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Executive Summary

The work of the Institute during the year can be subdivided under the following seven headings:
- specific programmes,
- exploratory research,
- support to the Commissions policies,
- third party work,
- Eureka projects,
- associated laboratories,
- large installations,

The work carried under each of the seven programme headings is summarised below.

SPECIFIC PROGRAMMES

Reactor safety

a) The Event sequence Reliability Benchmark Exercise, based on the Grohnde Nuclear Power Plant, has been completed and final analysis of the results are underway. The aim of the exercise was to access methods and techniques used in the analysis of complete accident sequences.
b) Work has continued on the development of the content of the Component Event Data Bank (CEDB) and on analysis methods for both the CEDB and the Abnormal Occurrences Reporting System (AORS).

For the CEDB a Benchmark Exercise was organised to study the comparison of methods used by the participants to estimate component reliability from raw data. In addition a study is underway on the use, of Fuzzy sets and possibility theory as an intelligent interface for CEDS interrogation. For the ADRS a two volume report has been published which describes the various analyses methods and standard procedures for interacting with, and displaying of, the contents of the bank.
A semi automatic transcoding programme, initially for use in CEDB, has been written and is in operation.

Safeguards

A specahsed laboratory is being set up to study the different characteristics of seals and optical surveillance systems and the general layout of another laboratory in connection with surveillance and containment has been finalised, and construction will start early in 1990. Collaboration has contained with the IAEA on LASCAR and with ESARDA on several projects of mutual contest. Work has continued on Seals and Identification techniques for PWR fuels assemblies including the use of surface topography fingerprint techniques.

Industrial Hazards

The BE on the comparison of the approaches to risk analysis for a refrigerated ammonia storage facility connected by pipelines to a sea terminal and transferring of ammonia to a

pressurised tank in a process plant has been completed, and the final report is expected in the middle of 1990.

Further work has been carried out on process diagnostics by ARMA modelling, this is a methodology for globally monitoring and on line diagnosing plants and process operations. Work has contained on the pooling of subjective data in a complex technological context with the aim of the formulation of a final judgement on the expected stochastic behaviour of a given complex system where information is collected from several sources of possibly different degrees of credibility.

In the field of digitising maps, a programme, has been written for the digitisation of transport networks in a form suitable for transfer to other computer systems. The stereo reconstruction of 3D models for industrial sites is now being extended for industrial risk applications. Work is also continuing to improve the 3D wire frame model of buildings using a stereo reconstruction process.

Reference Methods and Reliability of Structures

In the field of reference methods for non-nuclear energy the main efforts have concentrated on evaluation and test methodologies for systems and components with the most important tool in this work being the ESTI facilities, which are probably unique in Europe, in providing a complex of test facilities for photovoltaic devices.

Work on the reliability modelling of structures has continued with further tests on the 1:5 scale pressure vessel. A crack appeared on vessel R2(A) after some 875000 cycles and the vessel will be subjected to XR and UT inspections before its destructive examination.

Related work on residual life time prediction, non-destructive testing, fatigue crack nucleation and residual stress measurements has continued as has work on the pressurised thermal shock experiment and on the behaviour phenomena of high stress regions.

In the field of Advanced Materials, the experimental apparatus has been improved and several types of damaged specimens have been tested including alloy type 500H and AISI 316L.

Fusion Technology

Under the heading of Engineering design and remote maintenance systems the Institute has collaborated in the pre-design of the ITER mechanical configuration, simulation studies for the remote removal and substitution of internal components, where the main work has been the equipping of a simulation laboratory. Studies have also been made on the electromagnetic effects on in-wall vessel structures due to plasma disruption, on instability analysis of first wall components subjected to electromagnetic transients, the thermo-mechanical analyses of the ITER diverter plates and on the Breeding Blanket design.

Safety and Environmental analyses have been carried out on the effects of a loss of vacuum, accident and on the feasibility aspects of the $D-He^3$ fuel cycle in Tokamak plants where it has been shown that the use of $D-He^3$ instead of the more usual D-T fuel leads to relevant design and operation simplifications of important components, such as the first wall and blanket. It has been concluded that there is the need for further studies on the conceptual design of $D-He^3$ power stations before moving to a more in-dept analysis of the safety and environmental aspects.

EXPLORATORY RESEARCH

a) Image processing and synthesis.
   Studies have continued on the analysis and synthesis of Holograms and on the analysis of the topographical structure of turbulent flows where images obtained from visualisation of the turbulent flow under coherent high conditions are analysed by image processing techniques.

b) Energy.
   Work has progressed on the Euro-Quebec Hydro-Hydrogen project, the aim of this 100 Mw pilot plant project is to demonstrate the provision of clear and renewable primary energy in the form of Quebec hydropower convented into hydrogen and shipped to Europe, where it is stored and used in different ways, such as electricity generation and vehicle propulsion; the detailed engineering phase of this project is due for completion by the end February 1991.
   Attention has also been given to the best ways and means of the maritime transport of large quantities of hydrogen in the context of the above project.

SUPPORT TO THE COMMISSIONS POLICIES

There have been several areas of the Institute support to the Commissions policies in the field of International cooperation, industrial policy, transport, environment, telecommunication and energy.

WORK FOR THIRD PARTIES

This work has been in four main fields VIZ: New nuclear energy and energy saving, reliability of structures (notably the BRITE project) safeguards and Industrial hazards where the main results have been in the setting up of a school for Civil Protection for training of personnel from the Italian region of Lombardy, the Ispra Risk Management Support System and a study of the problems associated with the transportation of dangerous substances.

EUREKA PROJECTS

The STARS project was officially started in 1989. The project uses Artificial Intelligence techniques in combination with conventional programming techniques for providing support to risk analysts and designers in performing safety and reliability studies in the field of process plant and the nuclear industry.

ASSOCIATED LABORATORIES

Collaboration has been made with several other outside companies in the development of the expert system ARTIC, the aim of which is the damage assessment and life-time prediction of pressurised steam headers of conventional power plants. Laser holographic interferometric measurements have also been made to determine the residual stress in welded joints.

LARGE INSTALLATIONS

The Institute has collaborated in upgrading and providing new facilities in ESTI. The general design office has carried out work not only for the Ispra Center but also for third parties, notably in connection with IGNITOR.

1. ISE Specific Programmes

1.1 REACTOR SAFETY

1.1.1 Reliability Benchmark Exercises Project

Event Sequence Reliability Benchmark Exercise

The Event Sequence RBE (ES-RBE) has been completed. The ES-RBE had the aim to assess the methods and techniques used in analysis of complete accident sequences. The main objective was to understand the ways logic models are developed for event sequences (e.g. event trees) and how these models are analysed. However, since quantification of the sequence models was asked, systems analysis, common cause failure analysis and human reliability assessment were involved and the state of the art in level 1 PRA could be assessed.

The reference plant of the ES-RBE was the Grohnde NPP. The reference initiating event was related with a long lasting (14 hours) emergency power mode. The functions required after occurrence of this initiating event are decay heat removal and emergency power supply, and the systems involved are:
1. the start-up and shut-down system: a 2x100% system which can feed the steam generators from a common feedwater tank:
2. the demineralised water supply system (2x100%);
3. the emergency feedwater system (4x100% system);
4. the first level (D1) emergency power supply system;
5. the second level (D2) emergency power supply system;
6. the main steam valve stations.

The ES-RBE was organised in documentation phase and two working phases:
1. In the documentation phase, Siemens produced and dispatched the full set of documents for the exercise. In addition to a detailed description of the reference sequence and of the systems involved in the sequence, the participants received a common set of reliability data for all components in the involved systems as well as common input regarding the quantification of common cause failures. Participants were given the opportunity to ask additional questions to the plant designer.
2. In the first working phase, all participants performed a first analysis of the complete sequence. Terms of reference were established for what concerns the thermoydraulic aspect of the sequence and for the scopes of human reliability and common cause failure analyses. The aim of this phase was to compare the results primarily with respect to logic sequence modelling, although a first quantification of the sequences yielding point values was asked.
3. In the second working phase the scope of the work was restricted by assuming boundary conditions regarding the failure or success of some of the systems involved in the exercise. In this way the number of sequences to be analysed was reduced. Furthermore, it was asked to model the retained sequences in detailed event trees, showing system states up to train level. For the quantification of the retained sequences, terms of reference were agreed regarding common cause failure quantification and human reliability contributions. The second phase included also an uncertainty analysis on the calculated frequencies of the reference sequences.

The final analysis of the results of the ES-RBE has yet to be finalised and reviewed by the participants. Therefore only preliminary and partial insights are reported here.

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The first working phase showed that problems arise in the analysis of complex sequences involving many systems interdependencies. In the case of the ES-RBE, these dependencies also impacted on the success and failure criteria along a determined sequence. It was concluded that it is preferable to develop event trees at a level of detail which allows representation of the main inter-system dependencies. In this exercise, it meant that the single trains of the involved front-line systems should appear explicitly in the event tree. If this is not done, the event tree can be trivial as important inter-system or functional dependencies remain hidden in the front-line system models (fault trees), and, hence, not transparent.

The second phase has shown that whether or not to include the support systems in the event tree is mainly a matter of the computer code available for the logic and probabilistic analysis of the sequences. Modelling the support systems in the front-line system fault trees ("small event tree approach") puts very high demands on the fault tree code used since a sequence must be analysed by analysing a large fault tree linking the fault or success trees of the systems involved in the sequence. It was shown that most current fault tree analysis codes have problems in coping with such large trees. Moreover, only few codes are able to handle trees containing "not" logic. Such logic is introduced in sequences involving success states.

On the other hand, modeling the support systems in the event tree ("large event tree approach") in order to try to render the events along a sequence independent of each other makes analysis of single sequences simple, but leads to a huge number of sequences to represent. This induces a risk of loosing transparency in the sequence model and creates difficulties for reviewing the model. It should be noted that the ultimate goal of rendering all events along a sequence independent of each other is hardly achievable, especially if intersystem common cause failures are to be considered. There was a consensus on the fact that for a qualitative representation of the sequences, the small event tree approach is clearly preferable. This means that the large event tree approach is to be considered rather as a tool for quantification than as a model for showing sequence development.

Human Factors Reliability Benchmark Exercise

The final report of the Human Factors Reliability Benchmark Exercise [1,2] was published.

References

[1] Poucet A. (1989). Human Factors Reliability Benchmark Exercise: Final Report. CEC Euratom Report EUR 1222 EN.

[2] Poucet A. (1989). The European Benchmark Exercise on Human Reliability Analysis. Proc. PSA 89 Int. Topical Meeting on Probability, Reliability and Safety Assessment. Pittsburgh, April 2-7, 1989.

1.1.2 CEDB Analysis

Development of CEDB Data Analysis Tools

The main effort of the Institute during 1989 has been devoted more to the development of an adequate set of analysis tools than to a thorough analysis of the data base.

The CEDB data are characterised by a large number of numerical and categorical variables (i.e. attributes) to describe the component and the failure event.

Due to the large number of categories, data extracted from the bank are often sparse. As a consequence, methods applicable to relatively small samples are of particular interest.

An example of analysis of a multidimensional contingency table generated from CEDB data related to pumps (table characterised by extremely sparse data, very asymmetric marginal histograms and built-in dependencies) is presented in ref. [1]. The problems posed by the high dimensionality of the data and the possible reduction of dimensionality (when is it legitimate to ignore one variable or pool two categories together?) and the associated consequences on the reduction on the information in the data are discussed in [2].

In the framework of multivariate analysis techniques development, logistic regression is being applied to model the probability of first failure of a component as a function of concomitant variables. A new method based on the fitting of linear models to the logic of the survival probability (i.e. the logarithm of the probability of survival divided by the probability failure) given the time the component operated and other concomitant variables is an on-going line of research. Some new original features (e.g. a randomisation process of the observed failure and suspension times) are under study.

Benchmark Exercise on Data Analysis

A Benchmark Exercise (B.E.) on data analysis has been organised by the Institute among the EuReDatA members. The aim of the B.E. is a comparison of the methods used by the various organisations to estimate component reliability from raw data. As a reference data set, data on pumps extracted from the CEDB have been adopted. The B.E. will be concluded with a seminar, planned for spring 1990.

