OSIRIS & ISIS REACTORS

THE ORIGINAL ASSOCIATION OF A MATERIAL TESTING REACTOR AND ITS NEUTRON MOCK-UP

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2 - ISIS MAIN CHARACTERISTICS

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OSIRIS FUEL QUALIFICATION
NEUTRON RADIOGRAPHY…
TECHNOLOGICAL IRRADIATIONS
NEUTRON CODE QUALIFICATION

4 - EDUCATION AND TRAINING
The ISIS and OSIRIS story is an influential myth in Egyptian mythology.

The god OSIRIS was murdered by his brother SETH who cut his body in 14 pieces and usurped his throne.

OSIRIS' wife and sister, ISIS restored her husband's body who came back to life to reign on the kingdom of death.
ISIS AND OSIRIS ARE ALSO TWO FRENCH RESEARCH Reactors

The INB 40 Facility of SACLAY Research Center includes these two reactors

- **OSIRIS Material Testing Reactor (MTR)**
  - Irradiation of nuclear fuel, vessel steel, cladding & structure material
  - Production of industrial and medical isotopes ($^{99}$Mo/$^{99m}$Tc, $^{131}$I, $^{192}$Ir…)
  - Neutron transmutation doping of silicon

- **ISIS Neutron Mockup of OSIRIS**

The INB 40 Facility was built to answer needs for material testing
(irradiation with a high flux of fast neutrons)

- Construction began in June 1964
- First divergence of ISIS occurred in April 1966
- First divergence of OSIRIS in September 1966
What is ISIS neutron mockup?

- In 1966, computational resources were limited:
  - It was necessary to test fuel and experiments at low power prior to full-scale irradiation
- ISIS Mockup is design to have identical conditions as OSIRIS (Except power)
  - same fuel, same geometry, same experiment locations, same moderation rate
- The goal of ISIS is to permit measuring nuclear parameters such as
  - Reactivity effects (for safety issue)
  - Neutron flux at different spectrum indexes (experimental knowledge & safety issue)
- The experimental database obtained in the ISIS mockup is easily extrapolated to OSIRIS MTR

The concept of the association of an MTR with its neutron mock-up had already been adopted in previous facilities
- SILOE MTR diverged in 1963
- SILOE also had a neutron mockup SILOETTE
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ISIS and OSIRIS are pool reactors with similar conceptions
- A primary loop
- A secondary loop (partly common)
- Light water is used as: moderator, coolant and biological protection

Cores are identical
- Identical aluminium 7x8 array in which are inserted elements

Everything is interchangeable between the two cores
- It is even possible to reproduce a core of OSIRIS in ISIS, using OSIRIS spent fuel

Main differences
- Nuclear power
  - OSIRIS: 70 MW
  - ISIS: 700 kW
- Cooling flow rate is adjusted in ISIS to have identical coolant temperature as OSIRIS (same temperature effects)
1) control rods engines
2) control rods safety magnets
3) mobile platform
4) primary loop chimney (S-Steel)
5) removable plate for loading
6) water outlet
7) mobile upper grid
8) water inlet
9) chimney (AG3 NET)
10) zirconium alloy container
11) array of holes in the base can be used to insert experimental devices in different location around the core
12) basis
13) pool decking
14) drain line
15) lower carriage dash pot control rod
16) fuel part of control rod
17) absorber part of rod
18) 38 fuel assemblies
19) 7 beryllium assemblies
20) neutron detection systems
21) steel casing pool
22) neutron detection systems movement devices
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ISIS was used to qualify every type of fuel used in OSIRIS reactor

- **Initial very high enriched UAl fuel: 1966**
  - ISIS diverged in April 1966, five month before OSIRIS
  - OSIRIS diverged in September 1966
  - ISIS maximal power increased from 100 to 800 kW in March 1967
  - OSIRIS maximal power increased from 50 to 70 MW in December 1968

- **Caramel nuclear fuel (UO₂– Zircaloy cladding): 1978**
  - Lower enrichment fuel developed by CEA for non proliferation reasons

- **U₃Si₂-Al nuclear fuel : 1998**
  - ISIS used to test fuels elements from 1992 to 1998

