NDE2002 predict. assure. improve.
**National Seminar of ISNT**
**Chennai, 5. – 7. 12. 2002**
www.nde2002.org

# BEST PRACTICE FOR EFFECTIVE IN-SERVICE INSPECTION

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## 1. Abstract

ISI is an increasingly important element in nuclear plant life management and its effectiveness strongly influences the availability and safety of plant. The paper discusses the Best Practice for achieving effectiveness of ISI. Both technical and managerial issues are considered, and the many measures (including risk based planning, inspection guidelines, personnel certification, use of standards, accreditation of NDT organisations/inspection bodies etc.) are placed in their correct context.

## 2. NDT Infrastructure

An NDT infrastructure has gradually grown up which provides some of the foundation stones and frameworks which can aid the planning and execution of effective ISI.

Figure 1 attempts to represent the infrastructure. In this figure the heavy boxes indicate the "doing activities" that make up NDT operation, i.e. Procedures, Equipment, Training and Certification, Human Factors, whilst the lighter boxes represent the various measures designed to achieve quality, with the types of organisations generally responsible shown along the foot of the diagram.

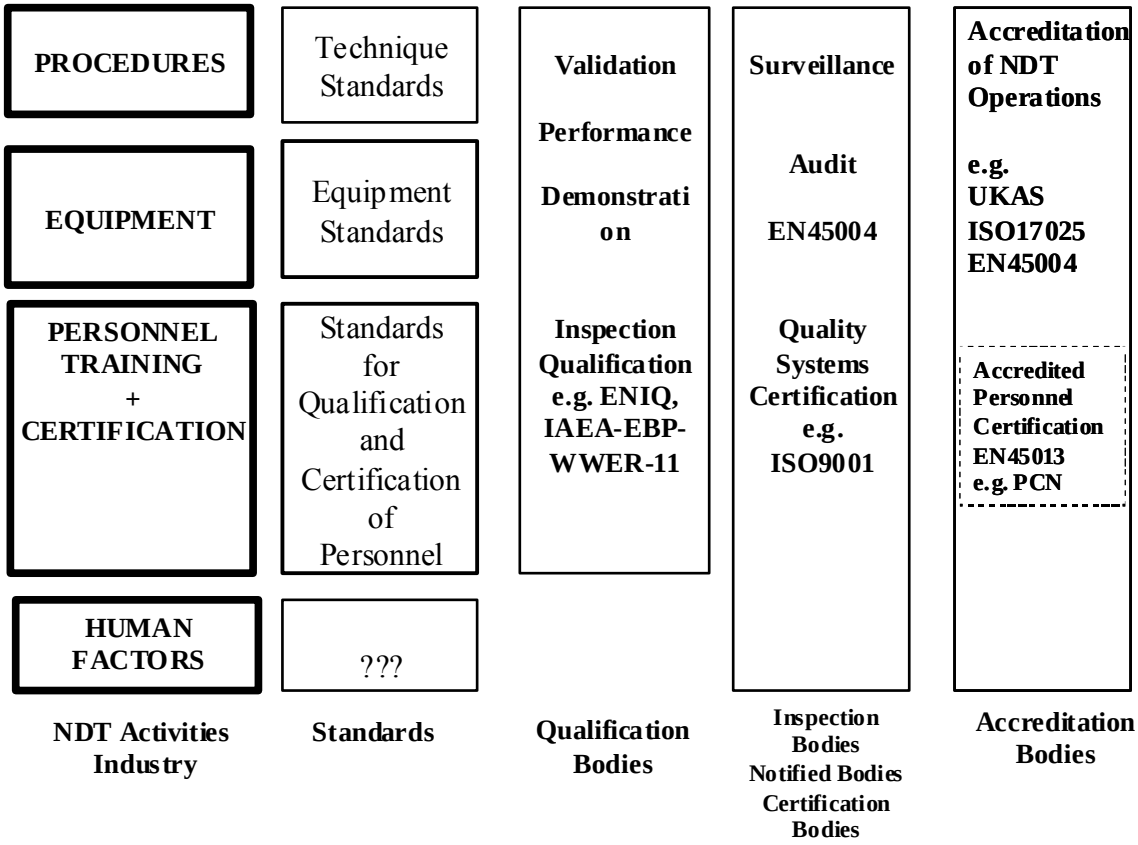


**Figure 1: The NDT Quality Infrastructure for Best Practice**

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## 3. Current Status of European Infrastructure and Global Developments

