RAS 7119

December 2, 2003

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

DOCKETED
USNRC

December 5, 2003 (11:25AM)

OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF

In the Matter of

DUKE ENERGY CORPORATION

(Catawba Nuclear Station, Units 1 and 2)

Docket No's. 50-413-OLA,
50-414-OLA

**BLUE RIDGE ENVIRONMENTAL DEFENSE LEAGUE'S SECOND SUPPLEMENTAL PETITION TO INTERVENE**

## I. INTRODUCTION

Pursuant to 10 C.F.R. § 2.714, Blue Ridge Environmental Defense League ("BREDL") hereby amends its Supplemental Petition to Intervene to set forth late-filed Contentions 10, 11, 12, regarding Duke Energy Corporation's ("Duke's) application for a license amendment to allow the use of plutonium Mixed Oxide ("MOX") Lead Test Assemblies ("LTAs") at the Catawba nuclear power plant. Letter from M.S. Tuckman, Duke Power, to U.S. NRC, re: Proposed Amendments to the Facility Operating License and Technical Specifications to Allow Insertion of Mixed Oxide (MOX) Fuel Lead Assemblies and Request for Exemption from Certain Regulations in 10 CFR Part 50 (February 27, 2003) (hereinafter "License Amendment Application").

This Second Supplemental Petition to Intervene amends Blue Ridge Environmental Defense League's Supplemental Petition to Intervene (October 21, 2003) (hereinafter "First Supplemental Petition to Intervene").

Contentions 10 and 11 assert that Duke has failed to address the implications of plutonium MOX fuel characteristics on its analyses of design basis accidents and severe

Template = SECY-037

SECY-02

accidents. Contention 12 asserts that the implications of plutonium MOX fuel characteristics should be considered in the Environmental Report. Contention 13 asserts that environmental analyses prepared by the U.S. Department of Energy ("DOE") with respect to the impacts of shipping plutonium to France and back are inadequate because they fail to consider the new information and significantly changed circumstances in the aftermath of the terrorist attacks of September 11, 2001. The contentions are supported by the attached Declaration of Dr. Edwin S. Lyman In Support of BREDL Contentions 10 Through 13 (December 1, 2003).

As discussed below in Section III, these contentions satisfy a balancing of the NRC's late-filing criteria.

## II. CONTENTIONS

The late-filed contentions fall into two categories: safety issues under the Atomic Energy Act and its implementing regulations, and environmental issues under the National Environmental Policy Act. The numbering of the contentions follows consecutively on the numbering of the contentions submitted by BREDL in its initial hearing request.

### A. Safety Issues Under Atomic Energy Act And Implementing Regulations

**Contention 10: Failure to account for uncertainties in MOX fuel assembly behavior during Loss of Coolant Accidents.**

Duke's safety analysis for design-basis loss-of-coolant accidents ("LOCAs") in Section 3.7 of the LTA license amendment application is inadequate, because it fails to account for uncertainties in the technical understanding of the behavior of MOX fuel

during LOCAs that may lead to significant deviations from low-enriched uranium ("LEU") fuel behavior.

**Basis:** In Section 3.7.1, Duke presents a deterministic analysis of the impacts of MOX fuel lead assemblies on LOCA analyses. According to Section 3.7.1, "MOX fuel phenomena that have the potential to affect LOCA results are addressed in Section 3.7.1.1." *Id.* at 3-20. The discussion in Section 3.7.1.1, however, does not include consideration of the fact that the experimental database for MOX fuel performance during LOCAs is woefully inadequate. As a result, there are uncertainties in aspects of MOX fuel behavior that may have a significant impact on Duke's LOCA analysis for the Catawba core with four plutonium MOX LTAs.

In a recent presentation to NRC staff, officials from the French safety authority Institut de Radioprotection et de Sûreté Nucléaire ("IRSN") proposed a series of tests at the Phébus experimental reactor to close gaps in the experimental database for both MOX fuel and high-burnup LEU. *See* slides presented by A. Mailliat and J.C. Mélis, IRSN, at "PHEBUS STLOC Meeting" with NRC Staff (October 23, 2003).[1] A copy of a printout of the slides is attached. The fact that French safety authorities believe that these tests are necessary is highly significant, given NRC's dependence on foreign MOX data (or lack thereof) in evaluating MOX-related submittals.

The IRSN presentation points out that plutonium MOX fuel relocation has been observed at a lower temperature than LEU fuel relocation (stated at the meeting to be 200°C -300°C lower), i.e., that during a LOCA, the MOX fuel pellet column collapses into the lower part of the fuel rod sooner than LEU fuel. *Id.* at 6. This would increase

[1] These slides are available on NRC's ADAMS system. The Accession Number is ML032970642.

power and negatively affect heat transfer, with a deleterious impact on important LOCA parameters. These parameters include increases in peak clad temperature (PCT) (stated at the meeting to be 100°C higher), clad oxidation (stated at the meeting to be a 5%-10% increase in the oxide layer) and clad hydrogen uptake. IRSN further pointed out that "this question is particularly important for end-of-life MOX fuel where power generation is not reduced, unlike for U02 fuel." *Id.* at 21.

The IRSN presentation further points out that modern, low-tin, high ductility cladding materials, such as the M5 cladding that will be used in the MOX LTAs, will form bigger "balloons" than conventional Zircaloy and are likely to have higher blockage ratios. *Id.* at 24-25. This effect, combined with MOX-specific behavior, cannot be fully assessed in the absence of the integral LOCA MOX fuel-bundle tests that IRSN is proposing. Thus there is insufficient information to provide confidence that the MOX LTAs will not cause coolant blockage during a LOCA that could lead to an unacceptable loss of core coolable geometry and an uncontrolled core melt.

Because of these unknowns regarding the behavior of MOX fuel during a LOCA, Duke lacks a factual basis for assuring that the existing emergency core cooling systems at Catawba will meet the acceptance criteria in 10 CFR 50.46. Accordingly, the application should be denied.

**Contention 11: Failure to consider uncertainties in MOX fuel assembly behavior on the probabilities and consequences of severe accidents.**

Duke's analysis of the impact of the plutonium MOX LTAs on the probabilities and consequences of severe accidents is inadequate, because it fails to account for uncertainties in the technical understanding of the behavior of MOX fuel during severe

accidents that may lead to significant deviations from low-enriched uranium ("LEU") fuel behavior.

**Basis:** In Section 3.8 of the license amendment application, Duke asserts the following:

> Duke uses probabilistic risk assessment (PRA) analyses to evaluate the risk to public health and safety due to operation of its nuclear plants. PRA analyses quantify the probability and consequences of severe accidents that involve core melt and containment failure events. Key considerations in PRA analyses are equipment requirements to prevent core melt (success criteria); ice melt times, containment pressurization rates, and potential containment failures (containment performance); and doses to the public (offsite consequences). The attributes of MOX fuel that impact these areas are fundamentally similar to uranium fuel . . .

*Id.* at 3-36. The discussion in Section 3.8, however, does not include consideration of the fact that the experimental database for MOX fuel performance during severe accidents is woefully inadequate. As a result, there are uncertainties in aspects of MOX fuel behavior that may have a significant impact on Duke's risk analysis for the Catawba core with four plutonium MOX LTAs.

Another part of the IRSN Phébus proposal presented to NRC at the October 23 meeting was a plan to address uncertainties in the behavior of MOX fuel during severe accidents. *Id.* at 6. Phenomena that could affect the probabilities of severe accidents include the poorer performance of MOX fuel during a LOCA compared to LEU fuel, which could increase the chance that the accident cannot be mitigated, as discussed in the basis of Contention 10.[2] Phenomena that could affect the consequences of severe accidents include both higher release rates and higher release fractions for both fission

[2] The basis of Contention 10 is hereby adopted and incorporated by reference into this contention.

products and actinides compared to LEU, as a result of the MOX fuel microstructure and different oxidation potential. *Id.* at 6.

As discussed above, the use of plutonium MOX fuel at the Catawba nuclear plant appears to pose a risk that plant safety systems will not be adequate to stop a LOCA from progressing to a core melt. At a minimum, the different characteristics of MOX fuel and LEU raise substantial uncertainties with respect to the probabilities and consequences of severe accidents for the MOX LTA core. Because of the potential for a significant increase in severe accident risk, these uncertainties should be fully analyzed in Duke's MOX LTA license amendment request.

### B. Issues Under National Environmental Policy Act

**Contention 12: Failure to consider effects of plutonium MOX fuel characteristics on severe accident potential.**

**Basis:** As discussed above in Contentions 10 and 11, plutonium MOX fuel has characteristics that may affect the potential for and consequences of a LOCA or severe accident. The bases of these contentions are hereby adopted and incorporated by reference into this contention.

In Section 5.6.3.1 of its Environmental Report, Duke addresses the environmental impacts of design basis accidents. License Amendment Application at 5-8. In Section 5.6.3.2, Duke addresses the environmental impacts of severe accidents. *Id.* at 5-8 – 5-9. Neither section discusses the susceptibility of plutonium MOX fuel to slumping during a LOCA or the adverse effect that slumped fuel may have on the ability of the safety injection system to cool the entire core. The Environmental Report should address the

significance of these characteristics with respect to the potential for and consequences of a design basis accident or severe accident.

**Contention 13: Failure to adequately address environmental impacts of plutonium shipments**[3]

Duke's license amendment application must be rejected because it is not supported by an adequate analysis of the security-related environmental impacts of shipping plutonium oxide to France, or the security-related impacts of shipping the LTAs from France back to the United States.[4]

**Basis:** In Sections 5.3.2 and 5.3.4 of the license amendment application, Duke concedes that shipment of polished PuO2 powder to France, and the return shipment of MOX fuel lead assemblies to the United States, are related actions whose environmental impacts must be considered. *Id.* at 5-3. Rather than providing such an analysis, Duke states that the analysis will be prepared by the DOE. *Id.* at 5-3. BREDL's Contention 8 challenged Duke's failure to address these impacts. *See* Petition to Intervene at 15.

