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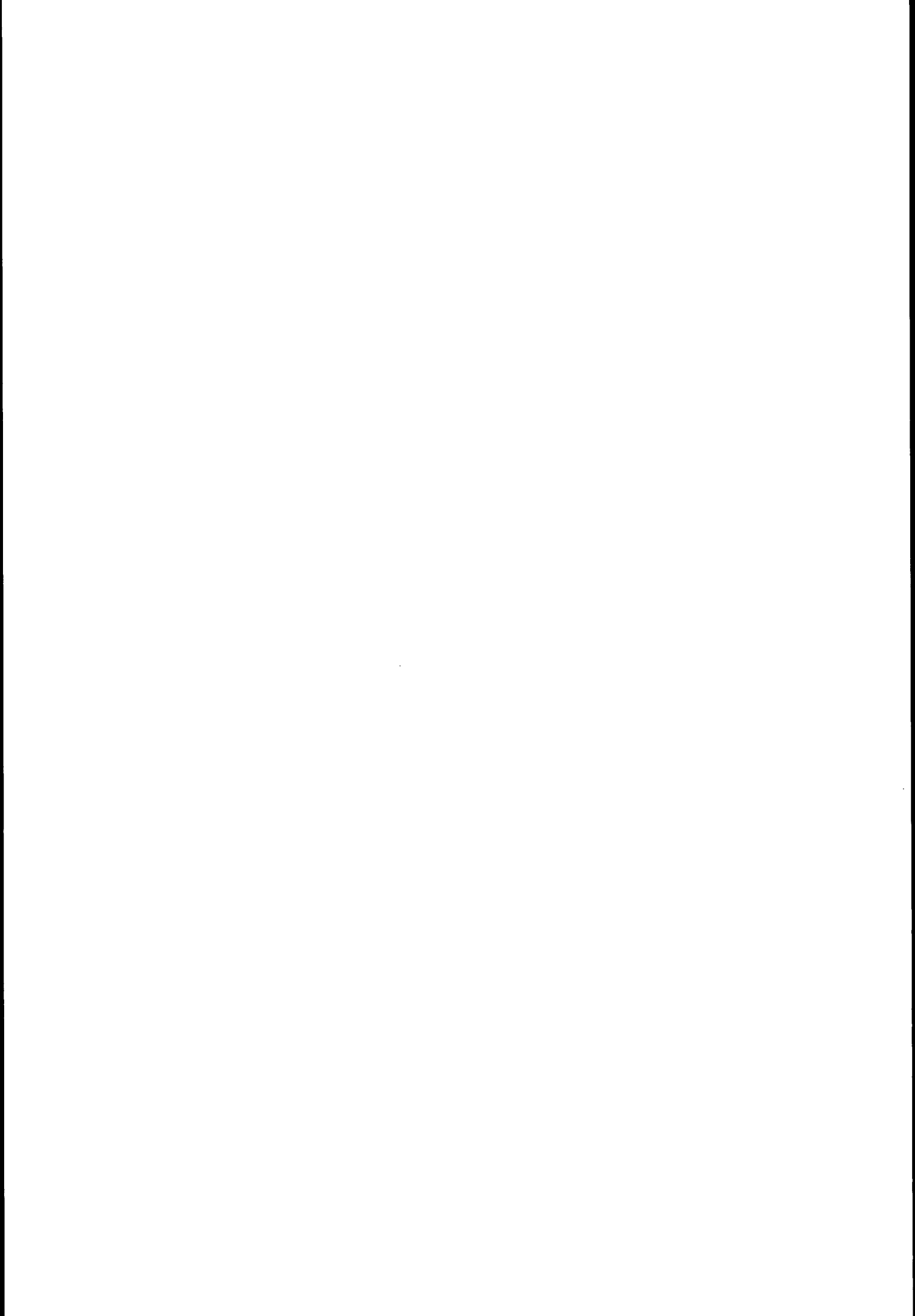
# **A summary of the PISC-II project**

PISC II Report No. 1 - September 1986

FINAL ISSUE

Programme for the Inspection of Steel Components

# **PISC**



## FOREWORD

In assuring light water reactor safety, it is vital to have confidence that no leaks or breaks will develop in the reactor pressure vessel and associated piping, which together constitute the primary coolant circuit. Initially small defects in these thick steel components can grow under the stresses arising from repeated pressure and temperature changes and the embrittlement of the metal caused by the radiation emanating from the reactor core.

Ultrasonic testing is widely used for detecting, locating and sizing flaws in primary circuit elements at various stages of plant life. The successive PISC projects have constituted the most notable sustained international effort to assess the effectiveness of these inspection techniques.

The Plate Inspection Steering Committee (PISC-I) programme (1976-1980) was intended to establish the capabilities of the 1974 ASME Code Section XI ultrasonic procedure. The Programme for the Inspection of Steel Components (PISC-II, 1981-1986) constitutes a more detailed evaluation of the best performance obtainable by modern ultrasonic techniques under optimal conditions.

The PISC-II Managing Group believes that the results of PISC-II are worth careful consideration by the sponsoring organizations (OECD-NEA and CEC Directorate XII) with a view to bringing them to the notice of licencing authorities, code and standard bodies.



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## 1. INTRODUCTION

This report summarises important aspects which are detailed in other volumes of the PISC II report. After a description of the background and motivation for PISC II, it outlines the organisation, objectives, and terms of reference. The main features of the Round Robin Test and of the Parametric Studies are indicated in Section 3 of this paper, including a brief statement on how the results were analysed. Section 4 of this summary is devoted to highlighting the major conclusions and trends so far identified from the results and is perhaps the most important Section for the general reader. The paper ends with some general comments on the achievements of the programme, on the availability of the detailed information and on future work.

It should be noted that the results have different implications and different ratings of importance to different groups of people such as different regulatory staff, reliability engineers, fracture mechanics, NDE developers and practitioners and those people responsible for the future validation work and NDE capability studies. Such differences in interpretation are to some extent matters of individual opinion and are dependent on background and environment; it is therefore considered better to leave such considerations to other reports and to present only the overall picture in this summary report.

The PISC programme was initiated in 1976 with the programme which is now called PISC I, the objective of which was to investigate the ability of the 1974 PVRC procedure (based on the ASME XI Code) to detect, locate and size flaws in thick reactor steels by ultrasonic methods. Three 20 cm-thick steel plates with welds containing deliberately-implanted flaws were shipped in turn to ten countries, where inspection teams tried to locate the flaws using ultrasonic ASME methods based on this procedure and selected alternative methods. The results and conclusions of the programme were presented in 1980 to the CSNI Working Group on Safety Aspects of Steel Components in Nuclear Installations. Endorsing the conclusions and recommendations that had been reached, the Working Group noted that a number of areas of uncertainty in the ASME approach had become apparent, and that there was a pressing need for further work to be done to develop the alternative methods. The Working Group asked the Plate Inspection Steering Committee which had managed PISC I to outline a second programme covering these areas.

### 1.2. Motivation for PISC-II

#### 1.2.1. The need for a further programme

In 1980, the growing emphasis on the in-service inspection (ISI) of nuclear reactors was making it increasingly important to validate the reliability of non-destructive testing (NDT) techniques and procedures, in particular as regards ultrasonic methods of inspection. The results of the PISC-I programme could not be regarded as definitive, owing to the limitations of the project and the impossibility of separating overlapping defects. The results indicated trends which needed further investigation.

There was clearly a need to collect more data in order to obtain better-defined results and broader conclusions. There was also a gap in the PISC-I results for flaws of intermediate size, from 20 to 70 mm in height. While results obtained with the alternative procedures demonstrated that these satisfied most in-service inspection requirements, precise conclusions could not be drawn because many parameters varied simultaneously, or because teams had presented procedures based on several techniques without identifying which of them was being used in a particular instance. Suitable techniques had yet to be identified for most of the actual inspection situations encountered for LWRs and their primary circuit components in particular. A second set of round robin trials was clearly called for.

#### 1.2.2. The need for parametric studies

It was considered necessary to add separate studies on certain parameters which influence defect detection and sizing, to assist both in understanding the dispersion in the PISC-I results and in assessing the performance of the specific techniques to be applied in the second RRT. The introduction of these parametric studies (PS) constituted an important difference between PISC-I and the new study.

The parametric studies increased the scientific content of the programme, widened its scope, helped in checking the validity of the results, and ensured an efficient application of resources and effort. These studies consisted essentially of laboratory exercises.

The PISC-I programme had made it possible to identify some potentially dominant parameters, and these were given first priority in the PS :

- defect position and geometry,
- equipment characteristics,
- presence and nature of cladding.

#### 1.2.3. Sponsorship and programme management (Table 1)

In November 1980, the NEA Committee on the Safety of Nuclear Installations (CSNI) agreed to sponsor, together with the Commission of the European Communities (CEC), a second programme following a proposal drawn up by the former Plate Inspection Steering Committee. It was agreed that overall management of the project, as one of the operational activities of the CSNI, should be vested in a new Managing Group made up of representatives of the participating countries, working to OECD Rules of Procedure, and with an NEA Secretariat.

The CSNI accepted a proposal that the Ispra Establishment of the CEC Joint Research Centre should be invited to act as Operating Agent, namely be responsible for the detailed organization and co-ordination of the project under the general guidance of the Managing Group. This included, in particular, organising the RRT and the parametric studies, performing the destructive examination of the RRT plates, evaluating the test results, and drafting reports on the work.



The PISC-II programme was included in the Direct Action Programme of the Ispra Establishment. As a result, resources for technical management and execution of the project were made available from the budget of the Commission of the European Communities. The Ispra Establishment also filled the function of Referee Laboratory for the programme. This involved resolving such matters as introducing benchmarks and reference defects in the test plates, ensuring confidentiality of teams identities, collecting and correcting inspection data and performing the evaluation of results under the guidance of the PISC II Managing Group (see Appendix III).

## 2. THE OBJECTIVES AND TERMS OF REFERENCE OF PISC-II

### 2.1. Objectives

The objectives of the PISC-II programme were :

- to evaluate the effectiveness of NDT techniques either in use or being developed for the inspection of reactor pressure vessel components, with regard mainly to detecting and characterising service-induced flaws.
- to identify techniques for acceptance tests, pre-service inspection (PSI) and in-service inspection (ISI) which could be generally accepted, and
- to bring the conclusions of the programme to the attention of the Code, Standard and Regulatory Bodies concerned with ISI.

Emphasis was put on examining ISI techniques and procedures, and on the second of the three objectives. It was thus hoped to have a majority of automatic scanning inspection procedures represented in the round robin test but manual scanning procedures to evaluate the effectiveness of individual techniques used or being developed for ISI were also accepted.

### 2.2. Terms of Reference

The programme had the following terms of reference :

- a) The test procedures selected for study were in use (or had potential to be used) for acceptance tests, and for pre-service or in-service inspection. It was requested from prospective participants in the round robin tests that they must document fully all proposed techniques and procedures for consideration by the Managing Group before they were accepted for the programme.

\* PSI refers to a baseline inspection prior to its entering service (i.e. "finger printing" the assembled vessel).

- b) In addition to the round robin tests (RRT), the programme included a number of parametric studies aimed at evaluating parameters which could affect the results obtained, such as : defect position and geometry, equipment characteristics, the presence and nature of cladding.

Such studies took the form of smaller specific experiments (laboratory exercises) which made it possible to reduce the number of variables that were involved in the large scale tests, and to evaluate each in more controlled experimental situations.

- c) The scheme for evaluating the results of the whole exercise had to be prepared in advance, taking into account the assumed capabilities of the inspection procedures considered (see point a). It was not expected that any simple statistical treatment would suffice to characterize the results (but in the event, results were so numerous that statistics were used in evaluating them).

- d) The carbon steel plates that were to be examined contained welds which incorporated deliberately-implanted defects. An essential part of the PISC II programme was that at least some of the test assemblies (hereafter called "plates") used would be of the high cleanliness characteristic of modern production, and that some of these test assemblies would be of a geometry representative of a reactor pressure vessel component. Thus, the plates had to be as realistic as possible as regards : base material (certified reactor quality), welding process (certified), cladding, and geometry of the nozzle (when present, see Table 2).

The plates bore clear, indelible reference marks. As far as possible, defects were of the service-induced type and had characteristics making it possible to correlate the results of the PISC-I and PISC-II programmes. Surface and near-surface defects of heights between 3 and 20 mm were introduced, as were internal defects varying in height from 2% to 35% of the plate thickness (predominantly in the range from 4% to 20%).

- e) It was originally intended to examine only reactor pressure vessel steel; stainless steel was considered in an ancillary exercise late in the programme.

- f) It was also intended that the nondestructive testing technique applied was that using ultrasonics; other methods were only considered in an ancillary exercise in the programme.

- g) The results of the PISC-II programme were to be reported in 1984.

- h) Co-operation was arranged with similar national and international programmes, in particular those of the United States PVRC and the Japan PVRC, and studies in the United Kingdom, Federal Republic of Germany, France and Italy.

### 3. A DESCRIPTION OF THE PISC-II PROGRAMME

#### 3.1. Testing Procedures Applied to the Round Robin Plates

As a result of the PISC-I exercise, the ultrasonic procedures included in the programme were based on techniques available (or likely to be used in the near future) for acceptance tests, PSI or ISI. Emphasis was put on ISI techniques and procedures (Ref. 1). The techniques were applied to the plates in such a manner that their performance in specific situations could be evaluated, with the aim to identify the best set of techniques for use in high-performance PSI and ISI procedures.

The procedures involved techniques such as :

- high-sensitivity pulse echo,
- tandem probes,
- focusing probes (contact or immersion) at  $70^{\circ}$ , longitudinal waves,
- special probes (e.g. twin-crystal),
- special wave modes,
- Electromagnetic Acoustic Transducers (EMATs),
- signal enhancement (for cladding and near-cladding regions),
- acoustic holography,
- surface waves,
- phased arrays,
- amplitude transit time locus curves,
- electromagnetic procedures (E.C.),
- Synthetic Aperture Focusing Techniques (SAFT),
- time-of-flight diffraction (TOFD),
- $0^{\circ}$ ,  $45^{\circ}$ ,  $60^{\circ}$ ,  $70^{\circ}$  angle probes in standard or modified ASME procedures,
- radiography (e.g. with a linear accelerator or cobalt-60 source); this was often used to help in establishing references.

The techniques were examined with regard to their ability to detect, locate and size the defects present in the test plates.

The ASME Section XI procedure was again included in order to establish a point of reference with PISC-I, and to examine the effect of modifications such as higher sensitivity, the use of supplementary probes, combinations of techniques, mechanized scanning, etc.

The participating teams, organisations and the procedures that they used are listed in Appendix V. The time schedule for the whole programme is given in Table 3.

Duplication of procedures was avoided as far as possible so that results would be obtained within a reasonable time. Intending participants were requested to furnish a proposal giving (for each of the procedures that they proposed to use) :

- a) a short description of the procedure, stressing its advantages and possible limitations, as well as any restrictions on the test block characteristics, flaw morphology and distribution that it could cope with,
- b) the estimated examination time,
- c) the preferred location for carrying out the examination.

It was decided that a procedure could involve many techniques, but these should be at least potentially applicable to ISI.

### 3.2. The flaws and the Plates

#### 3.2.1. Flaws

The flaws included in the round robin test plates were mainly planar flaws of the types that could be service-induced, but some manufacturing flaws were also considered (Ref. 1).

The following requirements were established for the service-induced flaws in the RRT plates :

- a) The flaws were to be distributed such that the majority (2/3) lay in the third of the plate nearest the cladding.
- b) The flaws were to be essentially perpendicular to the surface (i.e. have limited tilt angles).
- c) Surface cracks were to be included.
- d) There were to be cladding boundary flaws and service-induced cracks initiated at fabrication flaws.

#### 3.2.2. Plates

There were four round robin test plates in all, two flat plates containing butt welds (Plates No. 1 and 2), and two plates with inset nozzles welded to them (Plates No. 3 and 9). The plates came from the national or international programmes mentioned above. Table 2 lists the principal characteristics of the four plates, which are illustrated in Figures 1 to 4.

Flaws were introduced into the plates using the following methods, as appropriate :

- by introducing poisons into the weld (copper, carbon, hydrogen),
- by simulating fabrication errors,
- by cycling (thermally or hydraulically) zones of the plate with or without a machined starter,
- by implanting coupons containing defects (mostly cracks); this involved using Charpy test specimens and artificial defects manufactured by diffusion welding, forging or machining if no other solution was feasible.

