International meeting
EQUIPMENT QUALIFICATION IN NUCLEAR INSTALLATIONS

Two qualification campaigns of sealing types for nuclear application

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cetim

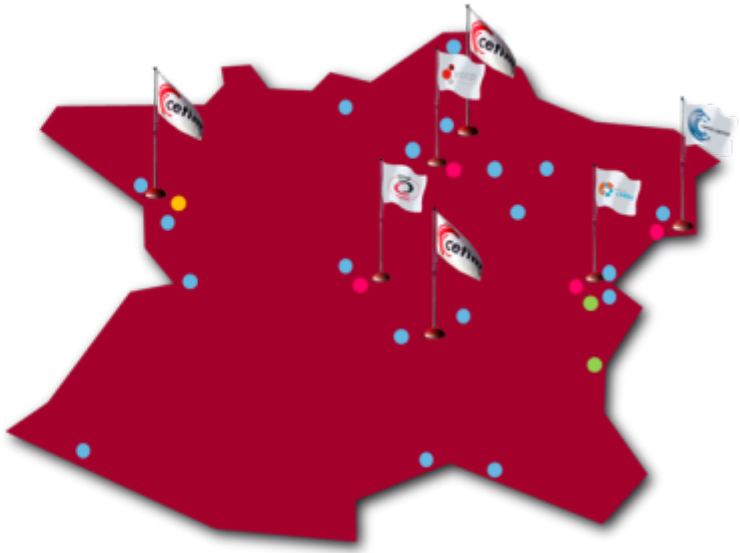
Outlook

- Quick presentation of CETIM
- Campaign 1 : Qualification of low friction valve packings for nuclear applications
  - Work program
  - Testing facilities
  - Results
  - Conclusions
- Campaign 2 : Qualification of static and semi-dynamic O-ring of mechanical packings
  - Work program
  - Testing facilities
  - Results
  - Conclusions

A regional, national and international player

The French mechanical centre close to its 6,500 subscribing companies

- 3 main sites:
  Senlis, Nantes, Saint-Etienne
- 19 delegations
- 4 associated centres
- 2 resource centres: Mechatronics, Non-destructive testing
- 2 subsidiaries dedicated to material testing for production monitoring



Fondationcetim
sous l'égide de la Fondation de France

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Scientific issues and technics linked to control and understanding of sealing mechanisms

FLOW
Multiphase flows
Thin films
Fluid couplings structure

TRANSFERTS
Diffusion
Heat science
Ageing laws

MECHANISMS
Mechanic of contact,
Tribology
Conception,
Process

Sealing: A multiphysical discipline

PHYSICS / MICRO-MECHANIC
Advanced measurements
Micro-sensors
Microfluidics

COMPLEXE MATERIALS
Rheology
Multiphysics materials, porous
Physic of materials

MATERIALS
Mechanical behaviour
Damages
Chemistry of materials
Non destructive controls

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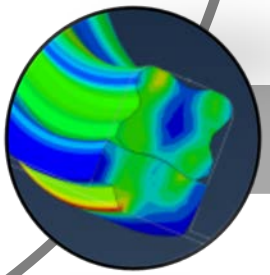
A triple expertise

Leak measurement expertise

Qualification characterisation



Sealing mechanisms

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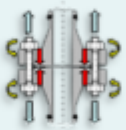
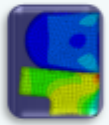
Our domains of intervention…

Leak measurement expertise
Detection, location, quantification

Characterisation Qualification
Products and sealing systems

Sealing mechanisms
Sealing systems modelling and analysis

Activities	Activities	Activities
 Helium leak testings	 Product qualification testings	 Design tools
 Alternative leak measurement methods	 Components qualification testing	 Sealing systems modelling
 On site leak measurements	 Characterisation test engineering in service conditions	 Material analysis and sealing performances improvment
 Diagnosis and support	 Test bench engineering	 Selection support/ sealing system design
		 Failure analysis

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Example n°1 : Qualification of low friction valve packings for nuclear applications

Introduction

- Friction forces of valve packings are identified by EDF as an axis of improvement to avoid either changes of electric actuator or heavy and expensive modifications of valves.
- In this context, packing manufacturers have developed graphite and PTFE low-friction packings whose performance must be known.
- From 2015 to 2018, in this project for nuclear applications, several types of packing are tested for
    - Corrosion at ambient and high temperature.
    - Cycling tests are performed to determine their sealing and friction performances.
    - And cycling tests coupled with irradiation phases are carried out to qualify their resistance to radiation.

Outlook

- Work program
- Testing facilities
- Results
- Conclusions

Work program

- Type of testing packing
  - PTFE braided rings + braided graphite end rings from various packing manufacturers

	Material
Sealing ring	PTFE
End ring	Graphite

  - Expanded graphite rings + braided graphite end rings from various packing manufacturers

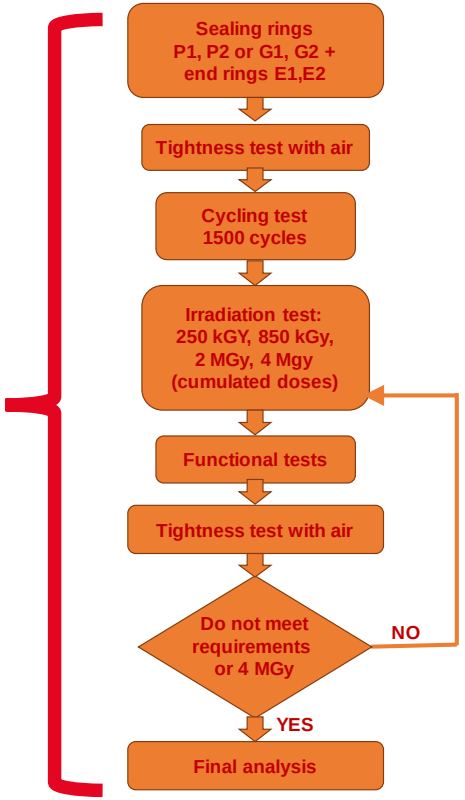
	Material
Sealing ring	Graphite
End ring	Graphite

Work program

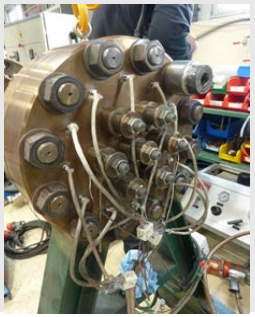
functional qualification under normal conditions

- End ring + PTFE or Graphite packing → Corrosion test at ambient temperature
- End ring + PTFE or Graphite packing → Corrosion test at high temperature
- End ring + PTFE or Graphite packing → Cycling test

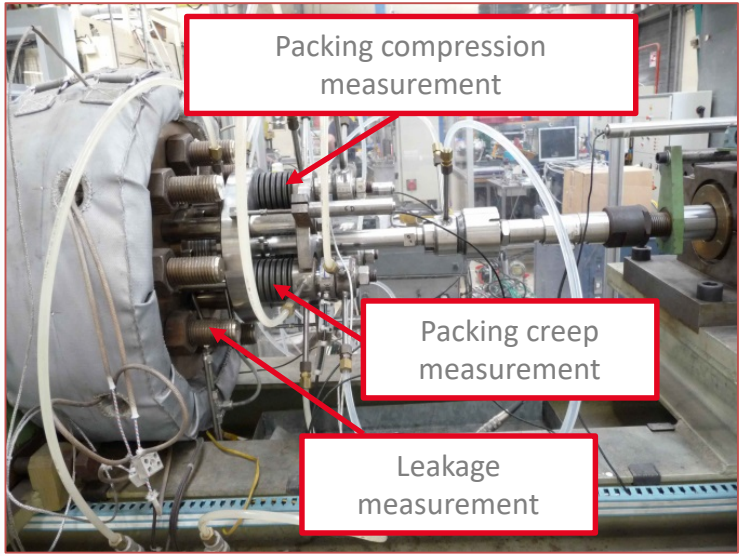
functional qualification under accidental conditions

