FROM RESEARCH TO INDUSTRY

REALIZING THE PNEUMATIC PRESSURE TEST OF A NUCLEAR PRESSURE VESSEL IN THE RESEARCH REACTOR CABRI

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IRESNE | ***Research Institute for Nuclear Systems for Low Carbon Energy Production***

Pneumatic Pressure Testing a Pressure Vessel in the CABRI Reactor

The CABRI Research Reactor

Location

Research center of Cadarache - FRANCE

Fuel

- ✓ UO2 (6% enriched)
- ✓ Stainless steel cladding
- ✓ 6 Hafnium control & safety rods
- ✓ 4 transient rods

Mission

Study of reactivity-injection accident (RIA)

Test device

- ✓ 1 rod max
- ✓ Pressurized water loop (155 bar 280°C)

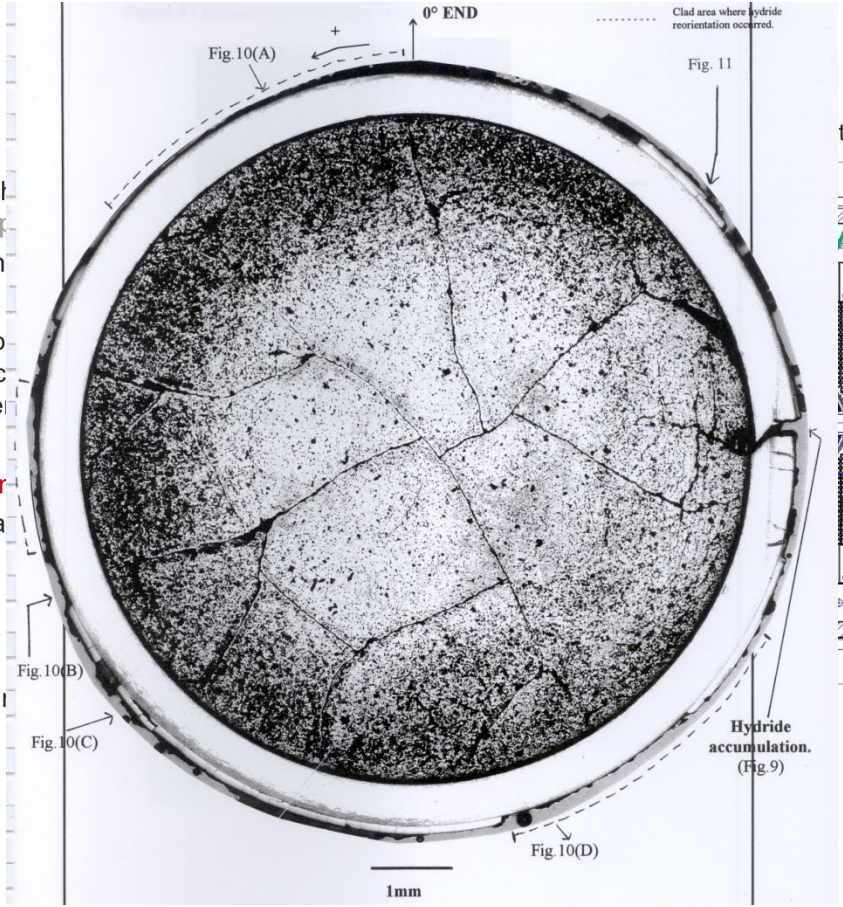
- ✓ Pool type reactor
- ✓ 25 MW steady state
- ✓ 21 GW pulse (10-80 ms)

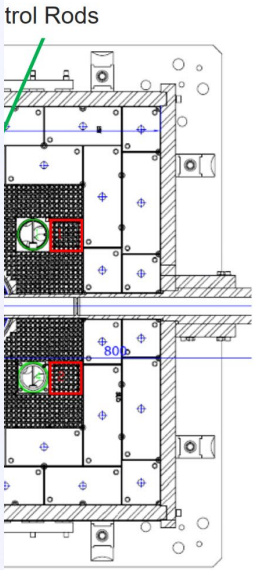
Equipment

- ✓ On-line multi-channel fuel motion detection system (Hodoscope)
- ✓ γ spectrometry, X-ray imaging

