Programme for the Inspection of Reactor Steel Components (PISC)
PISC III – Status Report

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INTRODUCTION

The safety of nuclear power plants depends on the mechanical integrity of the materials, particularly the welds, used in their structure and on the ability to detect any degradation at an early stage or prevent it entirely. Non-destructive methods have been developed for finding surface and internal flaws that might develop and for determining their size. Techniques using sound waves of ultrasonic frequency are among the most widely applied, particularly for the important vessels and piping of the reactor plant. These components present very challenging inspection problems because of their size, complex shapes, combination of materials and difficulties of access after construction.

Various inspection procedures using ultrasonic techniques have evolved to deal with particular circumstances but, in some cases, uncertainties have remained about their capability and reliability. Such problems were first addressed in several national programmes of round robin inspection trials. It was recognized that such trials could be more effective if they involved the much larger number of teams and additional procedures available if a number of countries participated.


PROGRAMME RESULTS

PISC I results showed shortcomings of some usual industrial ISI procedures; PISC I was in fact analyzing the existing ASME 1974/1977 procedure [1].

PISC II RRT results [2] (as well as some trials of PISC I) showed that:

a) improvement of the usual industrial NDE attitude was possible; consequently, some changes of the ASME procedure were proposed:
   i) 20% DAC instead of 50% DAC;
   ii) use of techniques adapted to the defects to be detected: e.g. 70 deg SEL probes;

b) several ISI procedures exist that met the requirements (such as the ones established by the UK LWR Safety Group).
For such procedures, no change was obviously required; optimization from an economic/industrial/reliability point of view was however necessary.

PISC II parametric studies on the effect of defect characteristics [3] showed the importance of defect parameters like the type of defects (planar or volumetric) the crack tip aspect, the position in depth, the angular position, the surface roughness.
These results were in fact the exact quantification of the trends shown by the PISC II RRT on welded assemblies. As a conclusion, it was understood that the blocks realized for the PISC parametric studies and containing cheap "realistic" artificial defects were good and even conservative for the performance evaluation of NDE techniques.

In 1986, starting from the PISC results, the ASME Code for pressure vessels and boilers, Section XI, has been discussed in the USA for its modification. Presently, the ASME Section XI Committee is even going beyond the modifications proposed in 1986 and two new appendices are announced on the qualification of Procedures and on the qualification of Personnel.

PISC III PROGRAMME STATUS

PISC III, the third phase of the PISC series insists on the capability demonstration with assemblies containing realistic defects (Table 1) [4]. The PISC methodology is also extended to all major parts of the primary circuit of the LWR reactors. Moreover, the work done on the austenitic steel testing is of real value for the inspection of LMFBR components.

Testing activities have begun in several of the PISC III actions. Substantial progress has been made in defining the final work to be undertaken in all the seven Actions and in acquiring the necessary test samples and other resources. The uncertainties that prevailed during 1986/87 concerning the level of budgetary support have mainly been resolved. Adequate resources from the CEC and the organisations of participating member countries are now assured to carry out the essential elements of all the planned actions. In particular, there has been a strong response from inspection organisations to participate in the various round robin and other test activities.

The objectives of each of these seven Actions of PISC III and the status of work are as follows:

Action No. 1 (Real Contaminated Structures) seeks to collect results from specific investigations and limited round robin tests (RRT) on real service induced defects in materials and structures of the primary circuit of light water reactors (LWRs). The hot cell facilities at JRC-Ispra are fully equipped for non destructive and destructive work on a collaborative basis. Cracked austenitic steel primary circuit pipes from Switzerland have been inspected to propose a full demonstration of the whole resources available. Further samples are available from Spain, Sweden, USA and Finland (Figure 1).

Action No. 2 (Full Scale Vessel Tests) validates results obtained by procedures in the PISC II exercise in realistic inspection conditions (Figure 2). As a start, the installation offered by Staatlich Materialprüfungsanstalt (MPA), Universitaet Stuttgart, Federal Republic of Germany is being used. It is made of a BWR full scale vessel plus modular full scale PWR components. Seven teams are presently participating in the phase 1 concerning the sizing of selected defects in order to establish the capability of sizing techniques; sizing results from the German national programme are also included.

Eight organisations have registered their interest in the phase 2 validation of ASME type procedures by an international JRC-Ispra team using an ISI robot offered by RWE and MAN to PISC for the period of the exercise (1989). It is foreseen that, in a third phase, individual teams will apply their ISI procedure.

