

# **DAMAGE DEGREE CLASSIFICATION FOR MTR TYPE SPENT FUEL IN WET INTERIM STORAGE**

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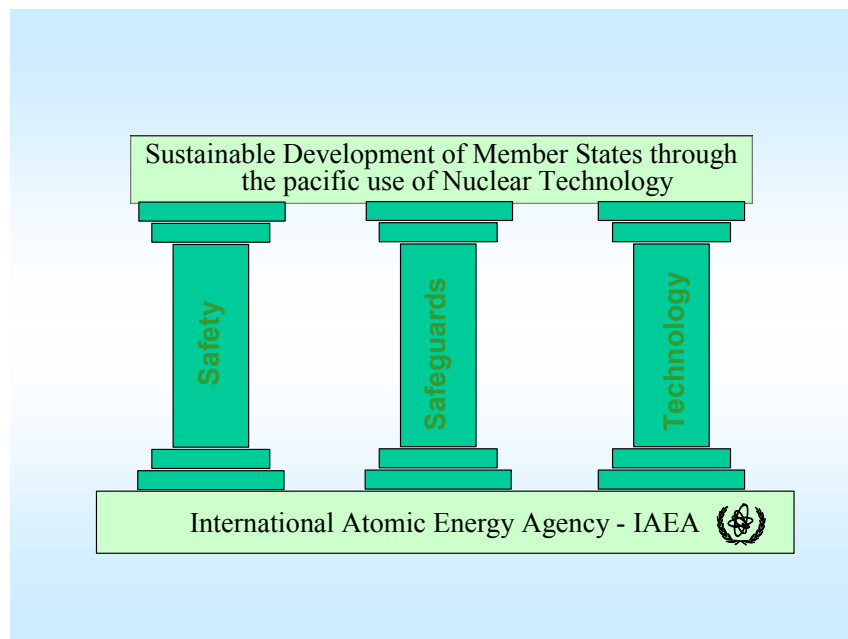
*10th International Topical Meeting on Research Reactor Fuel Management  
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# Introduction

- MTR type fuel: usually aluminum-based cladding and structural parts.
- Corrosion may appear on fuel surface during long term wet interim storage due to:
  - Loss of integrity produced by inadequate fuel handling (reactor / storage facility)
  - Water and environment of storage facility not adequately maintained
- Work objectives:
  - Present proposal of damage degree classification for MTR type spent fuel: Evaluation of photographic images
  - Set basic features of SF Visual Inspection Program for wet interim storage
  - Set common criteria among facility operators for SF characterization

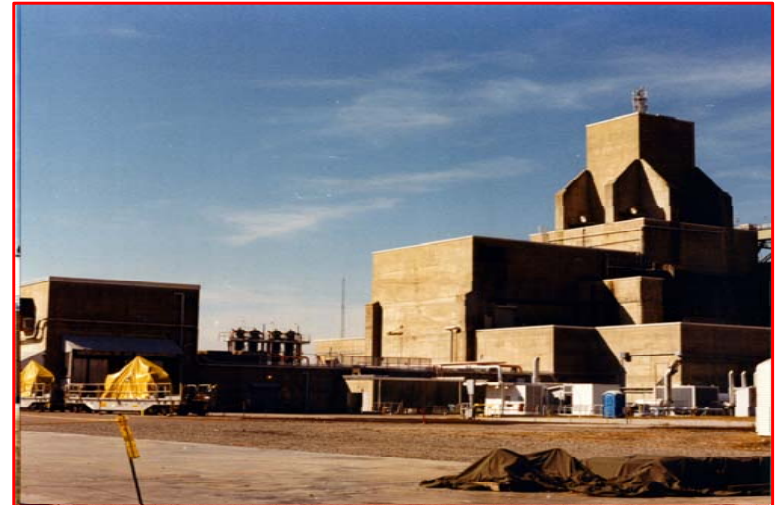
# Frame: Technical Cooperation

- IAEA Technical Cooperation Regional Project RLA/4/018 “Management of Spent Fuel from Research Reactors”
  - Countries of Latin America: Argentina, Brazil, Chile, Mexico and Peru
  - Team of researchers joined efforts to determine what is needed for spent fuel characterization
  - Expertise from outside the region
  - Outputs (among others):
    - i) Catalogue of spent fuel video stills according to corrosion damage degree classification
    - ii) Recommendations for the elaboration of a visual inspection program for spent fuel stored in basins



# Background

- SF remote visual inspection campaign
  - Performed on 207 HEU MTR fuel assemblies
  - Argentina, 1999
  - Frame: USA Spent Fuel Take-Back Program
  
- Large experience accumulated in spent fuel characterization in basins of Savannah River Site.



