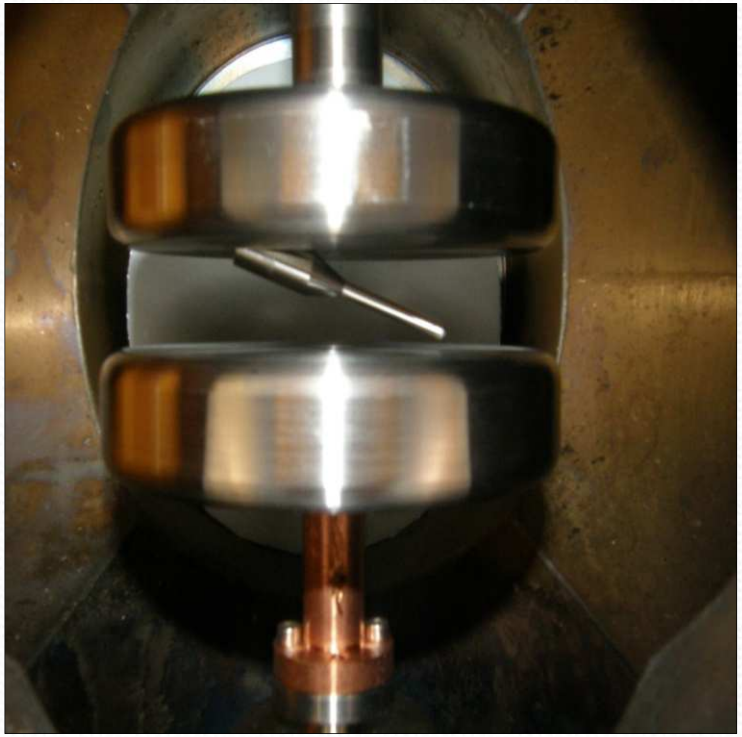
Cern MeVarc Symposium
5 – 7 Novembre 2013

Impact of electro-chemical cleaning on the dielectric strength in sealed vacuum interrupters



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Abstract :

• Vacuum interrupters (VI's) are used in medium voltage circuit breakers to protect electrical distribution systems. Today the world wide annual production exceeds 2 million units.

• Size reduction of VI's and application in solid insulated systems tend to increase the dielectric stresses inside these VI's. Cleaning is a key parameter to obtain reproducible dielectric results.

•Here the impact of electro-chemical cleaning will be discussed. Considerable progress is obtained in the dielectric strength over the last 5 years.

•A great difference persists to exist with respect to Cern published results.

What is a vacuum interrupter

In MV network Circuit breakers to protect the network against short circuits

Vacuum interrupters contain the main contacts of the circuit breaker under a pressure of 10^{-5}Pa to 2 Pa

Typical size
Diameter 90 mm
Length 180 mm

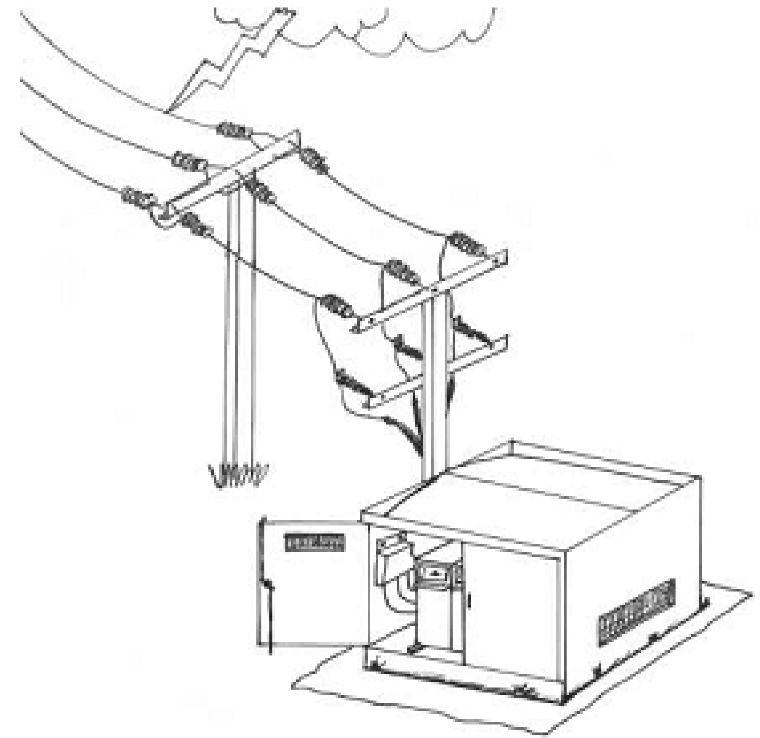
What is the dielectric challenge

In OPEN position VI must withstand lightning stroke to protect circuit.

Lightning impulse of 110kV
Duration 1.2µs/50µs

In case of breakdown :
Power : 40MW 50µs
(Line impedance 300 Ohm)

Consequence :
Metallisation of isolator



by B.Yvars

Fig. 1. "Artist impression": lightning impact on an overhead line connected to MV/LV substation by cable.

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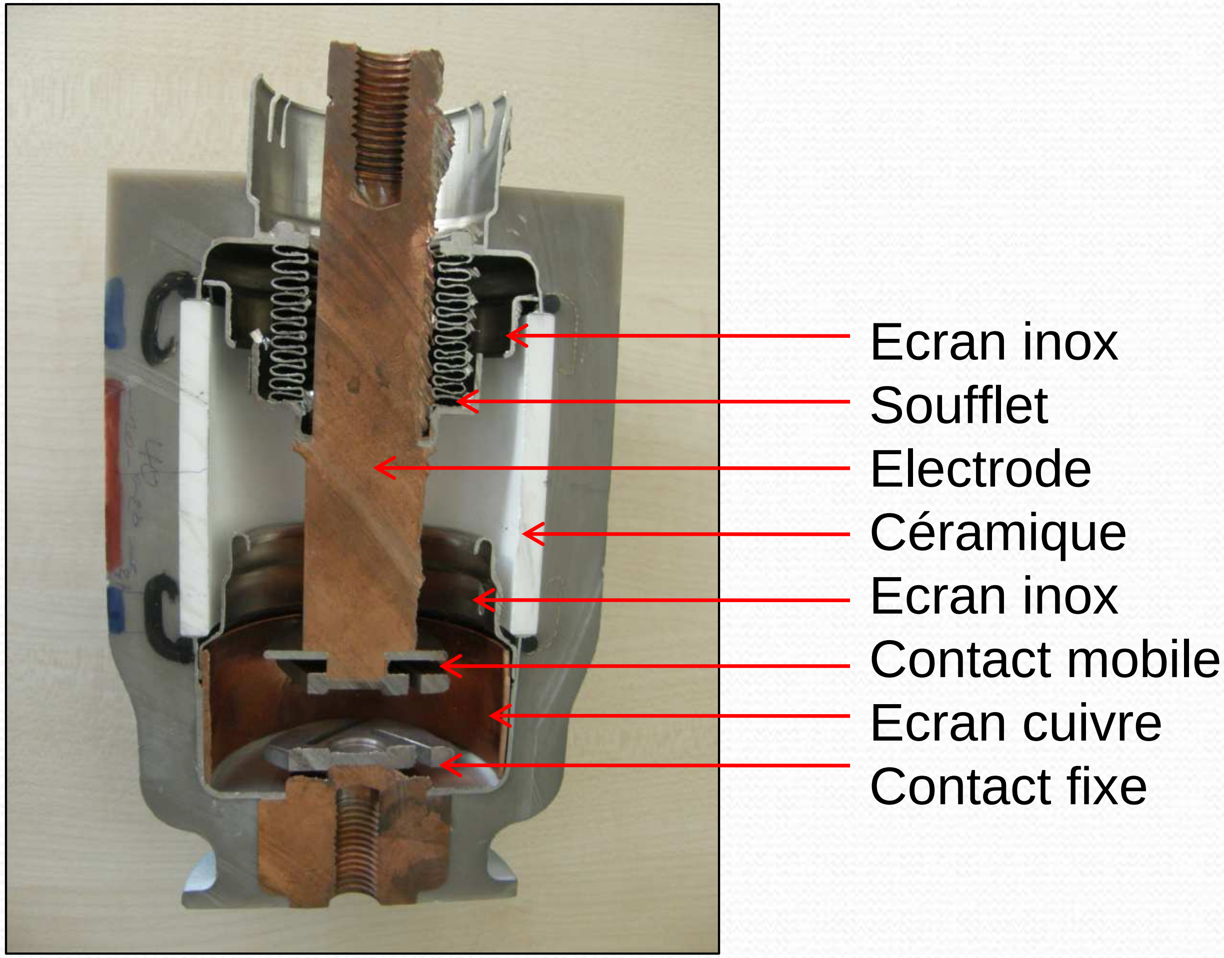
Vacuum interrupter with solid insulation and earth screen



