Westinghouse
Presentation on
ZIRLO Characterization Plant
(Slide Presentation of July 11, 2002)

June 2002

Westinghouse

A BNFL Group company

ZIRLO^{TM} Characterization Plan

Westinghouse Electric Company

Presented by:

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July 11, 2002

ZIRLO™ Characterization Plan

- Meeting Objective
  - Present Low Tin ZIRLO™ Characterization plan to support license extension for Low Tin ZIRLO™ cladding consistent with presentations to NRC in 2001 and 2002
  - Obtain feedback on scope of planned efforts

ZIRLO™ Characterization Plan

- Program Objective
  - By performing Low Tin ZIRLO™ Characterization, we will demonstrate that Low Tin ZIRLO™ is not a new material, but a minor change within the technical envelope of a well-proven ZIRLO™ cladding

ZIRLO^{TM} Characterization Plan

- Background
  - Westinghouse intent to license Low Tin ZIRLO^{TM} presented to NRC on Oct 29, 2001
  - Strategy to develop Low Tin ZIRLO^{TM} characteristics database defined
    - Low Tin ZIRLO^{TM} characteristics will be demonstrated to be compatible with standard ZIRLO^{TM} properties
  - Westinghouse intent to license Low Tin ZIRLO^{TM} and strategy reiterated to NRC on May 14-15, 2002 semi-annual meeting
    - General approach seemed reasonable

ZIRLO™ Characterization Plan

Changes in fabrication	Benefit or impact
Change tin level range from [ ]a, c	Reduce Corrosion
esting	
Ex-core	Provide data used in reload evaluation
In-core - Exposure in LTA	Gather PIE data to validate models and demonstrate benefits

ZIRLO^{TM} Characterization Plan

a, b, c

[ ]

ZIRLO™ Characterization Plan

- Low Tin ZIRLO ™ Ex-Core Testing

  – Test Material

    – ZIRLO™ with nominal tin content of [ ]a, c

    – ZIRLO™ with nominal tin content of [ ]a, c

    – Standard tin ZIRLO™ (C)

  – Planned Tests

    – Physical properties

    – Mechanical Properties

    – Microstructure

    – High Temperature/LOCA Tests

ZIRLO^{TM} Characterization Plan

- Summary of Basic Properties Characterization

Physical tests

Density

Emissivity - oxidized and unoxidized

Specific Heat

Thermal Conductivity

Thermal Expansion

Axial / longitudinal

Diametrical/hoop or transverse

Alpha-Beta Transition Temperature

Mechanical Tests:

Axial Mechanical Test:

Yield Strength

Ultimate strength

Elongation at failure

Modulus of elasticity

Poisson's ratio axial/diametral

ZIRLO^{TM} Characterization Plan

- Summary of Basic Properties Characterization (Cont'd)

  Hoop Burst Test:
  - Yield Strength
  - Ultimate strength
  - Strain at failure
  - Modulus of elasticity

  Biaxial Burst Test:
  - Ultimate strength

  Microhardness Traverse

  Fatigue

  Microstructure:
  - Particle Size

  High Temperature/LOCA tests:
  - Quench Tests
  - Ring Compression Tests
  - Metal-Water Reaction (High Temperature)**
  - Burst Test (Strain & Temperature @ burst)
  - LOCA creep

ZIRLO^{TM} Characterization Plan

Physical properties

–Density (A, B)

» Immersion Method

» At Room Temperature with extrapolation to higher temperature based on measured value of thermal expansion

–Emissivity (A, C)

» Oxidized and unoxidized Condition

» ASTM Method C-835

» Minimum 500 C and maximum 1200 C

–Specific Heat (A,B,C)

» ASTM method E1269-01

» From Room Temperature to 1200 C

ZIRLO^{TM} Characterization Plan

Physical properties (Cont'd)

–Thermal Conductivity (A, C)

» Modified Kohlaruse technique

» Up to 1210 C

–Thermal Expansion (A, B, C)

» Alpha-Beta Transition temperature

» Axial/longitudinal

» Diametral/Hoop

» From Room Temperature to 1200 C

ZIRLO™ Characterization Plan

a, b, c

[ ]