In its November 11, 2003, response to Contention 8, Duke asserted that the DOE has "addressed the transportation question" in two documents: the 1996 Programmatic Environmental Impact Statement for Storage and Disposition of Weapons-Usable Fissile Materials (DOE/ES-229) (hereinafter "Storage and Disposition PEIS"); and DOE's

---

[3] This contention is presented as a substitute for Contention 8, which is hereby withdrawn. *See* First Supplemental Petition to Intervene at 15.

[4] BREDL recognizes that it is NRC policy not to address the environmental impacts of terrorist attacks, sabotage, or other acts or malice or insanity in its Environmental Impact Statements. *See, e.g., Pacific Gas & Electric Co.* (Diablo Canyon Nuclear Power Plant, Independent Spent Fuel Storage Installation), CLI-03-01, 57 NRC 1 (2003). BREDL submits that the instant circumstances are distinct, in that the DOE and not NRC is responsible for the EIS for disposition of plutonium, and DOE has affirmatively decided to address the environmental impacts of terrorist attacks. Having undertaken to evaluate these impacts, DOE is subject to review for the reasonableness of its analysis.

November 2003 Supplemental Analysis, Fabrication of Mixed Oxide Fuel Lead Assemblies in Europe (DOE/EIS-0229-SA3) (hereinafter "Supplemental Analysis").[5]

For a number of reasons, the 1996 Storage and the Supplemental Analysis are completely inadequate to support the shipment of plutonium to and from France. First, the Supplemental Analysis does not address the existence of significantly changed circumstances since 1996, which cast grave doubt on the wisdom of overseas plutonium shipments. The 1996 Storage and Disposition PEIS predates the terrorist attacks of September 11, 2001, on the World Trade Center and the Pentagon. The September 11, 2001, attacks graphically demonstrated that the potential for terrorist attacks on U.S. facilities is far greater and more lethal than previously thought. Moreover, the measures that have been taken in response represent a sea change in the way the U.S. government views the threat of terrorist attacks and the importance of measures to address it. The federal government has reorganized and devoted enormous amounts of resources to identifying vulnerabilities in nuclear facilities and protecting against the terrorist threat. The NRC has also upgraded the licenses of every operating nuclear power plant and Category I facility in the United States to provide improved security measures.[6] As summarized by then-Chairman Richard Meserve, security has become a "central concern" in the aftermath of these attacks, posing a significant challenge to the federal

[5] Duke served the Supplemental Analysis on the ASLB and parties by Federal Express on November 10, 2003. Duke also included a copy of DOE's Amended Record of Decision, also issued in November 2003. The Amended Record of Decision was published in the Federal Register on November 14, 2003, at 68 Fed. Reg. 64,611.

[6] *See* Orders for Modification of Licenses of All Operating Power Reactor Licensees, EA-03-086, 68 Fed. Reg. 24,517 (May 7, 2003); Order Modifying License to Nuclear Fuel Services, Inc., Docket No. 70-143, License No. SNM-124, EA 02-087, 68 Fed. Reg. 26,676 (May 16, 2003).

government. Speech by Dr. Richard A. Meserve at INFOCASE Conference (September 11, 2002).[7]

Without any doubt, the events of September 11, 2001, the lessons learned from them, and the federal government's response to those events, constitute the type of "significant new circumstances or information" that warrant revision and republication of the 1996 and 1999 draft EISs for public comment. *Marsh v. Oregon Natural Resources Council,* 490 U.S. 360, 374 (1989). *See also Warm Springs Dam Task Force v. Gribble,* 621 F.2d 1017, 1023-24 (9th Cir. 1980); *Friends of the Clearwater v. Dombeck,* 222 F.3d 552, 558 (9th Cir. 2000).

There are a number of alternatives and mitigative measures that demand serious consideration in a newly issued EIS regarding disposition of weapons-grade materials. First, should the risk be mitigated by upgrading the outdated international standard for protection of plutonium under export licenses? Second, how can the potential for terrorist attacks be re-evaluated in light of what we now know about the motives and practices of terrorists? Third, how might the consequences of such attacks be affected by deliberate attempts to exacerbate the adverse effects of a plutonium release, for instance by causing a fire or explosion sufficient to reduce plutonium particles to an extremely fine size? It is woefully insufficient to merely cross-reference the DOE's discussion of accident impacts in the 1996 Storage and Disposition PEIS and 1999 SPDEIS.

Finally, the new information and changed circumstances that have come about since September 11, 2001, unequivocally call for reconsideration of the option of postponing fabrication of the plutonium MOX LTAs until the proposed MOX fabrication

[7] The speech is available on the NRC's website.

facility at the Savannah River Site is built. At the time the 1996 Storage and Disposition PEIS was prepared, the DOE did not give serious consideration to this alternative because it would delay the use of plutonium MOX fuel in nuclear plants. *See* Record of Decision for the Surplus Plutonium Disposition Final Environmental Impact Statement, 65 Fed. Reg. 1,608, 1,612 (January 11, 2000) (explaining that LTA fabrication at Los Alamos National Laboratory is the "preferred alterative" because infrastructure already exists). DOE's concerns about timeliness must now be balanced against the new concerns that have arisen since September 11, 2001, over the risks of (a) sending plutonium across the ocean in vessels with questionable security measures, (b) to a country whose measures for safeguarding the plutonium are shrouded in secrecy, (c) under international security standards that are grossly outdated. Moreover, anticipated delays in carrying out the parallel U.S.-Russian MOX programs reduce any pressure on DOE to have the MOX LTAs manufactured in Europe on a rapid timeline.[8]

Accordingly, these issues must be addressed in a new EIS for the disposition of weapons grade fissile material. Moreover, the EIS must be published in draft form, so that members of the public can be involved in the decision-making process.

## II. THESE CONTENTIONS SATISFY A BALANCING OF THE NRC'S LATE-FILING CRITERIA.

These contentions satisfy a balancing of the NRC's late-filing criteria in 10 C.F.R. § (a)(1)(i)-(v). First, BREDL has good cause for filing late. Contentions 10, 11, and 12

[8] "Obstacles" that threaten to impede the international MOX program include inadequacy of funding for the Russiann program, expiration of the 1998 U.S. Russian agreement on technical cooperation for the plutonium disposition (including liability protection programs), and U.S. concerns over possible Russian support for the Iranian nuclear program. *See* Answer of Duke Energy Corporation to the "Blue Ridge Environmental Defense League's Supplemental Petition to Intervene" Etc. at 32-33 (November 11, 2003).

are based on a slide presentation that was made at a meeting between IRSN and the NRC Staff on October 23, 2003. The slides were not available at the meeting, and were not placed in the NRC's CITRIX system until November 4, 2003.[9] Contention 13 is based on the DOE's Supplemental Analysis, which was not provided to BREDL until November 11, 2003. Therefore, all the contentions are being filed within 30 days of receipt of the documents on which they are based.

BREDL also satisfies the other four elements of the late-filing standard. Aside from this proceeding, BREDL has no means ofr protecting its interest in ensuring that the testing of plutonium MOX lead test assemblies is conducted in a manner that adequately protects health and safety and complies with the environmental safeguards of NEPA. In addition, BREDL's participation in the proceeding may reasonably be expected to assist in the development of a sound record. BREDL will be presenting the views of Dr. Lyman, a highly qualified expert who has extensive experience regarding nuclear power plant safety, environmental and security analyses. Moreover, there are no other parties who can represent BREDL's interests in this proceeding. Finally, while granting a hearing on BREDL's supplemental contentions may broaden the proceeding somewhat, these effects will not be unreasonable, given that the contentions are being filed early in the proceeding. Accordingly, a balancing of the late-filing factors favors the admission of the contentions.

## IV. CONCLUSION

For the foregoing reasons, the ASLB should admit Contentions 10 through 13.

---

[9] Undersigned counsel for BREDL recently discovered that the slides were not put on NRC's ADAMS document retrieval system at all. At our request, the slides have been put on ADAMS. The Accession Number is ML032970642.

Respectfully submitted,

Diane Curran
Harmon, Curran, Spielberg, & Eisenberg, L.L.P.
1726 M Street N.W., Suite 600
Washington, D.C. 20036
202/328-3500
e-mail: dcurran@harmoncurran.com

December 2, 2003

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

| | |
|---|---|
| In the Matter of | |
| DUKE ENERGY CORPORATION | Docket No's. 50-413-OLA, 50-414-OLA |
| (McGuire Nuclear Station, Units 1 and 2, Catawba Nuclear Station, Units 1 and 2) | |

**DECLARATION OF DR. EDWIN S. LYMAN**
***IN SUPPORT OF BREDL CONTENTIONS 10 THROUGH 13***

Under penalty of perjury, Edwin S. Lyman declares as follows:

1. My name is Edwin S. Lyman. I am a Senior Staff Scientist at the Union of Concerned Scientists.

2. On October 21, 2003, I submitted a declaration in this proceeding which set forth my professional qualifications in this matter.

3. I am familiar with the licensing-related filings and correspondence that have been submitted by Duke Energy Corporation in support of its application for a license amendment to use lead test assemblies of mixed oxide fuel at the Catawba nuclear power plant. I am also familiar with the environmental impact statements and other analyses prepared by the U.S. Department of Energy ("DOE") with respect to disposition of plutonium and other weapons-grade fissile materials. In addition, I am familiar with regulations and guidance of the U.S. Nuclear Regulatory Commission ("NRC") and the DOE governing plutonium processing facilities. I am also familiar with the requirements of the National Environmental Policy Act.

4. I assisted BREDL with the preparation of Contentions 10 through 13, regarding deficiencies in Duke's license amendment application and the DOE's environmental analyses. The factual assertions in those contentions are true and correct to the best of my knowledge and belief, and the opinions expressed therein are based on my best professional judgment.

5. If any of BREDL's contentions, including 10 through 13, are admitted, I plan to submit expert testimony regarding those contentions.

Edwin S. Lyman, Ph.D.