The ISE contribution to this B.E. is reported in [1,3]. In this study much effort has been put in statistical inference, aimed at the assessment of reliability parameters. At a component level the binomial-beta model is used as the reference model for estimating constant failure probabilities (both in operation and on demand): i.e. binomial sampling is assumed both for time processes and for on demand processes, while the failure probability is modelled (in a Bayesian approach) by beta distribution.

Development of an Intelligent Interface for CEDB Interrogation, by Making Use of Fuzzy Sets and Possibility Theory

On the basis of a collaboration with the Paul Sabatier University, aimed at the development of a Reliability Parameter Estimation System (the fourth bank of the European Reliability Data System) [4], a feasibility study of an intelligent interface for CEDB interrogation, by making use of fuzzy sets and possibility theory, is being performed.

The CEDB can be regarded as a multi-source information system, where the elementary sources are represented by the individual component histories. The feasibility of realising another query procedure, based on the use of the possibility theory and the combination process embodied in the RPES is under study.

The advantage of using possibility theory instead of the probability (the traditional frame to deal with uncertainty) lies in the large number of combination rules which the former offers.

References

[1]   Jaarsma R.J. and Kalfsbeek H.W., "EuReDatA Benchmark Exercise on Data Analysis - Intermediate Report II", Commission of the European Communities, JRC-Ispra Establishment, Technical Note I.89.41, March 1989 (internal document, restricted distribution).

[2] Kalfsbeek H.W. and Arsenis S.P., "Properties of Incident Reporting Systems in relation with Statistical Trend and Pattern Analysis", Proc. CSNI-CEC Specialist Meeting on Trend and Pattern Analysis of Operational Data from Nuclear Power Plants, Rome, Italy, 3-7 April 1989.

[3] Jaarsma R.J., "EuReDatA Benchmark Exercise on Data Analysis; Preliminary Results, CEC JRC-Ispra T.N. I.88.109, September 1988 (internal document, restricted distribution).

[4] Sandri S.A., Besi A., Dubois D, Mancini G., Prade H. and Testemale C., "Data Fusion Problems in an Intelligent Data Bank Interface", Proc. Sixth EuReDatA Conference on Reliability Data Collection and Use in Risk and Availability Assessment, Siena (I), 15-17 March, 1989, Springer Verlag, 1989.

1.1.3 Analysis Methods for the AORS

The various analysis methods and standard procedures for interacting with and displaying of the contents of the AORS databank have been documented in a two volume report [1]. These methods and procedures were developed in the period 1985 to 1987, after the available backlog of data had been stored into the AORS and the quality checks had been finalised. The procedures are programmed in NATURAL (version 1.2) and all reside together in a library named AORSLIB. The first volume of the above mentioned document gives an overview of these programmes, according to their specific areas of application, and lists for all of them a program data sheet, containing a description of the purpose and the approach chosen to accomplish this. In the second volume the complete source listings are given, which an enduser needs in order to be able to customise a specific method to his specific application.

A Possibilistic Procedure for Expert Judgement Elicitation and Processing

A procedure for the elicitation and processing, i.e. assessment and aggregation, of expert judgements on both quantitative and qualitative information, using possibility theory as uncertainty representation model is currently being developed [2]. Possibility distributions are directly elicitated from the experts by asking for a set of confidence intervals. Bias of the judgements is determined by the technique of scoring rules, where a series of judgements are compared with known true values. From such assessments individual expert reliability measures are derived, which are taken into account when pooling judgements from several experts. Possibility theory is used because it is regarded to better accommodate the thinking in terms of uncertainty (elicitation) than for instance, subjective probability, and because it is better suited to handle dependencies (pooling of expert judgements). Nevertheless, end results of the procedure are always converted to subjective probabilities in order to make them suitable for incorporation into a decision process. The procedure will be implemented, tested and compared with traditional probabilistic methods.

References

[1] Kalfsbeek H.W., "The AORS Analysis Program Library AORSLIB", Commission of the European Communities, JRC-Ispra Establishment, Technical Note I.89.89/I and /II, August 1989 (internal document, restricted distribution).

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[2] Kalfsbeek H.W., "A possibilistic procedure for the elicitation, assessment and pooling of expert judgment", Commission of the European Communities, JRC-Ispra Establishment, P.E.R. 1598/88, March 1989 (internal document, restricted distribution).

1.1.4 The ISE Semi-automatic Transcoding System

The transcoding of huge amounts of data is a very time-consuming task, which requires a great deal of expertise. In fact the logical entities in the various databases do not necessarily correspond because of the different design philosophies.

In 1986 a feasibility study for the development of a generalised semi-automatic transcoding system to be applied to the European Reliability Data System was started. The principal aim of such a system was to reduce the amount of manual transcoding needed. It was also expected that the quality of the transcoded data would be improved.

The study addressed the construction of a generic system, independent of any specific application - i.e. a particular source database and a particular target database within ERDS. The intention was to use expert techniques. After a favourable conclusion from the feasibility study, the realisation of such a system was started in 1987; it will be operated in 1990. The first application will be using the Component Event Data Bank as ERDS target database and the French Système de Recueil des Données de Fiabilité, SRDF-EDF as source database.

The main characteristics of the system are:
- it deals with transformations of format (measurement units, dates), and of contents, considering not only 1-1 relations between codes, but also more complex relations, represented by conditional expressions and relations involving algorithms of transformation;
- it gives a trace of its reasoning;
- it provides a user-friendly procedure for the transcoding rules;
- it produces input forms for the target database.

The basic software system consists of a set of programs which are applicable independently, namely:
- the transcoding program, running both in batch and on-line mode, which can be considered as a kind of inference engine for the system in the sense that it makes control decisions on the use of the knowledge base (Figure 1);
- the two procedures used to define a rule for input, i.e.:
  . the input and output model definition procedure,
  . the rule definition procedure which translates the rule language into a suitable internal representation.

The function of these two procedures is similar to the knowledge acquisition module of typical knowledge system architectures.

The languages used for the implementation of this basic software are NATURAL (Software AG) and COBOL.

1.2 SAFEGUARDS

1.2.1 Characterization of Performances of C/S Devices and Systems

Because of the increasing role of C/S in safeguarding modern large and automated nuclear facilities, the need is strongly felt to characterize the performance of C/S devices and com
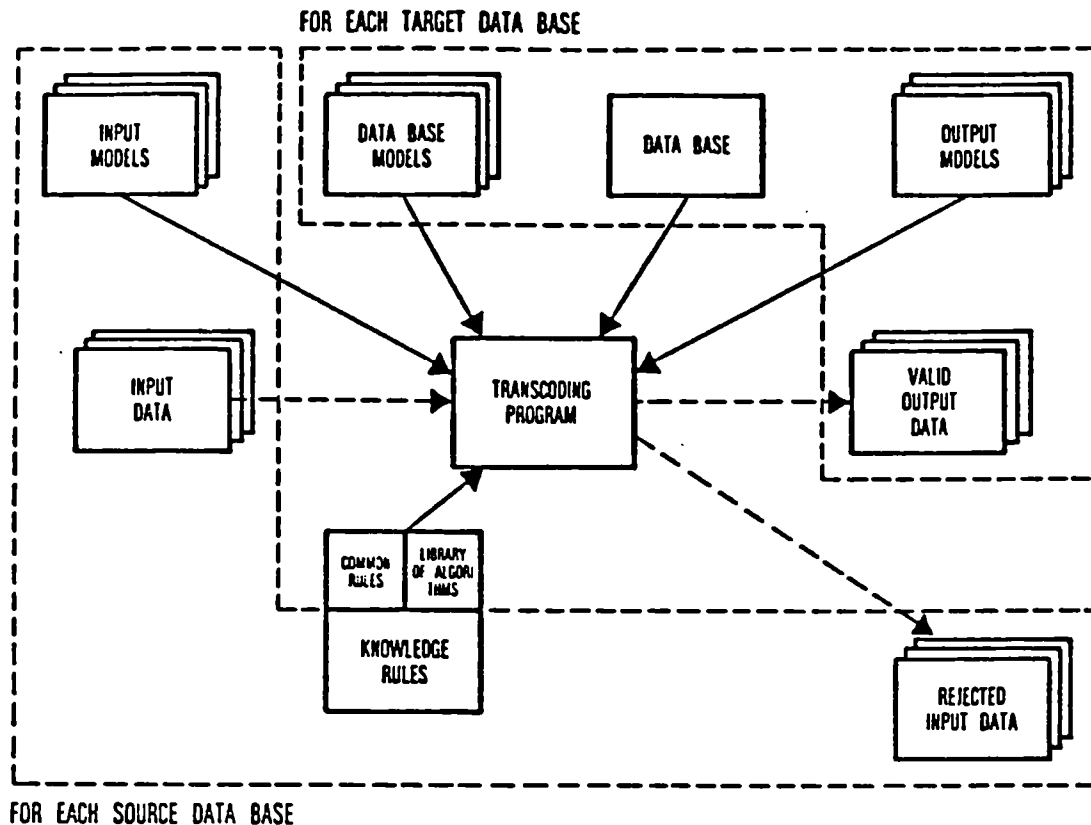
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Figure 1 - Overall transcoding system architecture.

plete systems. Contrary to the area of nuclear measurements (where objective statements can be made on performances), in C/S a number of subjective (efficiency against diversion routes) and objective (reliability) statements have to be combined to express the performances. A first attempt has been made to formulate on the basis of realistic examples, the different characteristics of seals and optical surveillance systems. It is with this objective in view that a specialized laboratory is being established at the Institute.

Laboratory for Surveillance and Containment (LASCO)

The objectives of LASCO (performance assessment, test of procedures and training in C/S) have been defined and discussed with potential users in the field of safeguards. The general layout of the laboratory has been studied and construction is to be started early 1990. The first experimental set up in a simulated automatic storage area has been designed using robots and surveillance devices for inventory verifications. An integrated multisensor system is also being studied to be extensively tested in LASCO.

Participation to the IAEA Working Group LASCAR

Three meetings of the reprocessing technology holder and safeguards inspectors were held in order to examine the application of safeguards to the large throughput facilities which will become operational in the near future. These meetings provide the JRC with the necessary input to study the applicability of existing technical means and those under development to future facilities.

Material Balance Evaluation

The computer program SSA (which performs errors evaluation in material balances) has been transposed from the McIntosh environment to the IBM-DOS environment. The new version is written in C language and has been tested on real plant conditions of a LEU fabrication plant and a MOX factory. The program has been documented.

Participation to ESARDA Activities

Organization of the Annual ESARDA Symposium (Luxembourg, 30 May - 1 June 1989) consisting of selection of the papers, preparation of the Symposium programme, invitation of distinguished speakers, preparation of summaries, definition of oral and poster sessions and finally editing, printing and dispatching of the Proceedings.

Definition and organization of the 1990 ESARDA Internal Meeting, which will be held in Como on May 15-17, 1990 with full responsibility of the JRC Ispra. About 120 delegates are expected to participate.

Edition of the ESARDA Bulletin. This work includes the acceptance of contributions with the approval of the ESARDA Board, the correction of the proofs in a three columns format, the updating of addresses of the mailing list for the Bulletin and finally the dispatching. One issue (ESARDA Bulletin No. 16) was made in June 1989 and a second one is envisaged for the end of 1989.

Permanent Secretariat of ESARDA. This included, among another tasks, the organization of 6 official meetings of the steering bodies.

Participation in the ESARDA Steering Committee and in the Project Coordinator's Committee.

Participation in the activities of the following Working Groups: "Containment and Surveillance", "Reprocessing Input Verification", "Low Enriched Uranium Fabrication Plants", "MOX Fabrication Plants".

1.2.2 Seals and Identification Techniques

P.W.R. Fuel Assemblies

The VAK-III ultrasonic sealing technique successfully developed in the past years for safeguarding BWR fuel assemblies is being studied for application to PWR fuel assemblies.

The following priorities had been contemplated for development, in consideration of the corresponding technical constraints and of the interest from the IAEA [1].

A sealing system for Fresh Fuel, in particular fresh MOX fuel (FFS).
A sealing system for Spent Fuel (SFS).
A sealing system for fuel Cycle (FCS).

