ESTABLISHING A NEW ISI STRATEGY FOR PAKS NPP

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Abstract

The owner of Paks NPP is aiming at reviewing and adjusting the plant's ISI program to meet the ASME code requirements. ISI in conformance with ASME requirements will provide an opportunity to compare these activities with worldwide acceptable safety requirements, which will help to reach the consent across Europe for Paks NPP's operational life extension. Meeting the Section XI requirements will allow the extension of the current four-year inspection interval up to an eight-year one, which will contribute to a more cost-efficient operation and maintenance regime. A substantial part of establishing a new ISI strategy was the comparison of the current Russian based ISI/NDE program, and the ASME code Section XI based one. The existing NDE procedures were also transformed taking into consideration Section V requirements. In addition, pressure test requirements as well as repair and replacement activities were included in the assessment. Since a prerequisite for application of Section XI is the meeting of Section III requirements, a design review of selected components is being done to justify the compliance with Section III requirements. It is assumed that structural integrity assessment of long-lived and passive components will achieve an internationally acceptable level. Apart from this, the new ISI strategy will create the basis for a proper ageing management program in the operational period beyond the design life.

1. Introduction

Paks, Hungary's sole nuclear power plant (NPP) consisting of four Russian designed VVER-440 model 213 units[1], was commissioned in the mid-eighties with a design life of 30 years. The plant owner is now preparing the operational life extension up to 50 years. The Hungarian regulation's licensing procedure of the extended period shows a vast similarity to the U.S. Nuclear Regulatory Commission (NRC) approach in license renewal according to 10 CFR 54 [1]. To ensure consistency with this approach, as well as to strengthen a Europe wide acceptability of the life extension program the plant owner decided to adapt the ASME code requirements for those operations and inspection/maintenance activities where it is logical and objectively possible. As it is well known the ASME code is a comprehensive, worldwide accepted and proven system for the NPP pressurized components, and its application is mandatory according to the 10 CFR 50 [2]. Meeting the ASME code requirements will also allow the extension of the currently used four-year inspection cycle to an eight-year one, which significantly contributes to a more cost-efficient operation and maintenance in the future.

[1] VVERs are Russian designed PWRs, 440 refers to the nominal electric capacity in MW, model 213 is the second generation of VVER-440s.

NPPs with VVER type reactors were designed fully in accordance with former Soviet rules and standards. These normative documents were developed practically independently from PWR ones even though the main safety principles are similar. Of course, differences in the level of science, safety approaches, technical and manufacturing capabilities and possibilities had a strong influence on their development. Moreover, some special technical approaches, mainly in integrity evaluation, were based on both the specific structure and independence of the Soviet research and design institutes. Thus, even some principal differences between the Soviet rules and the ASME code exist that result in smaller or larger non-consistency either in approaches and/or in final solutions.

2. Rational for comprehensive adaptation of the ASME code

The Hungarian regulatory rules [3] do not explicitly determine the applicable codes and standards either for plant construction or for In-Service Inspection (ISI) and In-Service Testing (IST). The only statement is that codes and standards must be *authoritative*. The Hungarian regulatory practice is based on former Soviet codes [4] issued in early seventies, which contain requirements for design, manufacturing, commissioning and for operation, mainly from a nuclear safety point of view. No document however deals with the evaluation of the integrity of pressurized components and piping during operation. No periodic revision and upgrading of Soviet codes were foreseen or realized[2] thus they do not follow the development in the areas of fracture mechanics and Non-Destructive Examination (NDE) that are necessary for integrity evaluation. Based on these, it is hard to say that the current Hungarian rules are *authoritative* but the ASME code obviously meets this criterion. This fact gives, on one hand, a clear opportunity because it does not exclude the use of any codes and, on the other, a moral pressure for the NPP underlying its plan to adapt ASME requirements.