### 3.1 Codes and Standards

Codes and Standards have an important role to play in achieving quality and reliability. There are International, European and national standards and codes for NDT techniques, equipment and personnel. In Europe, national NDT standards are being progressively replaced by European (CEN) standards. American standards (ASME, ASTM, AINSI etc.) are widely used around the world. A comprehensive review of standards for ultrasonic testing has been published by Schlengermann [1].

However, most codes and standards focus on manufacturing inspections and in some cases in-service inspections may be outside the intended scope. Codes and standards are qualified on the basis of general experience and do not in themselves provide a defined level of effectiveness.

### 3.2 Personnel Training and Certification

The training of NDT personnel is very important - both before and subsequent to certification examinations. Attention must be given to job-specific training before an operator is asked to carry out jobs which may be outside the scope of his certificate.

In the field of personnel certification there are two types of standards: those which cover central, independent certification and those for in-house certification. Central independent certification as defined in standards such as the International Standard ISO9712 [2] and its European equivalent EN473 [3] is increasingly being accepted internationally, including in the United States. For in-house certification the American ASNT document SNT-TC-1A is widely used in place of a standard [4].

In most countries in Europe there is a 'national' Certification Body, which provides NDT personnel certification to the EN473 standard in each main NDT method at three levels (Level 1, 2 and 3). The majority of these bodies have gained independent accreditation to EN45013 by a recognised Accreditation Body (such as UKAS in the United Kingdom) and participate in the EFNDT Mutual Recognition Agreement. To further improve harmonisation which complies with EN473 EFNDT [5] has developed a scheme, known as ECP, which will allow Certification Bodies to use standardised sectors and examinations (theory and practical).

Globally, the very similar ISO9712 standard has been adopted in a large number of countries (including China, India, Canada, Japan, Australia, South America, Korea, USA) and Certification Bodies are providing independent third party certification accordingly. A group of certification bodies in the Asia-Pacific region are developing a mutual recognition agreement based on the EFNDT model. The International Committee for NDT (ICNDT) and the IAEA continue to promote ISO9712 as a basis for global harmonisation of central certification. ICNDT has initiated the revision and update of the training syllabi ('body of knowledge') for each method. Under the Vienna Agreement ISO and CEN are committed to converging ISO9712 and EN473 into a common standard.

Users of central certification schemes need to be aware due to the lack of detail in the standards there is some considerable variation between different Schemes, in depth and

breadth of certification and thus in the need for additional in-house job-specific training and assessment. This should be addressed in a company's quality system or NDT Written Practice and is essential for effective ISI.

In the USA, and countries using American standards, there continues to be widespread reliance on in-house certification in accordance with ASNT document SNT-TC-1A, albeit with increasing reliance on independently certified Level 3s. SNT-TC-1A allows NDT procedures to tailor training and certification more closely to the specific company needs but lacks the benefits of independent examinations by a central body.

In the author's view there should be a gradual coming together of the central independent and in-company approaches. The former are increasingly aware of the need for central certification to be used in the correct way - as part of an organisation's quality systems for NDT or written practice - and the standards for in-house certification are bringing in requirements for external assessment e.g. independently certified Level 3s.

Both EFNDT and ICNDT have working groups, which focus on the certification of personnel with international harmonisation and recognition as prime objectives.

### 3.3 Accreditation of NDT Operations

In a growing number of countries in Europe (including FSU countries such as Russia and Belorussia) NDT Service company operations are being accredited by Accreditation Bodies. For critical inspections of nuclear power plant in Sweden such accreditation by SWEDAC is mandatory.

