CABRI CIP0-1 PRELIMINARY TEST RESULTS

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IRSN

THE CONTEXT

- Most utilities request, for economic reasons, an increase of the fuel discharge burn-up.

- MOX fuel is largely introduced

- Key points :

+ improve clad alloys (M5, Zirlo, Duplex, MDA,…) which properties are limited by corrosion
+ improve MOX microstructure (TU2, SBR) to minimize fission gas release

OBJECTIVES

- Determine UO2 and MOX high burn-up fuel behaviour under RIA conditions
- Determine safety margins
- Propose new safety criteria more adapted to high burn up fuel

THE CIP (1/2)

- In 2000, IRSN proposed a new program under the auspices of OECD
- 12 tests planned
- 14 organisations from 11 countries have signed an agreement with IRSN

THE CIP (2/2)

- 2 first tests performed in the Na loop environment (reference)

  + CIP0-1 75 GWd/t cladded with Zirlo - 30 ms pulse width
  + CIP0-2 75 GWd/t cladded with M5 – 30 ms pulse width

- Both tests performed in November 2002

- CIP0-2 (M5) exhibited no clad failure

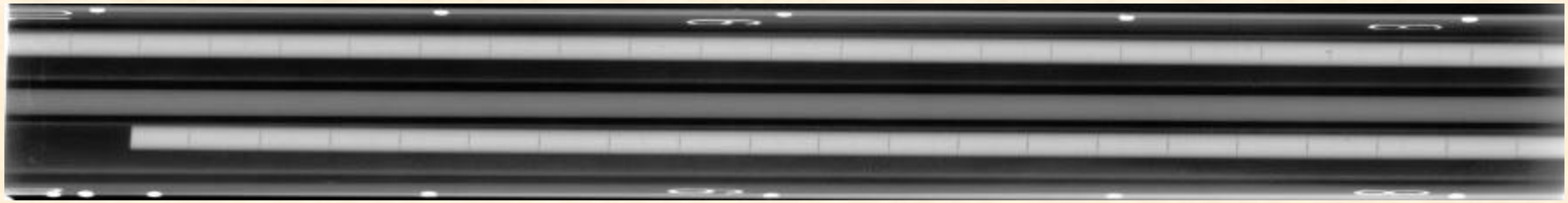
CIP0-1 FUEL ROD

- Irradiated in the Vandellos reactor (Spain) up to 74.8 GWd/t (pellet burn-up)
- Examined and refabricated in the Studsvik Labs (Sweden)
- Shipped to Cadarache in June 2002

CIP0-1 NDE

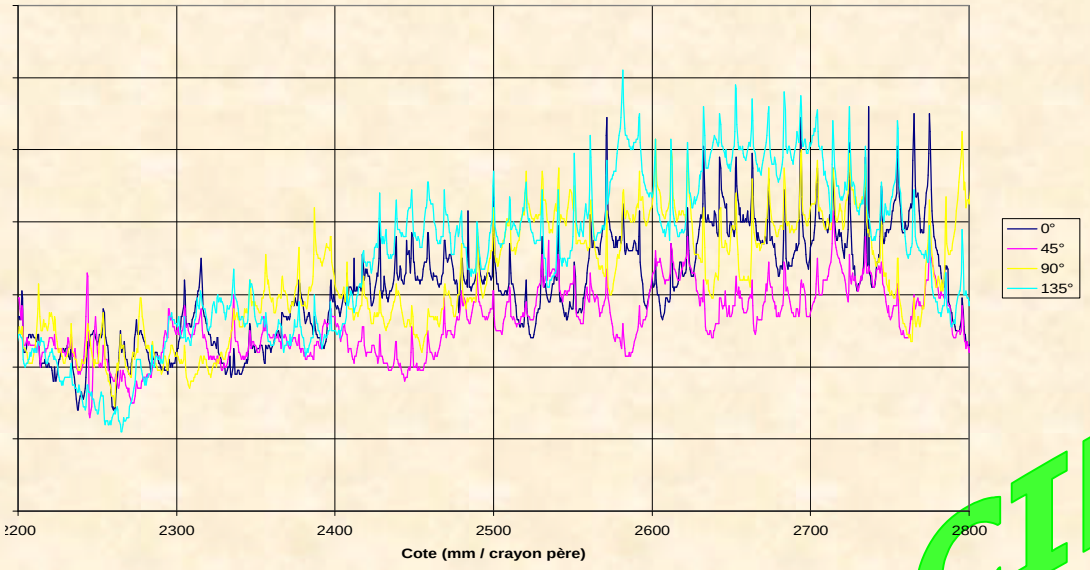
Examinations

Neutronography : hydride concentrations at pellet-pellet interface



Metrology:

