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ENIQ TGR DISCUSSION DOCUMENT

UPDATING OF RISK-INFORMED INSPECTION PROGRAMMES

ENIQ Report No 37

2009

ENIQ

European Network for Inspection and Qualification

JRC
EUROPEAN COMMISSION

EUR No 23929EN

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http://ie.jrc.ec.europa.eu/

Contact details:
Luca Gandossi
Tel.: +31 (0) 224 56 5250
E-mail: luca.gandossi@jrc.nl

EUR 23929 EN
ISSN 1018-5593
Luxembourg: Office for Official Publications of the European Communities

Printed in the Netherlands

European Commission
Directorate-General Joint Research Centre
Institute for Energy
Petten, the Netherlands

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December 2009 *ENIQ Report No 37* *EUR 23929 EN*

Approved by the ENIQ Task Group on Risk

ENIQ, the European Network for Inspection and Qualification, publishes three types of document:

Type 1 — **Consensus documents**
Consensus documents contain harmonised principles, methods, approaches and procedures and stress the degree of harmonisation between ENIQ members.

Type 2 — **Position/Discussion documents**
Position/discussion documents contain compilations of ideas, express opinions, review practices, draw conclusions and make recommendations from technical projects.

Type 3 — **Technical reports**
Technical reports contain results of investigations, compilations of data, reviews and procedures without expressing any specific opinion or evaluation on behalf of ENIQ.

This 'ENIQ TGR Discussion Document - Updating of Risk-Informed Inspection Programmes' (ENIQ Report No 37) is a type 2 document.

FOREWORD

This report is the outcome of one of the activities of ENIQ's Task Group on Risk (TGR) concerning risk-informed in-service inspection (RI-ISI).

ENIQ, the European Network for Inspection and Qualification, was set up in 1992 in recognition of the importance of the issue of qualification of NDE procedures used in in-service inspection programmes for nuclear power plants. Driven by European nuclear utilities and managed by the European Commission Joint Research Centre (JRC) in Petten, the Netherlands, ENIQ was conceived as a network for managing the available resources and expertise at European level. It was also recognised that harmonisation of codes and standards for inspection qualification would offer major advantages for all involved, with the ultimate goal of increasing the safety of European nuclear power plants. Further information on the ENIQ network and its activities can be found at: http://safelife.jrc.ec.europa.eu/eniq/.

ENIQ's work is done by two task groups: the Task Group on Qualification (TGQ) focuses on qualification of in-service inspection (ISI) systems, while the Task Group on Risk (TGR) focuses on risk-informed in-service inspection (RI-ISI) issues. The TGR has published the European Framework Document for Risk-Informed In-Service Inspection and is producing more detailed recommended practices and discussion documents on several RI-ISI-specific issues.

This discussion document is intended to help users involved in an RI-ISI application to maintain and update an RI-ISI programme. It also provides an overview of current ISI updating practices in most EU Member States with nuclear power plants in operation.

The members of the ENIQ Task Group on Risk are:

R. Alzbutas	Lithuanian Energy Institute, Lithuania
V. Chapman	OJV Consultancy Ltd, United Kingdom
D. Couplet	Tractebel, Belgium
C. Cueto-Felgueroso	Tecnatom, Spain
C. Faidy	EDF, France
R. Fuchs	Leibstadt NPP, Switzerland
L. Gandossi	JRC, European Commission, the Netherlands
J. Gunnars	Inspecta Oy, Sweden
P. Lafrenière	CANDU Owners Group, Canada
P. Luostarinen	Fortum Engineering Ltd, Finland
L. Horacek	NRI, Czech Republic
G. Hultqvist	Forsmark Kraftgrupp AB, Sweden
E. Kichev	Kozloduy NPP, Bulgaria
A. Leijon	Ringhals AB, Sweden
D. Lidbury	Serco Assurance, United Kingdom
J. Lötman	Forsmark Kraftgrupp AB, Sweden
P. O'Regan	EPRI, United States
C. Schneider	The Welding Institute, United Kingdom
K. Simola	VTT, Finland
P. Stevenson	Westinghouse Electric, United States
A. Toft	Serco Assurance, United Kingdom
A. Walker	Rolls-Royce, United Kingdom
A. Wegeland	Ringhals AB, Sweden
A. Weyn	AIB-Vinçotte International, Belgium

This ENIQ type 2 document was approved for publication by the ENIQ Task Group on Risk.

The authors of this report are Kaisa Simola of VTT and Luca Gandossi of IE-JRC. Contributions were made by Dénes Szabo (Hungary), Robertas Alzbutas (Lithuania), Reinhard Fuchs (Switzerland), Paul Lafrenière (Canada), Sorin Ghelbereu (Romania), Olavi Valkeajärvi (Finland), Juraj Neupauer (Slovakia), Burkhard Neundorf (Germany), Adam Toft (United Kingdom), Emil Kichev (Bulgaria), Ladislav Horacek (Czech Republic), Jan Lötman (Sweden), Carlos Cueto-Felgueroso (Spain) and Damien Couplet (Belgium).

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1 INTRODUCTION

The European Framework Document for Risk-Informed In-Service Inspection (RI-ISI) [1] is intended to provide general guidelines to utilities both for developing RI-ISI approaches and for using pre-established approaches or adapting them to the European nuclear environment, taking into account national regulatory requirements and utility-specific characteristics.