# Visual Inspection Program

- Experience has shown that video imaging can provide:
  - Information about general structural conditions of fuel
  - Information about nature or type of damage suffered
  - An estimate of breached cladding and exposed fuel meat
- Information from visual inspection may contribute towards:
  - Addressing regulatory and operation needs for demonstration of safe storage throughout basin storage period
  - Verifying appropriate conditions of fuel for its transfer to dry interim storage
  - Assessing impact of shipping stored fuel in standard shipping casks
- Spent fuel stored in interim wet storage should be periodically inspected until removed from basin either for storing in dry interim storage or for final disposition

# Visual Inspection Program: Criteria

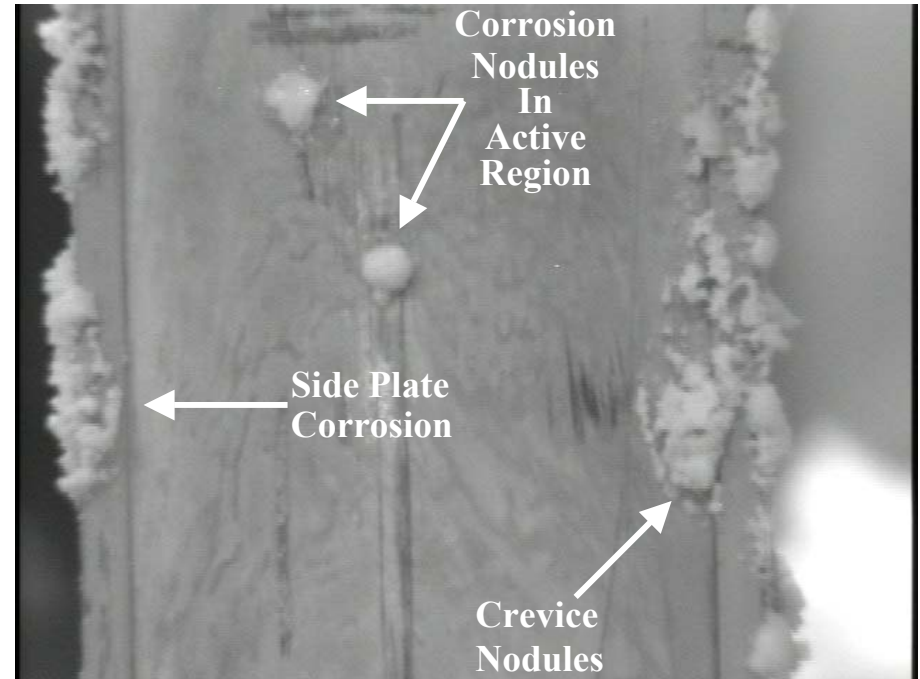
- Each fuel assembly in basin storage should be examined and information obtained should be properly recorded
- Underwater video imaging equipment should be used
- Pictures of submerged fuel taken above water not sufficiently clear to evaluate fuel condition
- Video system should allow for still images to be recorded to meet examination requirements
- Both color or black and white images are acceptable
- Initial baseline examination of each fuel assembly should be performed as close to removal from reactor as possible
- Fuel assemblies should be re-examined within 10 years of previous examination
- More frequent examinations of fuel in storage may be performed at the discretion of facility operator