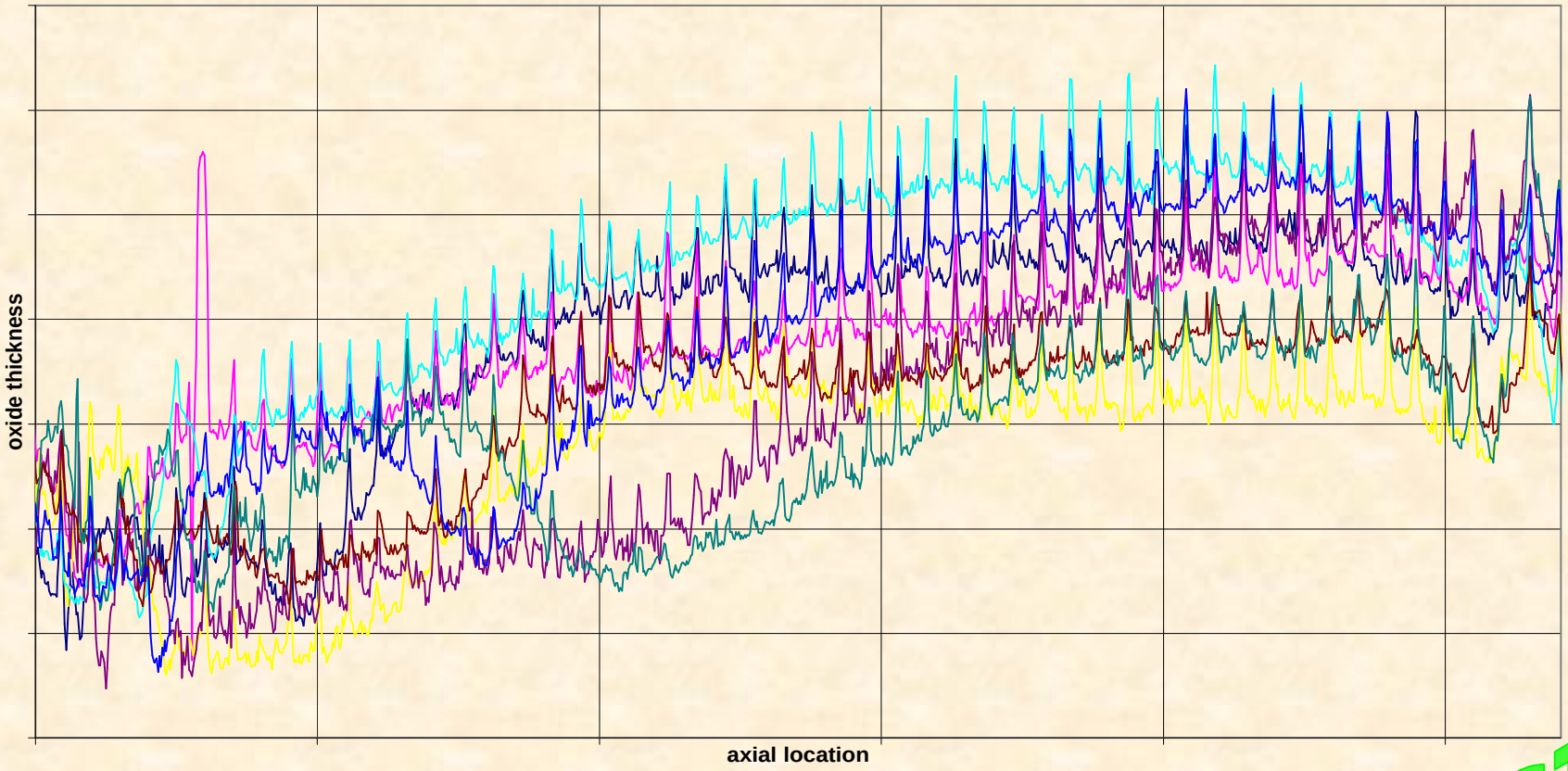
Typical of high burn-up fuel (ridges, ovalization)



CIP

CIP0-1 Zirconia layer before test

Important zirconia layer (75 µm average) with large axial azimuthal variations



CIP

CIP0-1 test conditions

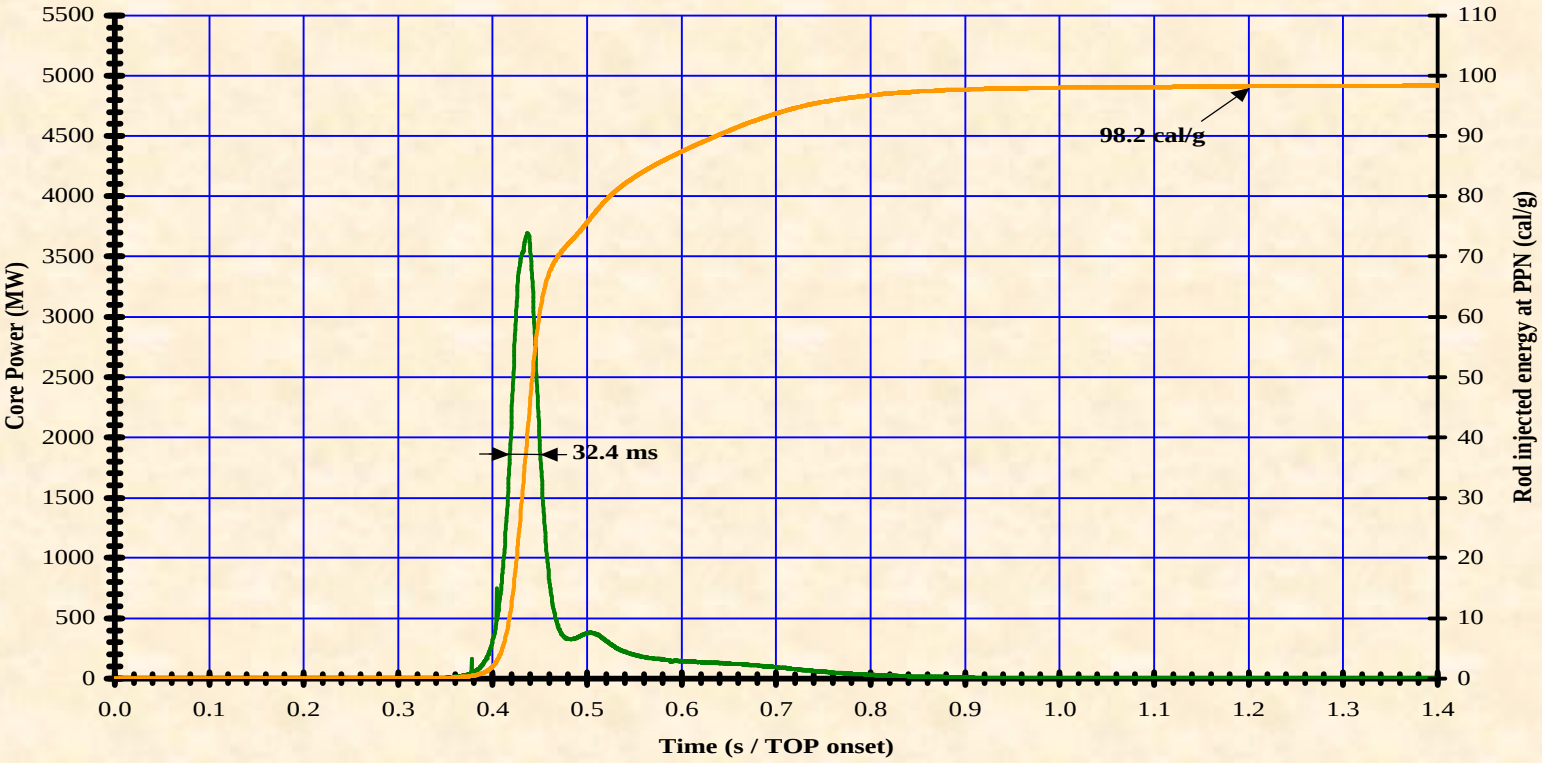
Mid-height width : 32.4 ms (30)