The Framework Document emphasises the process of keeping RI-ISI living, i.e. updated, and briefly discusses the concept of living RI-ISI. An effective risk-informed inspection strategy requires a feedback procedure to update the risk ranking after changes are made to the plant or other relevant information is acquired. Furthermore, the document published by the Nuclear Regulatory Working Group [2] highlights performance monitoring and updating of RI-ISI programmes. A US document on RI-ISI updating [3] gives several examples of plants which have completed updates of their RI-ISI programmes.

This European Network for Inspection and Qualification (ENIQ) discussion document is intended to help users involved in an RI-ISI application to maintain and update an RI-ISI programme. It also provides an overview of current ISI updating practices in most EU Member States with nuclear power plants in operation.

2 CAUSES OF CHANGES IN RISK RANKING

Risk ranking of piping is the most important of several aspects which could influence risk-informed selection of inspection targets. Others include accessibility, radiation doses, inspection costs and availability. One typical criterion for acceptance of an RI-ISI programme is that the impact of implementation must be risk-neutral (or result in no more than a very small increase). Changes to the risk ranking could pose a challenge to meeting this criterion. This report focuses on factors that can affect the risk ranking. This section describes and defines possible causes of changes in risk ranking.

Changes in risk level can basically arise either from a change in the failure probability or from a change in the consequences of the failure. There will not necessarily be a change in the ‘true’ probability or consequence, but the estimate can be updated based on better understanding.

The main issues with a potential influence on risk ranking are:

- plant changes;
- changes in operating and maintenance procedures;
- changes in input information for failure probability and consequence evaluation, due to, for example, operating experience;
- changes in models used for failure probability and consequence estimation.

The causes may be classified based on whether they affect the consequence or the failure probability. One key aspect is that the failure probability is affected by changes related to a specific piping element, whereas the failure consequences depend on changes not directly related to the piping element or system in question. These major issues are described in more detail in Sections 2.1 to 2.4; the effects on both probability and consequence assessment are also discussed. Chapter 3 further discusses issues related to consequence evaluation with the probabilistic safety assessment (PSA) model.

2.1 Plant changes

Plant changes are the most evident and significant reasons for changes in risk ranking. Changes directly related to the piping system in consideration could be physical, such as installation of new piping or equipment, piping supports, etc. Other changes, for example in piping loadings and environmental conditions (e.g. due to changes in chemistry), may also have to be considered. All these changes can affect the failure probability of the piping in question. The impact of such changes should be evaluated when any ISI programme, whether risk-informed or deterministic, is updated.

Plant changes not directly related to the piping system in question do not normally have an impact on the failure probability, but they can affect the consequences of a piping failure. For example, as a result of a change, the plant response to a pipe failure can be different. The impact of such changes should be evaluated with the PSA model once the plant changes have been incorporated. The PSA updates will indicate whether there is any significant change in the consequence assessment.

2.2 Changes in operating and maintenance procedures

Changes in operating and maintenance procedures could influence the risk ranking. These will mainly have an impact on the consequence assessment. For instance, changes to the test intervals for stand-by systems affect the unavailability time estimate in the PSA, since this is assumed to be half of the test interval. If the frequency of testing or maintenance work to verify the operability of a system is increased, this will affect the PSA results by reducing the consequences. On the other hand, more frequent testing could contribute to increasing the probability of piping failure if the testing places significant loads on the system. Changes in operating procedures can influence the crediting of action by the operator in accident situations, which is reflected in the consequence assessment.

2.3 Updating of model input information

As discussed above, physical and procedural changes to plants should be reflected in the input for failure probability and consequence analyses. In addition, the input information can be affected by both industry-wide and plant-specific operating experience. This includes degradation, leak and break experience, feedback from inspections on the piping systems included in the RI-ISI programme and any failure data updates for systems contributing to the plant response.

Operating experience can have a big impact on the risk ranking, for example if new degradation mechanisms are discovered or if the severity of a known degradation mechanism needs to be re-evaluated. If the failure probabilities are evaluated quantitatively, the estimates based either on statistical analyses of service data or on structural reliability models (SRMs) need to be updated. In a more qualitative approach, new experience could give reason to change the degradation category of some segments.

In the case of consequence analysis, updating model input information means PSA maintenance (see Chapter 3), where initiating event data or equipment performance data in PSA models are updated with new knowledge. These updates are likely to have very little influence on the RI-ISI risk ranking.

2.4 Changes in models used for failure probability and consequence estimation

If the failure probabilities are quantified using SRM tools, further development of such tools could have an impact on the resulting failure probabilities. Better knowledge could resolve any significant uncertainties to which SRM input parameters are subject and lead to improvements in the models. Examples of model development range from inclusion of a new degradation mechanism in the analysis tool to improved modelling of residual stresses or of crack growth and more realistic detection probability. The impact of such changes is, in most cases, probably rather small.

Development of the PSA model, for instance extending the scope of the PSA by including low-power analyses or internal flooding hazards, can have a significant effect on the consequence evaluation. If the PSA originally used for determining the RI-ISI programme undergoes such major upgrades, changes in the risk ranking can be expected. Even smaller PSA updates can have an impact on the consequence evaluation. PSA issues are discussed further in Chapter 3.