Using the term of "adaptation" refers to the fact that the ASME requirements have to be placed in a special situation because Paks NPP was not constructed, commissioned and has not been operated, up to now, in line with the relevant sections of ASME code. This procedure is not unique in the world; however it is far from automatism and also can not be applied for each code criterion (e.g. selection of structural materials or manufacturing processes).

The ASME code is a systematic and logical structure of the requirements. Its logic is because the components inspected in accordance with its Section XI [5], and tested in accordance with the OM code [6] during operations, were constructed in line with other ASME code sections mainly Section III [7] requirements. This requires a systematic review of the operational licensing conditions, see 10 CFR 50, and the comparative assessment of relevant ASME code requirements. Adaptation of the ASME code requirements covers not only the nuclear sections but requires a comprehensive analysis and evaluation. It covers, primarily, sections II, III, V, VIII, IX and XI as well as the OM code (2001 edition), and the relevant aspects of the entire legislative and regulatory framework within the United States and Hungary, and standards and regulatory guides referred to in the documents. Since a prerequisite for

[2] A second set of the Russian documents was published between 1987 and 1990 but VVER-440 type reactors (including Paks NPP) were practically designed in accordance with the first set.

application of Section XI is the meeting of Section III requirements, a design review of selected components is being done to justify compliance with the Section III requirements.

3. Main features of the current ISI system at Hungary

3.1. General aspects

The currently used Hungarian ISI program differs in both its structure and technical parameters from that of Section XI. Its scope is narrower: it covers the planning, scheduling and implementation of the inspections, recording and evaluation of the results. Other items such as IST, repair and replacement are included in different regulations and plant procedures in accordance with the regulatory rules. The Hungarian ISI program consists of three major components: periodic NDE, structural examination and system pressure test. Periodic NDE and pressure test do not need further explanation; the structural examination's equivalent may be the VT-3 type visual examination in Section XI. There is no single Section XI-like framework document in Hungary; instead individual documents for the various systems, entitled Technical Inspection Plans, exist.

The components safety classification of the relevant Hungarian regulation and that of the Section III do not show remarkable differences. Thus, the scope of Subsections IWB, IWC and IWD of Section XI are comparable with the scope of their Hungarian equivalents. Only the containment ISI requirements in Hungary differ significantly from the Section XI requirements, as a consequence of the significantly different design of VVER-440 NPPs (active pressure-suppression function, no reinforced concrete). ISI of pump casings and valve bodies are currently included in the scope of a predefined maintenance work bank (except for the main cooling pump and main gate valve[3]).

3.2. ISI/ NDE program

The roots of the initial ISI (more precisely the periodic NDE) program at Paks NPP go back to early '80s, which was the period of the construction and commissioning of the units. The first version of the program was summarised in a set of documents consisting of two main parts. Part one was practically the NDE program in itself (actually the entire program consisted of ten individual sub-programs), and part two was a complementary document to the program describing the NDE methods used. This latter one entitled Methodology and Criterion Document was not yet a systematic procedure but included all the important setting and calibration parameters, which were necessary for ensuring the reproducibility of the examinations. It also contained the evaluation criteria for each inspection area and NDE method. These ISI/NDE rules had been applied during the validity of the first Atomic Energy Act. The ISI/NDE program as well as the Methodology and Criterion Document were subjected to the approval of regulatory authority, and had to be revised annually. After issuing the second, modified Atomic Energy Act in 1996, the regulator issued a Guideline on Periodic Material Testing (focussing on NDE) [8] requiring the restructuring of the existing NDE documents in three parts: NDE program, acceptance standards, and NDE procedures. Thus,

[3] Main gate valve is a specific VVER feature; each loop contains two isolation valves with an isolation function mainly during maintenance outage.

the NDE instructions became separate volumes having a unified form and structure. These NDE procedures also had an extended and more detailed content in comparison with the former ones. According to the latest version of the regulatory rules, it is not necessary for the NDE procedures to be approved anymore.