Total energy deposit : 98.2 cal/g (100)

Fluid velocity : 4 m/s

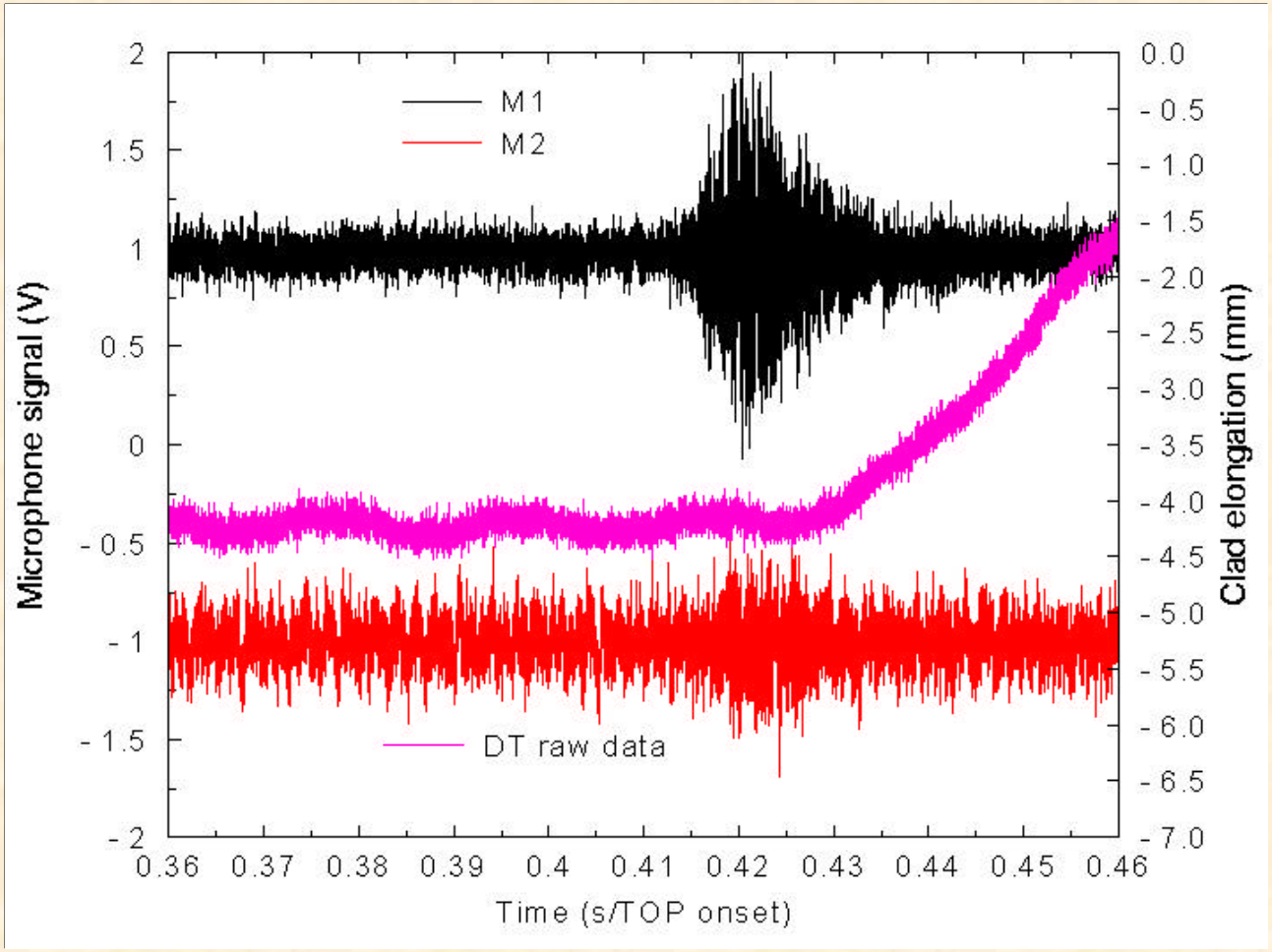
Coolant temperature : 280°C

Core power : 100 kW



CIP0-1 First event

Microphone event linked with axial clad elongation



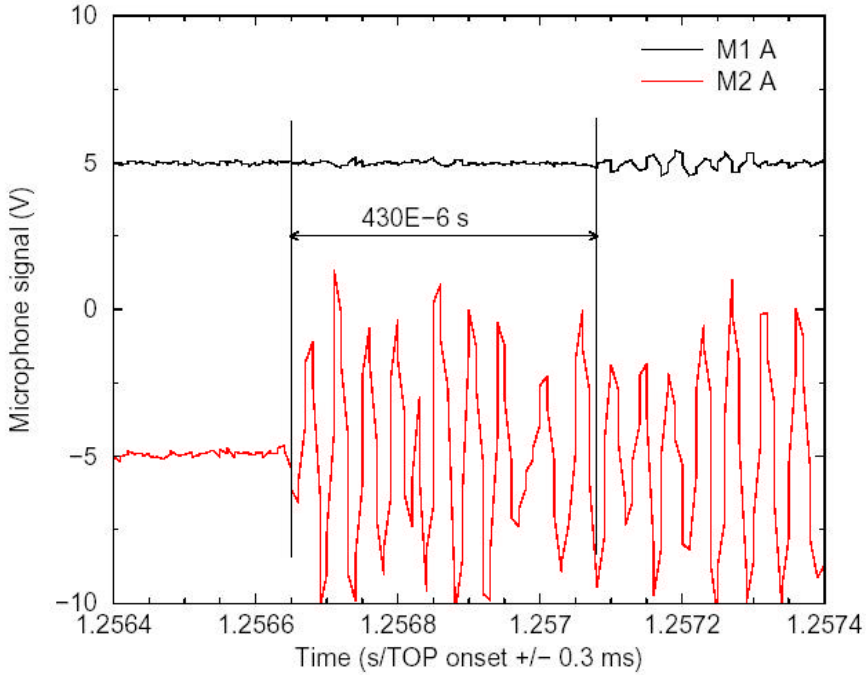
Time: TOP+0.41 s

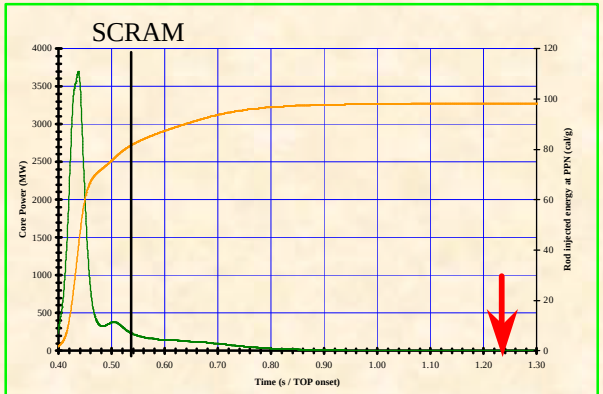
Energy: 8.5 cal/g

CIP

CIP0-1 late event (1)

