Improving Inspection Reliability Through Operator Selection & Training

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Abstract. A number of years ago the UK's Health & Safety Executive sponsored a series of three projects investigating the application of manual ultrasonics, which endeavoured to establish the necessary steps that ensure a reliable inspection is performed. The results of the three projects were each reported separately on completion and also presented at number of international conferences.

This paper summarises the results of these projects from the point of view of operator performance. The correlation of operator ultrasonic performance with results of aptitude tests is presented along with observations on the impact of training and qualifications of the operators. The results lead to conclusions on how the selection and training of operators could be modified to improve reliability of inspections.

Introduction

Starting in 1997 and running through to 2007, the UK's Health & Safety Executive initiated and sponsored the Programme for the Assessment of NDT in Industry (PANI). The impetus for the work came out of a desire to assess the effectiveness of NDT as applied outside of the nuclear industry in the UK. There had been many projects such as PISC which had led to changes in the way NDT was applied in the nuclear industry but the impact on NDT outside of the nuclear sector was not known. The first PANI project was instigated to provide this information.

The results of the first PANI project led to a second project to support the first's recommendations. This in turn led to a third project in an effort to address the issues highlighted by the second. The third PANI project was an investigation into the human factors of the manual ultrasonic task and an assessment of the organisation of NDT and the NDT process. The PANI 3 report which is available from the HSE website [Ref. 1] gives a lot of information regarding steps that can and should be taken to improve the reliability of NDT. This paper describes the issues raised by the PANI projects that relate to the operator training and selection and re-iterates the recommendations made in the PANI 3 report.

Why Do We Need to Improve Training and Selection?

Any inspection is made up of three important factors: the inspection procedure and the intrinsic capability of the technique to be applied; the process that is applied before, during and after the actual inspection and the contributions or otherwise of the organisations involved; the influence of the operator and the training and qualification requirements.

It is worth noting that the PANI projects did concentrate on the more difficult manual ultrasonic inspections in ferritic material: those where geometrical features such as backwall echoes, unfused land, weld roots and weld caps provide confusing echoes, making it more difficult to identify defect responses. On simple geometries, when the defect responses have to be identified from the general background noise then detection capability is very good. In the more difficult geometries then the results from all three projects show a large variability in operator performance.

Figures 1 and 2 show the results from PANI 1 and 2 respectively. In Figure 1 the x-axis shows the number of defects detected expressed as a percentage of the number of defects inspected (known as the flaw detection frequency, FDF). It can be seen that the overall performance is not what may be required in inspections requiring high reliability but there is also a wide variation in performance between operators who were of similar experience and held similar qualifications.

