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Contract FIKS-CT-2001-00172

Nuclear Risk-Based Inspection Methodology

for passive components

(NURBIM)

Final Report
(short version)

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Content

1 Objectives

Inspection and maintenance of nuclear power plants (NPPs) is a prerequisite for safe operation but represents a significant burden for plant operators in Europe. If the European nuclear industry is to remain competitive and maximise its contribution to the reduction of global warming, then more focussed inspection and maintenance schedules are needed that will reduce costs and outage times, while maintaining or increasing plant safety. The conclusions of EURIS were that this could be best achieved through a 'Risk Based Management Philosophy'. The objective of the project NURBIM (Nuclear Risk Based Inspection Methodology) is to further pursue the recommendations of EURIS and subsequent work of ENIQ TG4 in order to develop improved procedures to identify where the highest likelihood of damage/failure is located in plant and, then, to provide quantitative measures of the associated risks. Within this context, risk is defined in terms of a consequence and the probability of incurring those consequences. Such a risk-based approach would, through the focusing of resources, lead to increased safety, reliability and availability of the overall plant. The NURBIM project will focus on the definition of best practice methodologies for performing risk-based analyses and establishing a set of criteria that can help Regulatory bodies in Europe to accept risk-based inspection (RBI) as a valid tool for managing plant safety.

2 Programme of work

The NURBIM consortium (see **Figure 2.1**) is formed of utilities operating PWR and BWR nuclear power plants representing half of the nuclear generating capacity within Europe and technical support departments and organisations with a strong background in structural integrity issues, risk assessment, inspection of nuclear power plant components and evaluation of operating experience. The project was divided into nine work packages (WP) dealing with the major aspects of a risk based inspection methodology (see **Figure 2.2**).

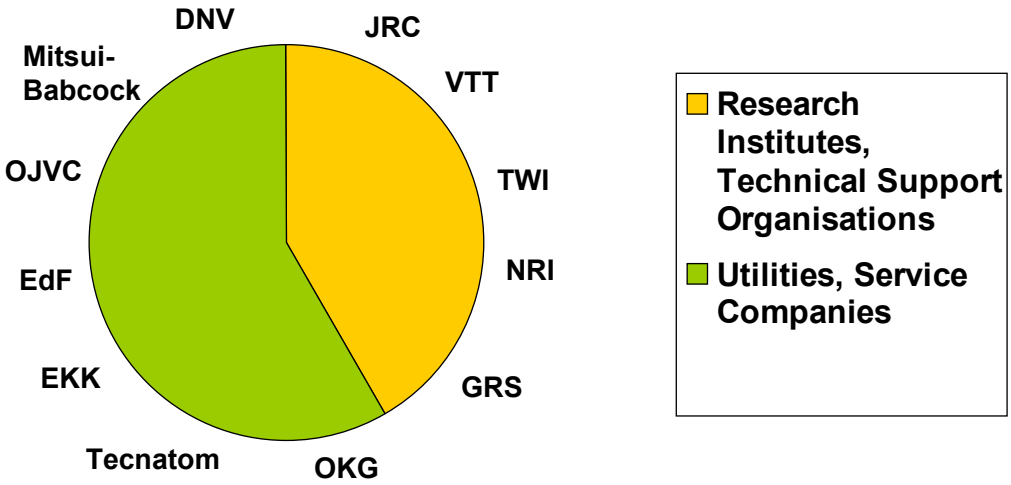

Figure 2.1: The NURBIM consortium (12 Members, 8 Countries)