Microphone event





Time: TOP+1.26 s

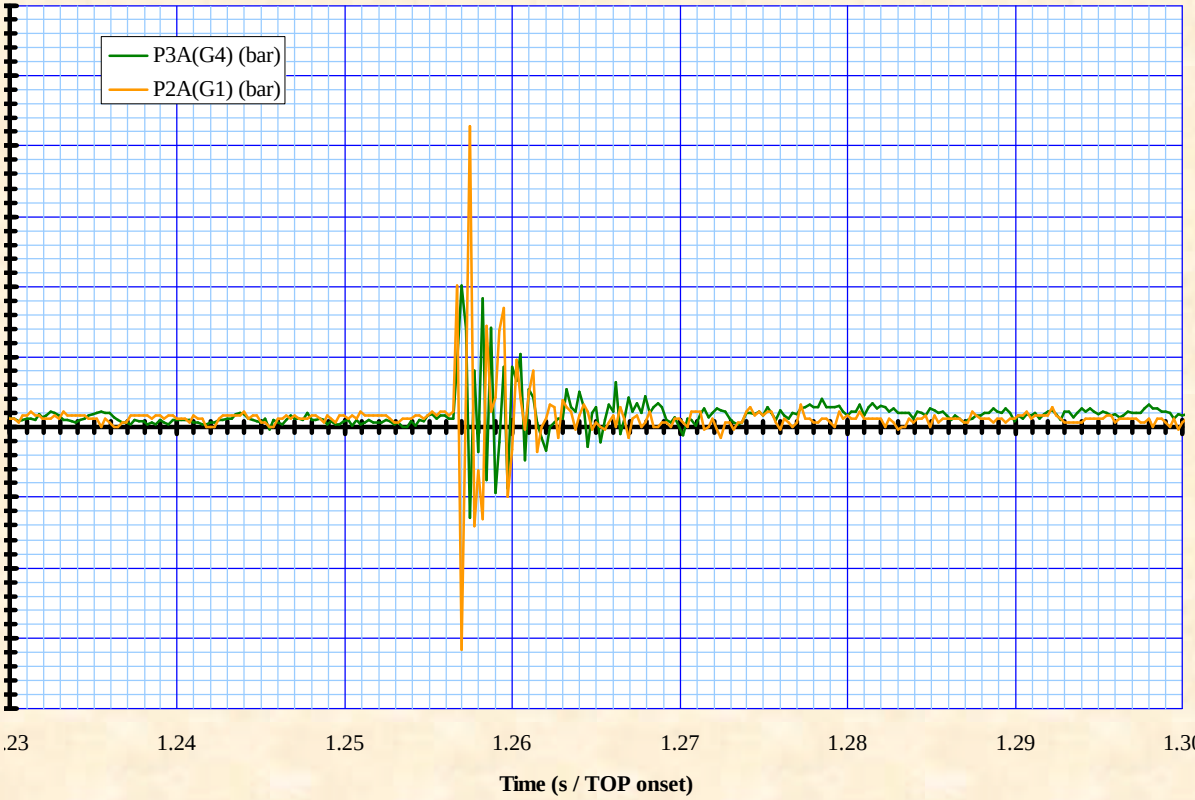
Energy: 98.2 cal/g

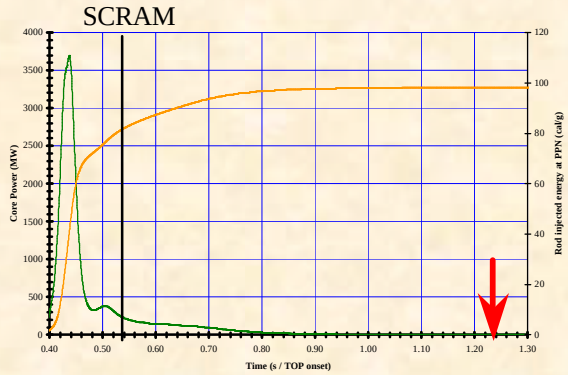
Location well above the tested rod !

CIP

CIP0-1 late event (2)

Pressure event





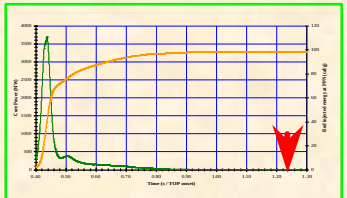
Time: TOP+1.26 s

Energy: 98.2 cal/g

150 µs before microphone event !!!

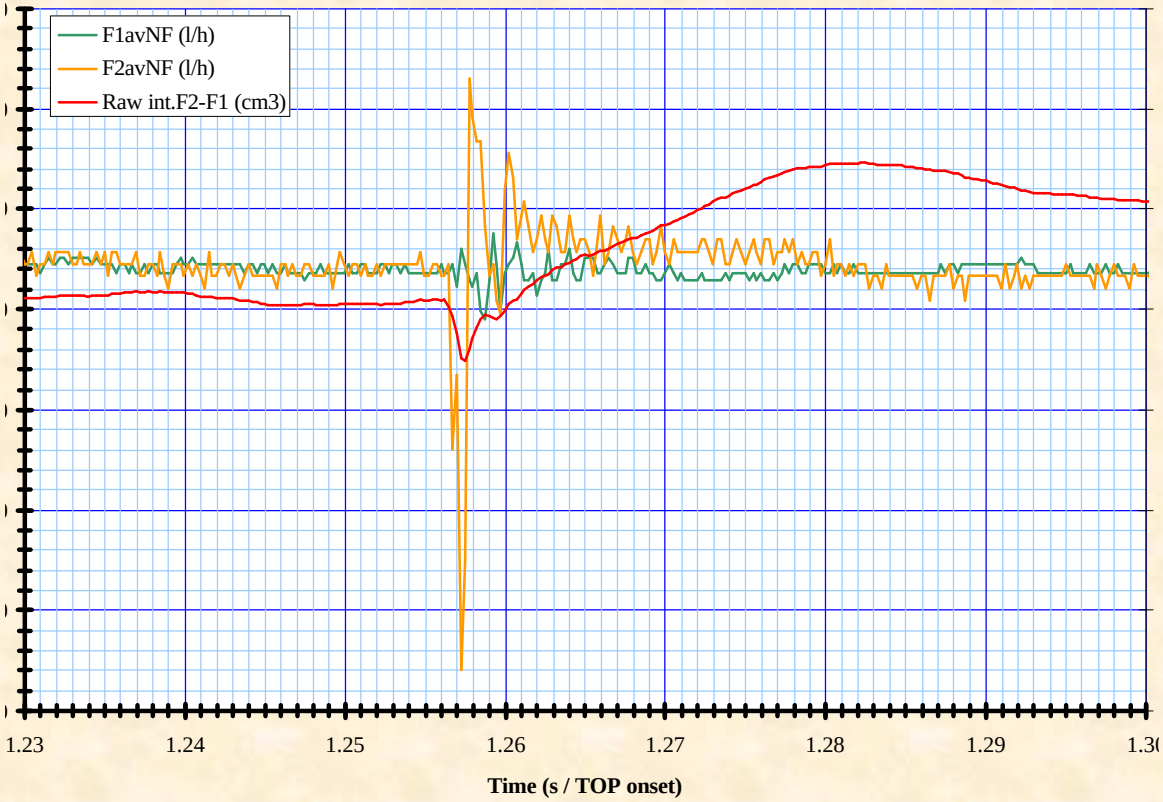
CIP0-1 late event (3)