In 1989, work has essentially been on the first priority (FFS). Shortened dummy Fuel Assemblies have been ordered from Fragema (F) and assembled in the laboratory. Two systems mainly using the "Sealing-Bolt" technique have been studied for the protection of the fuel assembly upper part and two prototypes built. One of them: a "Sealing Plate" is shown on Figure 2 Such system has to be removed prior to loading the assembly into the reactor core. It is "intrusive", therefore usable for fresh fuel only.
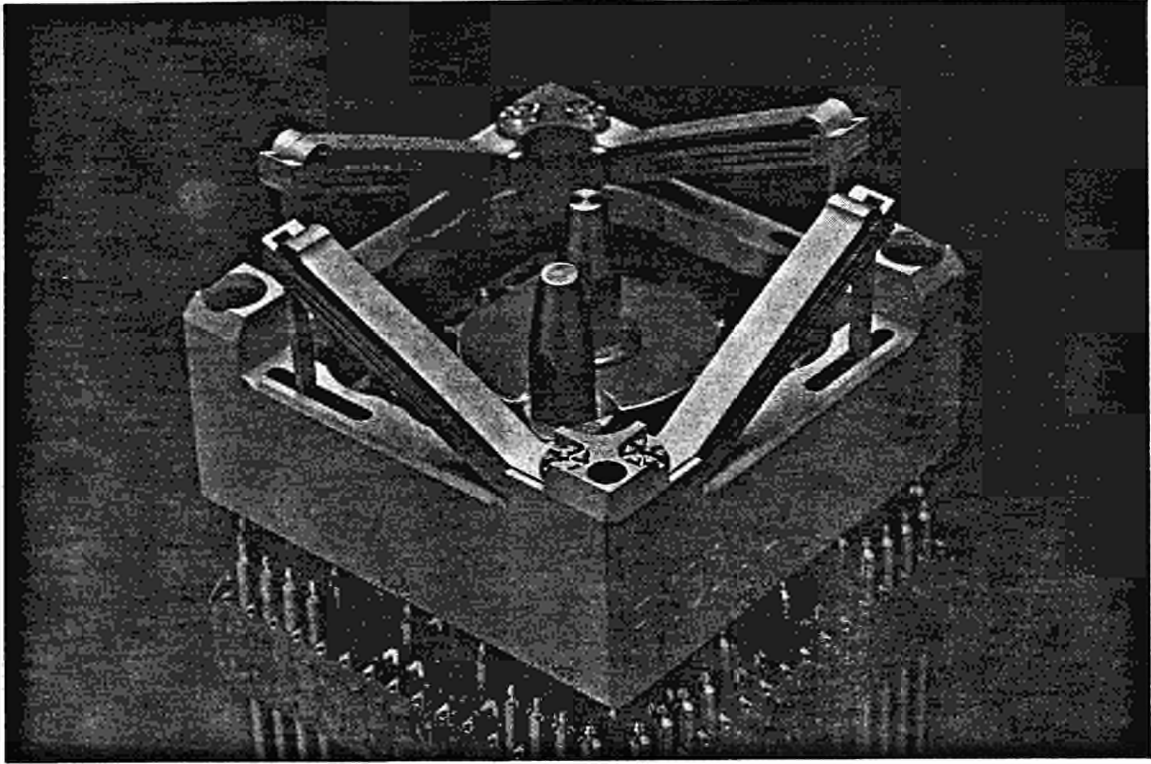
Figure 2 - A Sealing-Plate installed on top of a 17x17 PWR Fuel Assembly.

On the PWR sealing system Reading Instrument, collaboration with Sandia National Laboratories (USA), has continued and encouraging demonstrations of the SNL Reading Box with ISE Seals took place in Ispra in March 1989 and in Orlando in July 1989.

A large amount of work has also been devoted to the production of improved and faster software to be used with portable computers for the automatic verification of the Seals.

The production of Seals Cores (the special parts giving a random signature to the seals they are embodied in) has been successfully obtained from industry on a larger scale (about 60 at once in place of one by one). They are used for the fabrication of PWR and other seals.

A special software has been developed and used for the systematic processing and statistical evaluation of all the seal cores (identity patterns) manufactured.

Identification by Surface Topography

The principle of this patented technique is to measure a small area of the surface of an item (structure, seal, key, etc.) and to consider it, due to its random aspect, as a "fingerprint" of this item.

The texture can be read by piezo or electrodynamic tasters which mechanically follow and copy the surface profile on a recorder. It can also be read by a special laser head, allowing a faster exploration and interpretation of the area under consideration.

This year, experience and training has been achieved on a new RASCAL system provided by the French SPECTEC company. Series of measures on natural or "scratched" metallic surfaces has shown difficulties for a fast relocation of the reading head. Conversely, a less sophisti-

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cated mechanically driven portable reading head has shown an excellent reproducibility of measurements through numerous tests in which software is used, similar to the one adapted to the ultrasonic seals identification.

References

[1] D'Agraives B.C., Toornvliet J. and Mascetti E., Progress in Adapting the VAK-III Technology to the Sealing of MOX PWR Fuel Assemblies, INMM 29th Annual Meeting, Orlando (Flo.) 8-12 July 1989.

1.3 INDUSTRIAL HAZARDS

1.3.1 Safety and Reliability Assessment

The Benchmark Exercise

The aim of the project was the comparison of the approaches to risk analysis for chemical installations in Europe. The reference plant was a refrigerated ammonia storage facility connected by pipelines to a sea terminal and transferring ammonia to a pressurized tank in a process plant.

18 teams participated as representing authorities, research organisations, industry and major consultant groups.

Funds were made available through SCA and DG XI, in addition to JRC.

In the working phase-1 (completed in 1988) the overall results of participant teams were compared.

It has appeared that the significant spread found on the risk figures evaluated was not only due to different failure data or physical data or physical models adopted, but also to:
- the extent of the hazard identification process;
- the retained assumptions on major failure modes of principal components;
- different assumptions concerning the physical behaviour of ammonia after its release (whether or not a pool is formed, whether or not it behaves as a heavy gas under certain release models, etc.);
- toxicity criteria assumed.

To identify the major contributors to the spread, the content of WPh-II has been designed in such a way that instead of performing an overall risk assessment, separate exercises, based on rather well defined boundary conditions, had to be executed.

These consisted of:
- a system reliability assessment concerning the event "overpressurization of the refrigerated storage tank";
- human action analysis concerning the success in isolating a piping break;
- selected cases of ammonia releases to be calculated both with a common vulnerability model and with the models assumed originally by the different analyses (these double calculations will contribute to identify the uncertainty due to the vulnerability models only), and namely:
  . a guillotine break of piping downstream of the pressurized tank,
  . a guillotine break of a feedline of the pressurized tank,

. a certain break of a piping connected with the refrigerated tank,

. a failure of assumed dimension of the roof of the refrigerated tank.

At the final meeting held in October 1989, this procedure appeared to have been very useful. Very interesting insights have been gained on the importance of the different topics. These will be included in a final report to be issued by mid 1990.

The DOMINO Package

A first package for analysis of "DOMINO" scenarios has been realised (see the flow diagram in Figure 3) by joining together a probabilistic approach based on the DYLAM technique with the appropriate fire and explosion models.

1.3.2 Process Diagnostic by ARMA Modelling

The Project

A methodology for globally monitoring and on-line diagnosing plants and process operations has been developed. It contains a set of mathematical and statistical procedures enabling the process under study to be modelled and, then, the actual model predicted behaviours to be contrasted. This technique is called Statistical Rupture Analysis because it identifies abnormalities and/or emergencies by analysing the ruptures at the models predictive capability. Modelling has been performed by a k-Multivariate Autoregressive Moving Average (k-ARMA), which is suitable to fit time depending stochastic systems, when linearity or quasi-linearity between input and output can be invoked.

The whole project has been subdivided in three sections: identification, simulation, analysis.

i) Identification. The system or the process under study is studied in such a way that all the possible stationary states can be identified and then recognised. Under some favourable physical conditions, e.g. soft changes, also operational transients can be enclosed. The modelling enables the dynamic behaviour of the system, i.e. the input-output relationship, to be represented as linear function between the present output vector X_{t-i} and E_{t-j}, $i = 1, ..., p$; $j = 1, ..., q$ through the identified polynomial coefficient matrices and ; p and q are the orders of complexity of the model.

ii) Simulation. The identified model needs to be studied and analysed in order to ascertain the practicality and sensitivity of the statistical rupture tests in the particular case under study. To this purpose an ARMA - generator computer program is able to simulate all the foreseeable situations, enabling the calibration of the statistical tests to be performed.

iii) Rupture Analysis. Suitable functions of the output of the process under study and the analogous functions of its model output are on-line contrasted and analysed by statistical tests. Control cards-like devices can be used to monitor system operations and report when and where the modelled operations no longer describe a healthy system.

State of the Project

Considerable work has been performed as far as the section i) and ii) are concerned [1,2]. The identification technique needs yet to be improved and tested with real cases; the first foreseen step is a simulation study. A simulation computer package can be considered finished as in-house product, whilst it needs some refinement and all the documentation for the external users. With regard to section iii) important tests have been put in working and
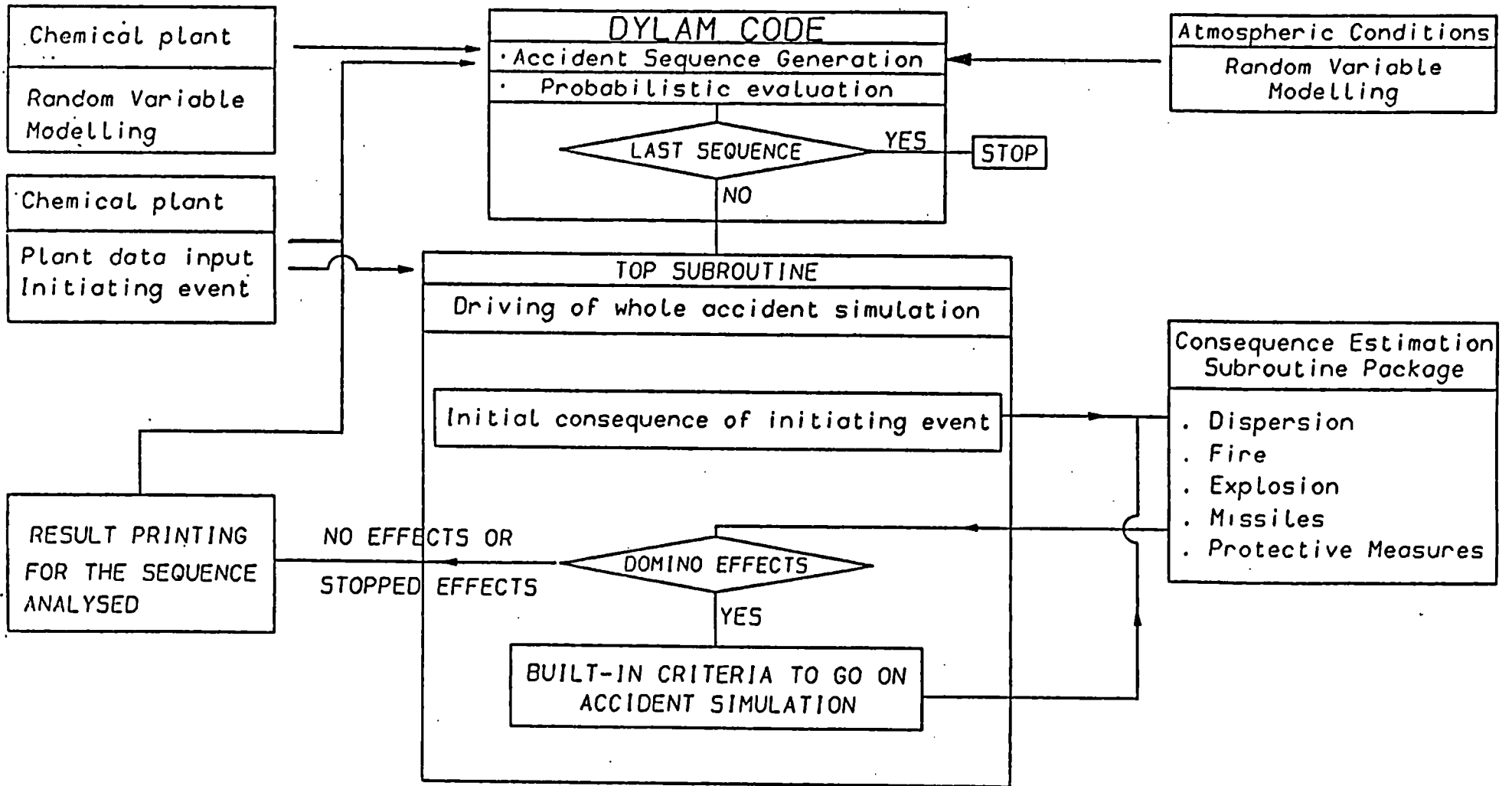
Figure 3 - General flow diagram for DOMINO effect analysis.

results are very interesting [3]. A handbook of references and software for process diagnostic is foreseen and its design work is already started.

