FROM RESEARCH TO INDUSTRY

UPGRADE OF AN OVERHEAD CRANE IN THE CABRI NUCLEAR RESEARCH REACTOR

2023 TRTR-IGORR Conference

D. BONVALET

June 2023

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

Upgrade of an overhead crane in the CABRI nuclear research 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)

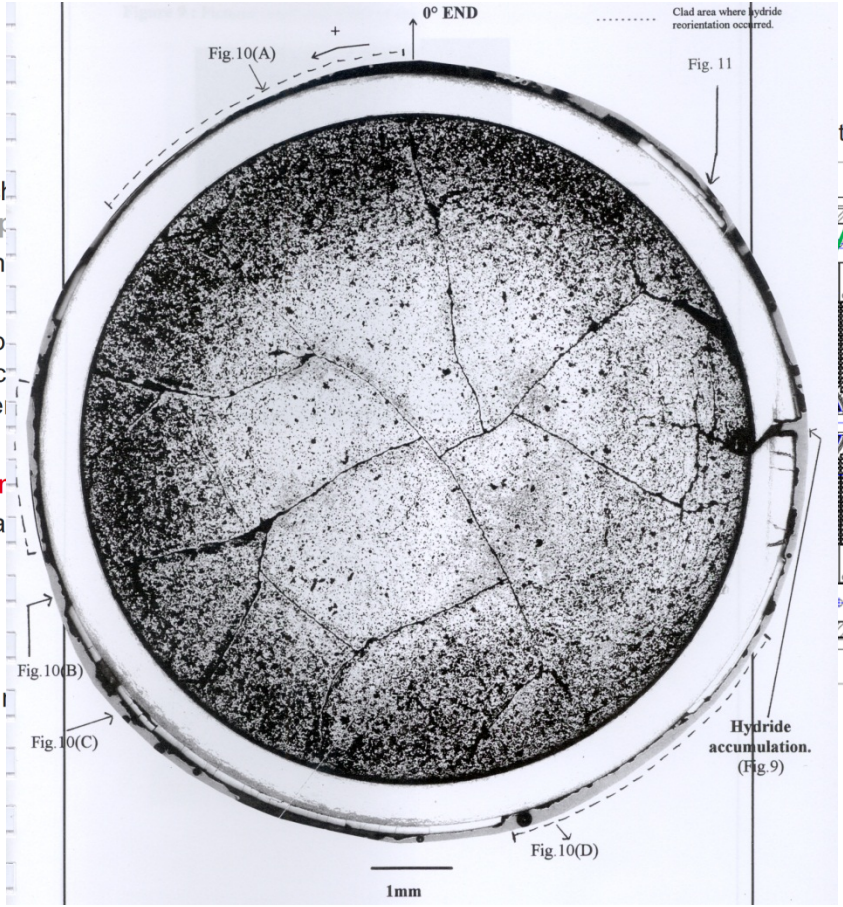
- ✓ Pool type reactor
- ✓ 25 MW steady state
- ✓ 21 GW pulse (10-80 ms)

