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THE IMPORTANCE OF HUMAN FACTORS IN UT AS A RESULT OF PISC III ACTION 7

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ABSTRACT

The reliability of inspectors during manual ultrasonic inspection is being studied in Action 7 of the PISC III programme. Dedicated facilities and techniques have been developed to enable the activities of the inspectors to be observed in a comparatively inobtrusive way, and these have been deployed in two environments; one is typical of laboratory inspection conditions and the other simulates an industrial environment. The results obtained so far indicate that significant mistakes can occur in the sample of inspectors studied which result in failure to detect or report defects.

INTRODUCTION

From the results of a retrospective analysis of the PISC II data (1) it was concluded that whilst in many cases inspectors had demonstrated a good capability to detect and size flaws accurately, nevertheless performance varied, even between inspectors working to nominally similar procedures. This, in part, could be attributed to the human factor and it was decided therefore that a study of the influence of the inspector on the reliability of manual ultrasonic inspection should be carried out as Action 7 of the PISC III programme. It was recognised that most of the inspections in PISC II had been carried out in laboratory-type conditions and so it was decided to investigate also the influence of a typical industrial environment on inspector performance. An experimental programme was proposed which involved the observation of inspectors working in two types of inspection environment. One represented laboratory conditions in which the basic skills and performance of an inspector could be characterised, the other simulated an industrial environment which the effect on reliability of factors such as long working hours, tiredness and tedium could be studied. Specialised facilities and techniques were developed to enable the inspection activities of each inspector to be observed and recorded for subsequent analysis.

Results have been obtained for the first sample of three inspectors and these are presented. However, in view of the possibility that the programme may continue detailed discussion of the errors observed behaviour of inspectors tested at a later stage.

FACILITIES AND EXPERIMENTAL PROGRAMME

The test programme for each inspector is divided into two phases. The first is conducted in the Human Reliability Studio at Risley under laboratory-type conditions using facilities and techniques developed specifically for the studies. These include a computer-based inspection simulator, test blocks with welds containing a range of flaws, psychological tests, and video and medical monitoring equipment. The second phase of each inspector's work is conducted in a specially designed transportable environmental laboratory (TEL) in which industrial-type conditions can be simulated covering temperature, humidity, lighting and noise. The aim of this stage is to determine any changes in working characteristics or accuracy due to the more demanding conditions by comparison with the data obtained in the first stage of the studies.

The tests must be managed full-time by a team of invigilators, and provision has been made to enable the invigilator to observe the inspector at work without unduly disturbing him. This is achieved by providing the invigilator with a separate room from which he can monitor activities through a one-way window. Operating instructions are prepared for the invigilator to ensure that, as far as possible, the same work schedule is presented to each inspector, and that consistent standards are maintained by the invigilator in his observational comments and personnel assessments. A standardised approach is adopted to ensure that each inspector approaches the examination with the same concepts and amount of information so that differences in performance do not occur that could be attributed to the state of knowledge of an inspector.

The inspectors hired for the tests are professionally qualified, manual inspectors used to working in the nuclear field. Each works for five days in the studio and, some weeks later, for eleven days in the TEL; the length of the working day is respectively eight and twelve hours in the two facilities. In specifying the environmental conditions for the TEL it must be remembered that there are many factors that could conceivably influence an inspectors reliability, and that a separate study of each would be neither practical nor productive, since in many cases the effect of a single influence can be compounded by that of others. The environmental conditions selected for study therefore, cover some of the main factors considered to be influential and are imposed as a set. They cover long working hours in unfamiliar surroundings, high humidity, and restricted and noisy environment.

EXPERIMENTAL METHODOLOGY

For the purpose of assessing the reliability of manual inspection, the processes may be divided into six stages of activity, which are: 1. Calibration of the equipment. 2. Search scans. 3. Maximisation of signals and comparing them with recording criteria. 4. Sizing of recordable indications. 5. Plotting our recorded sizing data. 6. Reporting results.

In addition the test programme includes a series of psychological tests which are intended to examine the inspector's attitude to and aptitude for the work, and to define his mental outlook as the week progresses. Included in this section are structured interview and questionnaires, given at the beginning and end of each day; simple mental arithmetic tests involving operations normally encountered in the inspection process; and formal psycho-diagnostic tests.

RESULTS OF CALIBRATION TESTS

In the calibration tests the inspectors used a 45° probe and standard flaw detector on a 100mm thick ASME calibration block to determine the gain required to raise the signals from each of the three side-drilled-holes to 80% full screen height. This was repeated three times per session. The absolute amplitudes of the received signals were altered by changes which the invigilator made on a calibrated stepped attenuator. The gain and attenuator settings were recorded and analysed to determine the distribution of amplitudes. The distribution obtained in the studio is shown in Fig 1a for the three inspectors and all have a standard deviation of less than 1 dB. In the TEL (Fig 1b) the distribution is similar, but there are instances of substantial errors being made and as a result the standard deviation varies from 1 dB to 3dB during the test period. These mistakes appear to be dependent, at least in one case, on the day of the week, but detailed information on this is being withheld until the programme is completed.