References

[1] Lessi O. et al., Statistical Aids in Man-Machine Interaction Problems, in Analysis, Design and Evaluation of Man-Machine Systems, Ed. J. Ranta, Oulu 14-16 June 1988.

[2] Fassò A. et al., ARMA Simulator for Testing Methods of Process Diagnostic. To be submitted to COMPSTAT 1990.

[3] Fassò A. et al., Rupture Analysis for Fault Detection and Diagnosis in Stochastic System. Submitted to 11th IFAC World Congress 13-17 August 1990 Tallinn, USSR.

Pooling of Subjective Data in a Complex Technological Context

The aim of the work is the formulation of a final judgement on the expected stochastic behaviour of a given complex system, when information is collected from several sources of possibly different credibility degrees.

With reference to linear regression models a Bayesian technique has been proposed to obtain a global information pooling density (GIP density) which, under assumption of a unique experimental design for all sources, provides a pooling of information coming from: elicitation of several experts, observation from real experiments, observations from simulation exercises, etc. [1].

A further step, still under development, is the extension to the general case, where both the different credibility degrees of the experts and their a priori assessment on the importance of model variables are taken into account [2].

A recent algebraic solution to the problem of the experimental design composition [3] enables the global information pooling density to be rewritten in the new expression A-GIP, where the diagonal matrix A weights the expert's assessments on the variable importance [4].

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1.3.3 Digitising Maps

Over recent years a need has arisen within the sector for digitising maps and other geographical information for use in transportation risk models. Using a P.C. based frame grabber such information can be rapidly digitised and converted into a useful form. A program - MAKEMAP - has been written to use the P.C. Vision system for this purpose, with particular orientation towards the digitisation of transport networks in a form suitable for transfer to other computer systems.

Over the past year the facilities provided by the program have been increased and improved to allow more user friendly operation. Also a compatible frame grabber and image processing system has been installed on a SUN work station. Since both the P.C. system and the SUN workstation have been connected by network, rapid transfer of images and digitised geographical information between them is now possible.

These methods have been applied to maps of Lombardy for use in the models HELP and PURPLE, and to a map of Denmark used in the TRIM model.

Stereo Reconstruction of Three Dimensional Models of Industrial Sites

Originally applied to buildings for energy auditing purposes this is now being extended to industrial sites for industrial risk applications. The first system developed relied on manually aided digitisation of the image features prior to the stereo reconstruction, but subsequent work has been oriented towards automating the whole process.

Good results are now being obtained on laboratory images using colour as an attribute to aid the stereo reconstruction process. Outside tests await the arrival on the market of a suitable magnetic disk camera which will provide a rapid means of transfer of images from outdoors into the Personal Computer.

3D Wireframe Completion

The output from the stereo reconstruction process is a 3D wireframe model of the buildings or site under observation. This model is invariably incomplete owing to deficiencies in the stereo reconstruction process, problems created by occlusions, noise and insufficient contrast in some areas of the images etc. Nevertheless a human observer of the wireframe can "complete" the model using his knowledge and intelligence. The project aims to investigate methods of automatically completing and correcting the wireframe model using model oriented reasoning techniques from the field of artificial intelligence. This will be an external Ph.D. project in collaboration with the University of Sheffield.

1.4 REFERENCE METHODS AND RELIABILITY OF STRUCTURES

1.4.1 Reference Methods for Non Nuclear Energy

This programme deals essentially with the applications of solar energy, both photovoltaic and thermal and with energy savings in buildings. The main efforts are concentrated on evaluation and test methodologies for systems and components. The results of these activities are being used in part as contributions to prenormative and normative bodies where experts of ISE are present in various technical committees and in part to improve monitoring procedures for solar systems. An important tool for the execution of the work is represented by

ESTI (European Solar Test Installation) which is, probably in Europe, a unique complex of test facilities for photovoltaic devices, being also largely utilised for third party work. The photovoltaic industry is expanding rapidly with a rate of growth of the order of 30% per year. The introduction of amorphous silicon photovoltaic modules requires the development of new testing procedures in which the JRC is involved. In the solar thermal and energy conservation fields the activities are concerned principally with testing and performance evaluation methods for solar passive technologies in buildings together with the intercomparison of various energy audit techniques for the characterisation of energy efficient buildings.

The main achievements in 1989 are:

- **Indoor Degradation of Amorphous Silicon Modules.** An existing simulator has been upgraded in order to allow for a unique degradation test in a controlled environment. This test is in the elaboration phase to be proposed as an international standard. The approach ensures reproducible conditions for the assessment for the today unsolved problem of efficiency degradation in some thin-film technology.

- **Sensor Calibration Study.** A measurement campaign was performed within the PV Pilot Plant Programme of the DG XII and included five European laboratories. It verified a simplified approach for secondary calibration of solar sensors used in pilot and demonstration plants: Guide-lines for sensors construction and calibration could be established.

- **Transient Effects in Flash Calibrations.** Problems related to the use of solar pulsed simulators were investigated. The samples under review included prototypes and commercial products. From the results it was concluded that certain state-of-the-art technologies as e.g. high efficiency crystalline silicon cells require longer pulse durations to meet the accuracy goals. A new pulsed solar simulator, expected to be available at the end of 1989, will meet these requirements.

- **Efficiency Limitations of Low Cost Solar Cells.** A study of the main parameters that limit the efficiency of low cost, crystalline commercial solar cells was undertaken in collaboration with a manufacturer and the Physics Department of the University of Ferrara. It was demonstrated that this new cell manufacturing process does not significantly deteriorate the starting material quality for photovoltaic applications.

- **Prenormative Activities.** A working group was created, the *"Thin Film Qualification Task Force"*, in order to establish recommendations for measurement and qualification procedures on thin-film photovoltaic products, as e.g. amorphous silicon. Two meetings have been held, one at JRC Ispra, the other at Freiburg/Germany. The group was attended by representatives both from industry and research laboratories. The main achievement is the draft of a qualification standard to be presented to CENELEC.

- **Contributions to the IEC (International Electrotechnical Commission).** The main results are the finalisation of an international standard titled *"Design Qualification and Type Approval of Terrestrial Photovoltaic Modules"*. ESTI will implement this standard already prior to their publication. A proposal of ESTI for the *"Determination of the Equivalent Cell Temperature of Modules"* was adopted and is currently circulated at the national committees.

- **Solar Active Systems.** An action of Technology Transfer from ISE concerning the implementation of advanced monitoring techniques for the efficient operation of solar thermal installations in Greece has been prepared together with the Greek Centre for Renewable Energies. This proposal has been presented and accepted within the programme "VALUE" of DG XII.

- **Recommendations for Performance and Durability Tests of Solar Collectors and Water Heating Systems.** This document finalising the four year cooperative work of 22 European laboratories and ISE has been edited. Parts of this document have been retained by ad hoc ISP (International Standard Organization) committees where an ISE expert has been invited.

- **Construction, in the frame of a collaboration with the Italian Institute ENEA,** of so-called *"Mediterranean Test Cell"* for the development of testing methodologies of solar passive components in hot climates. This activity is carried out in close relation with the PASSYS programme of DG XII. Within the same collaboration with ENEA, a study on the seasonal storage in the ground of cold has been presented at the ISES Conference of KOBE, Japan.

1.4.2 Reliability Modelling of Structures

A. Tests on 1:5 Scaled Pressure Vessel Models

State of Experimentation

The experimentation on vessel model R2 (A) has been completed with the appearance of a leak in the lower dome; due to a crack nucleated in the attachment weld of the water inlet tube and which then propagated to the base material till it achieved the condition of a through crack.

Some 875.000 cycles have been performed at 1 or 2 pcm (except during peak marking periods; carried out at 4 pcm).

Results of Residual Lifetime Prediction

The prediction of damage accumulation and of the residual lifetime, performed by an ISE team and by four external laboratories (in the frame of Shared Cost Actions) and the comparison with experimental evidence allow the following conclusion to be drawn:
- defect characterization (nature, shape, position, dimensions) is a very critical point and constitutes the main source of uncertainties;
- undercladding microcracks, quite difficult to detect, may act as stress intensifiers and cause crack nucleation in high stress regions such a nozzle corners;
- cladding residual stresses did show rather high values and strongly affected fatigue crack growth, slowing down propagation and towards the inner side of the vessel wall;
- "a priori" predictions are quite likely to be uncorrect; periodic updatings on the basis of monitoring and inspection data are necessary;
- raw-data pre-elaboration and uncertainty modelling are very critical and may constitute one major source of prediction scattering;
- a sensible assessment of structural lifetime cannot be achieved without the use of large amounts of non algorithmic knowledge (heuristics and domain expert experience).

Results of Non Destructive Evaluation

As far as non destructive inspection and monitoring are concerned, the following techniques have been applied: acoustic emission, laser holographic interferometry, multifrequency acoustic holography, EMAT, various UT methods and procedures for defect detection and sizing, microstructural fatigue damage assessment by UT scattering methods.

As expected, none of the above techniques turned out to be the panacea for NDE problems, although each of them constituting an effective tool for part of the problem. This means that a proper combination of different techniques, chosen according to problem specifications (geometry and material of the structure, environmental conditions, expected damage process, safety requirements) will improve effectiveness, reliability and resolution of non destructive evaluation.

The main outcomes of the techniques employed on the scaled vessel, can be summarized as follows.

During acoustic emission monitoring (carried out continuously), only a few primary emissions were detected, the large majority being secondary emissions (fretting, etc.). Detection and location of defects are straightforward, while monitoring of propagation is more difficult and can be achieved by improving rejection of noise, e.g. by pattern recognition methods.

The use of the EMAT techniques (electromagnetic acoustic transducer) for the evaluation of cladding integrity allowed detection and location of clad and near clad defects, while their sizing is rather difficult.

The use of permanent UT sensors for a continuous monitoring of crack tips and highly stressed zones allows the detection of crack tip advance and crack nucleation, with a sensitivity dependent on UT beam diameter. The resolution reached is of about 3 mm.

Laser holographic interferometry is very effective for non contact, high resolution (better than 0.3 micron) strain measurement and, consequently, for the detection of surface microcracks and buried cracks affecting the surface strain distribution. Periodic interferometric measurements allow following of crack growth. Ultrasonic and magnetic methods for microstructural damage detection was successful in case of microscopic plastic deformations.

Future Work

Vessel R2 is now to be inspected by XR and UT before its destructive examination.

In particular, the destructive testing and the fractographic examination, by electronic microscope, of the lower dome through crack will be performed by CISE-Milano. The relevant data will be used in the frame of the existing collaboration contract JRC Ispra-CISE Milano-EPRI USA, aimed at exploiting experimental results on environmentally assisted fatigue in pressure vessels and at implementing, in the COVASTOL code, a new model for FCG in PWR environment.

Fatigue Crack Nucleation

A collaboration contract has been set up with the Mechanical Department of Politecnico di Milano. The object of the contract is the study of fatigue crack nucleation in high stress regions of pressure vessels in SA533. ISE is supplying the specimens, while the contractor will perform all the fatigue tests, on CT specimens and on nozzles.

Residual Stress Measurement

Cladding residual stress measurement carried out at the end of life of the vessel showed almost the same values found at the beginning of life, which means that the cycling did not cause any release of these stresses.

B. Pressurized Thermal Shock Experiment

The main PTS parameters have been analysed from the point of view of their uncertainties: heat transfer coefficient in the nozzle corner region (as a function of the cooling water flow subdivision), the dimension of the nozzle corner crack (as determined by NDEs) and the cladding residual stresses.