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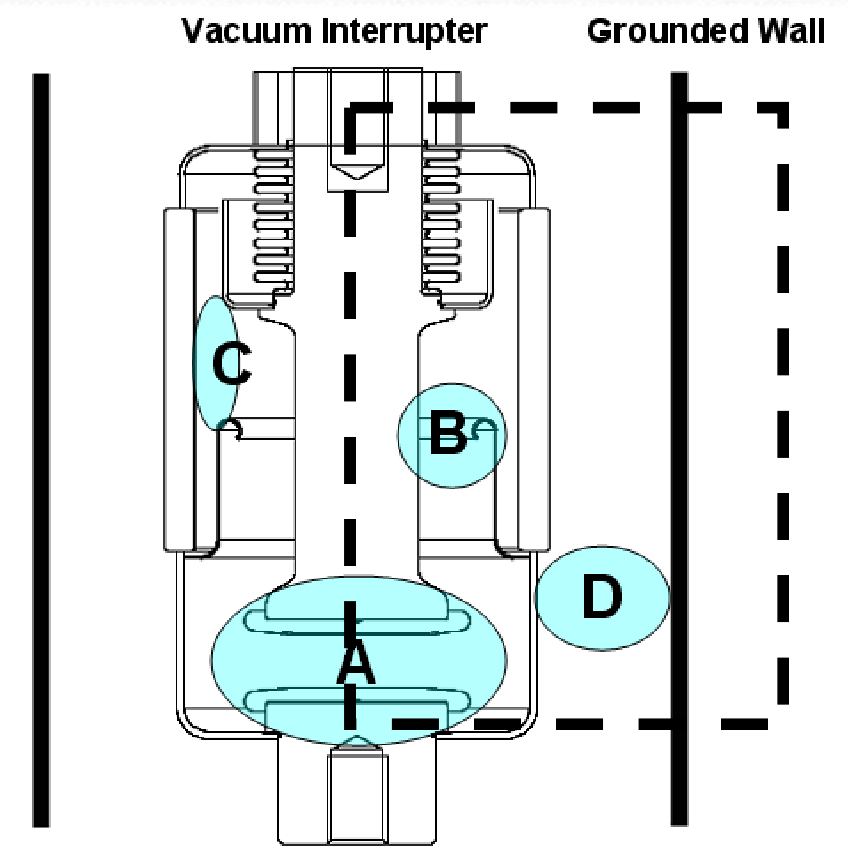
Design : Optimisation – 1 Application



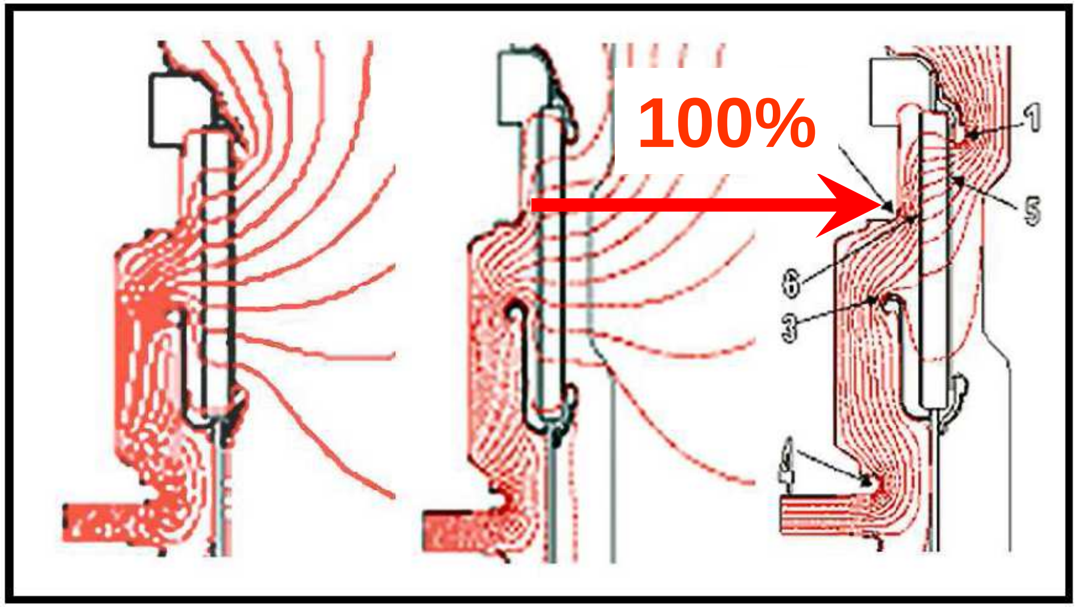


Fig. 2 : Electric field distribution inside and outside the VI
for : a - air insulation, b – epoxy insulation, c – earth screened epoxy

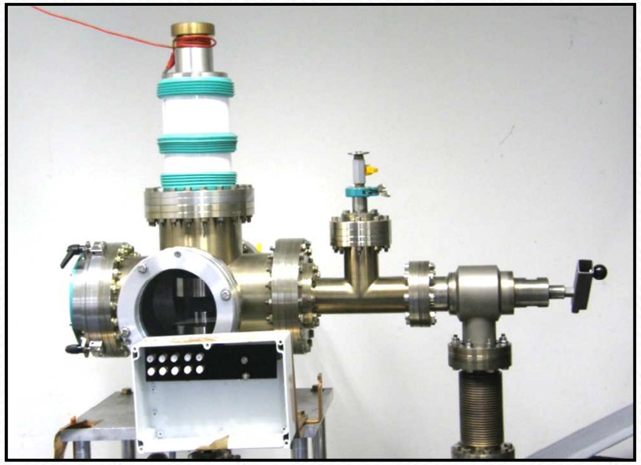
Table 1. Dielectric stress in kV/mm for geometries in fig. 2
2a – Air insulation, 2b – Epoxy insulation,
2c – Earth screened epoxy insulation

Location	Geometry			Breakdown Strength
	2a	2b	2c	
A : 4 (*)	23.3	23.3	23.3	22 – 25 (CuCr)
B : 2 – 3	9.7	9.3	18.7	~ 11 (StSt – Ceramic)
C : 6	2.8	2.8	3.6	No data available
D : 1 – 5	7.6	4.8	21.6	SF_6 1bar : 8 Epoxy : 24