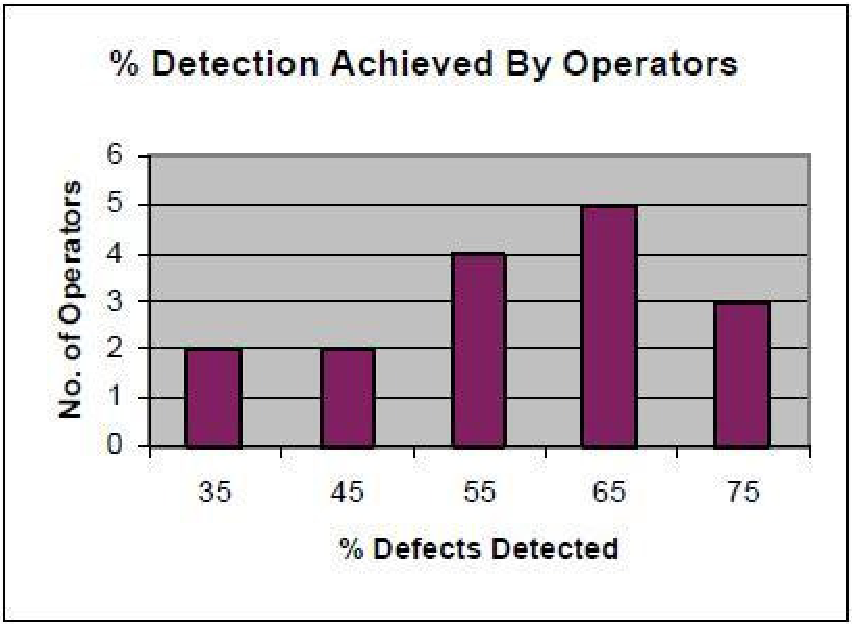

Figure 1 The PANI 1 Defect Detection Results

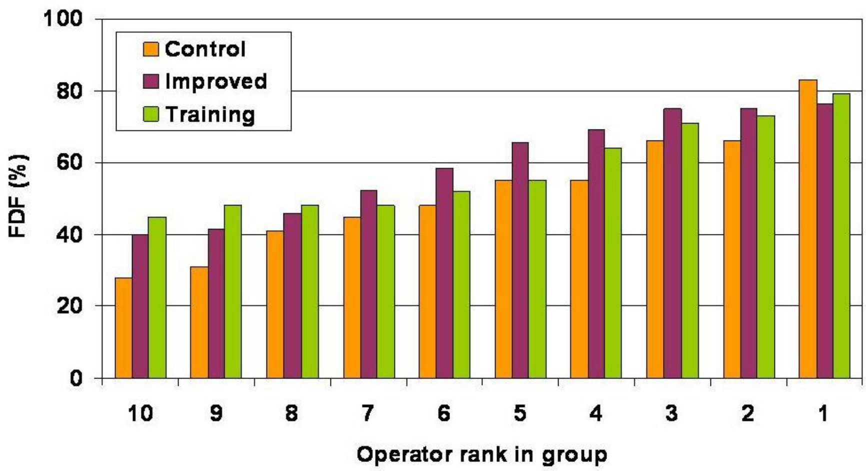

Figure 2 PANI 2 Defect Detection Results

In Figure 2, the PANI 2 results show that this variability between operators is still present even when steps are taken to provide better procedures and job specific training.

The PANI 3 results show a similar spread but fewer defects were inspected in the experimental phase.

Following the PANI 1 project, PCN, the UK's operator certification scheme, reviewed the need to have a qualification which addressed in-service inspection but concluded that there wasn't sufficient difference between ISI and manufacturing inspection to warrant such a step. The trade association for engineering insurance bodies, SAFed, did decide that a central qualification for the inspection of shell boilers was required due to the particular difficulties of such inspections. Following PANI 2, the authors were aware that some NDT Vendors changed the way they operated by giving operators practice inspections before actually going out on site. This had the benefit of refreshing the operator's technique and providing confidence in his ability prior to undertaking the inspection.

If any reader has any doubt on the impact an operator can have on an inspection then they should have a look at any optical illusion.

Supporting Knowledge

In order to perform an inspection an operator needs to have an understanding of the principles behind the manual ultrasonic task. In PANI 3 the operators were asked to provide written answers to a number of theoretical questions regarding defect scenarios and QA aspects of the tasks. The conclusions drawn from this part of the project showed that operators appeared to have a good knowledge of what could be considered every day practice. This included features of a component that would affect ultrasonic inspection and what content needs to be included in an inspection report. However, there appeared to be a deficiency in the knowledge which is less frequently called upon. This includes the QA which supports the everyday manual ultrasonic practice and a deeper understanding of ultrasonics and ultrasonic techniques.

On this topic, there is a presentation given by Birring [Ref. 2] which can be found on the internet. During interviews in 2007 to 2008 Birring discovered that very few of the Level 2 interviewees knew the basics of ultrasonic testing with the majority not having an understanding of things like wave mode, frequency and attenuation. He says that he went on to select individuals with Good Mechanical Aptitude and set up his own training school to give the necessary training.

Process Knowledge

An objective of the experimental work in PANI 3 was to investigate the decision making process that the operator applies when they observe indications. The debrief questions were aimed at establishing how the operators had used information from the ultrasonic A-scan in deciding whether to sentence an indication as a defect, and hence reportable, or a geometric response.

The results show that better training could improve this part of the inspection process. 46% of operators correctly characterised an indication using the main detection probe and cracks were the flaw most correctly characterised. 54% of operators would sentence the indication on the basis of main detection probe whilst 46% would not. The operators were asked if they applied IF-THEN logic. This is the technique which follows the deduction that IF the defect was planar and detected by probe X THEN the application of probe Y would provide the necessary information to confirm or contradict the deduction. 44% of the operators were not familiar with the IF-THEN term. 80% of the operators would use other probes but only 29 % had thought about which probe to use.

The experimental trials were recorded using CCTV and a Human Factors consultant analysed the tapes on completion. The findings from the CCTV confirmed the conclusions drawn by the trial supervisor. The findings imply that the 'good inspector' displays clear characteristics e.g.

- They seemed to 'Get on with the job'.
- They appeared confident and focused.
- They were not easily distracted.
- Their technique was consistent and methodical

These are all characteristics of what may be considered a desirable employee i.e. are these exclusive to NDT?

A key finding was that each inspector applied the procedure differently: of those observed, none appeared to complete all the scans; all scanned in a different order with different probes.