Besides the probabilistic approach, based on the use of stochastic finite elements for thermal and stress analysis; analytical tools like possibility theory and fuzzy algebra have been employed for dealing with imprecision of non stochastic nature. A Knowledge Engineering (KE) tool for management of the PTS experiment has been implemented. KE is introduced at the level of a "human interactive computer" acting as a connection between the experiment supervisor (operator or analyst) and the task interactive computer controlling the test rig. A three-level control is therefore realised:

- level 1 operator (supervisor/analyst),
- level 2 human interactive computer (high level computer control),
- level 3 task interactive computer (low level computer control).

Following the conclusions of a preliminary research phase, there has been developed a new analytical tool for the heat conduction, stress and Fracture Mechanics analysis (Study contract with MPA Stuttgart). The prepocessor FRAP (Front-end for the ABAQUS Finite Element Programme) has been thus developed; the diagram of FRAP functionality is shown in Figure 4. FRAP is designed for a user with limited experience with ABAQUS and is also designed to cover the gap between the typical experimental output (temperatures and strains) and the required ABAQUS input, consisting of the heat exchange coefficient behaviour on the test piece surface and with time.
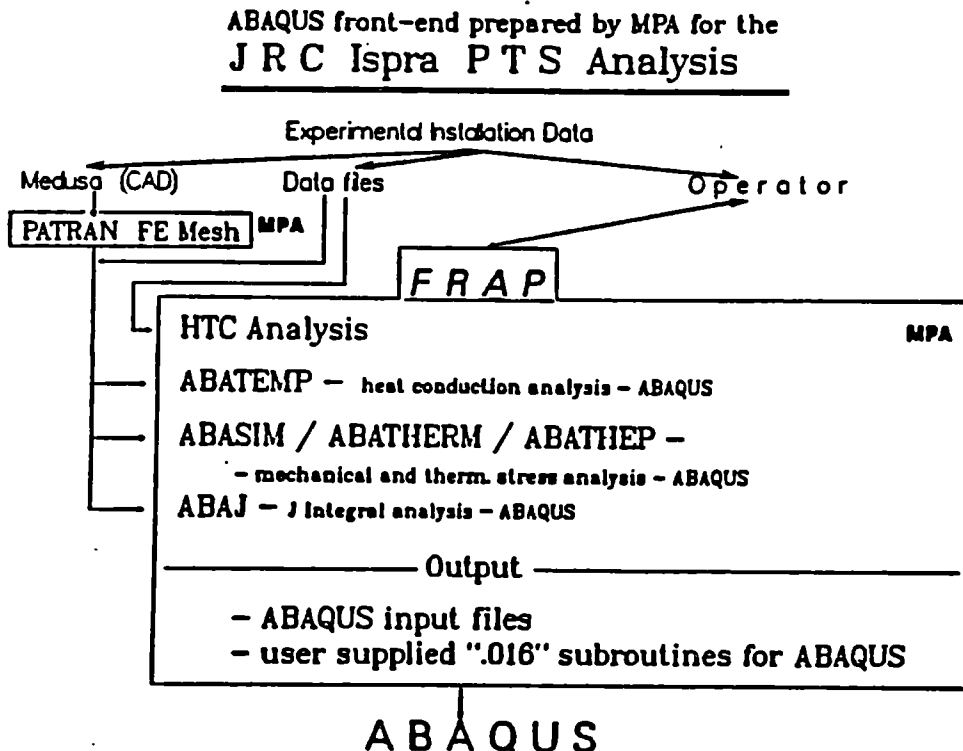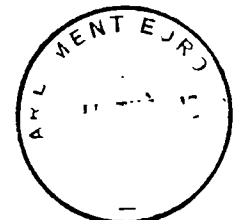
Figure 4 - The FRAP prepocessor.

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C. Non Destructive Evaluation Techniques

The possibility of performing accurate strain analysis on non directly accessible regions by laser holographic interferometry via optical fibres has been proved. Single-mode fibres turned out to be the most suitable for carrying the reference light; in particular those maintaining the light wave polarisation would allow for a better quality interference.

A small, versatile endoscopic probe has been developed.

Figure 5 shows the interferogram of inside of a cylindrical surface using the optical fiber probe.

A procedure for the application of statistical pattern recognition technique to the analysis of acoustic emission signals has been implemented and applied for AE source classification on the scaled vessel (STRIKE Labo) and on FM specimens (DAM Labo).
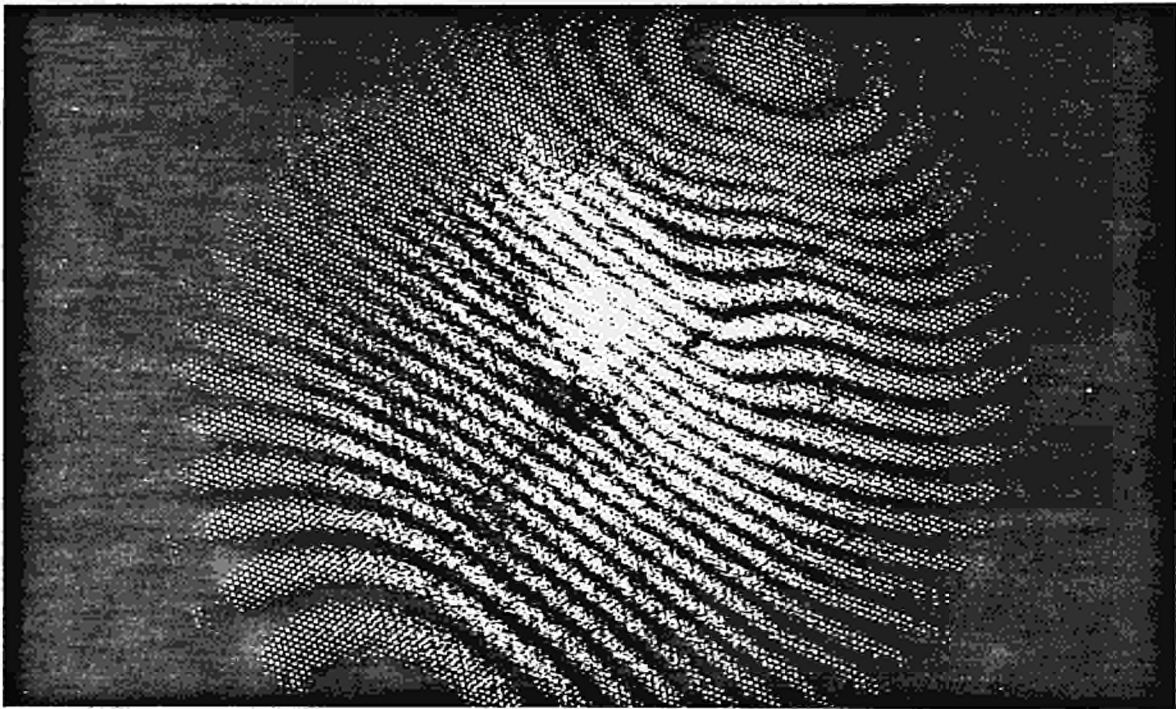
Figure 5 - Interferogram of the inside of a cylindrical surface using the optical fiber probe.

D. Analytical Tools

Autoregressive integrated moving average processes have been employed for the modelling of the number of cycles over the crack size for the fatigue crack growth.

A seasonal ARIMA process has been found to represent very effectively the whole set of the fatigue crack growth records. Its forecasting capabilities are quite good.

Every such model is built, based on the primary form of information of the crack growth, i.e. the (N,a) sample functions, and consequently is suitable for a specific set of geometric and loading conditions. The quality of the forecasts depends upon the origin; an early origin allows for short forecasts while a latter origin yields unconditionally good forecasts.

An in depth comparative study has been carried out of our computer codes COVASTOL and RELIEF for damage accumulation and end of life forecasting. Based on a large collection of experimental data on fatigue crack growth, the study compares the performances of the two

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approaches, pointing out their essential differences and their validity and applicability limits on real structures.

The progress in the development of the expert system RAMINO is reported in the Chapter "Work for third parties".

E. Behaviour of high strain regions

The activity was centered on the phenomena at regions, like nozzle corners, where high peak strain; large strain gradient and confinement by surrounding elastic areas are encountered.

Appropriate, new specimens have been designed, much smaller than the wide-plate ones, and allowing an excellent reproduction of the desired strain field.

The main tests performed have led to proposing new COD expressions for the high strain zones. Similar indications have also been obtained with regard to other fracture mechanics parameters.

1.4.3 Advanced Materials
Properties, Performance, Characteristics and Improvements of Structural Materials.

Damage Identification by Thermal Emission

The experimental apparatus has been improved with additional hardware and with the writing of a comprehensive computer program for the data acquisition and elaboration and the control of the testing machine. Attention of the measurements has primarily been focused on the behaviour of two curves: stress vs temperature and temperature vs time.

Several types of damaged specimens have been tested.

Initially, small creep damaged alloy 800H specimens (supplied by JRC Petten) were tested with satisfactory results: different thermal responses were obtained, depending on the level of accumulated damage. Next, cylindrical AISI 316L specimens were used for the assessment of the influence of cross-head speed and for the determination of an optimum value. Later, specimens having received different levels of fatigue damage were tested. The results have shown a quite definite trend together with the evidence that the research should differentiate between material and damage cause.

In the framework of this activity, some specimens were supplied by the Centro Ricerche FIAT, Torino. They included specimens of different materials (cast iron 65-48-05, cast iron 90-52-05 and steel 40NiCrMo4) all of which were low cycle fatigued.

The thermal emission characteristics of these specimens have shown distinct differences but further experiments would be required for a reliable quantification.

1.5 FUSION TECHNOLOGY AND SAFETY

1.5.1 Engineering design and remote maintenance systems

Participation to the 1989 ITER predesign worksession

Contribution to the predesign of the ITER mechanical configuration. (Task shared with the NET team of Garching).

Via the participation of one professional to the ITER predesign activity in Garching in close collaboration with the NET team, and with the support of the home basis activity inside the SER Division, JRC Ispra contributed to the predesign of the overall machine configuration of the vacuum vessel and of the plasma facing components layout.

The main results have been the preparation of the vacuum vessel reference drawing, the definition of the first wall and blanket segmentation, by taking into account the remote maintenance procedures for the substitution of the internal components, and the compilation of the ITER interim Report of the 1989 activities.

In this framework particular attention has been devoted to the preliminary definition of the interface between blanket segments and vacuum vessel, in view of the design of the attachment systems.

Simulation studies for the removal of internal components

The studies of kinematics for the definition of the trajectories used for the removal and substitution of the blanket segments of the NET - 1 design, whose detailed drawings were carried out during 1988, have been completed this year and the results have been given to the NET team at Garching.

The main activities in this field have been those related to the equipment of a simulation laboratory, in view of performing remote maintenance simulation studies on the new designs of ITER/NET.

The approach for performing this design activity of remote handling procedures and tools is based on the use of computer simulation and engineering animation techniques, with the possibility of experimental validation on mock-ups.

For the computer simulation some appropriate hardware and software tools have been already provided and others are being supplied and developed.

With reference to the present ITER design, this activity has been undertaken by modelling both the components to be remotely maintained and the remote handling equipments, starting from the available CAD system, in view of transferring the models on an appropriate graphic workstation, where the engineering animation and simulation are obtained by means of software tools, which can take into account the dynamic behaviour of the components considered.

The design of the remote handling systems can be in such a way optimised and developed.

In parallel, a validation facility has been designed and is now in construction.

This facility, which will be installed in the experimental validation laboratory in construction, will allow to verify on mock-ups in scale 1:3 of ITER/NET designs and of the robotic equipments, the removal and substitution of the first wall and blanket segments.

Electromagnetic effects on in-vessel structures due to plasma disruption

The main activity is related to the NET Task "Structural design of the removable first wall segments related to plasma disruptions events".

This Task, established between NET Team and JRC Ispra, has been initially proposed in July 1988 to contribute to the solution of the structural design problems arising from the effects of the electromagnetic-type phenomena induced by a plasma disruption on the removable in-vessel components.

The electromagnetic and mechanical behaviours of the first wall (FW) segments and their connection with the vacuum vessel (VV) by means of fastening and guiding support systems are investigated.

The proposed methodologies are also applied to the ITER design of the internal FW components.

The following different steps are interacting during the NET Task execution:
- Conceptual design of FW segments and support,
- Electromagnetic studies,
- 3-D structural/mechanical analyses.

3-D transient dynamic structural simulations have been performed for the cases under examination (using ABAQUS code).

