LESSONS LEARNED FROM THE PISC III STUDY OF THE INFLUENCE OF HUMAN FACTORS ON INSPECTION RELIABILITY

R A Murgatroyd(1), G M Worrall(1), S Crutzen(2)
(1) AEA Technology, Risley, UK, (2) JRC Petten, Netherlands

ABSTRACT

Les études ont été effectuées des contrôleurs aux ultrasons à main à fin d'examiner leur fiabilité dans des conditions industrielles simulées et d'établir les causes fondamentaux des points faibles. Les résultats principaux de ce programme et leurs conséquences pour l'industrie de contrôle sont presentés.

INTRODUCTION

Results from the PISC II Programme suggested that differences existed between manual inspectors in terms of their skills, knowledge and working practices which could exert a significant influence on the reliability of an inspection (1). Therefore, a programme of work on human reliability studies was initiated in the PISC III Programme as Action 7, with the objectives of studying and identifying causes of variability in inspection activities, and identifying some of the factors influencing the reliability of inspection in industrial conditions. It was foreseen that the information from Action 7 would aid in the development of methods for reducing the incidence of human error in inspection activities. This paper gives a brief summary of the programme and describes the lessons learned as a result of the work. A considerably more detailed description of the work is available as a PISC report (2).

EXPERIMENTAL OUTLINE

The underlying philosophy of the studies was to observe professionally qualified manual inspectors at work in typical inspection tasks, and to note and record the standard of performance achieved and any errors made. To this end, special facilities and techniques were developed which would enable comprehensive monitoring and recording of an inspector's activities to be performed in as unobtrusive a manner as possible. The two main test facilities were the Reliability Studio and the TEL (Transportable Environmental Laboratory). The former was used for tests in an environment representative of laboratory conditions, the latter for tests in simulated industrial conditions. The inspection conditions and environment in these facilities could be controlled according to the programme specification.

Broadly, this specified normal 8 hour day working for a period of five days in the Studio, and 12 hour shift working over 11 days in the TEL with ambient temperatures of up to 27°C, humidity in the range 40% to 50% and a background noise level of 80dB in the working area.

The monitoring equipment included video cameras and recorders, a computerised system for monitoring physiological condition, and a computer-based inspection simulator (the simulator) which recorded the details of each inspection, including the coverage achieved during scanning and the effectiveness of ultrasonic coupling. Other equipment included ferritic steel test plates and items for testing calibration repeatability.

Special tests were devised for the studies, and these included evaluation of calibration repeatability, inspections on the steel plates and the simulator, and assessment of the accuracy of plotting and reporting manual inspection data. The main parameter.measured in the inspections was flaw detection frequency (FDF), and this was used to assess and compare the capability of the inspectors, and to investigate how performances varied between the laboratory-type conditions and the simulated industrial environment However, the precise value of this parameter has no significance outside the conditions applicable to this test programme.

A psychological monitoring programme was applied throughout the studies to gather information on the inspectors' attitude to the work, and their physical and mental condition, with the aim of correlating the information with their inspection performance over the test period.

The programme specified that the inspectors taking part in the studies should be professionally qualified to ASNT Level 2 or their national equivalent and have recent experience of working in nuclear inspection tasks. Six were hired from major inspection organisations in Europe and they and their companies were guaranteed complete anonymity in the reporting of the results. The test programme was managed by invigilators who also operated the monitoring equipment and controlled the documentation

RESULTS

The main lessons learned from the programme can be summarised as follows.

CALIBRATION VARIABILITY

Inspector variability in calibration is acceptably small (2 to 3dB) in benign conditions typical of laboratory inspections (Fig 1a). This is also the case for the vast majority of calibrations performed in the industrial conditions simulated in the TEL, but a small number of mistakes were made in this test environment which resulted in significant calibration errors (up to 13dB) (Fig 1b). These are attributed to the onset of tiredness in the inspectors.

DETECTION RELIABILITY

The flaw detection capabilities of the inspectors varied significantly, although all were experienced and professionally qualified to similar levels. For some inspectors flaw detection varied by a factor of two from day to day, or from morning to evening (Fig 2). This variability is caused in many instances by changes in technical skills, such as scanning and maintaining ultrasonic coupling, but a number of errors arose for other reasons, principally loss of concentration and vigilance, arising from tiredness.

The amplitude of some signals obtained during the initial search scan was reduced by scanning deficiencies, and in the present studies an increase in scan sensitivity of about 10dB over the reporting threshold would have been necessary to achieve overall high reliability.