3 PSA ISSUES

The main difference between a traditional and a risk-informed inspection approach is the evaluation of consequences. As in the Framework Document [1], this section refers to approaches using a plant-specific PSA model to determine the consequences of a pipe failure. The role of living PSA in RI-ISI updating is discussed, along with aspects related to the level, scope and level of detail of the PSA. The IAEA Technical Documents [4, 5 and 6] give more detailed information on living PSA, PSA applications and related quality issues.

In order to be able to review the risk ranking and update the RI-ISI programme, a plant-specific living PSA should be available. The IAEA gives the following definition of 'living PSA' [5]: 'A 'living PSA' (LPSA) can be defined as a PSA of the plant, which is updated as necessary to reflect the current design and operational features, and is documented in such a way that each aspect of the model can be directly related to existing plant information, plant documentation or the analysts' assumptions in the absence of such information.'

According to the IAEA guidance [5], the LPSA should be updated whenever changes occur in any aspect of plant operation or design or in the event of improved understanding of thermal-hydraulic or accident phenomenology, new information leading to revised data or advances in analytical techniques. The following types of change can be identified:

- plant changes, such as changes to the permanent configuration, hardware, plant operating procedures, maintenance procedures, etc.;
- changes to the component unavailability data due to a review of the plant-specific data;

- changes related to generic issues such as technological progress, availability of new information or feedback based on experience (e.g. real events not properly represented by the PSA).

According to the ASME standard on PSA, changes to the PSA model can be categorised as PSA maintenance or as PSA upgrade, defined as follows [7]:

- PSA maintenance: updating of the PSA models to reflect plant changes such as change of procedure or plant performance (data);
- PSA upgrade: incorporation into a PSA model of a new method or significant changes of scope or capability. This could include new methods for analysing human error, new data update methods, new approaches to quantification or truncation or new treatment of common causes of failure.

The coverage of PSA models can vary considerably from one country and nuclear power plant (NPP) to another. The levels of modelling of fires, flooding, external events, low-power modes and level 2 PSA have an impact on the quality of any risk-informed applications. In connection with RI-ISI, internal flooding studies are particularly important. The shut-down analyses are also needed to account for systems that are highly important during the revision period, such as residual heat removal systems.

All operating plant modes and initiating events should be addressed in the consequence evaluation in any RI-ISI process. If these were not covered in the PSA model at the time of the RI-ISI project, the missing modes and elements should still have been evaluated in a more qualitative way. Some of these originally missing elements can be modelled later along with a PSA upgrade and could, in turn, influence the risk ranking.

The impact of any PSA changes on RI-ISI should be assessed by people knowledgeable in both PSA and RI-ISI.

4 RI-ISI UPDATING CYCLE AND DOCUMENTATION

An RI-ISI programme should be updated regularly, but no specific guidance will be given in this document on the updating frequency, since it depends on national regulations, ISI cycles applied earlier, etc. Some general guidelines are provided in this section.

If the RI-ISI programme has been approved for only a single inspection interval, a major update has to be provided prior to the new interval. Clearly, if major changes are made to the plant during the ISI interval, a review and update of the RI-ISI programme should be considered. Relevant changes are not necessarily limited to changes affecting the piping systems covered by the RI-ISI programme. For instance, major modernisation of plant automation could significantly affect the plant response to a pipe break and thus change (reduce) the consequence and, accordingly, the risk level. The updating frequency for a living PSA should be in line with the RI-ISI updating, although the PSA might require more frequent updating than the inspection programme.

Changes to the RI-ISI programme are submitted for a regulatory review and acceptance. National regulations may give guidance on the content of the reporting.

Normally, more detailed documentation will be required prior to a new inspection interval. During the inspection interval, if significant changes causing a review of risk ranking have occurred, the changes in the inspection programme should be reported. In connection with the PSA updates, if there is no reason to change the ISI programme, a statement indicating that RI-ISI is not affected should be sufficient.

5 STATUS IN EUROPEAN COUNTRIES

This chapter summarises the situation in European countries regarding ISI updating regulations and practices. In countries where risk-informed ISI is accepted, guidance for RI-ISI updating is also given or being developed. Many European countries have not yet run RI-ISI projects. In these cases this chapter describes the ISI cycle and any demands for updating of the 'deterministic' ISI. Furthermore, in some cases the position expected if RI-ISI were to be applied in the future is described.

5.1 Countries with RI-ISI applications

RI-ISI has so far been applied in three European countries. Spain has adopted the Pressurized Water Reactor Owners Group (PWROG) methodology [8] and applied it to class 1 piping at several plants. In Sweden, the operators of BWR plants inspect their piping systems in accordance with the Swedish Nuclear Power Inspectorate's Regulations (SKIFS) [9], which use risk-informed principles for assigning components and parts of components to inspection groups, but do not use the PSA results in this process. The operators of the Swedish PWR units in Ringhals have applied the PWROG method. In Finland, RI-ISI is a regulatory requirement and at the Loviisa 1 plant all piping systems are starting to be inspected in accordance with the recently developed RI-ISI programme.

5.1.1 Finland

In Finland, Regulatory Guides YVL 2.8 [10] and YVL 3.8 [11] require use of risk-informed approaches for developing inspection programmes.

The Finnish regulatory guides do not specify the ISI updating cycle. The inspection programmes and procedures and the related documentation must be regularly reviewed and, if necessary, revised. The ISI programmes and procedures may have to be revised for the following reasons, among others:

- changes in standards and requirements;
- improved inspection techniques;
- inspection experience;
- feedback on the qualification system;
- experience gained from operating nuclear power plants in Finland and elsewhere.

