LEAK BEFORE BREAK CONCEPT BASED ON FRAMATOME EXPERIENCE

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workshop on

NEW CHALLENGES TO LBB

NOTE EER TS 01.0585

METHODOLOGY

1. **EVALUATE THE INPUT DATA**
   - loads (service and accident)
   - material properties including the aging effects
   - leak detection capabilities

2. **DEMONSTRATE THE ABSENCE OF ANY INDIRECT FAILURE OVER THE ENTIRE LIFE OF THE PLANT THAT COULD CHALLENGE THE INTEGRITY OF PIPING**
   - water hammer
   - creep
   - erosion-corrosion
   - stress corrosion cracking
   - fatigue

METHODOLOGY

3. PERFORM FRACTURE MECHANICS ANALYSIS

- IDENTIFY ALL SENSITIVE AREA REGARDING THE WORST MATERIAL PROPERTIES OR THE HIGHEST STRESS LEVELS
- UNDER SERVICE LOADING, DETERMINE THE DETECTABLE FLAW SIZE FOR EACH SENSITIVE AREA
- UNDER SERVICE + ACCIDENT LOADINGS, DETERMINE THE CRITICAL FLAW SIZE LEADING TO PIPE RUPTURE FOR EACH SENSITIVE AREA
- THE LBB CONDITIONS ARE FULFILLED WHEN THE CRITICAL FLAW SIZE IS VERIFIED TO BE MUCH HIGHER THAN THE DETECTABLE FLAW SIZE FOR ANY AREA IN THE COMPONENT (A MARGIN OF 2 IS CURRENTLY USED FOR LBB ANALYSIS IN PIPING).

INTRODUCTIVE REMARKS

DEVELOPMENT OF LBB CONCEPT FOR THE LAST 20 YEARS:

- IN THE FRAME OF INTERNAL R&D STUDIES
- IN THE FRAME OF THREE-PARTY CO-OPERATIVE STUDIES BETWEEN CEA, EDF & FRAMATOME
- AT AN EUROPEAN LEVEL IN THE JOINT STUDIES WITH SIEMENS IN GERMANY
- AT THE INTERNATIONAL LEVEL IN THE FRAMEWORK OF SEVERAL RESEARCH PROJECTS (IPIRG I &II, DP3,…)

APPLICATIONS ON VVER

- WITHIN TACIS PROGRAMME, EXAMINATION OF THE LBB BEHAVIOUR OF THE MCL OF VVER 440/230 NPP KOLA 1&2 AND NOVOVO 3&4

- WITHIN MOCHOVCE CONTRACT, EXAMINATION OF THE LBB BEHAVIOUR OF THE MCL OF VVER 440/213 MOCHOVCE UNIT 1&2

APPLICATIONS ON BELGIUM PLANTS

- THE LBB CONCEPT WAS SUCCESSFULLY APPLIED TO THE MCL OF TIHANGE 2 AND DOEL 3 IN BELGIUM.

APPLICATIONS
AS DEFENSE-IN-DEPTH CONCEPT

- LBB APPLICATION WAS SUCCESSFULLY LED FOR THE MCL OF 900 MWe FRENCH REACTORS, INTRODUCED HERE AS A DEFENSE-IN-DEPTH CONCEPT TO SUBSTANTIATE THE PROOF OF THE INTEGRITY OF CAST STAINLESS STEEL ELBOWS.

FUTURE EPR PLANTS

- WITHIN EPR PROJECT, PREPARATION OF A LBB PROCEDURE WITH APPLICATIONS.

LBB IMPLEMENTATION ON MCLs OF NPP TIHANGE 2 & DOEL 3

- 900 MWe 3 LOOPS PWRs COMMISSIONED IN 1982
- UTILITY: ELECTRABEL
- NSSS SUPPLIER: FRAMATOME
- ARCHITECT ENGINEER: TRACTEBEL

MAIN BENEFITS

- REMOVAL OF TWO LARGE SNUBBERS ON EACH REACTOR COOLANT PUMP
- REMOVAL OF SOME RESTRAINTS TO FACILITATE SG REPLACEMENT AT DOEL 3
- REDUCTION OF THE LOADS ON RPV INTERNALS IN FAULTED CONDITIONS
- JUSTIFICATION OF REACTOR COOLANT PUMP BEHAVIOUR IN CASE OF OVERSPEED

RECOMMENDATIONS FOR LBB IMPLEMENTATION ON MCLs OF VVER 440

FRAMEWORK: TACIS 91

VVER 440/230 NPP KOLA UNIT 1&2 and
NOVOVORONEZH UNITS 3&4

WEST CONSORTIUM SIEMENS-EdF-FRAMATOME &
THE RUSSIAN SUBCONTRACTORS HEADED BY
VNIIAES

MAIN RESULTS

- NPP's K1, K2: RESULTS ALLOW TO IMPLEMENT LBB
- NPP's NV3 & NV4: RESULTS SHOW THAT LBB COULD BE IMPLEMENTED TAKING INTO ACCOUNT THE RESULTS OF THE STUDY CONDUCTED. IN OTHER WORDS, A SAFETY ENHANCEMENT PROGRAM HAS BEEN ESTABLISHED
- IMPROVEMENT OF MATERIAL DATA BANK OF VVER 440 NPP (SEE FIG. FOR RESULTS)
- CONSISTENCY OF RESULTS CONDUCTED BY SIEMENS AND FRAMATOME TO VERIFY THE FULFILMENT OF THE LBB REQUIREMENTS STRENGTHENS THE VALIDATION FILE OF OUR PREDICTIVE METHODS