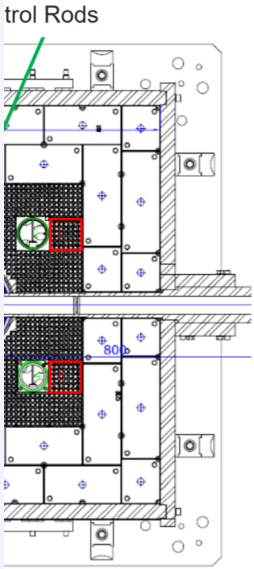
Equipment

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

The CABRI Research Reactor and experiments

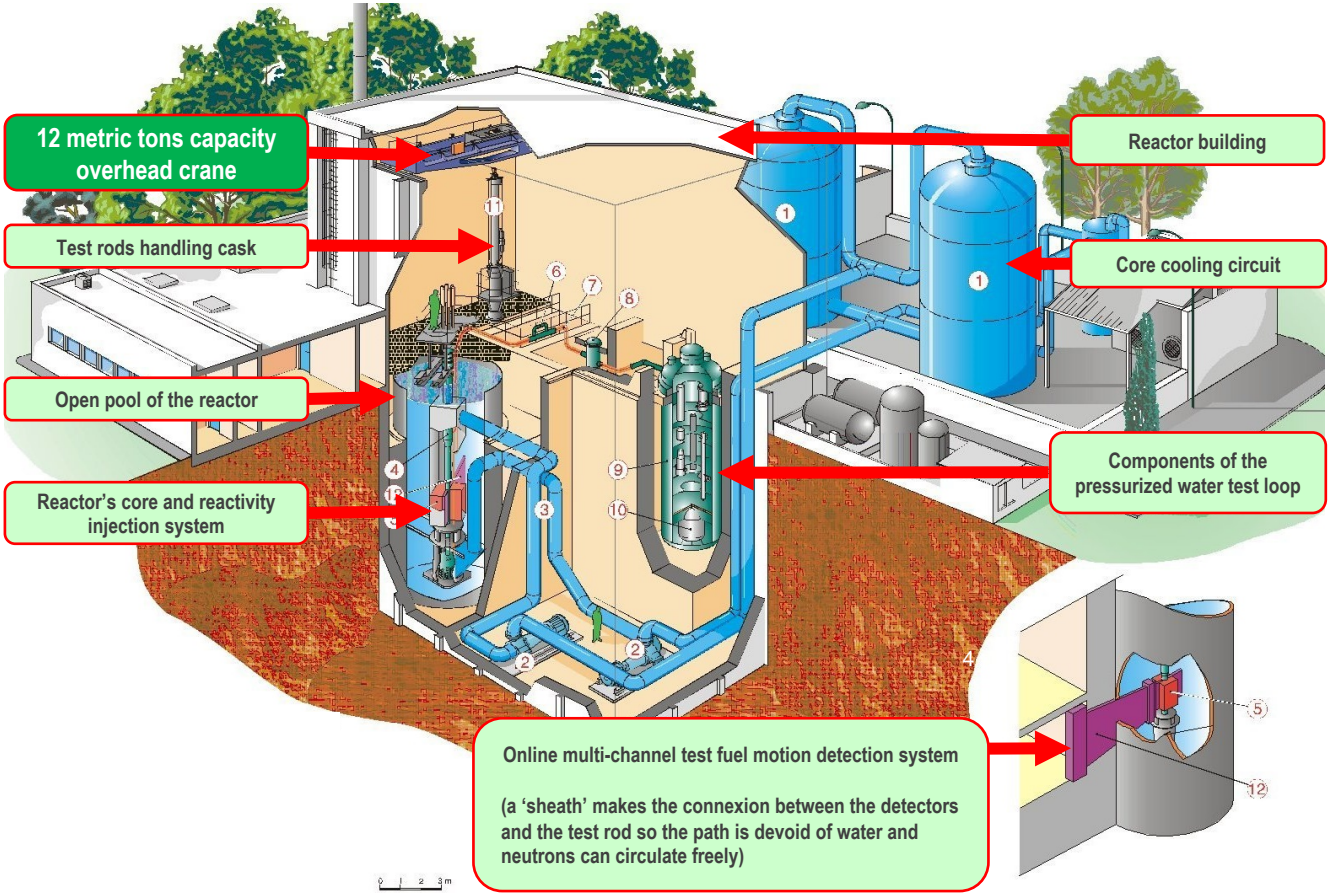
- **UO_2 fuel** (6% enrich
  surrounded by grap
  - Immersed in ligh
- **Test fuel pin** in a p
  conditions in the c
  dedicated instrume
- **Pressurized ^3He (r**
- Various types of tra
  depressurization:
  - $P_{max} \approx$ 20 GW,
    FWHM $\approx$ 10 ms
  - $P_{max} \approx$ 6-8 GW,
    FWHM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