When risk-informed methods are used for choosing components for inspection, changes in the facility itself or in the PSA could create a need to change the process for selecting the components inspected.

The licensee must update the PSA regularly to bring it into line with operating experience. In addition, the PSA model must always be updated whenever a substantial change is made to the plant design or to the procedures or a new substantial risk factor is found.

Comprehensive updating of the Finnish regulatory guidance is under way and is scheduled to be completed in 2010. In this connection, the guidance related to ISI is also being reviewed.

5.1.2 Spain

In Spain, several applications of PWROG RI-ISI to class 1 piping systems have been approved.

The Spanish guideline for development of RI-ISI applications for piping [12] and CSN Safety Guide 1.17 [13] indicate that the following changes must be taken into account in the periodic updates of the RI-ISI programme (because of the potential effect on segment definition, selection of structural elements, Core Damage Frequency (CDF) and Large Early Release Frequency (LERF)):

- changes in plant design (e.g. new piping or equipment, power uprating or changes in testing frequency and operating procedures);
- changes in postulated conditions or assumptions;
- examination results (e.g. detection of leaks or flaws);
- operating experience from the industry (e.g. failure due to new or degradation mechanisms or a non-postulated mechanism);
- changes in the PSA.

RI-ISI programmes must be updated during every inspection period (there are three inspection periods of three or four years each during the ten-year ISI interval). However, if the PSA is updated more frequently or new degradation mechanisms are detected, the RI-ISI application must be updated earlier.

Regarding changes in the PSA, Safety Guide 1.15 [14] establishes the aspects that should be considered for both updates and maintenance of the PSA due to its consequences and potential impact on the fault trees, event trees, hypotheses, interval between tests, human reliability models, etc. These partly overlap with the aspects listed above. They are:

- design changes;
- changes in periodic testing and surveillance procedures;
- changes in normal operating procedures;
- changes in abnormal operating procedures and in emergency operating procedures;
- changes in emergency plans;
- changes in the accident management programme;
- changes in knowledge of the plant as a result of specific operating experience;
- changes to the technical specifications;
- changes in maintenance policy (e.g. online maintenance);
- changes in the training programmes for operating personnel;
- safety analyses on refuelling;
- power uprates;
- licensing of new operating conditions.

The same safety guide requires operators of plants that apply the PSA for supporting risk-informed applications to perform a systematic evaluation of changes to the plant and operating experience at the time of every refuelling outage and, if applicable, to incorporate them in the PSA (this is called ‘second-level maintenance’) or only incorporate the operating experience and maintenance of the PSA database (‘first-level maintenance’). The changes to be incorporated in the second-level update (i.e. more significant changes) must be notified to the regulator not later than six months after the last refuelling outage and implemented as soon as possible, whereas implementation of less significant updates (i.e. first-level maintenance) may be delayed until the next second-level maintenance.

5.1.3 Sweden

In Sweden, a qualitative risk-informed approach was introduced in 1988 and became mandatory in 1992. Regulation SSMFS 2008:13 [15] allows use of both qualitative and quantitative RI-ISI methods. Ringhals NPP has run an RI-ISI project to define inspection programmes based on the PWROG approach and the current inspections are performed in line with the new risk-informed programme.

There is a regulatory requirement to review/update the ISI programmes based on experience, changes to the plant or changes in operating conditions (pressure, temperature, flow, chemistry, etc.). The review and update must be performed on a yearly basis [15].

As regards PSA updates, the safety analyses (deterministic and probabilistic) must be updated (section 4(1) in [8]). For instance, in Forsmark the PSA is updated every 12 to 24 months, depending on what kind of changes have been made.

ISI programmes based on PSA have to be reviewed and updated on a yearly basis. If the timing between ISI and PSA updates is different, the least that needs to be done is to make a judgment on whether there have been changes that could have an impact. In practice, this should not be a major issue, since most of the changes to the PSA analysis are fairly minor.

5.2 Countries which have run RI-ISI pilot studies

Several European countries have run pilot studies to test RI-ISI approaches. In these countries there is no guidance on updating RI-ISI programmes. Nevertheless, this subsection summarises some of their views and principles related to updating existing ISI.

5.2.1 Bulgaria

5.2.1.1 Bulgarian Regulatory Framework of ISI Activities

There are general requirements from the Bulgarian Nuclear Regulatory Agency (BNRA), relevant to In-Service Inspection activities in NPP. These are described in the following documents:

- Regulation for Providing the Safety of Nuclear Power Plants (NPPs) (published in May 2004, amended in September 2005).
- Regulation on the Procedure for Issuing Licenses and Permits for Safe Use of Nuclear Energy (published in July 2004, amended in June 2007 and June 2008).
- BNRA Instruction for In-Service Inspection (published in 2004).

An instruction for in-service inspection of base and weld metal of equipment and pipelines must be developed by the Licensee and must be part of the documentation submitted to the Regulator in the case of issuing an operating license for a NPP unit.

The components in the primary circuit must be designed, manufactured and located in a way that allows periodical testing and inspection during the whole period of operation of the NPP. The programme for control of the primary circuit must ensure monitoring of the influence of the radiation, development of cracks due to stress corrosion, embitterment and ageing of the materials especially in the places with high radiation levels and other factors. The condition of the base metal and the welded joints of SSC important to safety must be periodically controlled by qualified non-destructive testing regarding the locations, methods, defects detection and effectiveness according to specially developed procedures. Some additional requirements concerning ISI inspection intervals are also defined based on Russian designer' and manufacturer' documents (e.g. PNAEG-7-008-89 "Rules for structure and safe operation of equipment and pipelines of NPPs".

