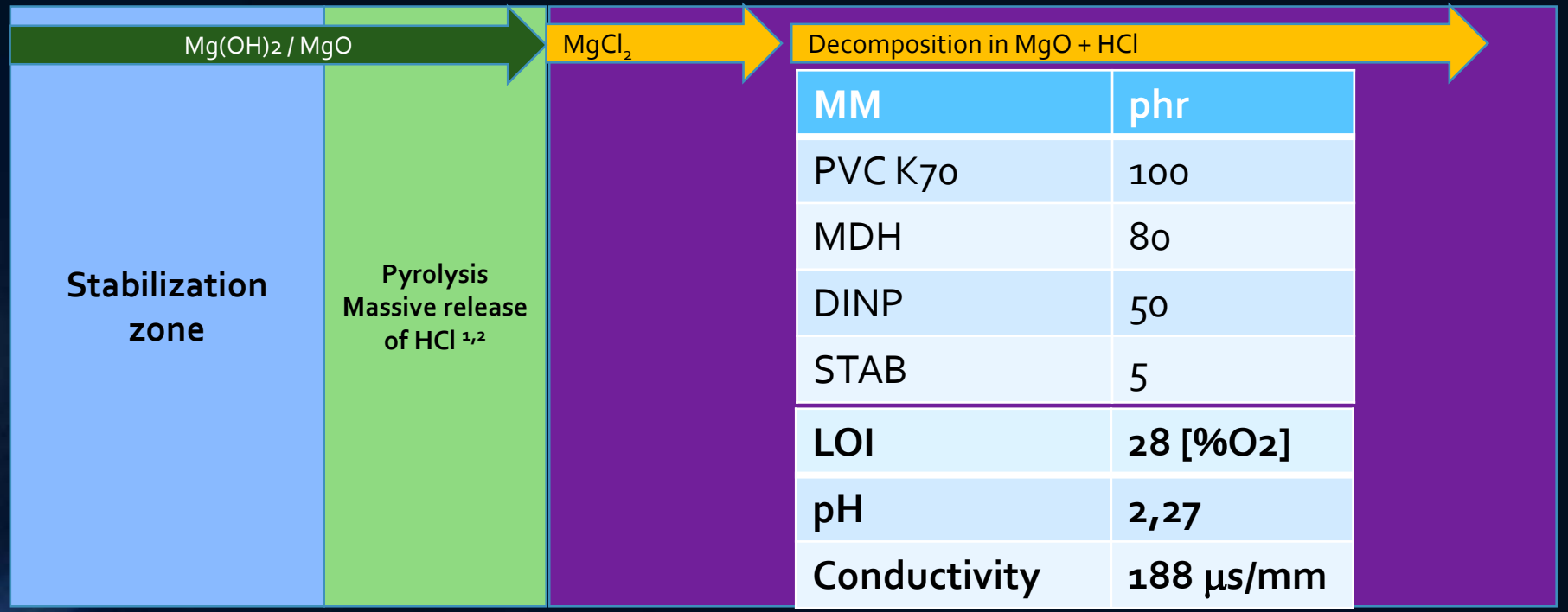
MM	phr
PVC K70	100
ATH	80
DINP	50
STAB	5
LOI	**28 [%O2]**
pH	**2,22**
Conductivity	**212 µs/mm**

Acid scavenging theory: ineffective AS

MDH starts the decompositions b/w 300°C - 320°C, releasing water. It acts as heat sink, dilutes the flame and as dilutes the polymer / plasticizers [3].

From AS point of view in single step reaction MDH is ineffective due to the instability of its reaction product [4]



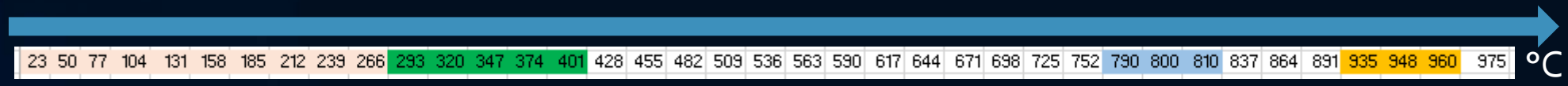


MM	phr
PVC K70	100
MDH	80
DINP	50
STAB	5
LOI	**28 [%O2]**
pH	**2,27**
Conductivity	**188 µs/mm**

Acid scavenging theory: efficient AS

AS5 is stable up to PVC is still alive and it reacts efficiently with HCl, trapping it in a reaction product.