It was hoped that the base material would be free of important defects in order to keep both testing and evaluation simple. The base material of the plates was specified to be to nuclear reactor standards. In any event, base material defects would not have been considered in the destructive examination-and thus the evaluation of results. Plate No. 1 however showed that one part contained inclusions of manganese sulphide. This fact distorted results on plate No. 1 as no team expected such defects to be present and therefore did not try to identify them or to separate the corresponding indications from those due to the intended defects.

### 3.3. Round Robin Tests

The round robin tests on the four main test plates extended over two and a half years, and ended with all the plates being returned to Ispra in September 1984 (Ref. 1).

It is necessary here to emphasise the meaning of the two terms of nomenclature : "techniques" and "procedures". The latter specify the way in which different techniques (see section 3.1.) should be used alone or in combination. The analysis of the results by procedures also led to general conclusions which can be drawn from the findings. As originally envisaged, PISC-II was to comprise two phases, which in essence were to examine techniques and procedures respectively. This is in contrast to the main part of the PISC-I exercise which was a round robin test using a single procedure based upon the procedure laid down in the ASME Code Section XI (1974), which became known as the PISC procedure).

Phase I was to consist of the round robin trials on four test plates (which actually took place in 1982, 1983 and part of 1984). This was to be mainly a study of inspection techniques, either those proposed explicitly by participants or included as a part of procedures, along with a series of parametric studies examining the effect of certain parameters on the performance of different NDT techniques.

The second phase (which might involve additional RRT or parametric work) would be a study of procedures, either as proposed or developed from specific techniques selected on the basis of the results from the first part of the programme. Phase II, then, would amount to validation of the results of Phase I.

This two-phase approach was changed during the course of the programme as the results of the RRT were clearer than forecast. It was eventually decided to recast the validation studies within a new programme on real defects and in real conditions (PISC-III).

### 3.4. Links with National and other International Programmes

In recent years, a number of countries have planned their own ultrasonic test programmes. Those conducted in the Federal Republic of Germany, Japan, USA, France, United Kingdom and Italy were linked to the PISC-II programme through common interest and were even partially integrated with PISC-II through the contribution of test plates for the round robin testing.

Because of a need to have some results on an earlier timescale, the United Kingdom had embarked on a test programme the Defect Detection Trials (DDT) to define and validate an in-service inspection procedure for PWRs; this programme involved four test plates, one of which was offered to PISC-II (Plate 2 - see Figure 2). Destructive examination of the DDT plates was performed at Ispra, and DDT data formed part of the final evaluation of the PISC-II results.

The first PISC programme had made use of three test plates provided by the United States PVRC; that organization has since continued its work using other similar test blocks. Seven United States' teams participated in PISC-II, producing data concerning the ASME Code Section XI procedure, which are being used as a basis for comparison with the PISC-I results. PISC-II has been a permanent point on the Agenda of meetings of the PVRC.

Japan participated with thirteen teams in PISC-II, and offered a nozzle plate for the RRT (Plate 9 - see Figure 4). Constant contact was maintained between the Japanese PVRC and the PISC-II work.

France participated in PISC-II through three large inspection teams, and also organised reduced PISC-type exercises of its own. Ispra destructively examined one of the Framatome plates, and the results were used in the final evaluation of the results of PISC-II.

The Federal Republic of Germany offered a plate to PISC-II (Plate 1 - see Figure 1), and several teams took part in the RRT, thereby linking PISC-II to German nuclear safety projects.

In association with JRC Ispra, Italy offered Plate 3 to PISC-II (see Figure 3) and contributed very important test results for numerous (sixteen) procedures.

### 3.5. Parametric Studies

#### 3.5.1. Parameters

As discussed above, the parametric studies were designed to complement the round robin tests. The importance of several parameters had become evident during the PISC-I programme, and seven groups of significant parameters in particular were readily identified. Four of these seven groups were selected for study as an essential part of the PISC-II programme. A leader was nominated to co-ordinate the elaboration of the detailed programme for each of these studies (see Table 1).

1) Defect position and geometry study (EDC)

The effect of defect position and characteristics had to be investigated to help in understanding the round robin results. Defect parameters such as shape, position (depth), height, inclination and surface roughness were studied using a number of special test blocks (see Figure 5). Measurements were performed at CISE (Italy) on material furnished by Ispra, and the results were compared to model predictions.

2) Equipment characteristics study (EEC)

This involved studying what effect different equipment characteristics had on the reliability of the NDT results. Electronic circuit parameters and different types of ultrasonic probes were examined using test equipment constructed by the Ispra NDT Laboratory (see Figure 6).

3) Cladding study (ECC)

This study was intended to help in evaluating the round robin test results, in particular to explain inconsistencies and limitations attributable to the cladding. For this reason, the initial programme was confined to the types of cladding used on the round robin plates. The programme was carried out by ECAN Indret, France.

4) Possible use of electromagnetic techniques study (EMT)

An enquiry and tests were performed by the IZfP (Federal Republic of Germany) on the possible use of electro-magnetic techniques for conducting non-destructive examinations.

5) Residual stresses

It was considered essential to assess the effect of compressive stresses on the detection and characterization of welding defects. This action was eventually carried out under other CSNI sponsorship (CSNI Principal Working Group No. 3 : Primary Circuit Integrity).

6) Base material defects

If it had become apparent that base material defects were influencing the results of the round robin measurements, a study of their effect would have been initiated. This turned out not to be the case.

7) Couplant thickness and surface finish of the test piece

The effect of couplant and surface finish has not been studied so far. A literature study would be desirable.

### 3.5.2. Test blocks

The test blocks for the parametric studies were very simple and much smaller than the round robin test plates (see Figures 5, 7, 8 and 9). Defects were introduced using implant techniques. The implanted coupons contained defects fabricated using: machining, spark erosion, diffusion welding, or shrink fitting.

### 3.5.3. Evaluation of results

To avoid having to make up and examine an excessive number of test blocks for the parametric studies, the blocks were designed (i.e. type and position of defects chosen) in accordance with appropriate statistical principles. The experiments were designed to facilitate interpretation of the results (which was based on the analysis of variance) to separate out the effects of the different parameters. Often however, these effects appeared to be sufficiently clear that no complex statistical treatment of data was necessary to draw conclusions.

### 3.6. Destructive Examination

It was the intention in the PISC II programme that all the plates used in the round robin trials would eventually be sliced up to obtain complete and precise information about the defects really present for the evaluation of the results (Ref. 2). Such destructive examination has been carried out for plates 1, 2 and 9 (Figure 4).

The approach adopted was the one used successfully for PISC-I and DDT where high-performance NDT was used to guide the successive phases of cutting. The destructive examination was as comprehensive as necessary to ensure that each individual defect was characterised in sufficient detail to permit the evaluation of teams' results.

Because of its cost and high value for future work plate 3 has not been destructively examined up to now. A very detailed knowledge of the intended defects as well as intensive X-ray testing has given sufficiently good information for the evaluation of results.

### 3.7. Analysis of the Trials Results

#### 3.7.1. General analysis scheme

A two-phase scheme for analysing the PISC-II round robin results was proposed (Ref. 3) :

- phase 1 largely followed the method used in the PISC-I exercise for detection, location and sizing, but with a different and more elaborate presentation of the results; and



- phase 2 was be a more thorough analysis of sizing and characterization of defects. The results of the parametric studies played an important role in the final interpretation of the round robin results.

Put simply : phase 1 was an evaluation of the best results obtained by each team in terms of the procedures it used. Phase 2 dealt with the various detailed techniques and incorporated some insights gained from the parametric studies.

### 3.7.2. Computer Program

A computer program called B.T.B. was written at Ispra to analyse the PISC-II results. It first corrects all data by comparing each team's data sheets to reference values and identifying any systematic errors in references or coordinates. This produce a first data bank the "BOAT", which contains all (corrected) data sheets. B.T.B. then creates a second data bank by eliminating false calls or indications corresponding to defects not retained for the evaluation (smaller than 3mm). This second data bank, the "TRAIN", is organised in terms of procedures and techniques so that simple statistics can be performed. The "TRAIN" is organized in "BUSSES"; a "BUS" corresponds to a technique or a well-defined procedure. The programme produces drawings, tables of statistics, cumulative error (location and sizing) diagrams and diagrams of :

- defect detection as a function of defect size,
- correct defect rejection as a function of defect size,
- correct defect acceptance as a function of defect size, and
- evaluated defect size as a function of real defect size.

Decisions on whether a defect would be accepted or rejected for safety purposes were made using the ASME XI IWB 3510 criteria (1974) (as for PISC-I), as well as other criteria decided upon by the PISC-II Evaluation Task Force.

### 3.7.3. Prior knowledge of defects

Participating inspection teams had to declare any prior knowledge of a defect. There were also enough uncertainties in the tests for biased results to be improbable.

#### 4. MAJOR CONCLUSIONS AND TRENDS OF THE PISC-II RESULTS

##### 4.1. General observations

Even at the level of the different procedures, without considering the details of the techniques, conclusions can be drawn from the results with respect to the influence of the major parameters:

- the use of a very low cut-off (e.g. % DAC) level is not needed and in some case may not even be desirable;
- the use of supplementary techniques such as tandem and special probes can have a very important influence in determining the capability of a procedure;
- mechanized and manual scanning both have advantages and drawbacks;
- a combination of techniques gives the best evaluation of the defects;
- on the average, undersizing occurs more frequently than oversizing for rejectable defects;
- the evaluation of defects seems more dependant on parameters such as defect position in the through thickness direction and defect size than does their detection; and
- a dominant parameter, often obscuring the influence of others, is the defect category : planar defects with sharp crack edges are always more difficult to detect and evaluate than volumetric ones.

As was the case for PISC-I, even though the PISC-II results show large dispersion, the capability of each group of procedures is clear. It is easy to identify which procedures (either advanced or in the spirit of ASME) achieve good detection (e.g. a detection rate of 90%), good rejection of large defects (e.g. rejection of 90% of the rejectable defects applying ASME criteria), and satisfactory acceptance of small defects (e.g. 70% of small defects).

##### 4.2. Importance of the amplitude cut-off level

As shown on Figure 11 relative to the four plates, it was found in the PISC-II work to be advisable to work at medium amplitude cutoff : e.g. around 20% DAC for the ASME calibration procedure. A 10% DAC would often not improve the detection performance, and would increase the false calls and the rejection of some acceptable flaws.

##### 4.3. Importance of supplementary techniques

Procedures in the spirit of ASME Section XI appear to perform better if 70° angle probes are added for longitudinal waves, either using the simple echo technique or with dual beam probes.

Tandem probes can also make an important contribution in some cases.

Figure 12 relative to plate No. 2 illustrates this importance of supplementary techniques : an ASME procedure at 35% DAC complemented with 70° angle probes and tandem probes matches or even betters the detection rate achieved with the 10 per cent DAC procedure.

#### 4.4. Influence of the clad layer

There is some indication that when scanning is carried out on the clad surface, the cladding makes sizing slightly more difficult but this may not be significant.

#### 4.5. Mechanized scanning

The numerous results based on the ASME type procedures obtained either with manual or mechanical scanning made possible a comparison between these two scanning modes when conducted along the same scan plan and with exactly the same ultrasonic techniques. This artificial comparison, as shown on Figure 13, demonstrates that manual scanning gives better results than a mechanized one, mainly for detection of defects. This observation should not be misinterpreted : it is dealing with manual type techniques conducted with mechanized systems. It does not take account of some important aspects such as reliability and the possibility of using more techniques or more elaborated techniques when using a mechanized scanner. In fact the best results on the most difficult plate, nozzle plate No. 3, were achieved mainly by automated procedures involving mechanical scanning. These automated procedures have produced results such as :

- . Detection rate : 90 to 100%,
- . Correct rejection rate of large defects : 90 to 100%, and
- . Correct acceptance of small defects : better than 50%.

Some of the most effective procedures were in the spirit of ASME (at high or medium sensitivity, and complemented with several techniques); others were based on different principles or complex combinations of traditional and advanced techniques.

#### 4.6. Errors in Location and Errors in Sizing

Figure 14 illustrates distributions of absolute errors in location and in sizing in the through-thickness direction. Dispersion is high and there are distinct tails in all the distributions.

In the case of Plate No. 1 the tails of distribution of sizing in the Y direction (undersizing) are due to a very long (1m) shallow crack which several ultrasonic techniques detected only in several separate parts.

Again, for Plate No. 1 the confusion made by several teams between intended defects and segregations in the base material is the reason for through thickness (Z direction ) sizing error distribution tails (oversizing).

In contrast, Figure 15 shows how precisely some procedures were able to size defects in Plate No. 3.

#### 4.7. Importance of the sizing uncertainty

Several teams declared an error band or uncertainty on the size of defects as evaluated with ultrasonic techniques, so trials were made using a tolerance on defect size as a parameter.

As shown on Figure 16, when adding a tolerance on the defect size varying from - 10 to + 30 mm, special full procedures achieved perfect rejection of rejectable defects when the reported defect sizes are increased by a tolerance addition of only 3 to 6 mm. The diagrams of figure 16 however shows that procedures in the spirit of ASME never reached perfect rejection : the upper limit of performance is equal to the detection rate of rejectable defects. Some advanced sizing techniques are shown to be able to reach 100% rejection of the rejectable defects which have been considered by these techniques. However, in most cases such techniques were applied on only few defects.

#### 4.8. Importance of defect position in the through thickness direction

Although detection does not seem to be too dependent on the defect position in the plate thickness, sizing quality is dependent on this parameter as shown on Figure 17. Defects located deep in the wall thickness are, on average, oversized. The chance of undersizing defects is greater for those defects located near to the clad surface.

#### 4.9. Importance of the defect size

Defect size appears to affect both detection and sizing of these defects :

- a. On average, there is a lower detection performance for defects smaller than 10 mm in height. This observation has, however, to be considered further as a function of the defect characteristics (see § 4.10).
- b. The error on defect size is dependent on the size of the defects as shown on Figure 18. The major chances for undersizing exist for rejectable defects when the average error on defect size is considered (Fig. 19).

#### 4.10. Importance of defect characteristics

When considering defect characteristics such as the crack tip aspect and surface roughness it is possible to divide all defects in the PISC II plates into three categories :

- A. smooth cracks with sharp crack edges (fatigue cracks),
- B. rough cracks and cracks which were strongly modified during implantation and have crack tip aspects not typical of real in-service cracks, and
- C. volumetric defects (slags and porosities).

The dispersion of the results as shown on Figure 20 for plate No. 3 disappears when defect categories are considered; good correlation is then obtained between detection rate and defect size.

Category A (smooth cracks with sharp crack tips) appears to be the most difficult case and from this it is concluded that future validation work, and even calibration, should therefore be conducted on plates containing such defects. Even the most powerful procedures show weaknesses for some defects of this family. Category A defects were nearly never detected and correctly evaluated by procedures in the spirit of ASME working at high cut-off levels such as 50 per cent DAC (Figure 21).

The division of the results into these four categories appears to be valid for the results of all four PISC-II plates. This way of presenting the data also seems to explain some results of the PISC-I and DDT exercises.

Since clear conclusions and good correlations are obtained when one considers crack tip aspect alone, it probably explains that this parameter dominates others, such as :

- variability of equipment characteristics,
- human errors, and
- calibration procedure employed.

#### 4.11. Contribution of individual techniques to the performances of full procedures

- a. Full procedures are made up of individual techniques which can be regarded as components. A major question is what is the individual contribution of each of these components to the overall performance of one full procedure.

In evaluating the results of techniques, parameters such as cut-off level, surface used for scanning, defect position, defect size and defect category have to be considered.

- b. Contribution of techniques in general.

The cumulative diagrams on Figure 22 show the performances which were reached by individual techniques applied at 20% DAC on Plate No. 3.

No unambiguous conclusion can be drawn although it seems that the contribution of the 70° angle probes for near surface defects is important compared to the performances of the 45° and 60° angle probes.

- c. Influence of the scanning surface considered.

Figure 22 also shows for Plate No. 3 the contribution of the different techniques when the unclad surface is used for scanning compared with that when the clad surface is used.

For plate No. 3 correct rejection of defects by techniques at  $45^{\circ}$  and  $60^{\circ}$  is systematically lower when the clad surface is used for scanning. Such an influence is not so systematic on the other PISC II plates.

A conclusion of the PISC II RRT is that the cladding did not influence strongly the performances of techniques but it could, however, affect sizing. This conclusion confirms the one obtained during the analysis of the results of procedures.

d. Influence of the cut-off level

From figure 23, conclusions are easy to draw as the contribution of techniques is clearly enhanced.