ZIRLO^{TM} Characterization Plan

a, b, c

[ ]

ZIRLO^{TM} Characterization Plan

a, b, c

[ ]

ZIRLO™ Characterization Plan

Mechanical Properties (A, B, C)

–Axial Tensile Tests

» **Properties:**
Yield Strength
Ultimate strength
Elongation at failure
Modulus of elasticity
Poisson's ratio

» Temperatures:
RT: Connect with large Production Certification databases and prior data
390 °F (200 °C) Intermediate temperature to improve temperature-property curves
660 and 725 °F (350 and 385 °C) Near operating temperature for a range of reactors.
1110°F (600°C) Abnormal conditions.

ZIRLO™ Characterization Plan

Mechanical Properties (Cont'd)

–Hoop Burst Test:

» **Properties:**
Ultimate strength
Elongation at failure
Modulus of elasticity
Temperatures:
RT, 390, 660, 725°F (RT, 200, 350, 385°C)

–Biaxial Burst Test:

» Ultimate strength
Temperatures:
RT, 390, 660, 725°F (RT, 200, 350, 385°C)

ZIRLO™ Characterization Plan

Mechanical Properties (Cont'd)

–Fatigue (A)

» Room temperature
» Up to 10 million cycles
» Tension and compression
» 6 stress levels starting from [ ] a, b, c at 20 MPa interval

–Particle Size (A)

» Size and distribution of intermetallic phase particles
» Minimum of 100 particles to be photographed per sample

ZIRLO^{TM} Characterization Plan

High Temperature/LOCA Tests (A, C)

–Quench Tests

»Demonstrate acceptable cladding ductility under LOCA quench conditions.

»Cladding will be rapidly oxidized in a high temperature steam environment to produce varying levels of oxide thickness.

»The sample will be quenched to room temperature by submersion in water.

ZIRLO™ Characterization Plan

High Temperature/LOCA Tests

–Ring Compression Tests

- » Measure ductility retained by cladding following rapid oxidation.
- » Cladding samples rapidly oxidized in a high temperature steam environment to produce varying levels of oxide thickness.
- » The oxidized samples will then be cut into rings and used as ring compression samples.
- » Compression testing provides quantifiable ductility data for cladding that has been severely oxidized.

ZIRLO^{TM} Characterization Plan

High Temperature/LOCA Tests (Cont'd)

–Metal-Water Reaction (High Temperature)

- Cladding samples will be oxidized at high temperature to produce a uniform oxide coating
- The weight gain of the oxide will be recorded , oxidation rates calculated and compared with previous ZIRLO^{TM} data

ZIRLO™ Characterization Plan

High Temperature/LOCA Tests (Cont'd)

–Burst Test (Strain & Temperature @ burst)

» [ ] sections of cladding are internally pressurized with argon.

» Rapid temperature transients are produced by infra-red heating of the cladding to simulate LOCA conditions.

» The burst temperature and physical condition of the tube following burst are recorded and used to calculate strain at burst.

ZIRLO^{TM} Characterization Plan

a, b, c

[ ]

ZIRLO^{TM} Characterization Plan

a, b, c

[ ]

ZIRLO^{TM} Characterization Plan

High Temperature/LOCA Tests (Cont'd)

–LOCA creep

- » Cladding tube sections are held at a constant temperature and pressure.
- » Temperatures will be chosen to provide test in all the alpha , alpha/beta , and beta phase ranges.
- » The diametral strain of the cladding will be measured as a function of time providing data about the creep behavior of the alloy.
- » Testing different temperature and pressure combinations will provide data on the cladding creep performance under LOCA conditions.