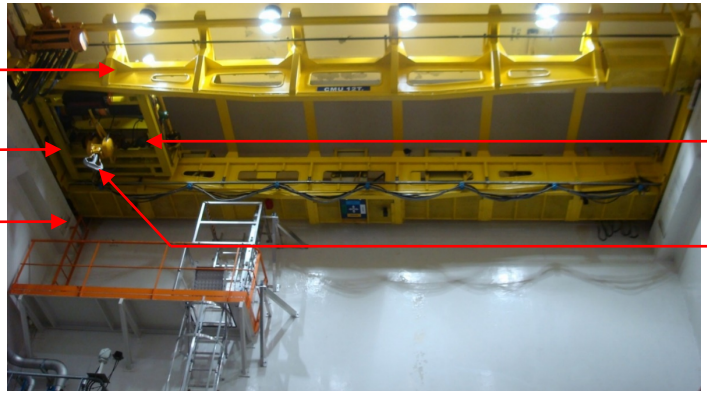


Upgrade of an overhead crane in the CABRI nuclear research reactor

The CABRI Research Reactor and equipments



The CABRI Research Reactor's main overhead crane



CABRI's overhead crane before the 2022 upgrade

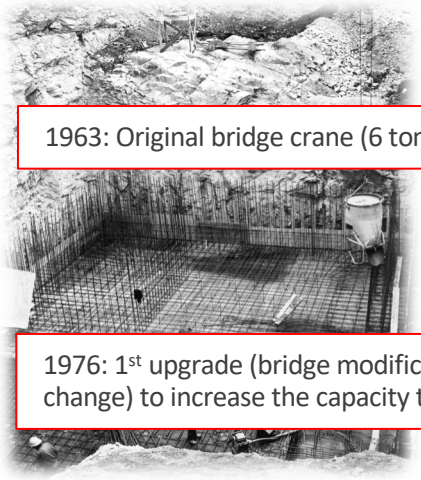
- The trolley travels on the bridge made of two beams (10 m), itself travelling on two rails that are part of the wall and span the whole 20 m of the reactor's building main hall.
- The lifting mechanism has a 12 metric tons capacity, along with the primary brake.
- The emergency brake installed during the previous upgrade, with a 10 metric tons capacity only because of technical limits regarding sizing.

Upgrade of an overhead crane in the CABRI nuclear research reactor

Crane and Reactor's history

Historical

- Mid 1962 : Start of construction
- December 1963 : Authorisation to start
- February 1964 : First divergence
- June 1964 : Authorisation to operate
- 1964 to 2004 : Different experiment programs with a sodium loop
- 2005 to 2017 : Adaptation (pressurized water loop) & renovation (seismic reinforcement, replacement of the core block, ventilation renovation)
- 2018 to 2025 (estimated) : Experimental program CIP (Cabri International Program), RIA (Reactivity Insertion Accident) in a pressurize water loop



1963: Original bridge crane (6 tons)

1976: 1st upgrade (bridge modification and trolley change) to increase the capacity to 12 tons

2003: Addition of an emergency brake (10 tons)

2013: Various reinforcements and extensive nondestructive testings (safety reappraisal)

Upgrade of an overhead crane in the CABRI nuclear research reactor
The Failure Mode Effects and Criticality Analysis (FMECA)

- Define the system
- Construct system block diagrams
- Identify failure modes (piece-part level or functional)
- Analyze failure effects/causes
- Perform criticality calculations
- Rank failure mode criticality
- Determine critical items