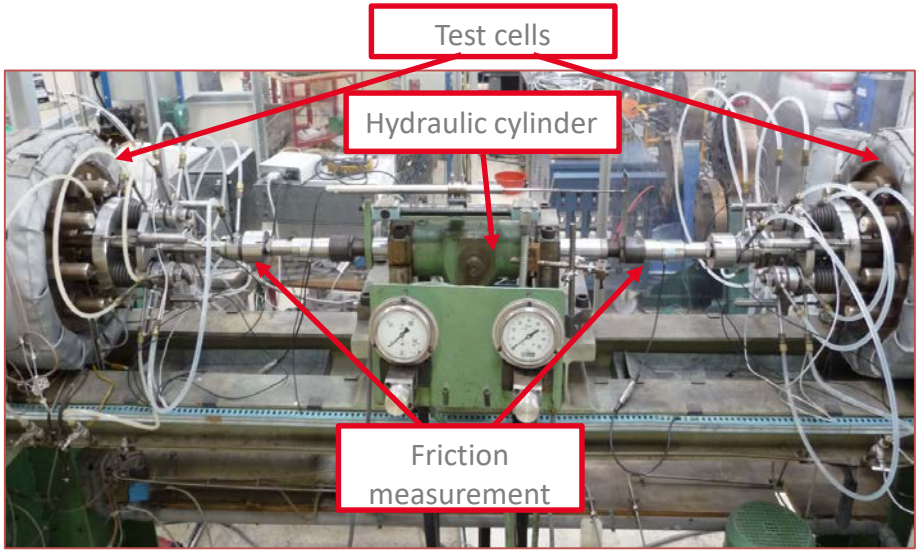


Testing facilities and procedures

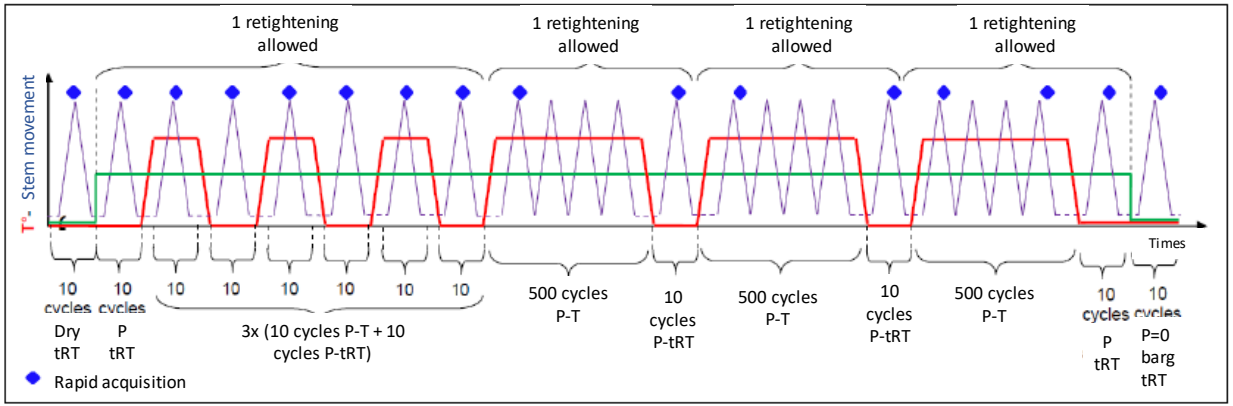
Corrosion test bench	Ambient temperature	High temperature
		
Test procedure	5 weeks	5 weeks
Pressure	Wet air	90 bar - demineralized water
Compression	30 MPa	30 MPa
Temperature	Room Temperature (tRT)	300°C
Analysis	Optical and Scanning Electron Microscope	
Criterion	No corrosion	