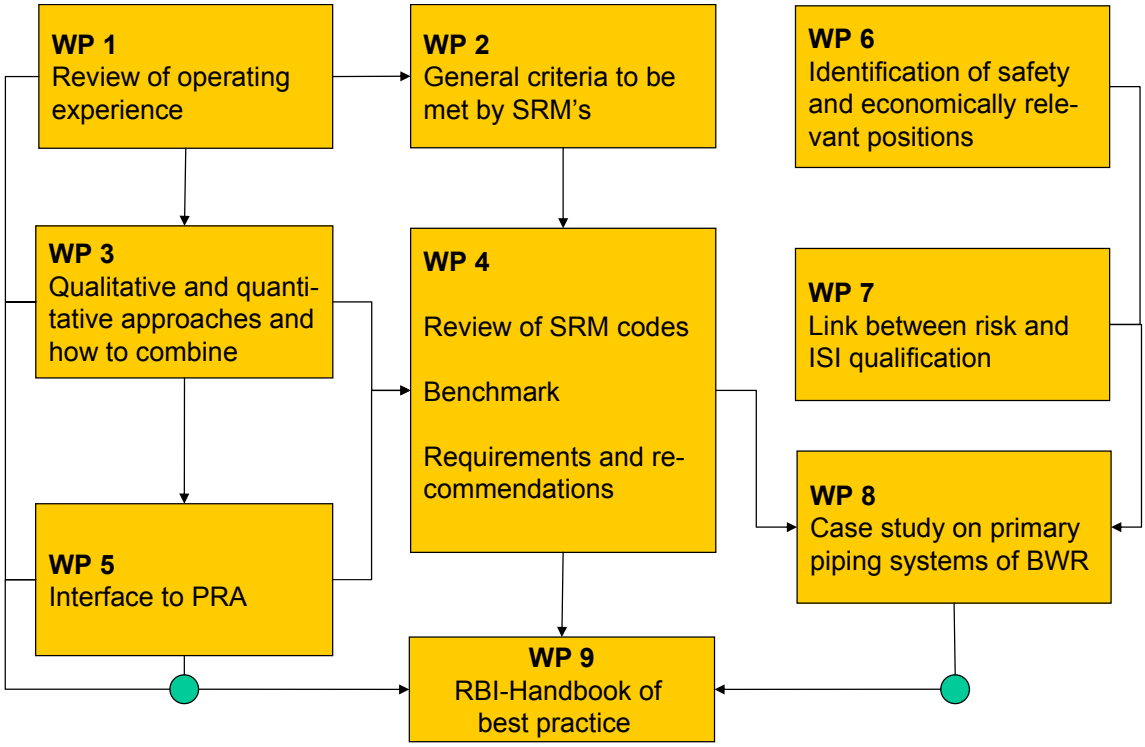

Figure 2.2: The NURBIM work packages (WP).

3 Results

In WP1 available information on relevant operating experience was reviewed. From that data a terminology of all observed active damage mechanisms was developed. A classification scheme assigning the damage mechanism to certain materials, affected components, potential failure mode was developed and the controlling variables and the principle characteristic (damage as a function of time or frequency of demand/load behaves linear, non-linear degressive, non-linear progressive) were identified. Furthermore a description of relevant data resources is given.

In work package 2 a general set of criteria that a Structural Reliability Model (SRM) should satisfy was established in order to demonstrate that it is suitable, verified and validated.

A questionnaire that will assist to assess whether it is feasible to use a SRM that can be verified and validated to determine the probability of failure of a plant component subjected to a particular degradation mechanism was developed in WP3. This questionnaire was completed by the NURBIM partners within their range of knowledge for the damage mechanisms identified in WP1. In this way opinions of the prospect for the development of SRMs for the different damage mechanisms were obtained. Furthermore a procedure of how to combine quantitative and qualitative risk assessments.

A benchmark study for the damage mechanism SCC and for fatigue have been conducted in work package 4. With the six SRM codes NURBIT, PRODIGAL, ProSACC, PROST, STRUREL and WinPRAISE failure probabilities were calculated for various pipe sizes under different loading conditions and a large number of parameter variations. From the evaluation of these results a set of requirements and

recommendations for the use of SRMs and associated software in risk based inspection studies were formulated.

Work package 5 investigates the interface between the probability of failure and the consequences by discussing how the loss of the pressure boundary barrier function is treated in present PSA's and resolving the limitations in view of a risk-based ISI methodology.

The first part of work package 6 deals with the question of how to identify risk significant locations. Starting with a review of the Westinghouse and EPRI approach it ends with the description of a developed seven step approach that gives a possible logical way of identifying risk significant locations. In the second part an example of a cost benefit analysis with the NURBIT software is presented, which can be used as a principle guide of how to conduct the different steps in a cost benefit consideration.

That a link between the risk-based in service inspection and the ENIQ qualification process can be established via a definition of user defined probability of detection curves is elaborated in work package 7. The main points defining a frame of a viable risk management process that optimises the inspection programme are presented too. Finally it is shown that only a partly optimised risk-based ISI programme is achievable with the current state of knowledge and conclusion together with future needs have been formulated.

In work package 8 a case study including some primary piping systems of a BWR plant was conducted. An analysis with the NURBIT code shows that the currently conducted inspection methodology can be optimised in terms of risk, radiation dose and costs.

The main results and outcomes from the above work packages were compiled in work package 9 into an electronic data collection covering the major elements of a risk-based ISI methodology (see **Figures 3.1 and 3.2**).

Although all technical reports which summarize the work performed are helpful documents for the planning, execution and review of a Risk Based In Service Inspection programme the most valuable parts of the project are the extensive benchmark of the Structure Reliability Models and the case study. The extend of the benchmark is unique and can be used in the future as a nucleus of a verification and validation platform.