Initially such accreditation referenced the European Standard EN45001 "General criteria for the operation of testing laboratories" but this is now superseded by the ISO/IEC Standard 17025 " General requirements for the competence of testing and calibration laboratories". When the NDT company's operations extend to those of an Inspection Body the reference standard is EN45004 " General criteria for the operation of various types of bodies performing inspection". UKAS has published guidelines for accreditation of NDT operations to each of these standards in the form of a document entitled RG07 "Accreditation for Inspection Bodies Performing Non-Destructive Testing" [6]. These guidelines explain the UKAS view of the difference between NDT Laboratory Accreditation and Inspection Body Accreditation, the latter including "determination of significance of defects found, based on test results".

Accreditation assessments are much more comprehensive and searching than a 'quality systems' audit to ISO9001 with greater emphasis on the inherent technical capability of the organisation.

### 3.4 Qualification of NDT procedures, equipment and personnel

The process of Qualification, previously known as Validation or Performance Demonstration was first developed as a result of the need to assure the capability of inspections of nuclear power plant.

In the USA, following analysis of the results of the PISC II Trials, the ASME Section XI committee adopted the principles of performance demonstration and introduced Appendix 8

to Section XI of the ASME code to define how performance demonstration trials should be conducted. Performance demonstrations to these code requirements are now being implemented through the Performance Demonstration Initiative (PDI) managed by the Electrical Power Research Institute (EPRI).

In Europe, a network of the nuclear electricity utilities and inspection companies known as ENIQ, (the "European Network for Inspection Qualification") have co-operated to draw up a document which deals with the objectives and role of NDT Qualification, including principles for the derivation of basic qualification requirements and how to organise the process of NDT qualification. A related document entitled "Methodology for Qualification of In-Service Inspection Systems for WWER Nuclear Power Plants" has been issued by IAEA. Utilities and regulators in Europe have begun to utilise these guidelines. For example, France has embodied the ENIQ methodology in the 1997 edition of the RSE-M code and pilot studies have been completed in East Europe on several plants. Under the auspices of EPERC studies are being conducted into how Inspection Qualification might be applied more widely and the CEN Technical Committee TC138 has established a working group to draft a general standard for qualification of inspections.

The ASME Board on Pressure Technology Codes and Standards has established a Section V/Post Construction Joint Task Group on NDE Performance Demonstration for the purpose of formulating standard requirements for qualification of NDE (beginning with ultrasonics), primarily in support of risk-based inspection processes being developed by the Post Construction Main Committee. The methodology being developed has similarities to both the ASME XI methodology and the ENIQ methodology. Three levels of qualification (Low rigor, Intermediate rigor and High rigor) are defined.

Qualification clearly has an important role to play in assuring the effectiveness of ISI but this role is limited to confirming that the inspection procedures, equipment and personnel have the necessary capability. Qualification per se does not ensure the effectiveness of implementation of ISI, except to the extent that the inspection and data analysis are automated.

### 3.5 Human Factors

"Human factors" which influence the reliability of implementation of NDT may in some instances be the weakest link in the NDT quality chain and the NDT quality infrastructure is least developed in this regard.

Attention is required to human motivation to achieve effectiveness. The motivation and commitment of NDT personnel is of prime importance in the quest for inspection effectiveness.

In some organisations the NDT staff are salaried, work regular hours and are included with other staff in personnel training schemes, staff development schemes, i.e. they are fully integrated, have the means of achieving a satisfying and worthwhile career and can call upon technical and managerial support. In contrast, in other cases NDT is carried out by agency staff or by temporary personnel, often self-employed. In the worst cases payment is by the hour or even by the metre of weld tested. Extended shifts and long periods without a day off are worked. There are no paid holidays, no sick-leave and maybe no technical or safety support by the employer. This is not conducive to high quality.

