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The PISC III Programme - A Status Report

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ABSTRACT

The PISC programme is presently in its third phase : PISC III, which involves several actions dealing with :

- expertise on real defects;
- evaluation of the effectiveness and reliability of NDE procedures when applied on : full scale pressure vessels, safe-ends, stainless steel piping welds, steam generator tubes;
- validation of mathematical models;
- identification and evaluation of human factors.

This third phase is also a validation excercise of the second one (PISC II) on heavy steel sections inspection.
Final reports will not be ready before October 1993.

INTRODUCTION

The PISC Programme has the general objective of assessing procedures and techniques in use for the inspection of pressure components (in particular the vessel and piping).

The Series of projects for the Inspection of Steel Components carried out since 1974 under the auspices of the CEC/JRC and the OECD/NEA is a major international effort to better assess the capability and reliability on Non-Destructive Inspection procedures of structural components.

Three projects are centered on the Ispra Joint Research Centre which, in its roles of Operating Agent and Reference Laboratory, manages the programme and provides with the participants of EC countries approximately 60% of the programme funding; the other 40% come via contributions in kind from the non-EC participating countries. OECD/NEA provides the Secretariat of the PISC Managing Board, consisting of representatives of 14 countries (8 EC and 6 non-EC countries).

The programme is now in its third phase (PISC III); the activities concentrate on the validation of the PISC II results (e.g. modification of the ASME Inspection Codes) on real structures containing service defects and the extension of the PISC methodology on most important structural components made of different materials. Most of the PISC test assemblies and structure pieces are representative of (or are coming from) nuclear reactor components.

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; for such procedures, no change was obviously required; optimization from an econoic/industrial/reliability point of view was however necessary.

PISC II parametric studies on the effect of defects characteristics [3] showed the importance of defect parameters like the type of defects (planar or volumetric, Figure 1), 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.

Since 1986, due to 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 going beyond the modifications proposed in 1986 and the new Appendix VIII on "Performance Demonstration" clearly starts from the PISC results, [4] (Figure 1).

PISC III PROGRAMME STATUS

PISC III, the third phase of the PISC series insists on the capability demonstration with assemblies of real geometry containing realistic defects. 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. Eight programme Actions have been established. There are identified in the Organization Scheme (Table 1).

Round Robin Testing activities are presently performed in several of the PISC III actions. The final work to be undertaken in all the seven Actions has been defined and most of the necessary test samples and other resources have been obtained. The uncertainties that prevailed during 1986/87 concerning the level of budgetary support have partly been resolved in accepting delays for the AST and for the SGT actions. Resources from the CEC and from participating organisations

(participation to inspection, and contribution in kind) are now assured to carry out the essential elements of most of the planned actions.
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. Contaminated and cracked austenitic steel of primary circuit pipes from Switzerland have been inspected to give a full demonstration of the whole resources available [5].
Further samples are available from Spain, Sweden, USA and Finland. Several of these components, after certification in the PISC hot cells, have been allocated to the Reliability exercise of Action 4 (Austenitic Steel Testing).

Action No. 2 (Full Scale Vessel Tests) validates results obtained by procedures in the PISC II exercise in realistic inspection conditions.
The installation offered by Staatlich Material- prüfungsanstalt (MPA), Universitaet Stuttgart, Germany is being used. It is made of a BWR full scale vessel plus modular full scale PWR components. Seven teams participated in 1988 and 1989 to 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 organizations participated in the phase 2 : validation of ASME type procedures by an international team using an ISI automatic scanner offered by RWE and MAN to PISC for the period of the exercise (September 1989 to April 1990) (Figure 2). This central mast manipulator for vessel inspection from the inside was operated with MAN crew for PISC. KWU and MAN ultrasonic and recording/evaluating electronics as well as technicians were used for the execution of this phase 2 by the "Super Team" made of the JRC Reference Laboratory and national experts (JRC, Germany, Spain, Switzerland, Italy, Belgium, USA for ASME certification). The same crews and electronics were used for Phase 3 type inspection (national full procedures) from September 1989 to end 1990.
One team of the ex-DDR took part to the exercise in fall 1990.