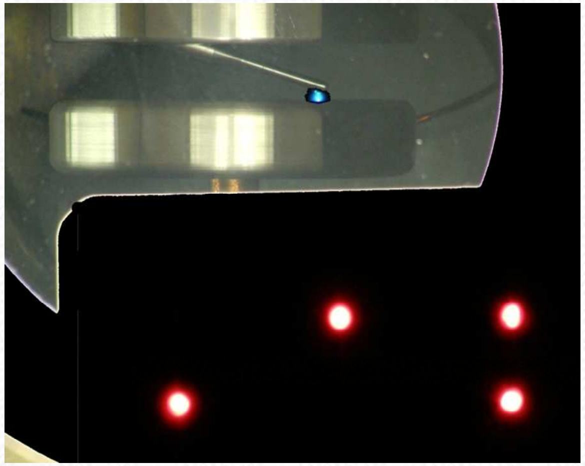
Fonctionnement

La machine

Test setup



Typical measurement



Comparison

Table 1. Comparison of test setups used in this study and in [1,2].

		Ref. [1]	This study	Ref. [2]
Pulse Generator				
	Voltage [kV]	400	150	15
	Pulse Duration	1.2 – 50 µs	1 – 5 ms	
	Current [A]	100	15	1
	Discharge Time	50 µs	10 µs	
	Method	Up - Down		
Vacuum Chamber				
	Contact distance	5 mm	1 mm	20 µm
	Contact position	Vertical	Inclined	Vertical
	Polarity Needle	Negative	Negative	Positive
Additional Analysis				
		Camera	Camera	Non

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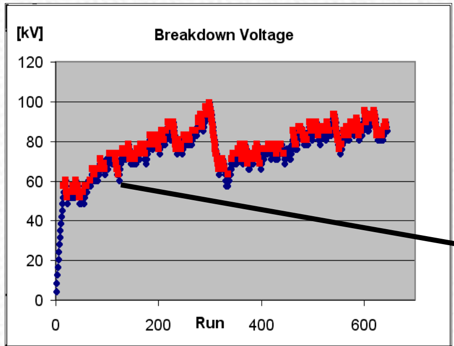
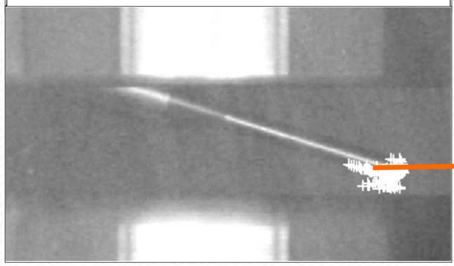
Fonctionnement

