FCC4 container

NRC-AREVA NP meeting
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AREVA NP

Purpose/Content

- AREVA is deciding on our future global container.
  - Two candidates are being evaluated: The MAP-14 and the FCC4
- Meeting with French and US authorities to identify any obvious licensing barriers, challenges or items of concern to assist in the evaluation.
- We are seeking your initial feedback on the FCC4 with recent knowledge of the MAP container in hand.

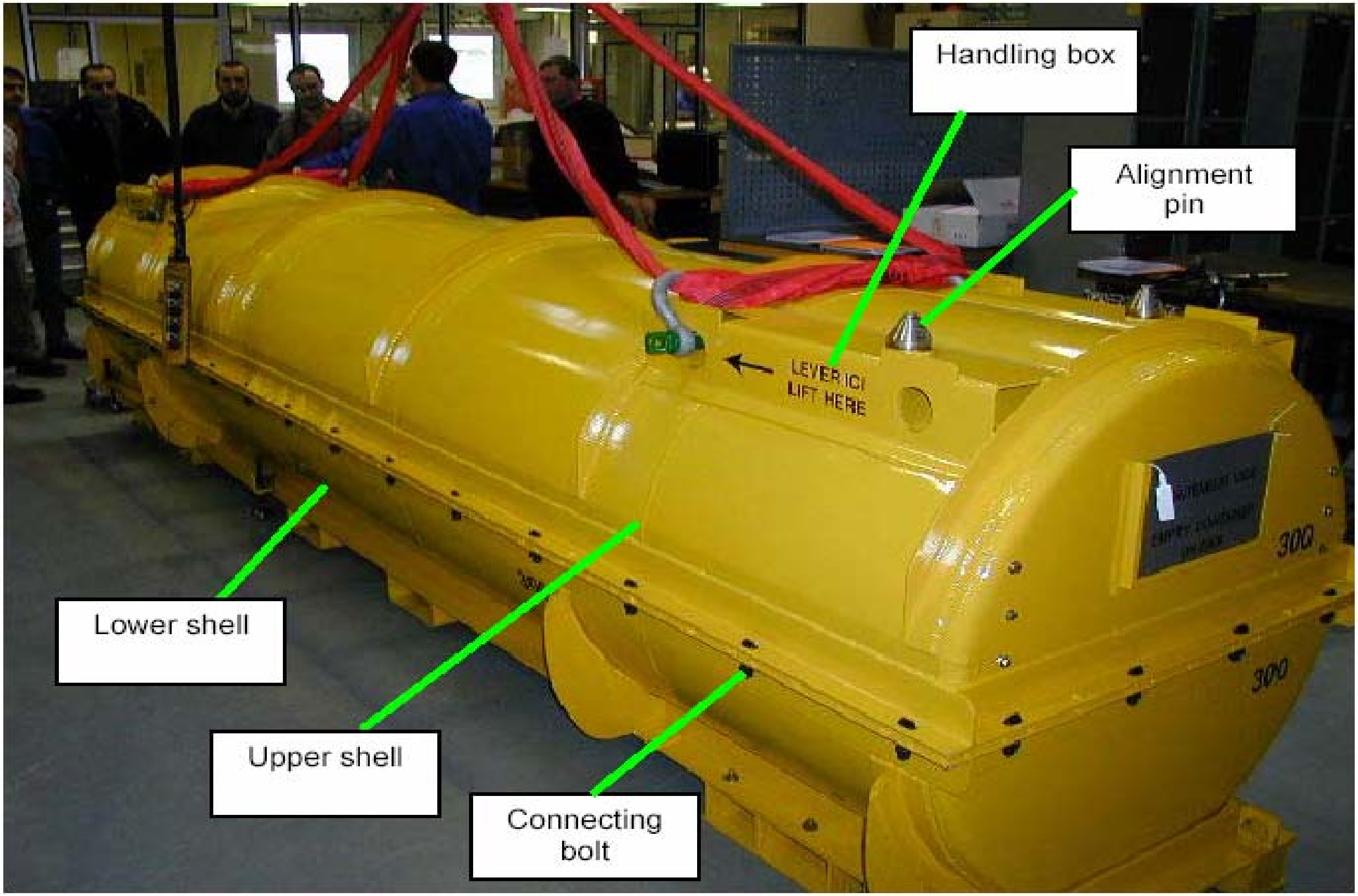
Presentation Contents

1. Introduction
2. FCC4 Packaging Description
3. Description of packaging contents
4. Analysis of compliance with regulatory requirements
5. Licenses that are in effect today
6. Adaptation of FCC4 packaging for EPR deliveries