Phase 1 and Phase 2 already reached the level of Data Evaluation and very first trends can be drawn from the results [6], such as good sizing capability of several techniques and effective validation of the PISC II results obtained on the Assembly No. 3 [2].

The work of Action No. 2 was largely supported by Germany: large Assemblies, availability of the MPA installation and logistics, Central Mast Manipulator, Action Management, ...

Action No. 3 (Nozzles and Dissimilar Metal Welds) closed in March 1991 the round robin tests of safe-ends 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 (Figure 3) and a Spanish PWR safe-end began their circulation mid 1989.

An important aspect of the RRT organization is the "Certification" of the defects in the assemblies. Such a certification ensures that all assemblies proposed for testing are of value and suitable to meet the aims of the Actions. It is conducted by the JRC Reference Laboratory, often in collaboration with the manufacturer of the assembly. It is to be noted that two of the three Assemblies used in Action No. 3 were offered by Japan and USA but the introduction of supplementary defects and the preparation of Assembly No. 25 were supported by the Reference Laboratory, JRC Ispra.

Action No. 4 (Austenitic Steel Testing) applies the PISC II methodology to the primary circuit piping of LWRs. Round robin tests for the capability assessment and parametric studies started in 1990; some reliability evaluation of the testing procedures are considered [7]. Wrought pipe samples were offered by the USA, Japan and France; moreover, large cast samples have been ordered by JRC (Figure 4). Twenty five teams have registered their intent to participate in one or more phases that will extend up to 1992. Large assemblies are still in fabrication for the RRT on cast austenitic steel.
This Action No. 4 of PISC III suffered very much of the non timely availability of resources necessary to gather the raw material, manufacture assemblies and introduce real and realistic defects. The orders placed to get material were also executed with long delays due to the character of these orders: small quantities (5000 Kg.) of "exceptional castings". The Action results 18 months behind schedule.

Action No. 5 (Steam Generator Tubes Testing) involves in its present phase round robin tests of individual tubes of steam generators containing realistic and artificial defects. 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 to acquire tubes and introduce and validate defects has been carried out from April 1988 to October 1989 (tubes with defects have been obtained from France, Japan, UK, the Netherlands and the United States). The Management Board has received advice from CSNI (Principal Working Group on Primary Circuit Integrity) on the defects types and characteristics of most importance with respect to safe operation. Twenty-eight teams from ten countries have registered an interest to participate in the RRT planned until 1992. The validation of defects has involved experts of Belgium, France, Germany, Italy, Japan, Spain, United Kingdom and United States of America. The Reference Laboratory (JRC Ispra) is preparing many artificial defects in tubes. Orders have been placed from the Operating Agent to get realistic corrosion defects by CEA, MITSUBISHI, CEGB, KEMA.
Emphasis has been put on corrosion defects (IGA, SWSCC, PWSCC) at three key locations: Tube Sheet (above the rolling zone), Tube Support Plates, U-bend transition.
The first training box (Figure 5) started its circulation in January 1990, the full RRT is expected to last until the end of 1992 due to the important participation (30 teams).

Action No. 6 (Mathematical Modelling on NDE) has the objective to validate experimentally mathematical models and perform parametric studies in order to assess the importance of defect characteristics. Sixteen organizations in eight countries have registered their intent to participate in studies to assess mathematical models of ultrasonic

inspection by validating the models with experiment and assessing the utility of these models in terms of limits of valid application, satisfactory and efficient computer performance and accuracy. Fifteen models have been offered for possible study [9]. 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. The Modelling Group of PISC III has selected (April 1989) three models that were studied by the Reference Lab for validation in 1989 (2 UK and 1 German models) as well as models to be studied in 1990 and in 1991 (1 UK and 2 French ones).
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 [10][11][12][13]. The validation of the three first models has given now the assurance that models can be used to draw graphs and tables, like the ones of the report in reference 13, without imperfections or errors due to the transducer characteristics (from one to the another transducer), to the various calibrations and normalization operations, to the imperfection of artificial defects, to the secondary effects like wave mode transformation often depending on defects sizes.
The Modelling Group of PISC III is also decided to start three new studies :

- validation of models of the ultrasonic beam and pulse shape;

- calculation of the tip (edge) signals from smooth ultrasonic reflectors, and hence the calculation of diffraction coefficients for ray models of ultrasonics;

- prediction of the signals detected from a smooth crack very close to the surface of the steel component.