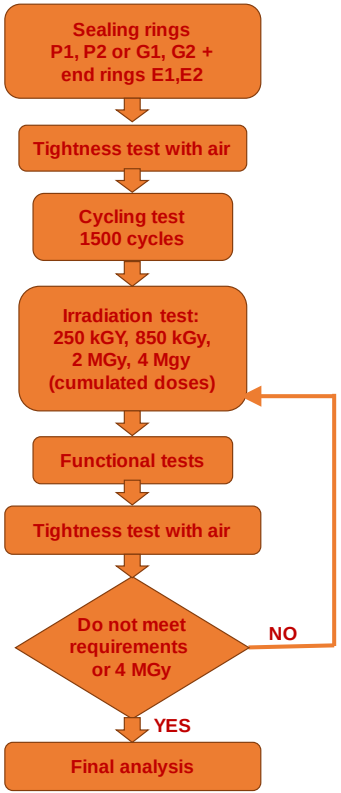
Testing facilities



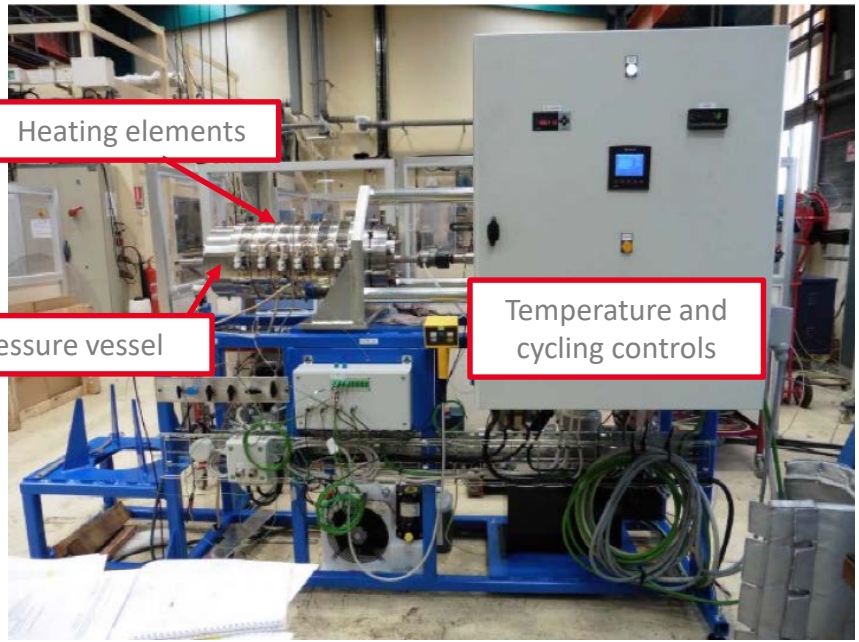


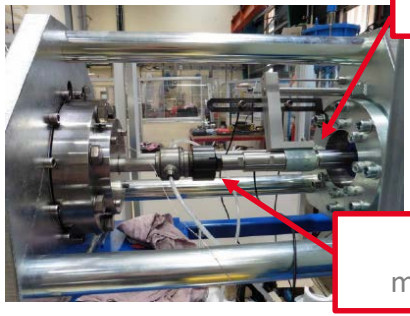
Testing facilities and procedures

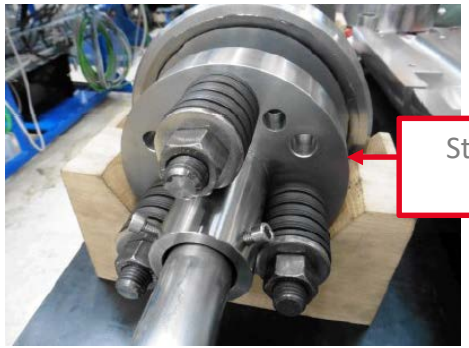




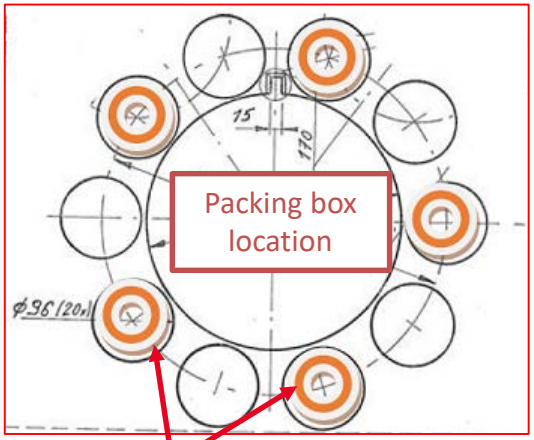
Testing facilities and procedures

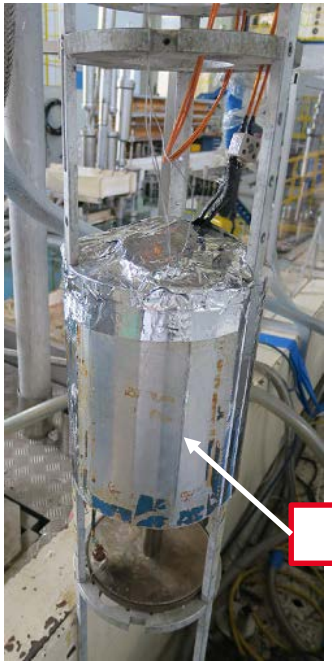






Testing facilities and procedures





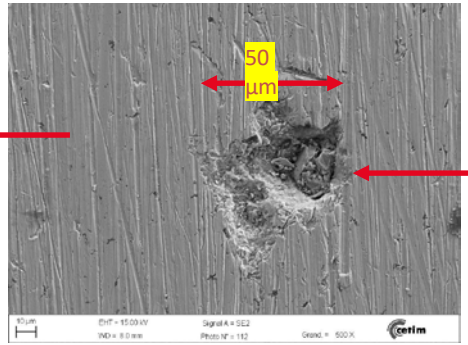
Temperature : 70°C (+/- 3°C)
Atmosphere : air
Dose rate : 8 kGy/h
Total dose : 250 kGy
+ 600 kGy (850 kGy)
+ 1150 kGy (2MGy)
+ 2000 kGy (4 Mgy)

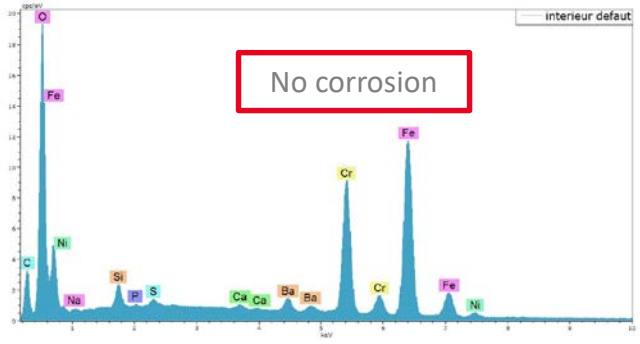
Results

Specimen after corrosion test at room temperature

Corrosion test	Ambient temperature	High temperature
PTFE 1	No corrosion	No corrosion
PTFE 2	No corrosion	No corrosion
Graphite 1	No corrosion	No corrosion
Graphite 2	No corrosion	No corrosion
END RING 1	No corrosion	No corrosion
END RING 2	No corrosion	No corrosion

Specimen after corrosion test at high temperature



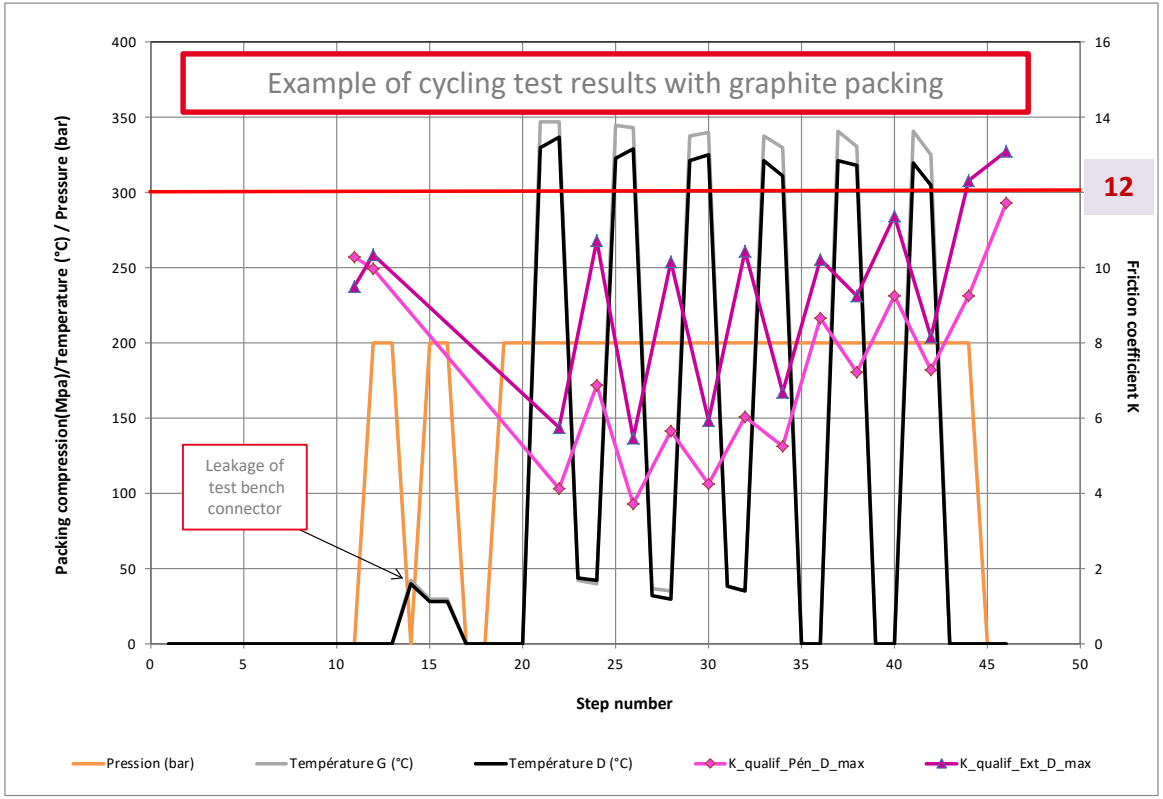


No corrosion

Qualification of low friction valve packings for nuclear applications.

Results

- Cycling tests
- Graphite
  - Leakage <5 ml/h
  - Friction K is lower than the previous packing generation at the beginning of the test (around -28 %)
  - However friction coefficient increases with cycles without exceeding 12
  - K≈ 12 at the end without pressure
- PTFE
  - Leakage <5 ml/h
  - Friction K is around 4-5 at the beginning of the test and decreases down to values lower than 1
  - K≈ 2 at the end (without pressure)