Several of the basic causes of non-detection could be rectified by specifically oriented training focusing on faults identified by the simulator, and the value of this approach to improving an inspector's performance has been demonstrated convincingly in another project (3).

EFFECT OF ENVIRONMENT

Working long shifts in an environment typical of industrial practice, can cause tiredness and demotivation for some inspectors, and these factors were found to have a profound effect on human reliability.

There appears to be an initial period of adjustment when working in the industrial conditions simulated in the TEL during which none of the inspectors achieved maximum performance (Fig 3). The results also suggest that the detection performance of some of the inspectors deteriorated mid-way through the second week in the TEL, due to tiredness or demotivation.

The psychological tests included in the programme assisted significantly in understanding the causes of failure to detect flaws, especially by providing an understanding the influence of inspection conditions and environment on an inspector's physical and mental condition.

DATA REPORTING

A significant number of errors occurred in the data plotting and reporting stage. The average percentage of flaws which were reported incorrectly owing to one or more mistakes in the plotting stage was approximately 5%. The number of mistakes in reporting data can be reduced by providing special plotting equipment adapted to the requirements of the data plotting task.

CONCLUSIONS

1. Substantial differences in detection capability occur from day to day for the inspectors, and in one case from morning to evening. This was due in many cases to variations in scanning skills, which affected scan overlap or coupling efficiency. In other instances non-detection was caused by loss of attention which resulted in failure to observe a signal or loss of place during scanning. Tiredness is considered to be a contributory cause of this behaviour.

2. Several of the basic causes of non-detection could be rectified by specifically oriented training aimed at faults identified by the simulator.

3. Where high detection reliability is required the sensitivity specified for the initial scanning stage should be substantially greater than the reporting sensitivity. The present results suggest that an addition of about 10dB would have been required for most of the inspectors in these studies.

4. Working long shifts in an environment typical of industrial practice can cause tiredness and demotivation for some inspectors, and these factors can have a profound effect on human reliability.

5. A significant number of errors occurred in the data plotting and reporting stage. The average percentage of flaws which were reported incorrectly owing to one or more mistakes in the

plotting stage was approximately 5%. The number of mistakes in reporting data can be reduced by providing special plotting equipment adapted to the requirements of the data plotting task.

RECOMMENDATIONS

The main recommendations made are:

1. The information obtained in the studies should be utilised to assist in the development and specification of precautions against human error.

2. In the light of these results, the conditions under which practical inspections are performed at nuclear plant should be reviewed by appropriate management and regulatory bodies.

3. The implications of the results on the environment and conditions under which examination and qualification tests are performed should be assessed to determine if some revision is necessary.

4. Certification and qualification bodies should consider using simulators as part of their examination methodology.

5. In view of the significant effect of the environmental conditions on the performances of many of the inspectors it is recommended that further psychometric studies are conducted on a sample of professional inspectors to determine if criteria can be established which will contribute to the selection of inspectors for specific tasks.

