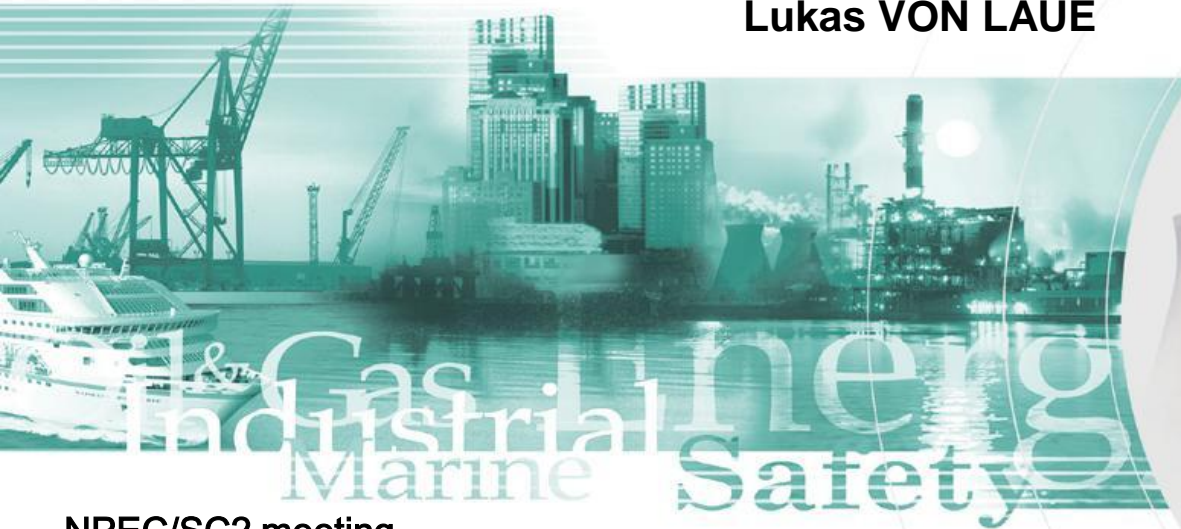




Worldwide Experience with Halogen Free IEEE 383 Qualified Nuclear Power Plant Cables

Lukas VON LAUE



**NPEC/SC2 meeting
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Abstract

Halogen free or FRNC (Fire Retardant Non Corrosive) cables are well adapted for use in nuclear power plants because they provide increased fire safety. In contrast to cables containing halogen, they have low smoke, low corrosive properties and low toxic emissions in case of fire.

Several IEEE 383 nuclear power plant qualifications are available for FRNC cables, including some for Canadian Projects (i.e. Cernavoda in Rumania and Qinshan III in China) and a recent US project (Lungmen in Taiwan).

The last part will give details on FRNC qualification using IEEE, ICEA and AEIC standards performed for the Lungmen Project.

Two different types of cables are used in NPP:

1) Halogenated cables

from the beginning and up to now

In USA , Korea , Japan:
EPR/CSP cables

In Europe : XLPE or EPR/PVC

2) Halogen free cables

since 1991

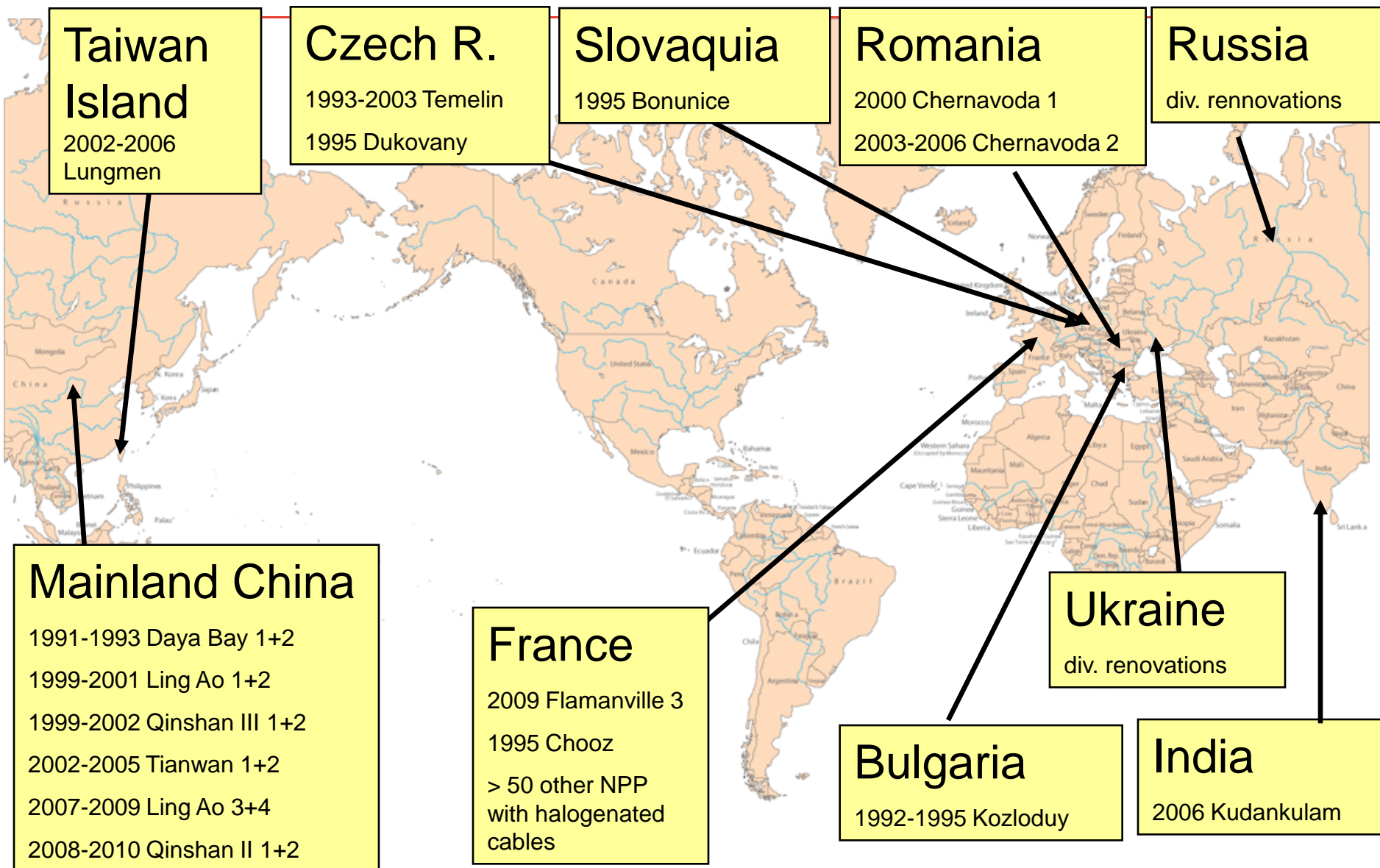
Often called FRNC
(Fire Retardant Non Corrosive)