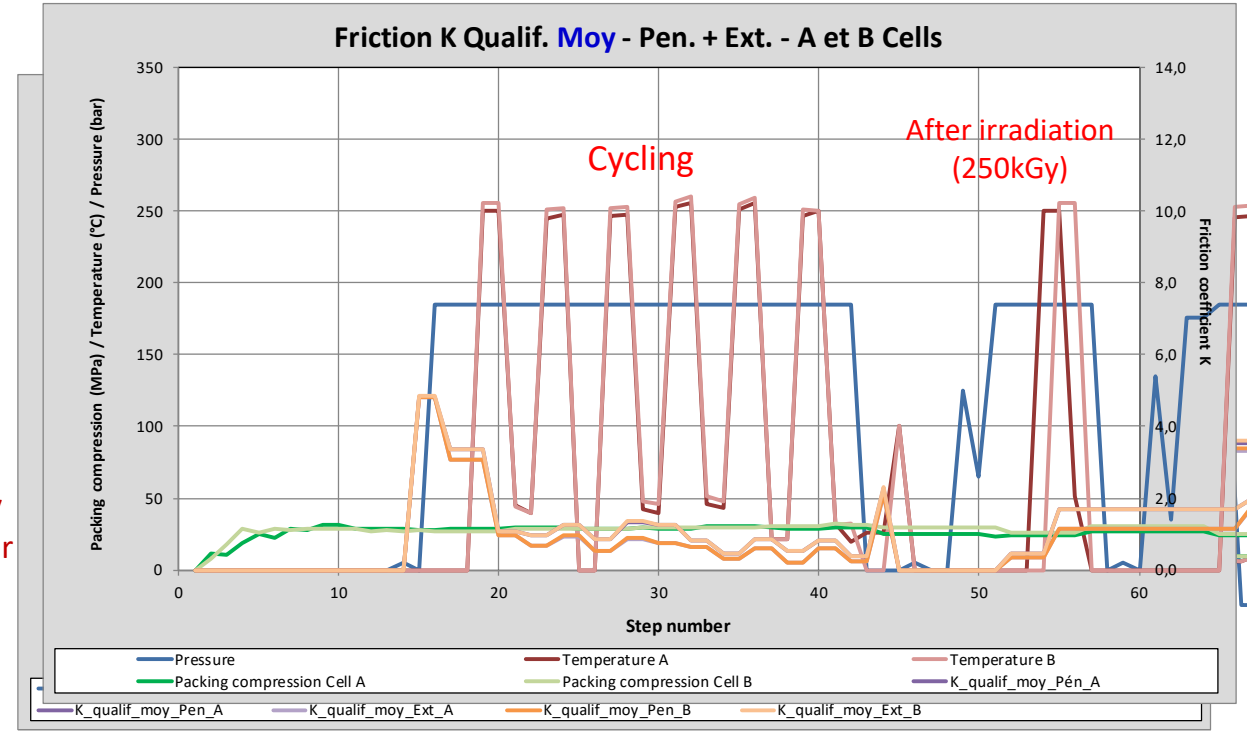


Qualification of low friction valve packings for nuclear applications.

Results

Irradiation test : graphite

- Leakage <5 ml/h (during cycling)
- Leakage <50 ml/h (after irradiation)
- Friction K is lower than the previous packing generation at the beginning of the test
- Friction coefficient K remains stable with cycling
- K≈ 9 (dry, tRT)
- K<6 (200 barg, 300°C)
- K≈ 8-10 (0 barg, tRT)
- K remains constant even after 4 MGy (no detectable degradation even after 4 MGy irradiation)

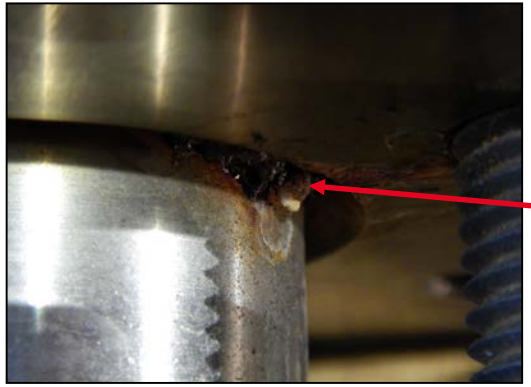


Irradiation test : PTFE

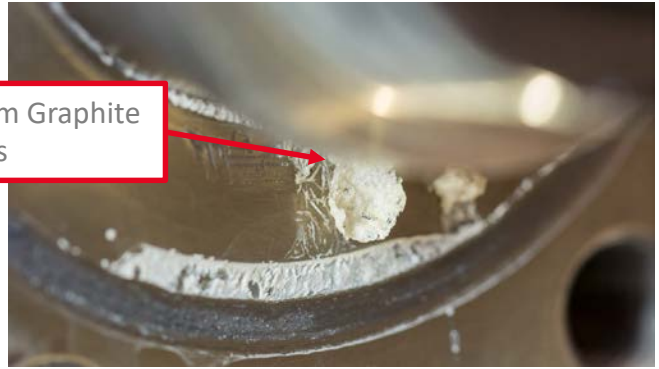
- Leakage <5 ml/h (during cycling)
- Leakage <50 ml/h (after irradiation)
- K≈ 2-5 (dry, tRT)
- K<1 (185 barg, 250°C)
- K≈ 1-2 (0 barg, tRT)
- K remains constant even after 4 MGy (no detectable degradation even after 4MGy irradiation)

Qualification of low friction valve packings for nuclear applications.

Results

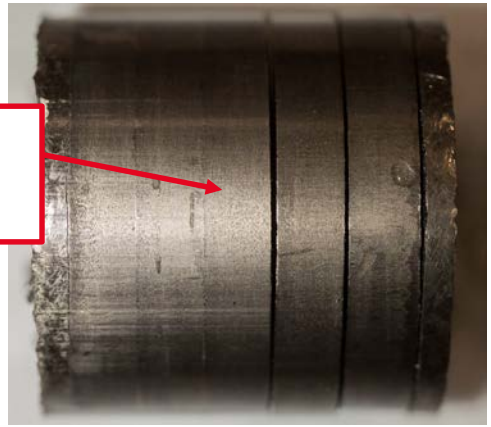


Brown particles with PTFE packing



White powder from Graphite packings

PTFE Packing after irradiation



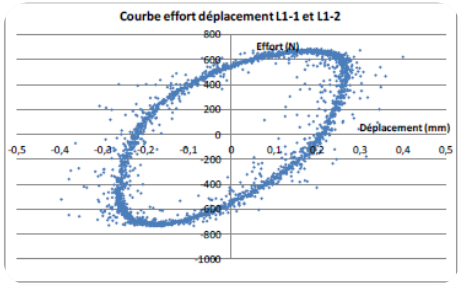
Except a slight extrusion, no significant packing damage

Conclusions

- Test procedures and test installations were developed by CETIM

- Various tests are performed :
  - ✓ Two types of braided PTFE and expanded graphite packings with graphite end rings
  - ✓ Corrosions test at ambient and at high temperature
    - ⇨ No corrosion is observed both for PTFE and graphite packing
  - ✓ Cycling tests
    - ⇨ Leakages remain under thresholds
    - ⇨ Frictions are lower than the previous products. However, for graphite packings, friction is increasing with number of cycles without exceeding 12. For PTFE packings, friction coefficient K decreases down to values lower than 1

- Irradiation tests
  - ⇨ Tests show that graphite and PTFE packings can support cumulated doses up to 4 MGy after 1500 cycles



Example n°2 : Qualification of static and semi-dynamic O-ring of mechanical packing

Introduction

Development of ultimate safety pumps needs the development of high performances mechanical seals.

LATTY International was solicited for study and conception of mechanical packings.

Considering service conditions, LATTY International chose a mechanical packing with static springs out of product.

The aim of this study was testing capacity of seals to resist to a high dose of irradiation after ageing representing its cycle of life.

It is then to qualify elastomeric semi-dynamic and static O-rings to accidental irradiations.

Outlook of this presentation

- Work program
- Testing facilities
- Results
- Conclusions

Work program

Type of Sealing material :