The CABRI Research Reactor and experiments

- **UO_2 fuel** (6% enrich
surrounded by grap
  - Immersed in ligh
- **Test fuel pin** in a p
conditions in the c
dedicated instrume
- **Pressurized ^{3}He (r**
- Various types of tra
depressurization:
  - $P_{max} \approx$ 20 GW,
FWHM ≈ 10 ms
  - $P_{max} \approx$ 6-8 GW,
FWHM ≈ 30-80 r





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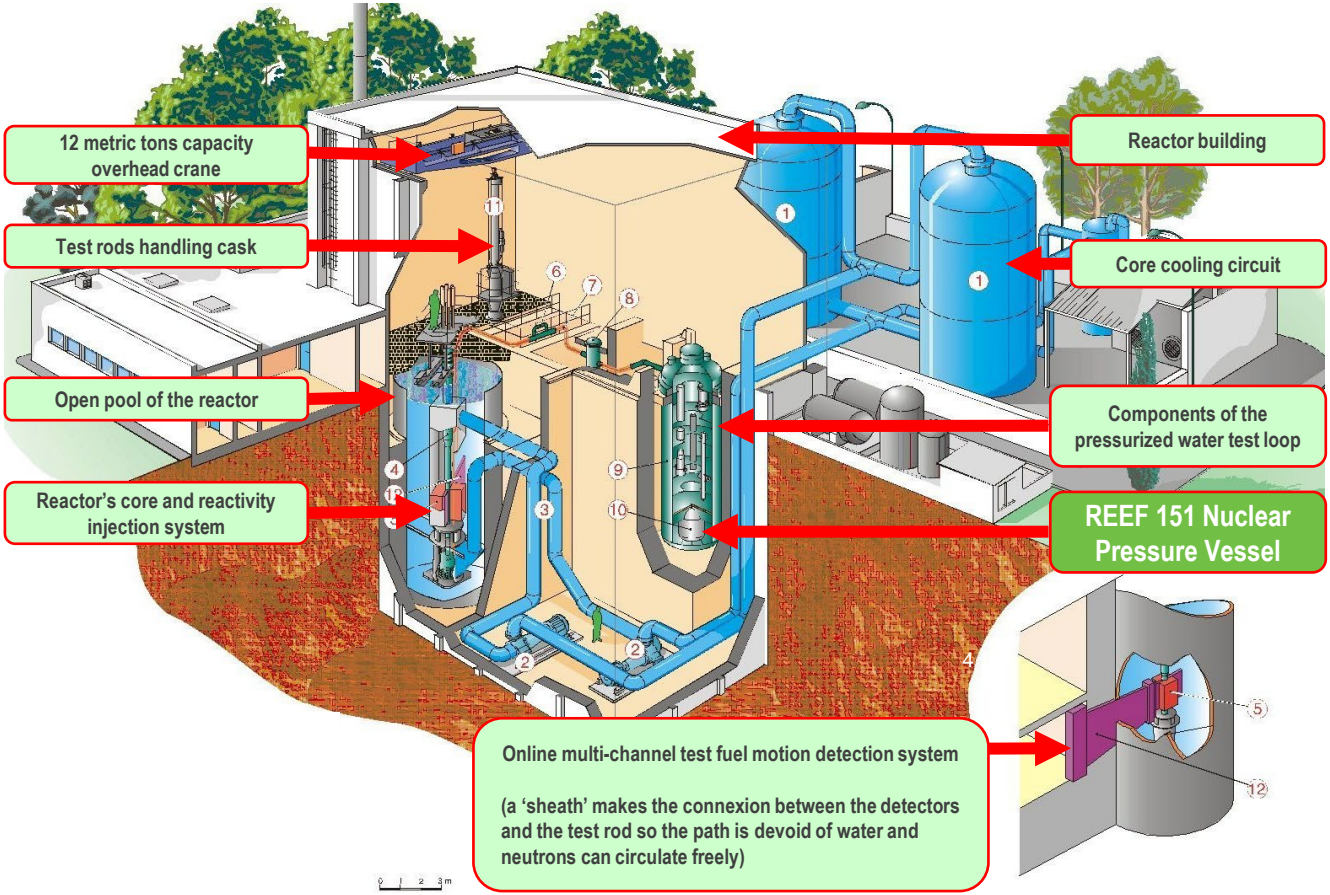
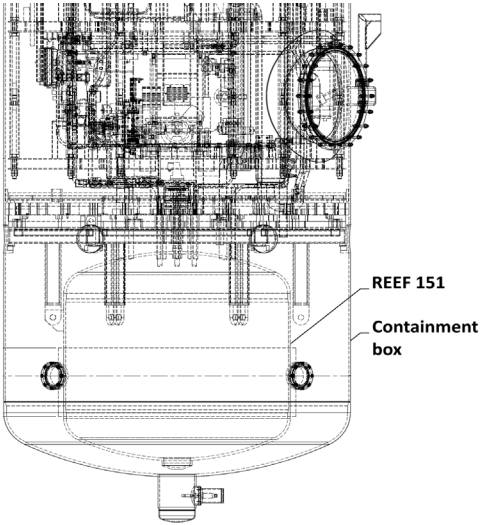
The CABRI Research Reactor and equipments