Its reaction product is stable up to the maximum temperature required by EN 60754-2



AS5

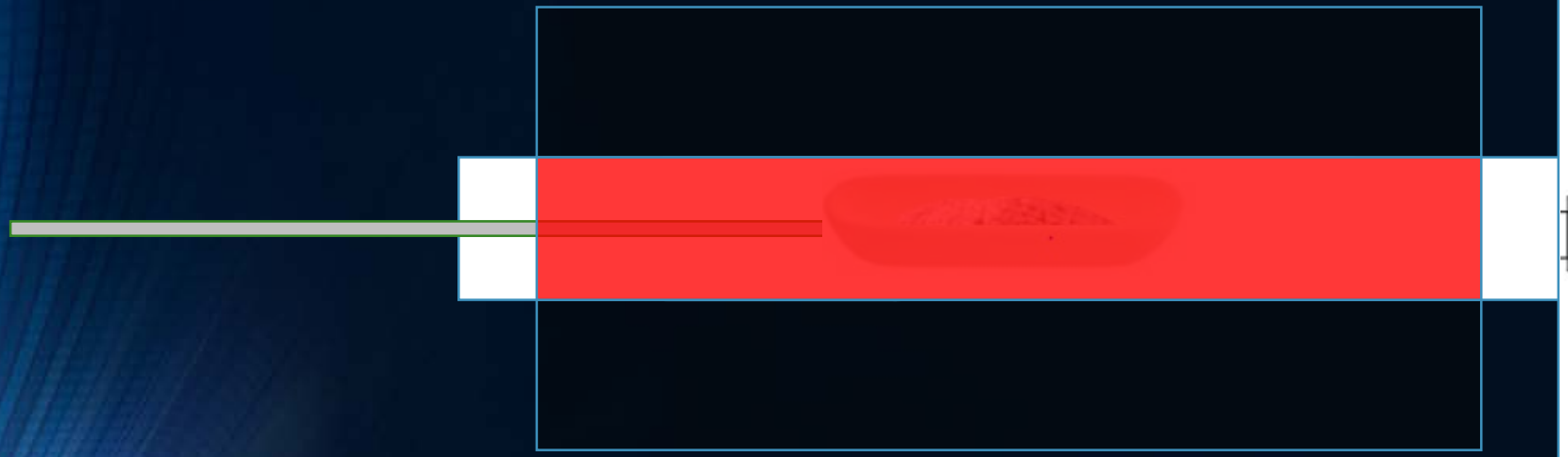
AS5-HCl

Stabilization zone

Pyrolysis Massive release of HCl [1,2]

