Fuel Assembly Poolside Inspection Technology of Pressurized Water Reactor

Ren Liang
Nuclear Power Institute of China
22nd September, 2014
1. Introduction

2. Poolside Inspection Techniques
   - Visual Inspection
   - Dimension Measurement
   - Oxide Thickness Measurement

3. Conclusions
1 Introduction

PWR Most Widely Used Types Fuel

French: AFA3G

USA: Performance+

Korea: ACE7

China: CF
1 Introduction

Influence Factors

- High Burnup
- Low Leakage
- High Power Peak
- Long Cycle Water Chemistry

Fuel Assembly Damaged
1 Introduction

PSI Technology Used to Identify the Damage and Deformation of Fuel Assembly

Water as Radioactive Shielding
1 Introduction

PSI Technology

1. Sipping Test
2. Visual Inspection
3. Dimension Measurement
4. Oxide Thickness Measurement
5. Ultrasonic Leak Detection
6. Fuel Reconstitution
7. Others

New Fuel Assemblies Research
Nuclear Power Plants Safe Operation
2 Poolside Inspection Techniques

Visual Inspection

- Most Direct and Important Method
- Surface Corrosion
- Obvious Deformation
- Visible Defects and Damage

Underwater Camera

Overall and Grid Appearance
2 Poolside Inspection Techniques

Dimension Measurement

- Measurement Range and Content Different
  - Image Method: Fuel Assembly Length, Bending and Torsion, Shoulder Gaps and Rod Gaps
  - LVDT Method: Rod Diameter and Grid Width

- Accuracy Requirement Not High
  - Difficult to Achieve Ensure Position
- Requirements of Precise Measurement
  - 0.01mm
  - 0.1mm
2 Poolside Inspection Techniques

Dimension Measurement-Image Measurement Technique

- Fuel Assembly Length, Bending and Torsion, Shoulder Gaps and Rod Gaps
- Based on Video and Calibration
- Image Acquisition
- Encoder Value
- Ruler and Pixel
- Grids Image Converted into Digital Video Signal
2 Poolside Inspection Techniques

Image Measurement - Fuel Assembly Length

Irradiation Growth, Total Height, Grid to Grid Gap, Camera Move from Top to Bottom
2 Poolside Inspection Techniques

Image Measurement-Fuel Assembly Bow

Focus on Top Nozzle and Vertical Line
Distance Difference from Vertical Line to Nozzles and Grids
Calculate the Image Maximum
2 Poolside Inspection Techniques

Image Measurement-Fuel Assembly Twist

Relative Twist Degree of Top and Bottom Nozzles

Move Camera Around, Make Two Vertical Lines Coincide When Recording Starts
2 Poolside Inspection Techniques

Image Measurement-Shoulder Gap

Camera Moved Around and Take Video, Pixel Values Achieved

Growth of Outer Fuel Rods
2 Poolside Inspection Techniques

Image Measurement-Rod Gaps

Gaps of Outer Fuel Rods

Two Adjacent Fuel Rods on Grids Span Along Axial

Pixel Values Achieved
2 Poolside Inspection Techniques

Dimension Measurement-LVDT Technique

LVDT (Linear Variable Differential Transformer)

Standard Rod Diameter Calibration

Change of Measurement Circuit Converted into Voltage, Variation Achieved
2 Poolside Inspection Techniques

LVDT Technique - Fuel Rod Diameter

Fuel Rod Contacted by LVDT Probe

Outer Rod Measured Each Span
2 Poolside Inspection Techniques

LVDT Technique-Grid Width

Standard Grid Width Calibration

Identify Transversal Growth of Grid

Control Cylinder Back and Forth to Measure

Grid Width Measurement Probe

Hydraulic cylinder control
2 Poolside Inspection Techniques

Oxide Thickness Measurement

Lift-off (valor de CI) = Esp. Óxido + CRUD

Water-side Corrosion of Cladding

Lift-off Effect Principle of Eddy Current Coil

Measure 50mm Each Span
Calculate Average

Eddy Current Probe

Eddy Current Thickness System

Calibration Curve of Standard Film
2 Poolside Inspection Techniques

Oxide Thickness Measurement

Oxide Thickness of Standard Rod

Using Metallographic Method to Compare with Standard Rod Thickness
Oxide Thickness Measurement

Spend Fuel Rod From Qinshan-2 After One Cycle: 5μm-10μm Consistent with the Similar Results, Such as French NPP.
3 Conclusions

◆ China had already mastered the PSI method.  
◆ PSI method had been successfully used for Qinshan NPP fuel assemblies inspection.  
◆ PSI method will be used for CF fuel inspection.
Thank You for Your Attention