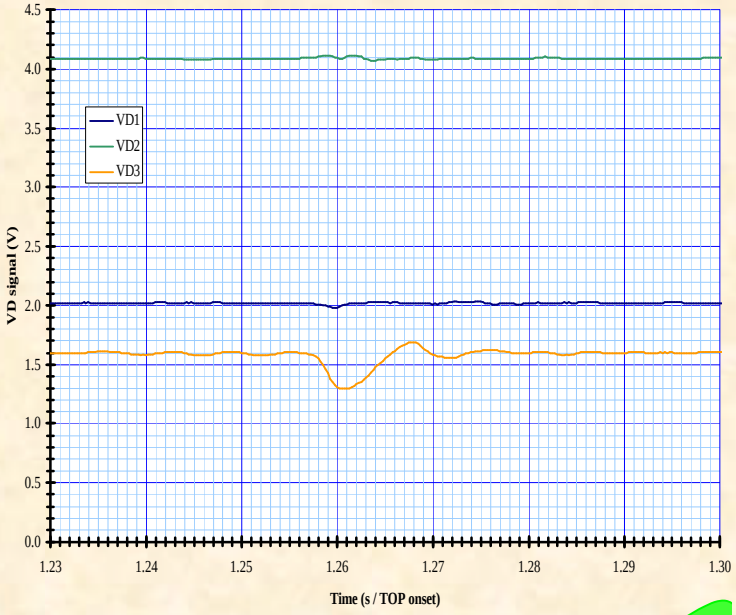
Flow and VD event



Time: TOP+1.26 s

Energy: 98.2 cal/g





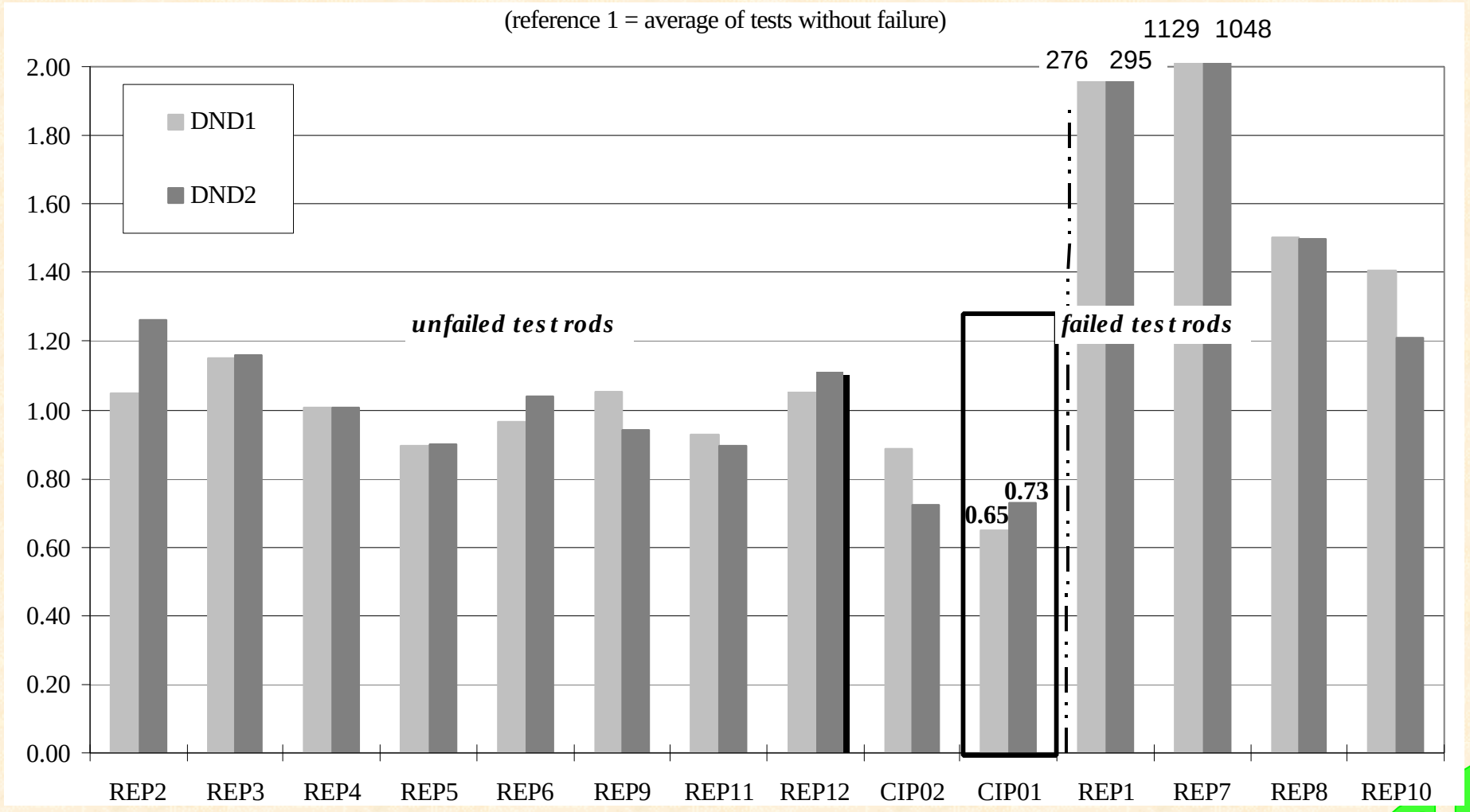
150 µs before microphone event !!!

