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VALIDATION EXPERIENCE AT THE IVC AND ITS APPLICATION AT EUROPEAN LEVEL THROUGH THE EUROPEAN NETWORK FOR INSPECTION QUALIFICATION (ENIQ)

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SUMMARY

This paper will describe the work of the Inspection Validation Centre and the process of inspection validation, and how this experience has enabled the development of its use at European level through the European Network of Inspection Qualification (ENIQ). It will describe briefly how the concept of validation was introduced and why this has resulted in demonstrated improvements in inspection capability. The methodology for independent validation of the ultrasonic inspections for the Sizewell 'B' reactor pressure vessel (RPV) will be presented together with the associated detection and sizing results. Other levels of validation will be described, in particular those for the petrochemical and aerospace industries. The important lessons learned from this work will be described, and how these lessons have been used to develop sensible guidelines that will ensure that inspection personnel, equipment and procedures are adequate for their intended purpose.

INTRODUCTION

The concept of Inspection Validation and performance demonstration for the non-destructive testing (NDT) of nuclear reactor pressure vessels and nuclear steam supply systems is now widely accepted. There are many ways of validating NDT and the challenge at the moment is to develop appropriate cost effective methodologies that will provide adequate assurance that the NDT is fully capable of meeting the requirements of detecting, locating and sizing defects of structural concern. The Inspection Validation Centre (IVC) was set up in 1982 to validate many of the ultrasonic inspections carried out during the manufacture and in service life of the UK's recently built Sizewell 'B' pressurised water reactor (PWR). The requirement of independent validation of the NDT was identified as part of the safety case for Sizewell 'B'. However, activities that would nowadays be described as validation have been carried out ever since NDT first assumed importance in verifying plant integrity and quality.

SIZEWELL 'B'

The validation process for Sizewell 'B' illustrates independent validation at its most rigorous. When Sizewell 'B' was first proposed by CEGB, it was to be the UK's first commercial PWR. Public awareness of the potential hazards of nuclear power was at a peak as a result of Three Mile Island and, in addition to the normal licensing processes for nuclear plant in the UK a public enquiry was held to examine the CEGB's proposal in detail. In the UK, nuclear plant is licensed by the regulatory body, NII, on the basis of submission of a satisfactory safety case by the plant owner. For PWR's, there is a number of components for which no engineering provision is made against failure. Safety is assured not by mitigating the consequences of failure but by taking steps to ensure that the failure is incredible. The most notable example of such 'incredibility of failure' (IOF) components is the reactor pressure vessel, but many other components also fall into this category. Many factors contribute to make an IOF safety case, but in many instances the NDT carried out is a key part of the argument. It is crucial to be able to demonstrate that no defects of significance to safety could be present at the start of life or are developing in the operating plant. This can only be achieved through highly reliable NDT and led the CEGB to propose that the NDT carried out on all IOF components would embody three principles to ensure their reliability:-

(i) Diversity, (ii) Redundancy and (iii) Independent Validation.

Diversity guards against common-mode failures and involves the use of many different defect detection mechanisms, eg 45°, 60° and 70° probes from two directions and two sides, tandem methods and the use of high sensitivity to detect defects by crack tip diffraction, diffuse scatter from facets of rough defects as well as specular reflection. Redundancy guards against human failings and is achieved through repetition of the same inspection by several independent means eg the use of manual and automated techniques. Finally independent validation then provides confirmation that equipment, procedures and personnel are adequate for the intended purpose.

INDEPENDENT VALIDATION

Validation of the equipment, procedures and personnel of each inspection agency has been carried out for each stage of inspection during the fabrication and in-service life of the Sizewell 'B' reactor pressure vessel (RPV) and other IOF components. The validation for the RPV consisted of both a theoretical appraisal and a practical demonstration of the inspection techniques applied. The theoretical appraisal required the inspection agency to provide a technical justification of the techniques applied according to the inspection procedures. This appraisal considered the effectiveness of the proposed inspections from the point of view of both coverage of the inspection regions and the expected signal amplitudes. Where necessary, independent mathematical modelling of the inspection technique was carried out to provide assurance that the claims of the inspection agency were valid. The practical demonstration consisted of test pieces replicating the relevant RPV geometry at full scale and containing appropriate well characterised defects. Knowledge of the number, location and size of the defects was strictly limited to the IVC. The practical demonstration was therefore a blind trial: the operators submitted did not know how many defects were present in each test piece, or the actual size or location of any defect encountered.

The inspection standards to be achieved were specified by CEGB (now Nuclear Electric), these required each operator to detect all of the credible defects in the test volumes allocated that were equal to or greater than fitness for purpose (FFP) size. The FFP size is that for which high reliability of inspection is required. It is based upon fracture mechanics assessments of critical defect size but contains a substantial safety factor. Smaller defect sizes were specified for underclad cracking inspection and the minimum detection rate to be achieved was reduced for this case. To obtain certification of sizing and location of defects each operator had to recognise, size and locate all of the credible defects equal or greater than FFP in his allocated test volume. The sizing and location accuracy demonstrated had to be within the Nuclear Electric specification. In addition the procedure performance was judged using the results of all the operators applying the procedure.