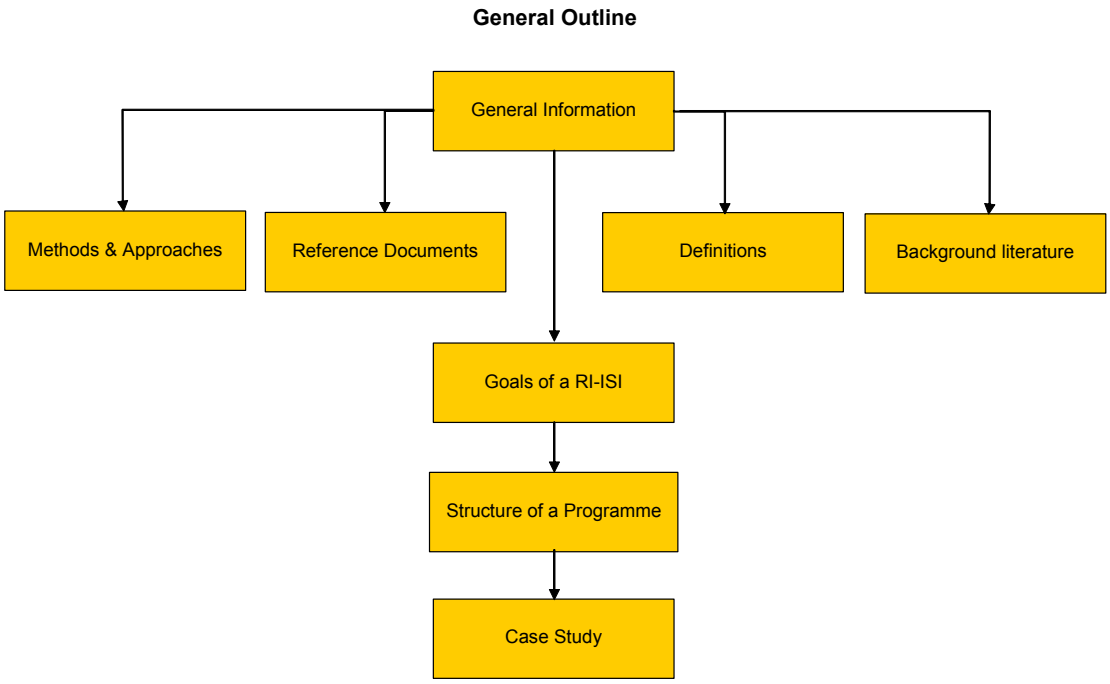

Figure 3.1: Content of the data collection

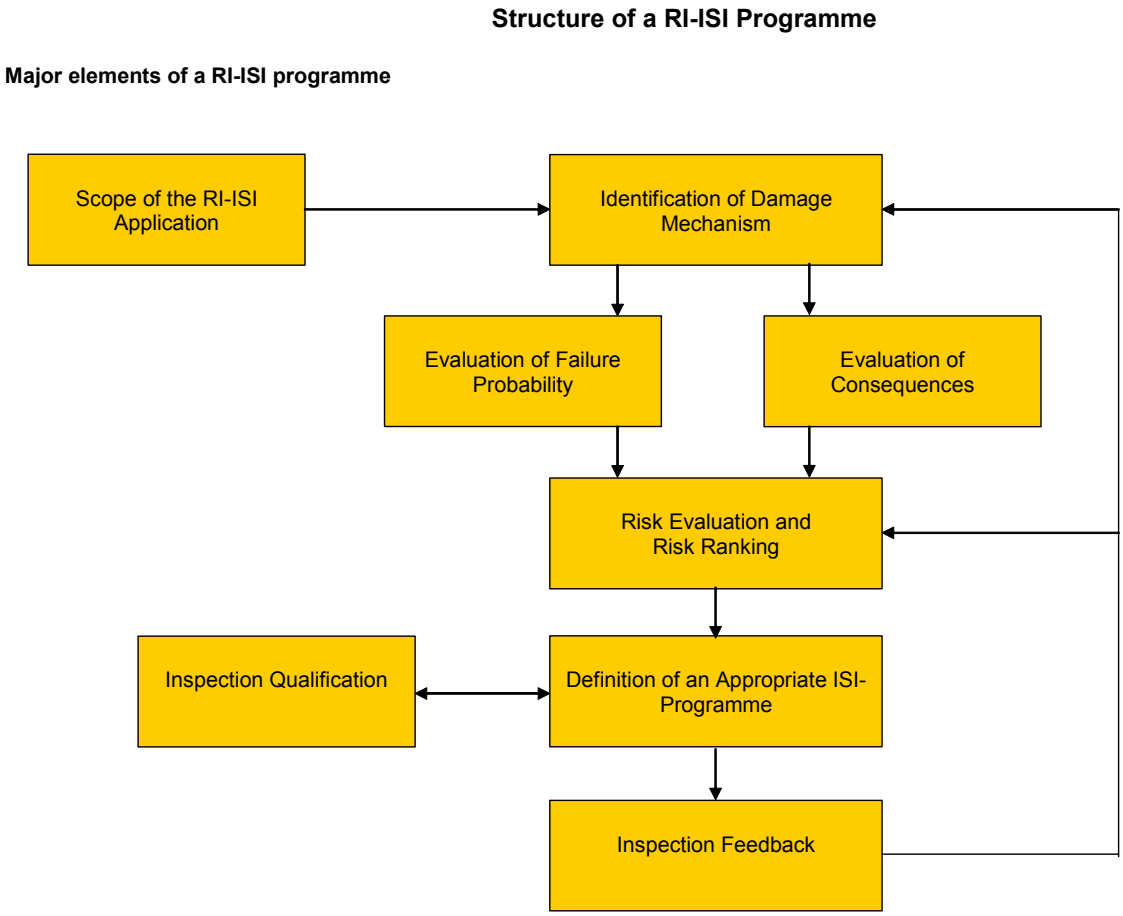

Figure 3.2: Major elements of a Risk Based In Service Inspection programme (content of the “Structure of a programme” box in Figure 3.2).

4 List of public available NURBIM reports

Title	Number	Author
NURBIM Final Report		T. Schimpfke H. Schulz B. Brickstad V. Chapman B. Shepperd S. Kelly S. Olsson J. Wintle A. Muhammed K. Simola
NURBIM Final Report (short version)		T. Schimpfke H. Schulz B. Brickstad V. Chapman B. Shepperd S. Kelly S. Olsson J. Wintle A. Muhammed K. Simola
Electronic handbook of RBI Major elements		T. Schimpfke H. Schulz V. Chapman C. Cueto-Felgueroso P. Dillström L. Gandossi S. Olsson
Compilation of current active or potential Damage Mechanisms in European Light-Water Reactor Power Plant Components	D1	F. Michel et al.
Definition of a set of criteria that should be met by a suitable structural reliability model	D2	V. Chapman
Development of a procedure/process of integrating qualitative and quantitative risk based assessments into a single risk based ISI programme	D3	V. Chapman J. Wintle
Review and benchmarking of SRMs and associated software	D4	B. Brickstad V. Chapman T. Schimpfke H. Schulz A. Muhammed
Review and benchmarking of SRMs and associated software, Appendix A1, SCC benchmark study	D4/Appendix A1	B. Brickstad
Review and benchmarking of SRMs and associated software, Appendix A2, STRUREL results for SCC	D4/Appendix A2	A. Muhammed

Title	Number	Author
Review and benchmarking of SRMs and associated software, Appendix B, Fatigue benchmark study	D4/Appendix B	T. Schimpfke
Review and benchmarking of SRMs and associated software, Appendix C, A short description of the Piping Reliability code PROST	D4/Appendix C	T. Schimpfke