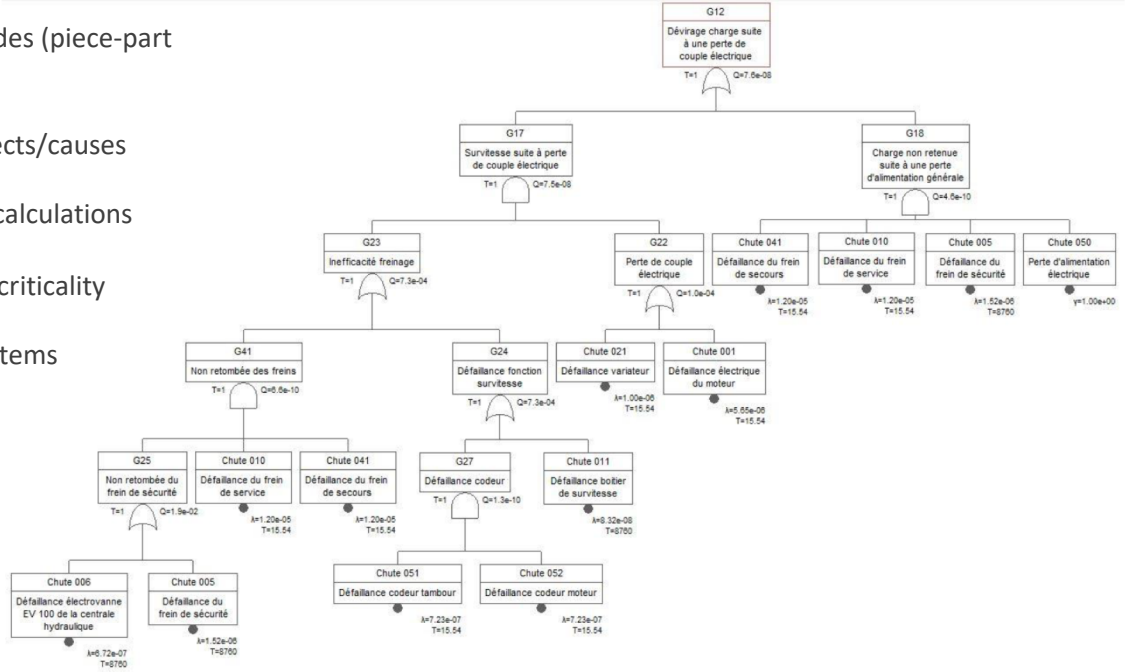
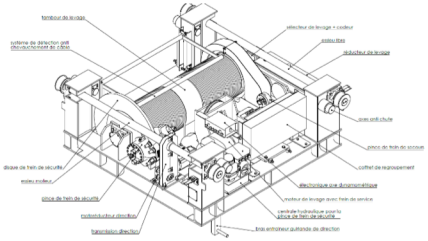
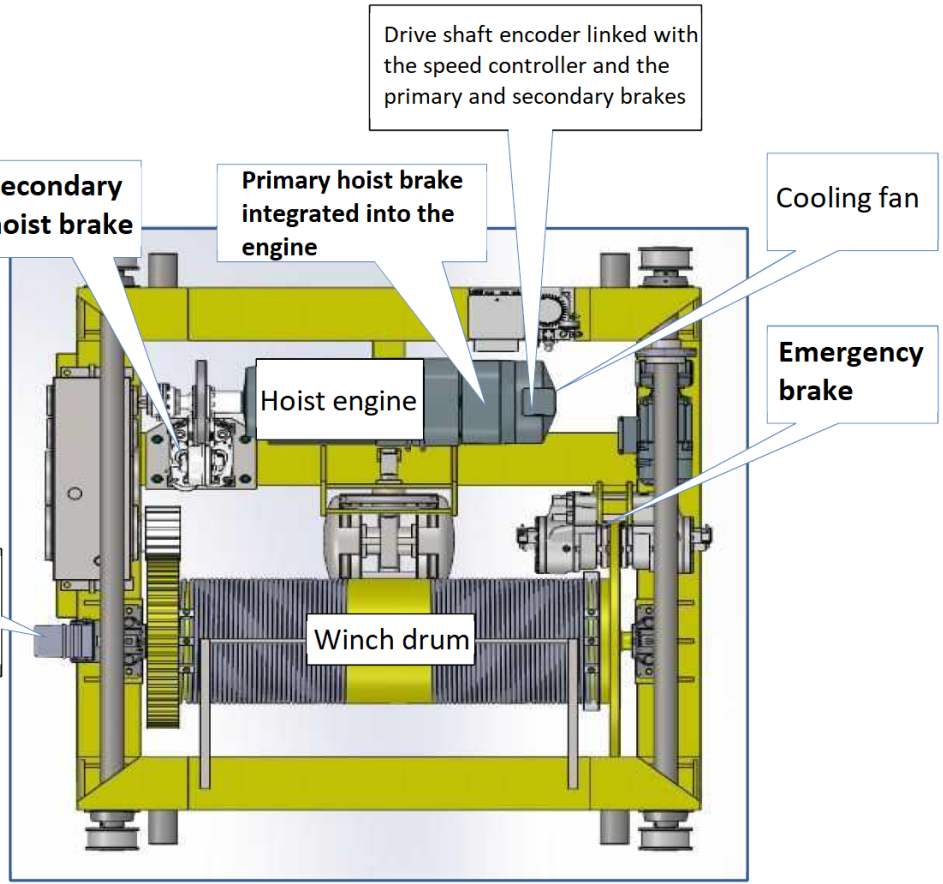


Figure 16. Porte G12 : Chute de la charge suite perte de couple électrique phase levage

Upgrade of an overhead crane in the CABRI nuclear research reactor

Layout of the major components being upgraded





Upgrade of an overhead crane in the CABRI nuclear research reactor

Studying the possibilities and making choices

- Modifying the trolley
  - + Cheaper
  - + Shorter overall fabrication time
  - + Less uncertainty/overseeing regarding the material and dimensions
- Changing the trolley completely
  - + Better design possibilities
  - + Shorter duration of unavailable bridge crane
  - + No ageing concerns at short term

- Quality concerns and choosing the company: REEL

- 75 years' experience in manufacture and implementation of lifting and handling in highly sensitive environments

- involved with the French nuclear sector in particular since its earliest days

Upgrade of an overhead crane in the CABRI nuclear research reactor

The fabrication process

ASSEMBLAGE DE QUALIFICATION - RAPPORT D'EXECUTION - *RECORD OF WELD TEST*

ASSEMBLAGE REPERE *Test Piece No* : 35-RR	Matériaux de base *Base material*	①	②
Type d'assemblage *Joint type*	Nuance *Grade*	S355J2+N	
☒ Bout à bout *Butt*	Norme ou spécification *Standard ou spécification*	EN10025-2 : 2004	
☒ Tubes ☐ Tôles *Tubes / Plates*	N° de coulée *Heat No*	S410208	
☐ Té *Tee* ☐ Piquage *Branch*	Groupe/Sous groupe *Group/Subgroup*	1.2	
☐ Pleine pénétration *Full penetration*	Epaisseur (mm) *Thickness*	12 usiné	
☐ Angle *Fillet*	Diamètre ext. (mm) *Outside diameter*	120 usiné	