There are no specific requirements of the BNRA to Risk Informed In-Service Inspection (RI-ISI).

5.2.1.2 RI-ISI Pilot Study

A pilot project, based on the PWROG methodology for RI-ISI has been carried out in Bulgaria. Specifically, the risk-informed approach used was based on: (1) the US NRC RG 1.174 ("An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis", Nov 1998); (2) the US NRC RG 1.177 ("An Approach for Plant-Specific, Risk-Informed Decision Making: Technical Specifications", August 1998) and (3) the US NRC RG 1.178 ("An Approach for Plant Specific Risk-Informed Decision Making for In-service Inspection of Piping", Sept 1998).

In general, the US NRC Regulatory Guides define a four-element approach to evaluate proposed licensing basis changes: Element 1: Define the proposed change; Element 2: Perform engineering analyses; Element 3: Define the implementation and monitoring programme; Element 4: Submit the proposed changes. The following text reviews some significant aspects of the Bulgarian pilot study.

Scope definition. The systems addressed were chosen based on safety significance, part of the original ISI programme, impact on outage, and exposure. IN particular, the systems selected were: main steam, steam generator feed water, primary make-up and blow-down, low-pressure system for emergency and planned cooling, main coolant; pressurizer system, and emergency core cooling passive part.

Segment definition. The piping for the seven systems was divided into segments. These segments, primarily defined based on the associated consequence of failure, formed the basis upon which the subsequent steps were analyzed.

Consequence definition. The direct effects (loss of fluid) and indirect effects (spatial effects of the fluid on surrounding equipment) of a piping failure were identified for each segment. The consequences were defined without and with operator action.

Probabilistic Safety Assessment. The conditional Core Damage Frequency/Probability (CCDF/CCDP) and Conditional Large Early Release Frequency/Probability

(CLERF/CLERP) were estimated for each identified consequence, using surrogate components in the PSA model.

Failure probability assessment. Failure estimates were generated for each segment and consequence using industry failure history, plant specific failure history, service experience, and other relevant information. The Westinghouse structural reliability and risk assessment code was used to estimate the failure probabilities.

Risk evaluation. A risk evaluation was conducted to calculate the relative importance of each segment. The risk is based on the impact of CDF and LERF considering the consequence without and with operator actions. The primary risk metric was the Risk Reduction Worth.

Expert panel categorization. A panel of plant experts was assembled to review the data collected and to determine the final safety significance of each segment using a blended approach process of probabilistic and deterministic insights.

Structural element and NDE selection. Welds were selected for inspection using an NDE method based on the segment's safety significance and failure importance. All of the HSS segments were identified for examination as part of the RI-ISI programme. All the welds (or structural elements) within the HSS segments being highly susceptible to an active degradation mechanism were identified for examination. For the remaining HSS welds, a statistical sampling technique based on a concept of consumer risk was used to identify the minimum number of welds selected for examination on each segment.

Delta risk evaluation. The impact on risk was evaluated by comparing the RI-ISI programme against the original ISI program. Overall, the RI-ISI programme had to result in a risk reduction or be risk neutral compared to the original ISI programme.

Programme implementation. The ISI program and associated documents, procedures, and work schedules were revised to reflect the new RI-ISI programme.

Feedback loop. The RI-ISI program is a living program. To monitor the effectiveness of the programme, the impact of plant design changes, plant and industry experience, and PSA model changes are periodically evaluated.

Economic impact. An analysis was performed using two methods: Method 1 (average flows incomes/expenses) and Method 2 (Monte Carlo simulation). The impact of unplanned reactor trips, implementation costs, operational costs, outage impact, risk impact and personnel exposure and used generic data were taken into account. A number of recommendations for changes in ISI activities of the systems addressed were provided.

5.2.2 Czech Republic

In the Czech Republic, pilot studies on application of the EPRI RI-ISI approach adapted to WWER-type reactors have been conducted at Temelin NPP (Low Pressure Emergency Core Cooling System (ECCS), main steam and feed water piping outside containment) and Dukovany NPP (main primary piping and pressuriser surge lines).

In the near future, a programme of activities prepared to meet the licence renewal (LR) programme requirements over the period 2010-2015 could provide the driving force to replace the current deterministic ISI programme by at least a partial RI-ISI programme for selected piping systems at Dukovany NPP (four WWER 440 units). In the short term, the proposed 30-year extension of operations will require prospective selection of piping systems to be assessed in accordance with the RI-ISI method, risk-informed in-service inspection assessment of selected piping systems and development of an appropriate RI-ISI programme.

In general, especially from the legislation point of view, there is no substantial objection to the application of any approved risk-informed approach at Czech NPPs, due to the fact that the Czech Regulatory Body SONS developed and discussed VDMI Regulatory Guide 109 (close to US NRC Regulatory Guide 1.174) which is applied in preliminary testing at Czech NPPs for specific approved issues.

The only R&D on application of the RI-ISI method in WWER NPPs is connected with the living RI-ISI approach being developed using specific PSA plant databases and other tools.