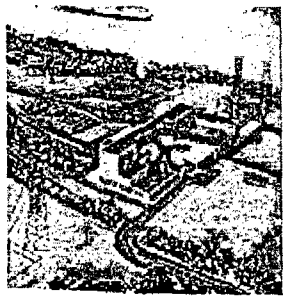
December 2, 2003

# IRSN
# Source Term Loca
# PROGRAM
# IN
# THE PHEBUS FACILITY

**Part 1 : The Safety Context**
**Part 2 : Source Term Part**
**Part 3 : The LOCA Part**

**A. Mailliat, J.C Mélis**

IRSN



## Evolution of the Market

***The production and distribution of electric power experience a dual evolution***

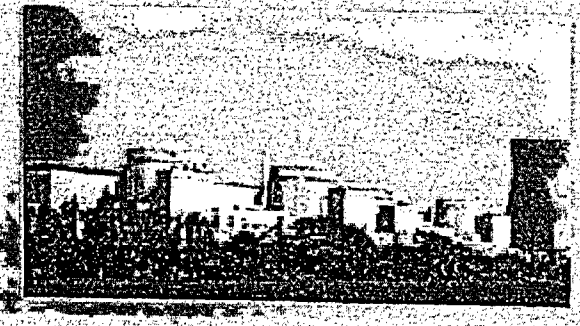
✓ Constructions and commissioning of nuclear power plants come to very low levels.

✓ Liberalisation and deregulation induce competition between operators on domestic and international markets.

***The answer : utilities enhance the effectiveness of their facilities.***

## Evolution of the Reactors

✓Increase in reactor power: from 900 MWe to 1,400 MWe
✓Increase in fuel burn-up: from 33 GWday/tU to 60 GWday/tU
✓Introduction of new types of fuel - from UO2 to MOX
✓Introduction of new cladding and control rods
✓Fuel cycle lengthening from 1 year up to 1,5 or even 2 years
✓U5 enrichment increases, poison additions, etc -



## Formerly : Wide Margins

Nuclear safety models were designed with wide margins in order to cope with uncertainties both in the data base and the accident phenomenology knowledge.

Conservative scenarios were taken as a basis for regulation and standard setting.

## Now : a Permanent Adjustment

***A permanent need to reassess reactor safety studies***

- ✓ Due to continuous demands on plant and core operations
- ✓ The increasing tendency of the operators to use best estimate codes and more realistic conditions for accident analyse
- ✓ probabilistic safety studies and source term evaluations are being refined and call for reducing uncertainties on the consequences of some specific accidental situations e.g Air Ingress, Core Quenching

***How much these margins are used by operators :***

- ✓ Are the criteria always appropriate ?
- ✓ Are the accident estimates always correct ?

## New Requirements

- ✓ data base extensions to broader conditions and materials
- ✓ But also an adequate quantification of the data base uncertainties for safety task uses

## Answer the future safety requests

***Taking advantage of existing information***
***By continuation of available tools***
***Optimising the efforts and the costs***

- **Updating and upgrading by continuation of the models**
  - Fuel behaviour, cladding properties, etc..
- **An optimized number of small-scale or semi-integral , out-of-pile or in-pile experiments**
  - Providing the additional data bases for model updating
- **A few integral in-pile experiments**
  - provide code assessments in terms of reactor applicability and simulation completeness.
  - Quantifying the calculation tool uncertainties and margins to criteria

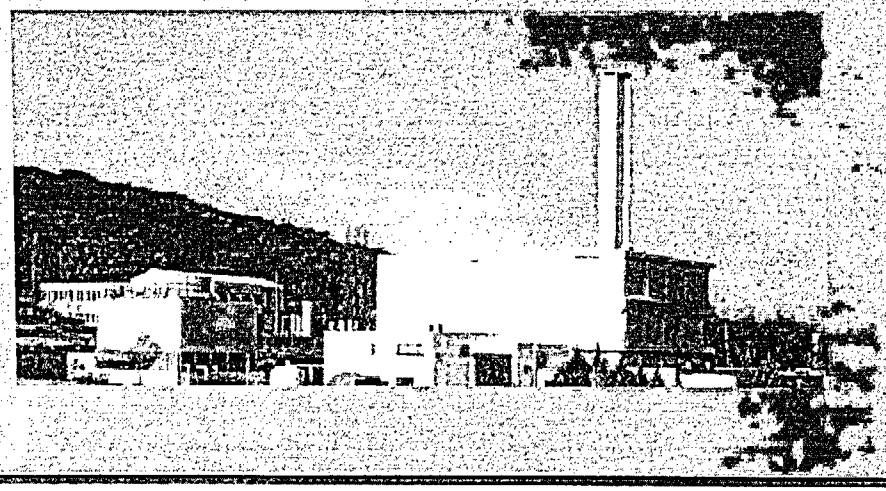
According to this context, IRSN is preparing Source Term Loca new program the PHEBUS facility,

- ***STL –LOCA Part*** devoted to Loss Of Coolant Accident (LOCA)
- ***STL –SourceTerm Part*** for Severe Accidents .

# Part 2

## Source Term Loca Program-*Source Term Part*

A. MAILLIAT
B. CLEMENT
J.C. MELIS

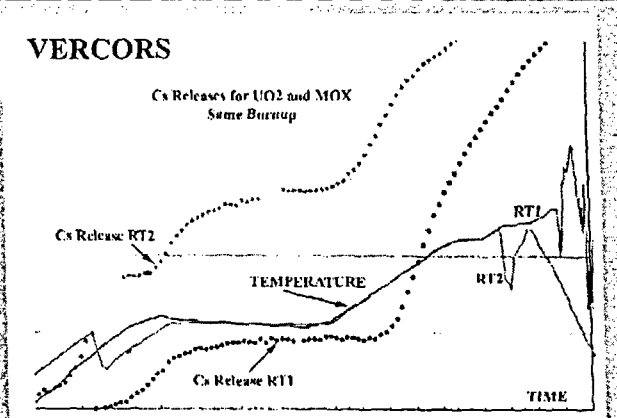


### CONTENT

- Severe Accident Pending Issues
- Rationale for Tests
- Source Term equipments

## Pending Questions :

### UO2 and MOX




**Release rates for MOX fuel , High Burnup UO2**

- ✓Fuel structure is different (RIM),
- ✓High burnup impacts fuel stoechiometry
- ✓Very high burnup in Pu rich clusters impacts on the FP distribution in the fuel phases
- ✓Pu-an U chemistries with regard to oxygen are different
- ✓FP release for observed earlier for MOX than for UO2 with the same Burnup
- ✓Low but significant release (<15%) of Nb, La, Eu, Mo, Ce, Np

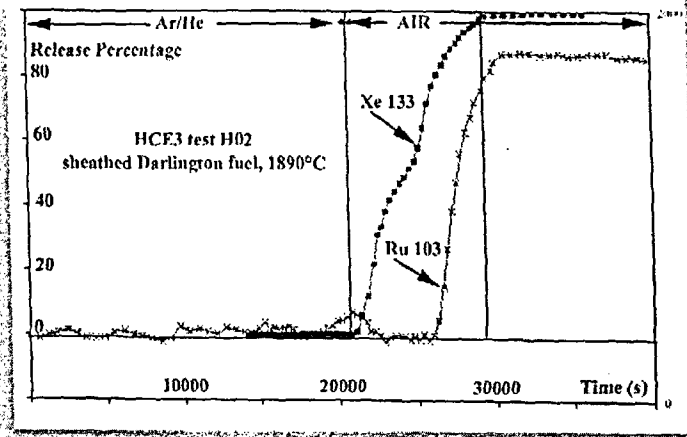
**Degradation process**

- ✓Possibly a different degradation process like the so called fuel foaming which might take place especially with high burnup fuel (400% swelling observed in ST1-2 tests in Sandia)
- ✓Mox fuel relocation was observed at a lower temperature than for UO2 (RT2 test)

**Representative Data Base are rather poor in terms of results for high BU an Mox**
**UO2 (BU in GWd/tU) : VI-4 (47), VERCORS 6 (60), HT1 (49,4) RT1 (47.3) VEGA 4 (47)**
**MOX (BU in GWd/tm) : RT2 (45,6), RT7(43)**

## Pending Questions :

### AIR




**The Zircaloy oxidation process is very violent**
**Degradation should be increased**

- ✓Zircaloy oxidation kinetics is faster than with steam
- ✓Energy generation with air (755kJ/mole-Zr ) is greater than with steam (459) from single rod tests Dressmann (Germany) and bundle tests CODEX (Hungary)

**Source term is modified**

- ✓Ru release is important
- ✓Ru and I can be revaporized when air is entering the primary circuit
- ✓Risk of RuO3 and RuO4 species in the containment in case of non equilibrium chemistry (Hot leg break)

## Pending Questions :

### QUENCHING

✓How much corium will be involved in the interaction with water ?
✓which are the reacting corium properties ?

✓How much steam and hydrogen are produced during the degradation process and especially during the core quenching ?

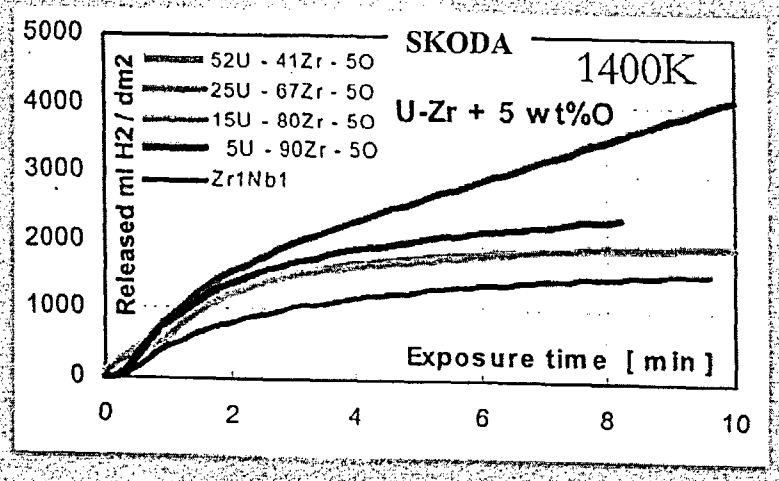
There is not much information (PBF-ST, LOFT-FP2, PHEBUS-SFD-B9R) available for representative conditions of a severe accident, even if some material is available from separate effect tests or electrically powered tests ( programmes CORA, QUENCH).