The effect of human factors on ultrasonic testing has been researched in the course of the PISC II and III programmes [7] and more recently in Sweden [8]. In both cases tiredness and motivation affected performance but there were no clear undisputable findings. Enkvist et al [8] attempt to explain some of the results by reference to a model of human performance in which "the attentional ability of a person is determined by his or her level of arousal". "The arousal level also determines the amount of attention resources that are available." In practical terms, this means that stress and pressure may initially lead to improved performance, but after a time this effect reverses. Boredom equates to lack of arousal and can have a very negative impact on performance.

There is a need for a code-of-practice on employment conditions for NDT staff. It is necessary to set down guidelines based on research as to what are appropriate employment conditions and working arrangements (time, pressure, noise, environment) for personnel engaged on quality critical activities. Such guidelines would be referenced by Accreditation Bodies and in contracts for ISI services.

## 4. Best Practice for Effective ISI

In Section 3 the various elements of the NDT infrastructure have been summarised. The question arises "Which elements of the infrastructure should be used when?". Or "What constitutes Best Practice?".

Guidance is available in the UK from the Health and Safety Executive which through a joint HSE-Industry Working Group has developed documents which describe "Best Practice for the Procurement and Conduct of NDT". Part 1 Manual Ultrasonic Inspection [9] and Part 2 Magnetic Particle and Dye Penetrant Inspection [10] are available to the public via the HSE web-site. Other parts relevant to other NDT techniques will be published progressively.

The HSE Best Practices have many recommendations including:

- Use an organisation Accredited for NDT operations with necessary technical management, i.e. don't hire a man, hire a competent organisation
- Contractual arrangements should be clear in the definition of who takes responsibilities. Users should think in terms of employing a service company capable of accepting technical responsibilities and providing back-up rather than employing operators as individuals. Either the purchaser of the service retains the key responsibility and simply 'hires a pair of hands' or the purchaser buys a service and specifies clearly his requirements. The supplier of the service may then have to qualify his offer if the demands are more onerous than he can guarantee.
- Define purpose of inspection, regions to be inspected, types of flaws and responsibilities of parties clearly (all-encompassing combinations would be prohibitively expensive)
- Use relevant Standards for Techniques, Equipment and Personnel
- Prepare Specific Procedures - specific to the material and geometry
- Carry out Capability trials when necessary - these are necessary if the task is outside the previous experience of the parties
- Use Certificated Operators
- Carry out Job Specific training - when inspection is not within scope of standard certification exams

- Prepare an Inspection Qualification report if the risks are high
- Carry out Audit and Surveillance of site operations to ensure operator performance

The Best Practice guidelines are recommending the use of all of the Infrastructure with increased emphasis on Job Specific Procedures, Job Specific Training and Technical Management of the inspection whenever high reliability inspection is needed. Figure 2 shows the NDT Infrastructure with the HSE Best Practice added.