Self Knowledge

A recent survey in the UK by a private health company, BUPA, reported that 80% of us are in the wrong job for our personality. The survey identified warm and people-oriented accountants, secretaries with leadership skills and people in creative jobs who aren't expressive and eccentric. In addition, the survey found that more than half the people surveyed held an incorrect view of their own personalities.

In NDT we have a dichotomy when it comes to the characteristics we want to see operators display. On the one hand we require the careful, methodical approach for safety-related requirements ensuring accuracy and complete coverage. But on the other hand we require a more pragmatic approach to cope with the practical problems such as restricted time, restricted access and commercial pressure when working on site. PANI 3 set out to investigate the characteristics which improve operator performance on the manual ultrasonic task.

The literature review identified the following abilities associated with good NDT Performance:

- General Cognitive Ability
- Spatial Visualisation
- Abstract Reasoning
- Mechanical Aptitude

The Personality characteristics associated with good NDT performance were identified as:

- Conscientiousness
- Stress-tolerance
- Self-efficacy / Self-belief
- Risk taking

The discussion amongst the operators during the workshop identified similar factors.

Psychologists from Manchester Metropolitan University selected a suitable suite of psychometric tests based on the following criteria:

- Demonstrated reliability & validity
- Available from test publishers
- Norms available for comparison

The following tests from the SHL Applied Technology Series were selected and administered by the psychologists:

- General Cognitive Ability

    - Following Instructions
    - Numerical Estimation
- Spatial Visualisation/Abstract Reasoning
    - Fault-finding
    - Spatial Checking
    - Diagrammatic Thinking
- Mechanical Aptitude
    - Mechanical Comprehension

The results of the operators' tests were analysed and compared with results from the wider population. It was found that ultrasonic operators scored higher than the average worker on Numerical Estimation and Mechanical Comprehension. Ultrasonic operators scored lower than average worker on Spatial Checking, Fault Finding and Diagrammatic Thinking i.e. Spatial Visualisation/Abstract Reasoning

The operators were also asked to complete The Gordon Personality Profile Inventory (GPP-1). This personality scale measures eight personality factors. Ultrasonic operators were seen to score higher on responsibility and cautiousness than the norm group of UK employed males. However, they scored lower on ascendancy (self assurance) and sociability (need for others) than the norm group of UK employed males.

When the results of the operator performance on the manual ultrasonic task was compared to the analysis of the ability tests and the personality profile, it was found that operator performance on the test pieces was related to one of the ability measures and two of the personality scales measured in the project. Better operator performance was associated with:

- higher scores on the test of Mechanical Comprehension and
- lower scores on the personality scales measuring Cautiousness and Original Thinking.

The relationship between these three psychometric measures and overall UT performance was stronger than that found between UT performance and the number of years experience that an operator had in undertaking UT assessments

Recommendations for Training & Selection

So what does this all mean for the training and selection of operators? The conclusion from the PANI 3 project was written as follows:

NDT organisations and operators should consider the ability and personality traits predictive of good inspection performance, in particular the use of ability and personality tests, in:

- Selecting new trainee NDT operators
- Tailoring training courses to meet individual's specific needs for development
- Developing procedures at a suitable level of detail to support operators when undertaking inspections
- Identifying skills that should be developed as part of NDT operator initial and refresher training

In relation to selection and training, there should be a focus on identifying and developing (respectively) mechanical comprehension in UT operators as this was seen as a key factor relating to performance. With regard to the personality factors it is important that operators are assisted in developing self-awareness of their own personalities so that they can recognise when their behaviour can impact on the performance of the ultrasonic task. For instance, they might recognise when they are behaving in an over-cautious manner.

Similarly, it is important that the operators develop self-awareness so that they might recognise when they are applying procedures which are not compatible with those prescribed for the (UT) assessments being undertaken.

From the results of the application of the theoretical questions and from the debrief, it is clear that where relevant to the operator's role, the requirements for operator training should be expanded to give operators both a better understanding of how to use a knowledge of the way in which ultrasound interacts with defects and a knowledge of the decision making process and how decisions about the origin of indications take into account all available information.

Finally, operators should be given a grounding in the requirements prior to going to site for an inspection, including the importance of the QA activities.

References

[1] PANI 3 Report. Available at http://www.hse.gov.uk/research/rrhtm/rr617.htm

[2] S. Birring, "NDT Training: Basic Issues and Needs in the Houston Area", Presented at the ASNT Houston Chapter, February, 2009. Available at on line. Accessed 3rd October 2013.

Acknowledgements

A lot of people have contributed to the various PANI projects, the results of which make up this paper. There are too many to mention but most will be covered by the HSE, various management committees, the operators and their companies, and colleagues across different organisations. Without their input the PANI projects would not have delivered the beneficial results described here in.