ENUSA EXPERIENCE ON ADVANCED TECHNOLOGY FUEL
Lead Test Rod (LTR) Program in Belgium

ENUSA INDUSTRIAS AVANZADAS S.A. S.ME. - SPAIN
OUTLINE

• Background
• Advanced Technology in the Demonstration Program
  ✓ Chromium coated cladding
• LTR program in Belgium (Doel-4)
  ✓ Scope and Description
  ✓ Design, Licensing and Manufacturing
  ✓ Surveillance Program
• Summary
• After Fukushima, enhancing accident tolerance is a priority for the industry and numerous programs started globally since then

• ENUSA enrolled the Westinghouse ATF's program EnCore® (2018-2020) in a Frame Collaboration Project based on the concept of Joint Development Programs

  JDP#6. Accident Tolerant Fuel (ATF)/Lead Test Rods (LTR) Introduction in Doel-4

• This JDP leads to the first introduction of ATF's Encore fuel in Europe for performance and benefits
  ✓ Confirmation of correct behavior under a wide array of operating conditions
  ✓ First hand information
  ✓ Preparation for other customers
ADVANCED TECHNOLOGY CR-COATED CLADDING

Chromium-coated cladding

- Thin (15-30 microns) adherent and dense chromium layer
- EnCORE® Cold spray as deposition technology
- Polishing by Westinghouse at Blairsville facilities
- Substrate cladding unchanged

Demonstration program

- Operational experience
- Data under real conditions
- Associated phenomenology
- Inspections
CR-COATED CLADDING PROPERTIES (1)

• Reduced oxidation/hydrogen during normal operation
  ✓ Longer life and increased margins allow use of higher density fuels
  ✓ Benefits for draft 10 CFR 50.46c rule
  ✓ Reduced embrittlement in dry storage

• Improved corrosion resistance in steam and air at high temperature
  ✓ Reduced exothermic reaction energy
  ✓ During and beyond design basis conditions
  ✓ Increased LOCA peak cladding temperature and long-term time limit
  ✓ Improved RIA margins

• Improved performance for ballooning and burst

• Enhanced resistance to wear (debris, grid-to-rod)
CR-COATED CLADDING PROPERTIES (2)

• Adherence and mechanical properties of the coating
  ✓ Excellent adherence in all tests
  ✓ No observable spalling even at very high strain

• No effect on mechanical properties of the substrate
  ✓ Standard tensile tests
  ✓ Measuring strain at start of cracking
    ─ At elevated temperature 1% strain does not produce cracking

• Scratching tests conducted
  ✓ Coating highly tolerant to scratching
DOEL-4 LTRS PROGRAM. SCOPE AND DESCRIPTION

Program

Design \rightarrow Manufacturing

Pre-characterization \rightarrow Follow-up during and after irradiation

Delivering

Fuel assemblies

4 FAs RFA-2 OPT XLR

32 LTRs

Cr coated Optimized ZIRLO

small non Cr-coated areas at top and bottom => free welding zone

UO₂ pellets

Doel-4 C31 in 2020
DOEL-4 LTRS PROGRAM MANUFACTURING

Manufacturing and inspection standard processes

- Handling and safety requirements
- New product definition
- New drawings and specs
- Manufacturing documentation revision
- Product reception guide at the plant

Characterizacion Plans
Tubes, Rods, Assemblies

Characterization Reports

Traceability
Follow-up during and after irradiation

- Assessment of coating integrity after each cycle
- Magnified visual inspections along the entire FA length
  - Comparison with standard Optimized ZIRLO rods
  - Reloadability evaluation
- All these inspections will be used to determine possible storage restrictions (if any)

LTAs surveillance program

Correct visual appearance!

More in Top Fuel 2022
SUMMARY

• Doel-4 Cr-coated Cladding Demonstration Programme comprises the activities of
  ✓ Design, licensing, manufacturing, pre-characterization, product delivery and follow up of
  ✓ 32 Cr-coated rods (8 per assembly) in peripheral positions to facilitate inspections

• No credit to the beneficial properties based on no limiting core location during the first cycle and limited number of LTRs

• Inspection at the end of the first irradiation cycles showed correct performance
  ✓ Coming inspections at the end of each cycle will be used to determine any restriction

• Joint work of Westinghouse, ENUSA, Tractebel and Electrabel for implementing ATF in Europe
  ✓ Design, manufacturing and operational experience to move forward