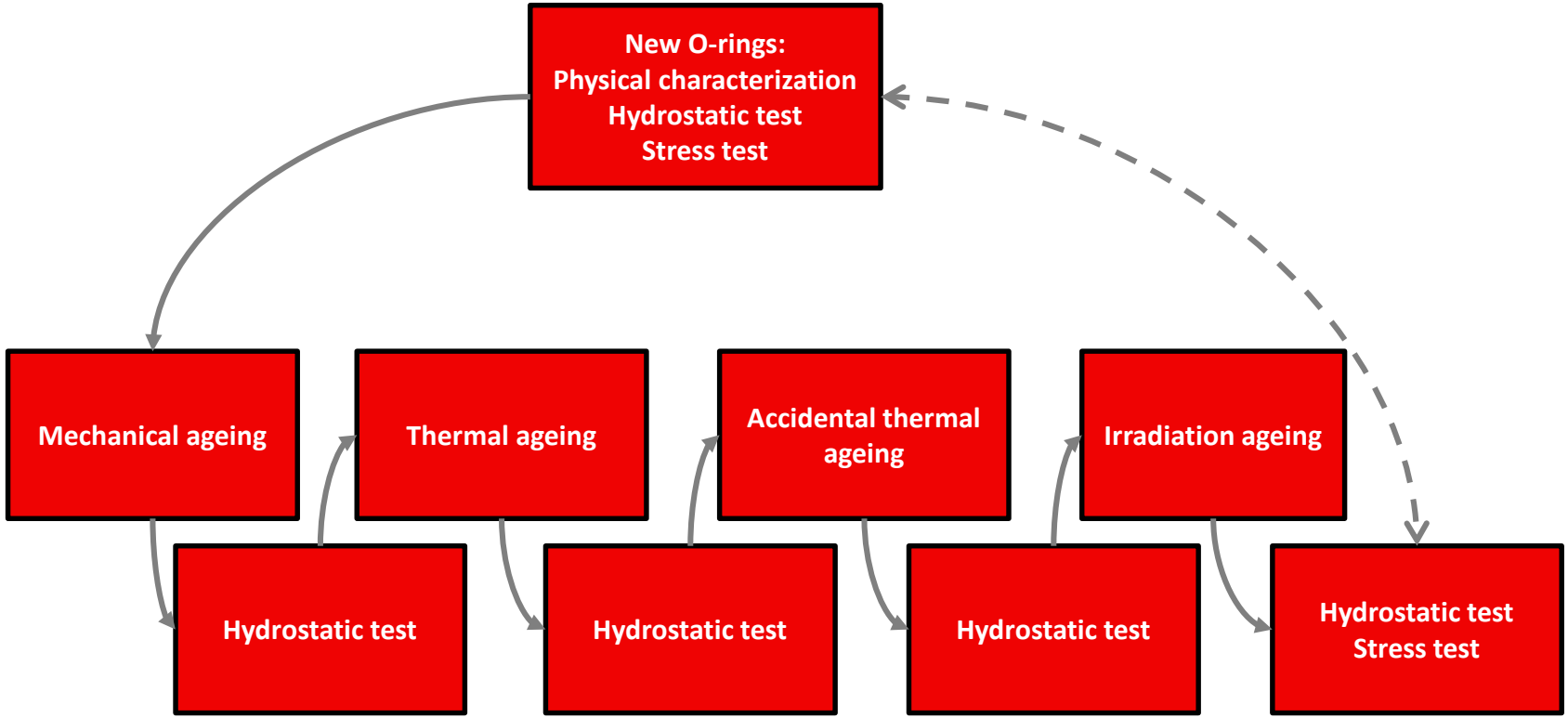
- **O-rings : 4 different materials (L1 to L4) from various manufacturers**




- 2 cells per material (cell 1: O-rings L11-L12, cell 2: O-rings L13-L14 for material 1)

Qualification of static and semi-dynamic O-ring of mechanical packing.

Work program



Qualification of static and semi-dynamic O-ring of mechanical packing.

Test facilities and procedure

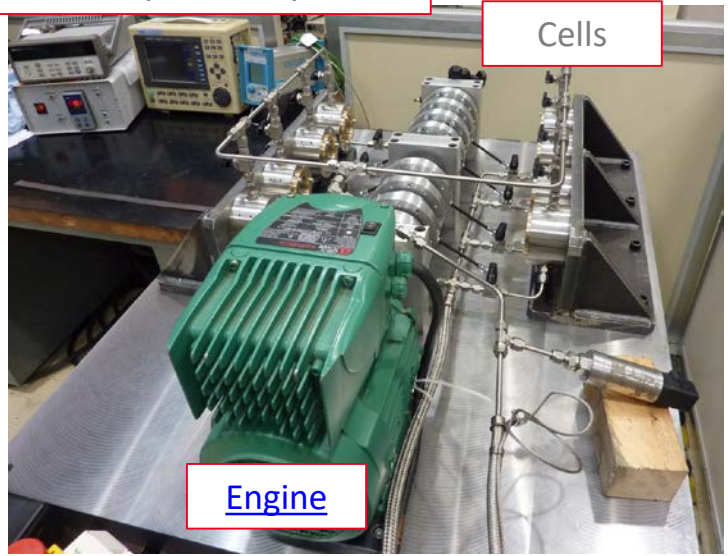
Conditions	Mechanical ageing	Thermal ageing	Accidental thermal ageing	Irradiation
				
Duration (h)	500	252	72 / 175	~1200
Pressure of water (Bar)	12	12	12	N.a.
Temperature (°C)	Room	120	140 / 130	70
Frequency (Hz)	5	N.a.	N.a.	N.a.
Amplitude (mm)	± 0,3	N.a.	N.a.	N.a.
Irradiation (kGy)	N.a.	N.a.	N.a.	600 / 1000 / 1700
Criterion	No leak	No leak	No leak	No leak 400% of initial stress

Testing facilities: mechanical ageing

Piston

Data acquisition system

Cells



Engine

Stress gauge

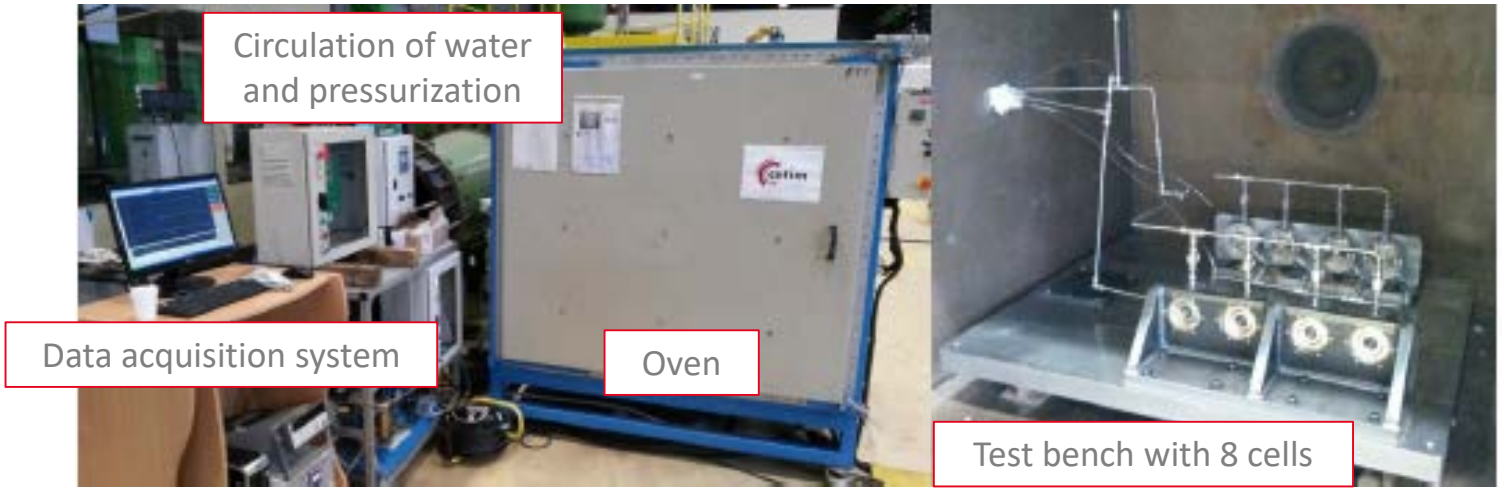
Leak measurement

Sleeve with 2 O-rings

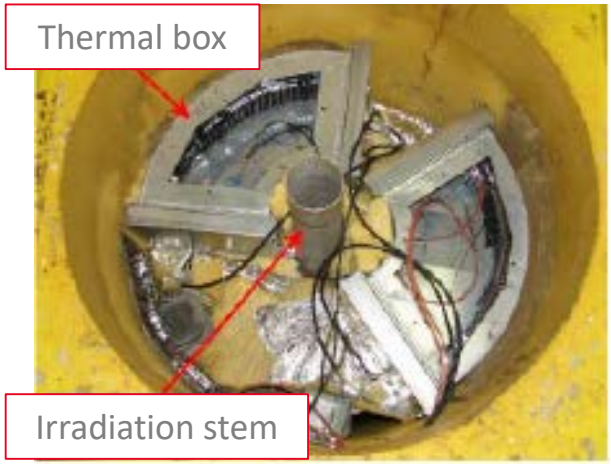
- Measurement of stress with a gauge
- Measurement of strain with a calibrated laser