ZIRLO™ Characterization Plan

- Low Tin ZIRLO ™ Licensing

  – A complete set of ZIRLO™ base material properties updated with Low Tin ZIRLO™

  – Regions will be licensed to all current criteria. Current models will be justified and compared to test data. Information will be submitted for review and approval in addenda to WCAP-12610-P-A and CENPD 404-P-A to expand ZIRLO™ definition to cover low tin condition for region introduction

ZIRLO™ Characterization Plan

- Planned Changes in ZIRLO ™ Specification
  - Are minor - similar to past changes in Zirc-4
  - Provide greater corrosion margin and higher fuel duty capability
  - Will be submitted for review in addendum's to existing topicals with updated material properties
    - WCAP-12610-P-A and CENPD 404-P-A

ZIRLO™ Characterization Plan

a, b, c

[ ]

ZIRLO^{TM} Characterization Plan

- Byron LTA 1st Cycle (high Duty, High FDI) Rod oxide Data Summary
  - Low tin ZIRLO^{TM}: [ ]a, c
  - Standard ZIRLO^{TM}: [ ]a, c

ZIRLO™ Characterization Plan

- Low Tin ZIRLO™ Introduction

Planned Schedule

–First NRC meeting to layout planned licensing path	• Oct 29, 2001
–Low Tin ZIRLO™ Characterization plan	• July, 2002
–Submit Low Tin ZIRLO™ Addenda to –WCAP-12610-P-A –CENPD 404-P-A	• Dec. 2002
–NRC Approval of Low Tin ZIRLO™ Addenda	• July, 2003
–Region introduction of low tin ZIRLO™	• [ ][a, c]

ZIRLO^{TM} Characterization

- Summary
  - Low tin ZIRLO^{TM} Characterization consistent with earlier presentations
  - Basic material properties characterization will be expanded
  - Low Tin ZIRLO^{TM} characteristics will be demonstrated to be compatible with standard ZIRLO^{TM} properties and submitted as addenda to current WCAPs (WCAP-12610-P-A, CENPD 404-P-A)

Westinghouse
Presentation on
DNB Testing
(Slide Presentation of July 11, 2002)

June 2002

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A BNFL Group company

Westinghouse DNB Testing

Gerald Sieradzki
July 11, 2002

Westinghouse DNB Testing

Outline

- Closing of Columbia Test Facility (HTRF)
- Requirements of DNB Testing
- Alternate Test Facilities
- Westinghouse Qualification Process
- Potential Licensing Applications

Westinghouse DNB Testing

Closing of Columbia HTRF

- Columbia HTRF is closing down by 6/30/03
- All W DNB test data supporting NRC - approved DNB correlations were obtained from HTRF
- Closing down of HTRF has major impacts on future safety analysis in the U.S.

Westinghouse DNB Testing

Requirements of DNB Testing

- W uses NRC-approved FCEP (WCAP-12488-A) for evaluating fuel design changes

- Fuel changes not covered by FCEP may require DNB tests
  - [ ] a, c
  -
  -

Westinghouse DNB Testing

Alternate Test Facilities

- W is actively evaluating alternate DNB test facilities
- All alternate facilities are [ ] a, c
- Primary facility under consideration is [ ] a, c
- Backup facilities include:
  - [
  -] a, c
  - Other facilities

Westinghouse DNB Testing

Westinghouse Qualification Process

- Over the years, W has developed a process for qualifying test facilities and data for safety analyses
  - Personnel qualification
  - Testing procedures
  - Data collection and reduction
  - Test bundle manufacturing, etc.

Westinghouse DNB Testing

Westinghouse Qualification Process (continued)

- The process was applied to Columbia HTRF and [ ]a, c
- The process will include [ ]a, c
- This same process will be applied to alternate test facilities
- NRC participation during qualification DNB testing of an alternate facility is welcomed

Westinghouse DNB Testing

Potential Licensing Applications

- DNB test data collected from an alternate test facility will meet W QMS requirements
- DNB test data on future fuel designs will be used for qualification of 95/95 DNBR limit
  - An existing NRC-approved DNB correlation
  - Minor adjustment to a DNB correlation
  - A new DNB correlation

Westinghouse DNB Testing

Summary

- Because of the closing down of Columbia HTRF, W is evaluating alternate DNB test facilities to meet regulatory requirements for future fuel design changes
- W intends to apply its proven qualification process to any alternate test facility
- DNB data from an alternate test facility will be used for justifying the 95/95 DNBR limit of a DNB correlation

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