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 was performed in the United Kingdom and at the JRC-Ispra utilizing the PISC II data and supplementary questionnaires. Studies on human variability [14] and influence of the limited access of welds for UT inspection were considered.

Other systematic observations are carried out at Risley UKAEA and at JRC Ispra through the inspection by industrial UT operators of special assemblies and components used in PISC Actions. Some of them will be inspected under conditions reproducing practical industrial reality such as temperature, humidity and time constraints in a mobile laboratory (Figure 6). The detailed objectives of this Action are as follows [5] :
- to study and identify the causes of variability between inspectors in calibrating their equipment, inspecting defective components and interpreting ultrasonic data in clean, laboratory-type inspection conditions;
- to study the influence of industrial inspection conditions on inspector performance to identify the significant factors and to aid the development of relevant safeguards.

Action No. 8 (Support to Code and Standard Organizations) proposed by the Management Board and approved by OECD-NEA and CEC-JRC is to give direct support through the PISC group of experts to C/S organizations. Such a proposal has been supported by all PISC members and involves three aspects :

- Information of C/S Technical Committees of PISC results and PISC related programmes results.
- On request, critical review by PISC members of technical documents made by national, international technical groups.
- Preparation of technical reports by PISC members related to Codes and Standards problems,for the benefit of National, CEN, ISO, IIW technical groups which elaborate standards.

The organization and Ssupport of Action 8, involve mainly the Operating Agent.

FUTURE OF PISC

PISC III is the last phase of a series of exercises :

PISC I - effectiveness assessment of an ASME type procedure (50% DAC) and indicative assessment of some special procedures; warning was given about some poor results;

PISC II - identification of performant techniques and procedures; identification of key parameters (e.g. defect category); first feedback on Codes and Standards (ASME XI);

PISC III - validation of PISC II results; extension of the PISC II methodology to other components than the pressure vessels: piping and steam generators; emphasis put on performance demonstration through the use of simplified mock-ups and realistic defects; better understanding hoped through models validation as well as easy parametrization; human reliability problems are considered; organization of a direct support to Codes and Standards is undertaken.

The part of the PISC III resources, made available by the Operating Agent (CEC, JRC), is depending on the present CEC multiannual research programme (1988-1991) and is thus assured until end 1991.
The erosion of the political support to Nuclear Energy in many countries is such that no proposal was made of further PISC work in the overall framework of Reactor Safety even if the ageing of the existing nuclear plants would require PISC type actions.

It is expected however that the need for international Codes and Standards will be such that the Operating Agent of PISC (CEC) will support Actions like Austenitic Steel Testing, Steam Generators Tubes Testing, Human Reliability Exercises until the effective possible use of their results by Codes and Standard bodies (1993).

The PISC programme is an example of international cooperation with effective conclusions, technical results and input to Codes and Standards. This example must be followed in other frameworks than NDT; it is the case for Fracture Assessment methods, at the level of the OECD-CSNI Committee (Principal Working Group 3).

The whole framework of Structural Integrity must be considered in international and collaborative exercises like PISC :
- Margin to Failure Evaluation;
- Inspection;
- Residual Life Evaluation.