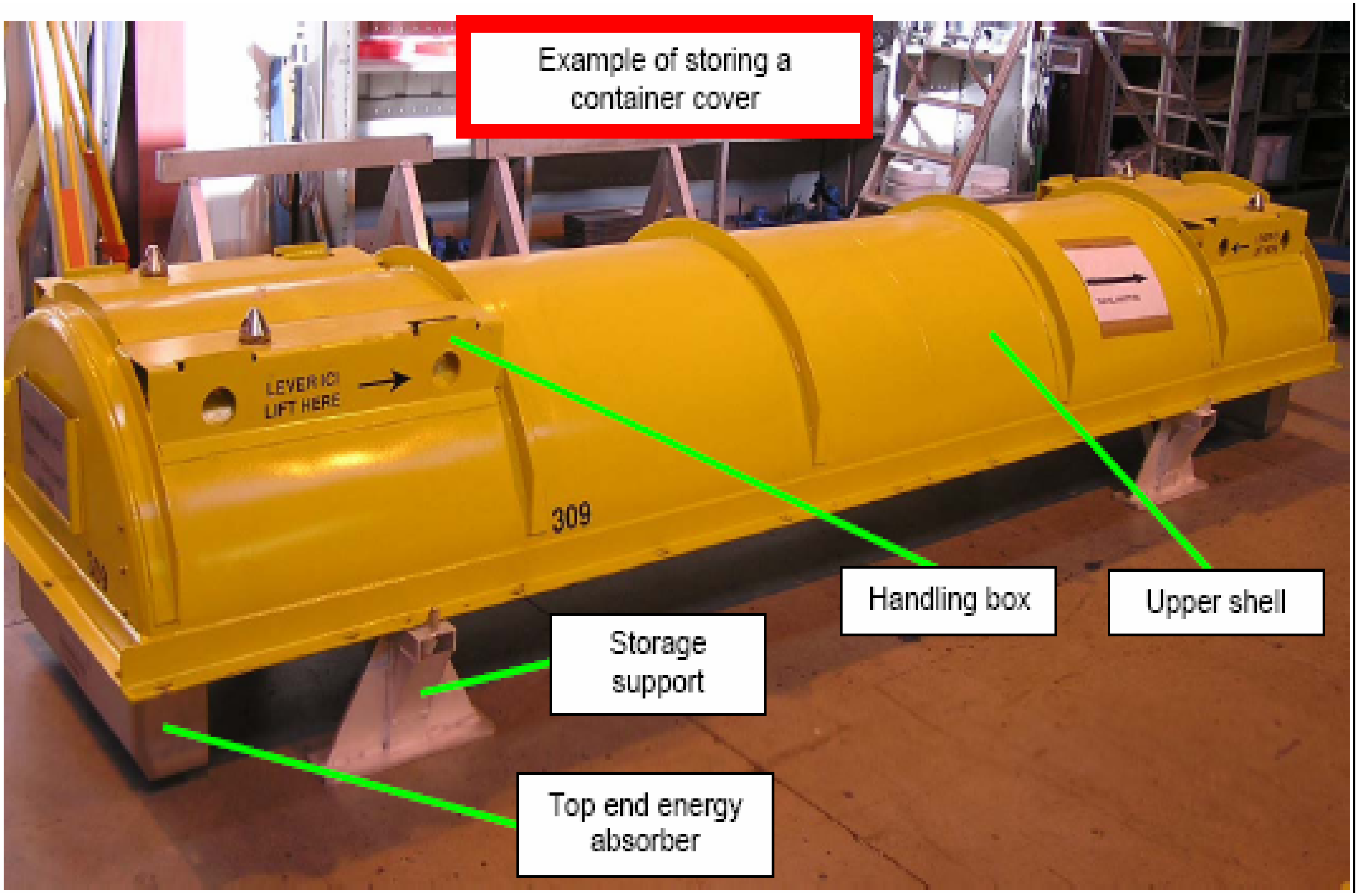
Introduction

- The FCC4 design was the next generation of the RCC and MCC packages
  - With improvements on the interior structure
  - Due to Regulation change :
    - IAEA 85 amended in 1990, IAEA 1996 for application in 2001
    - Compliance with regulatory tests : drop and thermal tests, subcriticality
- Any PWR fuel assembly design
  - All patterns from 14x14 up to 18x18 (FCC3/FCC4)
  - UO2 enrichment up to 5% 235U for ENU & ERU
- Package:
  - Empty Weight: 3670 Kg / Full Weight: 5400 Kg
  - L: 5740 mm (226 “) / W: 1130 mm (44.5 ”) / H: 1293 mm (51 “)
- First certificate issued in January 2000 by ASN, F/348/IF-96
  - Type IP2 (Industrial package type II), ref. IAEA-96 regulations (TSR-1)