Pneumatic Pressure Testing a Pressure Vessel in the CABRI Reactor

The REEF 151 Nuclear Pressure Vessel

- 3.1 m^3, 9 bar, 15 mm thick SS
- Used to transit primary coolant after cladding failure
- Safety function: receive and condense primary coolant (300°C) into water vapor

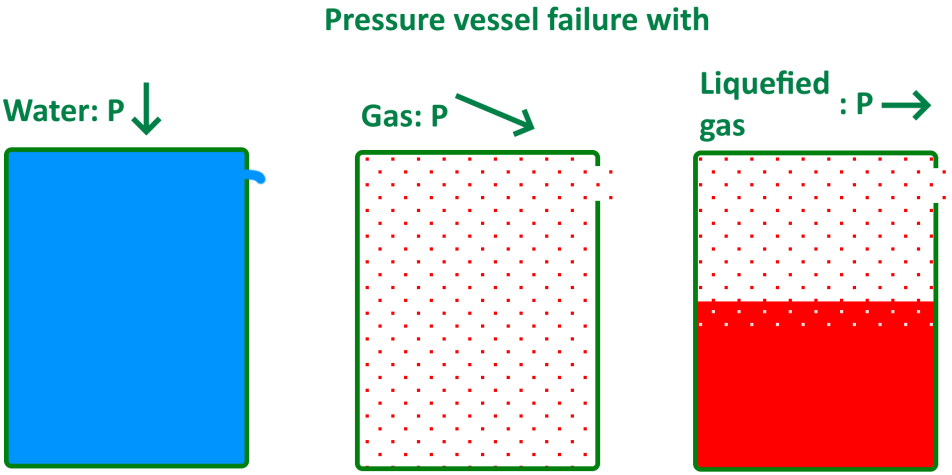


Pneumatic Pressure Testing a Pressure Vessel in the CABRI Reactor

2015 Pressure testing

- Every 10 years, nuclear pressure vessels have to be tested at 120% of maximum authorized operating pressure (previously 150%)