☐ Support envers *Backing strip* — Permanent ☐ oui *Yes* ☐ non *No*

Nature : *Type*

☐ Gougeage ou meulage envers *Back gouging or Hoking*

Schéma de préparation *Joint design* — 60°

Disposition des passes *Welding sequences*

Préciser nuances *Indicate grades* ① ②

Préciser épaisseur déposée par procédé *Indicate deposited thk per process*

N° des passes *pass number*		1		2		3		4-5-6
Position *position*		PF		PF		PF		PF
Procédé, degré mécanisation* *process, d° of mechaniz.*	141	M	141	M	141	M	141	M
Mode de transfert *transfert mode*								
Nom du soudeur *welder's name*		REULLARD Rodolphe		REULLARD Rodolphe		REULLARD Rodolphe		REULLARD Rodolphe
Matériaux d'apport *Filler material* — Fabricant *manufacturer*		ESAB		ESAB		ESAB		ESAB
Appellation commerciale *trade mark*		OK Tigrod 12.60		OK Tigrod 12.60		OK Tigrod 12.60		OK Tigrod 12.60
Désignation normalisée *std. designation*		W2Si		W2Si		W2Si		W2Si
Diamètre *diameter* (mm)		2		2		2.4		2.4

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EXAMEN REALISE

Repère d'identification : 35 - RR
Méthode : Macrographie
Réactif : FeCl3
Date d'exécution : 10/12/2015

RESULTATS

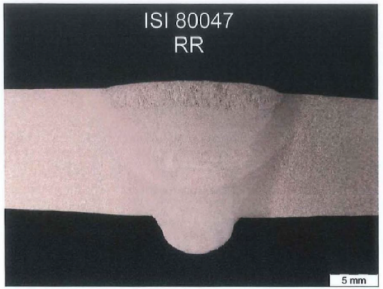
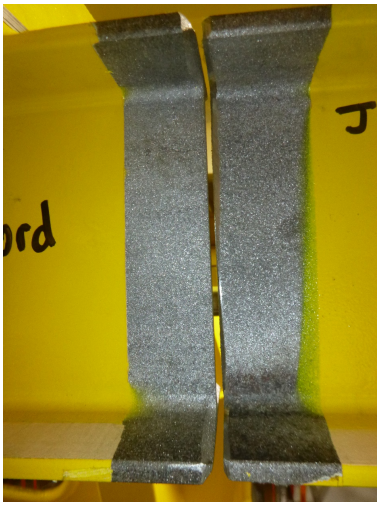
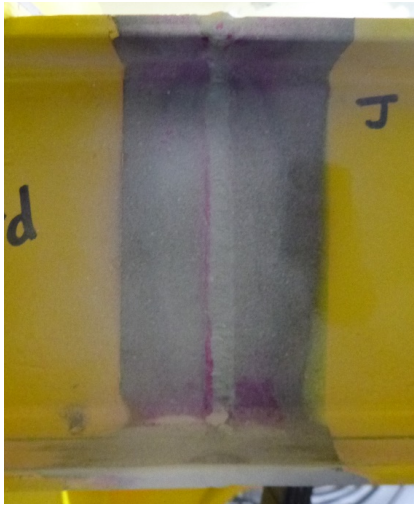


Figure : 1
Grossissement : 3.4

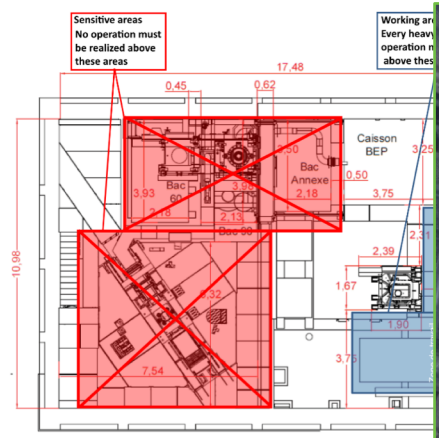
Localisation : Coupe transversale
Résultat : Aucune anomalie constatée.