As far as the electromagnetic computer programs are concerned, the effects of the plasma disruptions in NET and ITER have been modelled using the available 2-D codes UNISH, SCILLA, CORFOU and the 3-D codes CRIDDI and TRIFOU. This particular effort performed at JRC Ispra represents a real opportunity to model the same situations with different codes and to compare their strengths and their limits of applicability.

The following milestones defined in the Requirements Definition Document for the different phases of modelling/analysis of the removable FW components have been achieved. They concern:
- NET-Technological Phase-Outboard Segments (10.8 MA),
- NET-Physical Phase-Inboard Segments (15 MA),
- ITER-Physical Phase-Inboard Segments (18/20 MA).

The available technical/scientific papers illustrate the large amount of information gained in that context.

Actually, two additional activities have been undertaken to improve knowledge in that field:
- software development to investigate real electromagnetic-mechanical coupling effects,
- validation studies with a proposed experimental facility able to recreate crossed (steady and transient) magnetic fields.

Instability analysis of first wall components subjected to electromagnetic transient

The stability of the outboard part of the First Wall module of a Tokamak reactor due to a postulated plasma disruption event whereby the plasma current decays from an initial value of 10.8 MA to zero within 20 msecs was studied. The electromagnetic loads were computed using the computer code SCILLA - neglecting the coupling between eddy currents and structural deformation - while the buckling analyses were performing using the code ABAQUS. All buckling analyses were based on room temperature material properties of virgin stainless steel type AISI 316L while the thermal I steady-state stress field was neglected. Apart from a simple elastic model an elastoplastic and viscoplastic formulation - whereby the stain-rate effort is taken into account - were considered. From the numerous instability analyses performed it was concluded that the structure is stable if the viscoplastic material law is applied while the opposite conclusion is reached for simple elastoplastic response. These results are being further analysed.

Thermomechanical analyses of the ITER divertor plates

Thermomechanical analyses for the ITER divertor concept have been performed. It consists of Carbon Fibre Composite (CFC) blocks acting as armor and heat sink with brazed molybdenum alloy cooling pipes. Double pipes; acting as a double barrier and as a possible crack stopper have also been considered in order to reduce the probability of water leakages.

Two alternatives of this concept are investigated, the molybdenum alloy coolant pipes being brazed to channels made inside the CFC blocks; or to CFC tiles.

A series of 2-D analyses (six cases) have been carried out considering different values of heat load (5, 10 and 15 MW/m²) and different dimensions of the block, to give a first dimensioning of the system. At the end of this preliminary study, a 3-D analysis of one selected configuration, also considering the pipe-continuity condition, has been performed.

The analyses showed a significant dependence of the maximum temperature on the CFC surface on the cross-section with, therefore a minimum reasonable value has been chosen in consideration of the possible manufacturing process. Referring to the 2-D cases, for a heat flux of 10 MW/m² and CFC height (including the support system) of 40 mm, the results have shown a maximum CFC temperature of 1278°C and a maximum Mises stress (on the top of the pipe) of 226 MPa. As regards the 3-D analysis a maximum temperature of 1151°C and a maximum Mises stress of 765 MPa have been found. Therefore the concept proposed may be a viable solution for the divertor of the present next step reactors.

Breeding Blanket Design

The main geometry of a NET-DEMO machine was subjected to further modifications with consequences to the available space for the LiPb breeding blanket. A new design was made for the distribution of the blanket unit (banana shaped modules) within the boxes of the outboard and inboard region taking into account these changes of geometry and achieving a better filling rate by different curvatures of the single elements.

Thermal hydraulic and stress analysis of the updated blanket units under normal operation conditions of DEMO have been performed. The results show a maximum temperature of about 400°C within the liquid breeder and 380°C in the structure material, which is martensitic steel in this case.

Three-dimensional stress analysis were made in the outer shell of the highest loaded modules in the first array of the breeding blanket.

The results predict that the maximum V.Mises stress will mot exceed 100 MPa in the shell caused by neutronic thermal load.

Stress analysis was also performed for the cooling tubes inside the modules considering the buoyance forces, the internal pressure and the axial thermal gradient. Here, the results show that the material displacement of the cooling tubes almost disappear by insertion of grids at 4 different poloidal positions. The maximum V.Mises stress amounts to 106 MPa during operation conditions.

1.5.2 Safety and environment analysis

Loss of vacuum accident

The accident's sequence investigated consists of: a breach in the vacuum wall of NET, the air ingress into the torus, the interactions within torus, the interactions within the torus and

the expulsion of radioactive products into the reactor's hall. Modelling of this accident has been carried out with two computer codes PUFFER and PUFFER-B developed to assess the cases of bare (AISI-316) and reactive (graphite tiled) first wall respectively.

Bare wall: the air - first wall interaction model has been improved. Beside the wall-air heat transfer, the energy input due to the air recompression within the torus has been taken into account. This effect reduces the air mass entering the torus and the amount of radioactive erosion dust entrained into the reactor's hall by the expanding air.

The present estimate of non fixed particulates present in the NET torus is in the range 1-3 Kg. From experimental findings in JET, their granulometry is expected to be mostly around 1 m, so that the air depletion within the torus will not play a dominant role.

Dust trapping in the inlet duct has been also neglected.

The main dependency of the duct fraction expelled is from the breach's size, but there is also an effect of the temperature difference between first wall and air.

For a 0.185 m² likely breach size (the ceramic seals of an ICHR launcher) and a 623°K first wall temperature the expelled dust fraction is 20%, with a specific radioactivity of 0.37 TBq/g. (Condition at the end of the NET Technological Phase).

This research has been performed in collaboration with the Institute for Safety Technology.

Further activity will consist of:
- Further improvement of the heat transfer model
- Evaluation of dust sticking on the inlet duct walls. From fission related studies sticking depends on physico-chemical properties of the particles and on variation in the fluid's speed.

Reactive wall: the graphite air interaction has been considered without combustion ($T_{wall} < 900°K$) and with combustion.

In the first case the accident development does not differ from that of the bare wall case. The graphite temperature being higher than that of bare walls, the air inflow and outflow would be faster and the air fraction expelled greater. The erosion dust expelled would consist essentially of graphite particles, with a lower specific radioactivity than the metallic dust but with high Tritium content.

If combustion should occur, the oxygen of the incoming air is assumed to react with graphite almost as soon as it enters.

The graphite surface temperature can be assumed constant during combustion.

Stack effects, which could be due to the opening of additional breaches, have not been considered.

With the previous hypotheses, combustion lasts till the oxygen in the torus is exhausted. The gas temperature reaches the maximum, then it cools to the wall temperature, and additional air enters the torus, with a possible apportionment of the combustion.

The process is strongly influenced by the breach's size. For a 0.185 m² area, the maximum gas temperature reaches about 2400°K and an overpressure of about 20 K Pa develops. For smaller breach's sizes, the maximum gas temperature is lower and no overpressure develops. A lesser influence is found on the possible apportionment of the combustion heat to the gas and the tiles.

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The radiological hazard is essentially due to the Tritium implanted in the graphite (tens of grams). The leaking of hot gases can produce severe damages in the reactor hall. Future activity will consist of improvement of the combustion model and consideration of the stack effects.

Feasibility aspects of the D-³He fuel cycle in Tokamak plants

A review was made of the studies concerning the use of D-³He as fuel in Tokamak power reactor plants, in order to orient an exploratory research in this area which is foreseen in the frame of the European Safety and Environmental Long Term Studies.

Compared to D-T, power stations with D-³He fuel present relevant design and operation simplifications of important components such as first wall and blanket. This is due to lower neutron and Tritium production which make, in general, easier the solution of the safety and environmental problems.

On the other hand, the D-³He power reactor will have to rely on advanced design and technology of some of their basic components. This applies in particular to the toroidal field magnets, which should be able to operate at high magnetic field and to the systems capable to convert into electricity a relevant part of the fusion energy. The question of the expected high plasma current and related electromagnetic effects in case of plasma disruption must be addressed. Fuel supply represents the major concern for the D-³He systems. Only supply from the lunar soil can be envisaged for power stations. According to the last discussions, also involving NASA, lunar mining and transport to the earth looks technically feasible. However, many other aspects, in particular the economic ones, are far from being clarified.

In the plasma physics area ignition represents a critical point. When moving the reactor operation, plasma refuelling appears difficult because it will require new techniques as compared to D-T systems. Little is known about the question of ash removal.

As a conclusion, the need of further studies on the conceptual design of D-³He power stations has been recognised before moving to a deeper analysis of the safety and environmental aspects.

2. ISE Exploratory Research

2.1 IMAGE PROCESSING AND SYNTHESIS

Analysis and Synthesis of Holograms

A study carried out in collaboration with the University of Milano has shown that the holographic synthesis is possible via the use of proper analytical illumination models. The analytical models respect the energy equilibrium and are global, i.e. the luminance values are calculated in the global scene and do not depend on view points: this makes it possible to use them in the context of holographic synthesis.

As far as the analysis of interferometric fringes is concerned, it has been proved that the use of a multi-orientation procedure using a pyramid (wavelet transform) scheme allows to obtain a smoothed and enhanced version of the original image, with non linear noise-rejection, and consequently to achieve a robust fringe detection.

Beside this, a more powerful and general approach, although more difficult, is being developed. It is based on modelling amplitude and phase variations by stochastic processes and on the assumption that the Paley-Wiener relationship applies, assuring that the process is a non deterministic, regular one and enabling the application of the theory of irreversible dynamic processes.

Analysis of the Topological Structure of Turbulent Flows

Starting from the consideration that some turbulent phenomena present a fractal structure, the research is aimed at the identification and the study of the fractal dimension of a particular phenomenon (growth of a pollutant plume in atmospheric flow). Images obtained from visualisation of the turbulent flow under particular lighting conditions (coherent light) are analysed by image processing techniques.

2.2 ENERGY

2.2.1 Euro-Quebec Hydro-Hydrogen Pilot Project

The Project

This 100 MW pilot project is to demonstrate the provision of clear and renewable primary energy in the form of quebecian hydropower, converted via electrolysis into hydrogen and shipped to Europe, where it is stored and used in different ways: electricity/heat cogeneration, fuel cell operation, power/drinking water generation, vehicle and aviation propulsion.

The Project is a Euro-Quebec project with the Commission of the European Communities and the Government of Quebec as sponsors. Both parties have separate project financing and contract separately their project management to engineering firms.

The project is to be carried out by a group of industrial firms/institutions forming a momentary association and acting as subcontractors to the project manager which is a legal entity and which contracts with the client, i.e. the Commission of the European Communities (for the European side). On the European side, some twenty/institutions/utilities from Belgium, France, Germany, Italy, Spain and Switzerland are participating.

The project shall be realized in 4 phases:
- *Phase I*   - Assessment, completed by March 1987.
- *Phase II*   - Detail Engineering, 1.1.1989-1.3.1991.
- *Phase III*   - Production of blue prints, planned to last 1-2 years.
- *Phase IV*   - Construction, planned to last 3-4 years.

JRC-ISE Activities

The Joint Research Centre (ISE) is collaborating in the Work Package "Maritime Transportation".

Three systems of transportation have been considered depending on the type of hydrogen vectorisation:
- toluene (methylcycloexane), leading to transportation by normal product carrier ships;
- liquid hydrogen transported by special ships using different types of ballast, as water or propulsion fuel (ballast is necessary due to the very low density of liquid hydrogen);
- liquid hydrogen transported by special ships using ethylcycloexane as ballast; in this case also the ballast contains useful hydrogen.

Special attention was given to the preliminary conception of the ships carrying liquid hydrogen.

These studies have been described in many publications and presented in national and international conferences and symposia.

Two posters were presented at the "Fiera di Milano".

3. ISE Support to the Community Policies

3.1 SUPPORT TO INTERNATIONAL COOPERATION

3.1.1 Systems Analysis

Simulation of reprocessing input measurements (in collaboration with ENEA and in the framework of the Support Programme to the IAEA). The computer simulator SPRIT has been adapted to the MITA facility (of ENEA) and to the CALDEX facility (prototype of the Wakersdorf reprocessing plant tank). The experiments performed at MITA were all simulated. Preliminary simulations of CALDEX experiments have been performed.