In case of leak, each cell can be isolated

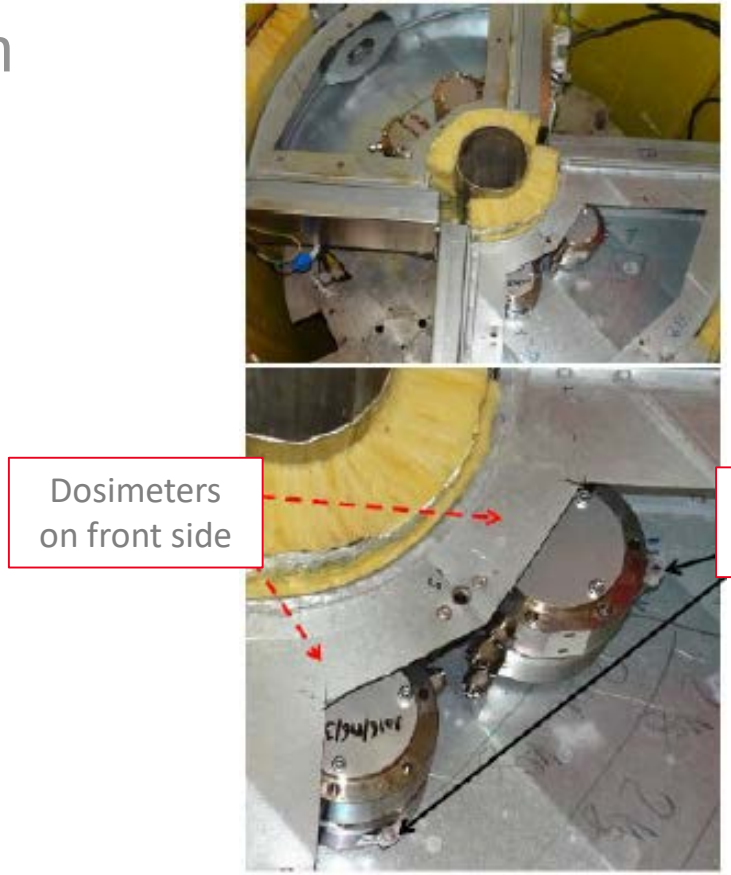
Testing facilities : thermal and accidental ageing



Testing facilities : irradiation



Temperature : 70°C
Atmosphere : air
Dose rate : 1,5kGy/h
Total dose : 600 ; 1000; 1700kGy

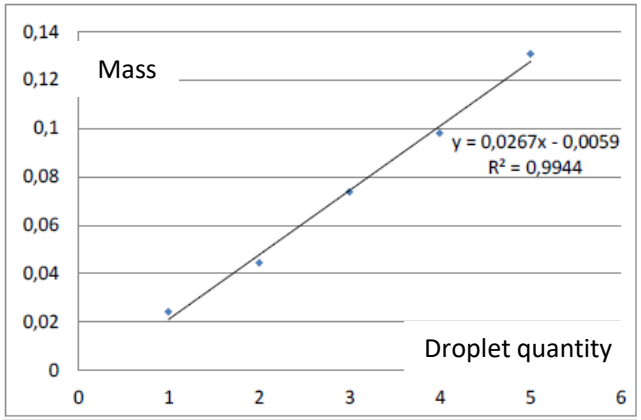


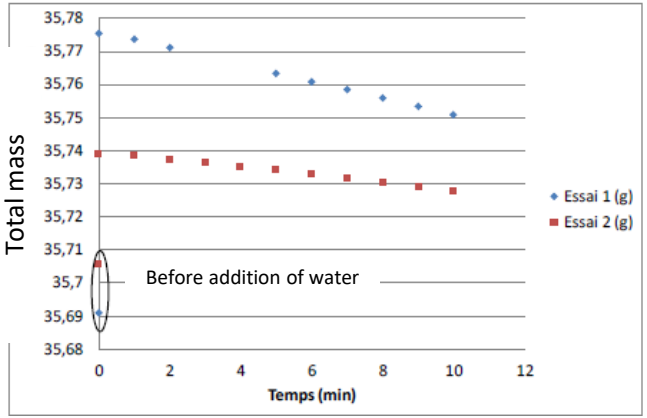
Dosimetry test

Results : Preliminary tests

- **Measurement of leak: weighing a tissu before and after hydrolic test**

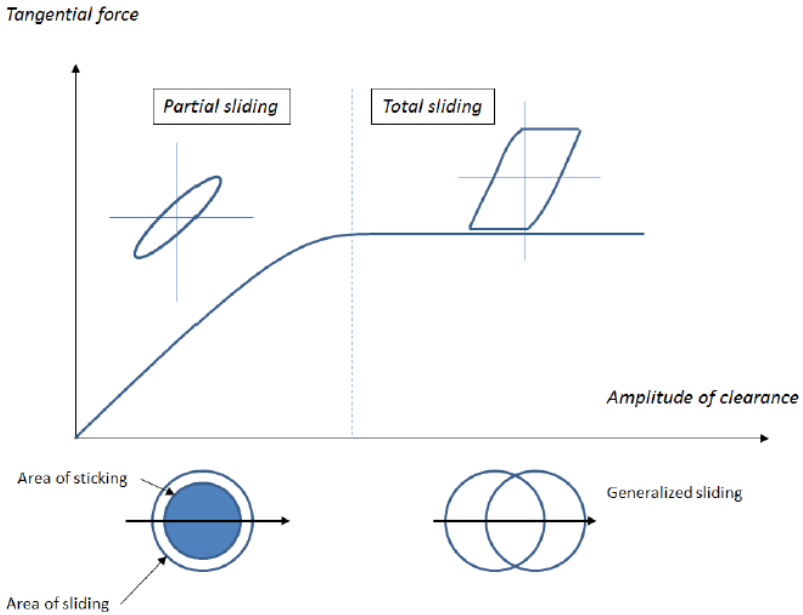
  - Calibration of droplet mass
  - Evaporation of water in tissu during time
  - Conclusions
    - A droplet weight is 22mg
    - Evaporation of water is ~20mg in 10 min
    - Measurement should be done in less than 10 minutes after end of hydrolic test





Results : Tests

Measurement of stress and strain:



• **Partial sliding**: no integral displacemnt in contact zone of the seal.

During cycling, hysteresis (stress/strain) is ellitique.

Slope = stiffness. It depends on pressure and contact length, geometry and mechanical behaviour of the seal

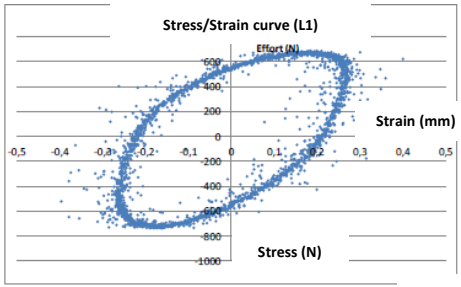
• **Total sliding**: contact surface of the seal move totally from the face against it. Sliding then happens.

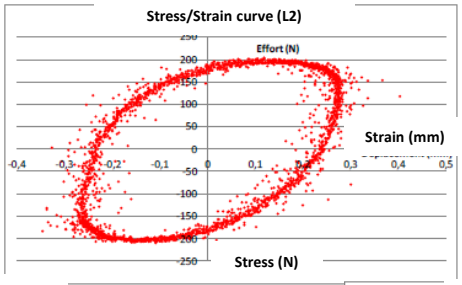
During cycling, hysterisis is dilated with constant stress while sliding beginning.

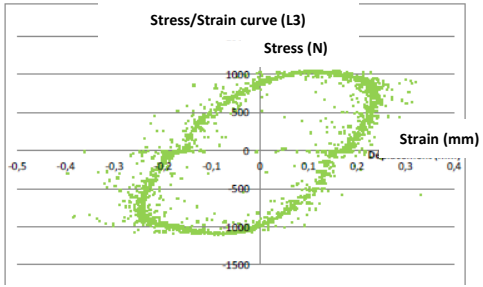
Sollicitations lead to particular friction which can damage surface of seal.