-  $70^{\circ}$  angle probes are efficient, even when the general level of 50% DAC is used as cut-off level.

-  $45^{\circ}$  and  $60^{\circ}$  angle probes produce similar results and are very weak at 50% DAC.

- The contribution of tandem probes appears poor but one has to remember that such a technique is not designed for near surface defects detection and is difficult to apply on geometries such as the one of Nozzle Plate No. 3.

e. Importance of the defect position in depth from the clad surface.

Although parameters such as defects characteristics dominate results, the characteristics of techniques generally appear to have the effect expected by logic, such as the importance of the dead zone for a simple  $45^{\circ}$  transducer.

f. Importance of defect size

As shown on Figure 24, for all three techniques when using the clad surface for scanning, the trend is that the largest defects are strongly undersized. This confirms the global evaluation of results at the level of full procedures.

No clear influence of the defect size on detection appears when defect height is larger than 10 mm.

g. Importance of defect characteristics.

As for full procedures, individual techniques show performances depending strongly on the defect characteristics, see Table 4.

Category A defects (smooth planar defects with sharp crack edges) are difficult to detect and size.

h. Optimization of procedures.

Using the data corresponding to individual techniques and combining all the recorded indications by groups of techniques, one can constitute artificial procedures, e.g.:

- ASME 20% DAC :  $0^{\circ}$ ,  $45^{\circ}$ ,  $60^{\circ}$

- Complemented 20% DAC :  $0^{\circ}$ ,  $45^{\circ}$ ,  $60^{\circ}$ ,  $70^{\circ}$  (S,L or SEL)

- Reduced ASME 20% DAC :  $45^{\circ}$ ,  $70^{\circ}$  (S,L, or SEL).

Table 5 shows the performances of these artificially constituted procedures.

It is to be noted that the combination of the only two techniques  $45^{\circ}$ S and  $70^{\circ}$  SEL (or S or L), on Plate No. 3 as well on other plates reaches a performance comparable to the complemented ASME. The contribution of Tandem techniques is not clearly identified in this work.

i. Complementarity of techniques.

Table 6 shows, for Plate No. 3, the contribution of each technique for each of the defects.

The complementary nature of the  $45^{\circ}$  and  $70^{\circ}$  techniques with one being effective on defects for which the other is less effective is clear. A similar complementarity exists between the  $60^{\circ}$  and  $70^{\circ}$  techniques.

Tandem techniques do not appear to increase detection systematically when couples of techniques such as  $45^{\circ}$  and  $70^{\circ}$  or  $60^{\circ}$  and  $70^{\circ}$  are used.

TOFD alone is found in this work capable of doing most of the job and it is clear that a combination of techniques involving TOFD must reach high performances. This is in fact the case for procedures identified as "special procedures" results for which are illustrated on Figure 15. However it should be noted that in PISC II because the teams using TOFD stated that they did not claim it was capable of detection of defects very near to or penetrating the cladding the assessment of TOFD omits assessment of its capability in handling such defects.

j. Resources used by teams

The PISC II Round Robin Test has been conducted in favourable conditions for the inspection of the plates.

Samples were accessible, scanners were specific and manual inspection was not performed in adverse conditions of temperature, humidity, and irradiation.

The effective resources used were very different from one team to the other. The PISC RRT was, however only an exercise aimed at the assessment of the performance of NDT procedures and not a reliability evaluation exercise. The application of extensive resources was not inconsistent with the programme objectives.

It is, however, important to have an indication on the resources needed to reach the results shown in the reports.

Table 7 gives results of an enquiry; a correlations is appearing between the performance obtained, the time needed for inspection and evaluation and the tertiary qualifications of the people in charge of the evaluation of results.

Such observations are relevant in the context of the general trend of resources applied, performance and results but there were extreme departures.

On plate No. 3 for example, one team (YC) performed the full inspection in less than one hour; evaluated the data very quickly and produced results to the standard of special procedures. Some other teams used the two weeks available for inspection and returned the data sheets several months later.

#### 4.12. Global results of the Parametric Studies

##### a. Effect of the Defect Characteristics (EDC).

Fabrication of test blocks with calibrated defects took more time than expected and financial constraints delayed the programme about two years.

During this period results available led to the parametric studies being reoriented towards the validation of mathematical models, which work will also continue in the PISC III programme.

The importance of parameters such as : defect length, defect tilt angle, and defect skew angle are considered.

One clear conclusion from the PISC II parametric studies is the experimental explanation of why defects of category A (smooth planar defects with sharp crack edges) are difficult to detect with ASME type procedures working at 20% DAC.

##### b. Effect of Equipment Characteristics (EEC).

The study has considered 38.000 possible cases of combinations of parameter values characterizing ultrasonic systems.

As a global conclusion, it appears that even after calibration on an ASME calibration block, in moving from one combination of parameters values to the other, one could get a variation of 10 to 20 mm in the apparent defect size both for 3 mm or 9 mm defects (or of beam width at -6 dB).

The parameters of importance are :

- the cable length ( $X_m$ ,  $Y_m$ ,  $Z_m$ )
- the damping resistance value (  $25 \Omega$ ,  $50 \Omega$ ,  $100 \Omega$  )
- the cable impedance (  $50 \Omega$ ,  $75 \Omega$  )
- ...

Such a variation of apparent size of defect (or of beam width at - 6 dB) explains part of the sizing error dispersion of the RRT as often a 6 dB drop type method has been used by teams.



c. Effect of Cladding Characteristics (ECC).

Measurements performed at ECAN indret (France) on chamfered blocks have shown the important perturbations the cladding could induce, independently of its surface state : as clad, ground or machined. Amplitude variations of 30dB often occurred and beam distortions making any sizing impossible are frequent when scanning in a direction perpendicular to the clad strips.

d. Possible use of Electromagnetic Methods (EMT) and comparison of results with Eddy Current inspection results.

Performances of EMATs for detecting defects in the near surface zone were compared with the performance of standard ultrasonic techniques (including Rayleigh waves) and with multifrequency Eddy Currents testing.

Signal to noise ratios show that EMATs can be used with success for several types of near surface defect :

- 2 mm diameter side drilled holes at depth positions of 5, 7, 9, 11 mm
- crack like defects at the interface between ferritic steel and clad material
- surface defects (notches, 2 mm deep).

Often, the signal to noise ratio given by appropriate EMAT techniques are higher than the ones from standard ultrasonic techniques. Eddy current methods gave weak results and lower frequencies could be used for increasing the penetration in depth.

## 5. CLOSURE

The PISC-II project was started with very precise objectives and terms of reference. The objectives were reached and the terms of reference were respected. Procedures capable of high performance have been identified. Code and Standards bodies as well as licencing authorities have been alerted to the need to know the performance of different procedures. The results of the RRT have raised new scientific questions.

The time schedule of PISC-II, especially for the round robin testing, was very demanding. Moreover, circulation of the plates was completed with only a few weeks of delay with respect to the first official proposal. Draft reports were issued in 1984 as forecast in 1980. The parametric studies lasted longer than originally foreseen. The amount of information available and the cost of the programme called for a more extensive evaluation of the results than originally envisaged.

PISC-II data are available through EURONET and on any standard magnetic support to any organization member of PISC interested in performing supplementary evaluations of the results. A vast amount of data is available for study : 18,000 detections and the locations and sizings of defects by 35 families of procedures. Data on individual techniques constitute a very large bank of more than 300,000 different "indications". The parametric studies have also produced banks of quantitative data.

PISC-II examined the capability of inspection procedures under optimal conditions. Plans have already been laid for a further programme of studies, to be called PISC-III. This will validate PISC-II results using real defects in samples with real component geometries and will use the PISC-II data to look at the question of the effect of variable human reliability in conducting inspections.

## 6. REFERENCES

1. Report No. 2 : The PISC-II Round Robin Test (July 1986).
2. Report No. 3 : Destructive Examination of the PISC-II Round Robin Test Plates (July 1986).
3. Report No. 4 : The Analysis Scheme of the Results from the PISC-II Test Plates (July 1986).
4. Report No. 5 : The Evaluation of the PISC-II RRT results.(September 1986).

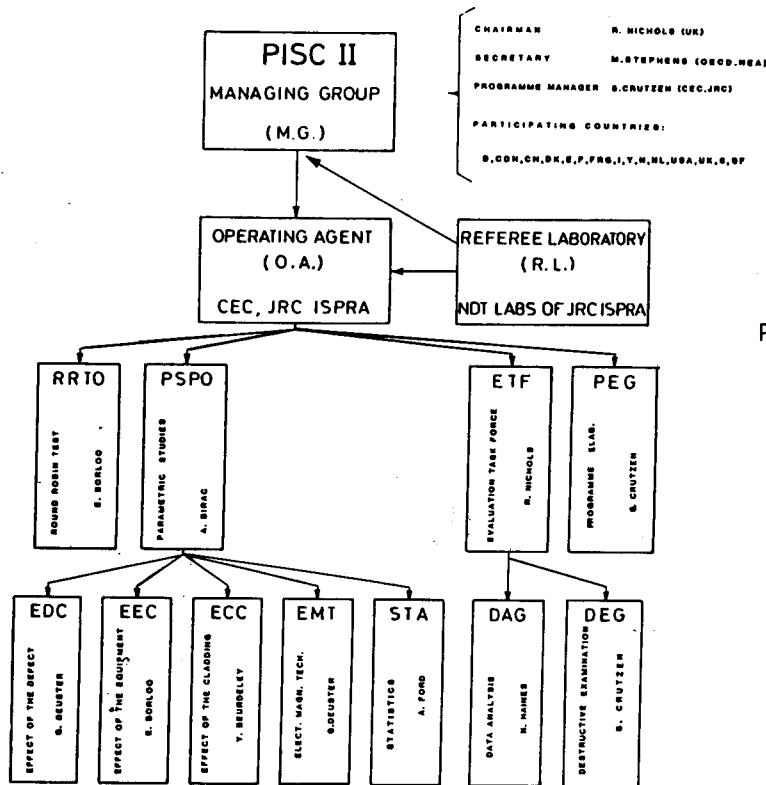


Table 1

PISC-II Organization scheme

Plate number (intercontinental numbering)	Country of origin	Type of plate	Welding process	Plate material	Nozzle material	Dimensions of the plate (mm)	Dimensions of the nozzle (mm)	Approx. weight of the plate (10 <sup>3</sup> N)	No. of defects	Type of defects
1	Federal Republic of Germany	. flat . longitudinal weld . clad	. submerged arc under lower bound conditions	ZDnMoHl	-	1050 x 1040 x 248	-	21.5	20	Fabrication defects
2	United Kingdom	. flat . longitudinal weld . clad	. automatic submerged . arc	ASME SA 533 grade B class 1	-	1525 x 1525 x 250	-	45	27	Service-induced defects and welding defects
3	Italy and CEC	. curved . with nozzle . clad	. automatic submerged . arc	ASME SA 533 grade B class 1	ASME SA 508 class 2	2300 x 2600 x 250	BWR nozzle Type OD-1370 ID-709 weld centre line O = 1530	156	40	Service-induced defects and some welding defects
9	Japan	. flat . with nozzle . clad	. automatic submerged . arc	ASME SA 533 grade B class 1	ASME SA 508 class 3	1950 x 1950 x 200	BWR nozzle OD = 535 ID = 292 weld centre line O = 890	65	17	Subsurface flaws including cold cracks and lack of fusion and flaws
									3	Fatigue cracks of the nozzle inner radius of depth 10, 25 and 25 mm (one of the latter two was repaired).

Table 2 PISC-II RRT Plates

		1982														
		1	2	3	4	5	6	7	8	9	10	11	12			
		4	8	13	17	22	26	30	35	39	43	48	52			
PLATES	T	SV DN VT			EC - CE - FE				VC		7x					
	C	DK N SF			F				B		F A G					
		CUST.														
NOZZLES	T	IM - CN - EN			5x			12x								
	C	E (#9 ONLY)			U.S.A			J								
		CUST.														
		1983														
		1	2	3	4	5	6	7	8	9	10	11	12			
		5	9	13	17	22	26	30	35	39	44	48	52			
PLATES	T	BE - BR - BV			IS SA		KA RT		CIATBREN							
	C	D GB			S		NL		1							
		CUST.														
NOZZLES	T	CE - EC - FE			VC		BE - BV - CE			7x			RT - KA			
	C	F			B		GB			F R G			NL			
		CUST.														
		1984														
		1	2	3	4	5	6	7	8	9	10	11	12			
		5	9	13	18	22	26	31	35	39	44	48	52			
PLATES	T	11x											IN - CN - EN		HA - RI	
	C	J											E		GB	
		CUST.														
NOZZLES	T	CIATBREN			DNVI		S/T		HA - RI		EN - TN - CN					
	C	I			N SF		S		GB		E					
		CUST.														