3.2 SUPPORT TO COMMUNITY INDUSTRIAL POLICY

3.2.1 World Shipbuilding Data Bank

The operation of the Bank has been improved using a new method for distributing the statistics. A computer program is now available to obtain the statistical tables on floppy disks from the main frame. The work for UNCTAD and EUROSTAT was continued to obtain an internationally agreed ship classification.

3.2.2 Seismic Risk

Establishment of seismic risk maps and development of a numerical code for nuclear seismic excitation.

3.3 SUPPORT TO COMMUNITY TRANSPORT POLICY

3.3.1 Preliminary Investigations on Specific Problems

Flammability of Aircraft Cabin Material

A meeting of European and non European experts in the field was held in Brussels with the cooperation of DG VII. The problem of toxicity was raised, because there is no universally accepted method for testing and classifying material toxicity.

Further meetings are planned at Ispra with European experts.

Network for Airport Intercommunication

Design of the relevant hardware and software for intercommunication between the existing nodes has continued.

Aircraft Accident Data Bank

The bank should be oriented to optimising aircraft maintenance.

Ship maintenance

Design of an expert system for diagnostics and maintenance management of ships. The project is related to ship safety assurance for prevention of sea pollution.

3.4 SUPPORT TO COMMUNITY ENVIRONMENTAL POLICY

3.4.1 MARS (Major Accident Reporting System)

This is a continuous activity consisting in collecting, storing and analysing the accident reports notified by the national authorities to the Commission. The desirability of pooling the experience gained from industrial accidents which have occurred within the Community and exploiting this information for a prevention policy has been confirmed by the Council Resolution of 16th October 1989, which also notes the relevant technical contribution made by the Joint Research Centre.

During 1989, the Community Documentation Centre on Industrial Risk (CDCIR) has been successfully launched with the aims of collecting, classifying and reviewing technical rules, guide-lines and documents concerning the requirements of the "Seveso" Directive, as well as documentation on accidents and videotapes. The interest raised by this activity both among the authorities and the industrial world shows for the organisation of an efficient service for the users. This will be developed during 1990.

To move towards a better understanding a harmonisation of the national practices:
- a comprehensive comparison of the national approaches to the preparation of the safety reports has been finalised;
- a very successful conference has been organised in Varese on 30 May - 1 June 1989, in collaboration with DG XI, on the very actual and central problem of "Communications with the Public About Major Accident Hazards"; and the Proceedings will be published in 1990;
- studies on national experiences with emergency plannings and risk communication have been promoted.

3.4.2 Communicating with the Public about Major Accident Hazards:
A European Conference

The ISE in collaboration with DG XII organised a Conference on the above topic at Varese on 30 May - 1 June, to help improve awareness and understanding in Europe of all aspects of major-hazard communication as required by Article 8 of the second amendment to the Seveso Directive. The prime areas were:
- stimulate the exchange of ideas among representatives of the many actors involved in public risk communication processes;
- offer a European forum for the presentation and collation of research and experience;
- integrate and analyse the uneven and fragmented experience of major-hazard communication to date;
- establish the key European research issues which need to be pursued to support successful implementations of the Seveso Directive and other related Community initiatives.

The event's statistics illustrate its success in bringing together a broad spectrum of interested parties to share their knowledge and expertise. There were over 170 delegates from 20 coun-

tries, including all EC Member States. The majority of delegates rated the conference content and opportunities for making relevant contacts highly.

More than 40 papers were presented in the intensive three-day programme. These were given largely by representatives of the main actors involved in the implementation of the Seveso Directive: the CEC, EC institutions, Member State national and local governments, regulatory authorities, industry, public-interest groups and the communications media. There were also important contributions from the USA, non-EC European countries and the OECD and United Nations Environment Programme (UNEP). The Proceedings have been published Comminicating with the Public about major Accident Hazards. Edited by H.B.F. Gow and H. Otway (Elsevier Applied Science).

3.5 SUPPORT TO COMMUNITY TELECOMMUNICATIONS, INFORMATION AND INDUSTRIAL INNOVATION POLICY

3.5.1 Secretariat Support to COST Activities

The work consists of the secretariat and the related activities for a) the COST technical Committee Telecommunications (TCT) and b) the COST project 211bis:

a) Activity related to TCT: Three meetings were held by the TCT: Sion, Switzerland, 8-9 March 1989; Leidschendam, Netherlands, 13-15 June 1989; Brighton, England, 11-12 October 1989.
The secretariat work implies the preparation and attendance at the meetings as well as the reports in three languages (English, French and German) and in addition the attendance at several other meetings, in particular the COST Senior Official meetings for reporting on the activities, presenting new projects and requests for extension or modification of running projects.
The following Memoranda of Understanding were presented in three languages: COST project 227 on Integrated Space/Terrestrial Mobile Networks, COST project 229 on Application of Digital Signal Processing, COST project 230 on Stereoscopic TV, Technology and signal Processing, COST 232 on Speech Recognition over the Telephone Line, COST project 233 on Prosodics of Synthetic Speech. Other projects are in preparation at the secretariat which provided a preliminary Memorandum of Understanding (MoU).

b) Activity related to COST project 211bis. The secretariat for project 211bis on Redundancy Reduction Techniques for Coding of Broadband Video Signals continued the activity as in the past years. The appearance of the new network scenario caused by ATM (Asynchronous Transfer Mode) will impose modifications and coding techniques will necessarily be reconsidered. COST211 bis in contributing to CEPT and ETSI (Europe) and CCITT and CMTT (world) for international standardization. In order to match the ATM needs a new project 221ter will be made. The secretariat already provided a draft MoU. It will start at the end of 1990 after completion of COST project 211bis. Two meetings of the Management Committee (MC) of the project were held during 1989: Lausanne, Switzerland, 4-5 April 1989 and Madrid, Spain, 20-21 October 1989.

3.5.2 Multipurpose Ultrasonic TITUS-I Seals

The TITUS-I is a multipurpose cable seal. Its head embodies a built-in transducer. When locked with special pliers, the steam cable is squeezed and the identity feature is set up into the seal body. The typical "fingerprint" signal can be acquired by simply contacting the seal with an appropriate jack and transmitting it to a portable ASTUS reading equipment.

This know-how for the fabrication of TITUS-I seals on an industrial basis has been transferred to the French company ELCA and a technical support is being given as well. The manufacturer was also provided with the ASTUS instrument specifications. Series of 75 and 125 seals are due by the end of the year for quality control in Ispra.

3.6 SUPPORT TO COMMUNITY ENERGY POLICY

3.6.1 Energy Bus

ISE Ispra collects and disseminates technical information and provides technical advice to the Community Energy Bus Programme dealing with the rational use of energy in small and medium size industries. 3 data bases of EDSES System, implemented and run by ISE, are now in full operation and contain about 16000 audits. In 1989 the audits of the sectorial activities were loaded.

3.6.2 Energy Conservation in Buildings

39 new demonstration projects proposals have been evaluated. Concerning the problem of *Demonstration Project Replication* a certain number of projects has been investigated. People involved, from proposers to possible replicators, have been interviewed. The information obtained will be used to propose an effective methodology to assess and promote replication. In support to *Building Energy Certification*, a promising experimental procedure for the energy certification (or labelling) of buildings is being studied. This procedure is based on the technique of Parameter Identification, already well known in control engineering but not as yet used in buildings. A EUROCOURSE Workshop on this subject was held at Ispra.

In order to test the applicability and reliability of this method to occupied buildings, a monitoring campaign has been set up on four apartment buildings in Varese.

A study was begun of ways of improving the **Degree-days** values contained in the EUROSTAT Energy Statistical Year Books. These are intended to give an indication of climatic severity, so that trends in energy consumption can be distinguished from meteorological effects.

3.6.3 Solar Energy - Photovoltaic Demonstration Projects

Operational data from more than 20 projects have been analysed (an overview paper of these results was presented at the 9th Photovoltaic Conference, Freiburg, Sept. 1989). 29 new proposals have been evaluated. The SESAME data bank is continuously updated.

Control visits on Demonstration Projects by ISE staff covered the rural electrification projects in the Sierra de Segura and at Ginostra on the isle of Stromboli, the illumination of

archeological excavations at Sovana and of the caves at Cetona, the lighthouse at Palmaiola and the runway lighting at Lucca Airport.

The "European Working Group on PV Plant Monitoring" has continued its activity to improve monitoring techniques and is issuing a Newsletter which has proved to be an important information tool on this subject.

3.6.4 Solar Thermal Demonstration Projects

This activity is following the same lines as for the photovoltaic demonstration projects. A "European Monitoring Working Group" has been set up and is dealing principally with the preparation of uniform monitoring guide-lines for solar thermal systems.

3.6.5 Transport

The activity in the transport sector consists mainly of the review and judgement of new proposals of Demonstration Projects and the study of particular subjects like energy saving and pollution reduction by limiting automotive traffic, set-up of information documents, perspectives of the use of Stirling engines for vehicle propulsion.

3.6.6 Sealing Bolts for Spent Fuel Containers

Since 1986, a number of JRC MARK-II ultrasonic sealing bolts are undergoing a long term underwater test in a storage pond in Sellafield (UK). Various demonstration campaigns have indicated that the Seals and the Portable Reading Equipment work properly [1].

In 1989, a particular effort has been devoted to simplify the reading technique by merging the "identity" and "integrity" features of a seal so that only one reading head would be used. This led to a renewed and shorter version (MARK-TI) of the MARK-II sealing-bolt (Figure 6) and to the possibility to extend use of that seal to other applications (identifiers, fuel assemblies, etc.).

MARK - II   MARK - T1
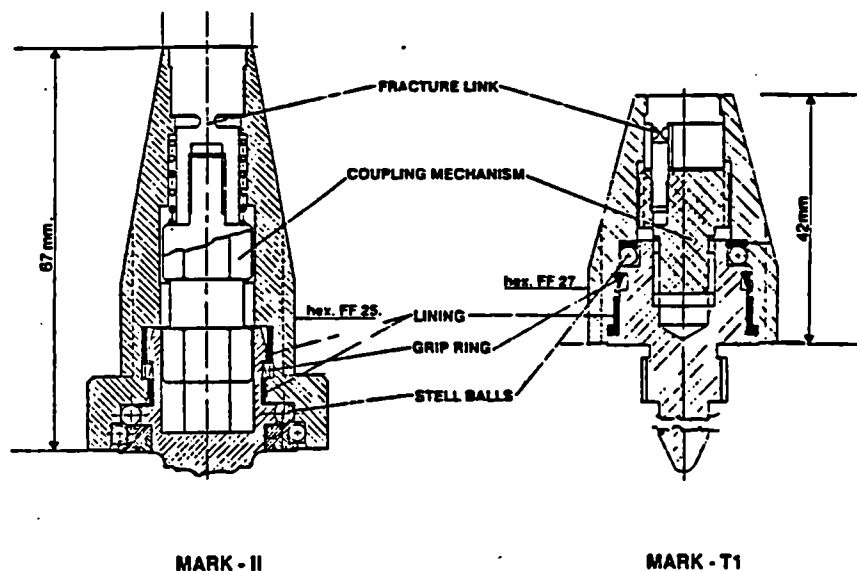
Figure 6 - Evolution of the sealing-bolt.

Along with the mechanical improvements to the sealing-bolts and to the related reading tools, here again, such effort has been devoted in order to provide a software adequate to the new integrity configuration.

Reference

[1] D'Agraives B.C., Toornvliet J., Mascetti E., Clegg E.. Second exercise of the long term experiment with Ispra sealing-bolts at the BNFL Sellafield facility. ESARDA 11th Symposium, Luxembourg, 30 May - 1st June 1989.

4. ISE Work for Third Parties

4.1 NEW NUCLEAR ENERGY AND ENERGY SAVING

Qualification of photovoltaic modules on ESTI

In 1989 eight new products of European and Japanese Photovoltaic manufacturers have been certified according to the CEC - Specification 502. An extensive assessment of various prototype devices for terrestrial applications was executed at the request of two European aerospace companies.

For the final acceptance of Europe's first Photovoltaic power plant for hydrogen generation, on-site power measurements have been performed.

Additional stress test could be offered to industry with the successful installation of new facilities.

Energy Analysis of regional Building Stock

The setting up of the database of the regional building stock is near completion. All the programs for the input data management have been implemented. Upon request of the Region, a simplified input was also provided in line with the application of the Italian law 308/82 on subsidies for energy savings.

