POST IRRADIATION EXAMINATION OF THE FUEL RODS OPERATED IN WWER-1000 MIXED CORES

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Introduction

- Ukraine has been implementing Ukraine Nuclear Fuel Qualification Project (UNFQP), within the frame of which SU NPP has been pilot operating mixed cores of nuclear fuel supplied by different vendors – OJSC TVEL and Westinghouse.
- Westinghouse has developed six WWER-1000 Lead Test Assemblies (LTAs) and delivered them to South Ukraine NPP 3 in 2005.
- The LTAs have completed 4 cycles of operation.
- LTA Design has been further enhanced.
- Westinghouse and TVEL fuel assemblies differ in some structural components and structural materials.

Design

- Design of 6 Westinghouse Lead Test Assemblies (WLTA) provides maximum compatibility with resident fuel.
- Basic design features:
  - 15 spacer grids located to match the axial locations of the resident fuel grids;
  - bottom additional grid for trapping fine particles;
  - WLTA has dismountable design (top and bottom nozzles are detachable for substitution of leaking fuel rods);
  - top nozzle design provides compatibility with shipping-and-handling devices of power unit;
  - top and bottom nozzle designs assure adequate fit with upper core plate and bottom support tubes, as well as appropriate fuel assembly lateral alignment and support;
  - grid tabs and nozzle features are designed to preclude inadvertent hang up the WLTAs and the resident FAs;
  - grids are robustly connected to the guide thimbles;
  - the grid loss coefficient is higher than for the resident fuel.

Loading of fuel assemblies into core

- WLTAs were loaded into the SU NPP Unit 3 core during 2005 outage. For loading WLTAs were used resident shipping-and-handling devices and procedures.

- Drag forces during loading in the core did not exceed 75 kgf.

- After 4th cycle of operation drag forces during unloading from the core did not exceed the design value 75 kgf and met the requirements of normative documents.

Loading of fuel assemblies into the storage pool rack

- The drag force of all WLTAs during their installation into the storage pool rack did not exceed a setpoint of 150 kgf.

- For comparison:

the drag forces for some resident FAs were 140-174 kgf.

Axial top nozzle positions

- At the first load in 2005 the height difference of top nozzle positions did not exceed 2 mm (the maximum value according to the normative document is 5 mm).

- Before the unloading from the core after 4th cycle of operation the height difference was 1 mm. This value corresponds to that obtained by the beginning of the 4th cycle.

Water chemistry

- During all 4 cycles of Westinghouse LTAs operation the core coolant chemistry was maintained within the RCS chemistry norms for different reactor power levels.

- Coolant quality control was effected using plant control methods and with the frequency which meets the regulatory requirements for V-320. The data provided shows that:
  - ✓ coolant quality during all cycles was consistent with the regulatory parameters for RCS chemistry;
  - ✓ no deviations in RCS chemistry from the regulatory requirements for reactors at power were observed;
  - ✓ RCS boron concentration was maintained at the level which ensured reactor operation at the prescribed power level in accordance with the Technical Decision.