One of the biggest differences between the Hungarian ISI/NDE rules and the Section XI rests in the different concept of the acceptance standards. For Ultrasonic testing (UT), which shows the most significant difference, Section V [9] and XI defines a Primary Reference Response (PRR), which may be either a Side-Drilled Hole (SDH) or a notch. In ASME code editions before 1989, the recording level was 50% PRR, after 1989, this value was reduced to 20% PRR. Upon exceeding this level a sizing is necessary. The 1995 and latter issues of Section XI require a qualified UT procedure. The fundamental difference between the Hungarian approach and the ASME rests in that Section XI acceptance criteria are determined for direct application in fracture mechanics evaluation.

In Hungary, as a consequence of the adoption of the Soviet approach, evaluation of UT has been based on a comparison between the amplitude and that amplitude given by a reference reflector. Reference reflectors are usually Flat Bottom Holes (FBHs). Thus, the acceptance level is characterized by an equivalent FBH diameter. The registration level is usually equal to that of the construction (component manufacturing), and the acceptance level is equal to the reference level plus 12 dB. Only if the amplitude exceeds this acceptance level a sizing and fracture mechanics evaluation have to be performed. This process likely shows an agreement with the process described in Subsection IWB-3000 of Section XI and suggests that the acceptance levels in both systems are the same. However, the agreement is only virtual, because there is not any physical content behind the amplitude-based acceptance level (equivalent FBH diameter) and thus, it is not compatible with fracture mechanics, being the tools of structural integrity assessment. This method may be called an “analogue” method referring to the analogy between the amplitudes as well as expressing its limitations. A real acceptance level has to be formulated in the language of fracture mechanics (namely in crack size), which would exclude the usage of the amplitude-based method. This simply means that there is no acceptance level according to ASME terminology in the current Hungarian ISI rule. The aforementioned are shown in Fig. 1. In case of Safety Class 1 components, the ISI interval takes four years, in case of lower safety classes eight years.