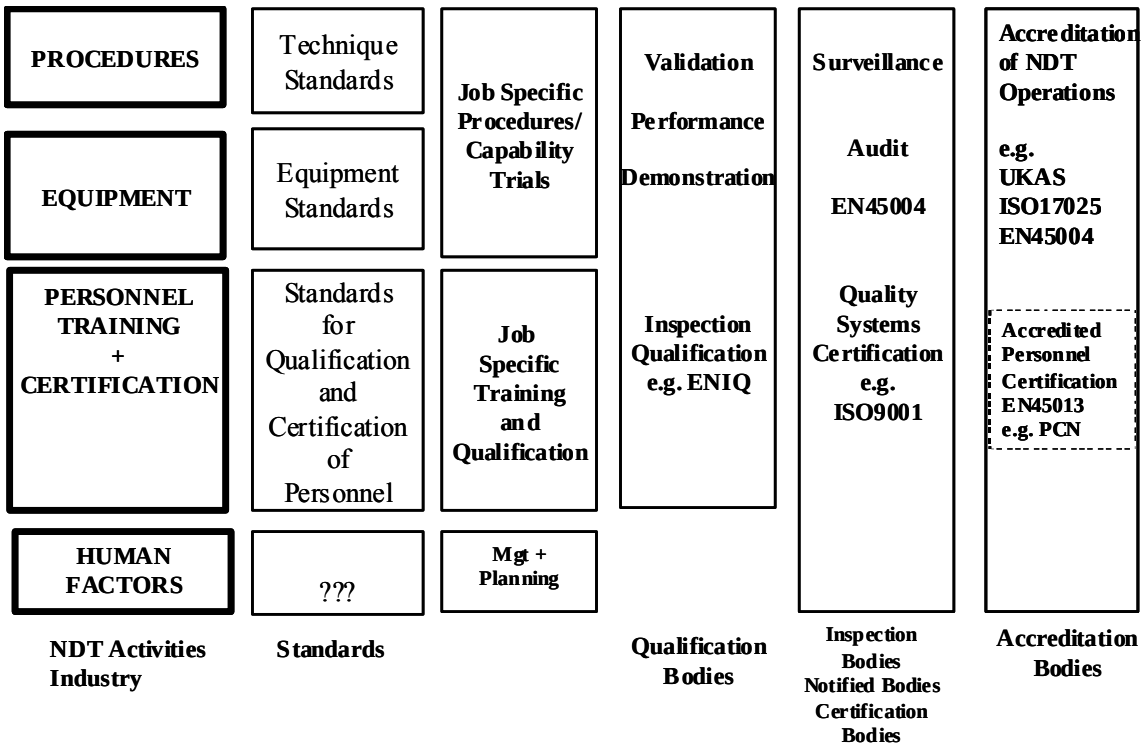


**Figure 2: The NDT Quality Infrastructure for Best Practice**

## 5. Best Practice taking account of Component Risk

The NDT Quality Infrastructure incorporates a large number of measures which can be taken to ensure inspections are as effective as possible, but each additional measure may bring additional cost.

In order to decide whether or not it is cost effective to invoke a particular measure it is necessary to consider the risk of component failure and the role of the proposed inspection. The risk of component failure is determined by a combination of the Consequences of Failure (e.g. health, safety, environment or economic) and the Likelihood of Failure (likely presence of significant defects, margin of safety, operating regime etc.). If the Consequence and Likelihood parameters are high then it will be much more important that the effectiveness of the inspection is high than if the consequence and likelihood are both low. This is illustrated in Figure 3.

Each proposed inspection can be plotted on a Risk-matrix (consequence and likelihood). The highest risks are at the top right hand corner, see Figure 3.

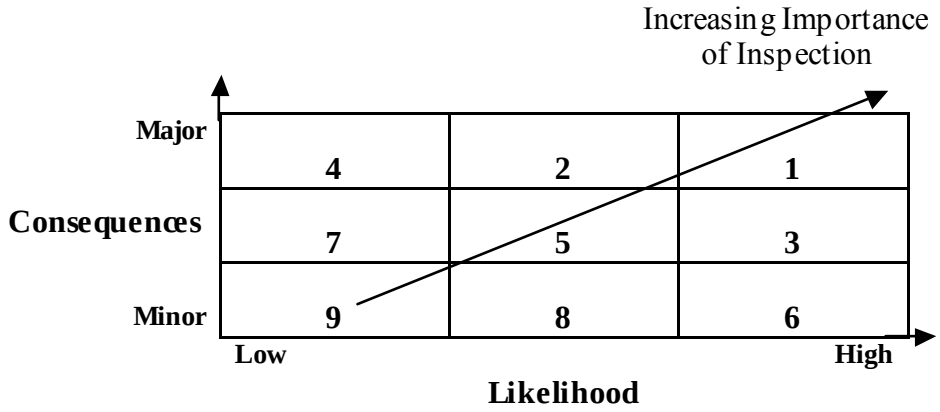


**Figure 3: Risk Matrix**

It is then possible to consider which quality measures are appropriate for each position on the grid. The author's proposals are given in Figure 4.

| **Quality Measure** | **Position in Risk Matrix** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Accredited Organisation | √ | √ | √ | √ | √ | √ | - | - | - |
| Definition regions/defects | √ | √ | √ | √ | √ | √ | - | - | - |
| Use Standards | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Specific Procedures | √ | √ | √ | √ | √ | √ | - | - | - |
| Capability Trials | √ | √ | √ | √ | √ | √ | √ | √ | - |
| Certificated Operators | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Job Specific Training | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Inspection Qualification | √ | √ | √ | - | - | - | - | - | - |
| Audit and Surveillance | √ | √ | √ | - | - | - | - | - | - |