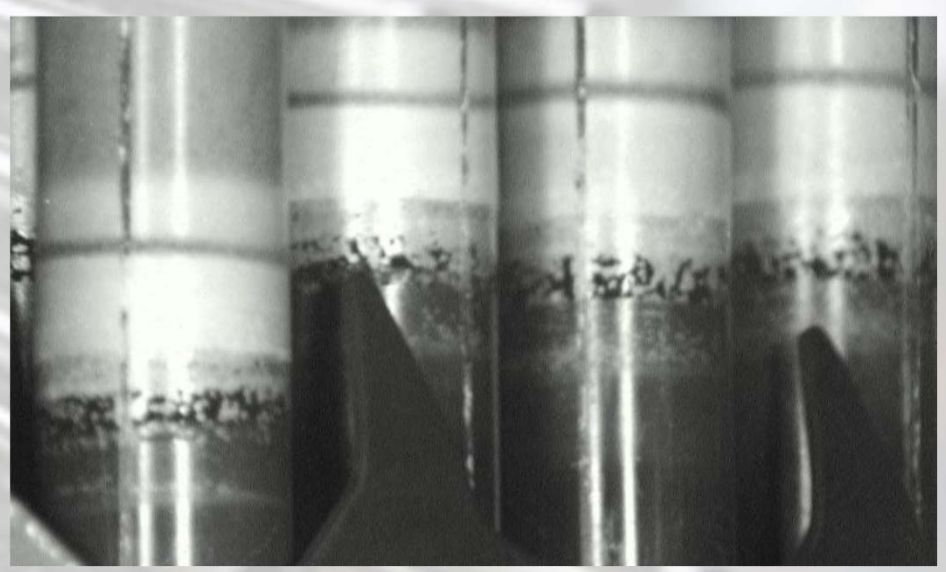
Visual inspection

- After the fourth cycle of operation the surface of WLTAs had oxide films of various shades.
- On the dark gray background of the clad in lower part of the fuel rod had contrasting light-gray spots, and the fuel rod surface showed good reflective properties.
- The size of gray spots increased towards the top of the WLTA.
- Starting with Grid 5, the fuel rod clad surface was gray with observable light-gray spots which increased in size towards the top of the WLTA.
- There were no spots in the plenum region, and the cladding surface was an even dim light-gray color.

Visual inspection: Weld Joints

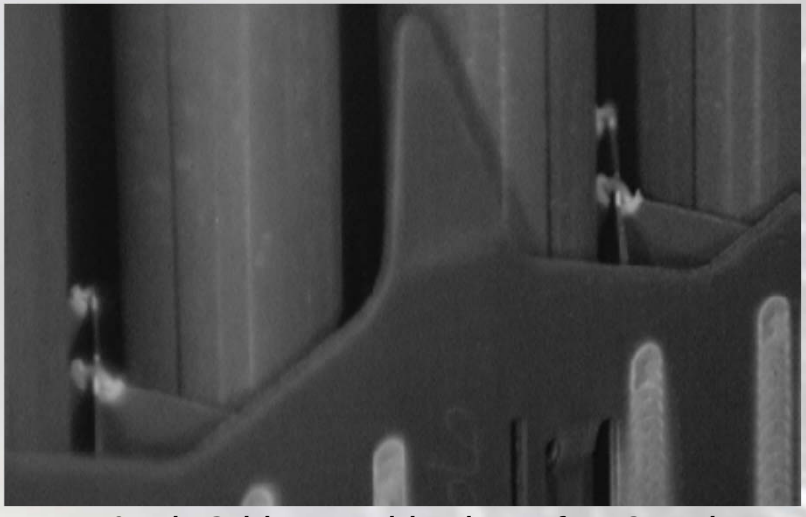
- The weld joints of the fuel rod top and bottom end plugs were uniformly light-grey.
- Some fuel rods, however, were observed to have cladding dimness in the weld joint area of the top/bottom end plug.