# Visual Inspection Program: Requirements

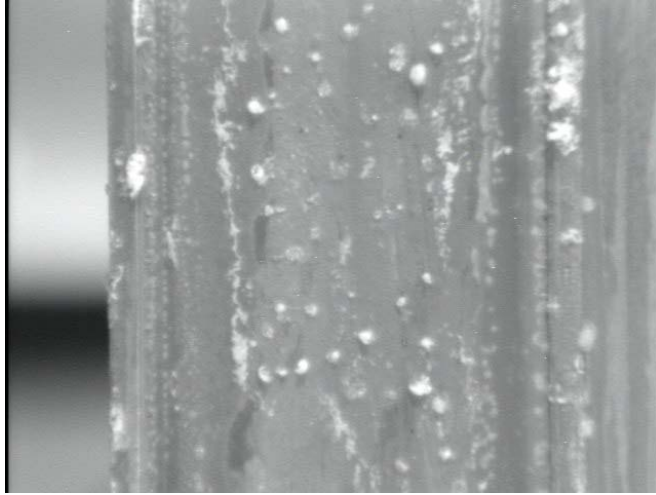
- Low magnification photographs:
  - Full view (length and width) of each of the four external plates of assembly
  - Typically wide-angle view
  - Alternatively: set of photographs used to construct full view
- Medium-magnification photographs:
  - Image of mid-length area of each external fuel plate
  - Actual size image (1:1)
  - Side plate edges should be visible to provide size reference
  - Top view of fuel:
    - Magnification should allow for complete view on 1:2 scale.
    - 1) Illumination from above ; 2) Illumination from the end fitting
- High magnification photographs:
  - Photographs of corroded or mechanically damaged areas.
  - Magnification should allow for, for example, a 3mm-diameter circle to be represented in a 2X image (6mm)
  - A reference marker should be present or added to recorded image to indicate size of observable damage.
- Images of non-active areas of fuel plate (top and bottom) presenting possible cladding deterioration

# Corrosion Damage

- **Principal cause of fuel degradation while in interim wet storage**
- **Increased by storage with very poor water quality**
- **Present mainly in the form of aluminum oxide nodules on fuel plates and lateral plates**
- **Typically, nodules are consequence of mechanisms such as “pitting” and “crevice corrosion”**
- **Side plate corners sensible to corrosion attack**



# Corrosion Damage: Pitting



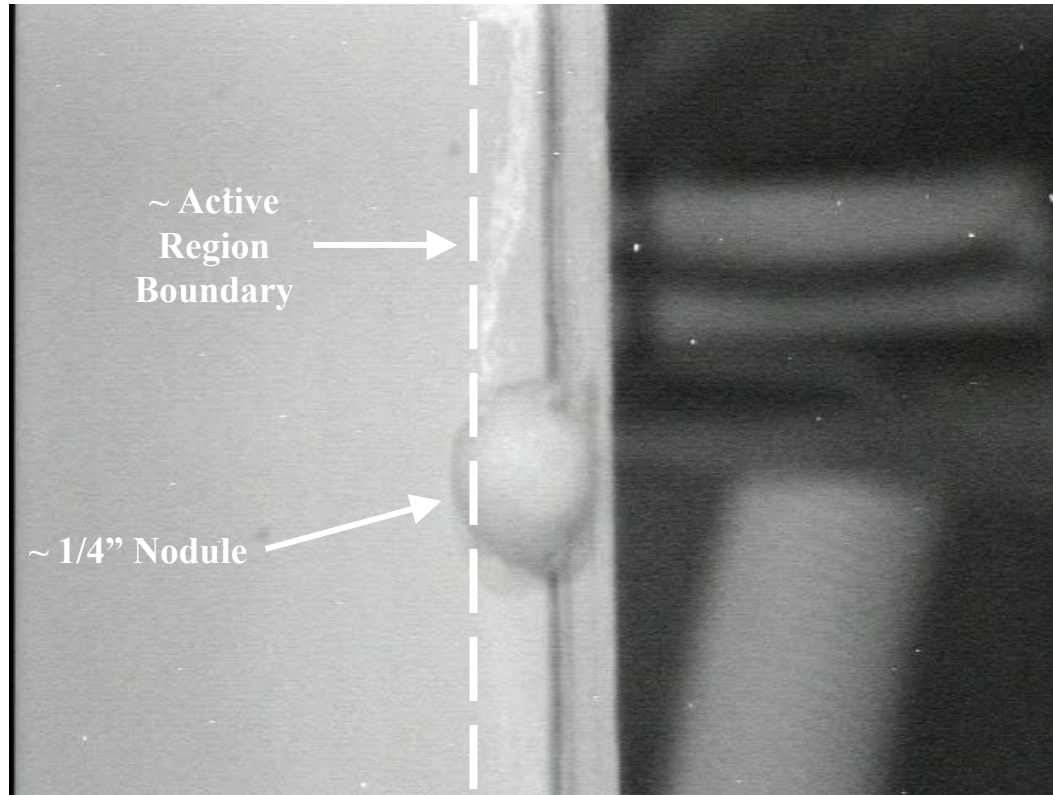
**Pitting on fuel plate active  
zone**



**Corrosion pits with fuel meat  
exposure**

- **Pitting corrosion process so advanced may penetrate aluminum cladding exposing fuel meat**