The results indicate that there are two types of error associated with these tests, one related to normal experimental measurements and the other related to human error, i.e. mistakes. The experimental error in equipment calibration in the studio and the TEL is similar for the three inspectors, and is within acceptable limits, since many procedures permit a variation of ±2dB between calibration and recalibration. However, the data also show that some results in the TEL lie outside the above band, and are caused by rather large mistakes, which were not recognised by the inspector. Since this occurs only in the simulated industrial conditions of the TEL, the cause is attributed to tiredness.

PLATE INSPECTIONS

In the plate inspections, the orientations of the plates and the sequence of the inspection varied from session to session, and a considerable amount of data was produced. The discussion will be limited to data obtained in the TEL from one plate, identified here as plate X. In these inspections, the weld was scanned from two directions on one surface, using 45° and 60° beams orthogonal to the weld centre line, with 6dB added to the recording sensitivity during the initial scanning stage. The results of the inspections during the two week period are summarised in Figure 2a and 2b for the three inspectors. The flaw detection frequency is given for each day. It is apparent that good results are obtained with the 60° probe by inspectors B and C throughout the test period. The results for Inspector A are not so good with 56% of the defects being detected.

The 45° probe is less effective in these studies, with B and C detecting about 60% of the defects and A detecting 33%. In the case of the latter inspector the data suggests that the detection rate started at an average of 70% and fell to 7% towards the end of the study. Similarly, the detection rate for Inspector B decreased from an initial average of 76% to 28%. Statistical analyses indicate that the chances of such low detection rates occurring as part of the distributions at the beginning of the test period are 10^{-3} or less, and it appears therefore that the tests conditions are exerting a deleterious influence. This is consistent with comments made during the debriefing interviews which indicate that the inspectors were physically and mentally tired, this effect peaking towards the middle of the second week. The cause of the difference in effectiveness between the 45° and 60° beams is probably due to the amplitude of the signals obtained on the flaws relative to the recording threshold. Variations in the value for the maximum amplitude signal are found to occur, and for signals near to the threshold this could result in failure to detect a defect, with obvious consequences on the reliability. Information on the gain needed during scanning to improve reliability is presented in the next section.

INSPECTION SIMULATOR

For the inspection simulator, a range of signals representative of 45° and 60° ultrasonic A-scans of known amplitude and position were presented to inspectors during inspections of a simulated test specimen. Scanning raster and coupling efficiency were recorded and the inspector's activities were monitored and recorded on video.

The 45° and 60° inspection data have been combined and results are shown in Figure 3 to show detection rate as a function of signal amplitude for the studio and TEL tests. The graphs show that reliability of detection is dependent on signal amplitude. At the recording threshold the detection rate is, in most cases, about 90%. However, four signals which were 4dB above the recording threshold were missed, which corresponds to 10 dB above the scanning sensitivity, since 6dB was added for the scanning stage. On this basis, it appears that procedures aiming for high reliability should aim for a scanning sensitivity level which is at least 10 dB above the recording threshold expected from any significant flaw.

The records of scan paths, produced by the simulator, show that there were considerable differences in scanning pattern, overlap and coupling quality during the tests. There were differences from man to man, scan to scan and sometimes within one scan.

DISCUSSION

Detailed presentation and discussion of the results could conceivably influence the behaviour of inspectors tested later. Whilst this is considered improbable given the knowledge of the inspectors' response to the test conditions during the tests, nevertheless a level of confidentiality is maintained concerning the detail of the extent and precise contribution of the errors observed, and thus this discussion concentrates mainly on the broad areas in which human error has been observed.

Although data analysis is not yet complete some generalised observations can be made. It is clear that for the inspectors studied mistakes are made in the important stage of calibrating the inspection equipment, which result in significant deviations from the specified search sensitivity occurring. The more substantial of these mistakes occur uniquely in the simulated industrial environment of the TEL and indicate the onset of tiredness or lack of concentration. Smaller errors are seen which suggest an intermittent deterioration in mechanical skills, these are found to occur predominantly in the TEL.

The results from the inspection simulator indicate that all three inspectors miss signals close to the recording threshold, and that overall in the simulator trials between 10% and 25% of the defects are missed. Many of these are relatively low amplitude signals which would not have been marked as being above the recording threshold. However, some are more significant, for instance, fourteen signals at 6dB and four at 10dB above the scanning sensitivity threshold are missed. Investigation of the underlying causes of non-detection using the data stored in the simulator from the scan stage, video records, and human factors information gathered during the programme, indicate that a range of mistakes was responsible for the detection failures. It is also apparent however that the smaller the signal potentially available to the inspector the larger is the chance of failure to detect it. Mainly, this is caused by variability in his mechanical skills, and it is considered that a substantial allowance would be needed between the recording threshold and the sensitivity employed during scanning for the present sample of inspectors to achieve high reliability in these tests.