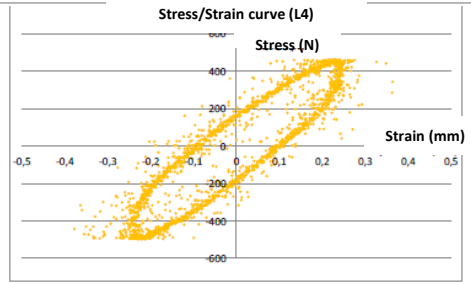
Results : initial test

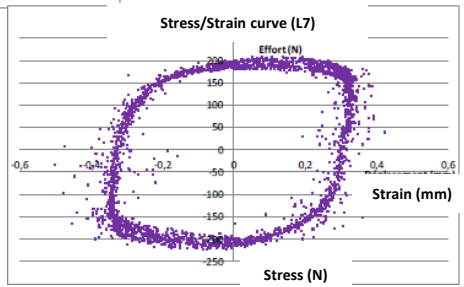
- **Hardness of elastomers**: variation between 65 an 75 shore A
- **Measurement of stress and strain**: partial and total sliding







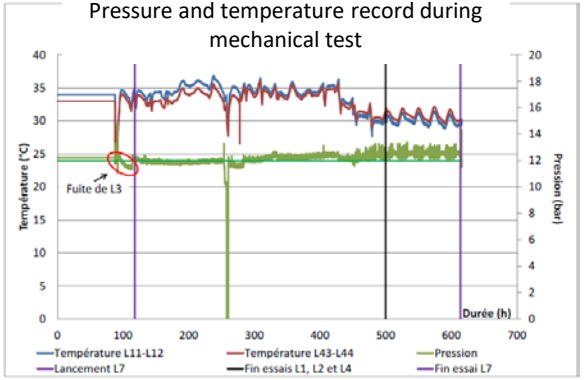


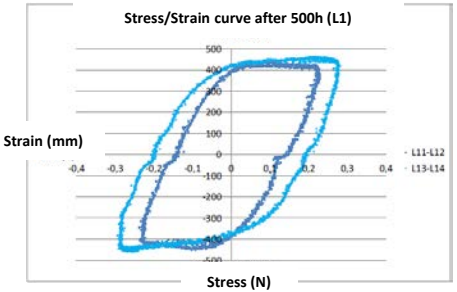


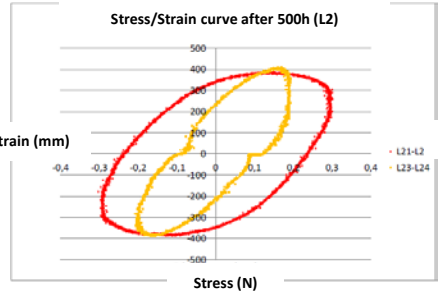
- **Leakage** : no leakage on 8 cells + 2 cells with L7

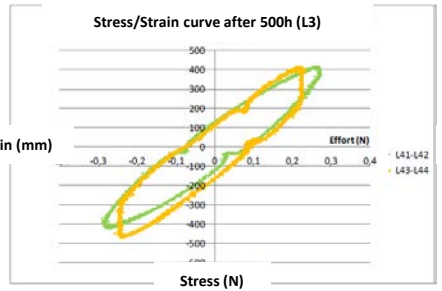
Results : tests after mechanical ageing

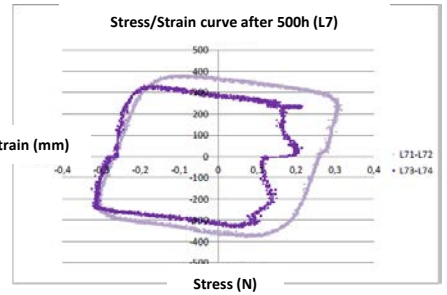
Leak of material 3 O-rings during mechanical ageing, replaced by material 7



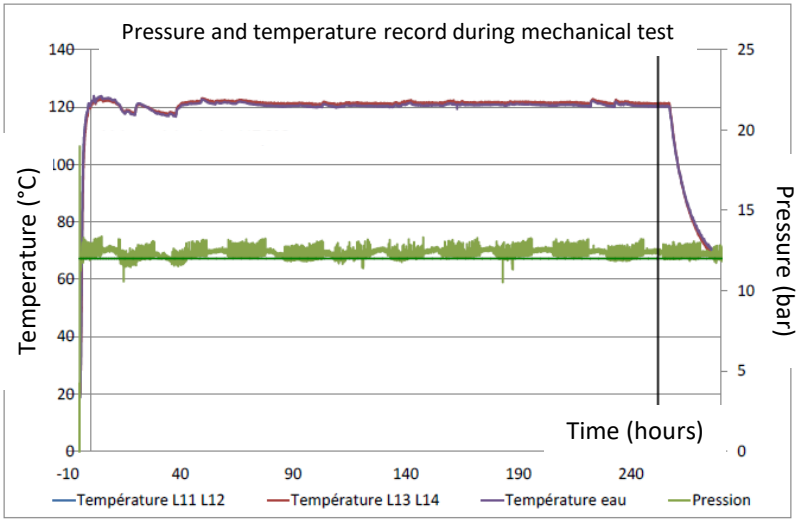


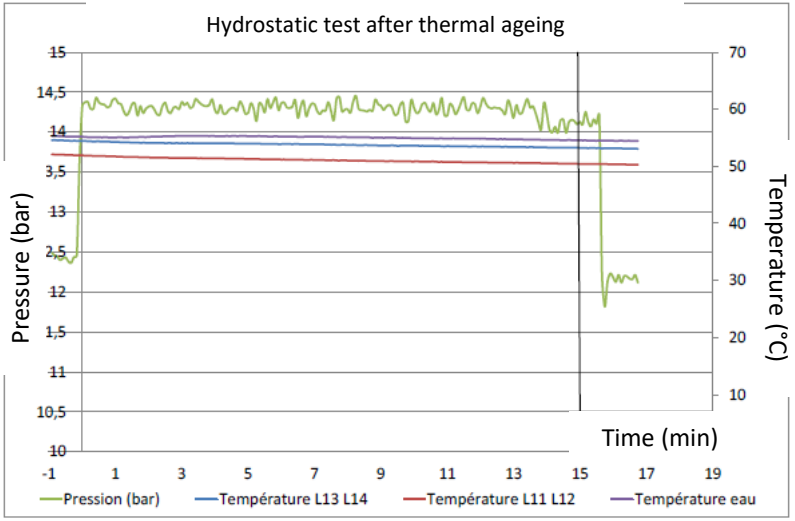






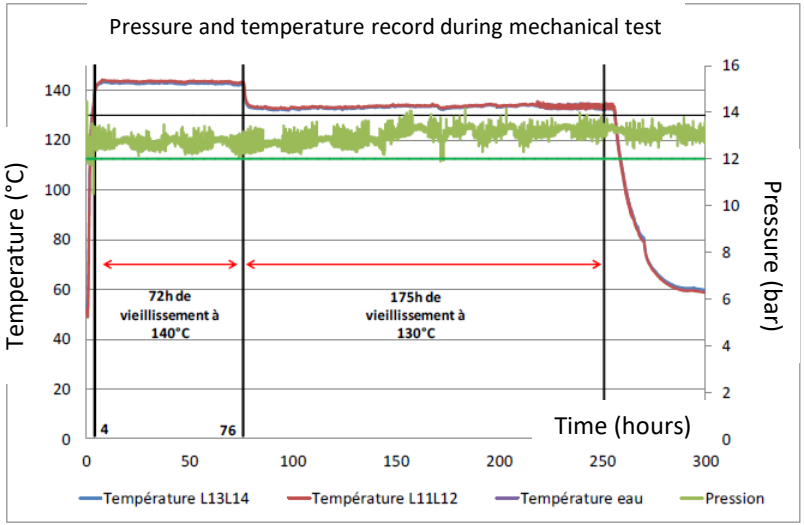
Results : tests after thermal ageing

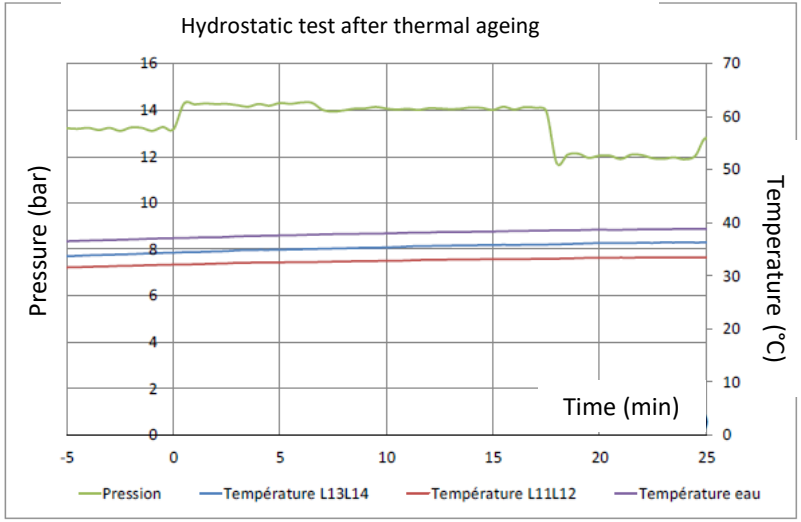




No leak observed

Results : tests after accidental thermal ageing





1 leak observed on L23 after hydrostatic test 1: 1,07cm^3/h
No leak when pressure relieved