# Crevice Corrosion



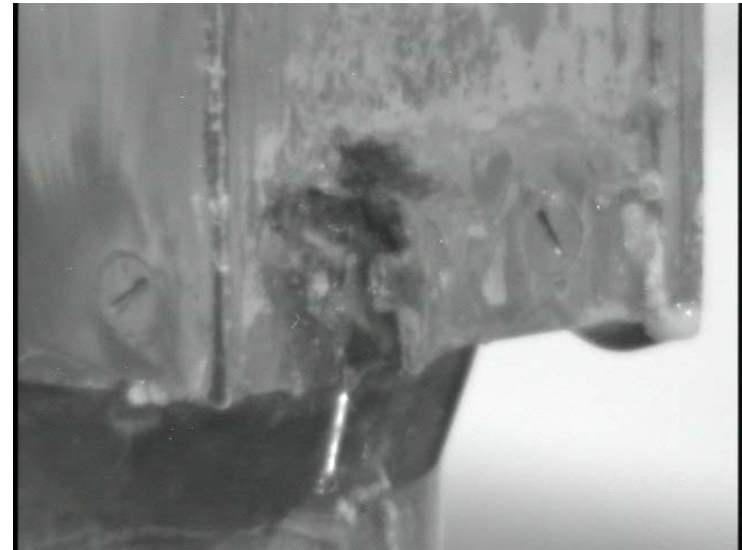
**Crevice nodule of ~ 6 mm that overlaps the active region boundary**

# Galvanic Corrosion

- **Galvanic corrosion due to contact of stainless steel and aluminum in fuel**



**End fitting of fuel assembly  
stored on SS liner tube**



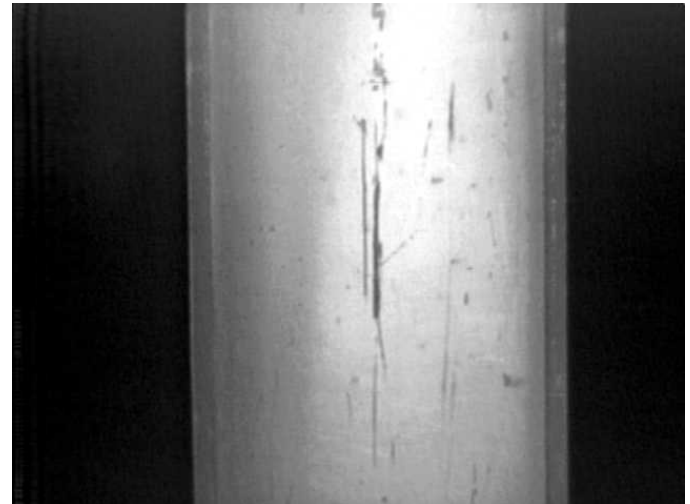
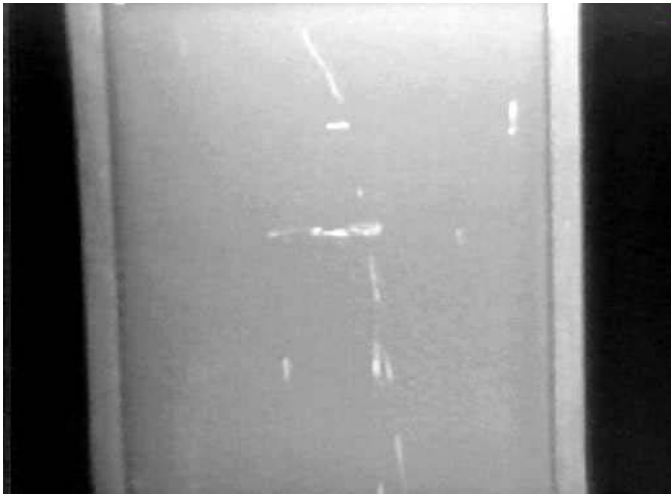
**Degradation of fuel plate. Bulging  
in zone of SS screws**