Action No. 3 (Nozzles and Dissimilar Metal Welds) has undertaken round robin tests of safe-ends and geometries representing some of the most difficult technical aspects of in-service-inspection. A Japanese-Italian BWR assembly of nozzle plus safe end is circulating since March 1988 to twenty teams in ten countries. An American BWR assembly with two nozzles and safe ends and a Spanish PWR nozzle and safe end will begin their circulation in mid 1989 (Figure 3). These round robin tests are planned to continue until January 1991.
**Action No. 4 (Austenitic Steel Testing)** will apply the PISC II methodology to the primary circuit piping of LWRs. Round robin tests for the capability assessment and parametric studies are considered as well as reliability evaluation of the testing procedures. Wrought pipe samples are available in the USA and from Japan, moreover, large cast samples have been ordered by JRC. Twenty five teams have registered their intent to participate in one or more phases that should start end 1989 and will extend up to 1991 (Figure 4).

**Action No. 5 (Steam Generator Integrity Testing)** will undertake round robin tests both of individual tubes and tubes in realistic uncontaminated and contaminated mock-ups of steam generators containing real and artificial defects. Capability tests and reliability tests will be included. The PISC Management Board has carried out a reassessment of the technical details to be considered taking into account the results coming from the Surry steam generator studies in the USA. Preparatory work is now under way to acquire tubes and introduce and validate the defects to be studied; tubes have been offered from France, Japan and the United States. France is preparing the hardware necessary for circulating the tubes and the mock-ups. The Management Board has received advice from CSNI - Principal Working Group on Primary Circuit Integrity on the defect types and characteristics of most importance with respect to safe operation. Twenty four teams from nine countries have registered an interest to participate in the RRT planned for 1990-1991.

**Action No. 6 (Mathematical Modelling on NDE)** has the objective to validate mathematical models and perform parametric studies in order to assess the importance of defect characteristics. Sixteen organisations in eight countries have registered their intent to participate in studies to assess mathematical models of ultrasonic inspection by validating the physics of the models, verifying it with experiment and assessing the utility of the models in terms of limits of valid application, satisfactory and efficient computer performance and accuracy. Fifteen models have been offered for possible study. An important objective is to promote the practical application of models as an aid to more effective and efficient inspection procedures and interpretation of results. Parametric studies are an essential source of data for verifying models; the studies commenced in PISC II have been extended in PISC III; four reports on the effect of defect characteristics on the ultrasonic signal response, one report on the effects of the cladding and two reports on the effects of the equipment characteristics are completed. This work was carried out in the United Kingdom, France, Belgium, Italy and at the JRC-Ispra.

**Action No. 7 (Human Reliability Studies)** seeks to evaluate the influence of human interpretation of inspection results, equipment malfunctions and human interaction on the overall inspection procedure. Part of this work is underway in the UK and at the JRC-Ispra utilizing the PISC II data and supplementary questionnaires. Other aspects will be undertaken within some of the round robin exercises, firstly in full scale vessel inspections.

**CONCLUSIONS**

PISC III is a large and comprehensive international exercise. The strong support from national authorities and NDE organizations attests to a wide-spread recognition that room remains for progress in understanding and improving inspection techniques applied to nuclear plant components, particularly for their optimal use in field conditions. The support also highlights an acceptance of the important role of collaborative efforts to achieve this goal.

**REFERENCES**

[1] PISC (Plate Inspection Steering Committee)
Full PISC I reports
CEC, EUR 6371EN Volumes 1 to 6 (1979-1980)
OECD, CSNI Report No. 48.
Ultrasonic Inspection of Heavy Section Steel Components
The PISC II Final Report

Summary of the PISC Parametric Studies on the Effect of Defect Characteristics (EDC)

[4] PISC (Programme for the Inspection of Steel Components)
The PISC III Programme

Figure 2: Full scale components at MPA, University of Stuttgart, used in Action No. 2 of PISC III: 3 PWR nozzles in a support ring on the top of a full scale BWR vessel.
Figure 1: Circumferential fatigue crack in a BWR safe-end as examined in the JRC hot laboratories, after removal from the reactor.

Figure 3: a. BWR (Type CAORSO, I) nozzle with safe-end. b. PWR (type Vandellos, E) safe-end with adjacent ferritic nozzle portion and austenitic pipe section.
Figure 4: Pipes and elbows from Japan with welds containing typical service defects for the PISC III RRT on austenitic steel welded assemblies.

Table 1

PROGRAMME FOR THE INSPECTION OF REACTOR STEEL COMPONENTS, PISC III

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<td>Budget</td>
<td>CEC budget half the resources, countries bear own costs and make &quot;in kind&quot; contributions</td>
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<td>Duration</td>
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<td>NEA Role</td>
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<td>Members</td>
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