5.2.3 France

The French utility EDF has developed the method called OMF Structures which uses risk-informed principles to optimize the preventive maintenance of structural components. The method has been piloted to 12 systems, and results of the studies are partially included in ISI programmes of several systems. However, the French Nuclear Safety Authority favours a deterministic approach strongly supported by experience feedback.

The requirements for ISI programmes in France are published in RSE-M Code for PWR plants with corresponding techniques, performance demonstration procedure and flaw evaluation procedure. The main difference with the ASME Code practice is the location and the performance objectives for the Class 1 piping ISI programme. All the locations are connected to the potentiality of mechanical degradation and flaw tolerance of the specific location. In addition to the inspections defined by RSE-M, additional inspections are done according to internal and external (EDF, AREVA and other NPP) experience feed back.

5.2.4 Lithuania

In Lithuania, an RI-ISI pilot study (IRBIS) was carried out at Ignalina NPP. The PWROG method adopted was applied in 2001. Details of the study are provided by Brickstad et al. [16].

After three years in operation, when the IRBIS project was completed, the RI-ISI programme was updated to take into account new data on pipe defects. A comparison with the previous RI-ISI programme was performed.

The main purpose of the updated study was to compare the results of two RI-ISI studies with slightly different initial data in order to investigate the robustness of the RI-ISI procedure and tackle the important question of uncertainty in RI-ISI methods.

The overall changes in the RI-ISI programme after updating were not very significant. However, they raised questions about the future need and procedure for RI-ISI updating. Analysis revealed that increased crack-initiation frequency was the main reason for such changes after updating.

At the time of the original IRBIS study, limited statistics were available and the data for the next three years showed increased crack-initiation frequency. This parameter can be estimated quite accurately if statistics from generic databases are also used. However, as the plant piping components age, crack-initiation frequency might gradually increase and it could be that RI-ISI studies use optimistic estimates for this parameter.

Although not applicable to the specific case of the Lithuanian study, but rather in general, another important reason for changes after RI-ISI updating is the change to safety barriers due to PSA updating. PSA studies are updated regularly in accordance with living PSA programmes to reflect the current plant-risk topography. The typical recommended updating period for PSA studies is five years.

The authors of the study consider that updating of RI-ISI programmes is necessary for similar reasons as in the case of updating of PSA studies. The same updating period as for the PSA could also be applied to RI-ISI programmes. However, further RI-ISI updating studies, especially including the results of PSA updating, could be useful in order to make more precise recommendations [17].

Current regulatory practice provides no guidance on the specific requirements for performance of PSA for any nuclear facilities or how PSA studies would be applied. The studies completed so far follow international practice and standards, mainly IAEA guides.

Risk-informed pilot studies showed that these require a change in the approach to regulation and that for implementation a more flexible regulatory approach needs to be adopted.

Up to now the Lithuanian regulatory body has not been using risk information directly for making changes to the regulatory practices and the way regulatory activities are carried out. However, a few regulations, for example the Regulatory Document for Assessment of IGSCC Damage in RBMK-1500 Reactors (issued in 2004) include risk-informed insights.

Presently, the regulatory authority in Lithuania is moving towards a risk-informed approach. The Lithuanian State Nuclear Power Safety Inspectorate (VATESI) is preparing PSA-related national regulatory documents (they are now at the internal review stage).

5.2.5 Slovakia

In 2008, Slovenské elektrárne, the Slovakian utility, ordered development of an RI-ISI method at VÚJE (the Nuclear Power Plant Research Institute), which had already been working on the topic for a long time. The method was issued at the beginning of 2008. At the same time, in order to test its feasibility, this method was applied as a pilot application to two systems: the surge lines pressuriser piping and the high-pressure injection system piping. The results were presented at the end of 2008. For the surge lines, no essential changes to the ISI programme were recommended. For the high-pressure safety system, a number of essential changes were recommended, e.g. introduction of volumetric examination of near-to-valve welds, reduction of outer surface examination methods, etc.

The method and the pilot study were presented to and adopted by the utility in January 2009. It was agreed that a workshop would be organised for all involved to explain the RI-ISI principles in more detail. In this way, a consensus will be reached between the utility and the regulatory body in order to decide how to continue with RI-ISI.

Recently, the following changes were made to the inspection periods for the main components of the four operating units (these inspections are not part of an RI-ISI programme):

- reactor: from 4 years to 8 years;
- pressuriser and piping: from 4 years to 8 years;
- main piping: from 4 years to 6 years;
- steam generator: from 4 years to 6 years.

These changes were based on specific documents, containing information such as reasoning reports, recommendations and assessments by the manufacturer, assessments of integrity and ageing, inspection results and history and inspection qualification. The changes were approved by the regulatory body and no RI-ISI approach was applied.

5.2.6 Switzerland

In Switzerland two pilot studies were performed a few years ago in two different nuclear power plants (Beznau and Leibstadt), using both the Westinghouse and EPRI methods. Since then, no real progress has been made.

At the moment the Swiss regulator ENSI (formerly HSK) is working on producing guidelines in accordance with the new nuclear law. So far, guidelines for PSA (general requirements on the scope, quality and applications of PSA) have been issued. At the moment, no risk-informed application is defined in these guidelines. ENSI will consider RI-ISI in the specific ISI guidelines when they are issued.

5.3 Countries without RI-ISI-related activities

This subsection summarises the ISI updating principles applied by some countries without risk-informed activities.