Weld Joints of Top End Plugs after 4 cycles

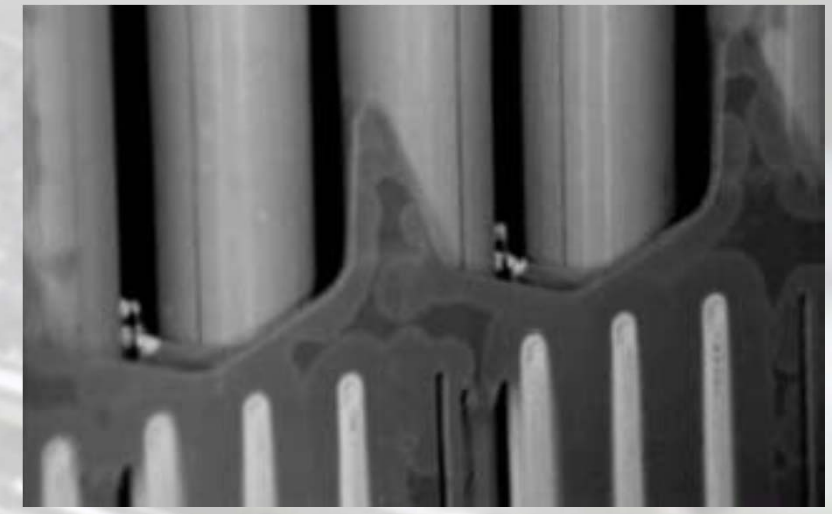


Weld Joints of Bottom End Plugs

Visual inspection: Weld Joints



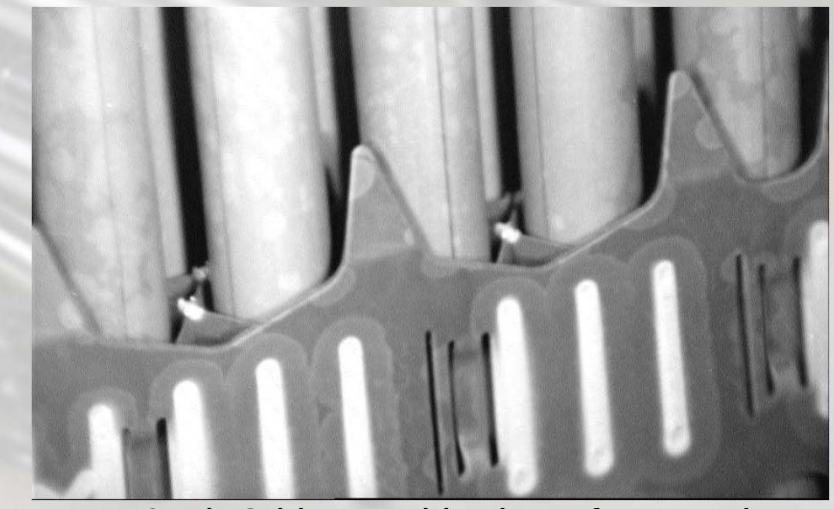
Zr1%Nb Grid 14 Weld Joints after 2 cycles



Zr1%Nb Grid 14 Weld Joints after 3 cycles

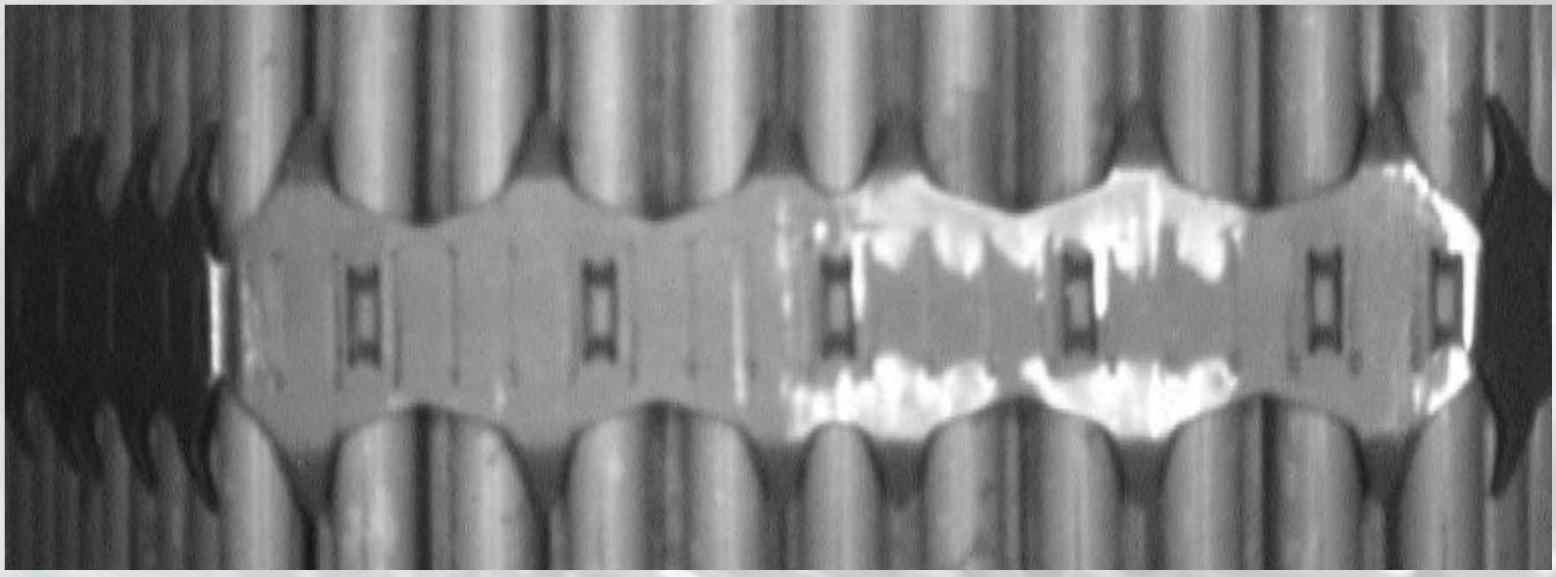
During visual inspection were not observed any visible defects such as corrosion plaques, pittings or cracks in the area of weld joints.