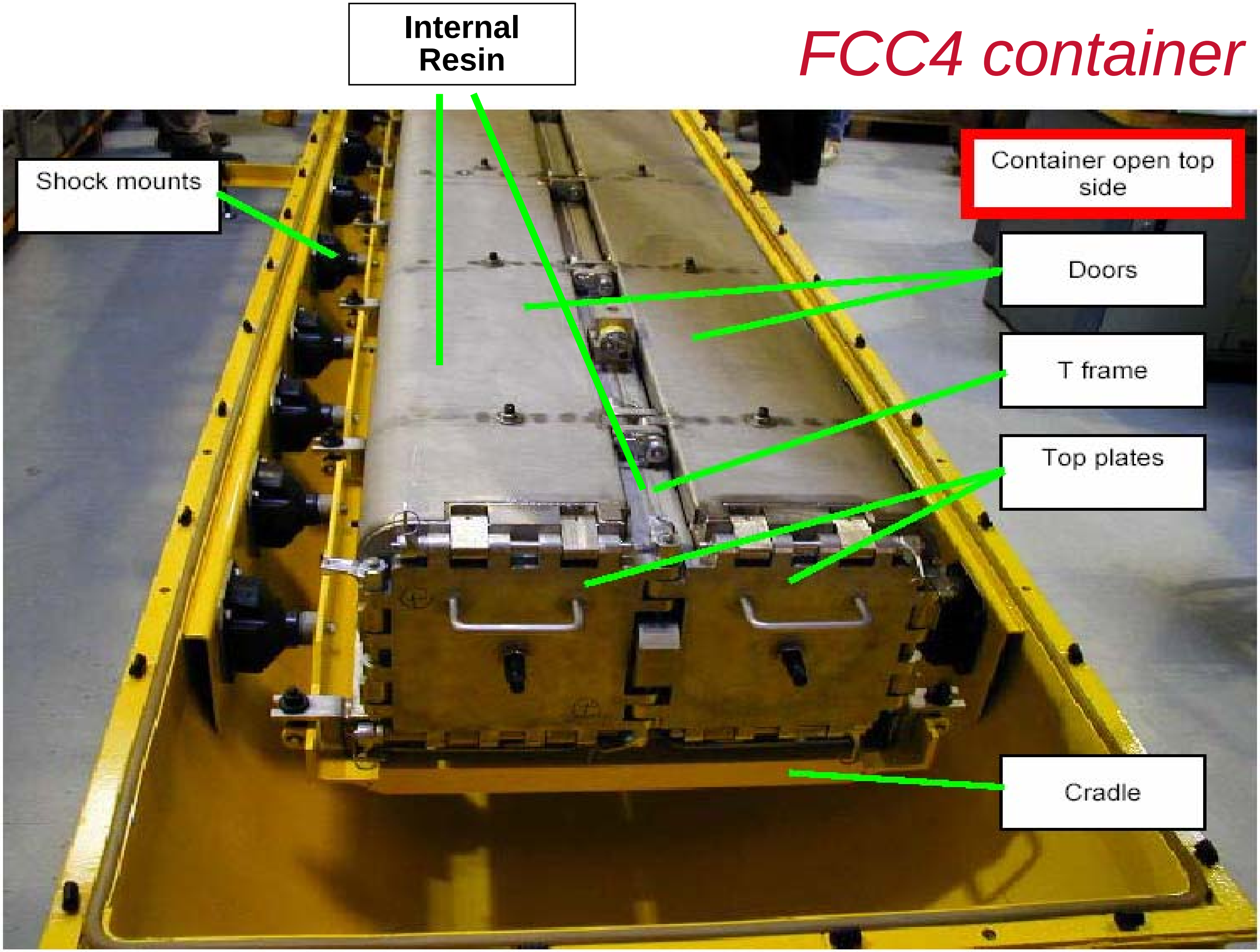
FCC4 container



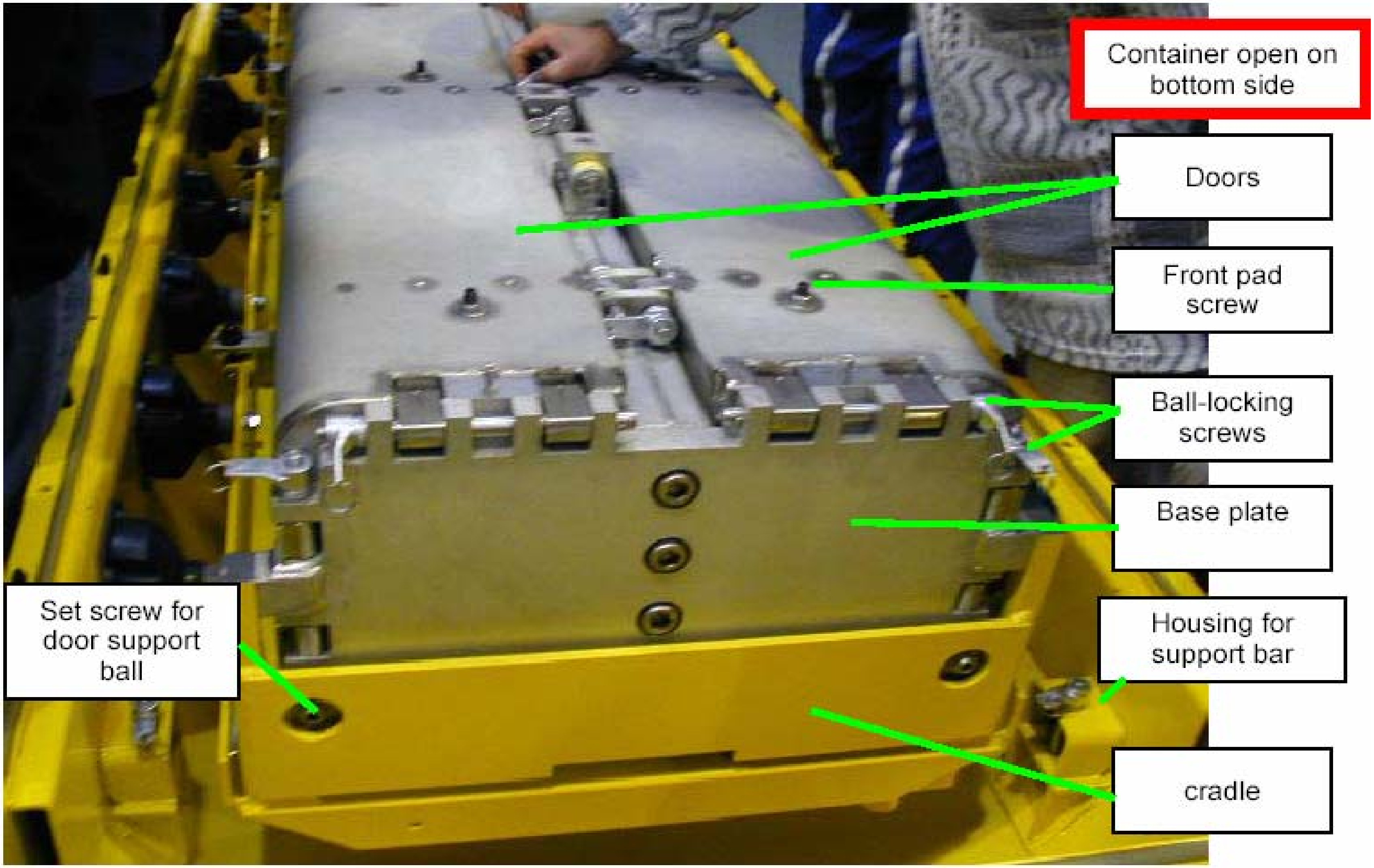
FCC4 container



FCC4 container



FCC4 container



FCC4 container

Full Length
Door Opened

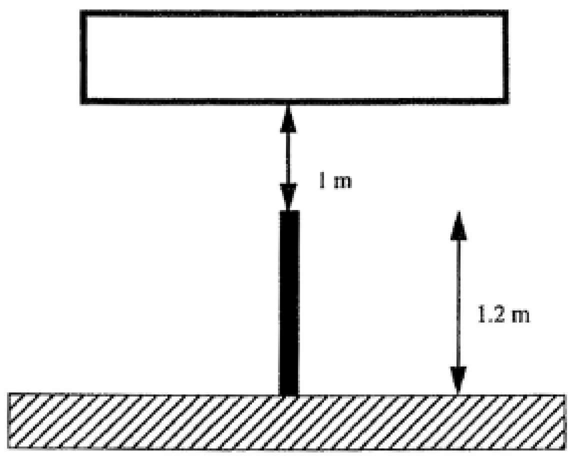
FCC4 packaging description

- Materials:
  - Shells: carbon steel S355 (E36.3 and E36.4)
  - Internal system structure, connecting pins: stainless steel (X2CrNi1809/X4CrNiMo16-5-1)
  - Screws: stainless steel (42CD4)
  - Resin: polymer resin (B: 2.1%, H: 4.65%, C, Si, O, Al, Zn, Mg)
  - Impact limiters: stainless steel enclosure containing balsa
  - Coating: corrosion inhibitor + paint, applied on the shells
  - Shocks mounts: rubber

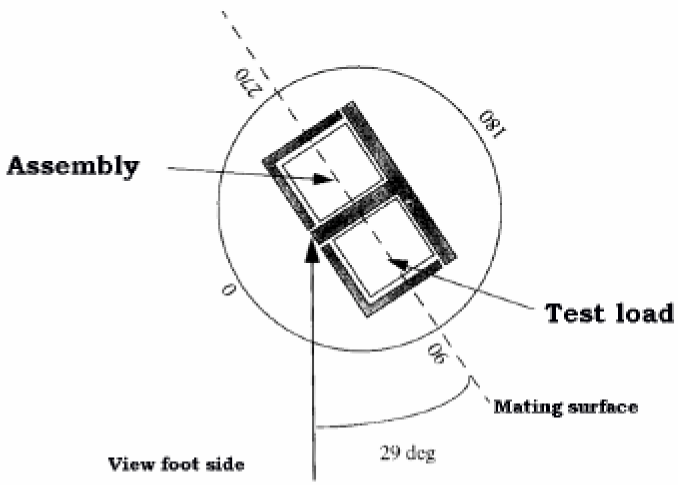
Compliance with regulatory requirements

- Drop tests performed on 1 FCC4 prototype (Sept. 1998, CESTA facility, France)