ISIS was also used to qualify every new configurations of OSIRIS core

ISIS was used to determine control rods efficiency (operation and safety issue)

- Use of soluble Boron for Burn up simulation
- These results (S-Curves) are used at every cycle in OSIRIS
Silicide $U_3Si_2-Al$ plates
- Aluminium cladding
- Enriched at 19.75 %

Control rod made of 2 parts:
- an upper Hafnium absorber part
- A lower Silicide fuel part

Rod efficiency is increased by the presence of fuel
ISIS was also designed to host NDT devices:

- 2 neutron radiography devices (no longer used)
- A gamma spectrometry device for fuel analysis.
  - Similar to OSIRIS’s

- Use of these devices without interference on OSIRIS activity
- Increase of the experimental capability and flexibility of the facility.
A TOOL TO IMPROVE THE QUALITY OF THE IRRADIATIONS IN OSIRIS

ISIS is a powerful tool to access to OSIRIS physics and improve the quality of irradiations on OSIRIS

- Extrapolation of ISIS measurements to OSIRIS
  - Neutron cartography
  - Calorimetry

- Dosimetry
  (Necessary for qualification of material experiments)
  - 1st stage in ISIS reactor for dosimetry (knowledge of exact irradiation conditions),
  - 2nd stage in OSIRIS for irradiation

- Test of experimental devices at low power
  - Irradiation devices,
  - New concepts of calorimeters…

Work on OSIRIS reactor
**TECHNOLOGICAL IRRADIATIONS**

**ISIS** allows technological experiments, for which a neutron **flux at very different levels and in different spectral indexes** is required.

**Instrumentation qualification**

- Tests of Sensors:
  - New fission chambers / boron chambers, (using ISIS measurement chains)
  - Test of new SPND (self powered neutron detectors, collectrons) (Response in thermal and/or fast spectrum)

- Acquisition chains
  - Electronics and acquisition measurement chains (using ISIS detectors as benchmarks)
In the sixties neutron mockups were intensively used for fuel tests.

Since then the role of scientific simulation has increased in nuclear engineering.

ISIS contributes to the improvement and qualification of neutron codes

- Unusual core configurations can be realised on demand
- Numerous measurements easily available (reactivity, neutron flux at different spectrum indexes…)

**Example**

- In 2013-2014, reactivity effects due to beryllium blocs were measured in several configurations (blocs withdrawn)
- Measurements were compare to computations to improve codes & models
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After the end of operation of ULYSSE training reactor in 2007, ISIS became the main reactor used by CEA for E&T.

Every year, about 350 trainees participated to 60 working days on ISIS. A third of this activity concerns international courses held in English.

These practical courses are addressed to a wide range of public and treat several aspects of the operation of a reactor.

- Reactor physics (role of precursors - temperature effects - shadow effect)
- Reactor operation
- Calibration curve and global worth of a rod
- Influence of experimental devices on the core reactivity
- Radiation protection applied to reactor operation
- Study and setting of the neutron detection systems
- Neutron cartography / Neutron activation analysis…

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Distant students can:
- interfere with the teacher
- visualise the evolution of reactor data
- access to ISIS webcam, zoom on the control room or on the core.

A first demonstration of this “Internet Reactor Laboratory” was carried out in September 2013 during the IAEA General Conference.

New demonstrations took place in 2014.
CONCLUSION
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For 48 years of operation, uses of ISIS have been in constant evolutions, from OSIRIS fuel qualification and dosimetry to code qualification and E&T

- A neutron mockup like ISIS can be operated on demand
- Core configurations that unusual for a MTR but of scientific interest can be easily tested
- Its equipment (like NDT devices) increase the flexibility and capability of the nuclear facility
- Measurements made in ISIS mockup can be extrapolated to OSIRIS to contribute to improve the quality of the irradiations performed in OSIRIS

Work on ISIS do not disturb or delay OSIRIS irradiation program

- In Egyptian mythology, ISIS played a discrete but major role in the fame, the power and the life of OSIRIS
- This conclusion also apply to Research reactors
THANK YOU FOR YOUR ATTENTION