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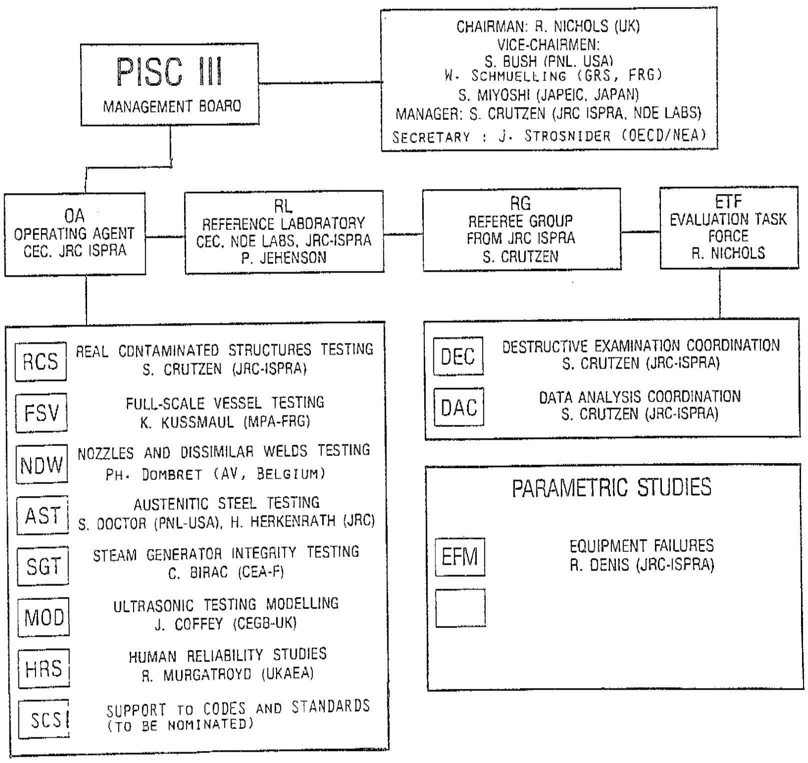

Table 1 - Organization of the PISC III Programme.

Budget	CEC budget 40% of the resources; countries bear own costs and make "in kind" contributions
Secretariat	NEA/OECD
Management	CEC Joint Research Centre, Ispra ,Italy
Members	Belgium, Denmark, Italy, Finland, France, Germany, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom and United States

Table 2 - PISC III Funding (evaluation made on November 1, 1990).

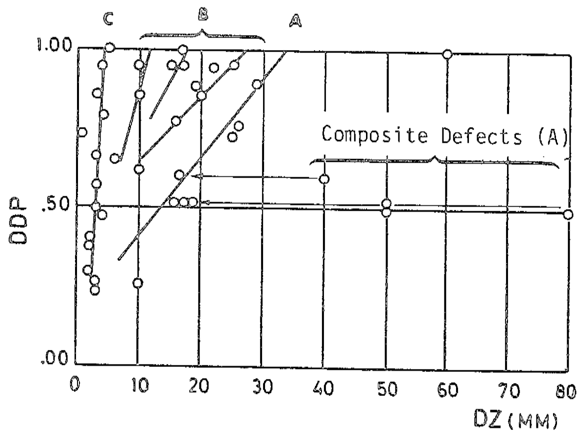

Figure 1 - Categories of defects. Detection probability of ASME type procedures with recording level at 20% DAC as a function of the defect through wall size (for the three categories of defects:

a. fatigue cracks (smooth, planar for ultrasonic wave length, sharp crack edges);
b. hybride defects or rough defects like hot tears;
c. volumetric defects (slags, pores, calibration holes like ASME 9.5 mm diameter side drilled holes or 3 mm flat bottom holes).

Calibration made on c. type defects can be a correct equipment setting but is not a performance demonstration for category a (e.g. fatigue crack) detection.

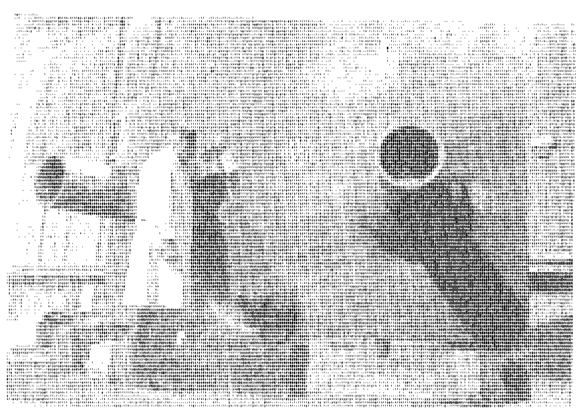

Figure 3 - PISC III Action No 3 (NDW). Assembly No. 20 with three nozzles and safe-ends of the BWR type : No. 21, No. 22, No. 23.
Assembly No. 20 is also a key element for any evaluation of new inspection possibilities of old plants considered for life-extension (May 1989) (offer and manufacture from USA, Japan, Spain).