In China, Taiwan, Europe :
halogen free cables,
for AREVA, GE, Westinghouse,
AECL, Atomstroyexport,
Electricité de France,
China Nucl. Power Engineering Comp.
Taiwan Power Company, etc.

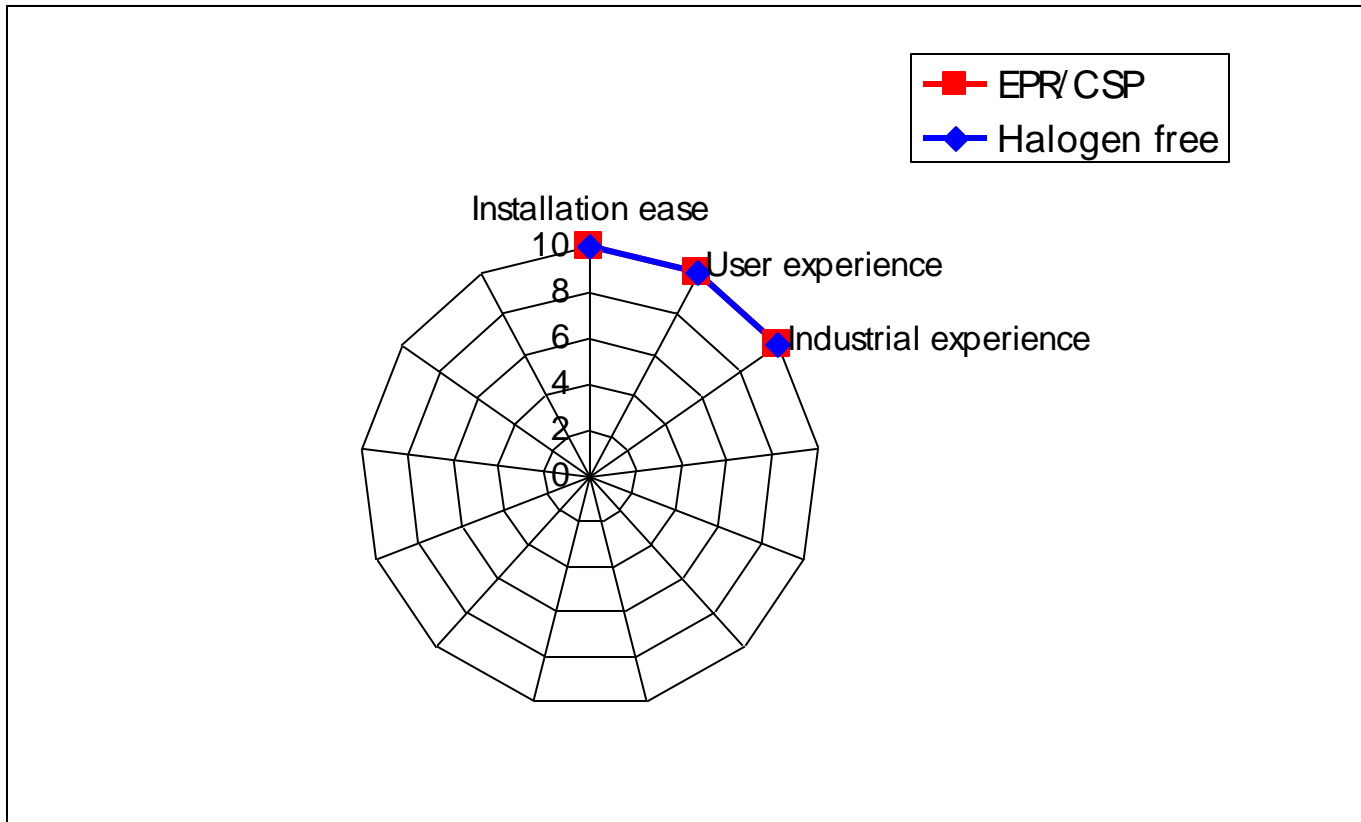
Introduction by Nexans of halogen free cables according to IEEE, ICEA, CSA and AEIC standards:

- For Lungmen NPP – Taiwan – GE BWR
- For Qinshan III – China – AECL Candu
- For Cernavoda II – Romania – AECL Candu

Nexans halogen free NPP cables installed from 1991 to 2009



Comparison Key Properties



Properties of Halogen free material

- Application in since 15 years
- Properties compliant with specifications
- Positive experience feedback

- Approved by
 - Westinghouse for Temelin
 - AECL for Qinshan III
 - AECL for Cernavoda II
 - Stone&Webster/GE for Lungmen





TAIWAN POWER COMPANY

Lungmen Nuclear Power Project

Attachment A4 - Technical Fill-in Data by Bidder

Document Number : 874-E0013F1 REV. N°8

Equipment : Class 1E 600V Power Cable
Quality Class : S

REVIEW RECORD STAMP

- 1 - Work Can Proceed
- 2 - Revise and Resubmit (Work Can Proceed)
- 3 - Revise and Resubmit (Work Can Not Proceed)
- 4 - For Information Only

Responsible Discipline:

- MEC13
- STB
- QA
- ELE
- I/C
- IT

Others()

Responsible Engineer

Print Name Signature/Date

[Handwritten signature]
L. VON LAUE J. CABANNE B. ALBOUY

25/02/2004
J.G. LATHUILLERE R. LORIOL B. ALBOUY

12/7/05
[Handwritten signature]

29/07/2003
L. NGUYEN S. JOLIVET R. LORIOL

18/06/2003
J.G. LATHUILLERE R. LORIOL

Page A-4.7: Addition of new models requested, items 38 to 44
Page A-4.8 onwards: Pagenumbers revised

Follow the NUC No 206204 comments to add the data as below :

- Page A-4.2 : Conductor characteristics stranding type, class
- Page A-4.2 : Tensile stress at 100 % elongation
- Page A-4.3 : Long term water absorption : max power factor & max SIC
- Page A-4.4 : Set max
- Page A-4.4 : After oil immersion 121°C for 18 hours
- Page A-4.4 : Abrasion resistance

- Addition of Quality Class S
- Replacement Annexes A, B & C by the document numbers
- Removal irrelevant documents (Non-Class 1E cables) from the contractual document

NEXANS furnish tensile stress at 100% elongation

Nexans

TAIWAN POWER COMPANY

Lungmen Nuclear Power Project

REVIEW RECORD STAMP

1 - Work Can Proceed

2 - Revise and Resubmit (Work Can Proceed)

3 - Revise and Resubmit (Work Can Not Proceed)

4 - For Information Only

Responsible Discipline:

MEC STR QA

ELE I/C I/T

Others ()