5.3.1 United Kingdom

The Nuclear Installations Inspectorate (NII) is the part of the Health and Safety Executive (HSE) responsible for regulating the safety of nuclear installations in the UK. NII's inspectors use the Safety Assessment Principles (SAPs) [18], together with supporting Technical Assessment Guides, to guide regulatory decision-making. The term ‘safety case’ is used in the SAPs to encompass all documentation submitted to the NII to demonstrate that high standards of nuclear safety are achieved and maintained.

5.3.1.1 UK living inspection programmes

There is a requirement in the SAPs that the safety case for each stage of the life-cycle should identify maintenance, inspection and testing procedures needed for the case to remain valid. Provision should be made for examination that is reliably capable of demonstrating that the component or structure is manufactured to the required standard and is fit for purpose at all times during service. This principle applies to both pre-service and in-service inspection and therefore may include ongoing confirmation of fitness for purpose by ISI.

The SAPs also prescribe that a safety case should be actively maintained throughout each stage of the life-cycle and described in a living series of documents, i.e. that the safety case should be kept up to date. The knowledge used at the time of writing the safety case needs to be supplemented by monitoring the plant and data from commissioning and continued operation, periodic inspection and testing and also from longer-term research or experience from other facilities. Processes need to be in place to make legitimate changes that may be needed on an immediate or a longer-term basis. In practice this requires incorporation of:

(a) changes arising from adjustments or new operating methods;

(b) changes arising from incidents, operating experience, examination or testing results, updated design, analysis methods, research findings or other new information;

(c) the outcome from major periodic and interim safety reviews; and

(d) changes arising from time-dependent degradation.

Since ISI can form part of a safety case, the general principles which the NII requires for updating ISI programmes are as described above.

5.3.1.2 RI-ISI in the UK

In the UK no application has yet been submitted to adopt an RI-ISI programme for a nuclear installation. Efforts are under way to develop such programmes. In Section 1.3.3(7) of [19] the HSE acknowledges that there is a need to develop RBI and RI-ISI methods which have been specifically validated for UK plant (or to adapt existing methods).

The HSE has published a best practice guide for risk-based inspection as part of plant integrity management [20], which is generally understood to be for non-nuclear industrial applications, e.g. in the oil and gas industries.

Reference document [20] recognises that a risk assessment is carried out on the basis of data and information for the plant in question and of the knowledge and experience of the RBI team available at the time the study was carried out. The importance of maintaining up-to-date risk assessments is acknowledged and the following changes and events that might justify a re-assessment are identified:

- a serious process or operational upset;
- failure of an item of equipment;
- change in the operating conditions;
- change in the internal or external operating environment;
- where time-dependent operating conditions exist, such as fatigue or creep;
- change in industry practice;

- change in plant management or ownership;
- change in the level of operator training and knowledge.

5.3.1.3 Application of PSA to UK NPP

The HSE endorses application of PSA in nuclear safety cases. The following is an extract from the SAPs:

'PSA provides an integrated, structured, safety analysis that combines engineering and operational features in a consistent overall framework. This in turn enables complex interactions to be identified and examined, and provides a logical basis for identifying any relative weaknesses. Hence it should be an integral part of design development and analysis. PSA also provides an input into risk-informed judgements both at the design stage and in operation.'

Reference document [21] is a Technical Assessment Guide which addresses PSA. This guidance recognises the importance of keeping PSA up to date:

'PSA should reflect the current design and operation of the facility or site.

This principle establishes the need for each aspect of the PSA to be directly related to existing facility information, facility documentation or the analysts' assumptions in the absence of such information. The PSA should be documented in such a way as to allow this principle to be met.

In addition, in order to meet this principle, the PSA should be kept living, i.e. it should be updated as necessary to reflect the current design and operational features and to incorporate feedback from internal and external operational experience, improved understanding of physical processes or accident progression and advances in modelling techniques.'

5.3.2 Belgium

In Belgium, the in-service inspections are performed in accordance with ASME XI, which is the mandatory code in the country. If RI-ISI were to be applied, it is expected to include a full review at ten-year intervals. Particular events requiring partial review are expected to be:

- major changes to the plant, with an impact on the risk categorisation;
- identification of a new degradation mechanism or new feedback based on experience about an existing one;
- feedback based on international experience with implementation of RI-ISI and changes in US requirements/regulations about RI-ISI;
- changes in the NDT performance.

5.3.3 Germany

In Germany the ISI scheme is based on a deterministic approach. The KTA Code applies to all relevant components.

KTA 3201.4 is used for ISI of the primary circuit and KTA 3211.4 for the outer circuit.

The inspection interval for the primary circuit is practically four years, which can be extended to five years under certain conditions. For most pipe welds a representative sample of up to 40 % of the welds is inspected. Representative pipes are selected on the basis of load, diameter, known or assumed damage mechanisms, material, temperature and energy of the medium. This approach is not purely deterministic, as both the consequences and the probability of occurrence of a defect are considered.

For the secondary circuit the inspection interval is four years. In general, about 50 % of the welds in the primary circuit are to be tested in that interval.

As a rule, the code should be revised every five years, but in the past this interval has been longer for many codes. New experience is generally included in the code when it comes up for revision. Normally, information on, for example, damage in national or international plants is evaluated to see whether it is relevant to the operator's own plant or not. If it is found to be relevant a special ISI programme is to be launched which may then be included in the next revision of the code. Typical examples of this were damage caused by IGSCC in the 90s or in dissimilar metal welds at the beginning of 2000.