6. Further human reliability tests should be performed to increase the sample size of inspectors.

REFERENCES

1. Retrospective Analysis of the PISC II results. Draft PISC III Report No.12. R A Murgatroyd et al.

2. Human Reliability in Inspection: Final Report on PISC Action 7 in the PISC III Programme. PISC Report No.31.

3. Evaluation of the Capability of Inspectors. To be published. P D Birchall et al.

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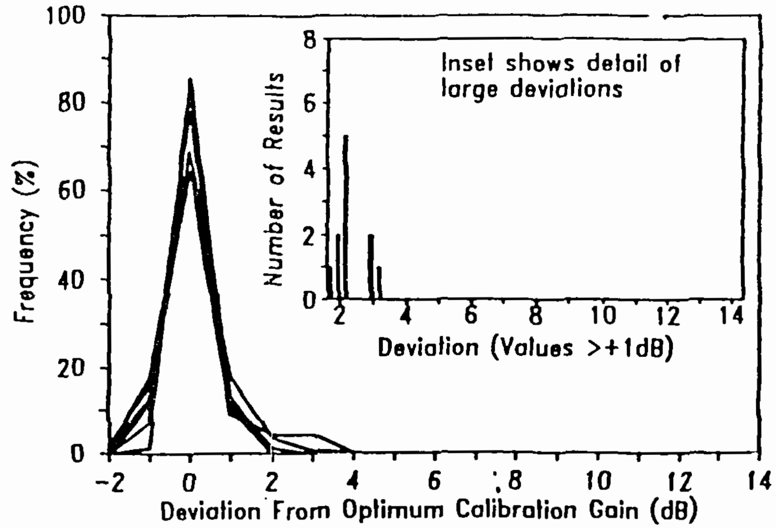
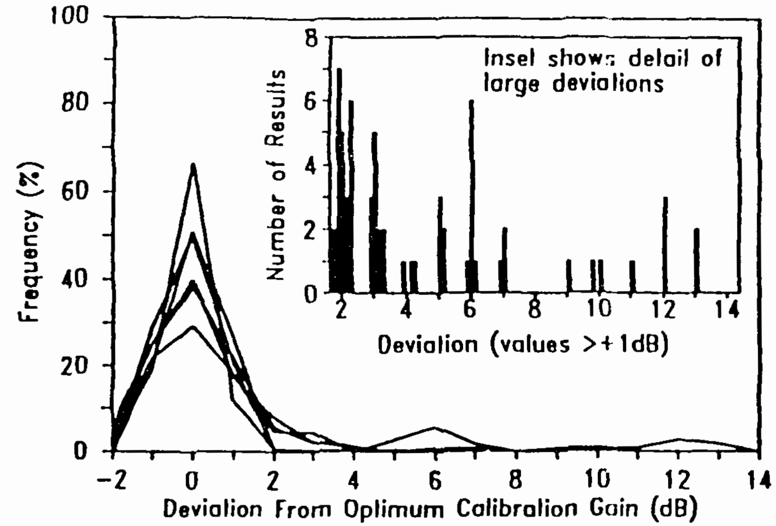
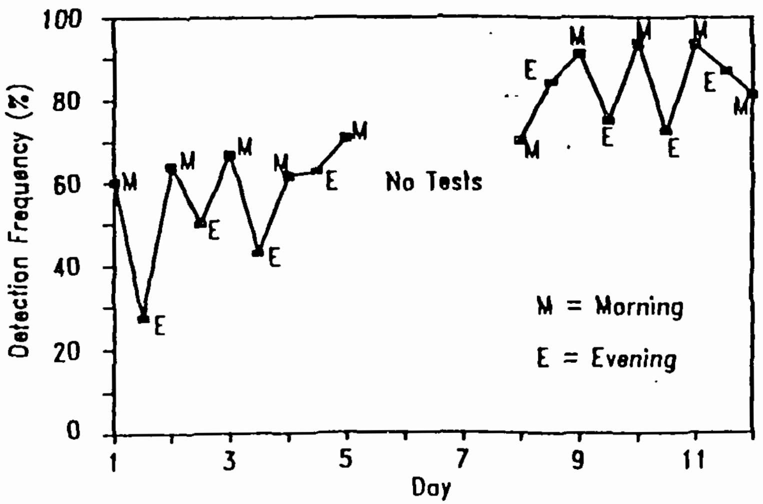


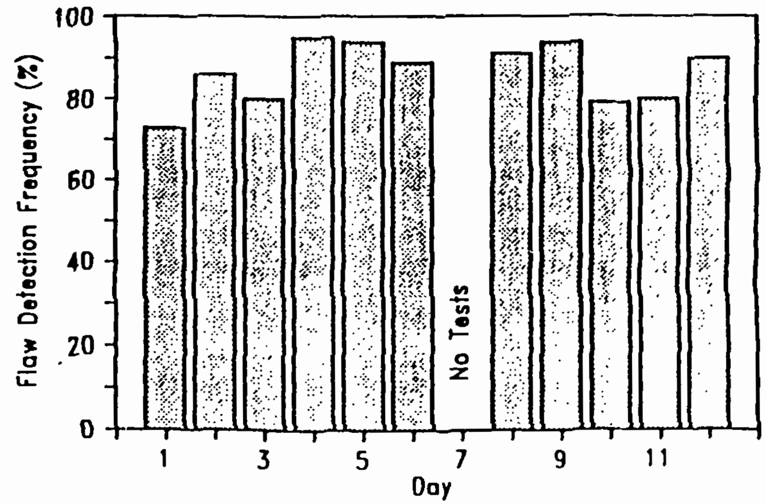
1a. Distribution of calibration results in the Studio



1b. Distribution of calibration results in the TEL



2. Simulator results in the TEL for one inspector



3. Average daily flaw detection frequency for all inspectors in the TEL