SUMMARY

The programme and analysis of data are still ongoing, however it is possible to make some tentative observations at this state.

1. The value of experimental error in these studies in calibration is acceptably small, but the magnitude of human error in some instances in unacceptably large.

2. Defect detection in these studies is found to be dependent on signal amplitude, and significant defects are missed due to scanning and coupling inadequacies. To counter variability in the scanning skills of the present inspectors it is considered that a substantial addition to the recording sensitivity would have been needed at the scanning stage.

3. It is considered that the detection performances of two of the inspectors was reduced by the simulated industrial environment.

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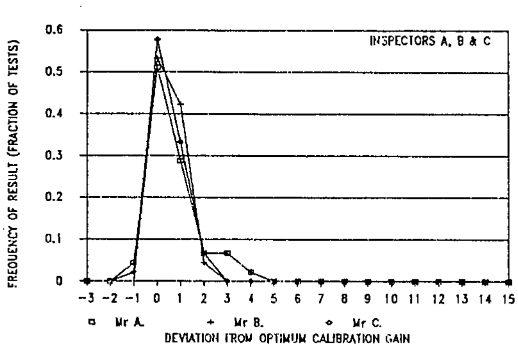

FIGURE 1a – CALTEST RESULTS IN STUDIO

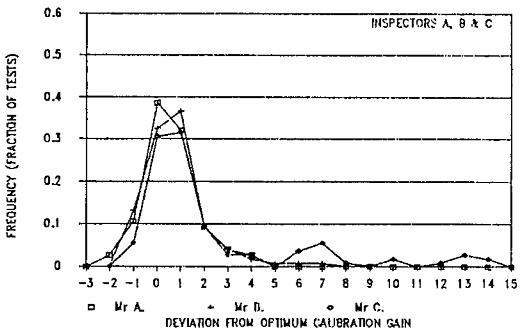

FIGURE 1b – CALTEST RESULTS IN TEL

FIGURE 1. CALTEST RESULTS

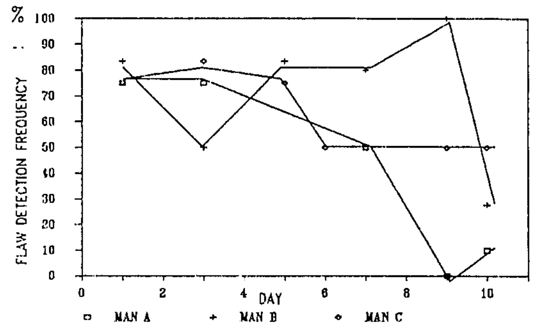

FIGURE 2a. 45 DEG. PROBE RESULTS.

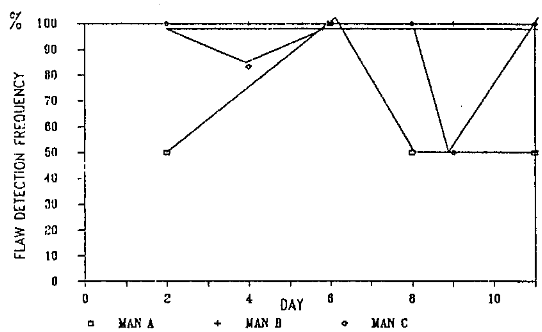

FIGURE 2b. 60 DEG. PROBE RESULTS.

FIGURE 2. DETECTION RESULTS FOR PLATE X.

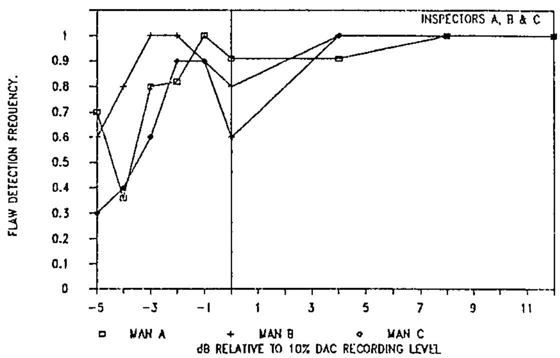

FIGURE 3a. SIMULATOR RESULTS – STUDIO

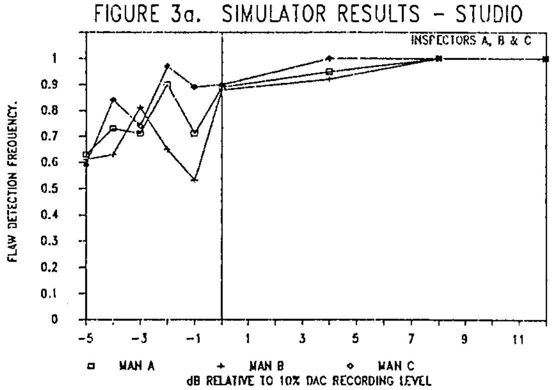

FIGURE 3b. SIMULATOR RESULTS – TEL

FIGURE 3. SIMULATOR RESULTS.