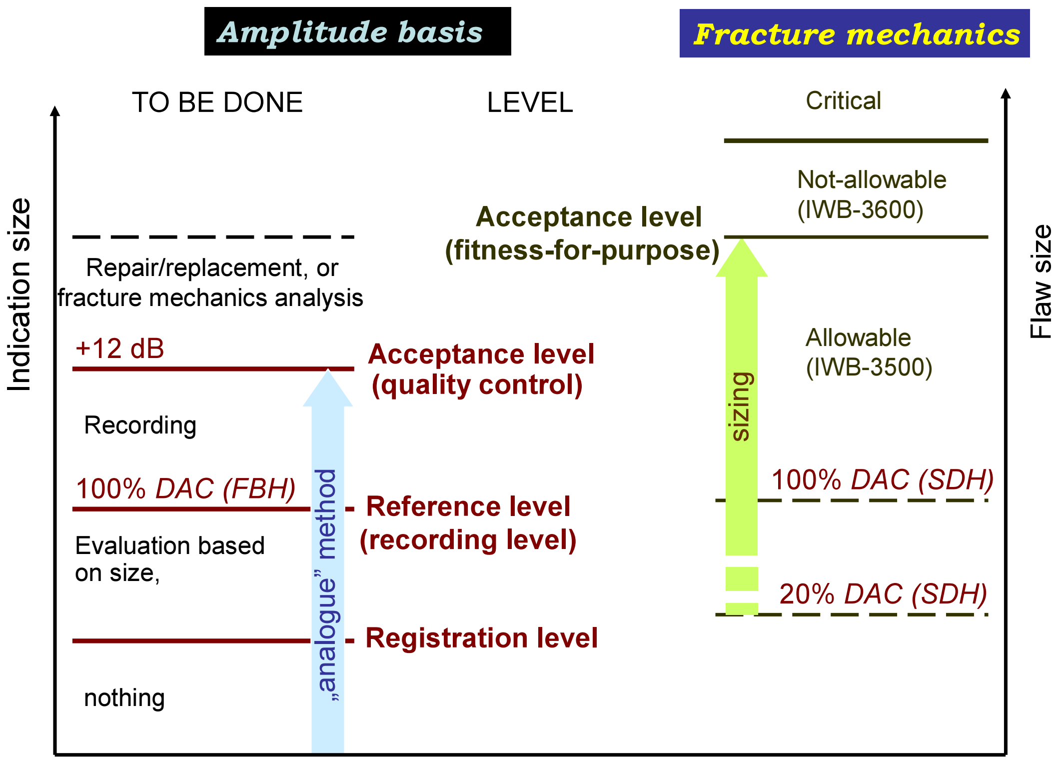

FIG. 1. Different evaluation concepts of the Hungarian ISI / NDE rules and the Section XI

3.3. Technical Inspection Plans

The Technical Inspection Plans consist of the conditions and parameters of the so-called "structural examinations" and the hydrostatic tests. These documents only refer to the periodic NDE, and assume their prior implementation and successful results. There appear to be some differences in the qualification of NDE personnel doing the "structural examination" (VT-3) as well as pressure test (VT-2), namely the Hungarian rules do not require these qualifications for these operations. There are also differences in the pressure test parameters. Pressure of both the system leakage and the hydrostatic tests, test condition holding time and instrumentation parameters differ somewhat (in general, pressure values used in Hungary are higher than the values given by the Section XI). The biggest difference is that there is a periodic hydrostatic test of Safety Class 1 components (in fact the primary coolant pressure boundary) after every four-year inspection cycle in an extremely high-test pressure. According to IWB-2500 and IWB-5000 this test has to be conducted only after repair/replacement activities.

Neither the ISI/NDE sub-programs nor any of the Technical Inspection Plans have clear instructions for those situations when NDE or other examination/test results exceed acceptance criteria.

4. Development of the new ISI system

A comprehensive analysis and evaluation of both Section XI and the relevant Hungarian documents (ISI/NDE program, Methodology and Criterion Document, Technical Inspection Plans, various maintenance procedures, etc.) have been conducted by various technical support organisations and consultants. As a result of this work, the relevant documents were modified, and also new documents were elaborated. The documents have been reviewed by competent independent consulting bodies, and the necessary corrections have been added.

4.1. ISI/NDE program

The ISI/NDE sub-programs did not require a complete restructuring. The necessary amendments such as inserting pump casing, valve bodies and welded attachments examinations were completed. Whilst doing their modifications to the relevant requirements in Subsection IWB, IWC, IWD-2500 of Section XI the results of component ageing assessment (and ageing management in general) were taken into consideration. Instead of the original four-year ISI cycle, an eight-year cycle was considered, which is not in contradiction to the Section XI inspection schedule, and to which the transition from the current system may easily be done.

4.2. NDE procedures

Preparation of the new NDE procedures needed a greater effort. During the course of their revision, the main goal was not only to adapt the Section V requirements but also to create a uniform set of documents in terms of format, structure and concept. In addition, the following requirements have been set up as basic aspects for the smooth transition from the old system to the new one:

a) The NDE results had to be fully comparable with the results of examinations performed when using previous procedures.
b) The co-ordinate systems used by preceding versions of procedures could not be changed.
c) The new procedures had to unconditionally fulfil all applicable internal regulations at Paks NPP.
d) The environmental and technological conditions of the given inspection should remain the same.
e) The certification of NDE personnel should conform to the requirements of the relevant Hungarian standard, which is identical with the European standard EN 473 [10].

All revised NDE procedures contain the same type of information under the same chapters and subchapters with the same degree of details and with same quality of wording. In the previous version, acceptance standards were an inherent part of the procedures, which has been maintained within the new ones because of the NPP request. Besides the former criteria the acceptance standards given in IWB, IWC, IWD-3500 of Section XI have also been introduced. Another new element of the revised procedures is the application of different visual inspection categories (VT-1, 2 and 3) according to Section XI, which was not taken into account before in Hungary.