  - Drop from 1m (3 ft) height onto a vertical bar (2 tests)
  - Flat drop from 9 m (30 ft) with slap down effect (1 test)
- Drop tests performed on 1 FCC3 prototype (Feb. 1998, CESTA facility, France)
  - Axial drop from 9 m (30 ft) (1 test)
  - *Drop on bar from 1m height (3 ft) (2 tests)*
  - *Flat drop from 9 m (30 ft) with slap down effect (1 test)*
- Thermal test: evaluated by calculation

FCC4 Pin test 1



DROP ONTO BAR N°1



PLATE

DROP N°1

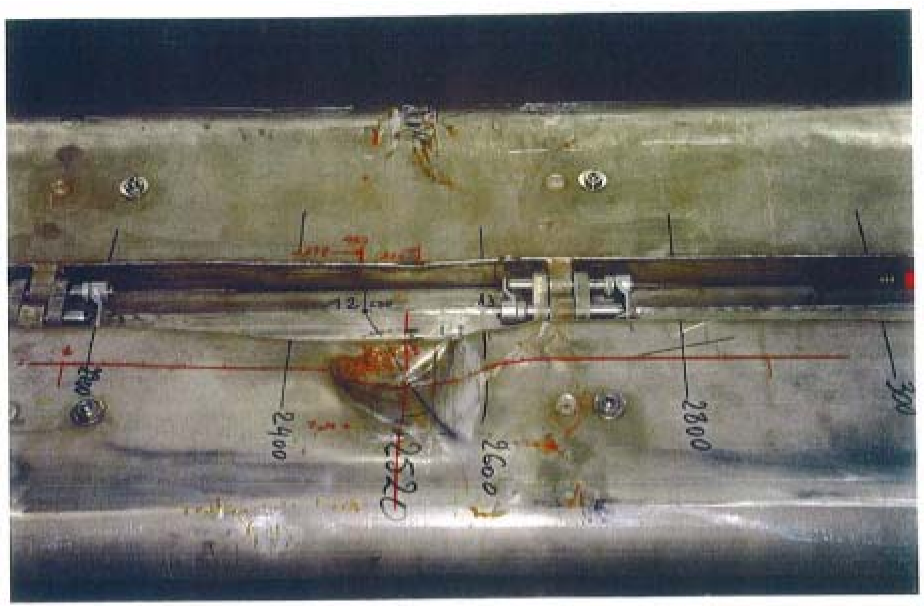
- 22.09.98

2.1.

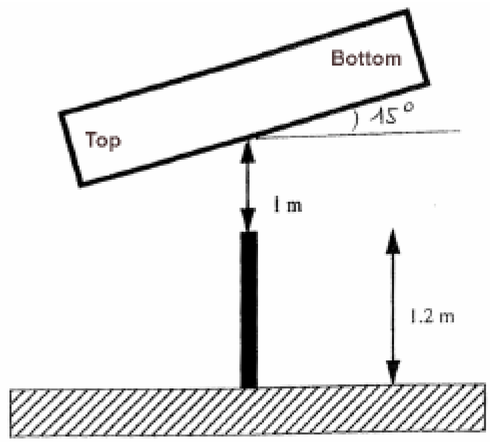
FCC4 Pin test 1

- Perforation of the upper enclosure 150-200 mm (6-8'')
- Indentation of the sheet metal doors, no rupture
- Doors hinge pins nearest the impact were intact
- Neutronic cavity remained undamaged

3.1.