# **Corrosion Damage: Estimation of Exposed Fuel Meat**

- **Damage degree: estimation of exposed fuel meat by extent of penetrating corrosion visible on outer fuel plates**
- **To estimate exposed fuel meat, the following assumptions were taken as valid:**
  - **There is not enough damage in the internal fuel plates to consider fuel meat exposure**
  - **When aluminum oxide nodules are present, area of nodules represents area of exposed fuel meat below them**
  - **Nodules less than 3 mm in diameter do not penetrate fuel plate cladding (no exposed fuel meat)**
- **Fuel assemblies categorized by means of Severity Index**

# Mechanical Damage

- **Scratching, denting, bending etc.**
- **Harms protective layer of aluminum oxide (boehmite)**
- **Damaged area then becomes preferred area for pitting attack**
- **In extreme cases, inadequate fuel handling can be a direct cause of cladding breaches.**

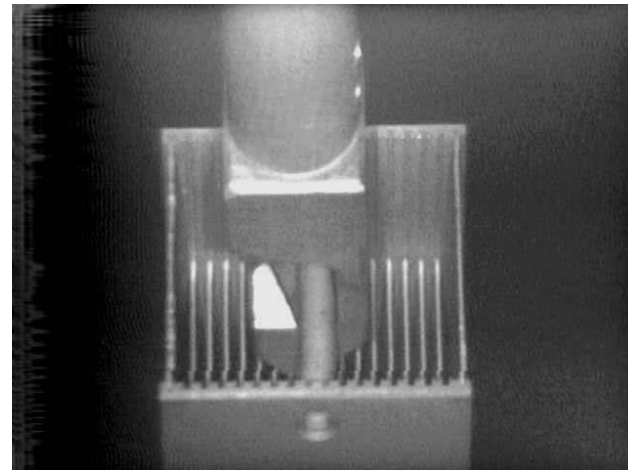
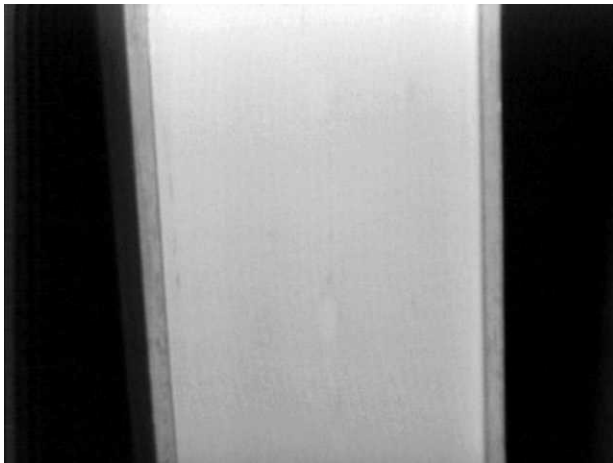


# Categorization of fuel damage by Severity Index

Fuel Status	Severity Index
No damage	V0
Loss of aluminum oxide layer <i>and / or</i> presence of corrosion <i>and / or</i> mechanical damage. No estimated exposition of fuel meat	V1
Presence of corrosion. Fuel meat exposed ( $< 0,5 \text{ cm}^2$ per assembly) <i>and / or</i> Minor mechanical damage at active region.	V2
Presence of corrosion. Fuel meat exposed ( $> 0,5 \text{ cm}^2$ but $< 1,0 \text{ cm}^2$ per assembly) <i>and / or</i> Mechanical damage at active region with possible cladding penetration	V3
Presence of corrosion <i>and / or</i> severe mechanical damage at active region with cladding penetration. Fuel meat exposed ( $\geq 1 \text{ cm}^2$ per assembly) <i>and / or</i> Any damage potentially significant to the structural integrity of fuel assembly	V4