Characterisation of electrode "cleanliness" β^1_m

Breakdown Voltage

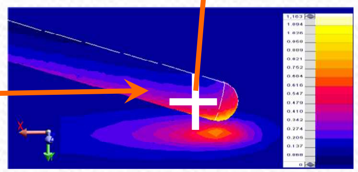


Breakdown Position

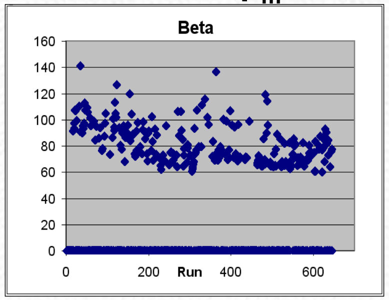


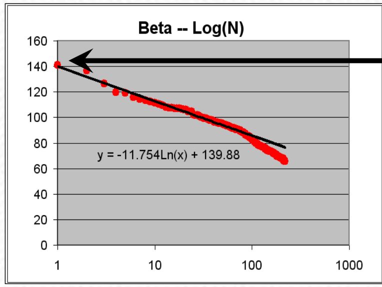
Correction for Local Field

$$\frac{1}{V_B}\times\frac{E_c d}{\beta_g}\Rightarrow \beta_m$$



Variation of β_m



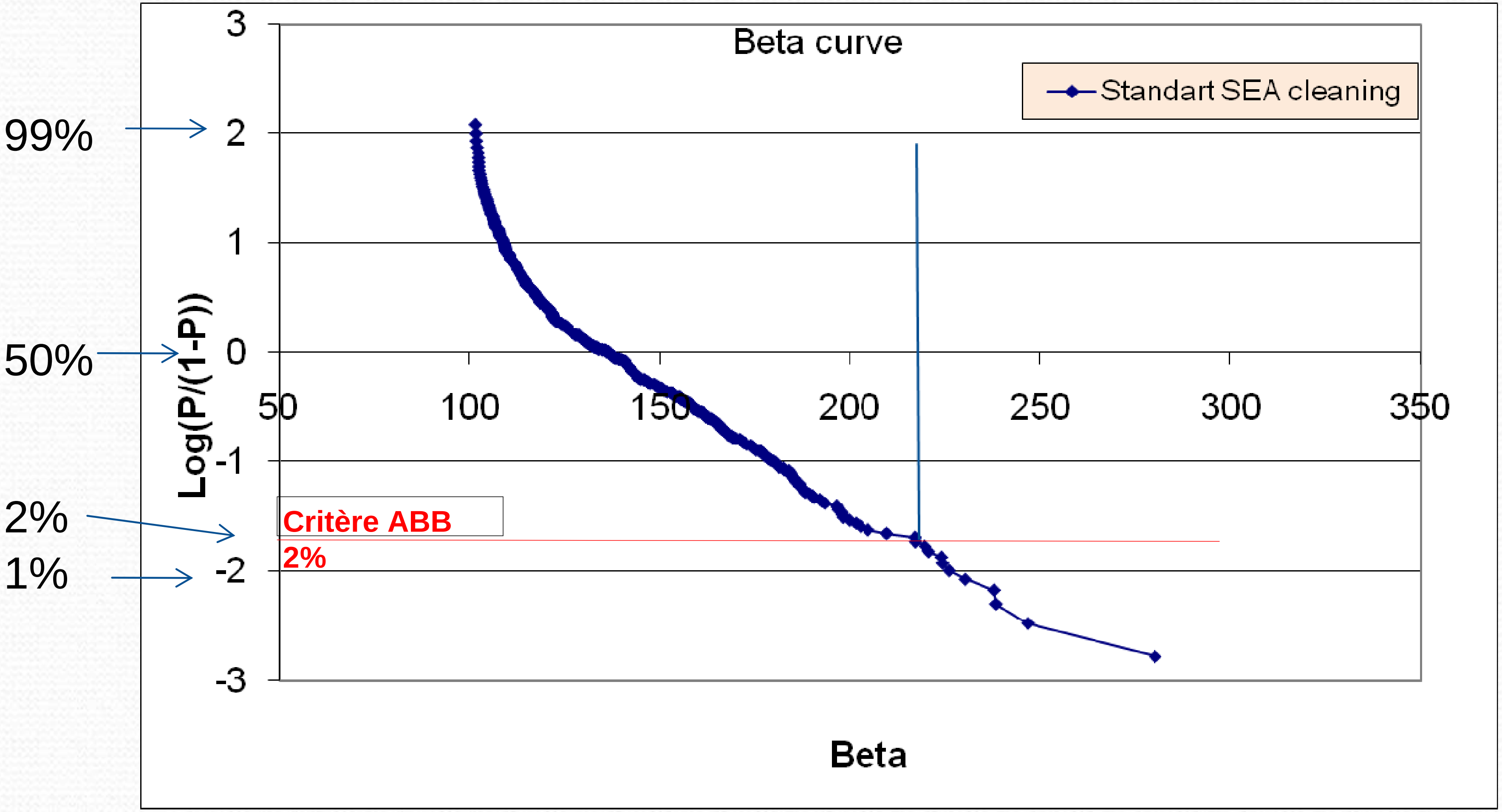


β^1_m

Fonctionnement

L'analyse du beta

P = Probabilité



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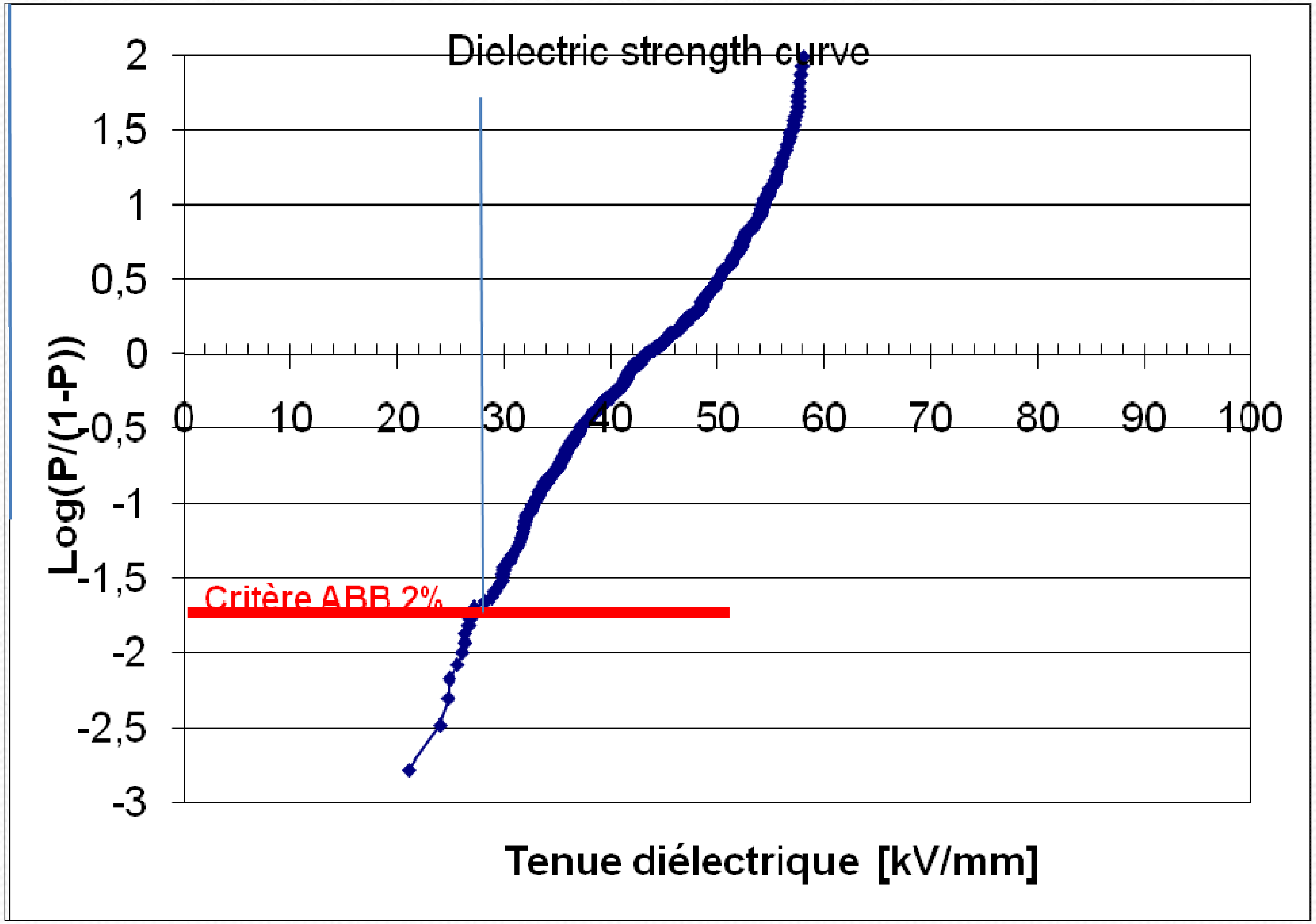
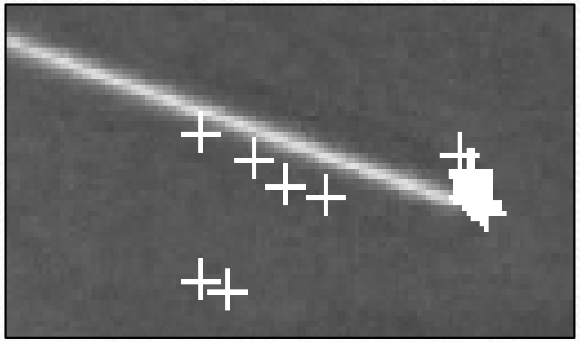
Fonctionnement

La tenue diélectrique

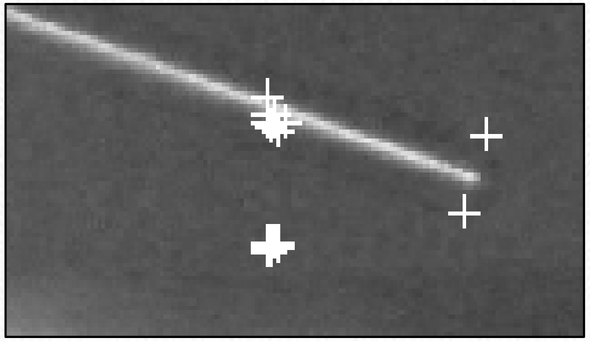


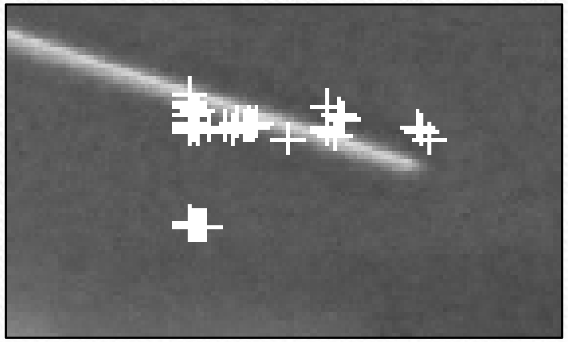
L'étude

Observations



Localisation des betas les plus élevés





Sites d'amorçages très espacés

- 180 < Beta de l'inox < 220
- Les sites d'amorçages sont espacés
- La tenue diélectrique est indépendante du temps de polissage