It gives the opportunity to state that this type of weld joint is operational in WWER-1000 conditions.



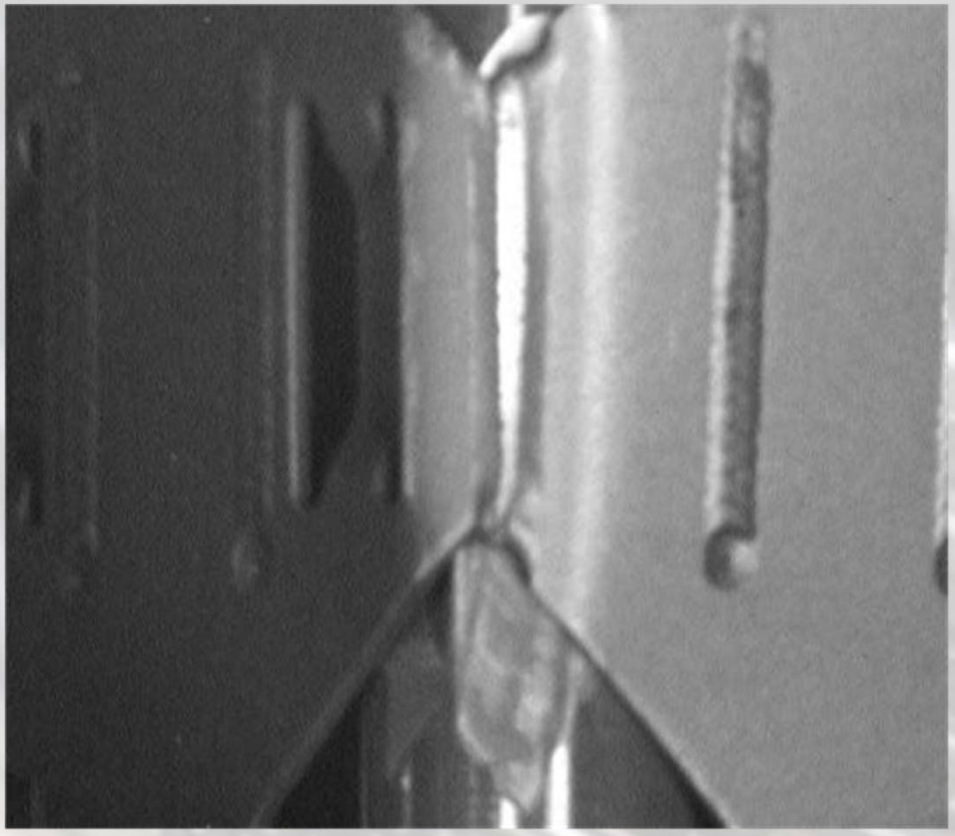
Zr1%Nb Grid 14 Weld Joints after 4 cycles

Visual inspection



Some grids on WLTAs had burnishes resulting from friction against the adjacent FAs during FA installation into and withdrawal from the core.