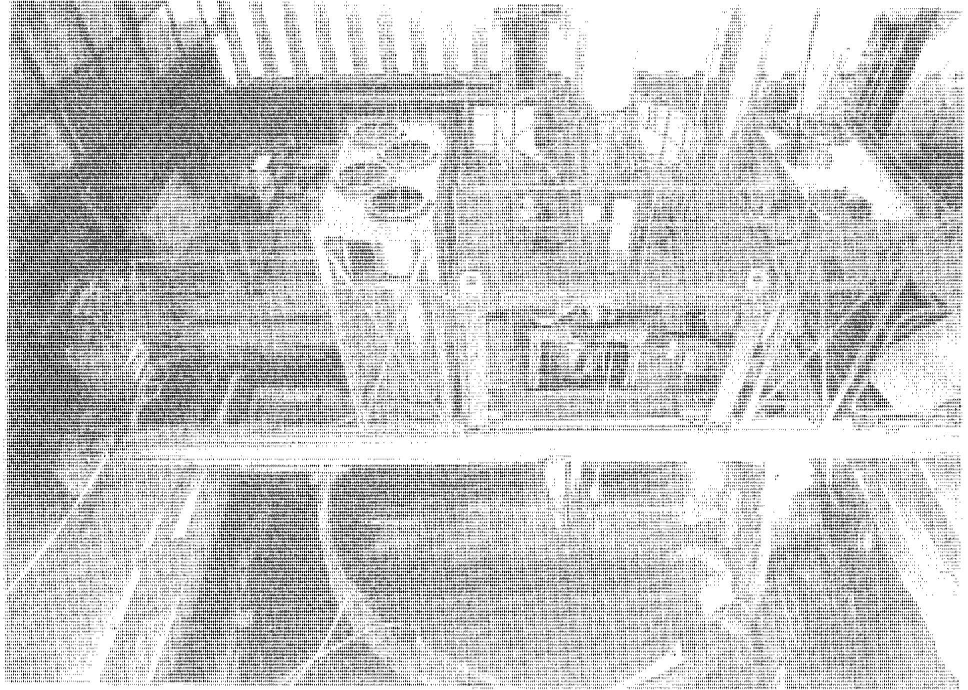

Figure 2 - RWE/MAN (Germany) central mast manipulator used with UT electronics and crew of MAN and SIEMENS, on the full scale components at MPA (University of Stuttgart, FRG) for Action 2 Phases 2 and 3 (1989-1990).

Figure 4 - PISC III Action No. 4, (AST). Large castings ready for assemblies manufacturing when the last budget allocation will be available. Offer and manufacture from France, JRC, Japan, Spain.