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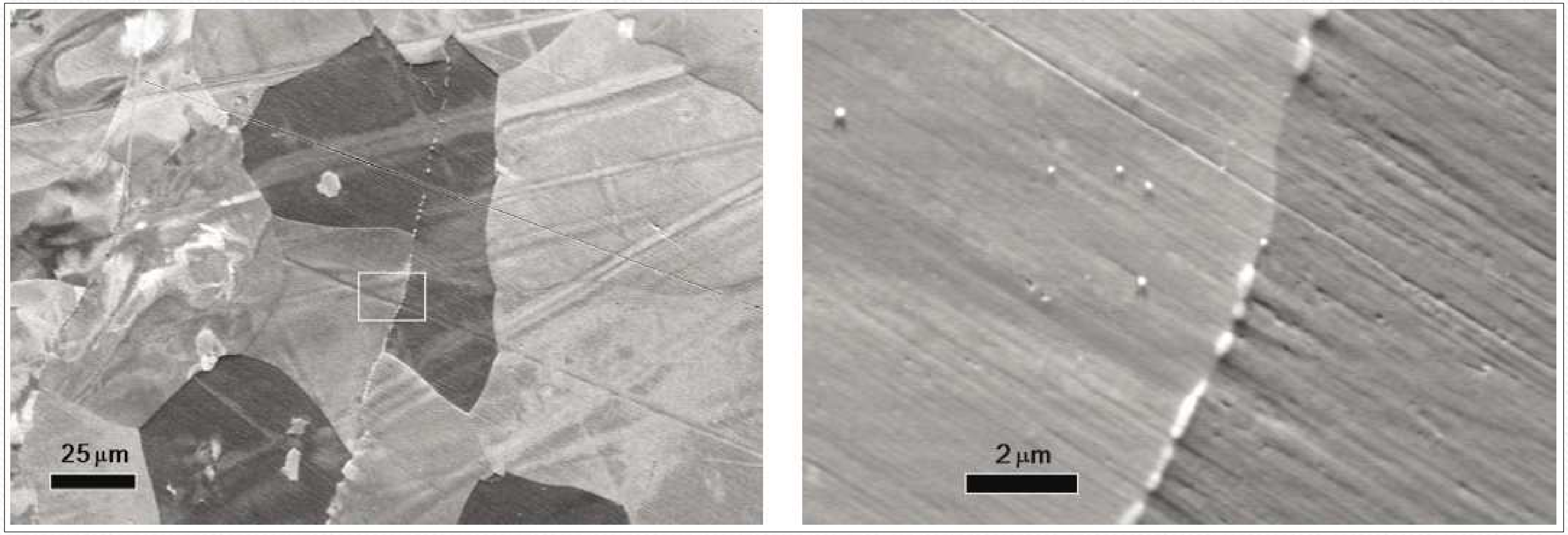
L’étude

Hypothèses de travail 2008



Référence: Phase identification of carbide and nitride precipitates in a ferritic stainless steel

Impuretés aux joints de grain

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L'étude depuis 2008

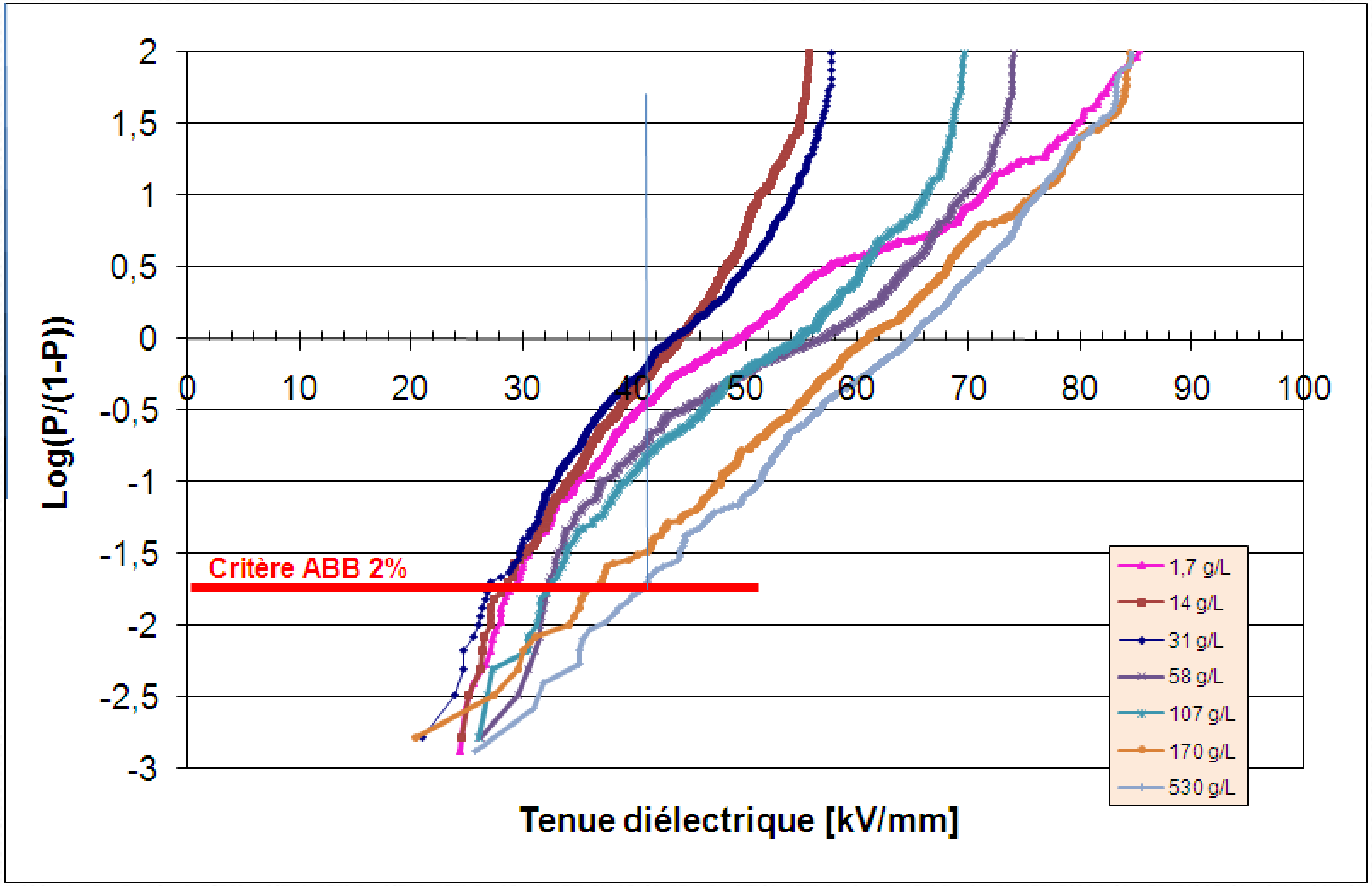
Solutions

➔ Pour éviter la présence de carbure, 3 différentes solutions:

1. L'électrolyse selective
2. Le dépôt Nickel
3. Utilisation steel without chrome « maraging steel »

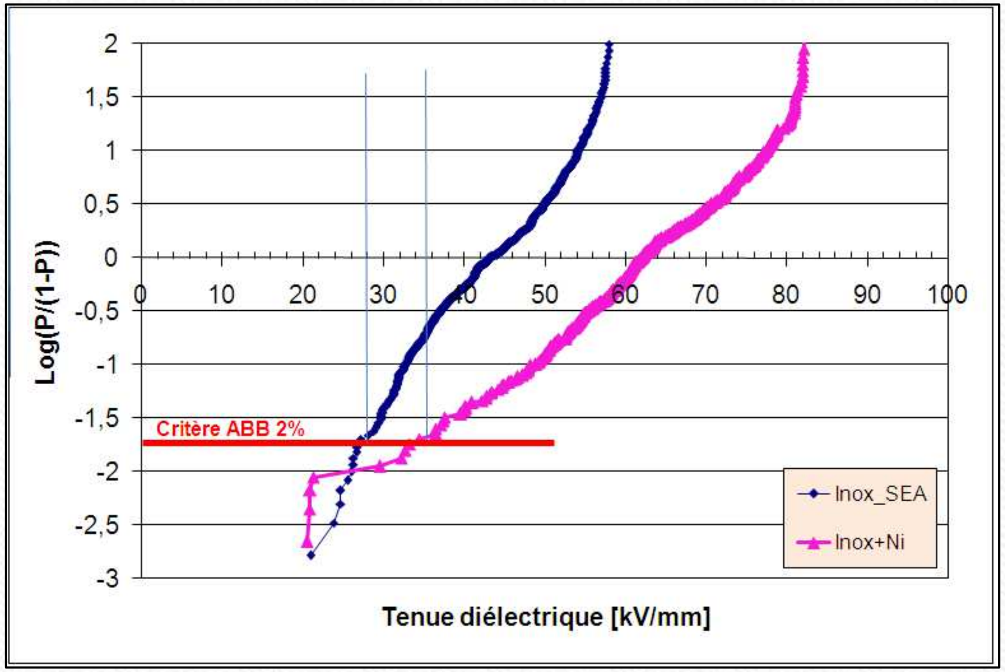
L'étude

1- Résultats: Electrolyse selective (pitting)