4.3. Acceptance standards

Concerning the acceptance standards, Paks NPP decided on the further use of the original acceptance level (quality control level, see Fig. 1.) regardless of the introduction of Section XI acceptance standards. The idea means that NDE results would first be evaluated against current criteria *(Level 1)* and, only if the results could not meet the criteria, they had to be evaluated according to the Section XI *(Level 2)*. This concept has been underpinned by the feasibility studies, which state that Section XI acceptance standards are usually less rigorous than Hungarian ones. The concept was named as the *Two-level Evaluation* concept, see Fig. 2.

Due to the fact that Section V uses SDHs as reference reflectors for UT calibration, a series of laboratory experiments was done. The PRR values based on FBH were compared with the ones based upon SDH. The results were intended to validate the equation for converting the different types of reference reflector to each other:

$$D_{FBH} = 0{,}67\sqrt{\lambda\sqrt{D_{SDH} * s}} \ , \qquad (1)$$

where

D_{FBH} = equivalent reflector diameter, FBH (mm),
D_{SDH} = equivalent reflector diameter, SDH (mm),
λ = wavelength (mm),
s = sound path (mm).

Equation (1) is valid for s >0,7 N ($N = D_p^{\,2} / 4\lambda$, length of near field in mm), D_p = effective probe diameter in mm, and D_{SDH} >1,5 λ. Experimental results showed however, that the validity condition s > 0,7 N seems too rigorous and thus, it often leads to inaccurate results. Contrarily literature data says that results with a sound path three to five-times near field length are reasonable [11, 12].

Test blocks from carbon steel with model reflectors (Ø3 mm and Ø6.3 mm SDH, Ø5 mm, Ø7 mm and Ø10 mm FBH) were used for the UT measurements. The validity of Eq. (1) could be justified for the range of FBHs = ∅5 - ∅7 mm, and s > N, using 2 MHz and 0° probes, and Distance-Amplitude Correction (DAC). In other ranges of FBH, due to the randomly variable influencing factors, instead of the exact results, was better to evaluate the tendencies: using DAC the conversion according to Eq. (1) for large FBH reflectors (Ø10 mm) resulted in smaller than real diameters. Measurements of FBH reflectors based on DGS (Distance-Gain-Size) are correct however; the conversion to SDH diameters shows greater than real values. The conversion does not seem to be correct (some times even extremely incorrect) but results always remain on the safe side. In the case of both types of sensitivity calibration, the measured and converted values with increasing sound path tended to approach the real values. Based on the results of these experiments, and the evaluation of real UT data according to Section XI, it was concluded that good conformity with ASME requirements can be achieved if for the *Level 1* evaluation, see Fig. 2, the reference level 100% PRR (FBH) shall be suggested.