MM	phr
PVC K70	100
AS5	80
DINP	50
STAB	5
pH	**3,11**
Conductivity	**30,1 µs/mm**

EN 60754-1: used before CPR



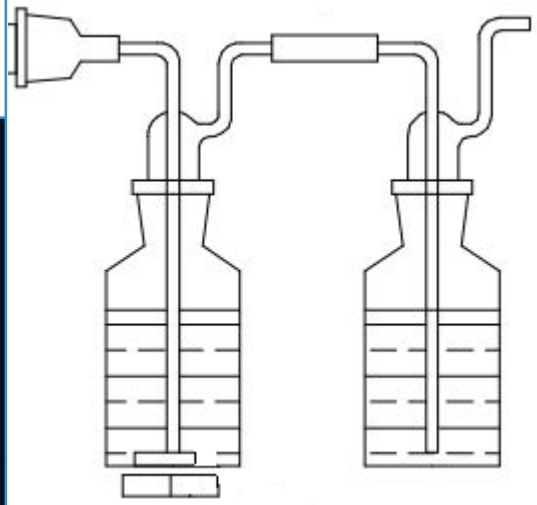
From 23°C to 800 +/-10 °C
@ 20°/min

Advantages

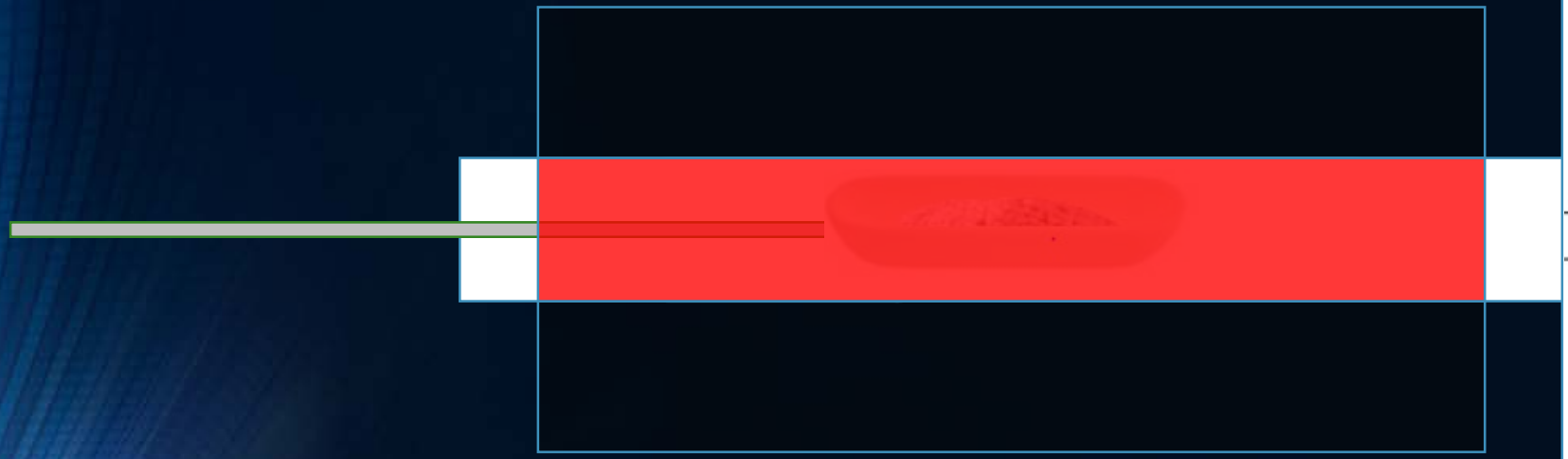
"800 °C" mean a higher number of stable substances

We can use easily multi steps reactions, enhancing synergism b/w substances

With temperature ramps the acid scavengers have more time to trap the evolving HCl



EN 60754-2: a.t. CPR



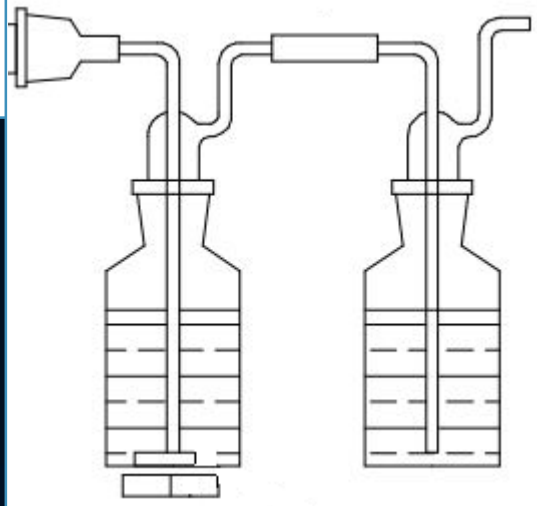
Fixed b/w 935°C and 960°C

Disadvantages

Higher temperature means a smaller number of stable substances

Decomposition makes free HCl again

Without temperature ramps the acid scavengers have no time to trap the evolving HCl efficiently



Differences in numbers

We tested the same compound with the two standards

EN 60754-2

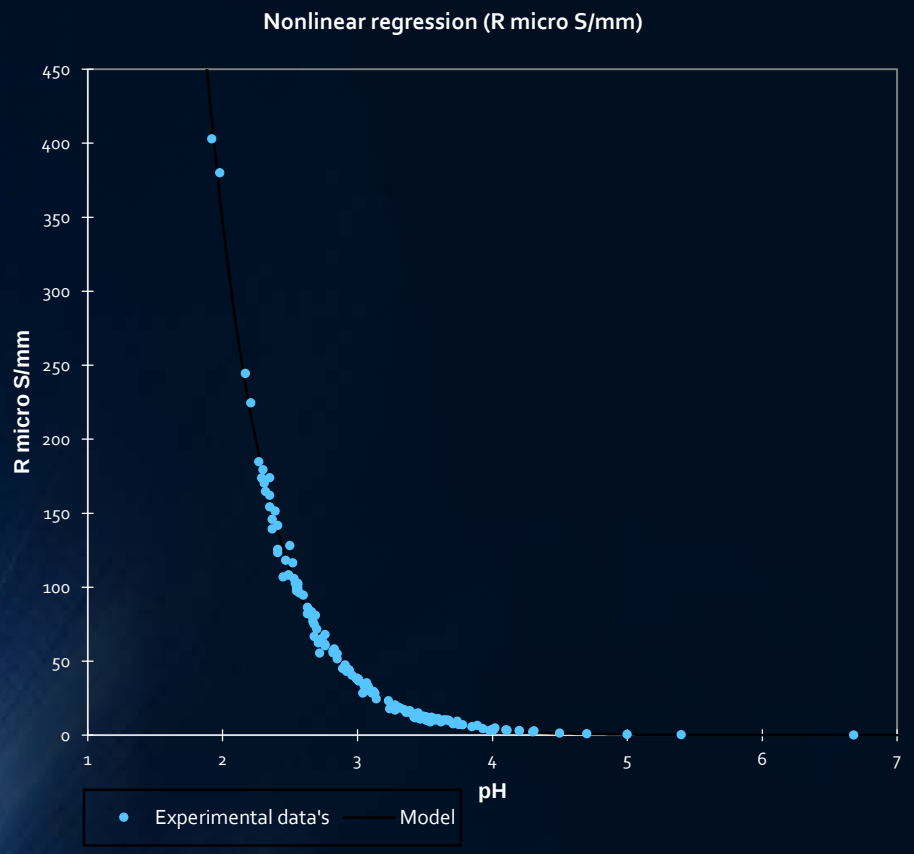
- **pH: 3,54** $[H^+] = 2{,}88 \times 10^{-4}$ mol/L
- **Conductivity [µS/mm]: 10,4**