L'étude

2- Résultats: Dépôt de nickel qq µm



Lot	Preparation		Surface beta
1	Wood Ni - Ni 1 to 2 µm - EDI + US Hot Air - 2H degreasing	Mean	200
		Sigma	17.7
2	Ni Wood - Ni 1 to 2 µm EDI + US - Hot Air	Mean	191
		Sigma	44.2

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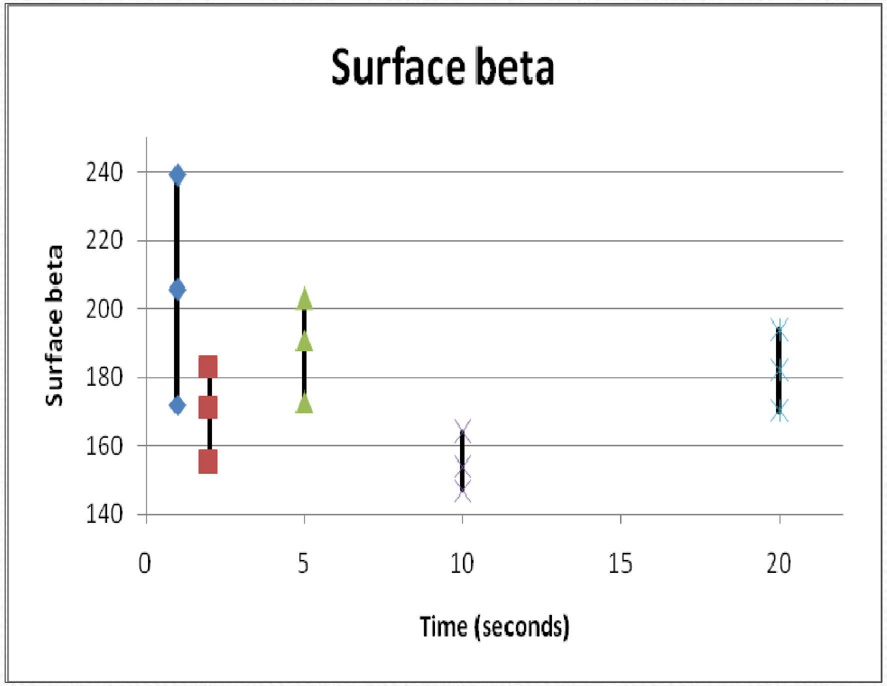
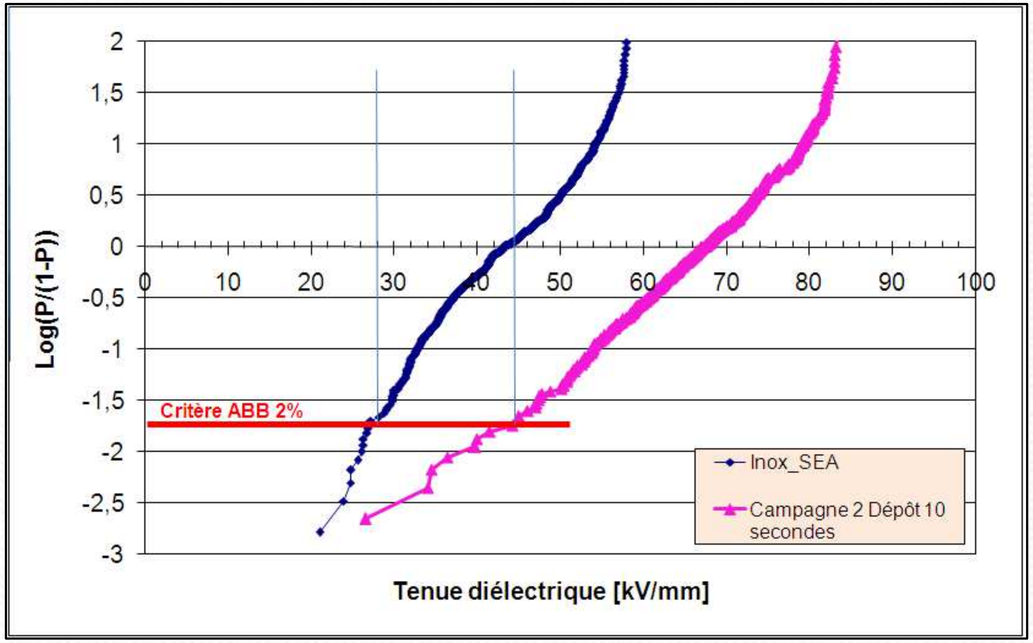
L'étude

2- Résultats: Dépôt couche mince



➔ 10 secondes = Conditions optimales



➔ 10 secondes dépôt Ni électrolytique = + 44 nm sur l'aiguille

L'étude

3- Solutions: Maraging steel (proposed by Farali ~1980)