specify

Responsible Engineer

St. Huang
Print Name

St. Huang
Signature/Date
3/17/04

Attachment A4 - Technical Fill-in Data by Bidder

Document Number : 874-E0013E REV. N°8

Equipment : Class 1E 5000V Power Cable
Quality Class : S

11

26/02/2004

J.G. LATHULLERE

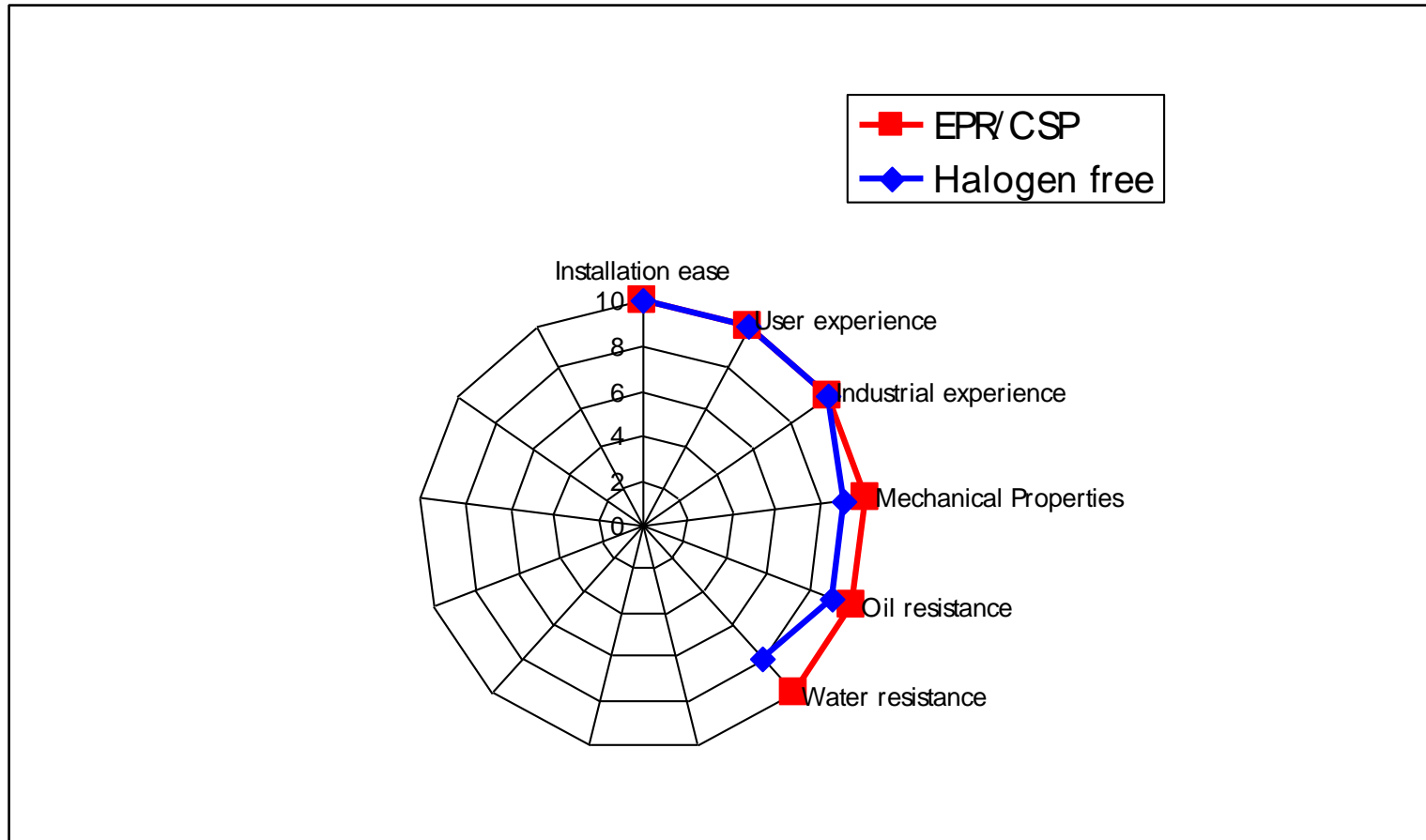
R. LORIOU

B. ALBOUY

Follow the NUC No 206204 comments to add the data as below :

- page A-4.2 : conductor non-metallic shield / Type of material
- page A-4.3 : partial discharge extinction level (corona) min kV
- page A-4.3 : insulation non-metallic shield / Type of material
- page A-4.4 : after oil immersion 121°C for 18hours
- page A-4.4 : factory ac test voltage (ac for 5 minutes)
- page A-4.5 : size of cable : read 3 AWG instead of 3 kcmil

Comparison Key Properties



Fire Properties : Non propagation of fire



For Candu (Qinshan III and Cernavoda II)
and GE (Lungmen) projects

type test and inspection tests made with FT4 and IEEE 383
tests

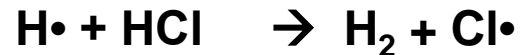
	IEEE 383	FT4	IEEE 1202	UL 1685
MV Power Cables	✓	✓	✓	✓
LV Power Cables	✓	✓	✓	✓
I&C Cables	✓	✓	✓	✓

⇒ halogen free cables are compliant

How do these halogenated flame retardants work ?

- Halogenated material : HCl or HBr can quench radicals:

HCl/HBr is released when material is heated, then



Cl• is less reactive than the other radicals ⇒ flame quenching

⇒ *good flame retardant, but negative side effect :*

SMOKE, TOXICITY, CORROSION



- 1 kg of PVC burnt produces about 2 liter of hydrochloric Acid of “Xi” concentration
- for CSP, “only” ~ 1 liter



How do these halogen free flame retardants work ?

➤ Halogen free flame retardants:

Metal Hydrates,

(eg. Aluminium Trihydrate, ATH)



(endotherm reaction)

⇒ ***ATH consumes heat and release water***

⇒ ***efficient flame retardant, without side effect***

1 kg of ATH filled compound can produce 216 g = 12 mol of water, equivalent to 268 liter of water vapor



Smoke Testing : ASTM E 662 and UL 1685



ASTM E662 classical smoke testing on material plates

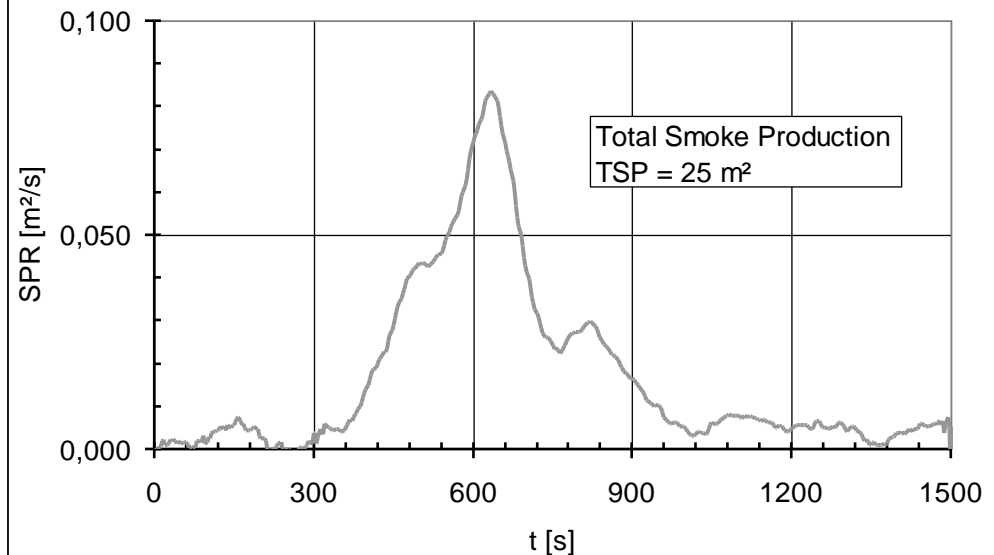


UL1685 smoke testing on cables

(results form test similar to UL1685 :
optically measured in
400mm exhaust duct
above the test chamber)