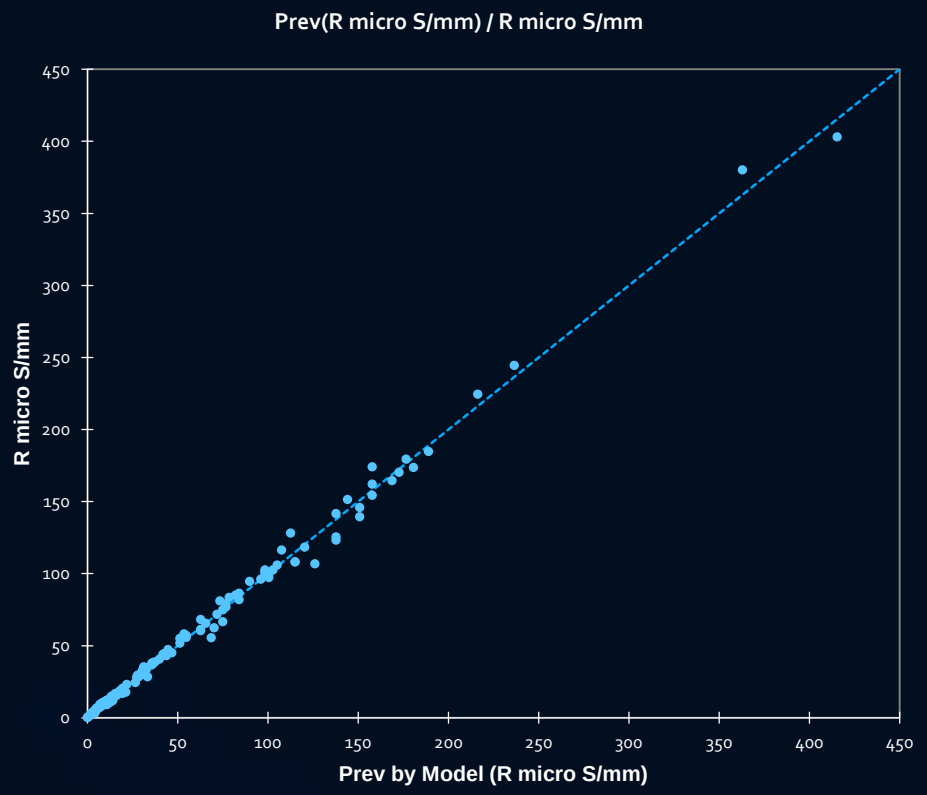
The concentration of protons is 3 times higher in EN 60754-2

EN 60754-1

- **pH: 4,00** $[H^+] = 1 \times 10^{-4}$ mol/L
- **Conductivity [µS/mm]: 3,8**
- The test is performed with the temperature ramp and the final temperature of EN 60754-1
- But pH and Conductivity are measured, instead of the mg's of halogens on gram of compound.
- That to permit a comparison b/w EN 60754-1 and EN 60754-2, focusing on the effect of ramp and final temperature on data's.

Relationship b/w pH and conductivity





In in the bubbling devices the stronger electrolyte is always HCl

The importance of R&D in PVC

Last «adjustments» were at the end of 90's for ROhS requirements

After 2008 an impoverishment of LV formulations is evident

HFFR eroded more and more market to PVC

Case history: Plenum cables in USA (NFPA 262): R&D permitted the production of compounds with a quite high flame retardancy with low smoke emissions, avoided the banishment of PVC from plenum conduits

Conclusions

The aim of the R&D is the innovation of the cables formulations

The new horizons of our R&D will be focused on the use of new additives, enhancing further the performances of cables formulations

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References

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THANK YOU

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