③ PLATE NO.3 ONLY  
CUST: CUSTOMS FORMALITIES

Table 3 PISC-II time schedule

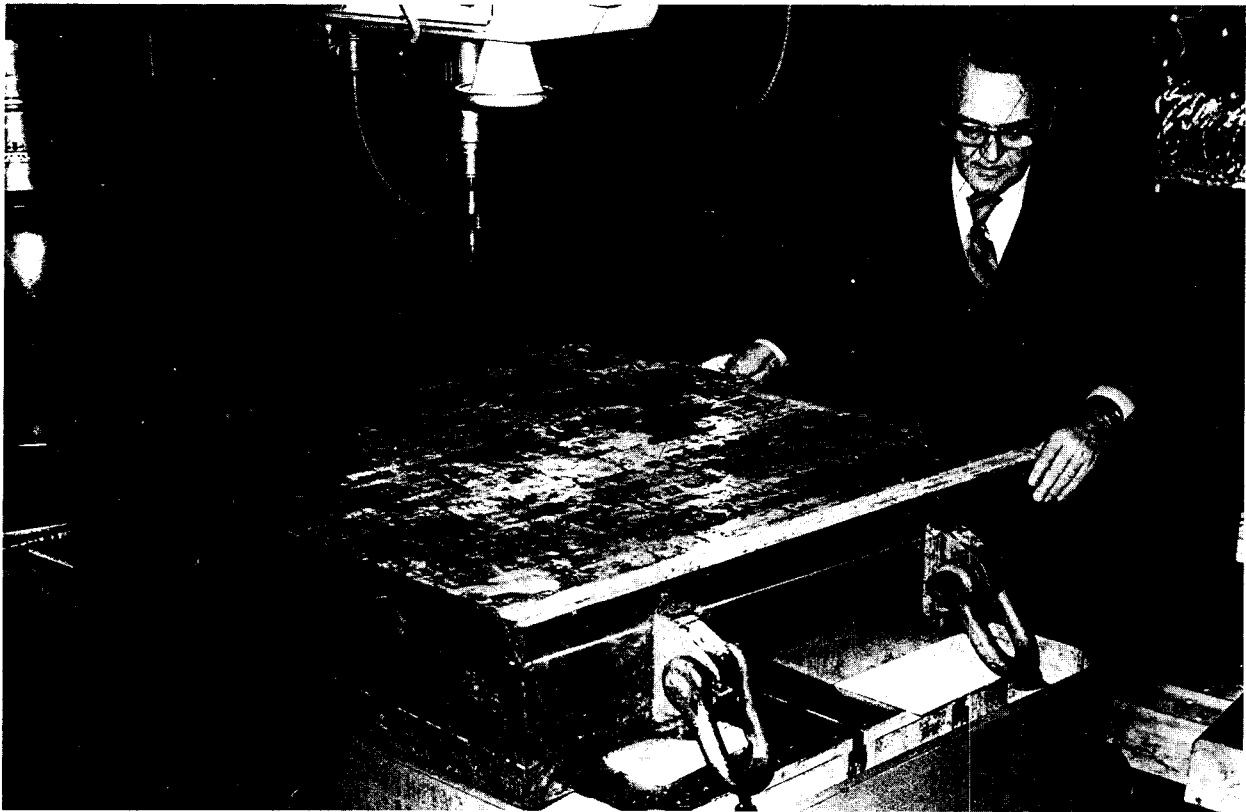


Figure 1 PISC-II Plate No. 1



Figure 2 PISC-II Plate No. 2



Figure 3 PISC-II Plate No. 3

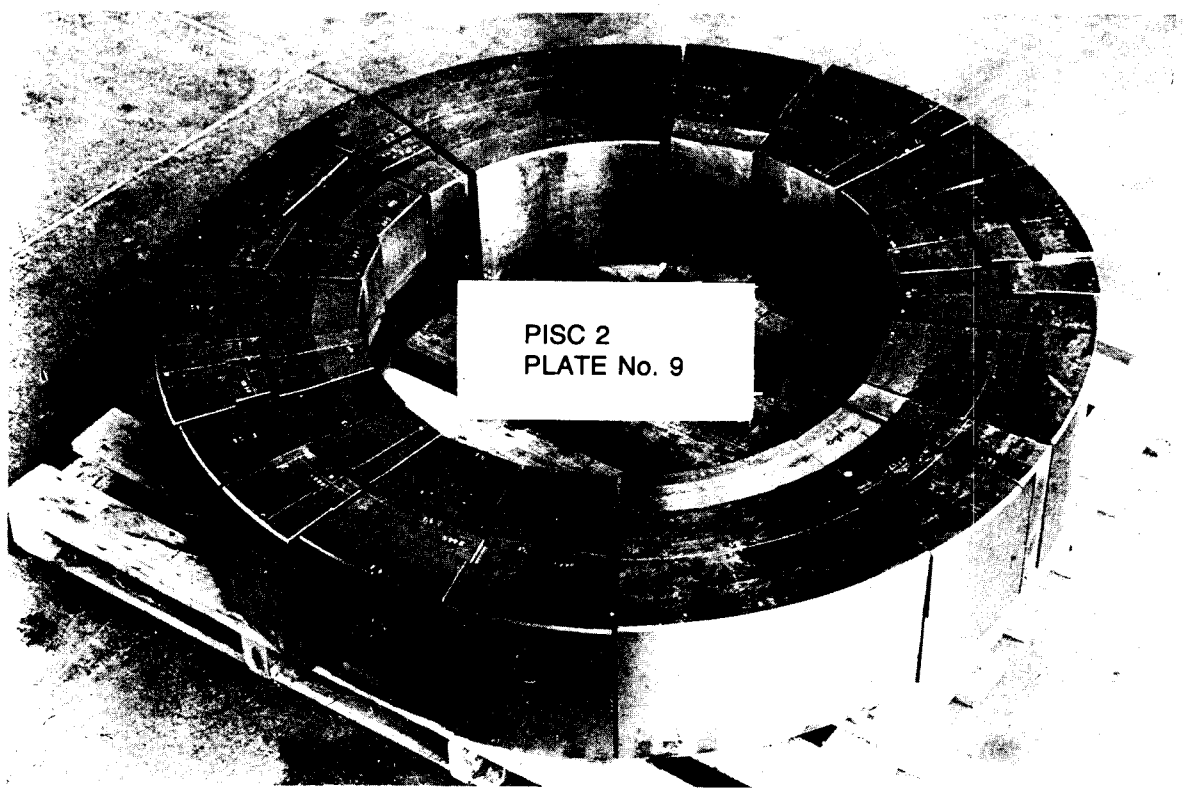
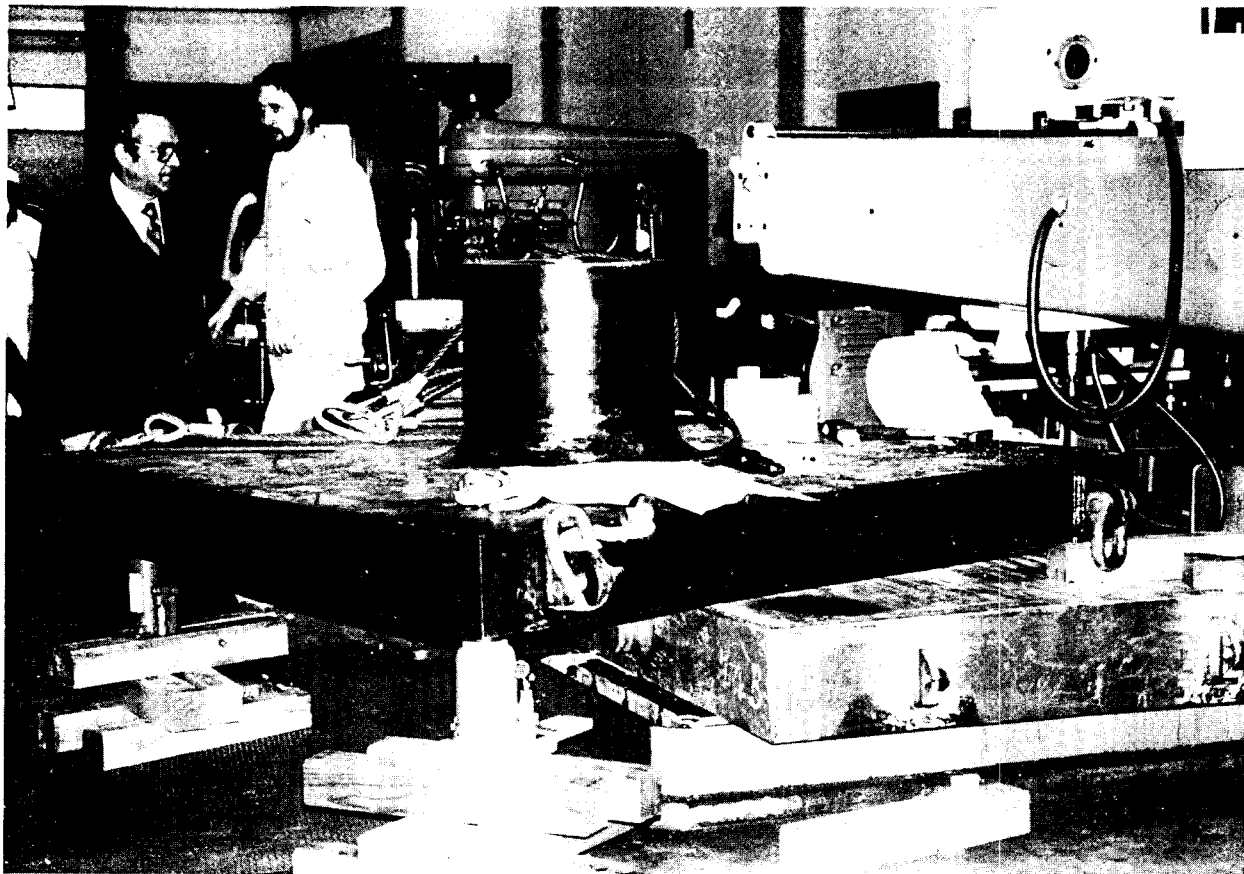


Figure 4 PISC-II Plate No. 9  
Before and after destructive examination

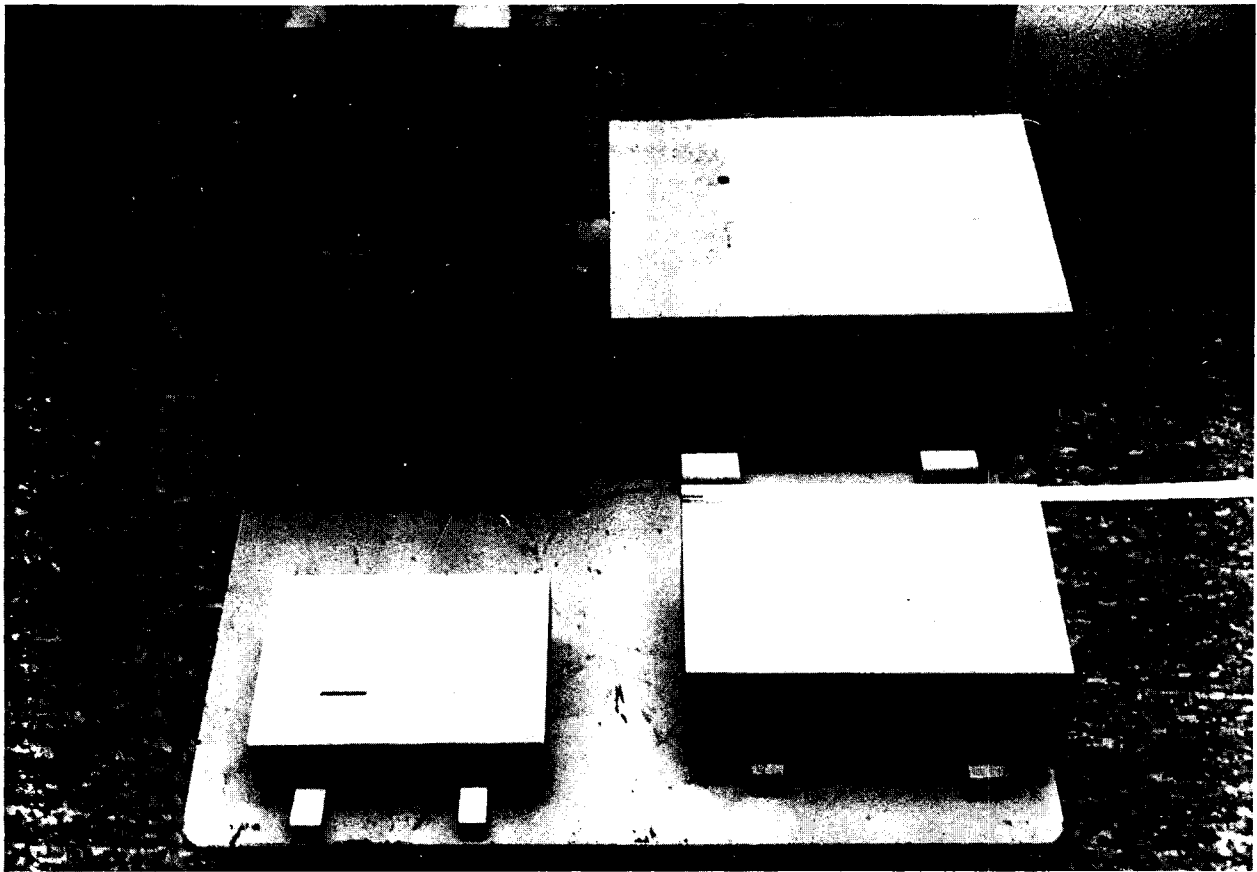


Figure 5 Test Blocks for the Parametric Study on the Effect of Equipment Characteristics



Figure 6 The Installation for the Parametric Study on the Effect of Equipment Characteristics

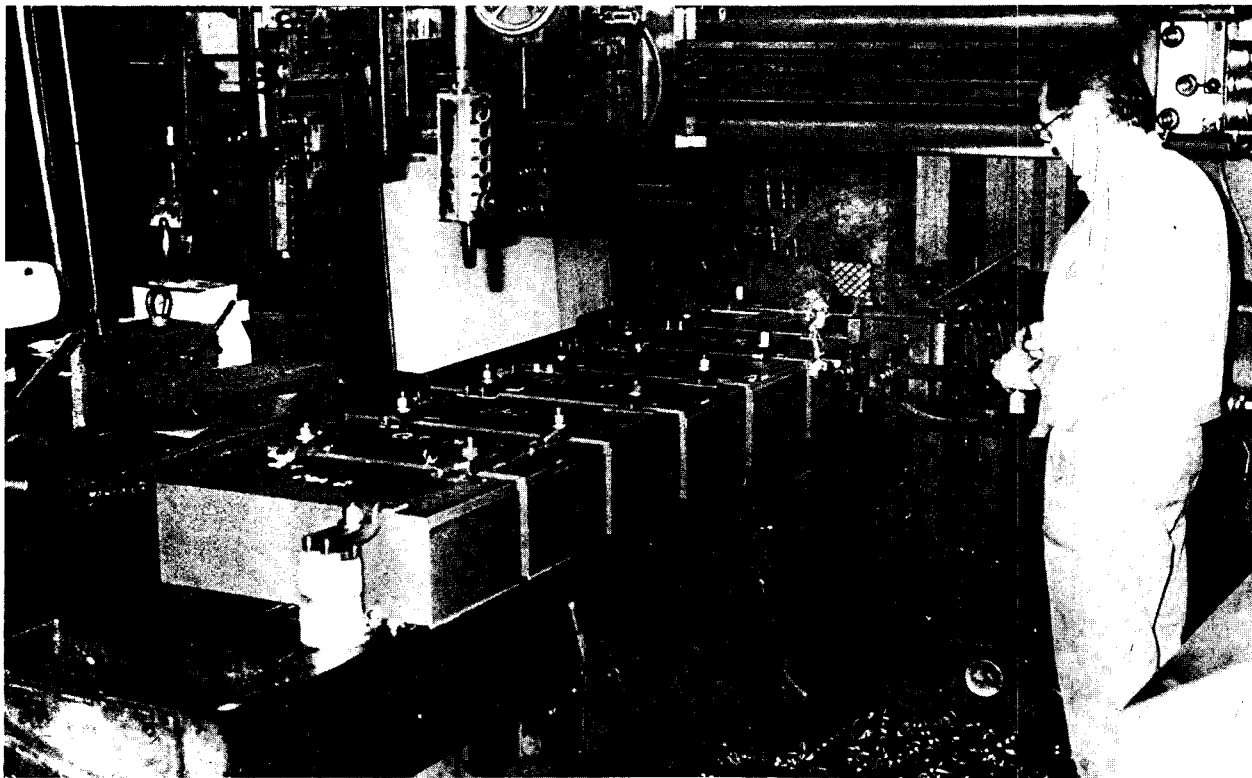


Figure 7 Base Material Plates for the Parametric Study Blocks





Figure 8 Fabrication of the Blocks for the Parametric Study of the Effect of Defect Characteristics

