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THE STEAM GENERATOR PROGRAMME OF PISC III

BIRAC C.*, HERKENRATH H.**

10th INTERNATIONAL CONFERENCE ON NDE IN THE NUCLEAR AND PRESSURE VESSEL INDUSTRIES
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THE STEAM GENERATOR PROGRAMME OF PISC III

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SUMMARY

The PISC III Actions are intended to extend the results and methodologies of the previous PISC exercises, i.e. the validation of the capabilities of the various examination techniques when used on real defects in real components under real conditions of inspection. Being aware of the important safety role that steam generator tubes play as barrier between primary and secondary cooling system and of the industrial problems that the degradation of these tubes can create, the PISC III Management Board agreed to include in the PISC III Programme a special Action on Steam Generator Tubes Testing (SGT).

It was decided to organize the programme in three phases, including Round Robin Tests (RRT):

- capability tests on loose tubes,
- capability tests on transportable mock-ups,
- reliability tests on fixed mock-ups including some interesting SURRY tubes.

1. INTRODUCTION

The SGT programme differs from those of the other PISC III Actions /1/ where heavy steel components are considered. Significant distinctions are material (INCONEL 600), geometry (diameter 7/8"= 22.22 mm, wall thickness 1.27 mm), the technique mainly applied (Eddy Current), and the number of defect types which can occur on steam generator tubes. The definition of the programme depended on the interest of the participating countries in the large variety of failure mechanisms. An inquiry inside of the countries helped to understand their priority of interest in the various defects.

In the meantime, results from international activities in the field (SURRY project) became available and are taken into account together with recommendations from international workshops.

The programme (sample matrix and test schedule) of Phase 1: capability tests on tubes, is formulated and the Round Robin tests have started in the beginning of 1990.

2. PRELIMINARY INQUIRY

Differences in the applied material, in design and operation conditions of steam generators utilized in the PISC member countries can cause a large variety of failure mechanisms on the steam generator tubes. Therefore, the first step undertaken for establishing a test matrix was an inquiry /2/ on the specific technical aspects and especially on the priority given to the different kinds of defects in the member countries.

The inquiry contained four categories of questions concerning:

- tube design characteristics,
- steam generator operating conditions,
- existence of failure mechanisms and degree of interest,
- availability of tubes and mock-ups.

Answers to the questionnaire arrived from eleven countries and showed the following trends:

- Wear, IGSCC and IGA are the failure mechanisms most frequently observed or of most potential interest.
- There are many proposals of tubes or mock-ups but they were corresponding to defects sparsely represented in the answers to the inquiry or not fully available.
- Service induced flaws are only represented by the SURRY steam generator tubes.

The SGT programme proposed to the PISC Management Board in Spring 1988 was based in large part on the information from this inquiry and got a positive response of 27 teams from 10 countries interested in the participation in related Round Robin tests.

3. IMPLICATION OF THE SURRY WORK

In the light of extensive information that became available from the USNRC Steam Generator Group Project (SURRY Project) there was a strong requirement to review the PISC programme on NDE of steam generator tubes /3/. A workshop on this matter, held at Paris in April 1988, made the following recommendations:

- There is a further need for studies to demonstrate the capability of detection, sizing and characterization of
  - . defect types as IGSCC and IGA (In the SURRY steam generator tubes the mainly observed defects were denting, pitting and wastage);
  - . complicated situations (combinations between different defects, between defect and deposit, between defect and tube geometry or environment).
- There is a need of performance demonstration of improved methods of data processing and signal analysis.

These recommendations became implemented in the Steam Generator Tubes Testing (SGT) programme of PISC.

4. CSNI WORKSHOP RECOMMENDATIONS

In October 1988 the CSNI - Principal Working Group N°3 organized a "Workshop on Steam Generator Integrity" at Staatliche Materialprüfungsanstalt (MPA) at Stuttgart /4/. The main objective of the Workshop was to discuss steam generator tube plugging criteria as applied in practice in different Member Countries, and to prepare recommendations and guidance for the PWG3 and the PISC Management Board on general integrity requirements and objectives. It was an updating of the general understanding of practices in the different countries and an aid to the evaluation of results on NDE testing of steam generator tubes in the PISC Round Robin test programme.