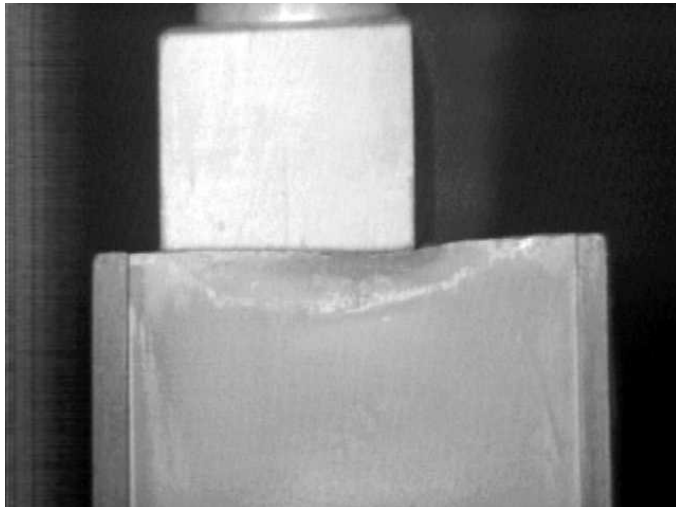
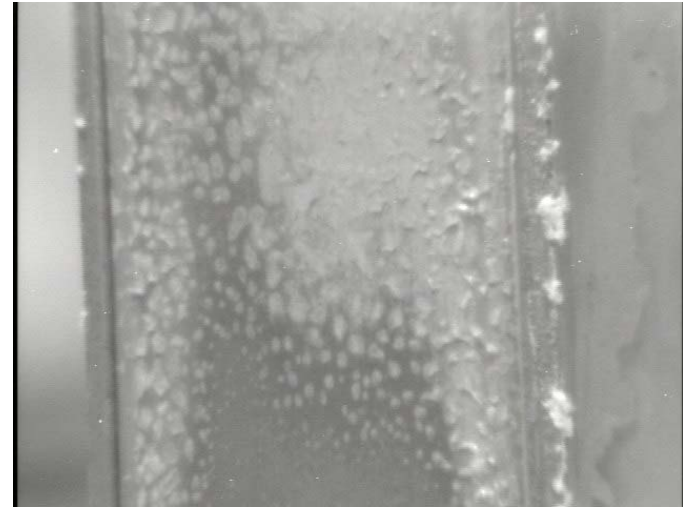
# Damage Degree Classification: Severity Index V0

- **Fuel assembly in good conditions**
- **No general corrosion**
- **No corrosion product nodules**
- **No mechanical damage**



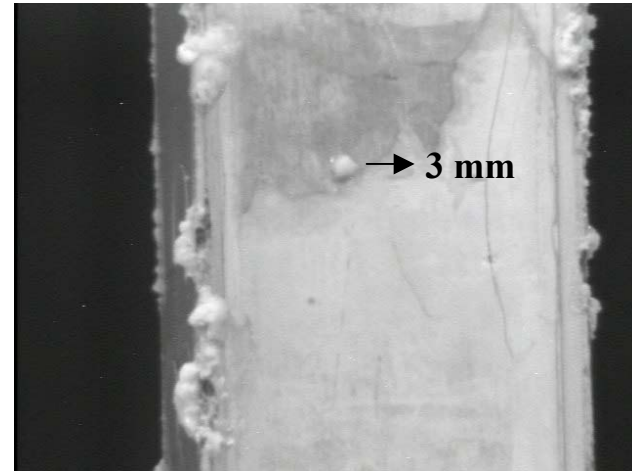
# Damage Degree Classification: Severity Index V1

- **Loss of aluminum oxide layer**
- **Presence of general corrosion**
- **Presence of blisters**
- **Corrosion product nodules**
  - **Nodules < 3 mm in diam.**
  - **No exposition of fuel meat**
- **Mechanical damage out of active region**