FCC4 Pin test 2

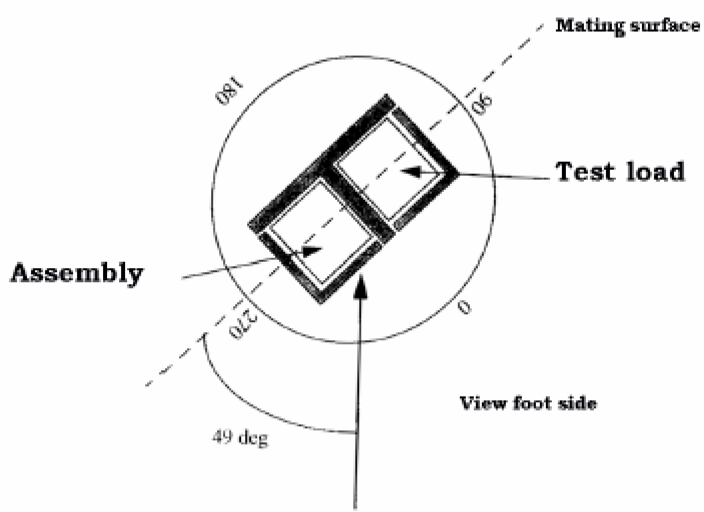


DROP ONTO BAR N°2

PLATE 5

5.1.

DROP N°2 - 23.09.98 -

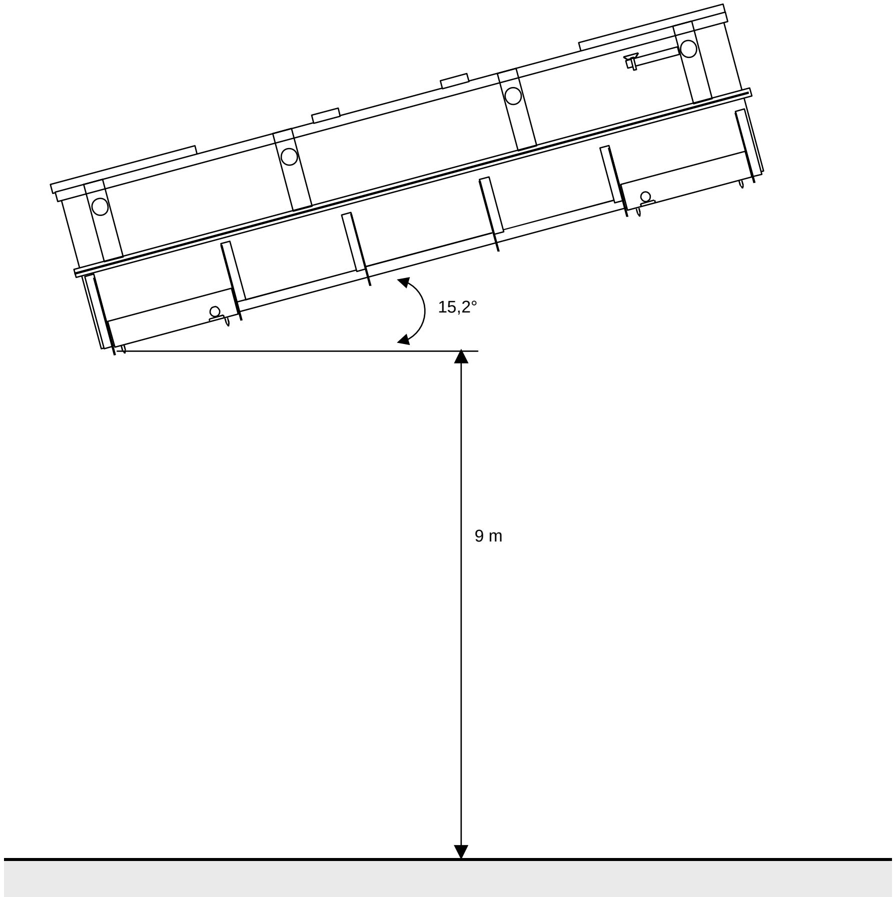


FCC4 Pin test 2

- Perforation of the upper shell (335 mm- 150 mm)(13’’-6’’)
- Indentation of the door plate
- Tearing of the door plate, along two axes