- Those tests are always realized with water, to prevent the risk of explosion



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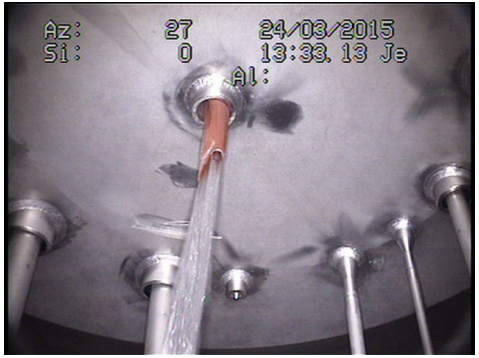
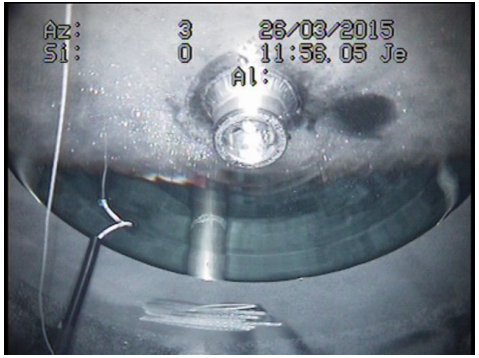
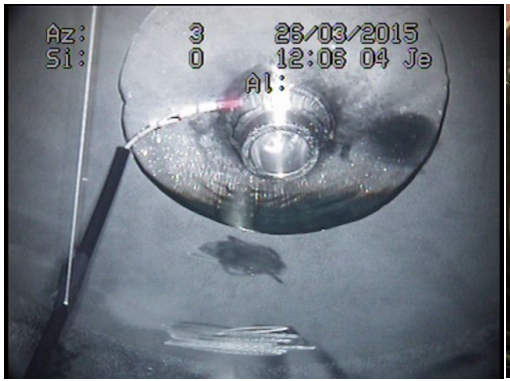
2015 Pressure testing

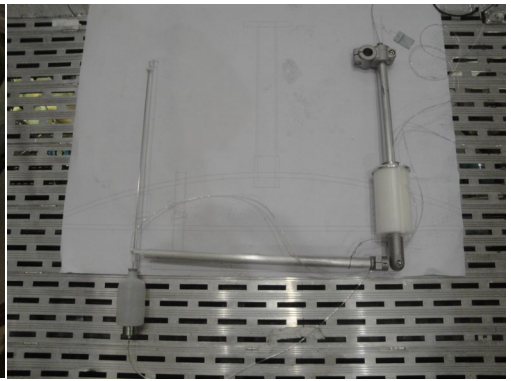
- Because of its conception, air bubbles (~14L) form when filling the REEF151 with water





- In 2015 the vessel had never been in contact with radioactive polluants yet, allowing a certain freedom in preparing and realizing its water pressure test





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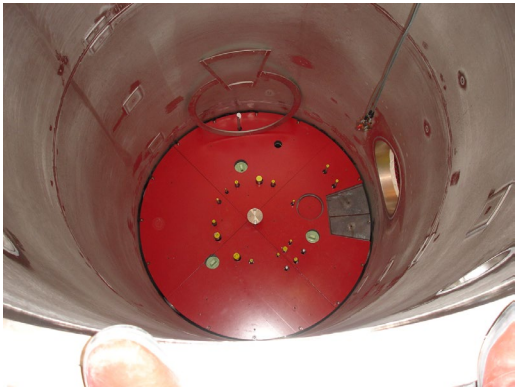
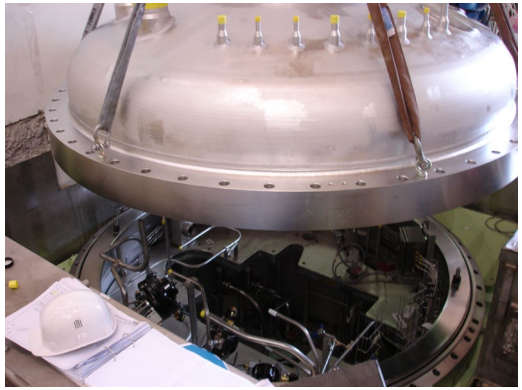
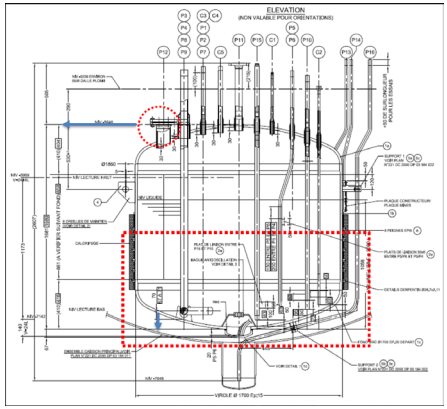
In case of vessel failure