Smoke testing	UL 1685 IEEE1202 FT4 requirement	typical result for FRNC cables
total smoke production	max 95m ²	10 to 30m ²
peak smoke rate	max 0,25m ² /s	0,05 to 0,15m ² /s

**Smoke Production Rate of
3x1,5mm² 0,6/1 kV halogen free cable**

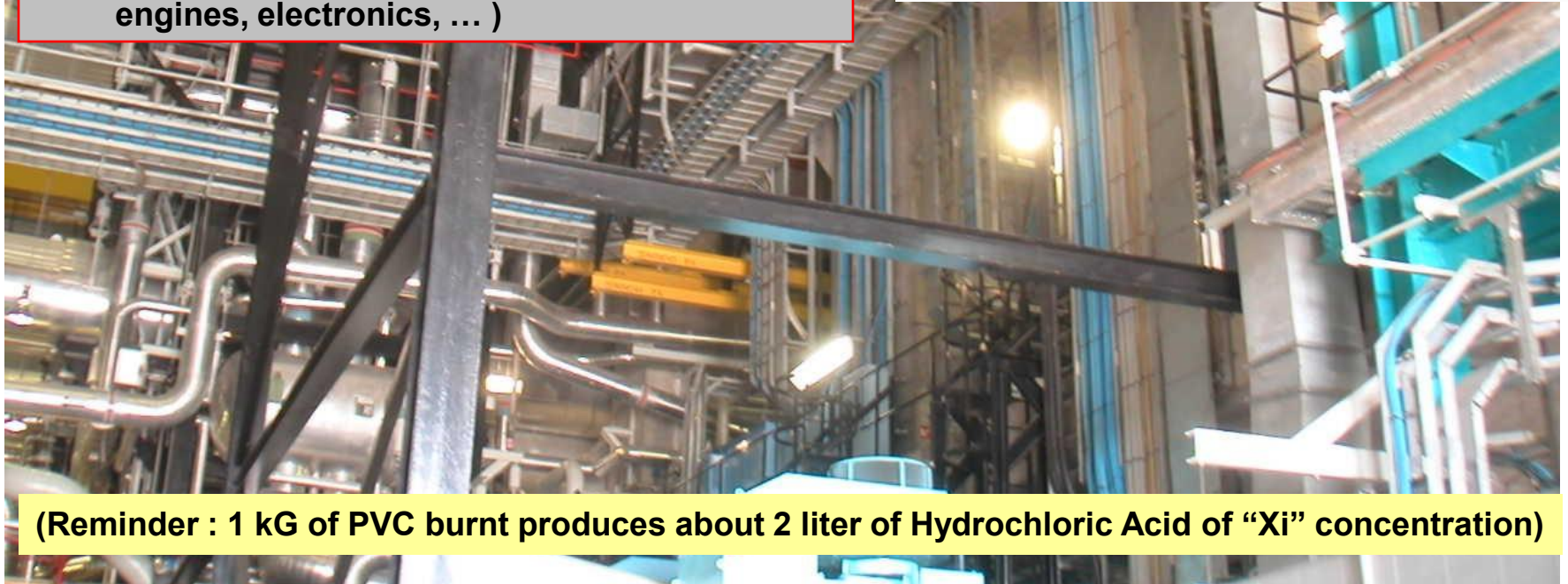
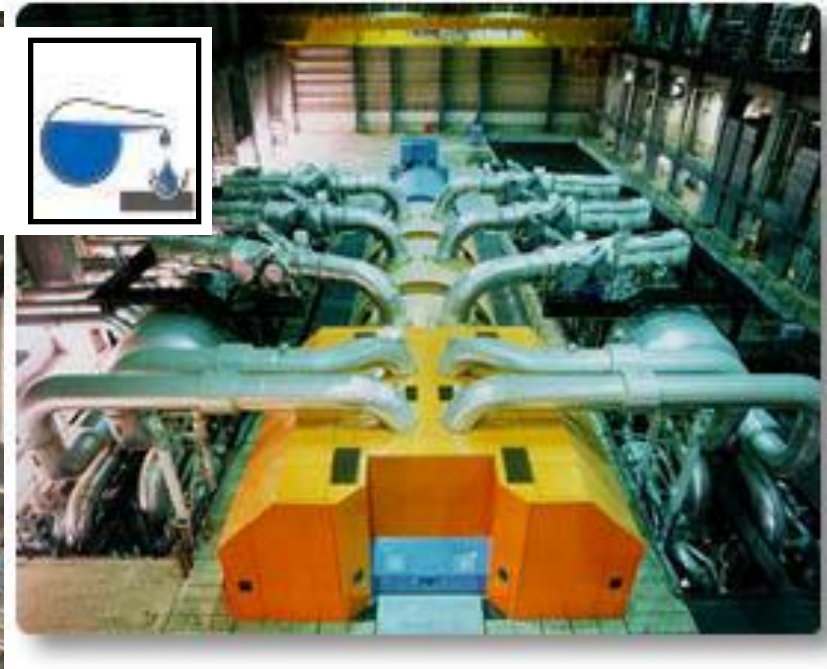


⇒ **Very low smoke for halogen free cables**

Fire Properties : Corrosivity





Halogen free cable in fire means:

- ✓ No HCl gas production or other halogen gas
- ✓ Avoid hydrochloric acid formation
- ✓ ***Avoid corrosion on metallic equipment***
(metallic structures, conducts and pipes, engines, electronics, ...)