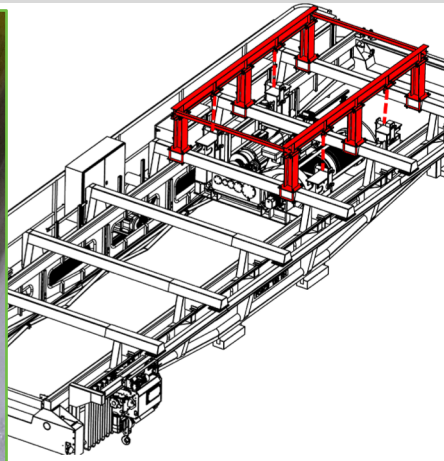




Upgrade of an overhead crane in the CABRI nuclear research reactor

Planning, preparing and managing the project on site





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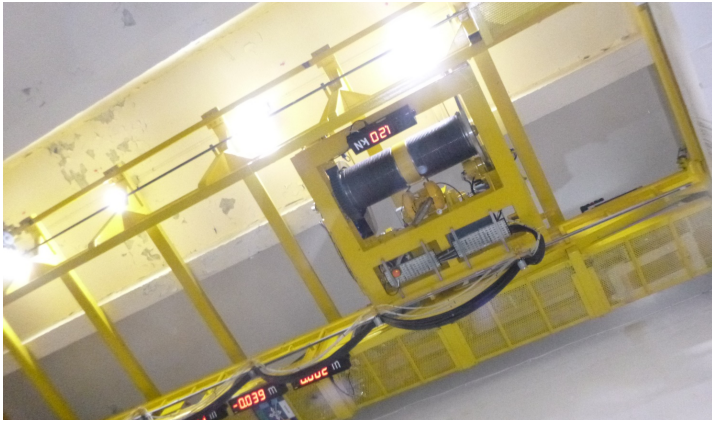

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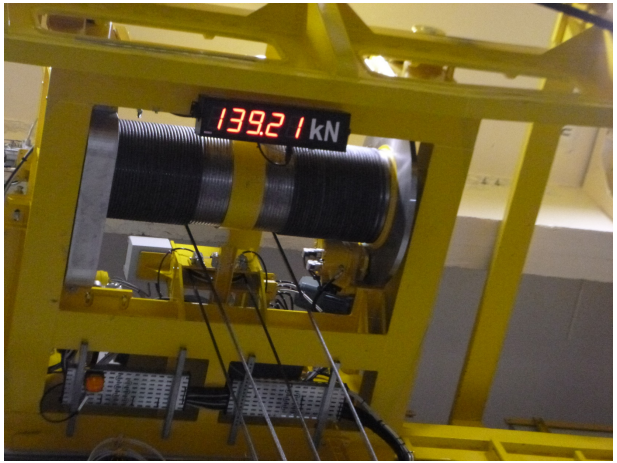


Upgrade of an overhead crane in the CABRI nuclear research reactor
Feedback

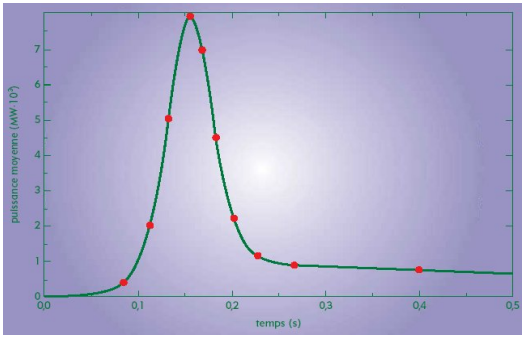
After one year of use:

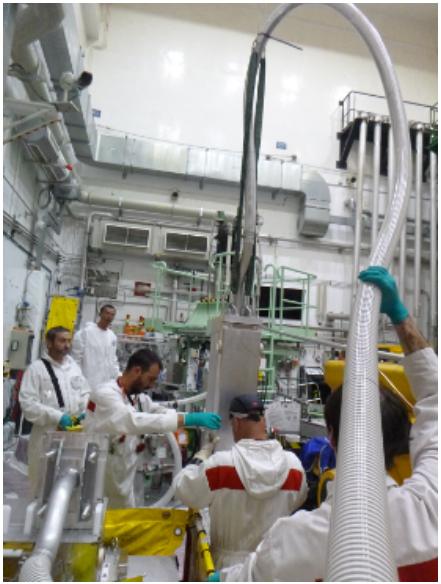
- The new range of movements is identical to the previous one (criteria met)
- The new speeds and the option of proportional speeds gives the operators better control of the load
- No component failures have been reported
- The brakes hold perfectly well
- Half-yearly maintenance found no change in their tuning nor wear and tear

With the new FMECA and its conclusion of reliability this gives a sense of security to the operators. The precautions that existed before to deal with the risk of brake failure are still being followed: they have become standard for the facility and only serve to improve nuclear safety.

Upgrade of an overhead crane in the CABRI nuclear research reactor
Use and perspectives in the reactor's life

- This upgraded overhead crane has been used to perform two of the six experiments of the CABRI International Program in the past year, as well as several smaller scale experiments.
- Built to last twenty years at the current intensive level of use before there will be any need to check on its structural integrity and potential obsolescence, we expect that it will perform its role flawlessly in carrying out the remaining part of the CIP as well as the new programs that will come after that, for which we are always glad to discuss possible need or opportunities.