6.1

FCC4 – 9 m drop test



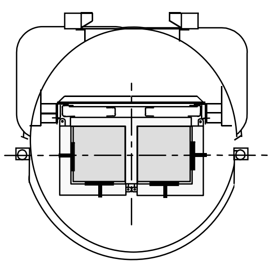


PLATE 8

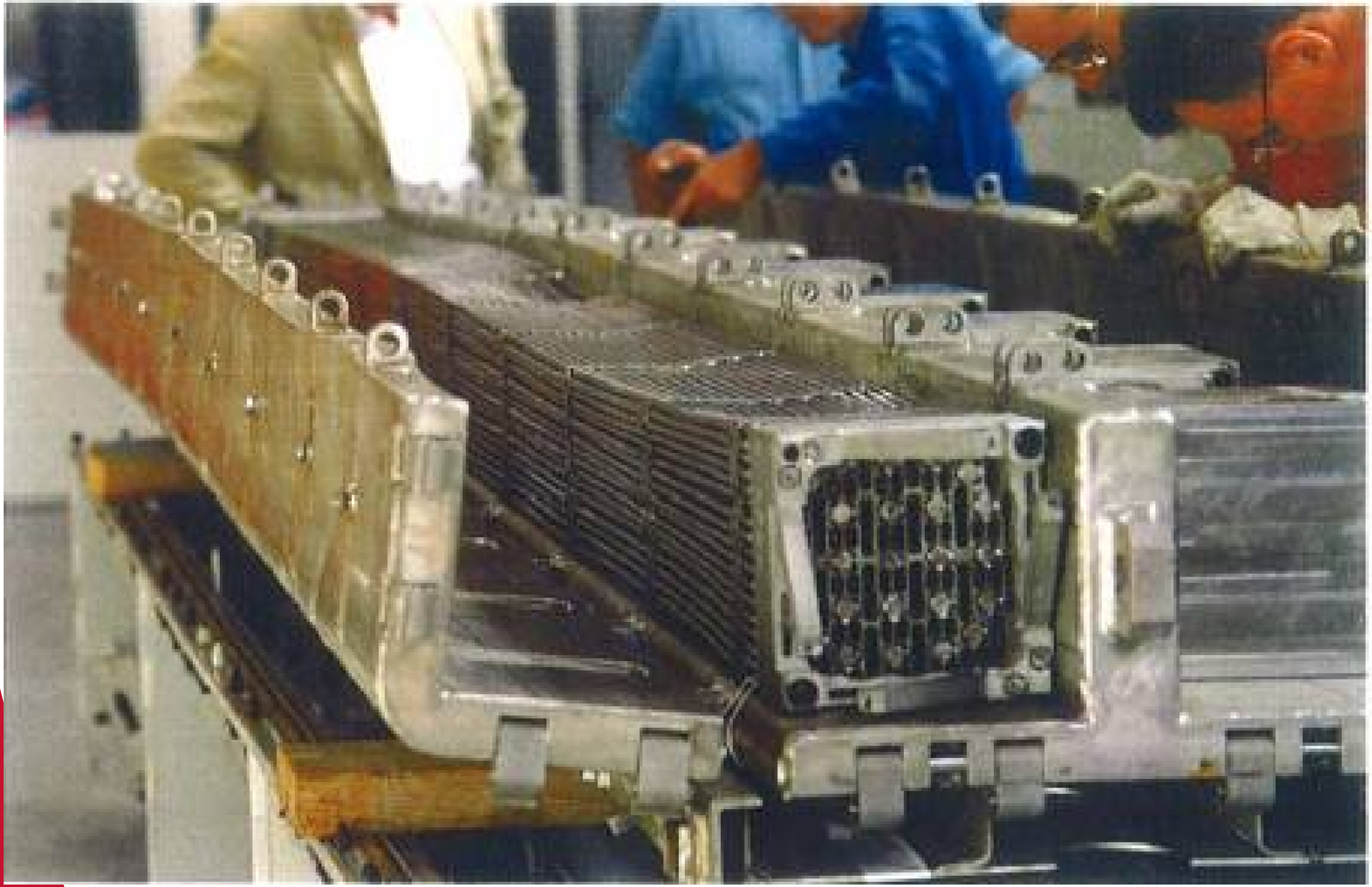
DROP N°

- 23.09.98

FCC4 9m drop test

- Container no longer cylindrical at the two ends
- All shells connecting bolts still in place
- Indentation of the upper shell
- Support frame and craddle pulled apart, but internal system still supporting the neutronic cavity
- 30 mm (1.2'') bowing of the frame-door assembly

FCC4 mechanical test



FCC4 Mechanical tests

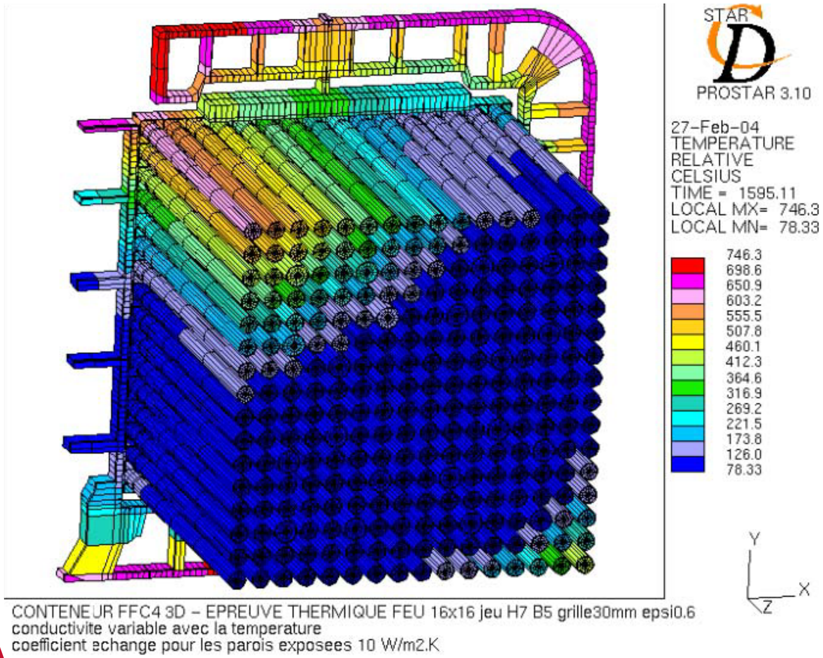
- Conclusions of the FCC4 mechanical tests:
  - Two shells still connected,
  - Impact limiters in place and undamaged,
  - Relative position and spacing between assemblies unchanged
  - Neutronic cavity fulfils its restraining function, geometry preserved,
  - Section of the cavity reduced overall, local maximum values bellow criticality assumptions
  - Resin thickness and characteristics unchanged
- Additional conclusions from FCC3 vertical drop test:
  - Two shells still connected
  - Impact limiters crushed from 165mm -> 89 mm (6.5'' -> 3.5'')
  - Internal housing end plates still in places
  - A few rods pins slid between nozzle and housing
- <u>No rod failure</u>: check for contamination research carried out with negative results