LBB AS A DEFENSE-IN-DEPTH CONCEPT

- **FRAMEWORK**: RESEARCH PROGRAM ON THE THERMAL AGING EMBRITTLEMENT OF PRIMARY CF8-M TYPE CAST SS ELBOWS OF 900 MWe REACTORS

  THE INTEGRITY OF SUCH COMPONENTS WAS SUCCESSFULLY DEMONSTRATED OVER THE ENTIRE LIFE OF PLANTS

- **OBJECTIVE**: LBB DEMONSTRATION INTRODUCED AS A DEFENSE-IN-DEPTH CONCEPT TO STRENGTHEN THE INTEGRITY DEMONSTRATION OF CAST STAINLESS STEEL ELBOWS

REPRESENTATIVE AREAS

- HOMOGENEOUS AND INHOMOGENEOUS GIRTH WELDS OF PRIMARY LOOP PIPINGS

- THE FIVE PRIMARY CAST STAINLESS STEEL ELBOW COMPONENTS

GIRTH WELD ASSESSMENT

1. MATERIAL PROPERTIES

FICTITIOUS MATERIAL COMBINING TENSILE PROPERTIES OF BASE METAL & TOUGHNESS PROPERTIES OF WELD METAL

2. GEOMETRY

STRAIGHT PIPE WITH MINIMUM REQUIRED THICKNESS

3. PREDICTIVE METHOD

J VALUES COMPUTED FROM EPRI HANDBOOK

ELBOW ASSESSMENT

- LOCATION AND ORIENTATION OF CRACK

  THE LEAST FAVOURABLE CRACK LOCATION IS:

  - 45° ORIENTED ON CROWN FOR HOT ELBOW
  - AXIAL AT THE INTRADOS FOR COLD ELBOWS

- CRITICAL CRACK SIZE AND BREAK AREA PREDICTIONS

  - ELASTIC-PLASTIC F.E. COMPUTATIONS TO BRACKET THE CRITICAL FLAW SIZE
  - DEVELOPMENT OF J ESTIMATION SCHEME TO COMPLETE THE CRITICAL SIZE AND BREAK AREA PREDICTIONS

EPR : ANALYSIS & RESULTS

For the Stability analysis:

Two postulated defects (5x50mm) and (5x70mm) in the most sensitive area (e.g. RPV outlet homogeneous and dissimilar welds):

- do not grow during the plant life,
- their stability is assured; no initiation is induced even under the most severe loading conditions: full power normal operating and Design Earthquake
- it is needed to submit the defects to equivalent of ten times the operating transients for one plant life to propagate through the wall-thickness
- an exceptional defect (5x415mm), upper bound of the conventional defect (5x140mm), does not go through the wall before the end of plant life; fatigue crack growth is very limited (< 3mm at deepest and surface points)
- the crack growth is less significant at surface points than through the wall thickness.

EPR : ANALYSIS & RESULTS

For through-wall crack analysis:

Weld areas connected to primary heavy components were investigated (e.g. RPV inlet and outlet, SG inlet and outlet, RCP inlet and outlet) and show that:

- concerning the cross over leg and the cold leg, critical crack sizes are greater than 700mm even under the most severe loading conditions (NOC + DE) and the leakage flow rate induced at NOC is higher than 800 l/mn,
- concerning SG inlet, the critical crack size is greater than 534mm under the most severe loading conditions (NOC + DE) and the leakage flow rate induced at NOC is higher than 500 l/mn,
- at the most loaded zone in the primary circuit (RPV outlet), even under the most severe loading conditions (NOC + DE), the critical crack size is greater than 250mm and the leakage induced at NOC is greater than 140 l/mn.

CONCLUSIONS

- PRIMARY PIPINGS OF 900 MWe NPP FULFILL THE LBB CONDITIONS WITH SAFETY MARGINS IN AGREEMENT WITH NRC REQUIREMENTS

- LBB IS INTRODUCED SUCCESSFULLY AS A DEFENSE-IN-DEPTH CONCEPT IN ORDER TO STRENGTHEN THE INTEGRITY FILE OF PRIMARY CAST SS ELBOWS

CONCLUSIONS

- LBB CONCEPT WAS SUCCESSFULLY APPLIED TO THE PRIMARY LOOP PIPING OF TIHANGE 2 AND DOEL 3. THE JUSTIFICATION WAS ACCEPTED BY THE BELGIAN SAFETY AUTHORITIES.

- LBB CONCEPT HAS BEEN SUCCESSFULLY APPLIED ON EPR DURING THE BDOP.

- LBB ANALYSES HAVE BEEN MADE ON VVER PLANTS WITH ESTABLISHMENT OF A SAFETY ENHANCEMENT PROGRAM.