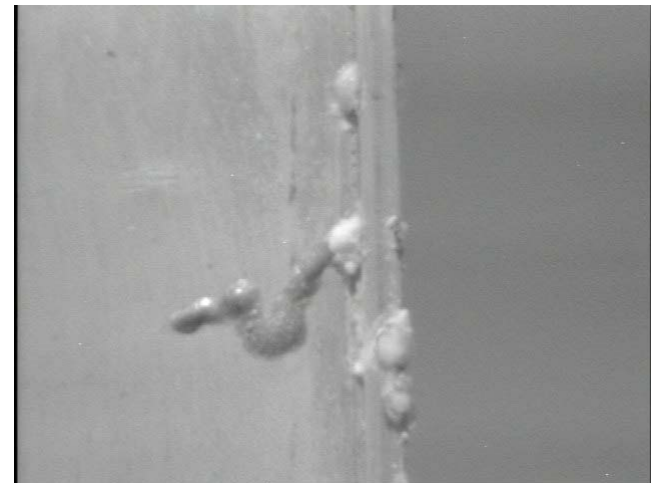
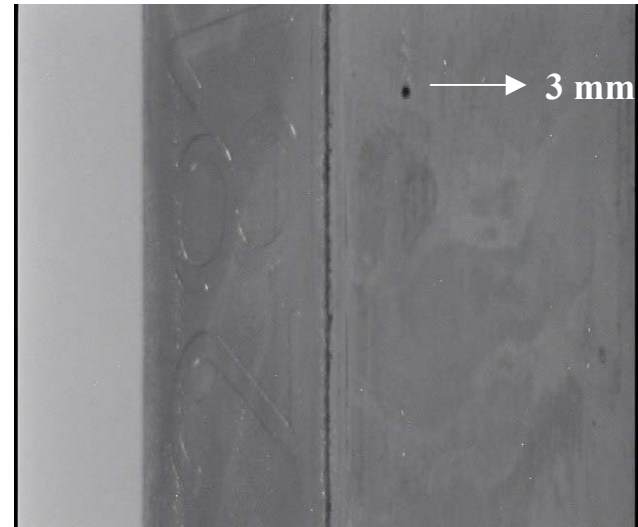
# Damage Degree Classification: Severity Index V2

- **i) Corrosion product nodules with estimated fuel meat exposure**
  - **Nodules  $\geq 3$  mm in diam.***and/or*
- **ii) Corrosion pits with fuel meat exposure**
- **Exposed meat for i) + ii)  $< 0,5$  cm<sup>2</sup>**  
*and/or*
- **Mechanical damage at active region with cladding deformation**



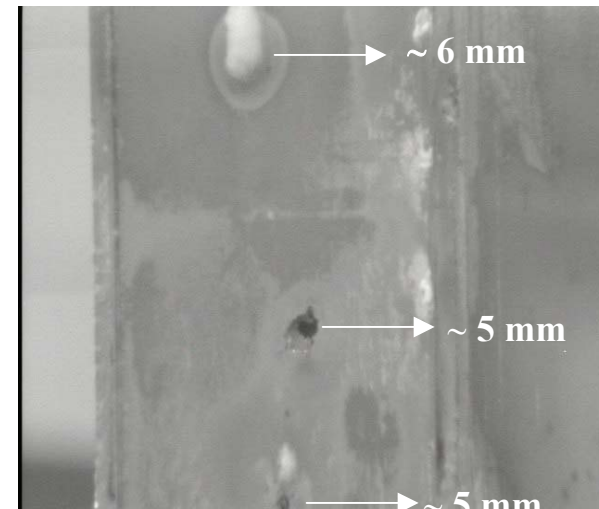
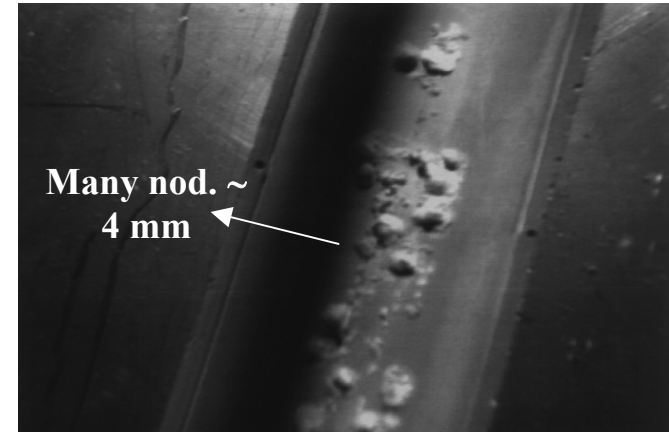
# Damage Degree Classification: Severity Index V3

- **i) Corrosion product nodules with estimated fuel meat exposure**  
*and/or*
- **ii) Corrosion pits with fuel meat exposure**
- **Exposed meat for i) + ii)  $> 0,5 \text{ cm}^2$  but  $< 1,0 \text{ cm}^2$**   
*and/or*
- **Mechanical damage at active region with possible cladding penetration**