**Figure 4 : Proposed NDT Quality Measures for different degrees of Risk**

The HSE Best Practice documents take a similar approach and give similar recommendations. In addition they give detailed guidance on specific technical measures that should be adopted for more important inspections. These include:

- coating preparation/surface finish/cleaning
- surface finish
- independent repetition
- adequate time allowance
- good working environment
- use of Level 3

## 6. Responsibility for the NDT Quality Infrastructure

As stated above, responsibility for the various elements of the infrastructure rests with a variety of bodies. Each concentrates on its own elements of the infrastructure. None is concerned with the complete quality chain.

Individual users and suppliers of NDT services are able to influence the development of the NDT quality infrastructure through participation in advisory committees, management committees and standards organisations. National NDT societies are in a position to take an overview of NDT quality and the more active seek to influence the whole quality chain. It is clear from that experienced gained in recent years that much greater influence can be achieved by the societies working together in their Regional Groups (e.g. EFNDT) and the International Committee (ICNDT).

### 6.1 European Federation for NDT (EFNDT)

To increase their influence at the European level where, increasingly, decisions are taken, the national NDT Societies have combined to form the European Federation for NDT (EFNDT). EFNDT is a non-profit legal entity registered in Brussels. National NDT Societies within the UN definition of Europe are eligible for membership. Each is represented on the General Assembly, which elects a President and Board of Directors. A Secretariat is provided by one of the member national societies. EFNDT has established a series of working groups covering topics such as WG1 Qualification and Certification, WG3 European Certification Process, WG4 Accreditation of NDT laboratories and Inspection Bodies and WG5 Detection of Anti-personnel Mine. These groups seek to support and complement (rather than compete with) the European committees/working groups of EA (European Accreditation), CEN, etc. and support national societies in their work at local level. Details and news of the EFNDT can be found on its website [11].

### 6.2 International Committee for NDT (ICNDT)

At International level, the ICNDT has revised its constitution with a view to improving its influence and effectiveness. The International Committee for NDT was formed in 1960. For most of its existence ICNDT's main role was to organise the World Conference. Since the mid 90s the more active members of ICNDT have been seeking to strengthen the organisation and make it more active. This culminated in the adoption of a New Constitution at the ICNDT meeting in Rome - by the member National NDT Societies (currently 50+). The National Societies each nominate two representatives to the ICNDT Committee. The committee then elects a Chairman, General Secretary and a Treasurer each for four years. It also elects Honorary Members. These people, along with nominees by each of the Regional groups (Europe, Asia-Pacific, Americas), form the Policy and General Purposes Committee. A Secretarial service is provided by an NDT Society (currently the Italian Society). Separately (now), the ICNDT chooses the Society to hold the next World Conference and that Society nominates the World Conference President. The next World Conference will be held in Montreal in 2004. Details and news of the ICNDT can be found on the ICNDT website [12]. ICNDT is mandated by its constitution to cooperate with other international bodies with an interest in NDT, including ISO, IAEA, IIW, etc.

## 7. Areas Requiring Development

The international NDT community should seek to promote and to harmonise the whole NDT quality infrastructure. More specifically:

- there is a need for more Best Practice Guidelines accepted internationally
- there is a need to develop an internationally accepted code-of-practice (guidelines) on employment conditions of inspection personnel.
- there is a need to educate purchasers of NDT Services, management of NDT Organisations, and Level 3s to recognise their responsibilities to manage NDT more professionally
- Personnel Certification Schemes should clarify the value of their products, introduce more Job-Related modules, introduce Management training courses to educate management.
- International bodies should take further steps to utilise the worldwide web to facilitate global access to capability data for use in inspection design/qualification (e.g. test piece and defect response databases accessible over the Internet).

## 9. References


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