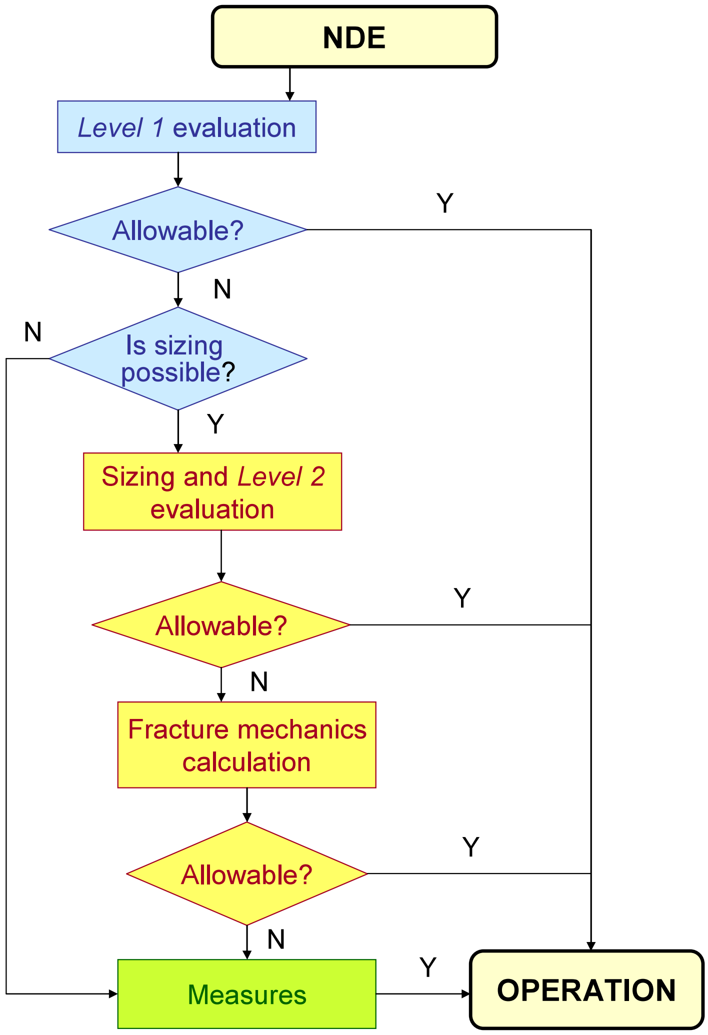

FIG. 2. Flow chart of the Two-level Evaluation concept

4.4. Structural examinations

Section XI does not talk about "structural examinations" but the requirements of VT-3 visual examinations actually seem to be equivalent with requirements of the structural examinations. Taking this into account it was decided to leave the institution of "structural examinations" as it was in the past. Those visual examinations where VT-1 requirements are prescribed, and which previously were part of the structural examinations (practically VT-3), will require NDE personnel having EN 473 certification (welded attachments for vessels, piping, pumps and valves, category D-A according to IWD-2500).

4.5. Pressure tests

Leakage tests are traditionally not part of the Technical Inspection Plans, they are conducted by operations personnel during re-start of the units. The fundamental change is in the application of Section XI hydrostatic pressure test values with special regard to the test of primary coolant pressure boundary. Until 1993 the test pressure value was 19.1 MPa (operations pressure at nominal power is 12.2 MPa), which is extremely high, and does not correspond to any safety rules, not even [4]. In 1993, the value was allowed by the regulator to be reduced to 16.6 MPa, which is still high enough compared with that of Section XI. The new ISI system, in line with the concept of ASME, which gives the preference to NDE against unnecessary component overloading by pressure test, would carry out a hydrostatic test of the pressure boundary in a lower test pressure.

4.6. Repair/replacement activities

As it has been previously mentioned repair and replacement was organized differently at Paks NPP from ASME approach. Procedures for the various activities (defect removal, welding repair, etc.) exist but the Section XI-like repair/replacement program and plan do not. To harmonize with Section XI requirements, a unified structure for repair procedures was developed using the existing ones as a basis.

5. The new ISI strategy

As a result of this large scale project an upgraded, and compatible with the Section XI and OM code ISI and IST program, has been compiled. As a basis for the new ISI program, it was decided to keep the main structure of the Technical Inspection Plans because it basically justified its applicability and was able to accommodate the Section XI requirements. The Technical Inspection Plans were renamed as ISI Plans which, puts a greater emphasis on their ageing management function, whilst at the same time, refers to the evolution of these documents. The new ISI Plans contain all periodic NDEs, structural examinations and system pressure tests, which were previously done in the framework of the Technical Inspection Plans, and also Section XI requirements.

An important issue is the transition from the current ISI system to the new one. The crucial thing is to keep all licensing conditions valid at all times, which means that a smooth transition, without loosing any examination, is necessary. Since the Hungarian regulator is expecting an overall concept on ASME adaptation, in which ISI plays the substantial role, Paks NPP has to work on this, and the regulatory approval of the new system may only be anticipated after the path and method of transition are included.

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