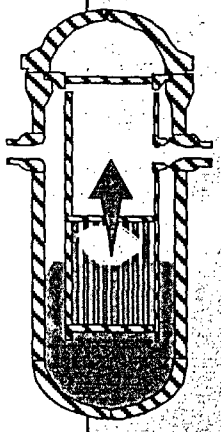
✓Are there any risk of a late pressurisation or steam explosion in the primary circuit ?
✓Induced containment bypass flow paths e.g SGTR due to primary circuit high pressure.

20-40 bars pressure peak observed in LOFT-LP-FP2 and TMI

None or very few information is available about
✓ Additionnal releases from fuel induced by temperature escalation or fuel fragmentation (some evidence from LOFT-LP-FP2),
✓ Re-entrainment of previously deposited materials in and above the core by large steam flow

To build valuable data bases, results are needed from experiments which will have to reproduce the physical mechanisms implied in the degradation and release processes with enough correctness.



Three points are essential to obtain such a correctness.

- Firstly, actual irradiated fuel (UO2 and MOx), with the appropriate burnup, is necessary.
- Secondly, for degradation correctness, the heat source to fuel has to be maintained despite its movements, melting and its metallurgical transformations.
- Finally, release rates and degradation mechanisms being so strongly related, they cannot be tackled separately.

# EQUIPMENT MAIN OPTIONS

Taking account the Phébus FP project experience, the main guide line for preparing this STLOC programmes and their associated equipment is to avoid any heavy decontamination operations which are time consuming and costly.

Such a constraint can be accommodated because the previously described objectives of the STLOC programmes do not require to investigate particular phenomena in the primary circuit (except the FP resuspension from core upper plenum) nor in the containment.

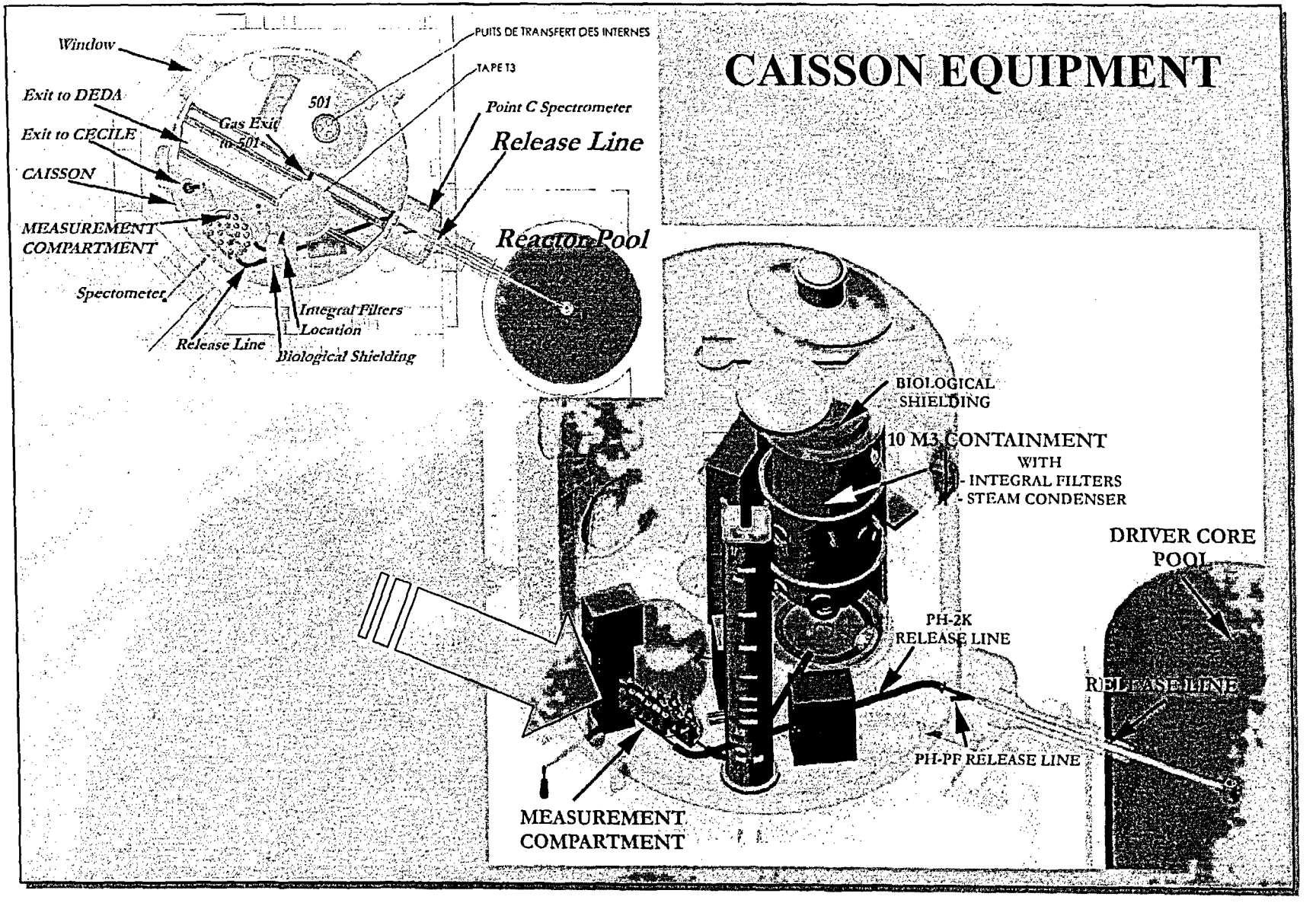
Therefore, the experimental equipment and instruments, by comparison with the Phébus-FP ones, can be

- reduced,
- simplified,
- designed in an integrated way.

# EQUIPMENT MAIN OPTIONS

- SIMPLIFIED CIRCUITS
  - NO MORE NEEDS FOR 700°C ON THE LINES
  - NO MORE NEEDS FOR ONE WEEK RE-IRRADIATION
  - NO MORE EXPERIMENTAL NEEDS IN THE CONTAINMENT
- A SIMPLIFIED SAMPLING STRATEGY
  - ONE SAMPLING LOCATION ABOVE THE BUNDLE IN THE TEST TRAIN
  - A SECOND SAMPLING LOCATION IN THE CAISSON INCLUDING ALL THE REQUIRED EXPERIMENTAL MEASUREMENTS
- DELAY AND COSTS
  - A REDUCED TIME GAP BETWEEN TESTS
  - A REDUCED INVESTMENT COST FOR EACH TEST

# CAISSON EQUIPMENT



# CAISSON EQUIPMENT

## MAIN ASPECTS OF THE MEASUREMENT COMPARTMENT

The measurement compartment (MC) is located in the caisson and includes all the experimental measurements.

The MC is included in a 150°C prototype furnace

The MC includes 16 sampling instruments with standardised connectors removable through remote operations

Each sampling instrument is equipped with commercial self sealing low pollution quick disconnect coupling

After sampling removals, sleeves replace the instruments and the decontamination is performed.

The MC can be transferred without any dismantling through the equipment lock T3

The STL-SoureTerm programme includes 2 MCs, one under preparation and calibration while the other one is under operation in the caisson for a test

# MEASUREMENT STRATEGY

Highlights on the measurement strategy for the STL-SourceTerm tests.

Fuel degradation measurements will be basically the same as for the Phébus-FP:

- ❑ A number of on-line sensors
- ❑ Sophisticated in-situ non destructive techniques (?-spectrometry, absorption and emission computed tomography).
- ❑ Detailed destructive examinations will also be performed.
- ❑ A special attention will be paid to measure transient hydrogen and steam productions during the core reflooding.

Realeases measurements will be performed through :

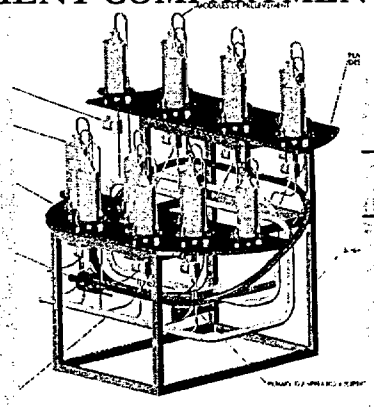
- ❑ Thermal gradient tubes, above the fuel, aiming at the determination of fission products deposition and re-entrainment during reflooding.
- ❑ The Measurement Compartment including a number of sequentially operated filters in order to measure both the transient and overall releases and impactors for aerosol particle sizing.

The basic technique will be ?-spectrometry, both on line and on the samples after their transfer to the CECILE hot cell.

For non-? emitters, chemical analyses will be performed to complete the experimental data base.

# MEASUREMENT STRATEGY

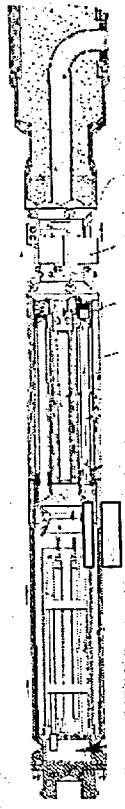
MEASUREMENT COMPARTMENT



ON LINE
- → GAMMA SPECTROMETRY

SEQUENTIAL
- → RELEASE RATE
- → RESUSPENTION RATE

POST TEST
- → GAMMA SPECTROMETRY
- → DESTRUCTIVE EXAMINATIONS
- → CHEMICAL ANALYSES



BUNDLE AND UPPER PLENUM

CONVENTIONAL
- → PRESSURE
- → TEMPERATURES
- → MASS FLOW RATES
- → POWER
- → HYDROGEN, STEAM CONTENTS

SEQUENTIAL
- → RELEASE RATE
- → DEPOSIT RATE
- → RESUSPENSION RATE

POST TEST
- → GAMMA Spec, TOMOGRAPHY
- → DESTRUCTIVE EXAMINATIONS
- → CHEMICAL ANALYSES

# Part 3

## Source Term Loca Program-*LOCA Part*

A. MAILLIAT
G. HACHE
C. GRANDJEAN
B. CLEMENT
J.C. MELIS
J. PAPIN

### CONTENT

- Rationale for LOCA Safety
- Pending Issues
- Rationale for LOCA Researches
- IRSN Future Programme

## Design Basis Accident : BASIC REQUIREMENT

*After any LOCA transient a core geometry which preserve its coolability must be guaranteed*

*It means* :

- → Shattering of the fuel rods has to be avoided
- → Core coolability has to be maintained

Application of these basic requirements imposes two different actions

To derive Criteria

Check that Criteria are not violated for reactor LOCAs

## TO DERIVE CRITERIA

*It means* : to know the quantities which control the cladding residual ductility back to cold conditions and core coolability, the values not to exceed.