CIP

CIP0-1 late event (4)

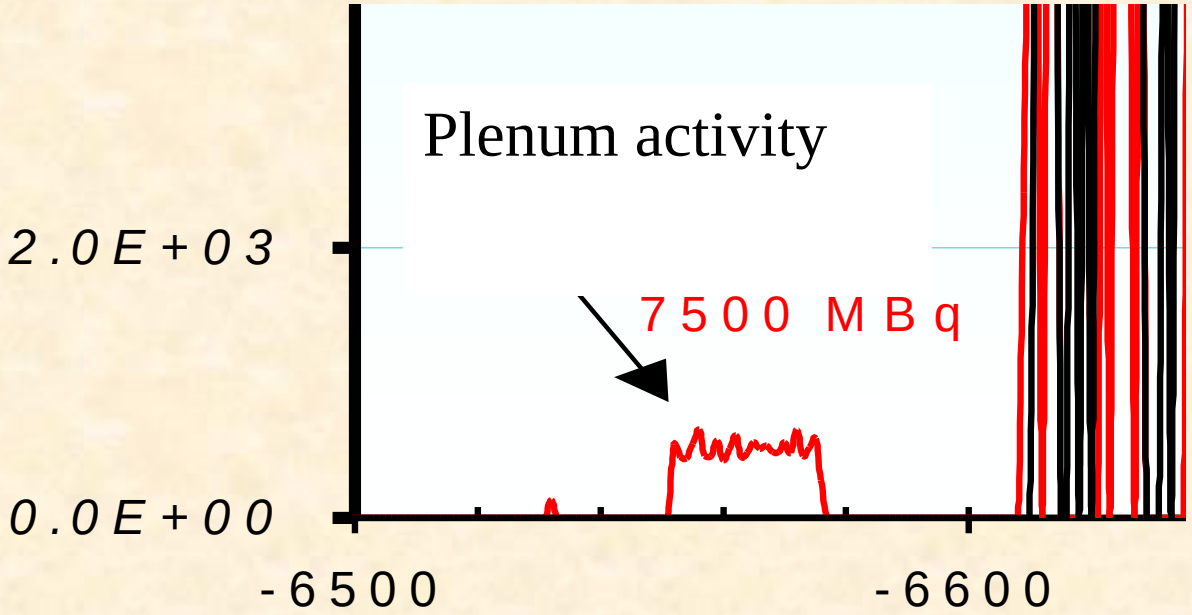
- Microphone event close to saturation on M2
- Flow, pressure and VD event
- This event could be interpreted as clad failure, but:
  - No detection on DND signals
  - No detection of ^{85}Kr on the Na cover gas after test
  - Unconsistent timing: P,Q before microphones
  - No failure seen during visual examination in hot cells
- Quantitative gamma-scanning on the upper plenum was performed

REPNa and CIP0 DND



CIP0-1 post-test NDE

Quantitative Gamma-scanning



Activity consistent with expected amount of FG release

CIP0-1 results

- First event = clad elongation
- Second event = most probably not a failure

The non failure will be confirmed by pin piercing in fall 2003

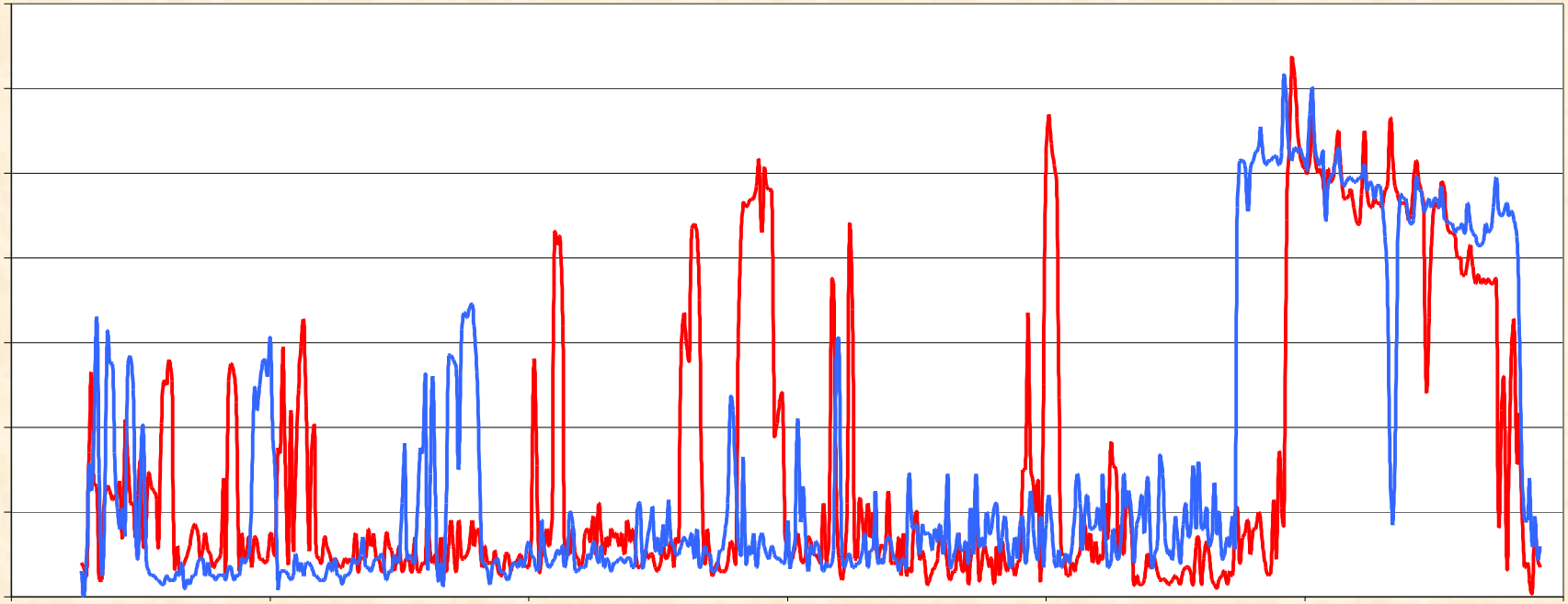
Non-destructive examinations performed :