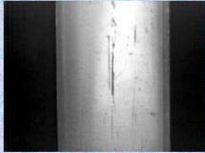
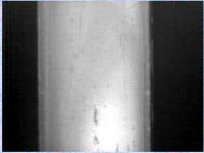

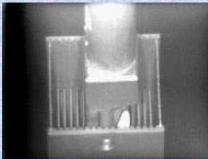
# Damage Degree Classification: Severity Index V4

- i) Corrosion product nodules with estimated fuel meat exposure  
*and/or*
- ii) Corrosion pits with fuel meat exposure  
*and/or*
- iii) Mechanical damage at active region with cladding penetration
- Exposed fuel meat for i) + ii) + iii)  $\geq 1 \text{ cm}^2$   
*and/or*
- Any damage potentially significant to structural integrity of fuel assembly



# VI Program: Records of Inspection Results

- **Examination:** Video recording & videotapes reviewing
- **Data Sheet:** 1 per stored SF and per examination
- **Selection of video stills** most representative of SF status
- **Inspection date;** video equipment utilized

Facility Name: IEA-R1 Research Reactor		Country: BRAZIL
<b>FUEL ASSEMBLY CHARACTERIZATION DATA SHEET</b>		
		<b>Fuel Identification : IEA-131</b> Supplier : Ipen Type - MTR - Enrichment : 20% Dimensions (cm) : 7,97x7,61x87,30 Material - U <sub>3</sub> O <sub>8</sub> - Al 1100 Cladding - Al ASTM 1060 Number of fuel plates : 18 Initial Mass of U-235 : 180 g Specific Mass - 1,9 g(U <sub>3</sub> O <sub>8</sub> )/cm <sup>3</sup> First day in Reactor Core : 16/02/89 Removed from core on : 08/09/97 Calculated Burn up (% <sup>235</sup> U) : 31,46 Measured Burn up :
		
<b>GENERAL REMARKS:</b> •Some risks on fuel plate 1 surface, in active region. (caused by handling; already oxidized).		
REVISION 0: November/2002 By JERS: AJS		
Date: <b>Oct/2002</b>		<b>Classification</b> Visual Inspection <b>V0</b> Sipping <b>S0 (Oct/99)</b>
This page designed for a 800X600 presentation		

• **Fuel: ID#;** procedence; fab. data (overall dimensions, enrich., fuel meat, U content, etc.); Bup; starting/discharge dates; etc.

• **Description of nature of damaged regions; Severity Index;**

• **Sip Test results (cross referenced); Reference of previous examinations**

# Conclusions

- **IAEA Technical Cooperation Regional Project RLA/4/018 “Management of Spent Fuel from Research Reactors” contribution (among others):**
  - **Setting of common criteria in characterization of fuel in wet storage: Corrosion damage degree classification**
  - **Catalogue of MTR spent fuel video stills according to classification produced**
  - **Recommendations for elaboration of visual inspection program for spent fuel stored in basins (under implementation in countries participating of Regional Project)**
- **Aluminum based nuclear fuel is susceptible to corrosion attack or mechanical damage. Therefore, a Fuel Inspection Program should be set in spent fuel wet storage facilities.**
- **Information on fuel status provided by Program can be used to:**
  - **Address regulatory and operation needs for demonstration of safe storage throughout basin storage period**
  - **Verify appropriate conditions of fuel for its transfer to dry interim storage**
  - **Assess impact of shipping stored fuel in standard shipping casks.**

# Conclusions

- **Visual inspection of spent fuel in interim storage with poor water quality showed corrosion mainly in the form of aluminum oxide nodules on the surface of external fuel plates and structural plates.**
- **Visual appearance of nodules tends to exaggerate actual extent of corrosion.**
- **Empirical knowledge shows that:**
  - **Corrosion damage tends to occur on external surface of fuel assembly**
  - **Nodules less than 3 mm in diameter do not penetrate fuel plate cladding**
  - **Corrosion in internal fuel plates rarely leads to fuel meat exposure.**
- **Assumption that area of aluminum oxide nodules greater than 3 mm of apparent diameter represents area of exposed fuel meat below them is conservative and may overestimate extent of cladding breach.**
- **Visual inspection should be combined with sipping tests for complete characterization of spent fuel status.**
- **An Inspection Program must be backed by:**
  - **Corrosion surveillance by means of evaluation of immersed aluminum coupons**
  - **Strict control of water quality and facility environment.**