Such information e.g. is the famous criteria 1 and 2 on Peak Clad Temperature (PCT) and Equivalent Clad Reacted (ECR)

## TO CHECK THAT CRITERIA ARE NOT VIOLATED FOR REACTOR LOCAs

*It means* : To demonstrate, through calculations tools, that whatever is the kind of LOCA transient, nowhere in the core, the criteria values are exceeded

For providing such correct estimates we are facing two main needs in terms of models

- Models for thermal and mechanical behaviours of the fuel rods in the reactor geometry during LOCA transients
- Models for thermal-hydraulic behaviour of the coolant during LOCA transients

In the context of a permanent need to reassess reactor safety studies imposes by reactor evolution, new types of fuel and cladding, increase of burnup ... IRSN is revisiting LOCA studies to check

- The adequacy of criteria
- That criteria are not violated for Reactors
- The available margins

On the next slides we will explore

- ☞ *the main pending issues which affect both criteria derivation and calculations correctness*

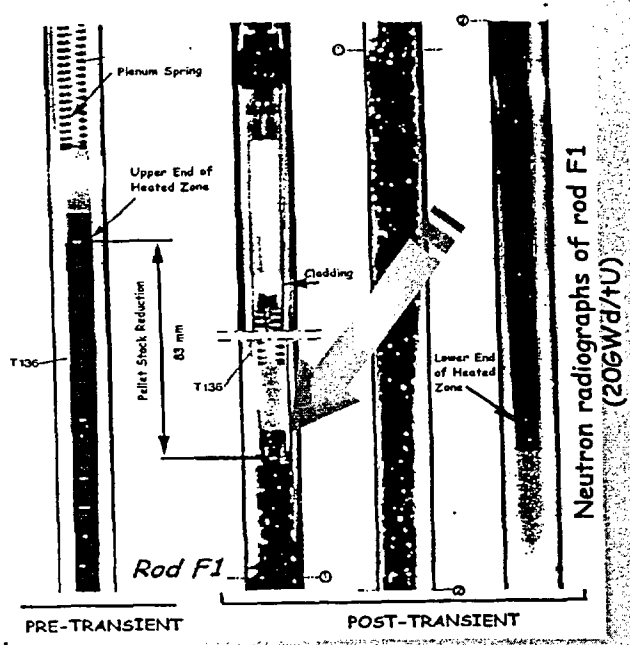
Then, from a comparison between the pending issues and the existing research programs

- ☞ *needs for additional researches will be deduced*

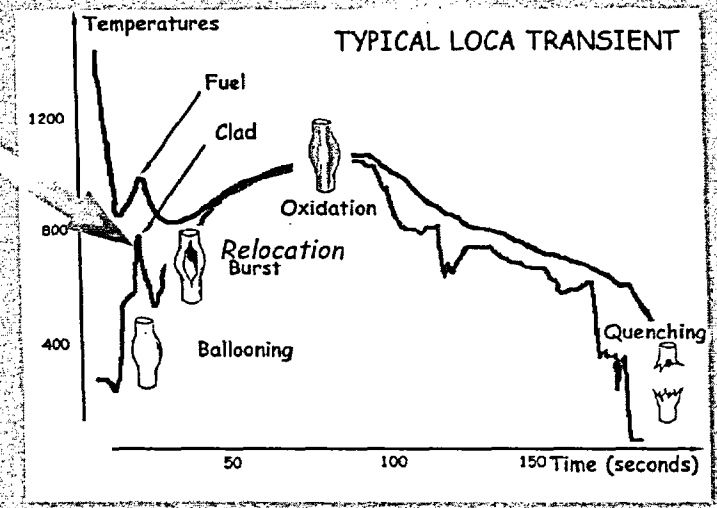
Finally,

- ☞ *IRSN STLOC program proposal regarding LOCA will be summarized*

## Pending Issues : Fuel Relocation




*See references 1 to 4




### Consequences

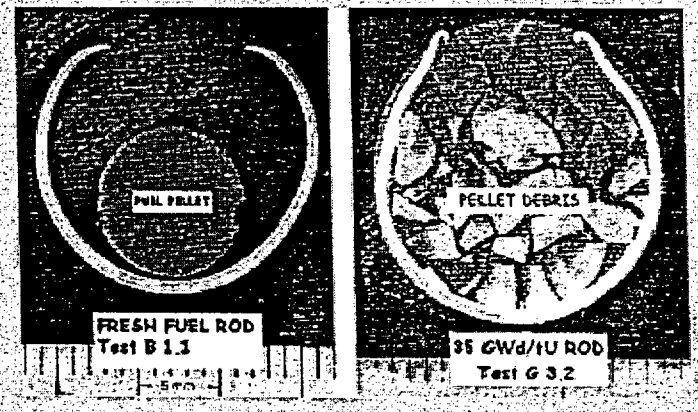
The increase of power
The heat transfer modification due to fuel accumulation
The steam access inside the balloon

### Impact on

Peak Clad Temperature
Final oxidation ratio and the consequences for quenching and post quench embrittlement
Hydrogen uptake and the consequences for quenching and post quench embrittlement

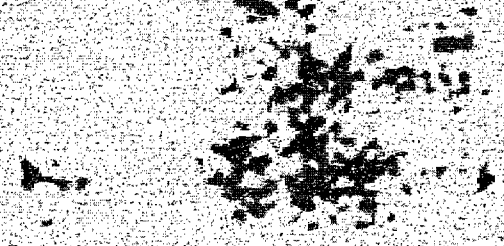
- Note that this question is particularly important for end-of-life MOX fuel where power generation is not reduced, unlike for UO2 fuel.

## Pending Issues : Fuel Relocation




*See references 1 to 4

- ✓ Instant of fuel movement at high burnup ?
- ✓ Are they any delay due to fuel-clad bonding ?
- ✓ Filling ratio of clad balloon at high burnup, with fragmentation of UO2 rim or MOX agglomerates ?
- ✓ Fragment sizes ?