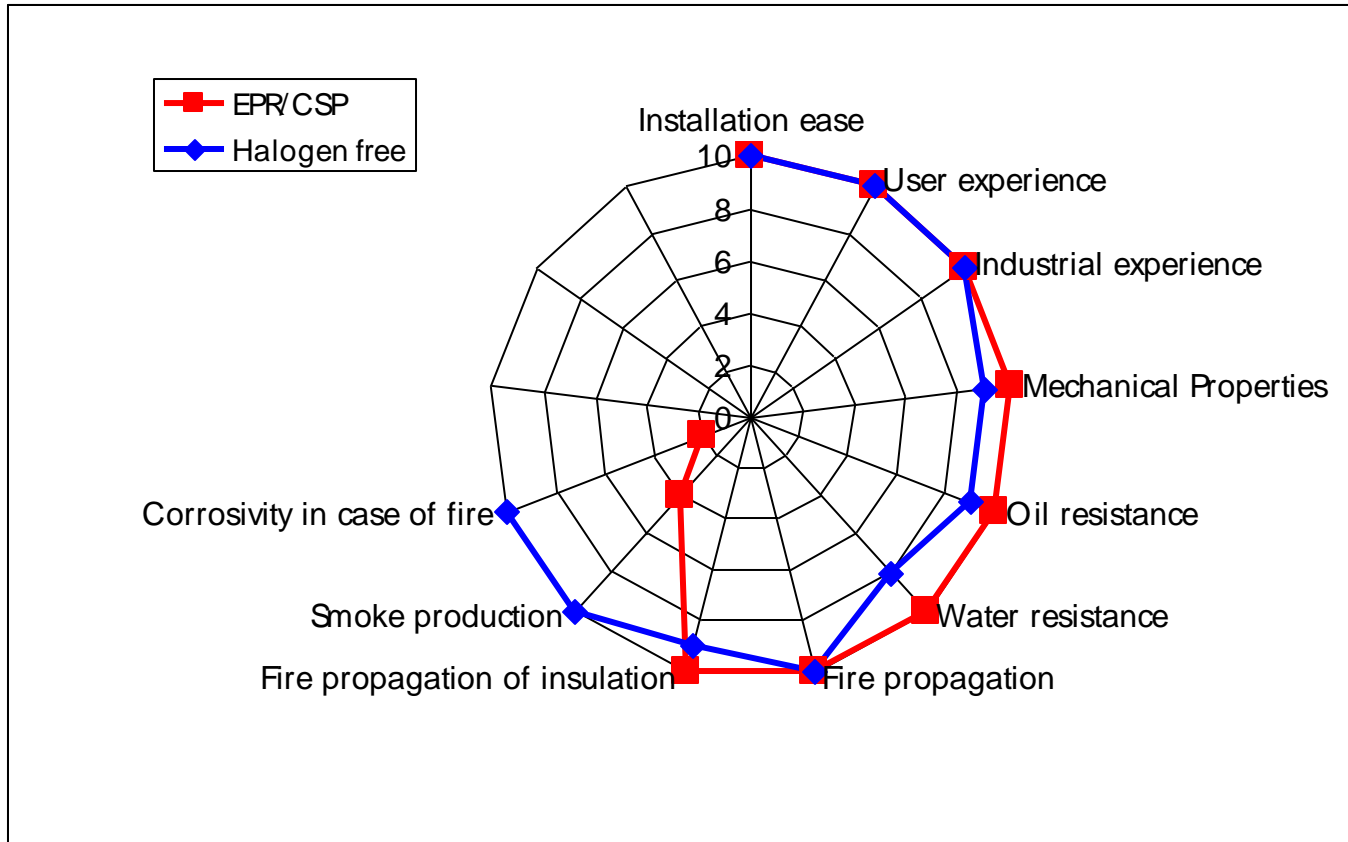


(Reminder : 1 kG of PVC burnt produces about 2 liter of Hydrochloric Acid of “Xi” concentration)

Fire risk in NPP

	 fire	 smoke	 corro- sivity
Halogenated products : good Fire Retardancy but releasing heavy smokes toxic gases corrosive gases (HCl, HBr, HF ..)	ok	not ok	not ok
<div style="display: flex; align-items: center;">  <div> Halogen Free products : Good Fire Retardancy Low Smoke Zero Halogen release </div> </div> <p>halogen free ≡ FRNC Fire Retardant Non Corrosive</p>	ok	ok	ok

Comparison Key Properties



Lungmen IEEE 383 Qualification



Lungmen 1&2, Taiwan, BWR from GE (USA)
FRNC Power and control cables from Nexans 2004-2006

1) Thermal Aging

Method:

Simulate cables qualified life by

- Arrhenius method -IEEE101
- Complete cable test according to IEEE 383

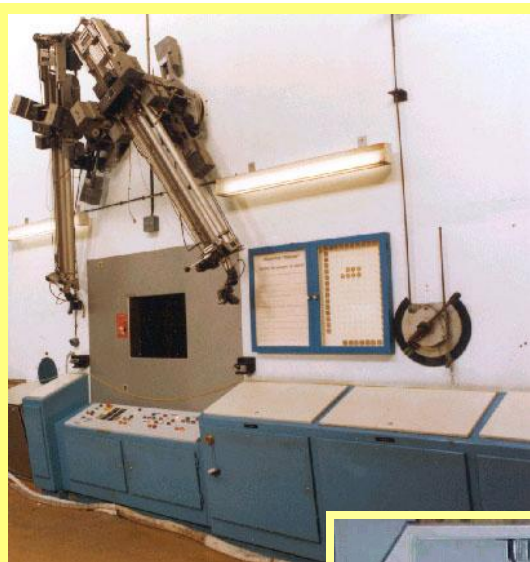
Requirement:

Electric evaluation after bending

- 40 years for Lungmen
- 60 years now



2) Gamma radiation



γ radiation
from ^{60}Co



PRODUCTION INDUSTRIELLE SACLAY/LABRA
Réf. : 02/818/MN/LB
N° d'affaire : 02-QN-12/indice A



CIS bio international

4/4

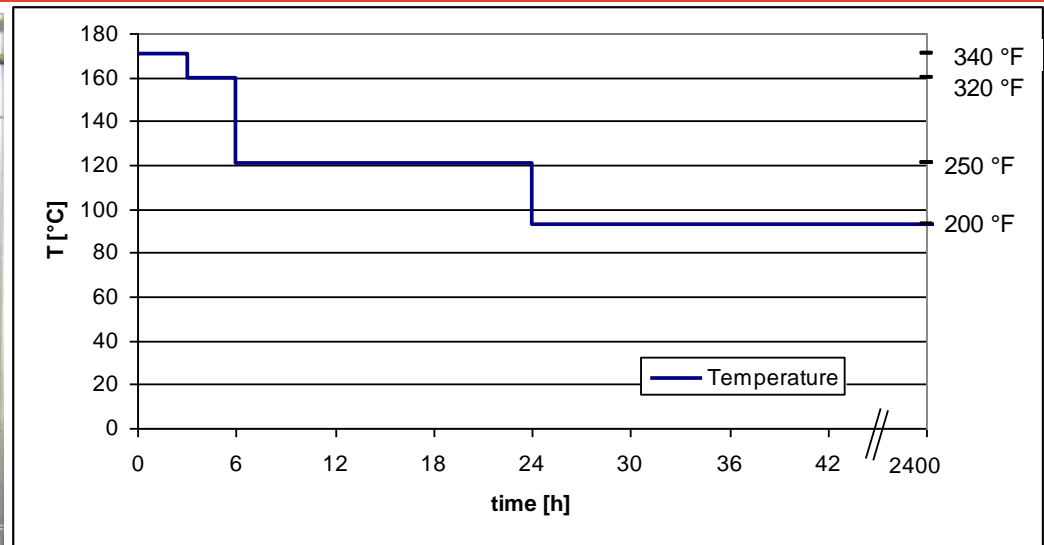
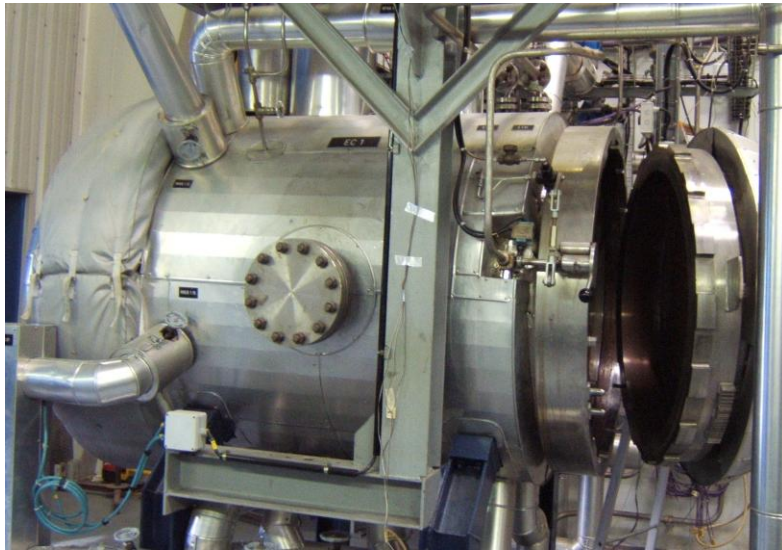
4.2 Irradiation

CER qualification :
- Dose rate : $7,80 \text{ kGy.h}^{-1}$
- Dose : $998 \text{ kGy} \pm 15\%$
- Room temperature

LUN qualification : Cables and plates were placed on two different supports.
- Dose rate : $7,80 \text{ kGy.h}^{-1}$
- Dose : $1998 \text{ kGy} \pm 15\%$
- Room temperature



3) Loss of Coolant Accident Simulation



Lungmen LOCA curve :