In Germany there is currently no acceptance for an RI-ISI-programme and there are no specific plans, such as for pilot studies. Nevertheless, as feedback based on experience from other plants is used in code revision and in special programmes and as representative components are inspected, the underlying reasoning is not purely deterministic.

5.3.4 Hungary

In line with the international trend, Paks NPP started planning the RI-ISI pilot project at the end of 2007. The idea was to involve Hungarian scientists and foreign experts who had detailed knowledge of RI-ISI methods in WWER-440 systems in order to manage development of the project. VEIKI, the Hungarian Electricity Research Institute, participated in the RISMET project, while the PSA models and their results had been used for safety assessment and in various PSA applications at Paks.

The project plan and the cost and resource calculation were finished in January 2008. The scope of the pilot study included the high-pressure emergency cooling system and the feedwater system class 1 pipelines. The project was ready to start, but the management postponed the launch because in 2002 the operator of the Paks NPP had decided — and the national regulatory authority had agreed — to adopt the US Nuclear Regulatory Commission approach to licensing an extended service life in accordance with CFR 10, Part 54.

To ensure consistency with this approach, the management decided to convert the existing in-service inspection programme into a system complying with the requirements laid down by the appropriate sections of the ASME Boiler and Pressure Vessel Code. The new ASME-based ISI regulation is now undergoing approval by the Hungarian Atomic Energy Authority.

As the risk-informed in-service inspection methods (both WOG and EPRI) have been codified in the ASME Boiler and Pressure Vessel Code, the management of the Paks NPP decided to postpone starting the RI-ISI pilot project until introduction of the ASME BPVC. The current schedule (which is lagging behind the original schedule) is for the ASME adaptation to be implemented in 2010. Consequently, the RI-ISI pilot project is not expected to start before the end of next year at the earliest.

5.3.5 Romania

In-service inspections at Cernavoda NPP are performed in accordance with Canadian Standards CAN/CSA N 285.4 'Periodic Inspection of CANDU Nuclear Power Plant Components' and CAN/CSA N 285.5 'Periodic Inspection of CANDU Nuclear Power Plant Containment Components' which have been endorsed by the Romanian regulatory bodies (CNCAN and ISCIR).

A mandatory Periodic Inspection Programme Document includes safety systems. In accordance with CAN/CSA N285.4 and N 285.5, the following or parts thereof are subject to mandatory inspection:

(a) systems containing the fluid that, under normal conditions, directly transports heat from nuclear fuel, and systems connected thereto, and other systems whose failure could result in a significant release of radioactive substances;
(b) systems essential for the safe shutdown of the reactor and/or the safe cooling of the nuclear fuel in the event of a process system failure; and
(c) systems, the failure or dislodgement of which could put in jeopardy the integrity of systems covered by item (a) and/or (b).

Supplementary in-service inspection programmes have been developed for the main components included in Plant Life Management (PLiM) Programmes, such as fuel channels, feeders, steam generators, heat exchangers, tanks, supports/snubbers, transformers, cables, DCC, turbo-generators, containment and piping surveillance (the Checworks(r) application is used to select the pipe areas to be inspected for erosion/corrosion).

These programmes were based on component failure modes, degradation mechanisms, R&D results and recommendations from COG, EPRI and WANO. Also, Cernavoda NPP is a member of the CANDU Owner Group (COG) and is actively involved in exchanges of information, joint projects and research and development programmes, including an inspection qualification programme.

The ISI programmes are periodically revised to address plant changes and internal and external operating experience (including any deviation from normal operating conditions).

CNE Cernavoda considers the approach described above consistent with the norms issued by the Romanian nuclear regulatory authority (CNCAN), which contain no specific requirements regarding RI-ISI, and therefore has no plans to use RI-ISI at this stage.

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European Commission

EUR 23929 EN — DG JRC — Institute for Energy
ENIQ TGR DISCUSSION DOCUMENT – UPDATING OF RISK-INFORMED INSPECTION PROGRAMMES

Authors

Kaisa SIMOLA	VTT Technology Centre of Finland
Luca GANDOSSI	DG-JRC-IE

Luxembourg: Office for Official Publications of the European Communities
2007 – 22 pp. — 21 x 29.7 cm
EUR – Scientific and Technical Research Series; ISSN 1018-5593

Abstract

The European Framework Document for Risk-Informed In-Service Inspection (RI-ISI) is intended to provide general guidelines to utilities both for developing RI-ISI approaches and for using pre-established approaches or adapting them to the European nuclear environment, taking into account national regulatory requirements and utility-specific characteristics.

The Framework Document emphasises the process of keeping RI-ISI living, i.e. updated, and briefly discusses the concept of living RI-ISI. An effective risk-informed inspection strategy requires a feedback procedure to update the risk ranking after changes are made to the plant or other relevant information is acquired. Furthermore, the document published by the Nuclear Regulatory Working Group highlights performance monitoring and updating of RI-ISI programmes. A US document on RI-ISI updating gives several examples of plants which have completed updates of their RI-ISI programmes.

This European Network for Inspection and Qualification (ENIQ) discussion document is intended to help users involved in an RI-ISI application to maintain and update an RI-ISI programme. It also provides an overview of current ISI updating practices in most EU Member States with nuclear power plants in operation.