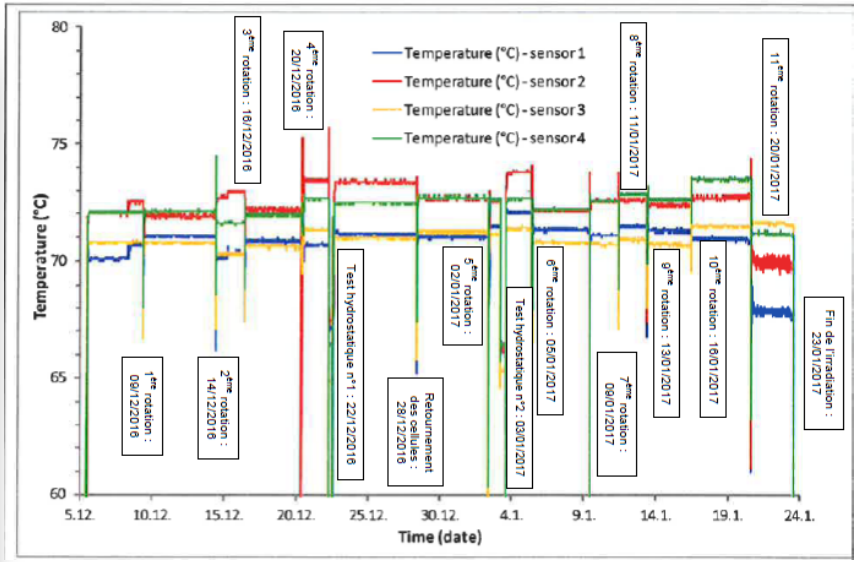
Limited accepted = 5,33cm^3/h

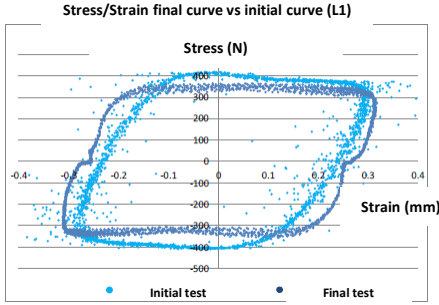
Qualification of static and semi-dynamic O-ring of mechanical packing.

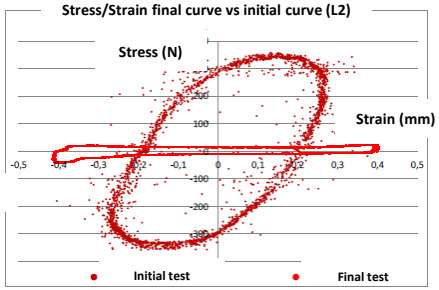
Results : Tests after Irradiation test

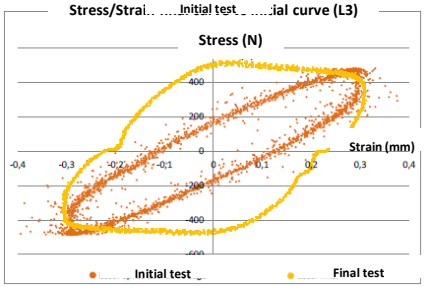
22/05/2019

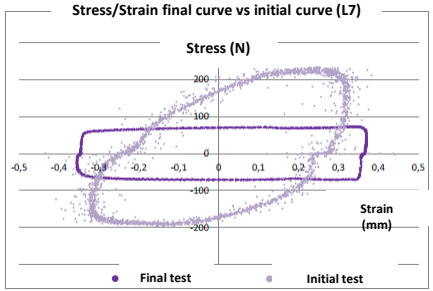
Average irradiation temperature: **(71.6 ± 1.4) °C**











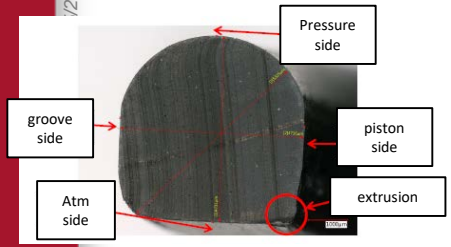
After irradiation,

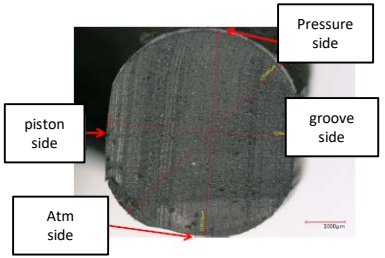
Cell still water: L11/L12; L13/L14; (L41L42); L43L44

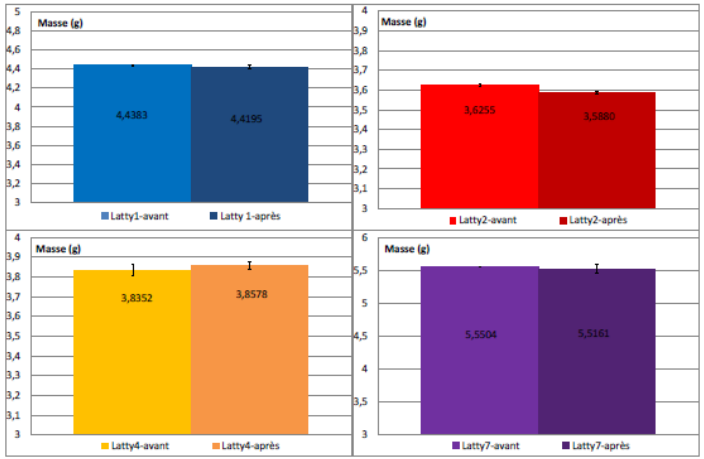
Cell without water: L21L22; L23L24; L71L72; L73L74

Qualification of static and semi-dynamic O-ring of mechanical packing.

Results : final tests







Conclusions

- From solicitations defined in LATTY International specifications, Cetim developed a test bench allowing to :
  - Achieve a short and quick friction test
  - Test O-rings in their grooves not only at room temperature but also in high temperature with circulation of water
  - Isolate cells full of water to irradiate O-rings with their sealing function
- O-rings in material called **Latty 1 and Latty 4 fill the criteria:** final hydrostatic test at 8,5 14 and 25 bars during 15 minutes + final stress < 400% of initial stress (after 90 cycles).
- O-rings in material called **Latty 3** presented a **leak during mechanical ageing**. They did not meet the criteria. They were replaced by material called Latty 7.
- O-rings in material called **Latty 2** presented a **leak** during hydrostatic test after an irradiation of more or less **600kGy**.
- O-rings in material called **Latty 7** presented a **leak** during hydrostatic test after an irradiation of more or less **1000kGy.**

QUALIFICATION OF LOW FRICTION VALVE PACKINGS FOR NUCLEAR APPLICATIONS.

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QUALIFICATION OF STATIC AND SEMI-DYNAMIC O-RING OF MECHANICAL PACKING

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THANK YOU FOR ATTENTION!

Towards the future