- visual examination, profilometry
- gamma-scanning
- zirconia layer : **extended spalling**

CIP0-1 post-test NDE

Zirconia measurement

extended spalling



CIP0-1 status

- Pin piercing and gas analysis in **Fall 2003**
- Destructive examinations will be performed :
  axial and radial cuts at the **beginning of 2004**
- The signal analysis is undergoing (explanation of second event)

MECHANICAL CHARACTERISATION OF ZIRLO CLADDING

PROMETRA Program defined within the CIP for advanced cladding materials (Zirlo, M5-6cycles)

Objectives : determine the stress-strain laws and failure data

Common test matrix

- 10 hoop tensile tests (doubled) : T= 280-800°C, 1 s^{-1}

T=480°C, strain rate : 0.01 s^{-1}

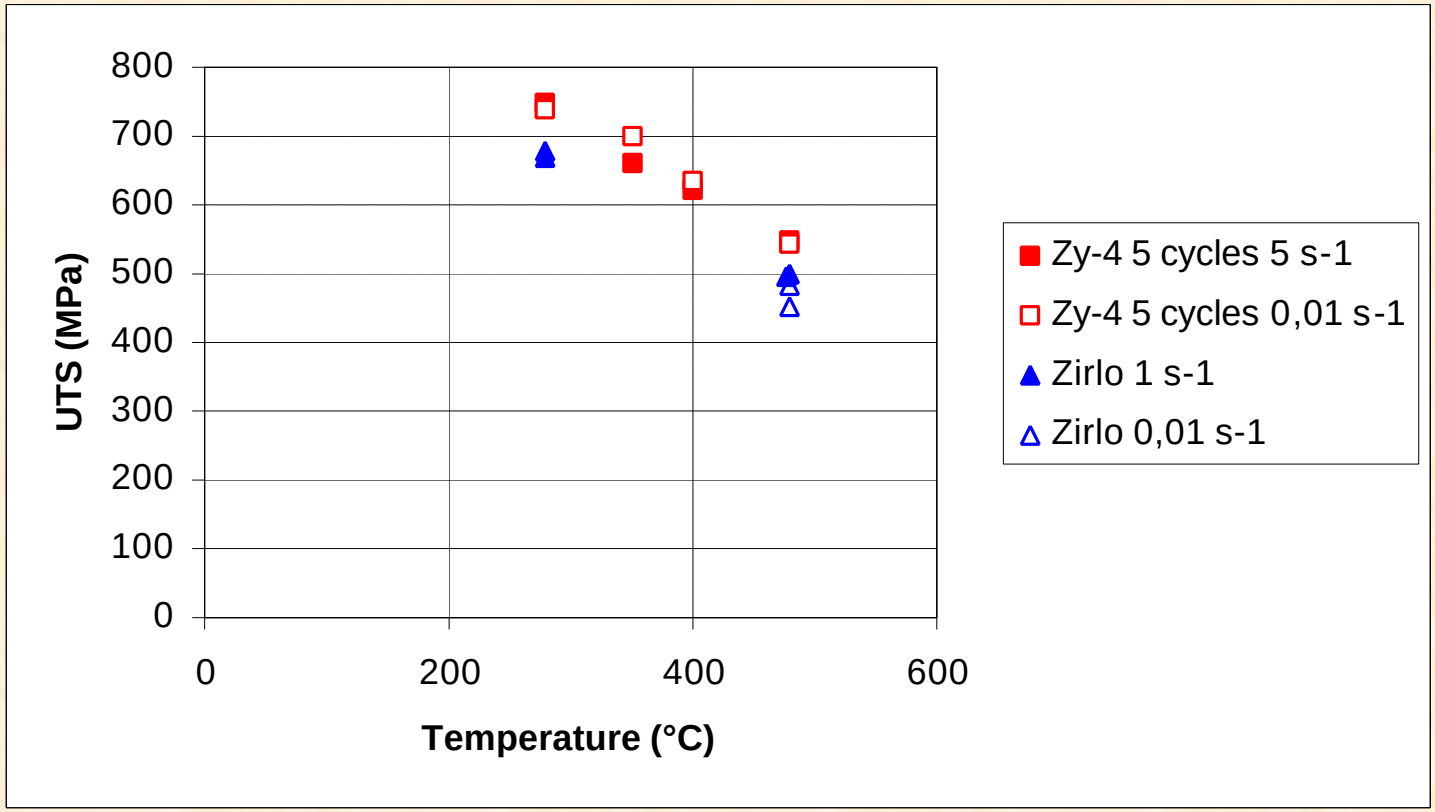
- 8 Penn-State type tests (doubled) : T= 280-800 °C, 1 s^{-1}

- 2 burst tests T= 280°C, 1 s^{-1}

CIP

MECHANICAL CHARACTERISATION OF ZIRLO CLADDING

Comparison of UTS results between Zirlo and Zr4-5 cycles



Hoop tests at higher temperature finalised

Following part of the test program in 2004

CONCLUSIONS

- CIP0-1 successfully performed
- Presumption of non failure – confirmation Fall 2003
- Physical origine of late event signals to be analyzed
- CIP0-1 very last test with Na loop
- 1st test (CIPQ) in the water loop foreseen in 2006