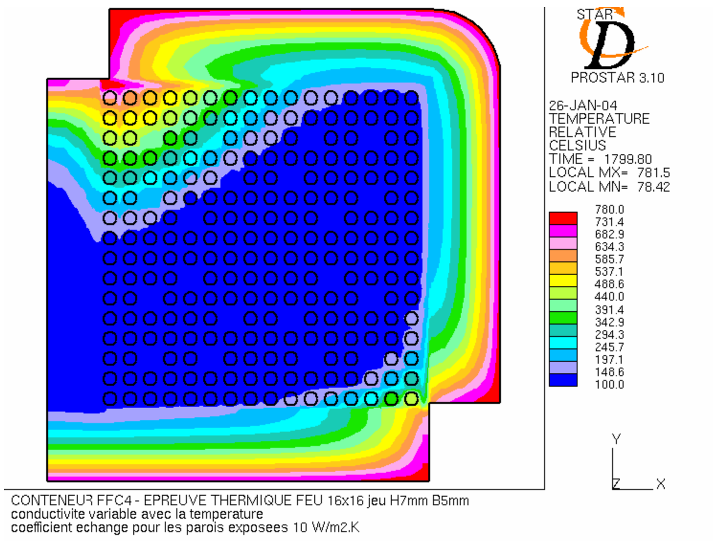
FCC4 Thermal test

- Package exposed to a thermal environment of 800 °C (1472 °F) during 30 minutes
- THERMAL TEST : analytical evaluation
  - Determination of rods temperatures using STAR CD code
  - Thermo-mechanical behavior of the rods under [Pressure;Temperature] increase
- Assumptions
  - Sun exposure during 24 hrs: initial temp. 70°C (158°F)
  - Flames directly applied on the outer skin of the housing [doors-Tframe]
  - Gap between doors and TFrame: max. local gap measured after drop tests, applied on the whole length

FCC4 Thermal test

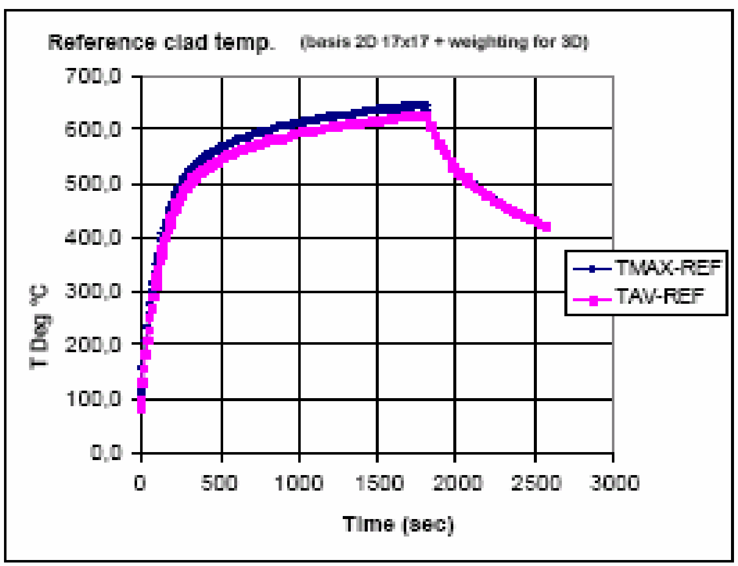
- THERMAL EVALUATION : modeling
  - 3D model for a section of the package as reference
  - 2D modeling for parametric study

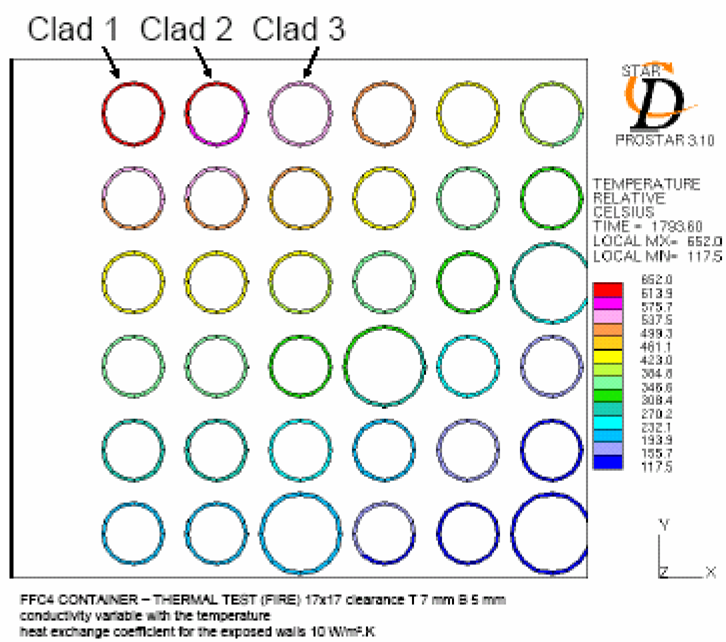




FCC4 Thermal test

- THERMAL EVALUATION: modeling
- Thermal results are driven by the convection of air inside the cavity
  - Higher temperatures are local
  - cooling is quick
  - Max. temp. fuel column (average) = 627 °C (1160°F)
  - (local) = 647 °C (1196°F)
  - Max. obtained at the end, in front of the void volume (top of fuel assembly)





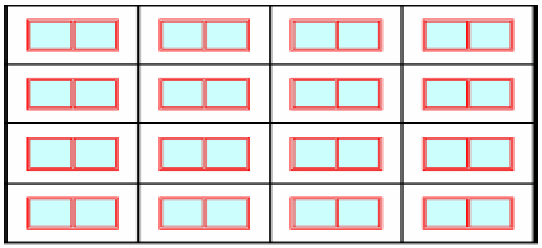
FCC4 Thermal test

- Calculation of cumulated strain under Pressure-Temperature increase, for clad 1(void volume):
  - < elongation limit
- Conclusion
  - No rods failure