SIZEWELL 'B' RPV VALIDATION DETECTION AND SIZING RESULTS

Table 1 contains a summary of the observed detection and sizing performance of the validation trials conducted in support of the ultrasonic inspections of the Sizewell 'B' RPV. It is not exhaustive but concentrates on the most significant factors associated with the quality of the inspection, namely, the detection and through thickness sizing of credible fitness for purpose size defects. Column 1 gives the stage of manufacture or service, column 2 the RPV component inspected, column 3 the inspection agency and column 4 the type of inspection. Column 5 is the detection success rate for all submitted operators and column 6 is the detection success rate restricted to individual operators who achieved certification. It can be seen from columns 5 and 6 that the demonstrated performance for the detection of credible fitness for purpose size defects is very good. Columns 7 and 8 show the mean and standard deviation of the sizing errors observed during validation. Column 7 is the error obtained using the results of all submitted operators. Column 8 is restricted to operators achieving individual certification, (the only operators authorised to carry out defect sizing on the Sizewell 'B' RPV).

In some cases it was agreed that sizing procedures need not be validated at PSI; this was because no defects were detected during the actual inspection of the Sizewell 'B' RPV. If, in future, in-service inspections show significant indications then validation for these sizing inspections will be required.

Figure 1 shows graphically the improvement of sizing performance realised by the validation process. Here a comparison is made of the sizing results obtained by a population of operators submitted for validation with a subset of the same population restricted to operators who achieve certification. Included in the graphs are the two standard deviation bounds within which it might be expected that 95% of the sizing results would lie.

OTHER LEVELS OF VALIDATION

Sizewell 'B' IOF Components

In addition to the RPV validation, the IVC have been involved in other IOF component validations such as for the inspection of the pressuriser and steam generator forgings and welds. These take a different form to those developed for the RPV. They, like the RPV validations, are more than adequate to give confidence in the NDT carried on these components and reflect the different structural integrity demands which fall on components other than the RPV. The main point is that the validation methodology has been tailored to the circumstances of the particular inspection.

Validation of NDT for Weld Root Erosion

To further illustrate the point about tailoring the validation procedure to individual circumstances, IVC has been involved in the validation of inspections for use in the petrochemical industry. In this case the industry wanted some assurance that the inspection techniques being applied in the field were adequate. A time of flight diffraction method (TOFD) had been developed to detect and assess weld root corrosion. No existing certification schemes cover TOFD and there was a need to develop the validation approach as an alternative way of giving confidence in the use of this method for this application. A successful low cost programme resulting in qualified equipment, procedures and personnel has been running for the past few years, where samples of piping from oilfields around the UK have been used to qualify personnel following job specific training.

Validation of New Inspection Techniques For the Aerospace Industry

The IVC is developing methodologies for the validation of NDT techniques for the Aerospace industry, as part of a consortium of European airline manufacturers, airline operators and maintenance organisations. The aim is to set up an inspection validation programme for the European Aerospace Industry.

LESSONS LEARNED FROM VALIDATION EXPERIENCE

i. Inspection Validation led to significant developments in procedures, personnel training and in some cases equipment modification.

ii. The time taken for validation should relate to the duration of on-site inspection time allowed.

iii. Technical Justification can provide a real benefit and can minimise practical validation work.

iv. Time spent in preparation and training including work on representative test pieces and defects is crucial.

v. Defect sizing causes most difficulty and future research should be targeted on providing the operator with data that will assist in producing a correct model of the defect.

THE WAY FORWARD

The IVC has produced an Inspection Qualification document that has now been accepted by British Standards as a Draft for Development. In addition the IVC is actively involved in using the experience it has gained to develop Qualification methodologies with its international partners through the PISC III Action 8 Group and the European Network for Inspection

Qualification (ENIQ). The membership of ENIQ is made up of national representatives of the CEC and EFTA countries. The general objective of ENIQ is the co-ordination and management of expertise and resources in the assessment and qualification of NDT primarily for nuclear components. The ultimate goal will be in supporting: i) industry, ii) codes and standard bodies and iii) regulatory bodies by making available results, technical tools and expertise that can be sponsored and managed at the European level. As a consequence, ENIQ should help in establishing a European attitude regarding inspection qualification.

It has already become clear that the European approach will seek to make use of as much relevant existing practical and theoretical evidence as possible. Such evidence, built into a Technical Justification, should minimise the need to produce and use the geometrically realistic blocks which represent the major cost of validation. In doing this, the European approach to qualification will continue to provide the necessary confidence in inspection but without the daunting cost and time penalties associated with purely test piece approaches.

Table 1. Sizewell 'B' RPV validation detection and sizing results.