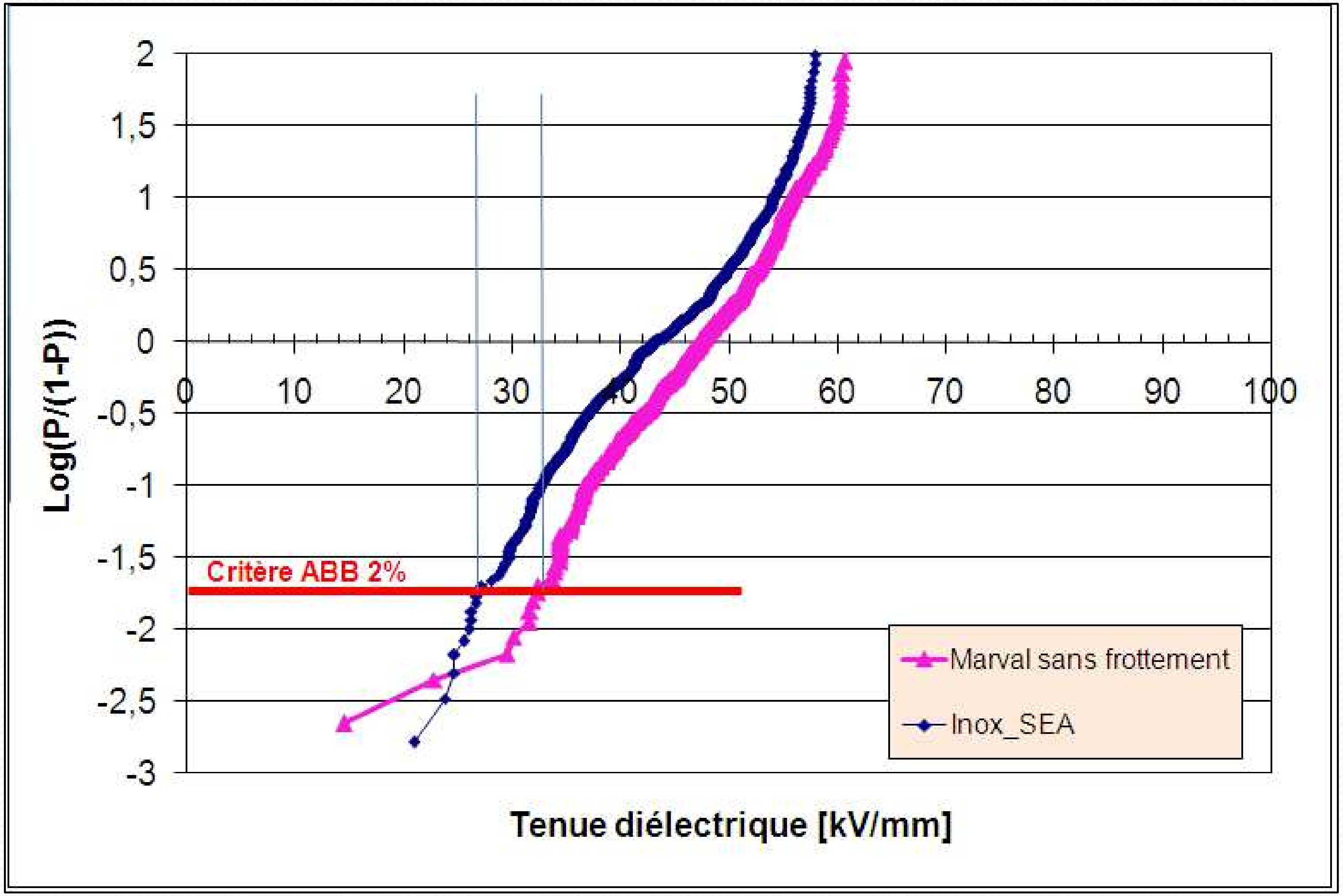
Proposed by Farall ~1980 : No Chromium carbide

➔ **Composition maraging steel:**

- Fer
- Nickel (18%)
- Molybdène (5%)
- Cobalt (8%)
- Carbone, aluminium et soufre (faible quantité)

L'étude

3- Résultats: Maraging steel



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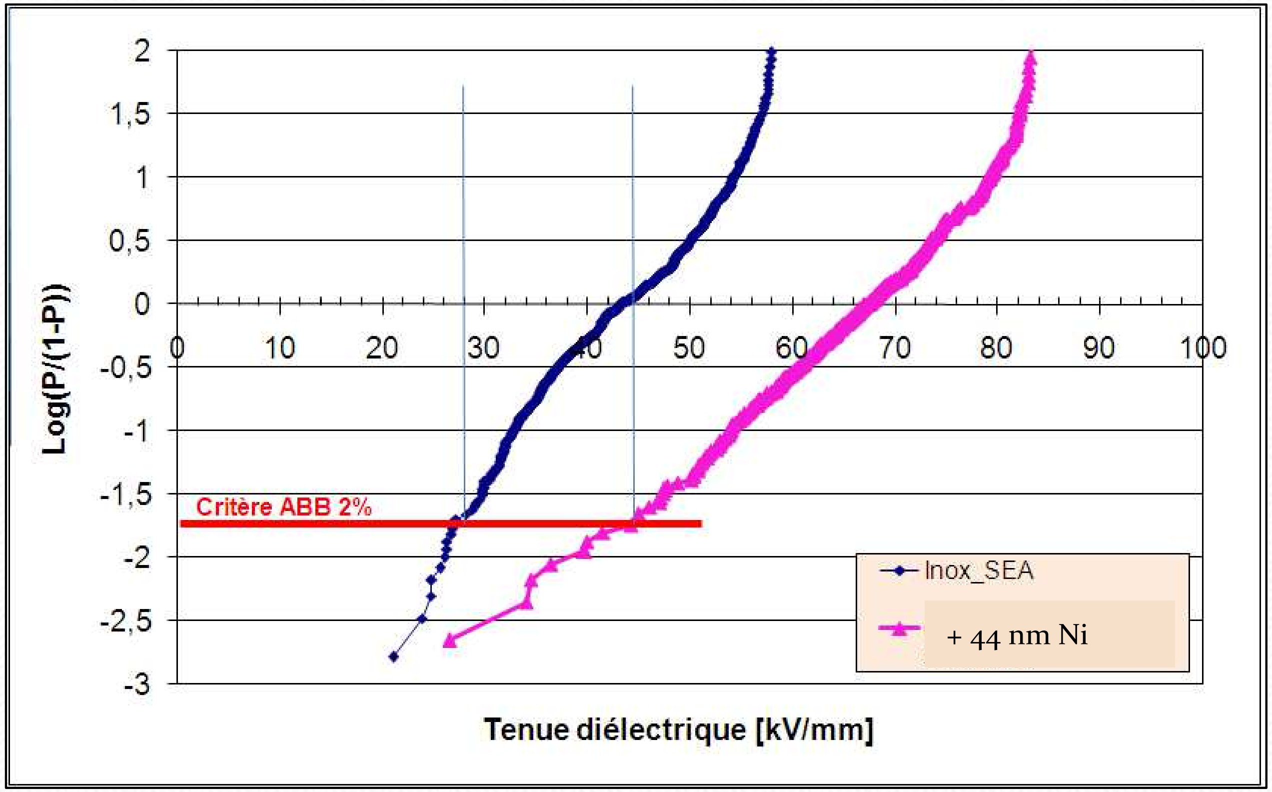
L’étude

Courbes de référence:



L'étude

Conclusion inox

Deux solutions sur trois validées:

- Electrolyse sélective ➔ 50% d'amélioration
- Dépôt Ni de 44 nm ➔ 57% d'amélioration
- Résultats avec le maraging steel : marginal