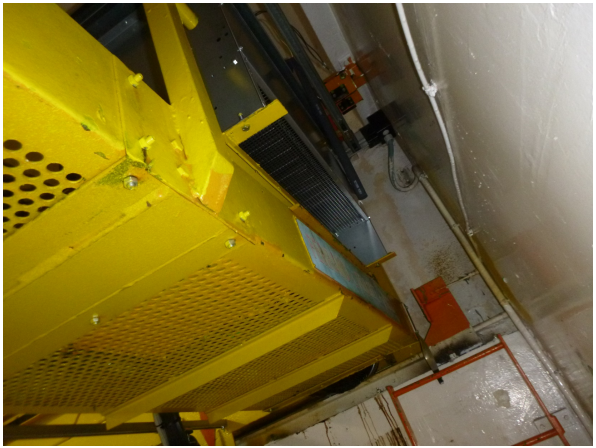


THANK YOU FOR YOUR ATTENTION

CONTACT : DAMIEN.BONVALET@CEA.FR

Upgrade of an overhead crane in the CABRI nuclear research reactor

Onsite difficulties



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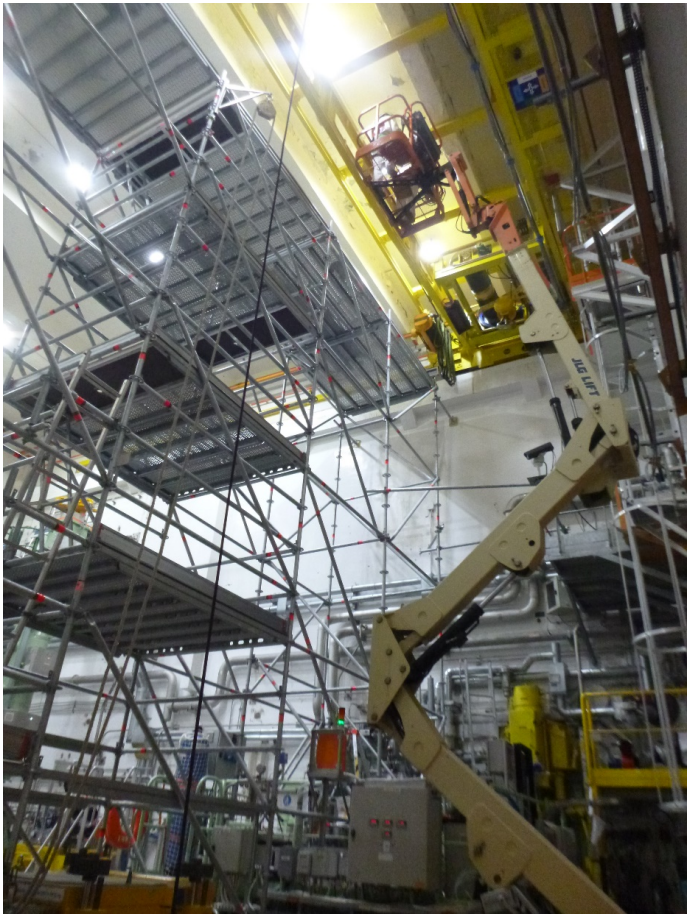
Onsite difficulties



Upgrade of an overhead crane in the CABRI nuclear research reactor

New external experimental positions

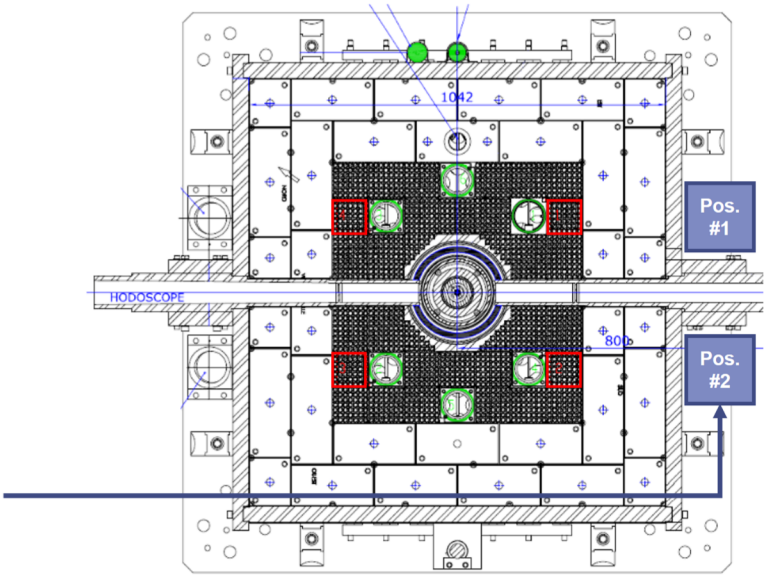
- More recently, creation of new irradiation positions in the CABRI reactor:
  - Without interference with transient tests
  - Easily accessible from above the core