Stage	Component	Inspection agency	Type *	Validation results: Detection % (a)	(b)	Sizing error mm (a) Mean±S.D	(b) Mean±S.D
1	2	3	4	5	6	7	8
A	Nozzle & shell	Creusot-Loire	m	100	100	--------	-------
	Nozzle & shell	BEL	aut	100	100	--------	-------
A	Stud & nut	OIS	m	100	100	-.3±3.4	-2.2±1.8
B,C	Closure head & main circ' welds	Framatome	m	100	100	4.0±4.2	2.3±3.2
B,C	Nozzle to shell welds	Framatome	m	98	100	-.4±6.9	1.4±4.8
B	Underclad (nozzles)	Framatome	m	96†	96†	-------	-------
D	Closure head & main circ' welds	BEL	aut	100	100	-------	-------
D	" "	BEL	m	---	---	-.5±3.8	-.5±3.8
B,D	Nozzle to shell welds	BEL	aut	98	100	-------	-------
B,D	Underclad (nozzles)	BEL	aut	86†	86†	1.9±2.9	1.4±2.8
E,F	Closure head dome to flange weld	RR&A	aut	100	100	-------	-------
E,F	Main circ' welds	RR&A	aut	100	100	2.2±2.1	2.2±2.1
E,F	Nozzle to shell welds	RR&A	aut	100	100	-1.2±5.3	1.5±2.4

A: Material procurement (forgings)
B: Fabrication (before final stress relief)
C: Fabrication (after final stress relief)
D: Post hydrostatic test
E: Pre-service inspectio
F: In-service inspection
* Inspection type: m (manual), aut (automated)
† 70% required
a) All operators, (b) Certificated operators only

BEL: Babcock Energy Limited
OIS: Oilfield Inspection Service
RR&A: Rolls Royce and Associates

COMPARISON OF VALIDATED AND UNVALIDATED SIZING PERFORMANCE

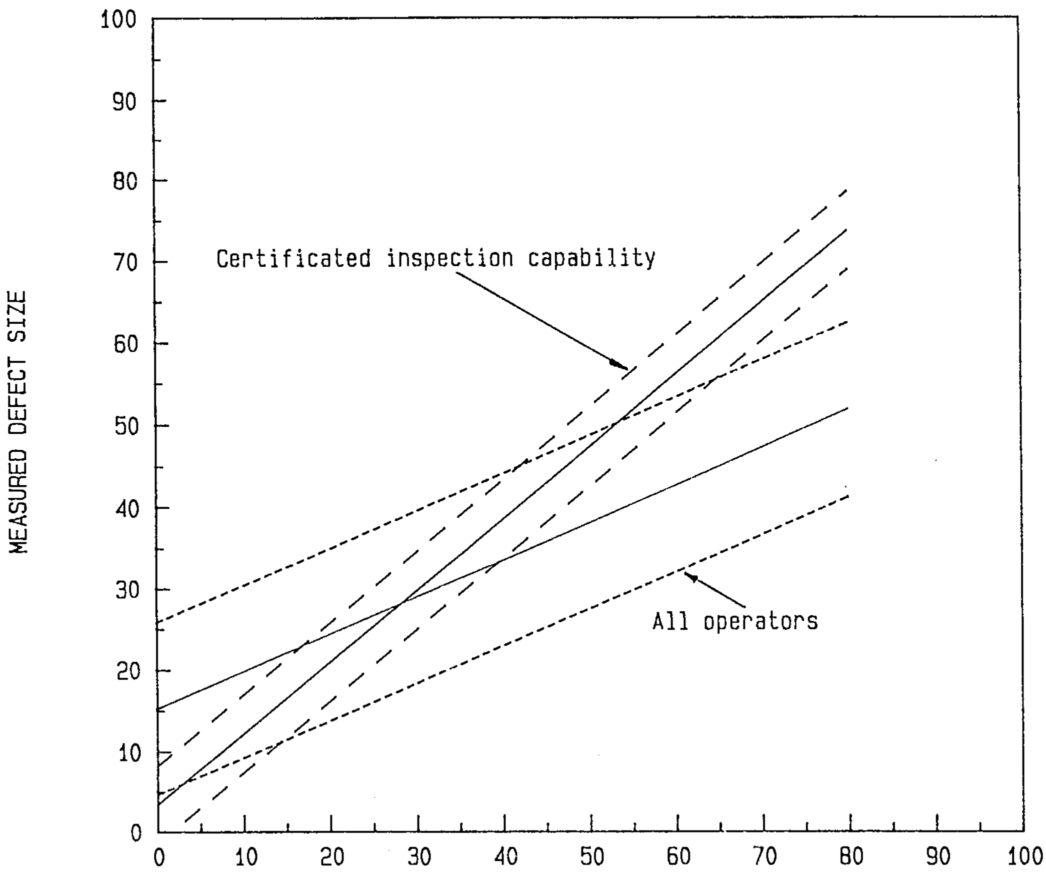

FIG 1. DEFINITIVE DEFECT SIZE (mm THROUGH THICKNESS EXTENT)