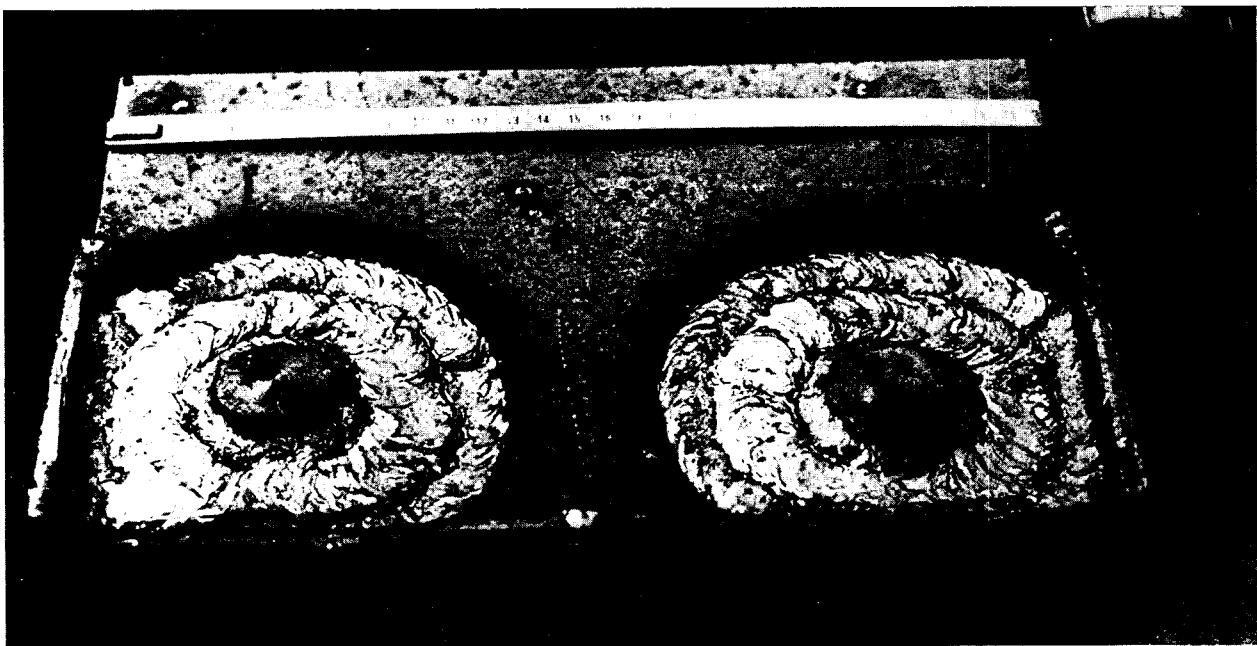


Figure 9 Welded Coupons in the Parametric Studies Blocks

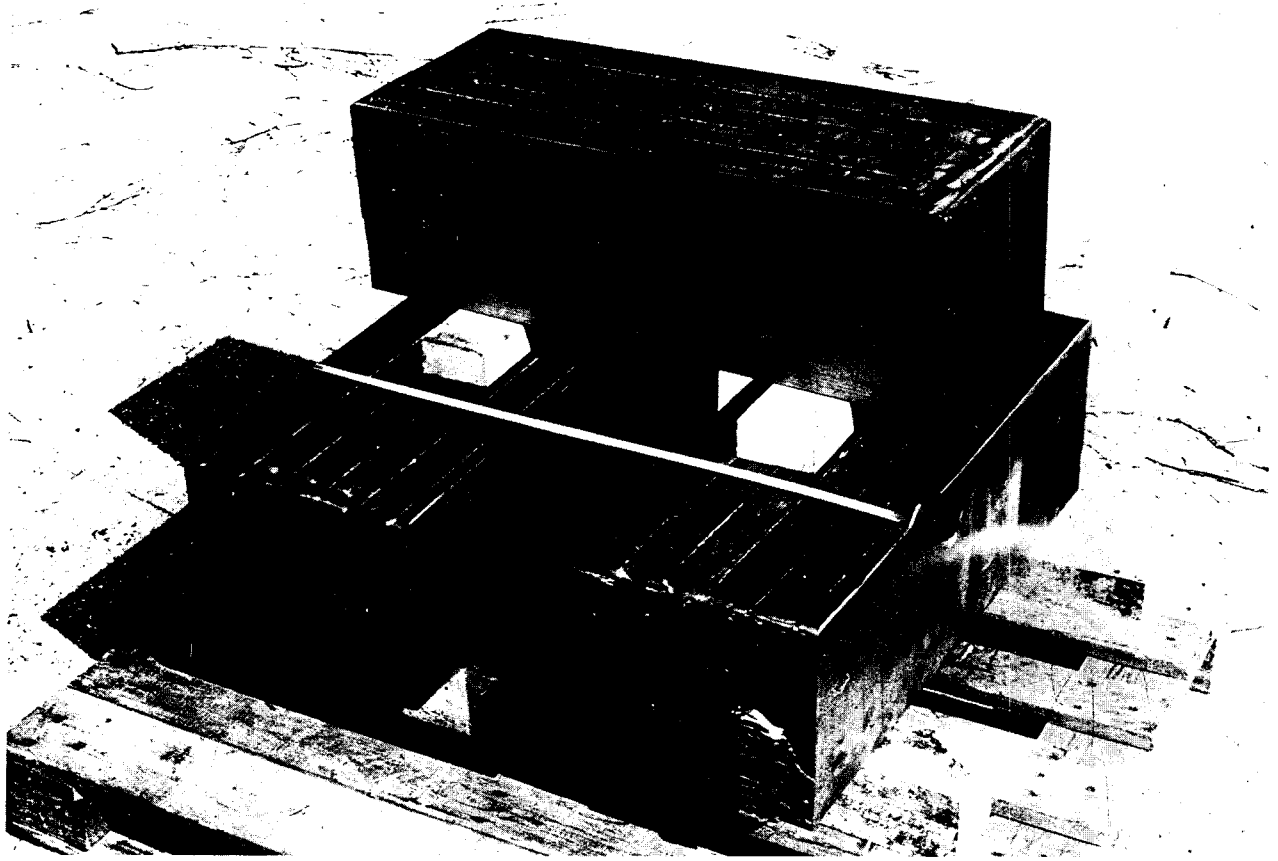


Figure 10 First Blocks for the Parametric Study on the Effect of Cladding Characteristics

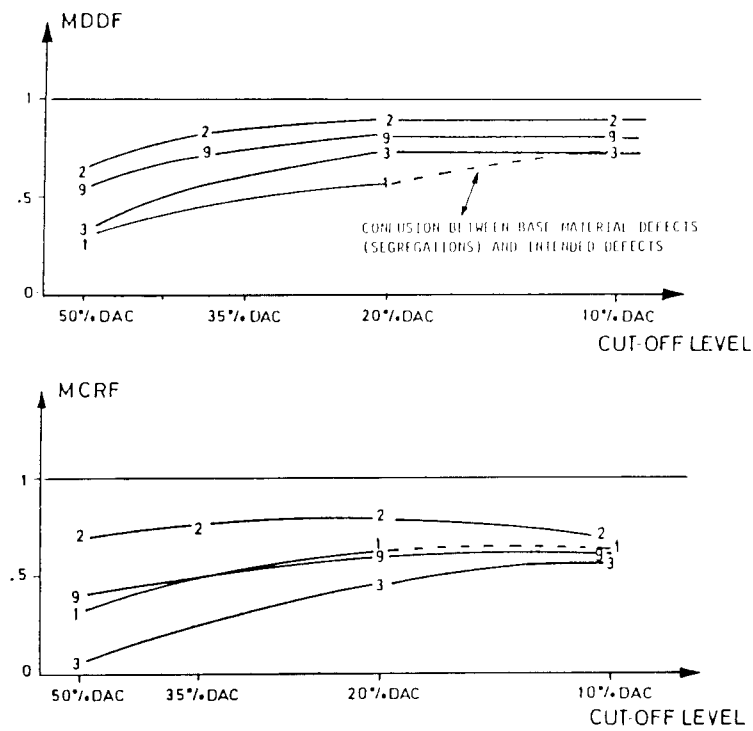
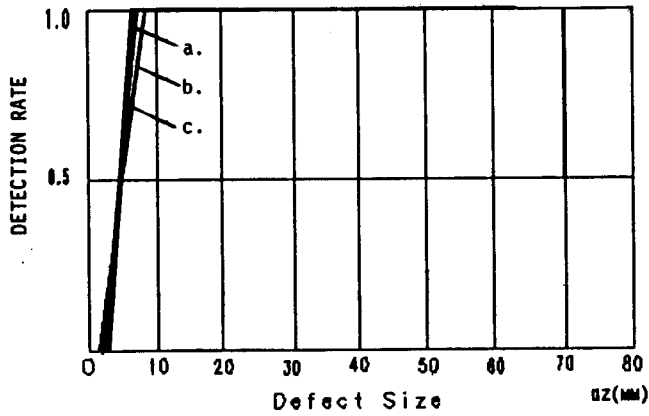


Figure 11 : Detection rate and correct rejection rate as a function of the recording level for ASME type procedures (All four PISC II plates).

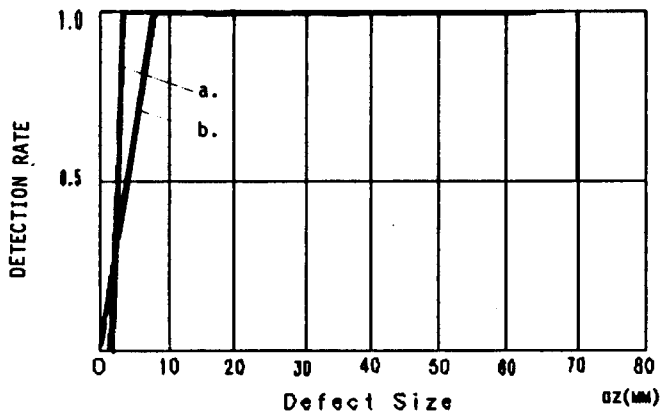
PLATE No. 2



- a. Low cut-off level (10% DAC)
- b. Medium cut-off level (20% DAC)
- c. Usual cut-off level (35 to 50% DAC) with supplementary techniques

Figure 12 Importance of supplementary techniques

PLATE No. 2



- a. Manual scanning
  - b. Mechanized scanning
- Both at 10% DAC

Figure 13 Comparison of mechanized versus manual scanning using the same procedure

NOZZLE PLATE No. 3

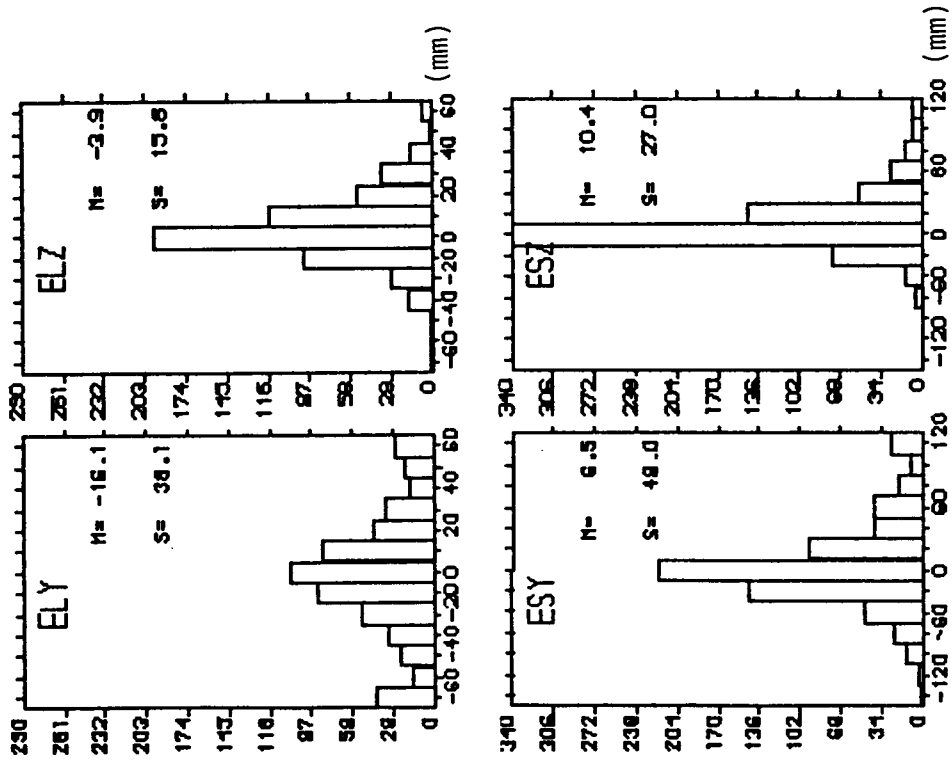


PLATE No. 1

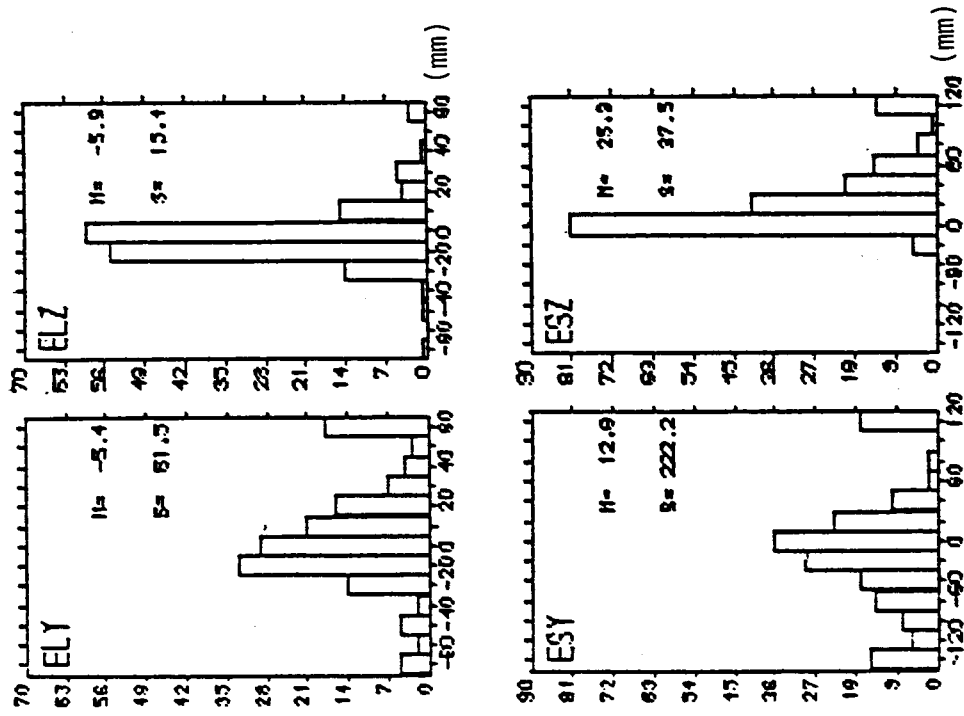


Figure 14 : Distribution of location and sizing errors for the defects

NOZZLE PLATE No. 3

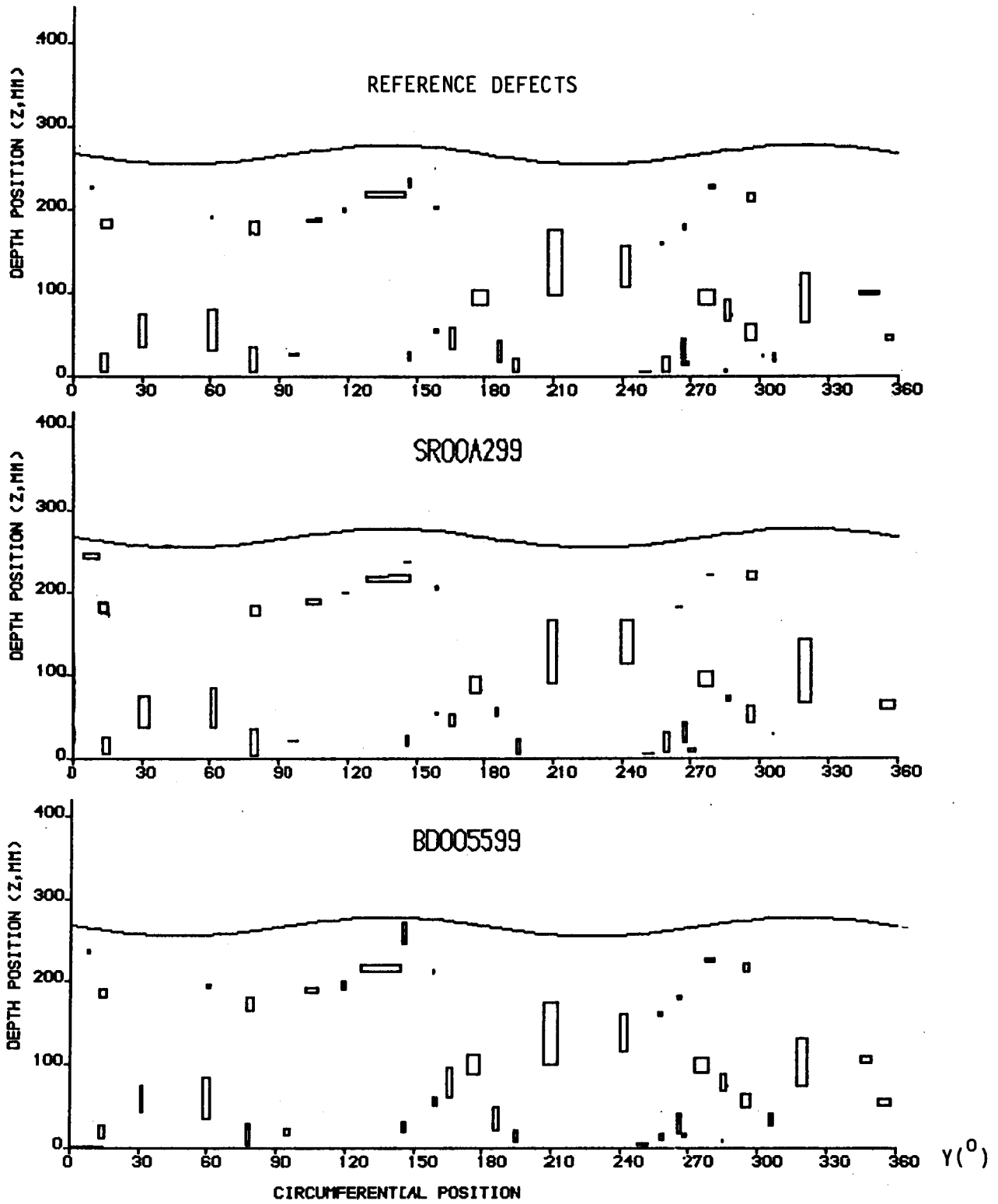


Figure 15. Illustration of some of the best results obtained in detection and sizing by mechanized procedures based on the combination of several techniques using different physical principles.