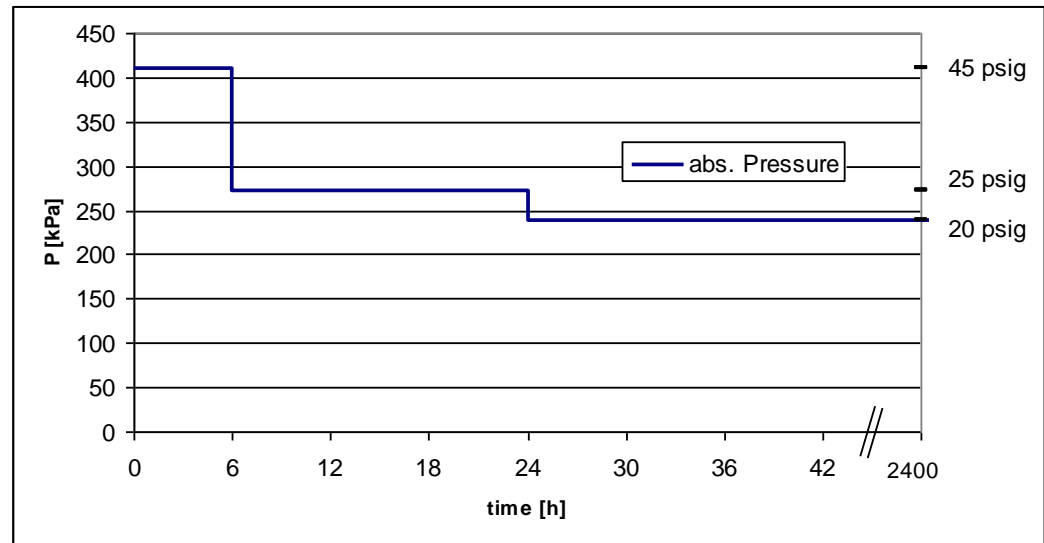
max. Temp 340°F

max. Pressure 45 psig

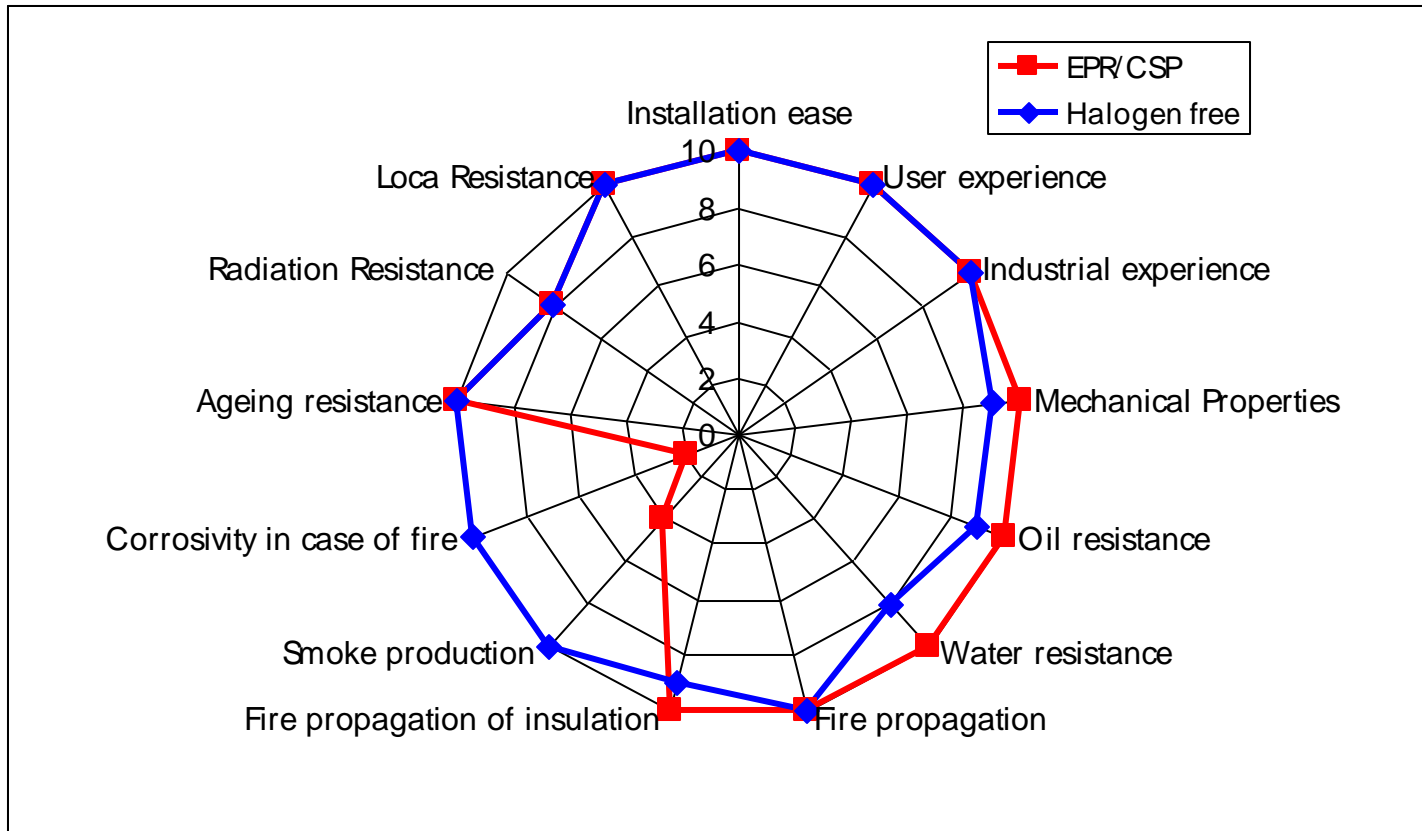
with FRNC cables

Many other LOCA curves are available

Up to 480° F



Comparison Key Properties



Halogen Free cables for new US NPP generation

- 15 years of positive experience
- Complete product range IEEE 383 qualified
- Important LOCA test range experience
- Design compliant to IEEE/ICEA/UL requirements
- Improved fire safety
- Cost saving solution

Thank you for your attention.