The discussions led to the formulation of the following recommendations to the PISC Management Board:

- A strong emphasis has to be put on IGSCC and IGA failure mechanisms.
- Not only the defect depth has to be retained, but also other defect characteristics like the length, the orientation, the location and the nature of the defect.
- Key values have been pointed out for some defect characteristics, about 40% for the depth and 16 mm for the length.

The last two recommendations will be taken into account in the frame of the evaluation of the programme results.

5. THE PISC STEAM GENERATOR TUBES TEST PROGRAMME

5.1 Objective and Content of the Programme /5/

The objective, relatively close to that of the heavy structures programmes, is the experimental evaluation of the performance of test procedures used for steam generator tubes in nuclear power plants during in-service or pre-service inspection.

The recommendations coming from the workshops have been taken into account for the definition of the sample matrix discussed later on. But the decision of the SGT programme in three Phases has been maintained:

- Phase 1 is a capability exercise consisting of Round Robin tests on individual tubes including calibration, training and blind test tubes (Fig.1).
- Phase 2 includes capability and reliability Round Robin tests on uncontaminated mock-ups adequate for automatic tools inspection (Fig.2).
- Phase 3 also consists of capability and reliability tests but on a contaminated mock-up, simulating real access conditions to the steam generator tubing. This mock-up contains tubes with service induced defects removed from the SURRY steam generator.

5.2 Matrix of Tubes and Samples for Phase 1

Although the SGT programme was accepted in general in Spring 1988, the PISC III SGT group and the Management Board decided that no RRT sample would be manufactured and proposed for circulation until the defects to be introduced would be certified as realistic defects.

The Reference Laboratory of PISC at JRC-Ispra (responsible of the preparation of the test samples for the Round Robin tests) organized a validation including destructive examination, of all defects acquired or made available by Member Countries. This action was actively supported by laboratories specialized in Eddy Current testing in Belgium, France, Germany, Italy, Spain and the United Kingdom The defects were mainly provided by Japan and the Netherlands, some mechanical defects by JRC-Ispra.

As a conclusion of the SGT group meeting in June 1989 it has been recognized that realistic defects are possible to be manufactured of the following categories: denting, wastage, fatigue crack simulations (EDM), pitting, deposit, wear.

With the information from this action and taking into account the recommendations from the activities mentioned in

Chapters 3 and 4, the SGT Group accepted part of a new sample matrix in terms of defect realism, nature, orientation and dimensions.

On the basis of artificial IGA and IGSCC (Figs.3 and 4) examined with NDT and metallurgically, it was recognized that further comparison was necessary of such artificial defects with corresponding real ones. Thus, in October 1989, during a restricted meeting, international NDT specialists and steam generator metallurgists illustrated and discussed the correlation between metallurgical aspects and NDT responses of artificial defects on the one hand, and real defects found in removed "pulled tubes" on the other. The agreement on the significant parameters to be respected when creating artificial IGSCC and IGA defects gave the Reference Laboratory the orientation for the choice of artificially induced defects of these types and the possibility to finalize the sample matrix.

From a fabrication point of view, or with regard to the origin of the sample, four categories of tubes will now be involved in the SGT Round Robin tests:

- blank tubes with different pilgrim noices, transition zones and environment (antivibration bar, support plate, tube sheet, etc.);
- tubes with machined simple defects but also combinations of defects, reproducing real detection and characterization probems;
- tubes with in-service induced defects, e.g. pitting, wastage, light denting and deposit-defect combinations;
- tubes with artificial chemically induced defects.

5.3 Organization of the Roun Robin Tests of Phase 1

In Phase 1: capability tests on loose tubes, the samples will be placed in sealed boxes. Special devices developed for these boxes will ensure

- blind test conditions during circulation;
- identical test conditions also after transportation of the boxes.

Three kinds of samples are in preparation for circulation:

- **Calibration tubes** (ASME and blank) for which material will be made available by the Reference Laboratory;
- **Training tubes** in 1 or 2 boxes with typical examples of simple defects, rarely composite defects;
- **Blind test tubes** in 10 boxes containing straight or curved tubes with simulation of structural elements. Each box contains 9 tubes of 1 m length with two defect zones each, i.e. about 20 defects per box. For the circulation the 10 boxes