# NOZZLE N. 3

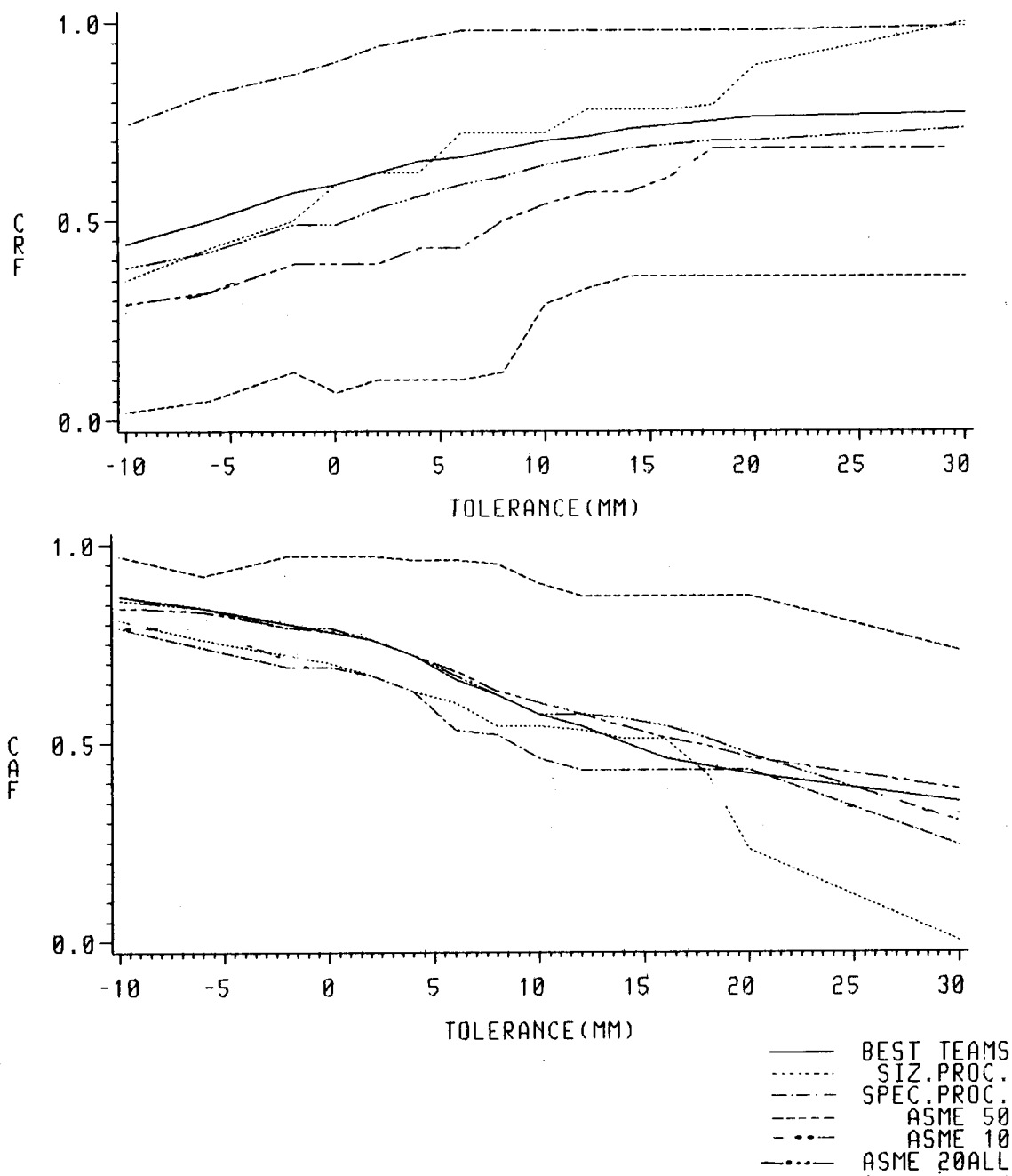


Figure 16 : Defect evaluation as a function of a sizing tolerance or uncertainty (Plate No. 3).

PLATE NO.3  
ASME 20% DAC

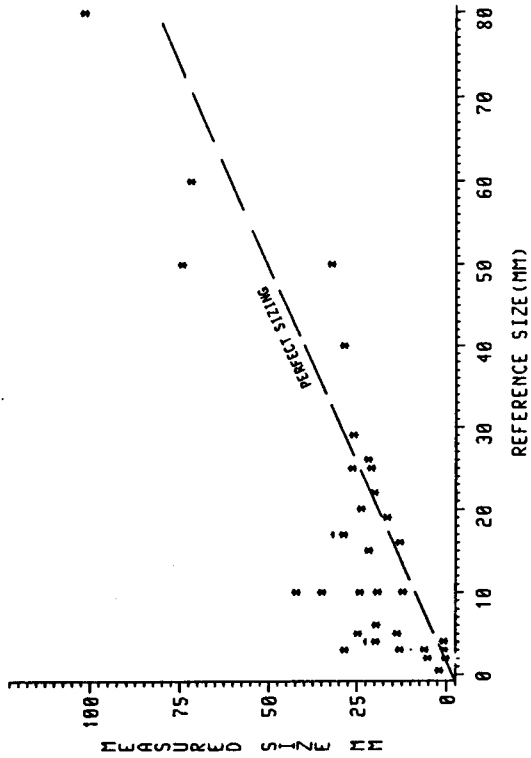


PLATE NO.3  
SPECIAL PROCEDURES

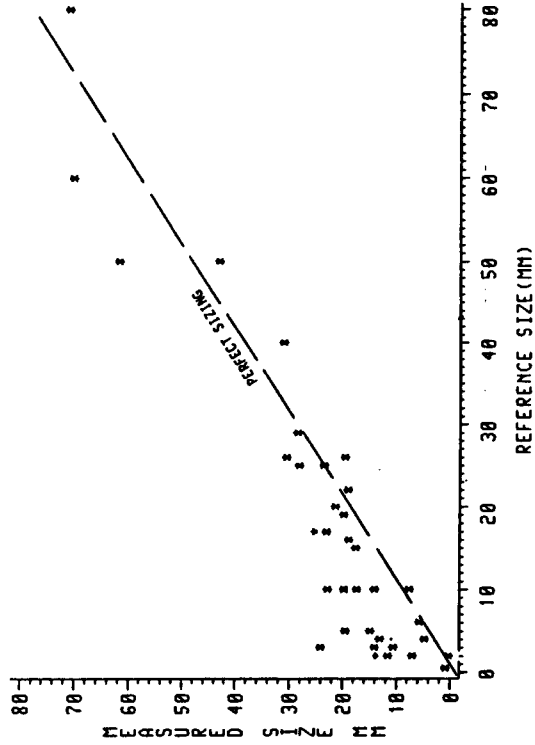


PLATE NO.2  
ASME 20% DAC

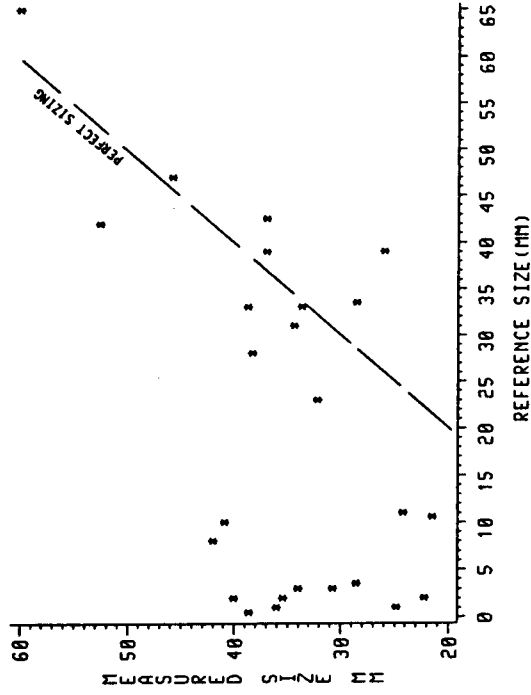


PLATE NO.2  
SPECIAL PROCEDURES

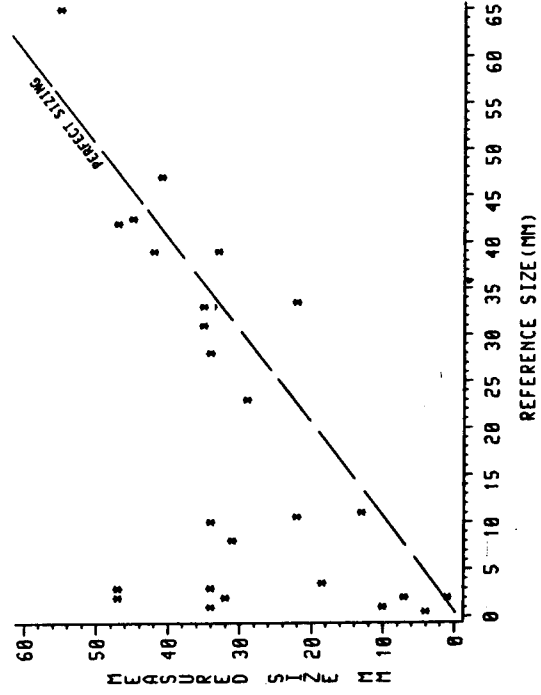


Figure 18 : Examples of sizing performances of ASME 20% DAC procedure and of special procedures.

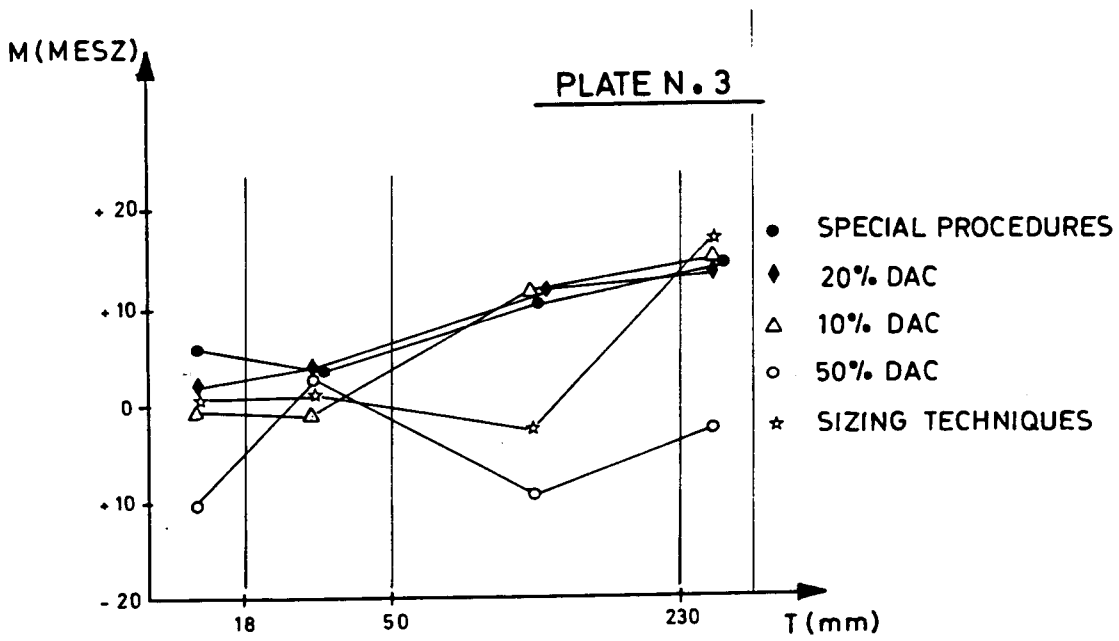


Figure 17 : Average sizing error as a function of defect location in the through thickness direction.

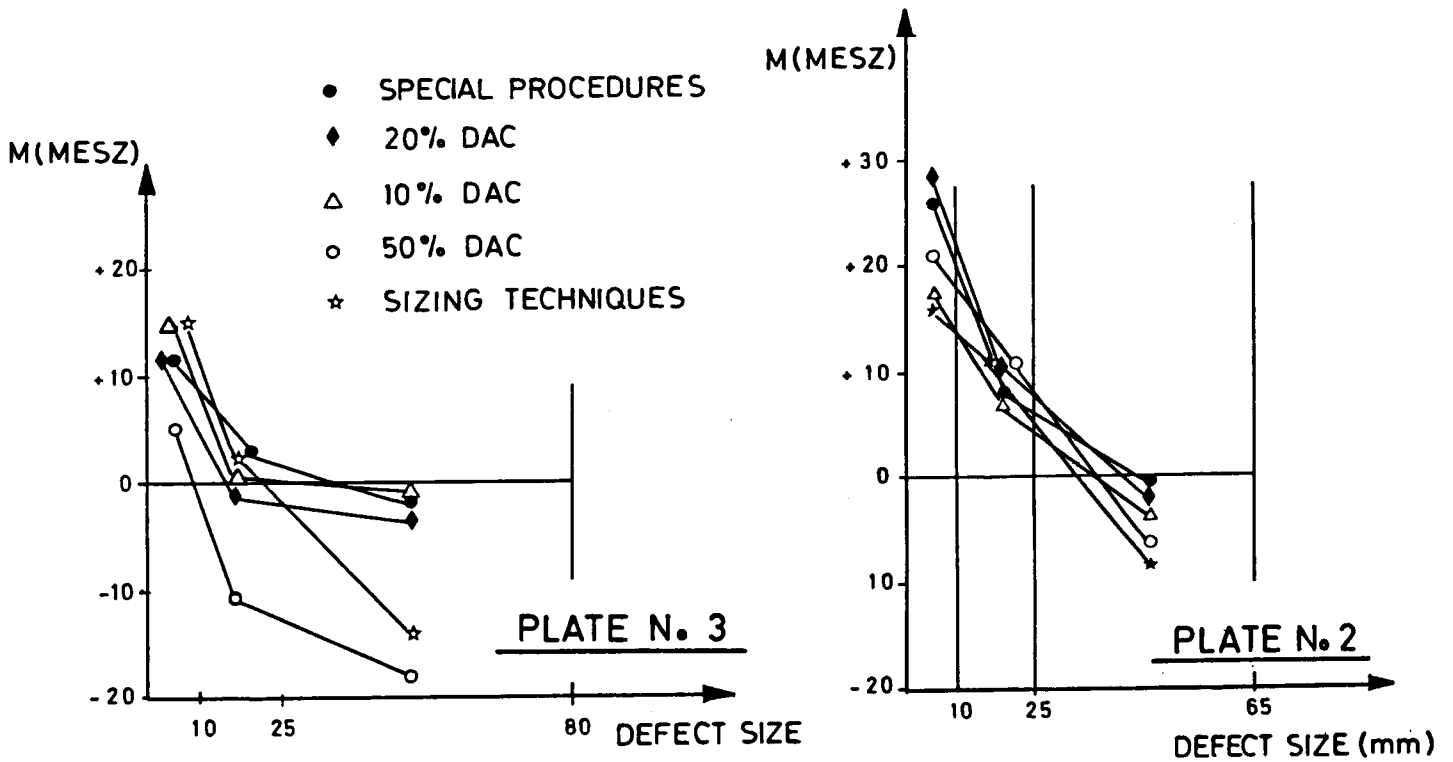
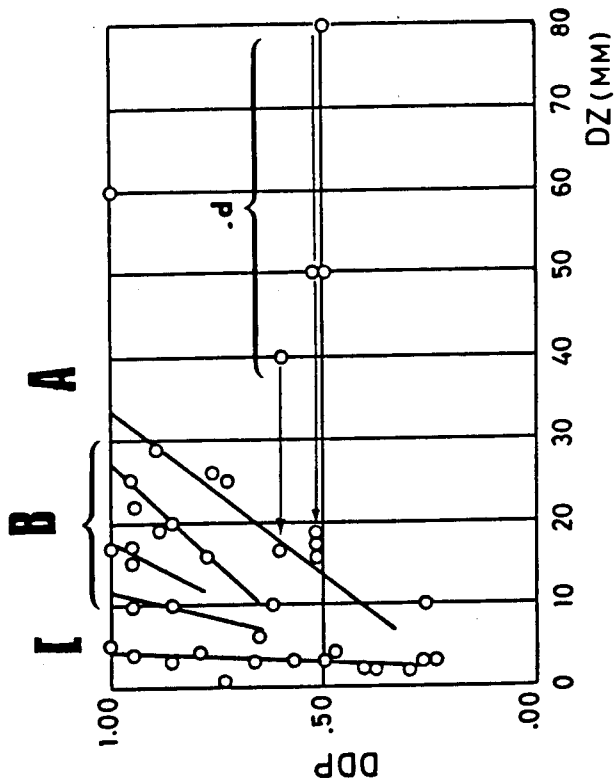


Figure 19 : Average sizing error as a function of the defect size.





- L** : VOLUMETRIC DEFECTS
- B** : ROUGH DEFECTS OR DEFECTS WITH LARGE CRACK EDGES
- A** : SMOOTH CRACKS WITH SHARP CRACK EDGE

Figure 20a. : Detection rate parametrized by the defect characteristics. Best results of each team are considered. (plate No. 3).