⇒ **2 positions located behind the graphite reflector**

- Available space:

800 mm x 200 mm x 200 mm

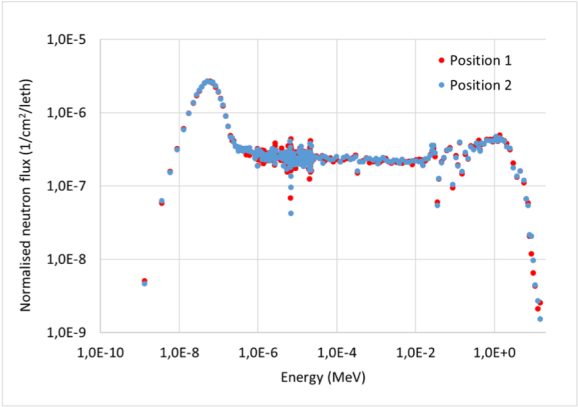
- Dedicated to material irradiation in mixed neutron-gamma field



Upgrade of an overhead crane in the CABRI nuclear research reactor

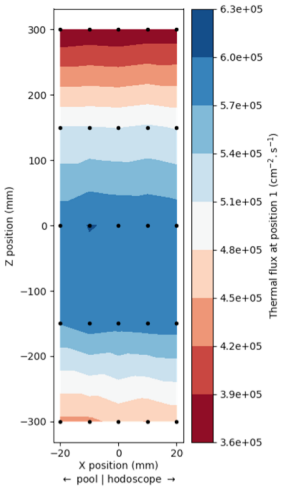
Neutron characterization of external experimental positions

- **Neutron spectrum**

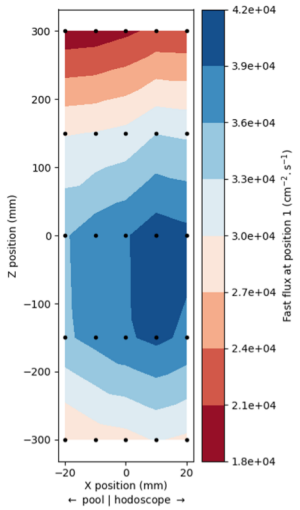


If the core is operated at 100 kW (low power):
Neutron Flux = 7,2 10^{10} n/cm²/s

- **Thermal flux** measurements
  - Flat along x-axis
  - Cosine-shaped along z-axis, shifted toward the bottom due to partial control rods insertion

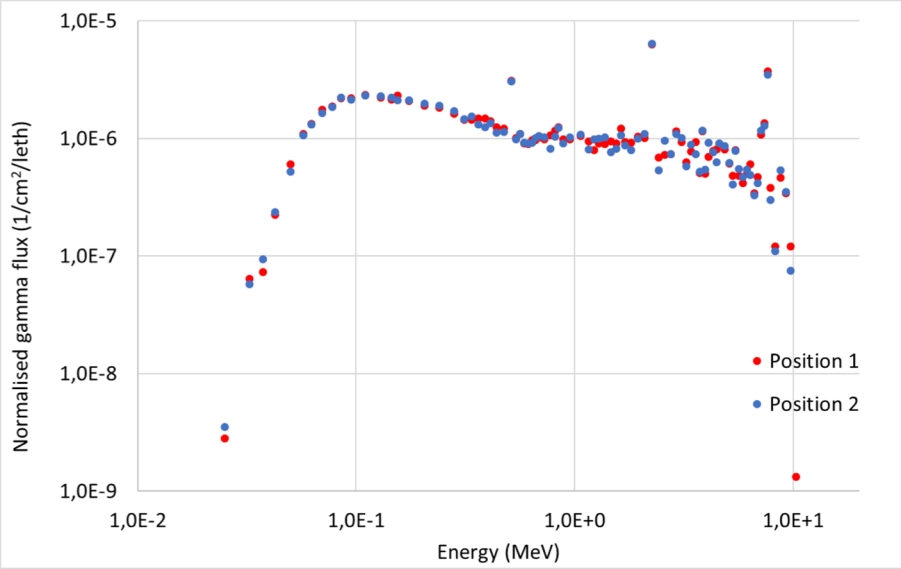


- **Fast flux** measurements
  - Maximum close to the hodoscope channel, due to neutrons streaming out of the channel



Gamma characterization of external experimental positions

Gamma spectrum



If the core is operated at 100 kW (low power):
Gamma flux = 5,5 10^{10} g/cm²/s