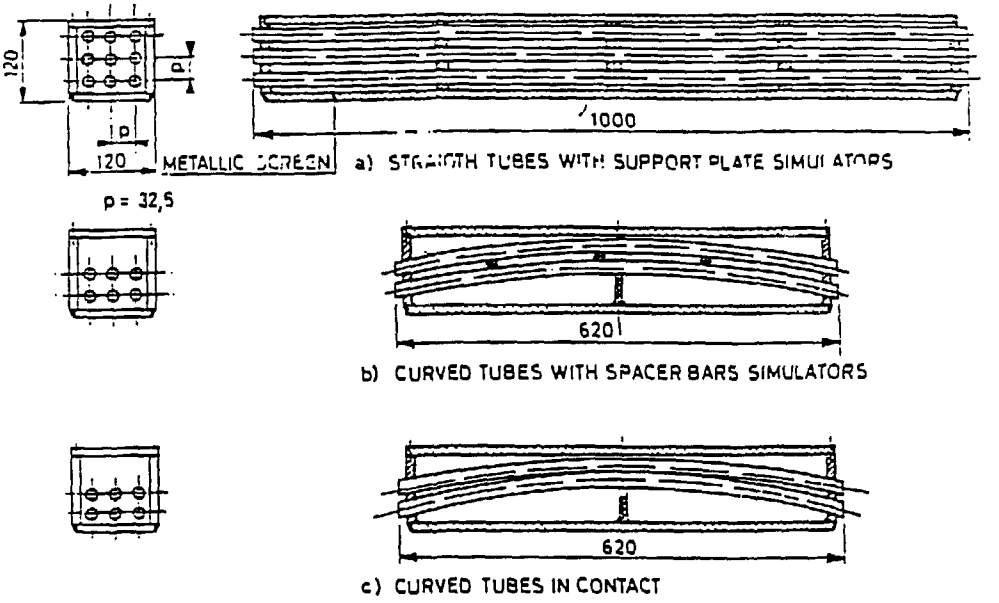
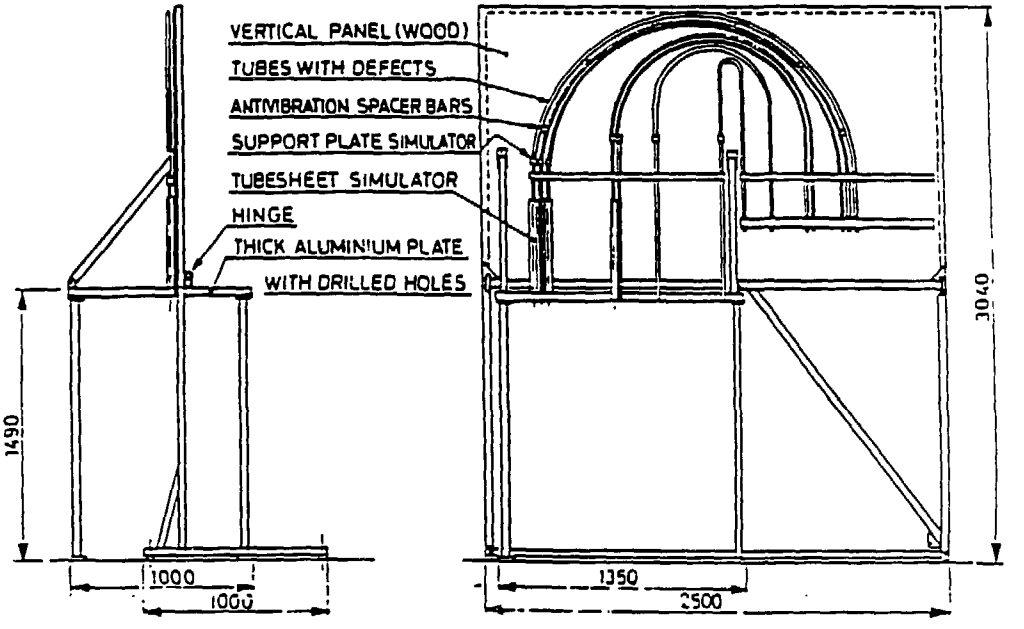


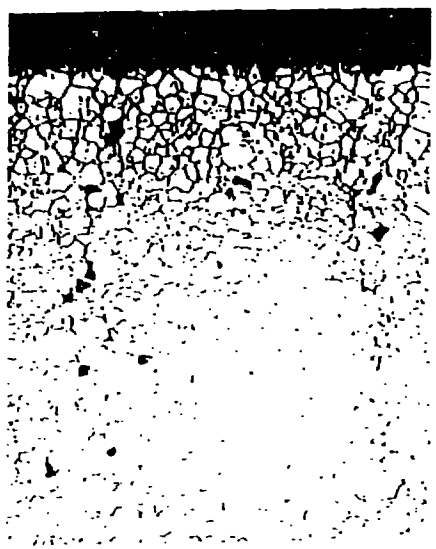
Fig. 1 - Sealed boxes for blind tube inspection.