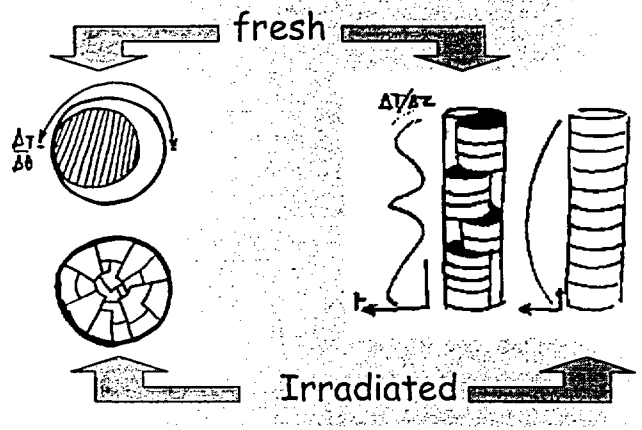


Pending Issues : **BUNDLE BLOCKAGE GEOMETRY**

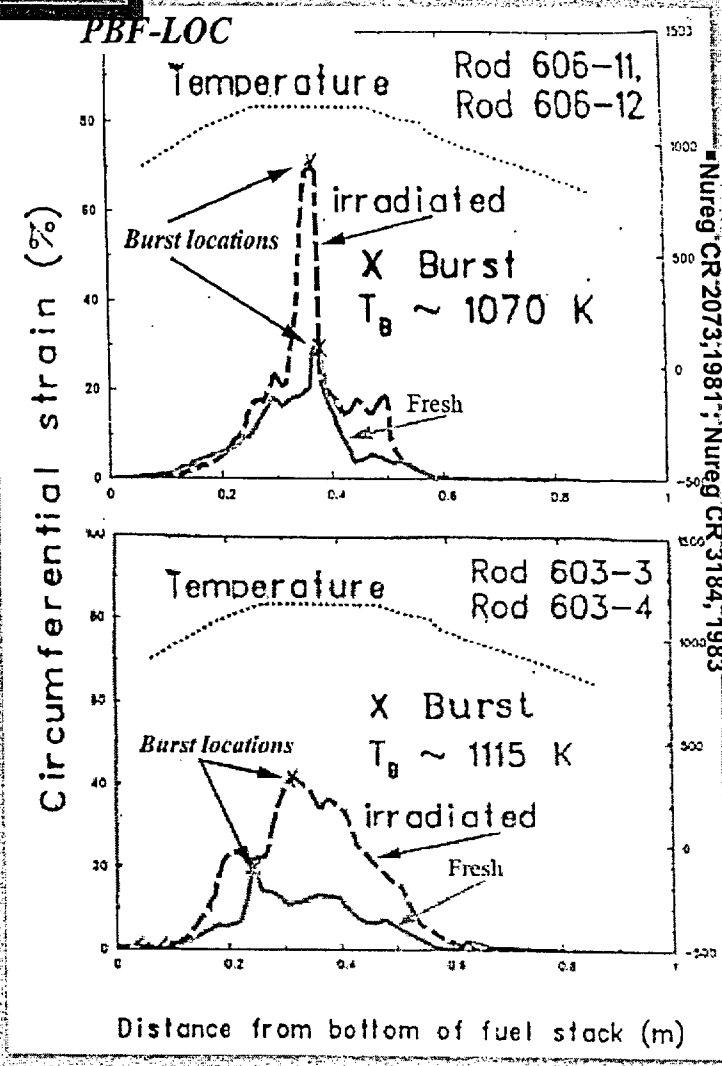
See references 4 to 6

**What is the bundle blockage geometry for irradiated bundles ?**

**Hot and cold points are less likely due to the fuel stack reorganisation during the irradiation.**




**Higher the symmetry bigger the balloons**



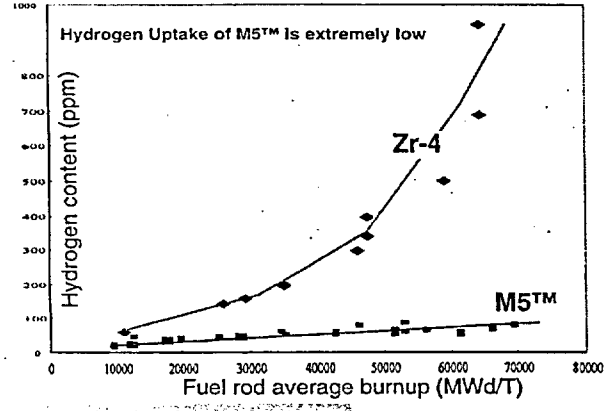

Nureg CR 2073;1981; Nureg CR 3184, 1983

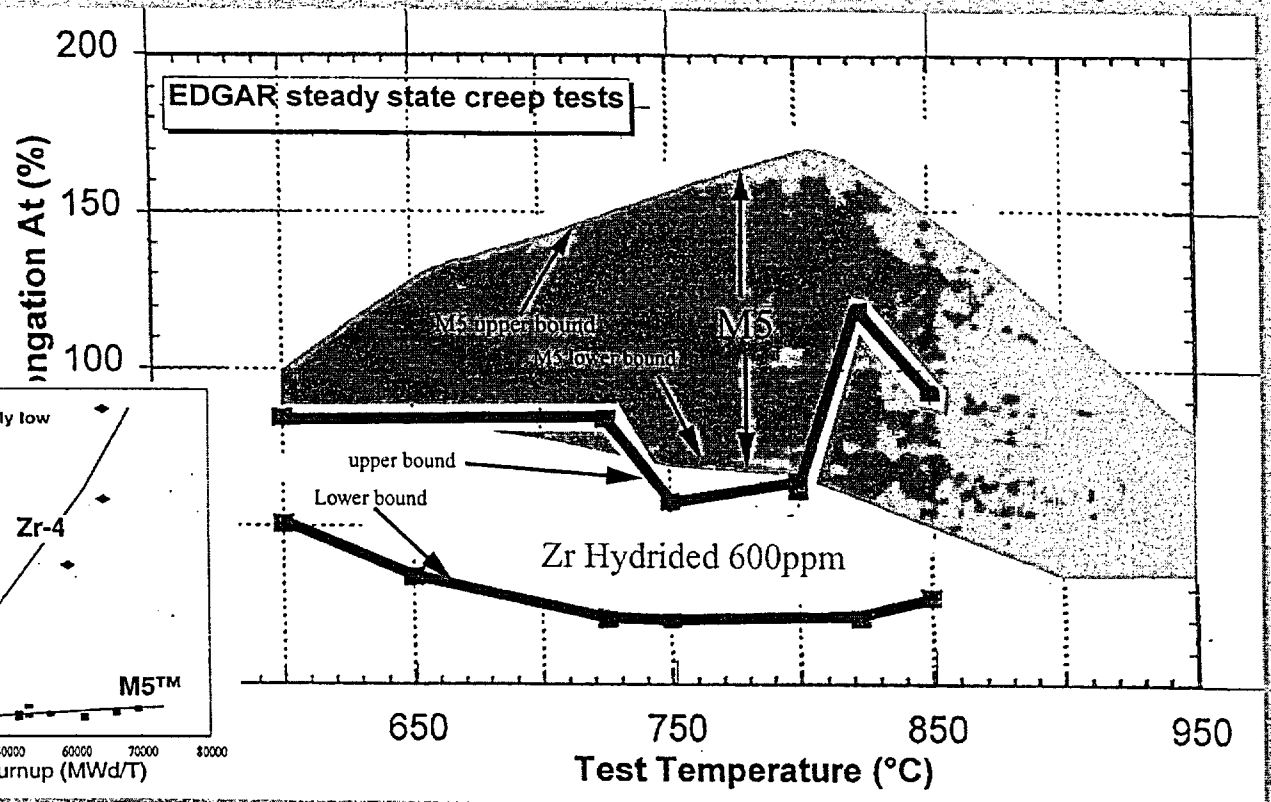
## Pending Issues : BUNDLE BLOCKAGE GEOMETRY

**Corrosion and hydrogen uptakes are lowered for modern clad alloys : ductility is better kept. Lower the corrosion, lower the associated H uptake, better the ductility, bigger the balloons**