Visual inspection



The bottom end plug of the corner rod between WLTA AA02-03 Faces 4 and 5 showed marks visually resembling wear signs or a foreign particle

Visual inspection

- Minor foreign objects were observed on the WLTA AA04-03 bottom nozzle and grids.

- Some of the particles observed on WLTA AA04-03 were flushed in the sipping test cask. WLTA AA04-03 requires further examination to identify the nature and type of the elements observed using the inspection stand to be supplied by Westinghouse under a separate contract.

Visual inspection

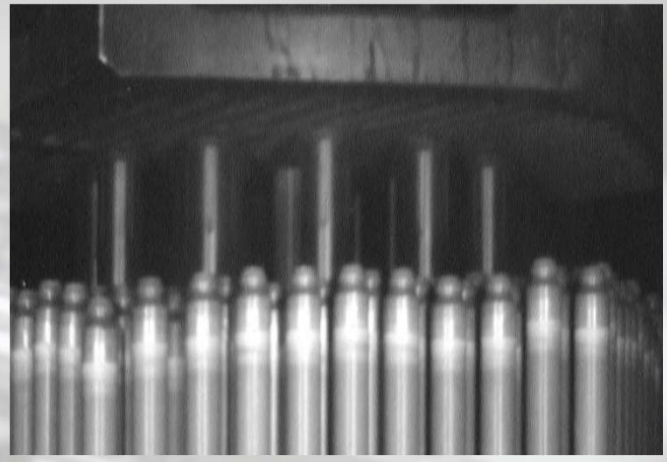
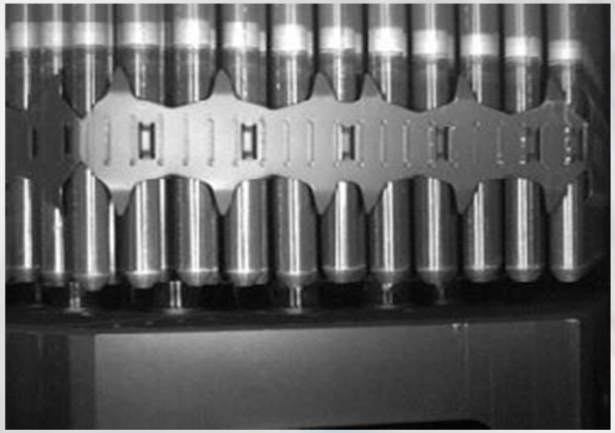
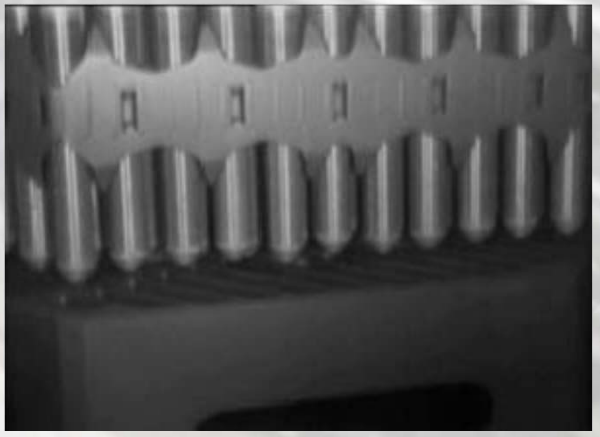
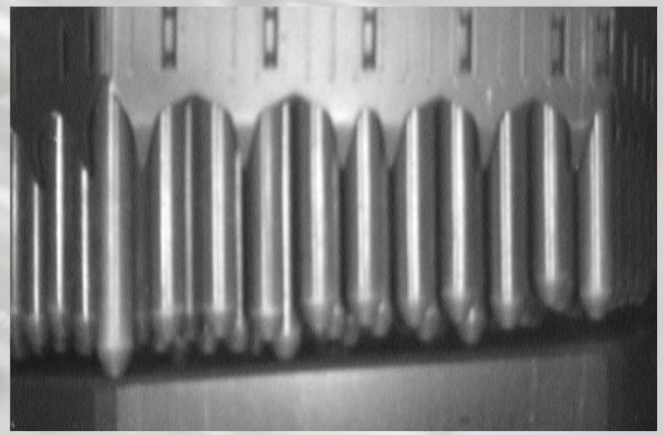
- Zirconium alloys Zr-1%Nb and ZIRLO™ showed excellent corrosion resistance operability.
- The visual inspection did not identify any visible damage to or non-design positions of individual LTA components, which could result in the engagement with the adjacent core components, equipment or FA handling devices.
- None of the six LTAs had any sings of damage, deformation or other defects preventing their handling.