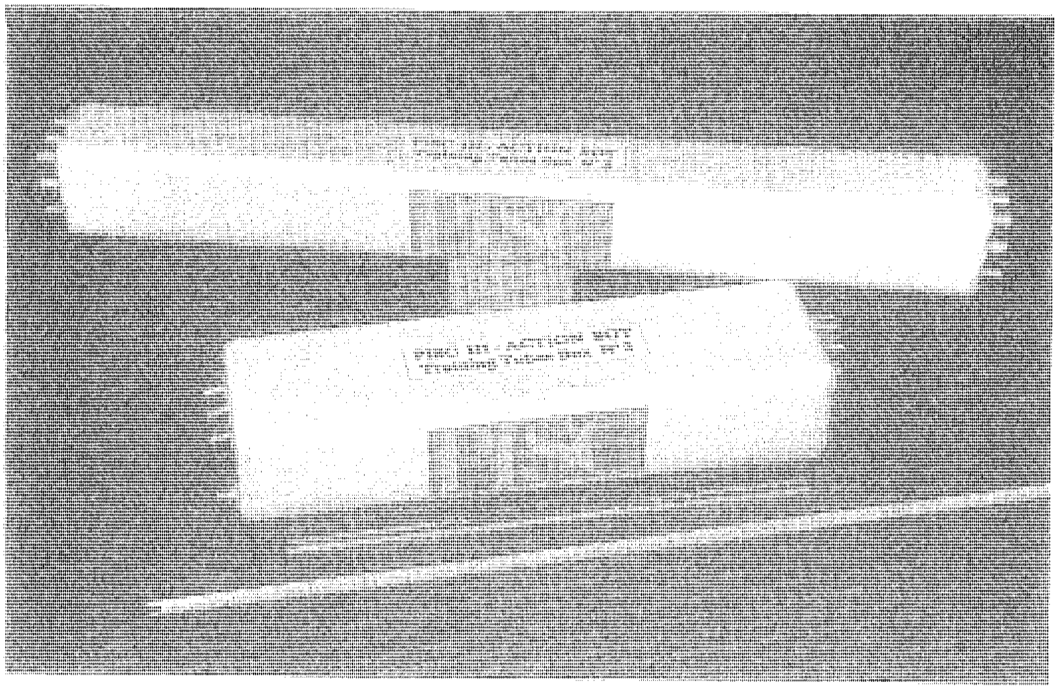

Figure 5 - Box of Steam Generator Tubes containing realistic and artificial defects for the RRT on loose tubes.

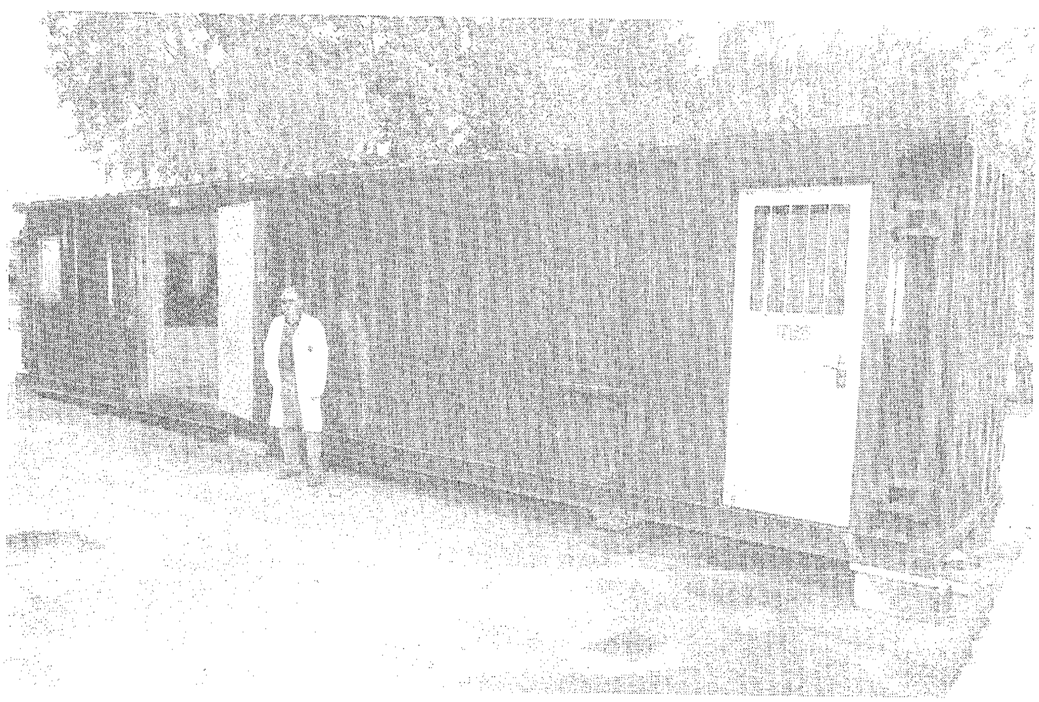

Figure 6 - PISC III Mobile laboratory for human factors identification.