- 12 mm thick SS containment box, tested at 8 bar: would hold to a 2 bar pressure wave





- 2 potential projectiles considered, “small” and “big”



	Small projectile	Big projectile
Max projectile speed	35 $m.s^{-1}$	35 $m.s^{-1}$
Max projectile energy	7 kJ	600 kJ
Max acceptable speed before perforation	150 $m.s^{-1}$	90 $m.s^{-1}$
Max acceptable energy before perforation	130 kJ	4 MJ

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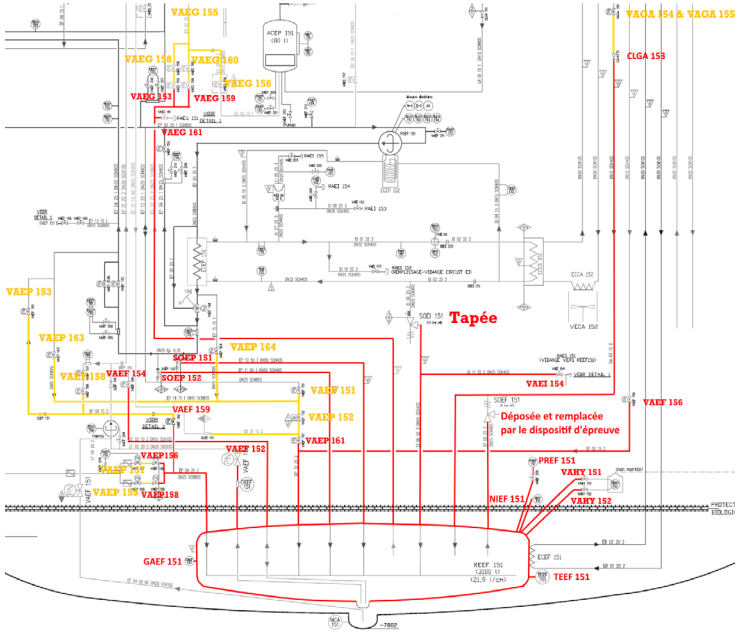
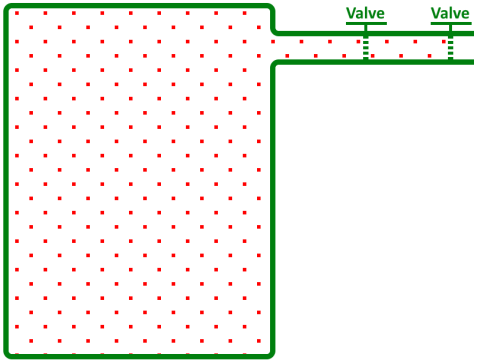
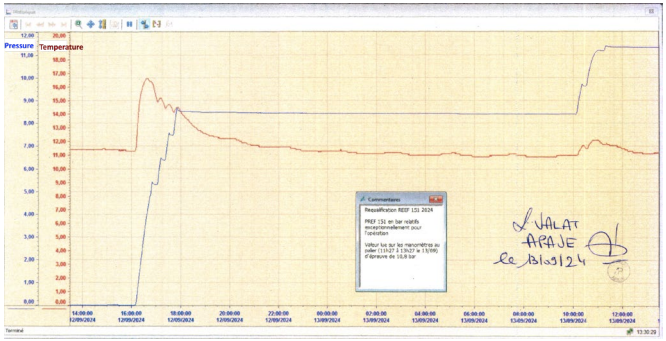
The Pressure test

- In complex processes, internal faulty airtightness can cause « false positives »
- Partitioning the test limits and heightening pressure by steps help with this issue