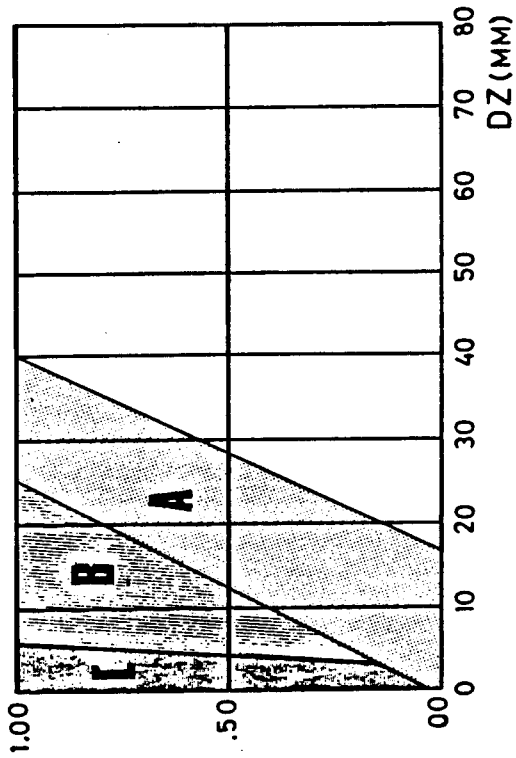


Figure 20b. : Detection rate parametrized by the defect characteristics (3 categories of defects) for the group of procedures in the spirit of ASME (20% DAC, M,B,S). (Plate No. 3).

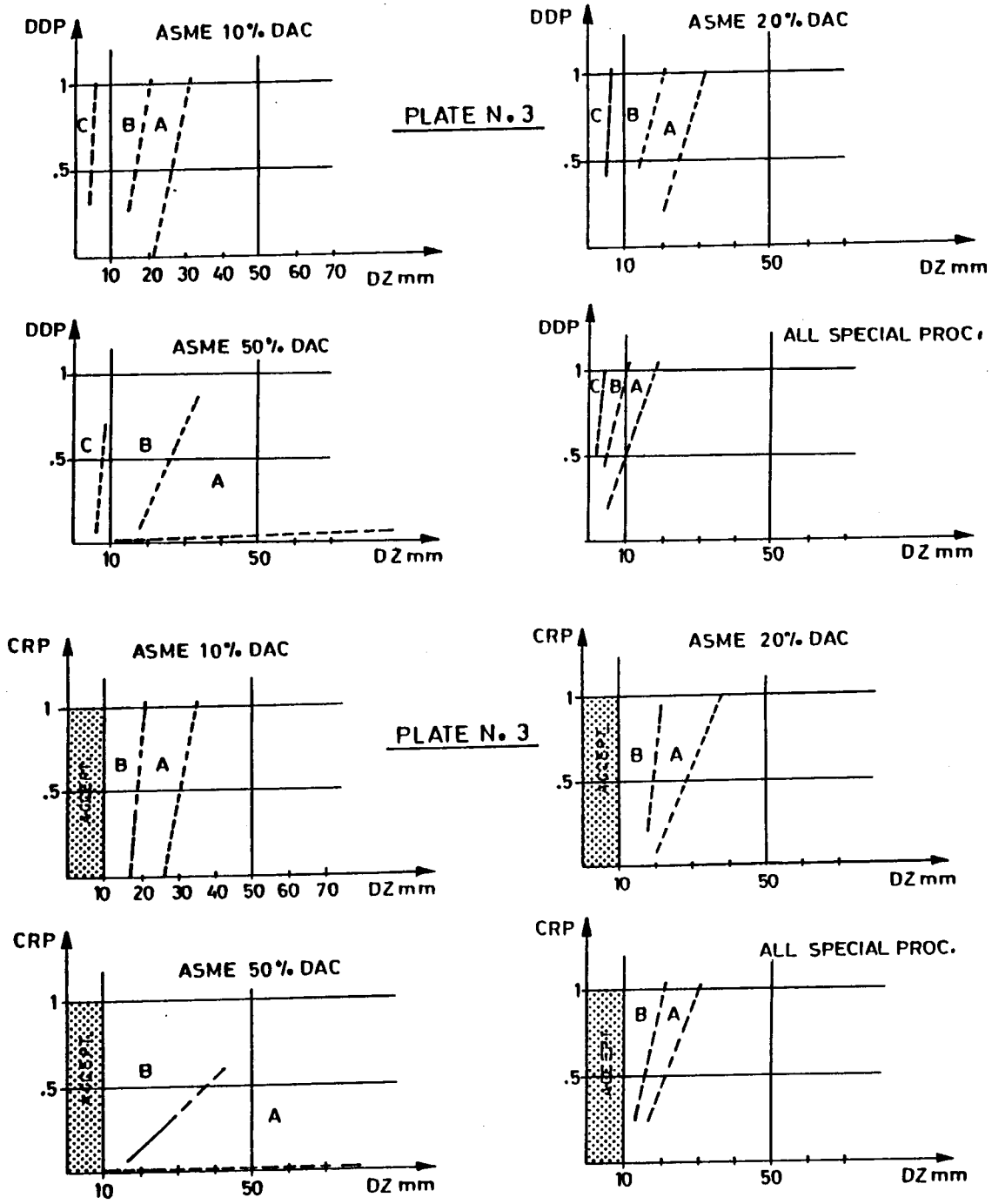


Figure 21 : Detection and correct rejection rates as a function of defect size and defect category.

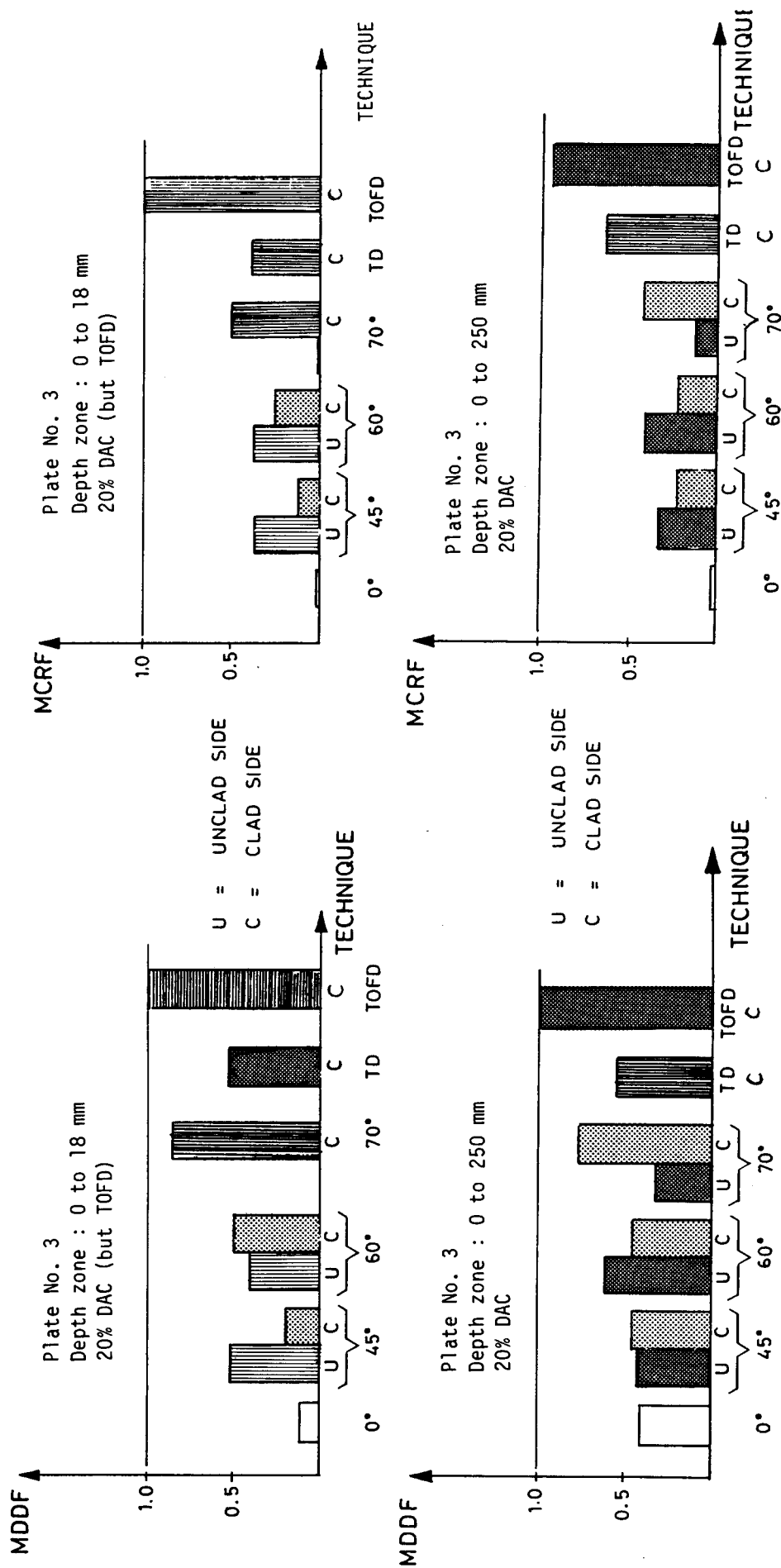


Figure 22 : Contribution of individual techniques on Plate No. 3.

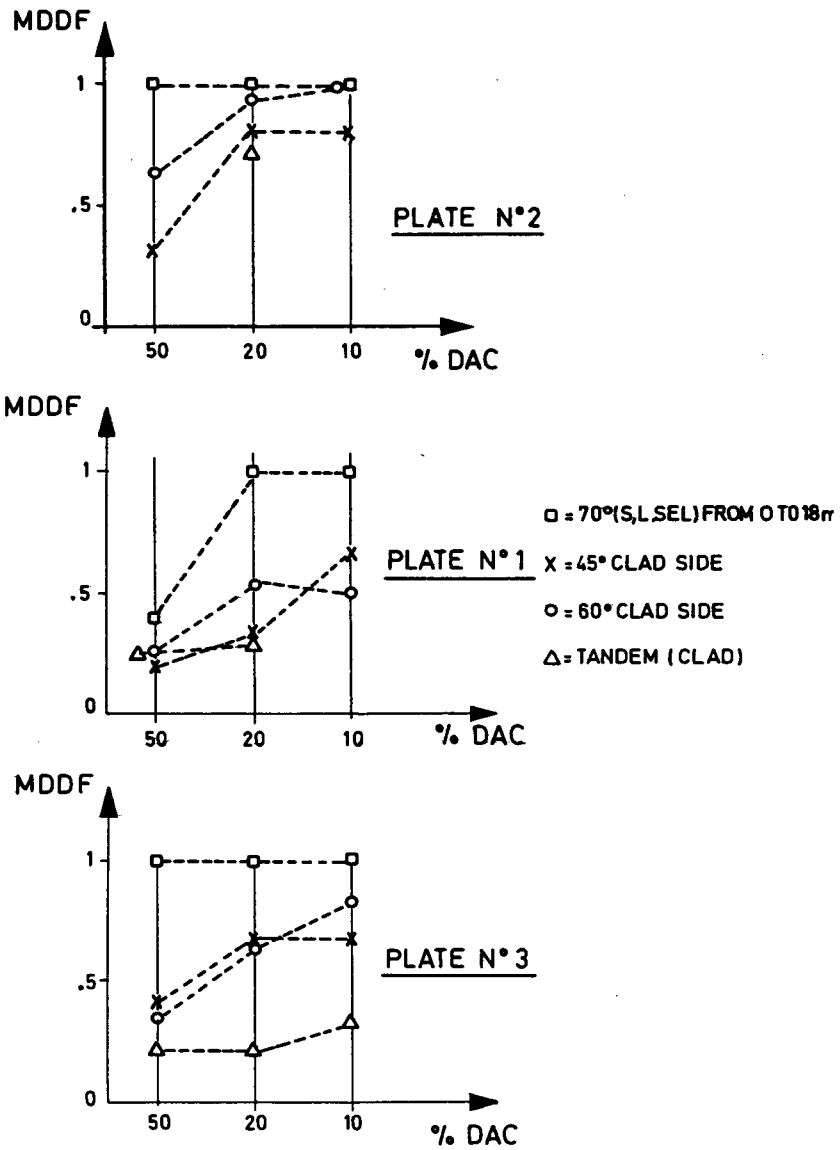


Figure 23 : Importance of the cut-off level on the performances of techniques.

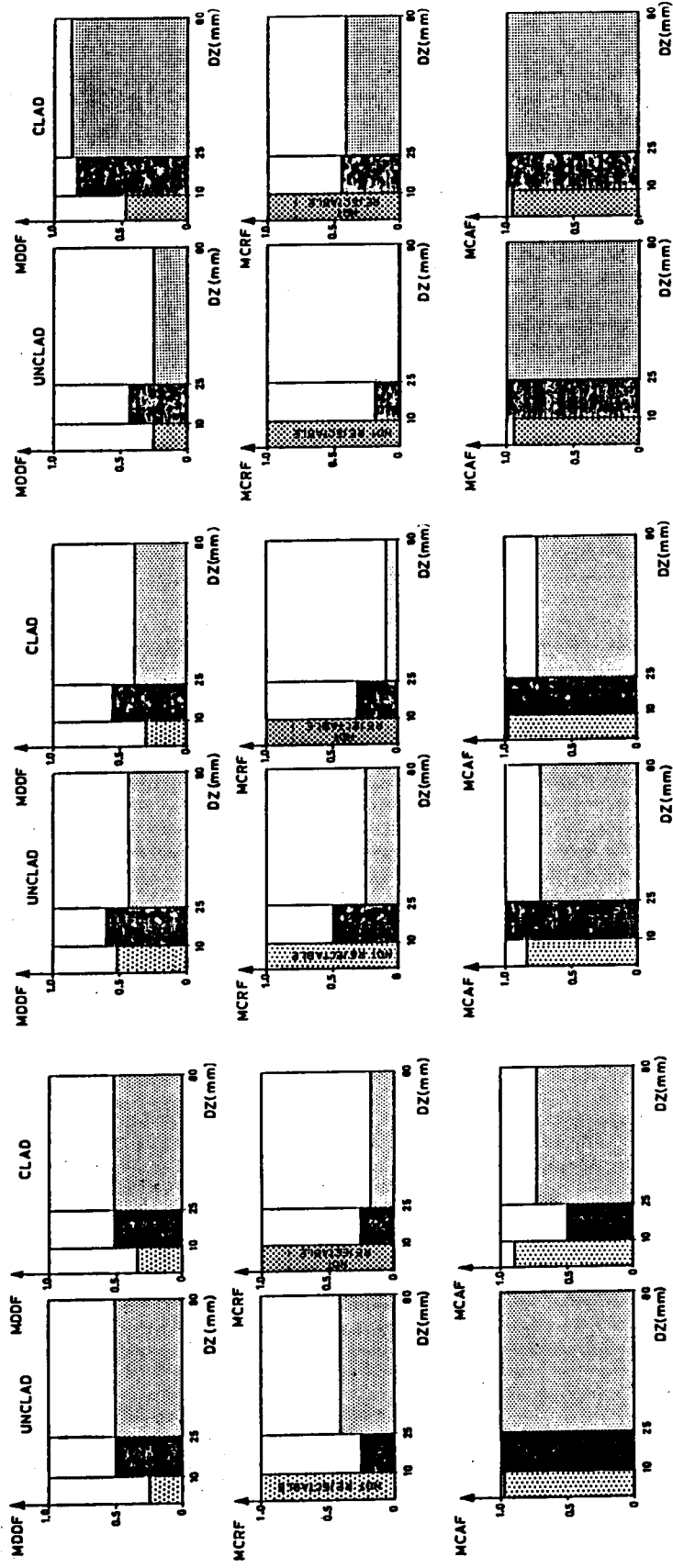


PLATE No 3  
Technique : 70 S,L,SEL

PLATE No 3  
Technique : 60S

PLATE No 3  
Technique : 45S

Figure 24 : Importance of the defect size on defect detection and evaluation. Plate No. 3, 20% DAC.

	Category A			Category B			Category C		
	MDDF	MCRF	MCAF	MDDF	MCRF	MCAF	MDDF	MCRF	MCAF
0°U 0°C	.05	0.	1.	.31	.08	.86	.50	-	1.
45° U	.27	.29	1.	.50	.25	1.	.50	-	.90
45° C	.27	.14	1.	.50	.33	.79	.70	-	.60
60° U	.36	.14	.88	.81	.58	.64	.60	-	1.
60° C	.36	.0	1.	.50	.42	.93	.50	-	.90
70° (0-18mm)	.90	.50	1.	-	-	-	-	-	-
70° U	only one defect on the unclad side			.58	.25	.86	.30	-	1.
70° C	.77	.50	.88	.77	.42	.93	.60	-	-
TD U	.73	.57	1.	.38	.50	1.	.40	-	1.
TD C	.18	.29	1.	.23	.17	1.	.20	-	1.
TOFD(C)	1.	.86	.0	1.	1.	.33	1.	-	.40

Table 4 : Contribution of the different techniques at 20% DAC (except TODF) as a function of the defect category in Plate No. 3.