***higher blockage ratio will be likely for modern alloys***

▪See references 7 to 9



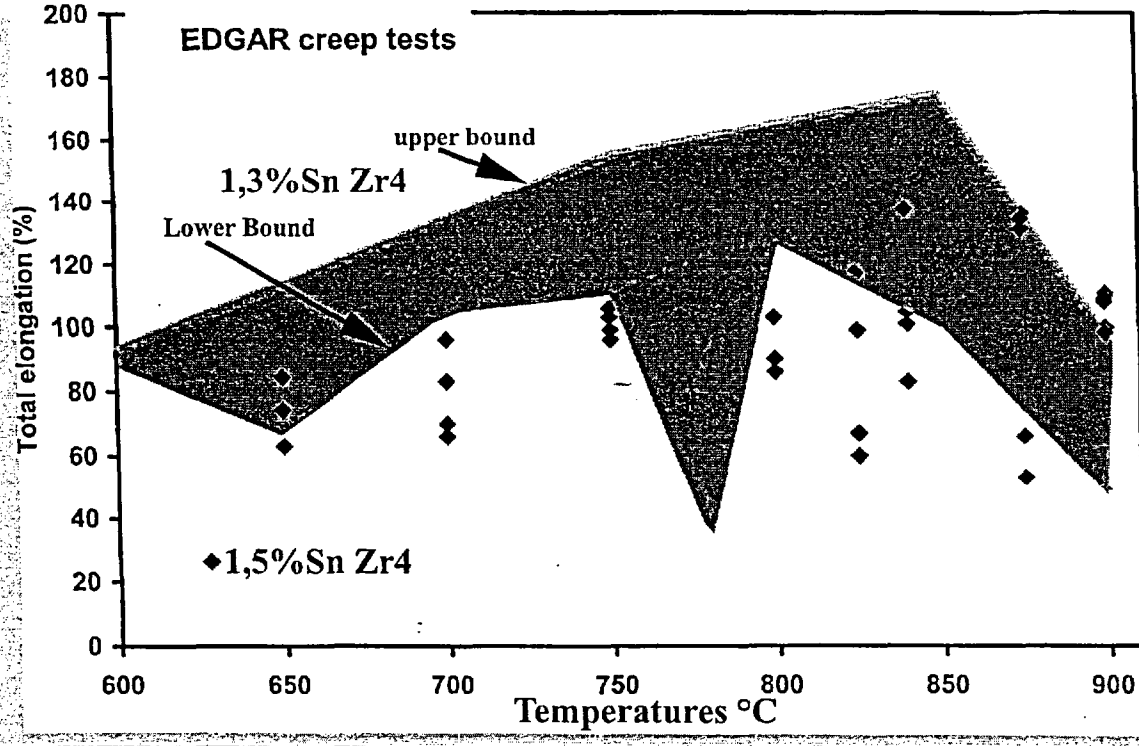



## Pending Issues : BUNDLE BLOCKAGE GEOMETRY

**Same Tendency is observed with low tin Zr alloy: lower the tin content, bigger the balloons**

***higher blockage ratio will be likely for modern alloys***

▪See references 8 and 10

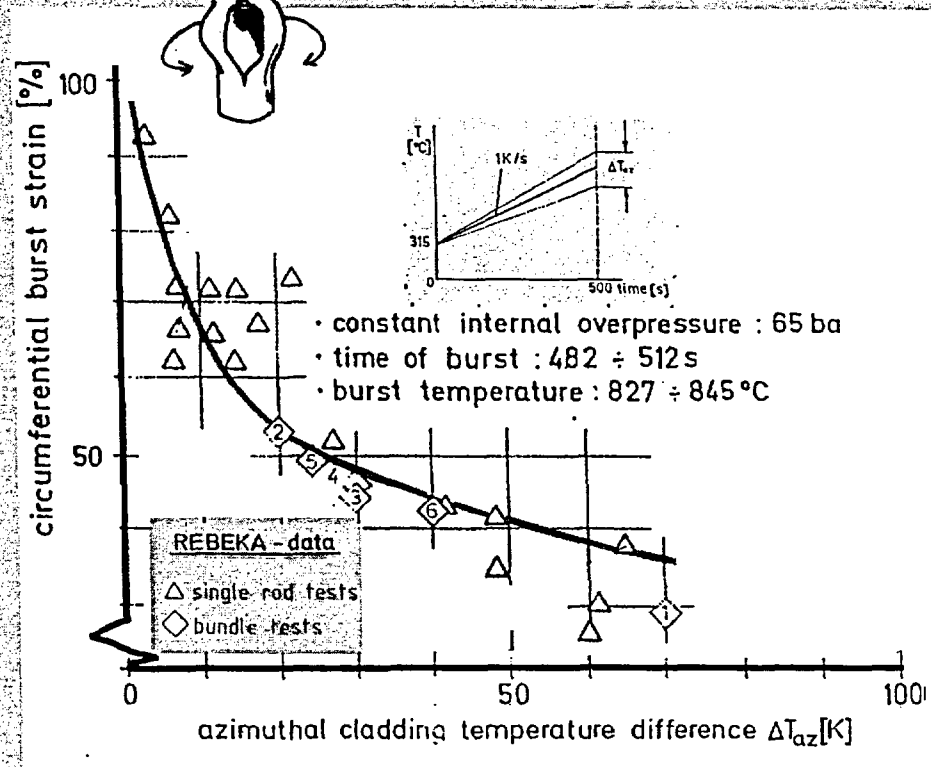


## Pending Issues : BUNDLE BLOCKAGE GEOMETRY

**A BUNDLE geometry is necessary to get realistic bundle blockage geometry :**

**It provides correct azimuthal temperature field around the tested fuel rod**

**Temperature field correctness is crucial to produce realistic balloon size**



Pending Issues : **BUNDLE BLOCKAGE GEOMETRY**

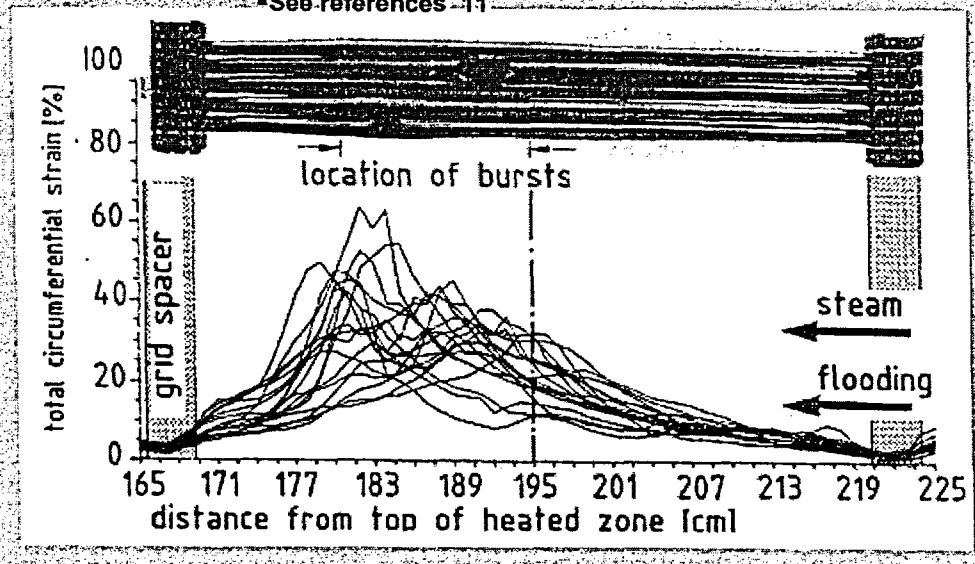
**A BUNDLE geometry is necessary to get realistic bundle blockage geometry :**

**The blockage ratio is not the linear addition of the single rod observations :**
**N times the single rod balloon geometry will produce unrealistic too high flow blockage.**

**A BUNDLE geometry**

**provides the correct no coplanar balloons distribution and a lower blockage ratio**

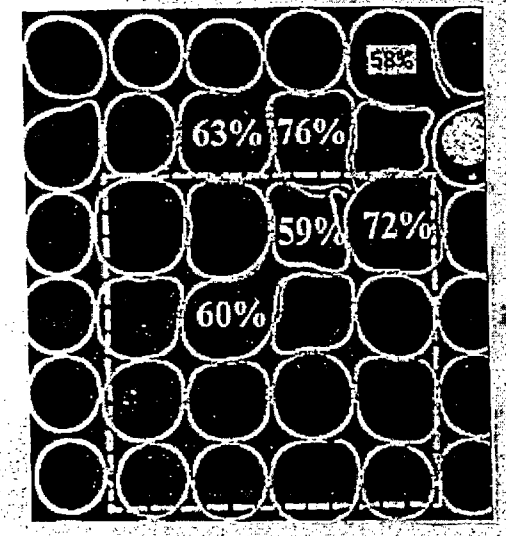
*See references 11



Pending Issues : BUNDLE BLOCKAGE GEOMETRY

**A BUNDLE geometry is necessary to get realistic Bundle Blockage geometry :**

**Radial interactions between adjacent fuel rods impact the balloon size and the bundle Blockage geometry**

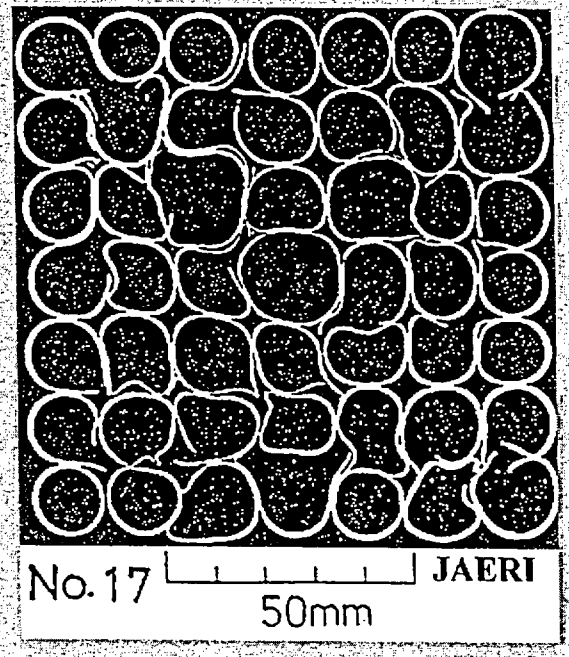



*need for row(s) of guard rods to ensure representative thermal and mechanical interactions with neighbour rods as recommended in 1981 by J. Broughton (INEL), in consideration of ORNL MRBT B5/B3 experiments)*

Pending Issues :

## HEAT SOURCE ACCUMULATION

**What is the maximum bundle blockage ratio that leaves coolable an irradiated rods bundle ?**

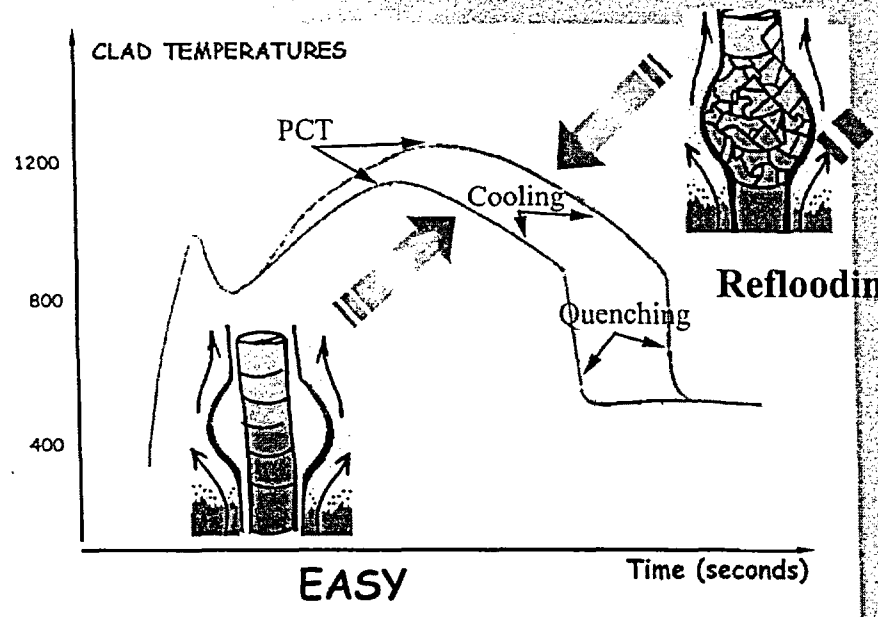



*See references 12

*The 90% value derived from results of flooding experiments (FLECHT-SEASET-SBFLEX-FEBA et al) on unirradiated rods arrays is questionable since these experiments did not take account of any fuel relocation and associated effects (lineic and surfacic power increase, gap reduction)*

## Pending Issues :

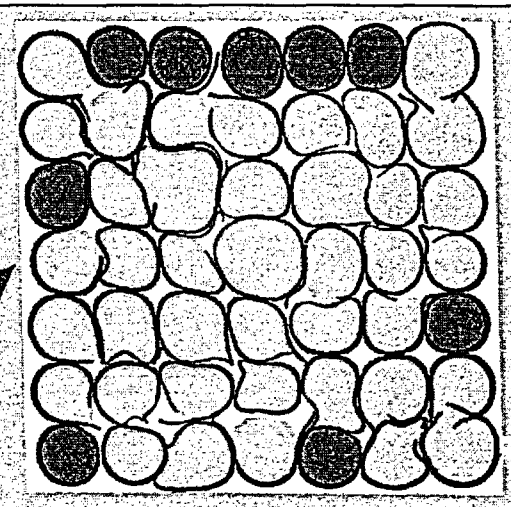
### BLOCKAGE COOLABILITY*




EASY

*FLECHT-SEASET-SEFLEX-FEBA et al*

**Reflooding requires to quench the cladding only**



*See references 12

NOT SO EASY

***REAL SITUATION***

**Reflooding requires to quench the cladding and a part of the fuel column**

# LOCA PENDING ISSUES

## Pending Issues :

### QUENCHING

**Are they any needs to modify the criteria related to post quench ductility if, during quenching, additional mechanical stresses are induced by fuel rods blockage in the assembly ?** See reference 14

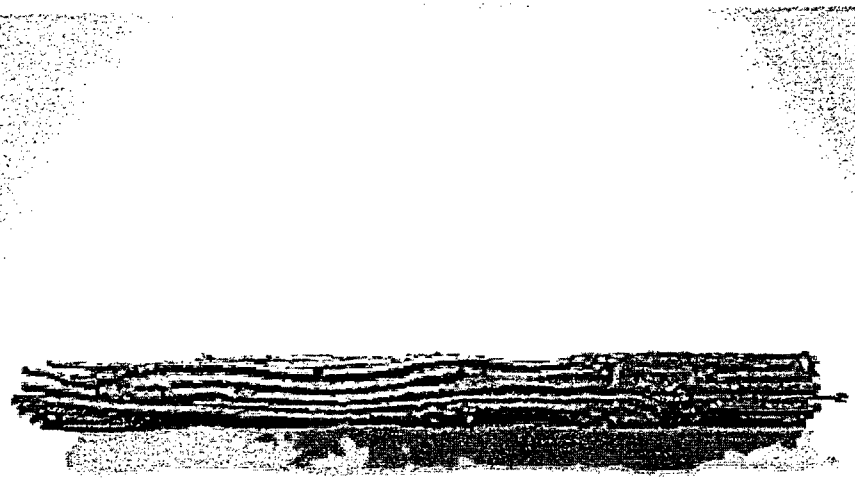
### Cooling

**Which is the residual ductility of the cladding after quenching ?** See references 13

# ALL FOR LOCA RESEARCHES

| | AVAILABLE OR PLANNED PROGRAMS |
|---|---|
| **TO DERIVE CRITERIA** | |
| *Post Oxidation ductility* | ANL |
| *Unconstraint Quenching* | TAGCIR HYDRAZIR CINOG |
| *Quenching with Constrained rods* | JAERI |
| **TO CHECK THAT CRITERIA ARE NOT VIOLATED FOR REACTOR LOCAs** | |
| *Cladding Burst* | EDGAR ANL JAERI HALDEN |
| *Relocation* | HALDEN in pile ANL out of pile |
| *Bundle Blockage Geometry And Heat Source Accumulation* | STLOC |
| *Cladding Oxidation* | TAGCIR HYDRAZIR CINOG ANL JAERI |
| *Bundle Coolability* | If necessary according to STLOC results |