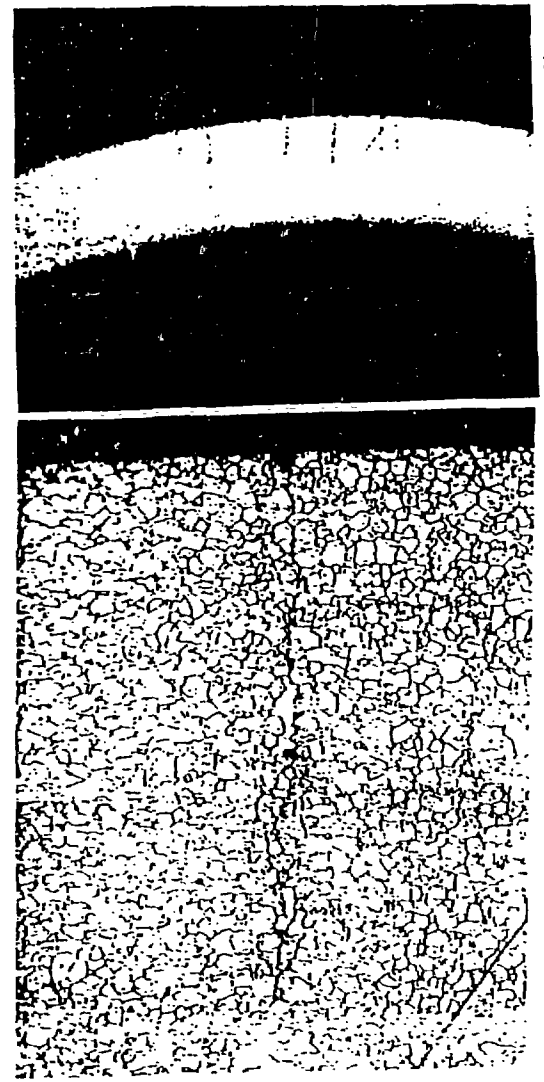
x20

DEPTH %

Target	Actual
50	40



200x



20x

DEPTH %

Target	Actual
50	46

200x

Fig. 4 - IGSCC sample (JAPEIC)

will be divided into three batches: 3 + 3 + 4 boxes.

It is agreed that each team has 1 week time available for testing 1 batch applying 1 procedure. The circulation schedule is based on the number of teams which expressed interest in participation (27 teams from 10 countries). The RRT have started with the circulation of the Training Tubes in January 1990. Taking into account the necessary transportation time between teams and countries, the RRT will be concluded near to the end of 1991.

5.4 Evaluation of Results

The Reference Laboratory (Operating Agent) is responsible for the collection of inspection and test data. The Reference Laboratory is responsible for the certification of defects and for conducting or directing all destructive examinations. The analysis and evaluation of results is the responsibility of the Operating Agent and will be coordinated by a Data Analysis Coordinator following methodologies approved by the Evaluation Task Force reporting to the PISC III Management Board. The Operating Agent will draft reports of the results for review by the Evaluation Task Force and for approval by the Management Board. The PISC Referee Group established by the Operating Agent has the responsibility to ensure the confidentiality of team inspection results.

6. CONCLUSION

The objective of PISC III Action N°5: Steam Generator Tubes Testing (SGT), is the assessment of capability and reliability of procedures as applied for the in-service inspection of steam generator tubes. The programme, proposed in Spring 1988, was based on the results of an international inquiry regarding the interest of each country in the different failure mechanisms which may occur on steam generator tubes. This programme has been revised taking into account the results of the USNRC Steam Generator Group Project (SURRY Project) and the recommendations of CSNI Workshops.

Specialists' meetings contributed to the definition of the defects and tube specimens to be used for the Round Robin tests of the SGT programme. Phase 1 of the programme, capability tests on loose tubes, have started in the beginning of 1990 and should be concluded near to the end of 1991.

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