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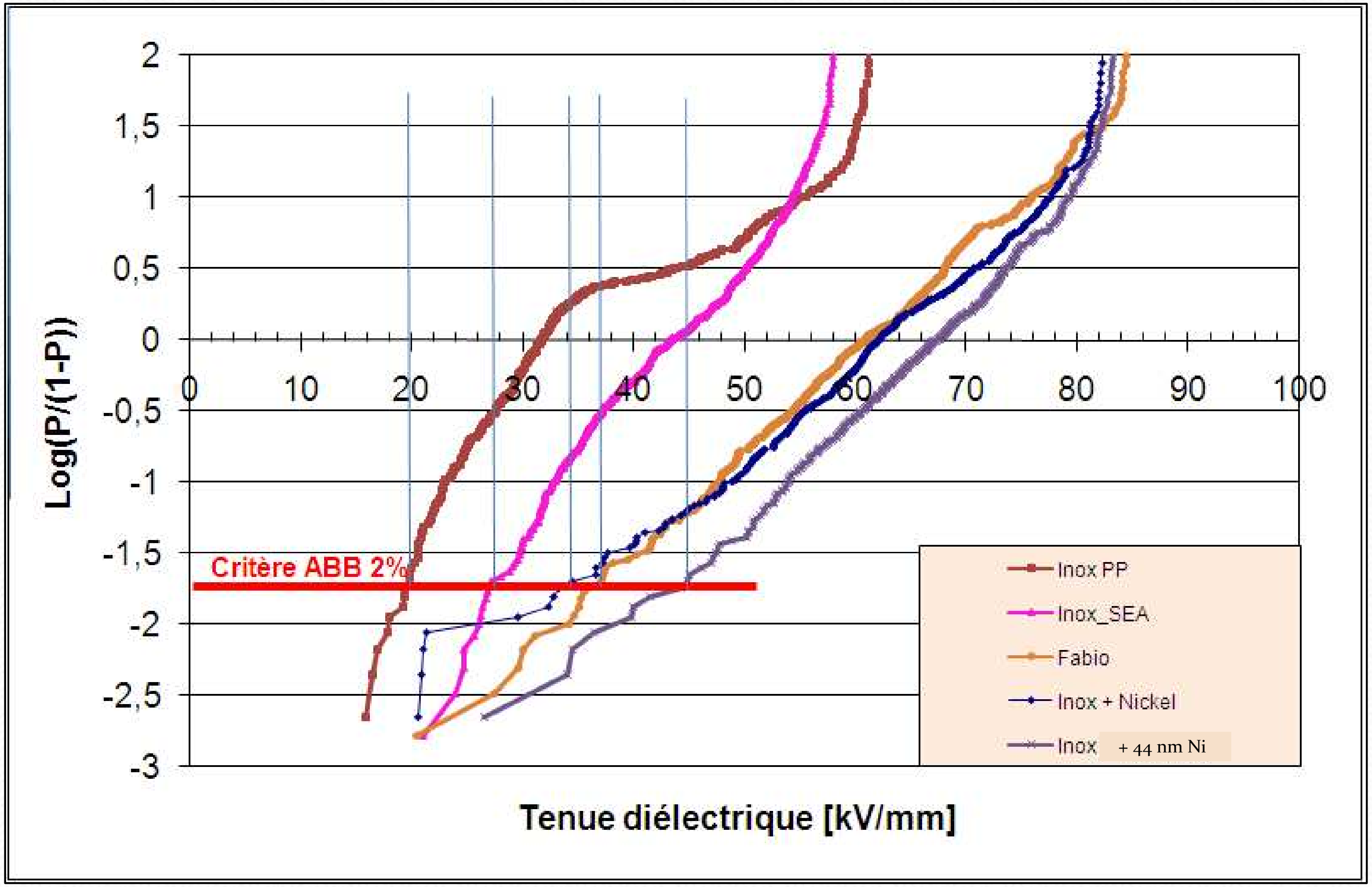
L'étude

Resumé : Inox



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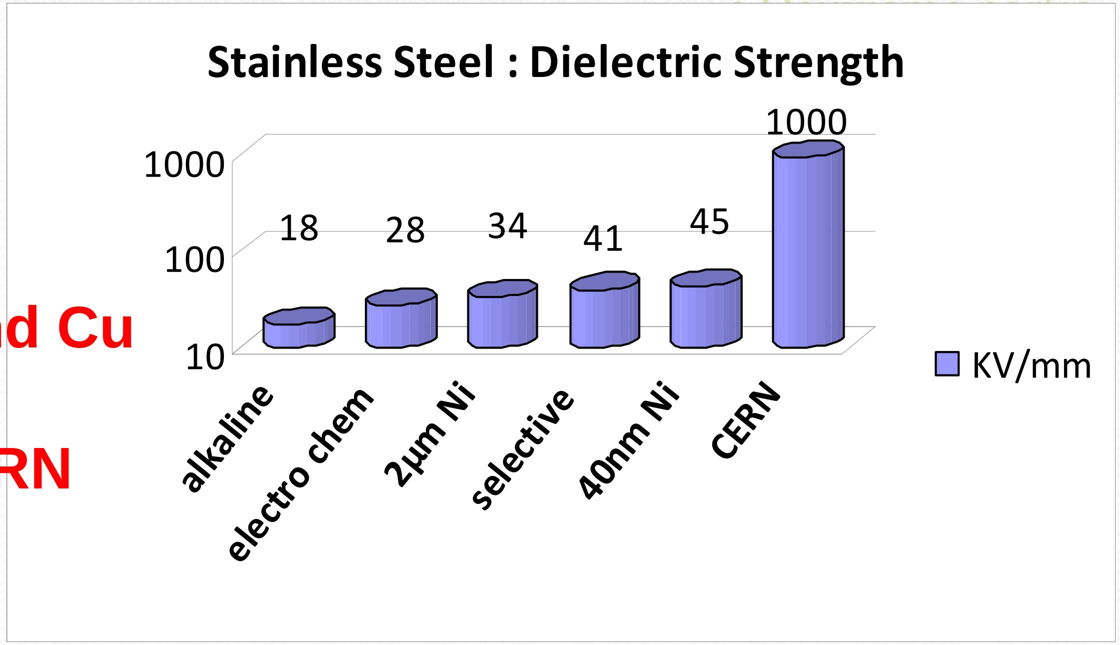
Discussion of results & Summary

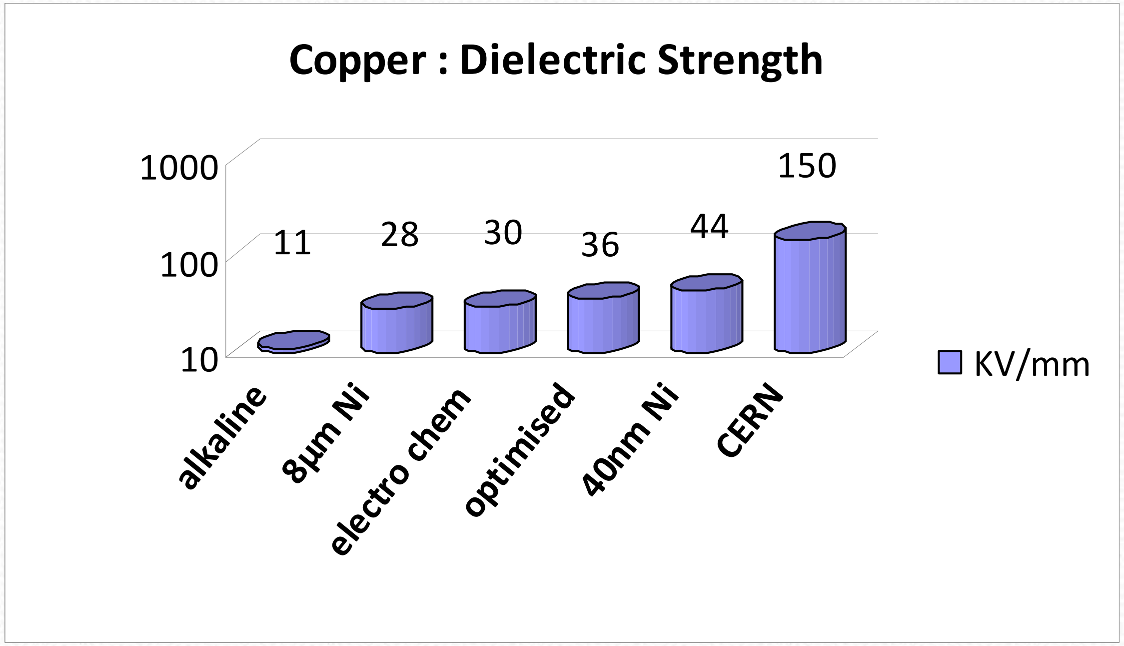
Significant improvement
- **250% * StSt**
- **400% * Cu**

No difference between StSt and Cu

Significant difference with CERN



Possible causes
- **Pollution after cleaning due to handling ?**
- **Cleaning still inefficient due to oxydes or alike ?**




Thank you for your attention