Qualification of VVER Steam Generator Tubes Inspection

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INTRODUCTION

- Inspection of steam generator tubes is an essential part of the component integrity assessment and greatly contributes to safe and reliable operation of the plant.
- Inspection performance shall be first demonstrated and later ensured through a QA program.
- Inspection performance is demonstrated on a qualification process.
- This paper presents Tecnatom approach to qualify its VVER steam generator tube inspection system.
QUALIFICATION STRATEGY

- Follow general rules of ENIQ TJ requirements
- Separate QUALIFICATION of inspection system components
  - Mechanical devices
  - ET instrument
  - Analysis software
  - Probes and inspection techniques
  - Inspection Procedure
  - Personnel
- Final “assembly” of documentation on TJ document
TECHNICAL JUSTIFICATION (TJ)

- COMPONENT DETAILS
  - Engineering data
    - Inspection area
    - Construction
    - Operation
  - Defect descriptions

- INSPECTION OBJECTIVES

- NDE METHOD AND TECHNIQUE SELECTION

- INSPECTION SYSTEM AND TECHNIQUES

- EXPERIMENTAL EVIDENCES

- ESSENTIAL VARIABLES VERIFICATION
COMPONENT DETAILS (I)

- Horizontal position of tube bundle
- Austenitic steel tubes 08XH18N10T (SS 321)
  - WWER 440: 5,500 tubes around
  - WWER 1000: 11,000 tubes around
- Tube supports of stainless steel stripes
- Relatively low flow velocity in the tube bundle
- Hydrazine ammonia water chemistry
- Collectors material
  - Austenitic stainless steel 08XH18N10T (SS 321) (WWER 440)
  - Low alloy steel (carbon steel) 10GN2MFA (WWER 1000)
COMPONENT DETAILS (II)

WWER 440

WWER 1000
DEFECT DESCRIPTION

- Type of defects:
  - Tubes
    - ODSCC
    - Pitting
    - Wear
  - Collector
    - Cracking of collector material
- 90% of defects located at tube support plate intersections in hot leg
ODSCC CHARACTERISTICS

- Initiated directly on the outer surface or in the bottom part of corrosion pits
- Preferentially oriented in the axial direction
- Main mechanism of crack propagation is IGASCC, but also some cases of transgranular SCC observed
- Distribution of indications does not follow general rules, each SG has its own particular flaw distribution
- Most indications located in the middle of tube Support plate intersection
EXAMPLES OF TUBE DEFECTS
COLLECTOR DEFECTS (I)

- Three (3) types of collector ligament cracks can be defined according destructive examination performed on replaced SG collectors
  - Satellite cracks (micro-dimension)
    width: up to 0.1 mm, length: up to 1 mm
  - Planetary cracks (between two adjacent holes)
    width: 0.2 to 0.5 mm, length: up to full thickness of ligament, depth: up to 30 mm
  - Arterial cracks (through several holes)
    width: more than 0.5 mm, length: up to 1000 mm, depth: up to 171 mm (wall thickness including cladding)
COLLECTOR DEFECTS (II)

- Planetary crack
- Arterial cracks
- Satellite cracks

Collector secondary side
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INSPECTION SYSTEM COMPONENTS

RPC ACQUISITION SYSTEM CONFIGURATION
MECHANICAL DEVICES QUALIFICATION

- Input documents: specification and design documents
- Test protocol developed to meet specification requirements
- Test protocol applied and verified
- Functional test
- Blank test
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ACQUISITION SCREEN
ET INSTRUMENT QUALIFICATION

- Internal qualification
  - According to Tecnatom development and manufacturing procedures
  - Version and configuration control
- External qualification
  - EPRI qualified: Rev 5 SG Guidelines
  - As part of inspection system: Forsmark (Sweden), KKL&KKM (Switzerland), Tsuruga (Japan), GE (USA), Kozloduy (Bulgaria), Loviisa (Finland), CNEA (Argentina), Maanshan (Taiwan)....
ANALYSIS SOFTWARE QUALIFICATION

- Internal qualification
  - Specification and design documents
  - Verification and configuration control documents
  - Final acceptance documents
  - User manual and qualified software as final product

- Versioning and verification documentation updated

- External qualification
  - EPRI qualified: Rev 5 SG Guidelines, Rev 6 in progress
EXPERIMENTAL EVIDENCE (I)

COLLECTOR INSPECTION

- Defect library
  - Realistic flaws on collector and tube material
  - EDM notches
  - Magnetic variation signals
- 100% of library defects detected
- Achieved inspection objectives
  - Detection of EDM notch of 1 mm depth, 3 mm length, 0.1 mm width on collector edge
  - Discrimination of false indications from magnetic variations
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EXPERIMENTAL EVIDENCE (II)

QUALIFICATION BLOCK

COLLECTOR CRACK

OD TUBE CRACK

MAGNETIC VARIATION

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EXPERIMENTAL EVIDENCE (IV)

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DIMENSIONS IN mm

INTERNAL AXIAL NOTCH
E1 / E2 / E3

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EXPERIMENTAL EVIDENCE (V)

- Tube defect library
  - Manufactured by NRI
  - Simulated Pitting
  - Realistic ODSCC
  - EDM notches
  - At different tube locations: bend, straight area, support plate intersections, expansion

- Open Practical Demonstration of Inspection Procedures
EXPERIMENTAL EVIDENCE (VI)

- Most results based on NRI manufactured tube library

- Very limited availability of pulled tube data
EXAMPLES OF SIGNALS

- Realistic SCCOD, 30% TW, 10mm L : 38% Bobbin
EXAMPLES OF SIGNALS

- Simulated Pitting, 50% TW, 1mm L : 46% Bobbin
EXAMPLES OF SIGNALS

- Realistic SCCOD at U bend, 50%TW, 10mm L: 21% Bobbin
EXAMPLES OF FIELD SIGNALS

PITTING
EXAMPLES OF FIELD SIGNALS
PERSONNEL QUALIFICATION

- Tecnatom personnel certified according to European (EN-473) and American (ASME, EPRI) rules
- EN-473 requirements
  - Training can be internal or external
  - External agency responsible for certification
- ASME: SNT-TC-1A, CP-189
  - Company responsible for certification implementation
  - Internal training and certification written program
- EPRI Guidelines requirements for analysts (QDA certification)
CONCLUSIONS

- Qualification of Inspection techniques is a complex task
- ENIQ TJ helps to organize and compile all qualification documentation
- Qualification should be kept updated to current system configuration
- Availability of pulled tube data will improve knowledge of POD on “real conditions”
- Personnel qualification and training is an essential part on the performance of the inspection