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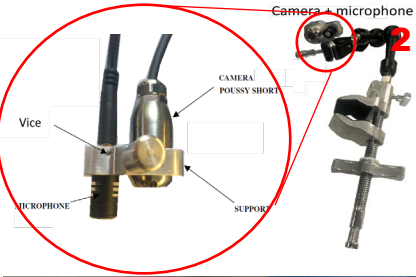
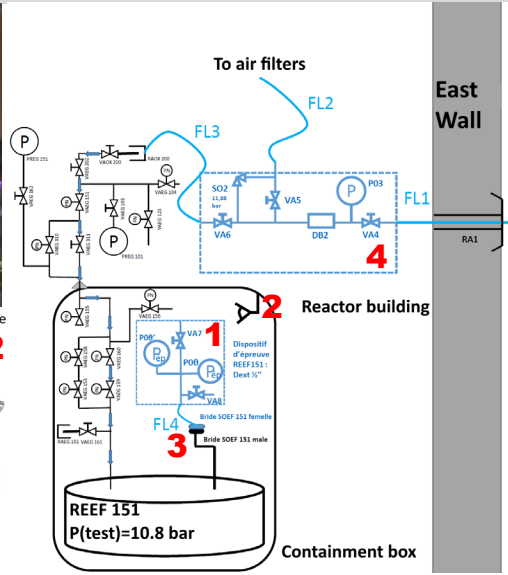
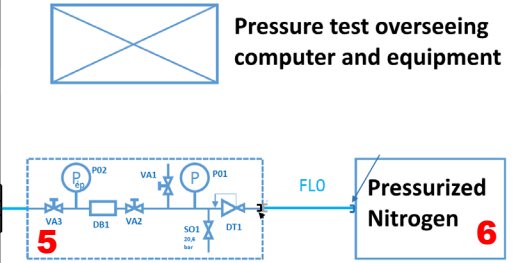
The Pressure test







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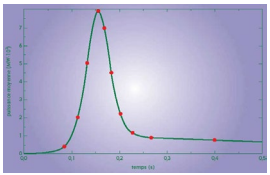
Feedback

- The challenges raised by performing a pressure test using gas instead of liquid are the associated risk of explosion, and the likeliness of internal leaks that would disrupt the pressure test itself. The former can be mitigated with the right configuration and organization – as well as calculations to ensure that everything is fully adapted to the risk – and the latter by use of the right equipment and process modifications.



- All of this involves a significant amount of work and time in addition to the already considerably amount involved with a more conventional pressure test, but with enough forethought and anticipation it allows for performance of a satisfactory uneventful pressure test whilst preserving the safety of human personnel by protecting them from interaction with radioactive pollutants, and reducing the production of radioactive waste in the form of water used for pressure tests.

- After its pressure test and certification, the REEF 151 was configured back to normal operating conditions and is now fit to serve for the remaining experiments of the CABRI International Program and the new exciting ones that will come after that.

THANK YOU FOR YOUR ATTENTION

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Projectiles' speed and energy

Méthode	Baker	UFIP	Baum
Vitesse initiale	**34,6 m/s**	68,9 m/s	14,5 m/s
Energie cinétique projectile 1	**6,7 kJ**	27 kJ	1,2kJ
Energie cinétique projectile 2	**575 kJ**	2,28 MJ	101 kJ

Méthode	Miyamoto	HPSC	HSE	INERIS	Zone locale
Vitesse initiale BAKER	**34,6 m/s**				
Energie cinétique projectile 1	**6,7 kJ**				
Energie perforation projectile	**199 kJ**	**129 kJ**	**78 kJ**	**75 kJ**	**36 kJ**
Vitesse perforation	**188,9 m/s**	**151,6 m/s**	**118,1 m/s**	**115,8 m/s**	**80,4 m/s**

Méthode	Miyamoto	HPSC	HSE	INERIS	Zone locale
Vitesse initiale BAKER	**34,6 m/s**			**34,6 m/s**	
Energie cinétique projectile 1	**575 kJ**			**575 kJ**	
Energie perforation projectile	**8,45 MJ**	**6,83 MJ**	**6,99 MJ**	**3,18 MJ**	**5,34 MJ**
Vitesse perforation	**132,7 m/s**	**119,2 m/s**	**120,8 m/s**	**81,4 m/s**	**105,5 m/s**

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Internal control

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Safety Valves and obturator