	Category A			Category B			Category C		
	MDDF	MCRF	MCAF	MDDF	MCRF	MCAF	MDDF	MCRF	MCAF
(45+70) U	-	-	-	.72	.47	.83	-	-	-
(45+70) C	.68	.43	.88	.77	.50	.71	.80	-	.60
(0+460) U	.55	.36	.88	.88	.83	.57	.80	-	.70
(0+45+60) C	.50	.21	.88	.65	.67	.64	.80	-	.40
A+B U	.55	.36	.88	.88	.83	.50	.80	-	.70
A+B C	.68	.43	.50	.85	.75	.50	.80	-	.40
A+TD (U+C)	.73	.57	.75	.88	.67	.50	.80	-	.50
A+B+TD U	.59	.50	.75	.88	.83	.50	.80	-	.70
A+B+TD C	.68	.43	.50	.85	.75	.50	.80	-	.40

Table 5 : Performances of artificial procedures on Plate No. 3 defects.

		CATEGORY A										CATEGORY B								CATEGORY C										
DEFECT N°		2	6	7	8	9	14	16	19	21	27	30	4	5	11	12	13	15	18	20	23	24	25	26	28	1	10	17	22	29
TECHNIQUES																														
DETECTION	0° L																													
	45° S																													
	60° S																													
	70° S.L.SEL																													
	T D																													
	TOFD																													

		CATEGORY A										CATEGORY B																	
DEFECT N°		2	6	7	8	9	14	16	19	21	27	30	4	5	11	12	13	15	18	20	23	24	25	26	28				
TECHNIQUES																													
CORRECT REJECTION	0° L																												
	45° S																												
	60° S																												
	70° S.L.SEL																												
	T D																												
	TOFD																												

Table 6 : Contribution of each technique for each defect in Plate No. 3.  
 One team only.  
 Cut-off level for the standard techniques :  
 20% DAC.

	ATTITUDE			INSPECTION TIME			INSPECT. QUALIF.		EVALUAT. QUALIF.		PERFORMANCES			
	INDUSTRIAL	TO BECOME INDUSTRIAL	TEST	DAY	WEEK	TWO WEEKS	INDUSTRIAL	ADVANCED	INDUSTRIAL	ADVANCED	MDDF	MCRP	MCAF	
ASME 50% DAC	█			█			█		█				█	100%
ASME 20% DAC	█				█		█			█			█	100%
ASME 10% DAC	█				█		█				█		█	100%
SPECIAL PROCEDURES	█				█		█				█		█	100%
ADVANCED SIZING TECHNIQUES		█	█		█			█			⊗		█	100%

PLATE N° 3

Table 7 : Resources used by teams for the inspection of Nozzle Plate No. 3.



## APPENDIX I

### RULES FOR PARTICIPATION; REFEREE LABORATORY

The PISC-II programme relied upon the goodwill of participants. Nevertheless it was necessary to draw up guidelines for participation in the round robin tests to avoid misunderstandings and minimize the possibility of dispute.

#### 1. Inspection Procedures

##### 1.1. Proposal for participation in the round robin test

Organisations which intended to participate in the round robin test were requested to submit, for all techniques and procedures they wanted to apply, a proposal giving :

- a) a short description of the technique(s) and the procedure(s) for applying it (them),
- b) the expected length of time required for their examination,
- c) the location where the examination could be done,
- d) the general form for the presentation of the records.

##### 1.2. Selection of techniques and procedures by the Managing Group

The Managing Group stressed that :

- duplication of techniques and procedures had to be avoided unless necessary,
- recognized techniques had to be used as far as possible,
- results had to be interpretable and comparable to those of other teams and techniques,
- the ASME Code Section XI procedure had to be adhered to scrupulously.

##### 1.2. Inspection of the Plates

- . The inspection teams had to carry out their examination of the test plates following the procedure that they had submitted.
- . While carrying out their inspection, participating teams had to be prepared to accept visits by Referee Laboratory representatives.
- . The teams had to keep a logbook containing a record of the details of their inspection and the results.
- . The format in which the data were to be reported was proposed by the Referee Laboratory.

### 1.3. Referee laboratory

The idea of having a "Referee Laboratory" (RL) was suggested during the formulation of the programme and appeared indispensable when the programme had been set out in detail.

The Referee Laboratory's function was to find suitable means for handling such matters as : confidentiality of the teams identities, making technical recommendations regarding acceptance of plates for the round robin tests, introducing benchmarks and reference defects in the plates, collecting inspection data, obtaining corrections of errors, consulting teams' log books, assessing reference data, evaluating the test results (under the direction of the Managing Group), and preparing draft reports.

### 1.4. Resolution of disputes

In the event of any dispute or disagreement which might have arisen over any technical matter relating to the execution of the PISC programme, the decision of the PISC-II Managing Group, advised by the Referee Laboratory , was final.

## APPENDIX II

### 1. FINANCIAL ASPECTS

It is difficult to make a detailed breakdown of the cost of PISC-II because of the diversity of the inputs to the programme and the fact that many of them took the form of contributions-in-kind.

The PISC-II programme was based upon the goodwill of the participants, each of which covered the costs of their teams' inspections and contributed to the common costs of the programme.

Important contributions were made by :

- France : Parametric studies on "The Effect of Cladding Characteristics";
- Federal Republic of Germany : Plate No. 1 and the parametric studies on "The Possible Use of Electromagnetic Techniques";
- Italy : Plate No. 3 (along with the CEC) and the parametric studies on "The Effect of Defect Characteristics";
- Japan : Plate No. 9; and
- United Kingdom : Plate No. 2.

A substantial financial contribution was provided by the CEC through the Ispra Establishment of its Joint Research Centre. This included work by technical staff, equipment, computer hours, etc., as well as the manpower needed to manage the programme, do the destructive examination of the plates, collect data, develop the computer code to analyse them, evaluate the results and perform some of the parametric studies.

Partial funding was also provided by the JRC and the CEC for the parametric studies and several specific actions by experts from CEC countries.

The following estimates made by Ispra give an approximate idea of the resources that were required to carry out PISC-II (1 European Currency Unit (ECU) = \$.75 US) :

- RRT plates : -fabrication	1,100,000 ECU
- transport	75,000 ECU
- PS : - sample fabrication	120,000 ECU
- special equipment	140,000 ECU
- other costs to Ispra	680,000 ECU
- manpower : - RRT inspections	35 man-year (m-y)
- PS studies	15 m-y
- provided by JRC Ispra	56 m-y
to fulfill role as	
Operating Agent	

Equating one man-year of effort to 100,000 ECU, the total cost of PISC-II was approximately 12,700,000 ECU, of which about 7,100,000 ECU (55%) was funded by the Commission of the European Communities Directorate General XII through its Joint Research Centre, Ispra Establishment and Directorate D (Nuclear Research and Development).

## APPENDIX III

### 1. PISC-II MANAGING GROUP AND ITS SUB-COMMITTEES

The organisation of PISC-II was based on an efficient complementarity of the roles played by the Managing Group and the Operating Agent. However most of the important specific tasks were put under the guidance of leaders who convened expert groups when necessary (see Table 1).

The most important of these groups are listed below :

#### 1.1. Managing Group (MG)

- . Chairman : Dr. R. Nichols, UKAEA, UK
- . Programme Manager : S. Crutzen, JRC Ispra
- . Secretary : a) P. Oliver, OECD, NEA, (1981-1984)  
b) Dr. M. Stephens, OECD, NEA, (1984 - 1985)  
c) Dr. J. Caisley, OECD, NEA (1985-1986)  
d) Dr. N.R. Mc Donald, OECD, NEA (1986)
- . Members : a) official representatives of the participating countries : Belgium, Canada, Denmark, Finland, France, Federal Republic of Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, United States of America.  
b) besides the Programme Manager, representative of the Operating Agent, other experts of JRC Ispra and of the participating countries attended meetings upon occasion to advise on technical matters.  
c) the Leaders of all the specific tasks or groups here under were members of the Managing Board.
- . Meetings : Generally twice a year. The Group worked to OECD Rules of Procedure.

#### 1.2. Round Robin Test Organisation Group (RRT0)

- . Leader : a. Ph. Caussin, Ass. Vincotte, B, (1980-1981)  
b. E. Borloo, JRC Ispra, CEC (1982-1984)

This group organized the RRT and followed its execution. It existed as a group only during 1980. E. Borloo reported to the Managing Group on the progress of the RRT from 1981 to 1984.

#### 1.3. Parametric Studies Organisation Group (PSP0)

- . Leader a. S. Crutzen, JRC Ispra, CEC (1980)  
b. A. Prot, CEA, F, (1981-1982)  
c. C. Birac, CEA, F. (1983-1986)

This group was dedicated to the detailed definition of the study programmes.

#### 1.4. Evaluation Task Force (ETF)

- . Chairman : Dr. R. Nichols, UKAEA, UK.

This group started in 1983 and gave guidance for the evaluation of results.

1.5. Destructive Examination Group (DEG)

. Leader : S. Crutzen, JRC Ispra, CEC

No group was ever convened : problems were discussed by the ETF directly.

1.6. Data Analysis Group (DAG)

. Leader : Dr. N. Haines, CEGB, UK

The group (4 members) defined the procedures for evaluating the RRT results.

It was active from 1983 to the end of the programme.

1.7. Group for the Parametric Studies on Defect Characteristics (EDC)

. Leader : Dr. G. Deuster, IZfP, FRG

Measurements and comparison of the results to the predictions of mathematical models were performed by Dr. M. Certo, (CISE) Italy.

1.8. Group for the Parametric Studies on Equipment Characteristics (EEC)

. Leader : E. Borloo, JRC Ispra, CEC

Measurements and evaluation of the results were performed at JRC Ispra by I. Bredael, CEC.

1.9. Group for the Parametric Studies on Cladding Characteristics (ECC)

. Leader : Y. Beurdeley, ECAN, F

Measurements and evaluation of the results were performed at INDRET by technicians of ECAN, of CEA and of EdF under the leadership of Y. Beurdeley.

1.10. Study on the Possible Use of Electromagnetic Techniques (EMT)

. Leader : Dr. G. Deuster, IZfP, FRG.

A comparison was made between the results of applying eddy current and EMAT techniques to a clad test specimen.

1.11. Expert on Statistical Aspects of the Parametric Studies and the General Evaluation of the Data (STA)

. Expert : Dr. A. Ford, SRD, UKAEA, UK.

1.12. Programme Elaboration Group (PEG)

. Leader : S. Crutzen, JRC Ispra, CEC

This group met 3 times from 1983 to 1984 and developed the technical proposal for a further programme to follow PISC-II : PISC-III.

APPENDIX IV

THE PISC-II MANAGING GROUP MEMBERS

<u>Belgium</u>	P. Dombret (Association Vincotte)
<u>Canada</u>	O.A. Kupcis (Ontario Hydro)
<u>Denmark</u>	N. Nielsen (Danish Welding Institute)
<u>Finland</u>	J. Forsten (Valtion Teknillinen Tutkimuskesku (VTT))
<u>France</u>	J. Beurdeley (E.C.A.N. Indret) C. Birac (Commissariat à l'Energie Atomique)
<u>Federal Republic of Germany</u>	G. Deuster (Fraunhofer Institut für Zerstörungsfreie Prüfverfahren) W. Schmuelling (Gesellschaft für Reaktorsicherheit)
<u>Italy</u>	G. Maciga (Ente Nazionale per l'Energia Elettrica)
<u>Japan</u>	Y. Saiga (Ishikawajima-Harima Heavy Industries (IHI)) M. Kishigami (I.H.I. Co. Ltd)
<u>Netherlands</u>	A. de Sterke (Röntgen Technische Dienst (RTD) BV)
<u>Norway</u>	O. Forli (Det Norske Veritas)
<u>Spain</u>	A. Esteban (Consejo de Seguridad Nuclear) E. Romero (Junta de Energia Nuclear)
<u>Sweden</u>	L.A. Koernvik (Swedish Plant Inspectorate)
<u>Switzerland</u>	D.H. Njo (Hauptabteilung für die Sicherheit der Kern- anlagen (HSK))
<u>United Kingdom</u>	E. Bevitt (UKAEA, Safety and Reliability Directorate) N. Haines (Central Electricity Generating Board) B. Hemsworth (M Nuclear Installations Inspectorate) R.W. Nichols (Head, UKAEA Risley Nuclear Power Deve- lopment Lab.) CHAIRMAN T. Nixon (UKAEA Safety and Reliability Directorate) J. Whittle (Central Electricity Generating Board)
<u>United States of America</u>	F.L. Becker (J.A. Jones Applied Research Co.) S.H. Bush (Battelle Pacific Northwest Laboratories) L.J. Chockie (General Electric Company) J. Muscara (United States Nuclear Regulatory Commis- sion)

Commission of the  
European Commu  
nities

S. Crutzen (Commission of the European Communities  
Joint Research Centre, Ispra Establish-  
ment) PROGRAMME MANAGER

H.A. Maurer (Commission of the European Communities,  
Brussels)

E.E. Borloo (Commission of the European Communities  
Joint Research Centre, Ispra Establish-  
ment)

OECD Nuclear  
Energy Agency

P. Oliver,  
M. Stephens,  
J. Caisley

N.R. McDonald (OECD Nuclear Energy Agency, Paris)  
(SECRETARY - in succession)



## APPENDIX V

### PARTICIPATING INSTITUTIONS

#### BELGIUM

Association Vincotte  
S.A. Cockerill

#### DENMARK

Danish Welding Institute

#### FINLAND

Valtion Teknillinen Tutkimuskesku (VTT)

#### FRANCE

Commissariat à l'Energie Atomique (C.E.A.) Saclay, Research Centre  
Framatome  
Etablissement de Construction d'Armes Navales (E.C.A.N.)

#### FEDERAL REPUBLIC OF GERMANY

Fraunhofer Institut für Zerstörungsfreie Prüfverfahren (I.Z.f.P.)  
Kraftwerkunion (KWU)  
Bundesanstalt für Material Prüfung (B.A.M.)

#### ITALY

Ente Nazionale per l'Energia Elettrica (E.N.E.L.)  
Ansaldo Termomeccanica  
Acciaierie Tubificio di Brescia (A.T.B.)  
Centro Informazioni Studi Esperienze (CISE)

#### JAPAN

Japan Power Plant Inspection Institute  
Ishikawajima-Harima Heavy Industries Co. Ltd. (I.H.I.)  
Mitsubishi Heavy Industries Ltd.,  
Hitachi Ltd.,  
Toshiba Corp.,  
Babcock Hitachi Copr.  
Japan Steel Works  
J.G.C. Corp.  
Chyoda Chemical Eng. Construction co., Ltd.,  
Kobe steel Ltd.,

Japanese Society for NDT Subcomm. 202  
Nippon Kokan KK  
Sumimoto Metal Industries  
Canon Hologonics Inc.,  
Hitachi Zosen Corp.

#### NETHERLANDS

Röntgen Technische Dienst B.V. (R.T.D.), in collaboration with :  
Ministry of Social Affairs - Den Haag  
Joint research Centre - Petten  
KEMA - Arnhem  
Kon. Sheel Labs. - Asmterdam  
KEMA N.V.

#### NORWAY

Det Norske Veritas

#### SPAIN

Tecnatom S.A.  
CIAT Nuclear S.A.  
Equipos Nucleares S.A.

#### SWEDEN

AB Staatens Anlaggningsproving  
Tekniska Rontgencentralen A.B. (T.R.C.)

#### UNITED KINGDOM

United Kingdom Atomic Energy Authority (UKAEA)-Harwell  
United Kingdom Atomic Energy Authority (UKAEA)-Risley  
Babcock Power Ltd.,  
Central Electricity Generating Board (CEGB)  
Rolls Royce & Associates  
A.O.T.C.

#### UNITED STATES OF AMERICA

Combustion Engineering Inc.,  
Nuclear Energy Services (N.E.S.)  
Chicago Bridge and Iron Company (C.B.I.)  
Southwest Research Institute (S.W.R.I.)  
Westinghouse electric Corp.  
General Electric Corp.  
Spectron Development Lab. Inc.  
Battelle Pacific Northwest Lab.