Visual inspection: Fuel Rod Displacement

- Fuel rod displacement resulted in making contact between some bottom end plugs and the bottom nozzle plate. No fuel rod was observed, however, to have been displaced towards immediate proximity with the WLTA top nozzle.
- Fuel rod downward displacement until making contact between the bottom end plugs and the WLTA bottom nozzle is a design feature and does not adversely affect nuclear, mechanical, and thermal hydraulic core parameters and does not result in violation of fuel rod and FA operability criteria.

Visual inspection: Fuel Rod Displacement, WLTA AA02-03, Face 4



inspection 2007 *inspection 2008* *inspection 2010*

Visual inspection

- During all inspections were not observed visible changes of geometrical dimensions of fuel rods as a consequence of irradiation growth and irradiation-induced swelling that can influence on decrease of operability.

- Also the inspection of Russian fuel which faced Westinghouse LTAs was done. Visual inspection have not revealed any appreciable impact of the new set of structural materials in the core on the corrosion behavior of the fuel rod cladding, FA spacer grids, and FA top and bottom nozzles of either Russian or Westinghouse fuel.

- In mixed core conditions were not observed any mechanical mutual influence both Russian and Westinghouse fuel.

Leakage test

- Leakage test was done after each operation cycle.
- After the 4th cycle one WLTA had fuel rod non-tightness. The defect was assumed to be minor "gas leakage". FAs found to be leaking based on statistical analysis, but having I-131 activity in the leakage test samples below $1.0*10^{-6}$ Ci/kg, can be further operated.
- The FA leakage test done in the operating reactor and during the outage found that after the 4th operation cycle five WLTAs were leakage-tight.
- According to results of 4 cycles of operation it was concluded that Westinghouse fuel can be operated in mixed cores of WWER-1000 reactors at temperature loads corresponding to the regulatory basis and in primary water chemistry.

Conclusions

- The post irradiation examination of WLTAs after 4 cycles of operation did not reveal any visible damage to or non-design position of individual FA components, which could result in the engagement with the adjacent core components, equipment or FA handling devices. Neither were there observed visible changes of geometrical dimensions of fuel rods as a consequence of irradiation growth and irradiation-induced swelling that could adversely affect operability. Further, PIE did not show any mutual influence of different sets of structural materials of both WLTAs and the resident fuel on corrosion resistance.
- Positive results of WLTAs operation allowed to install during 2010 outage 42 FAs produced by Westinghouse and enabled NNEGC Energoatom to enter into a contract with Westinghouse for delivery of fuel for three WWER-1000 units.

Thank you!

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