Review and benchmarking of SRMs and associated software, Appendix D1, A short description of the NURBIT Piping Reliability program for stress corrosion cracking analyses	D4/Appendix D1	B. Brickstad
Review and benchmarking of SRMs and associated software, Appendix D2, Independent Review of NURBIT	D4/Appendix D2	A. Saarenheimo K. Simola
Review and benchmarking of SRMs and associated software, Appendix E, A short description of the WinPRAISE Piping Reliability program for fatigue and stress corrosion cracking analyses	D4/Appendix E	C. Cueto-Felgueroso B. Brickstad
Review and benchmarking of SRMs and associated software, Appendix F, Description of PRODIGAL	D4/Appendix F	C. Bell V. Chapman
Review and benchmarking of SRMs and associated software, Appendix G, A short description of ProSACC	D4/Appendix G	P. Dillström
Review and benchmarking of SRMs and associated software, Appendix H, A short description of STRUREL	D4/Appendix H	A. Muhammed
Investigate the interface between the probability of failure and the consequence for use in a risk based analysis	D5	K. Simola H. Schulz
Identification of risk significant locations	D6-1	V. Chapman
Cost-Benefit considerations in Risk Based ISI	D6-2	B. Brickstad
The Relationship Between Risk Based Inspection and the ENIQ Qualification Process	D7-1	B. Shepperd S. Kelly B. Brickstad
The Link Between Inspection Capability/Reliability and RBI-Review of existing information	D7-2	S. Kelly L. Fabbri et al.
Proposal of a viable risk management process that optimises the inspection programme	D7-3	V. Chapman
Set of Recommendations to Optimise Inspection Programme	D7-4	V. Chapman
Case Study, Primary Piping Systems at Oskarshamn 2	D8	S.Olsson
NURBIM Technical Implementation Plan (TIP)		T. Schimpfke H. Schulz