*Movie produced from transmission tomography data (Test PHEBUS FPT1)*



**STLOC**

***Bundle Blockage Geometry***
***And Heat Source Accumulation***

## STLOC

STLOC will be an unique source of data for bundle geometry at burst and the heat source addition induced by relocation. It is also an integral test which includes the major phenomena of the LOCA transient

## TWO TESTS IN THE PHEBUS FACILITY

- 9 High burn up rods with a ring of 16 fresh fuel rods
- Temperature ramp from low power under steam condition

### A FIRST TEST

Cladding for which a maximum blockage is expected (M5, Low tin)

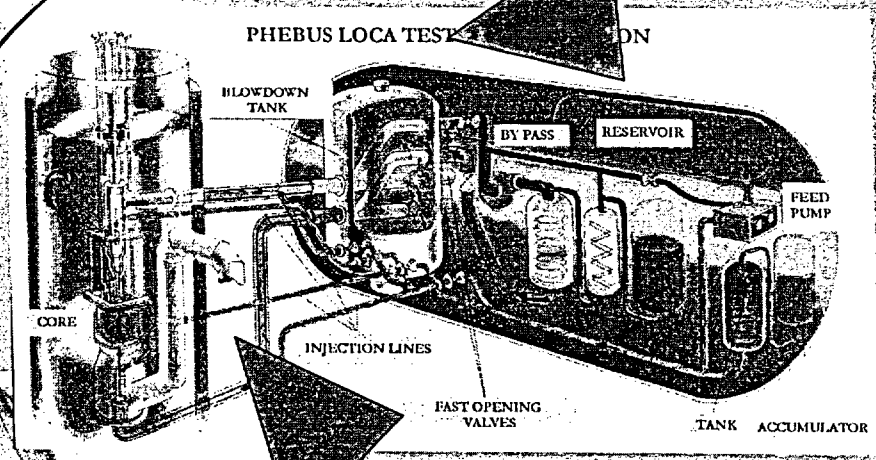
Fuel UO2 Hight Burnup impact of microstructure (>=60 Gwd/tU local)

### A SECOND OPEN TEST (to be defined)

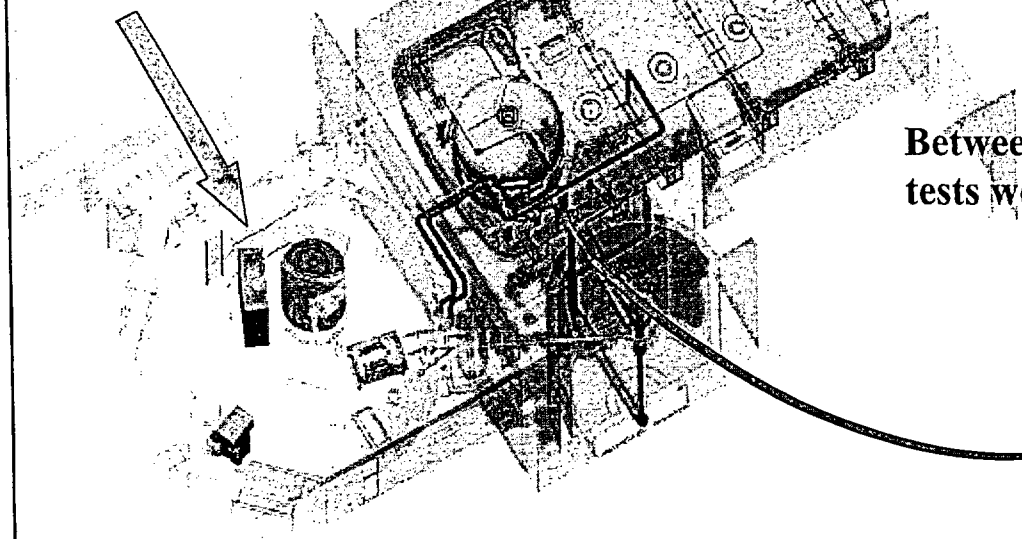
- Cladding Zr low tin / Fuel UO2 end of 1st cycle
- Cladding Zr / Fuel MOX 52 GWd/tM
- Back-up Test for Relocation with bundle geometry

# IN-PILE DEVICE

*Such a programme should take place in the PHEBUS Facility. By this way IRSN will take advantage of the know-how accumulated when the previous LOCA programme with fresh fuel was run*




Phebus FP Caisson



**Between Years 76 and 83 20 LOCA bundle tests were run in the PHEBUS Facility**

- In-pile investigations at the Phébus facility...., J. Duco, M. Réocreux, A. Tattegrain et al., 5th Int. Mtg. Thermal Reactor Safety, Karlsruhe, Sept.10-13,1984
- A study of fuel behavior in PWR design basis accident: an analysis of results from the PHEBUS and EDGAR experiments, M. Réocreux, E. Scott de Martinville, Nuclear Engineering and Design 124 (1990) p363-378

## REFERENCES


1//LWR fuel rod behaviour in the FR2 in-pile tests simulating the heat-up phase of a LOCA, E. H. KARB et al, KfK 3346- March 1983

2//Relocation of fuel fragments in ballooned fuel rods. NRC memorandum, M. L Picklesimer, March 30th,1981

3//NRC Generic Safety Issue N° 92, Fuel Crumbling during LOCA, April 1983

4//Behaviour of irradiated fuel during LOCA, G. Hache, First mtg. OECD/NEA/CSNI Task Force on fuel behaviour, 19-20th june,1997, Paris, France

5// PBF LOCA test LOC-6 fuel behaviour report, J. M. Broughton et al, Nureg/CR-3184, April 1983

6// PBF LOCA test series, tests LOC-3 and LOC-5 fuel behaviour report, J. M. Broughton et al, Nureg/CR-2073, June 1983

7// Experiment and modeling of Advanced Fuel Rod Cladding Behaviour under LOCA conditions : Alpha-Beta Phase Transformation and EDGAR Methodology T. Forgeron et al, ASTM/STP-1354, January 2000, p.256

8// Influence of Hydrogen Content on the Alpha-Beta Phase Transformation Temperatures and on the Thermal-Mechanical Behaviour of Zy4, M4 and M5 alloys During The First Phase of LOCA Transient, J.C. Brachet et al, ASTM/STP-1423, December 2002, p.673

9// Behaviour of M5 Alloy under LOCA conditions (as comared to Zy4 behaviour), N. Waeckel et al, Fourth Mtg OECD/CSNI Special Experts group on fuel safety margins, 1st April 2003.

10// unpublished IRSN results

11// Cladding Tube Deformation and Core Emergency Cooling in a LOCA of a PWR, F.J. Erbacher , Nuclear Engineering and Design, August 1987, vol 103(1), p.55

12// Multirods Burst Tests Under Loss-of-coolant conditions, S. Kawasaki et al, Meeting on water reactor fuel safety and fission product release in off-normal and accident conditions, RISO, 16-20 May 1983

13// LOCA ductility tests, R.O. Meyer, Nuclear Safety Research Conference, Washington, 29 October 2002

14// Results from JAERI research program on high fuel behavior under LOCA conditions F. Nagase et al, FSRSM, March 4-5,2002, TOKAI, Japan

## CERTIFICATE OF SERVICE

I hereby certify that on December 1, 2003, copies of Blue Ridge Environmental Defense League's Second Supplemental Petition To Intervene were served on the following by e-mail and/or first-class mail, as indicated below:

Ann Marshall Young, Chair
Administrative Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Mail Stop: T-3F23
Washington, D.C. 20555
E-mail: AMY@nrc.gov

Anthony J. Baratta
Administrative Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Mail Stop: T-3F23
Washington, D.C. 20555
E-mail: AJB5@nrc.gov

Office of Commission Appellate Adjudication
U.S. Nuclear Regulatory Commission
Mail Stop: O-16C1
Washington, D.C. 20555

Thomas S. Elleman
Administrative Judge
Atomic Safety and Licensing Board
4760 East Country Villa Drive
Tucson, AZ 85718
E-mail: elleman@eos.ncsu.edu

Office of the Secretary (original and two copies)
ATTN: Docketing and Service
U.S. Nuclear Regulatory Commission
Mail Stop: O-16C1
Washington, D.C. 20555
E-mail: HEARINGDOCKET@nrc.gov

Susan L. Uttal, Esq.
Antonio Fernandez, Esq.
Kathleen A. Kannler, Esq.
Office of the General Counsel
Mail Stop - O-15 D21
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001
E-mail: slu@nrc.gov axf2@nrc.gov, KAK1@nrc.gov

Mary Olson
Southeast Office, Nuclear Information and Resource Service
P.O Box 7586
Asheville, NC 28802
E-mail: nirs.se@mindspring.com

Lisa F. Vaughn, Esq.
Legal Dept. (PBO5E)
Duke Energy Corporation
526 South Church Street (EC11X)
Charlotte, NC 28201-1006
E-mail: lfVaughn@duke-energy.com

Janet Marsh Zeller, Executive Director
Blue Ridge Environmental Defense League
P.O. Box 88
Glendale Springs, NC 28629
E-mail: BREDL@skybest.com

| | |
|---|---|
| David A. Repka, Esq.<br>Anne W. Cottingham, Esq.<br>Winston & Strawn, LLP<br>1400 L Street, N.W.<br>Washington, D.C. 20005-3502<br>E-mail: drepka@winston.com<br>acotting@winston.com | |

Diane Curran