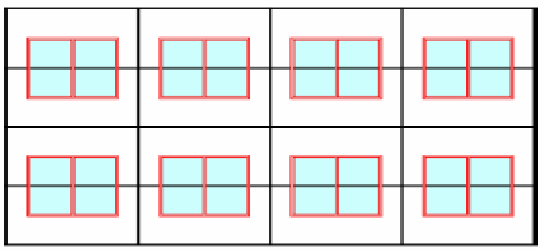
FCC4 - Criticality safety analysis

- Safety limits (Keff < 0.95) met for normal and accidental conditions using CRISTAL calculational tool
- Geometry Assumptions After Drop and Thermal Tests:
  - Cross section of the assembly expanded on 1 third of its length,
  - Crushing of the shell to a reduce section
  - Resin burnt (results of a fire test on a resin sample)
  - Differential flooding
- Safety case:
  - Keff = 0.943 under ACT, for 17x17 14’ fuel assemblies,
  - Including an uncertainty of 682 pcm (CRISTAL calculations for the present study)
  - N=80, CSI = 0.63
- New Analysis done for 25% poison reduction = smaller array

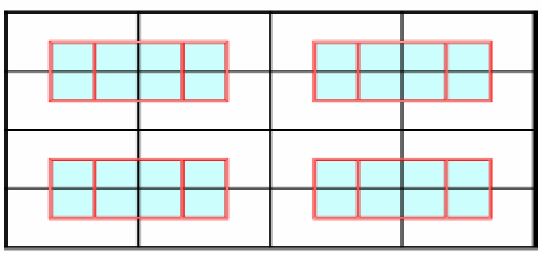
FCC4 Criticality – Accidental conditions of transport



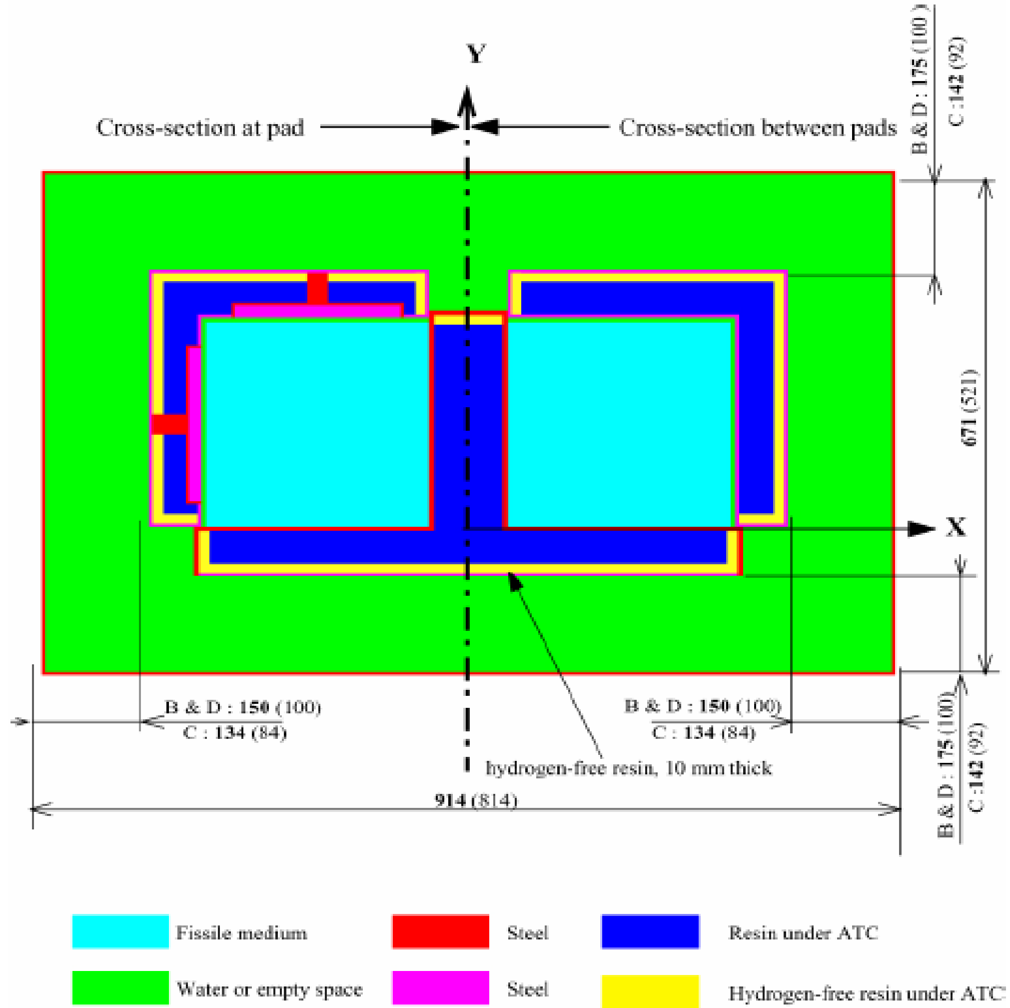
Case 1: Cavities centred in the shell (normal configuration)



Case 2: Cavities vertically off-centre (forming groups of 2)



Case 3: Cavities vertically and laterally off-centre (forming groups of 4)



B: 15x15 & 17x17 - C: 16x16 & 18x18 - D: 17x17 XL

NB: the two colours of steel have the same chemical medium Dimensions stated in mm
The dimensions are stated relative to the inside of the 3-mm thick shell

Status of FCC4 certificates

- Licensed in France (2010), Belgium for road, rail and sea shipment
  - For fuel assemblies and rod boxes
- Validation in Germany
- FCC4 design is similar to FCC3:
  - FCC3 currently validated in Sweden, UK, South Africa, Netherland
  - FCC4 may undergo same validations due to need of deliveries

FCC4 – Adaptation to EPR

- Changes Currently Being Evaluated:
  - To eliminate carbon steel → to adopt stainless steel
  - To remove balsa material → foam
  - To allow transport of RCCA inserted in fuel assemblies → modification of the top plate
  - To design a new stowing/lifting system
  - Options:
    - To modify external shells shape