A second monitoring measurement campaign on 4 apartment buildings has been carried out. The SPIEL program (for evaluation of energy savings in buildings), interfaced both with a dedicated CAD system for architectural design and with a stereo-image geometrical data collection system, is being adapted to the needs of the Lombardy Region energy auditors.

4.2 RELIABILITY OF STURCTURES

BRITE Report

Aim: enhancement of inspection and maintenance of industrial structures using reliability based methods and expert systems.

Collaborating institutes: ELF-Aquitaine-F, Framatome-F, Synthesis-I, Politecnico of Milano-I, Siemens-KWU-D, Technical University of Munich-D, OC/CSR-DK, Swansea Univ.: College-UK, JRC Ispra.

A complete review of standard and non standard non destructive inspection techniques has been carried out, as well as an analysis of damage models relevant to nuclear pressure components.

The ISE's main contribution to the project is the development and the implementation of the expert system RAMINO, for which the following points have been realised:
- organisation of the relevant data bases;
- design of the general architecture of the expert system;
- start of knowledge representation and of implementation of inference mechanisms.

RAMINO is organised with units at four level of increasing "intelligence", namely:
- data bases;

- operators;
- intelligent interface modules;
- overviewing supermodule.

It allows integration of existing software packages.

-- A schematic view of RAMINO functionality is shown in Figure 7.
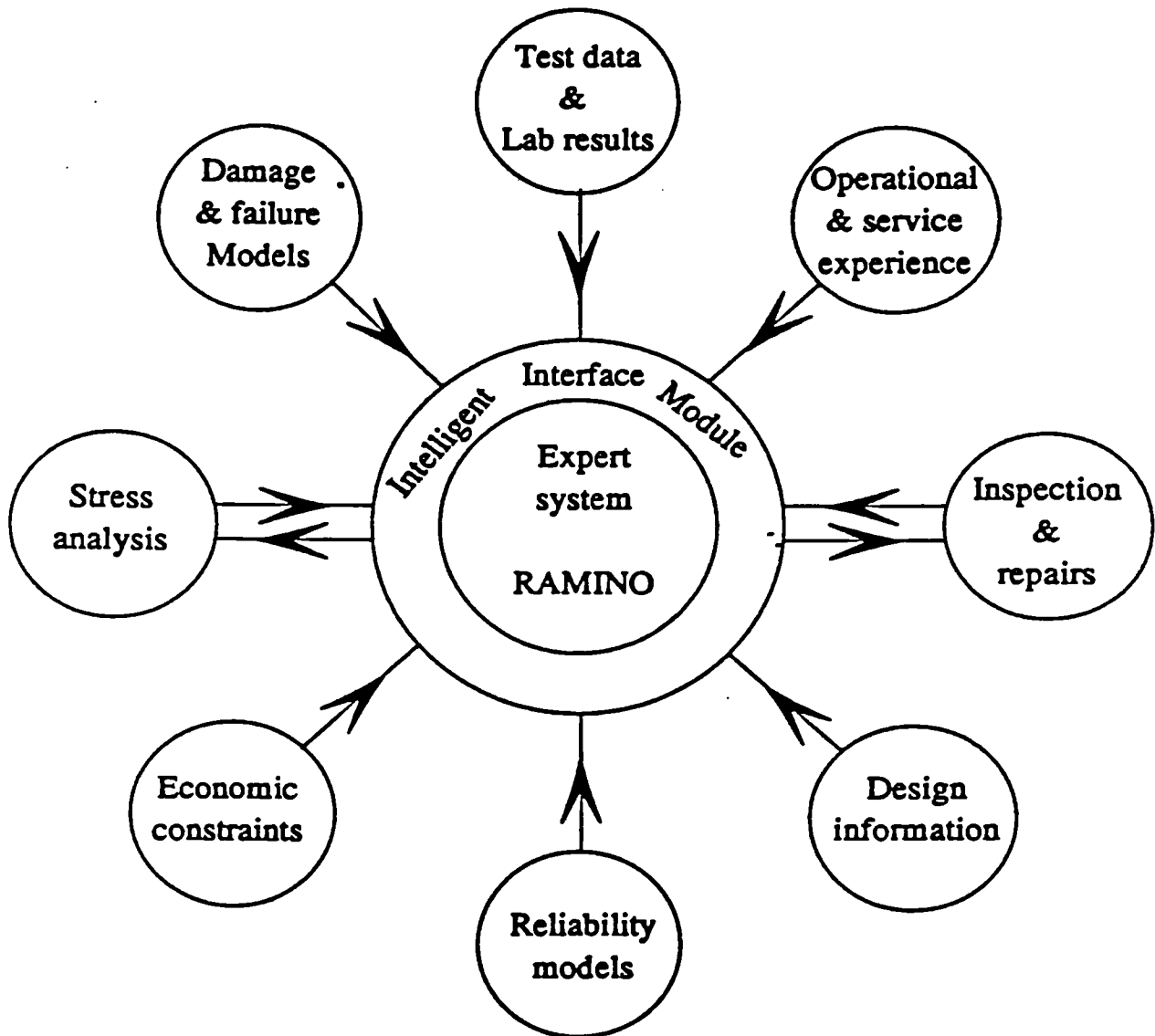

Figure 7 - Schematic view of the RAMINO functionality.

4.3 SAFEGUARDS

Identifier (Tags) for Fuel Transport Casks

In 1989, after a visit to Ispra where the Sealing-bolts technique was demonstrated, experts

from the French CEA have indicated a potential use of such bolts as "identifier" of the transport containers for spent fuel to reprocessing plants.

Visits to the cask storage at La Hague have been organised and a proposal was made to CEA and COGEMA for the development of such a system, specific to the purpose of identifying casks. A prototype has been built in Ispra to allow reading the bolt in horizontal and dry conditions. Exchanges of letters and information have led to a contract with CEA in the framework of the French Support Programme to the IAEA.

School for Civil Protection

The work is made for the Lombardy Region and consists in the organization of a school for achieving the certificate of Coordinator of Civil Protection (for University graduated attendants) or Operator of Civil Protection (for High School graduated attendants). This Institute of Systems Engineering contributed to the general organization, in particular in the definition of the technological sector and in direct teaching in some disciplines.

4.4 INDUSTRIAL HAZARDS

Risk of transportation of dangerous substances

The project carried out as a subcontractor of the University of Pisa in the frame of the Italian Council for Research (Consiglio Nazionale delle Ricerche), was completed with the delivery of 2 reports on the subject, and an analysis of the transportation of chlorine in an Italian region.

Risk Management Support System

The development of the Ispra Risk Management Support System (IRIMS) and the customisation of the system together with the Dutch Ministry for Housing, Physical Planning and the Environment (VROM) was continued.

The development of the transportation risk management system (TRIM) has continued, with integration of geographical and demographical information from Italy. Historical data for transportation accident from open sources was studied and an empirical frequency-consequence relationship for transportation was developed.

A theoretical study identifying potential paradoxical situations in risk communication was carried out, and the first European conference on communicating with the public about major accident hazards was organised in May/June 1989 (see Section 3.4.2).

Further improvements were made in the PC based system for digitising maps, and a compatible vision system was installed on a SUN workstation, and the computer communication network was upgraded to allow faster transfer of images and data between different machines.

A decision support system was developed for study of siting problems related to urban waste disposal, and the use of Petri Nets for modelling of complex decision processes had also been investigated, and specific software was acquired.

5. Participation in Eureka Projects

5.1 FORMENTOR

Summary

FORMENTOR is a Eureka project in the development of real-time computer systems for catastrophe prevention. The project was originally established by a consortium of French and Norwegian companies, who in 1986-7 carried out a preliminary "pre-project". In early 1989 the Institute joined the consortium to start work on the main "development" phase of the project, which was formally launched later in the year.

Background and Project Description

FORMENTOR aims to help operators of hazardous installations to cope with potentially dangerous situations. The application industries cover a wide span, including chemical process plants, oil production and processing facilities, satellite launches and operation, and aircraft operation; the features these have in common are the complexity of the processes involved and the wide range of different sources of knowledge which must be consulted and used to ensure safe operation. The objective of the project is to assemble a "toolkit" of techniques and software packages to enable the building of knowledge-based computer systems which will analyse the installation in real time and offer advice to the operator as to the causes and possible consequences of deviant behaviour.

FORMENTOR applications are intended to be integrated with existing automatic process control and surveillance mechanisms, and to provide an extra, higher, level of operator dialogue based on an understanding of the entire system under observation (including himself). Thus the objective is not to replace existing automatic mechanisms, but rather to supplement them with an extra level of safety control, which draws attention to possible dangers, proposes countermeasures to avert these dangers, and explains its reasoning and the diagnoses it offers.

The central domain of interest of FORMENTOR thus lies at the intersection of three technical areas:
- Risk analysis.
- Artificial intelligence.
- Real-time computing.

Progress to End 1989

At the beginning of 1989, the Institute for Systems Engineering of the Joint Research Centre was invited to join the consortium of:
- Aérospatiale (F).
- Cap Sesa Innovation (F).
- Det norske Veritas Industrial Development A/S (N).

The FORMENTOR workplan for the development phase covers four years, divided into two-year work periods. The workplan is divided into five workstreams:
- M (Methodology).
- A (Applications): two pilot applications in the first work period, and two full-scale applications in the second.

- G (Generic system): to build the FORMENTOR toolset;
- C (Commercial): establishing industrial user requirements, also market research and public relations.
- P (Project management).

The development phase was formally launched in spring 1989. Over the next few months work was started on 3 workpackages in the M stream, and on several workpackages in the C and P streams. The Institute participated primarily in work on the methodology standards, on the conceptual model of a FORMENTOR application, and on the selection of basic techniques, particularly in the areas of risk analysis and artificial intelligence.

Work on the Application streams took longer to establish, and by the end of 1989 only one pilot application had been identified. This is a study of the in-flight operation of the Airbus 310 in the phase of approach to an airport, and work on this application is due to start in 1990. It is hoped to have a second application in the process industries, and negotiations are underway with several possible industrial partners.

6. ISE and Associated Laboratories

6.1 THE STARS PROJECT

The STARS (Software Tools for Analysis of Reliability and Safety) [1,2,3] project was officially started. The project uses the techniques of artificial intelligence in combination with conventional programming techniques for supporting risk analysts or designers in the performance of safety and reliability studies. The objectives of the project are to develop a coherent set of tools for assisting the various phases of such studies. Target application sectors include the process plant industry, the nuclear industry and other industrial sectors in which complex electro/mechanical systems are involved.

The project was launched as a joint venture between four partners: the National Research Laboratory of Denmark (RISØ), the Technical Research Centre of Finland (VTT), the National Research Centre of Italy (ENEA) and the Joint Research Centre.

The activities covered by STARS can be seen from the overview scheme given in Figure 8. They include:

1. Initial data collection and updating of this information: this includes the description of the plant or system under analysis in terms of the functions, the processes involved, the P&I diagrams or functional diagrams of the system(s), the characteristics of the components and the description of system operation, process control and protection.

2. Qualitative analysis: for the identification of hazardous events or event sequences and the ranking of such events and event sequences in terms of the severity of their consequences. This task can be performed by Hazard and Operability Analysis (HAZOP) and/or by Failure Mode and Effect Analysis (FMEA).

3. Event sequence modelling: for the structuring of the identified events and event sequences into logic models. This includes construction of event trees and/or master fault trees.

4. Systems modelling: for the construction of logic models for the system malfunctions that appear in the event sequences or event sequence models. This includes the construction of fault trees and the generation of state graphs or transition matrices. Moreover, modelling includes the identification of dependencies between subsystems or components.

5. Model analysis: for the logic and/or probabilistic analysis of the constructed models for systems and event sequences. This includes event tree analysis, fault tree analysis, Markov analysis and possibly reliability simulation. Moreover, the analysis phase considers also the quantification of dependencies if dependent events have been identified in the previous phase.

In order to provide the user with "intelligent" support, a knowledge based approach is adopted for realising the qualitative analysis tools (HAZOP and FMEA tools), the logic and probabilistic modelling tools (sequence modelling and systems modelling, Event tree, Fault tree, Markov tools) and the dependency identification tool. These tools will draw their knowledge from four knowledge bases (KB's):
1. a plant/unit KB;
2. a substance KB;
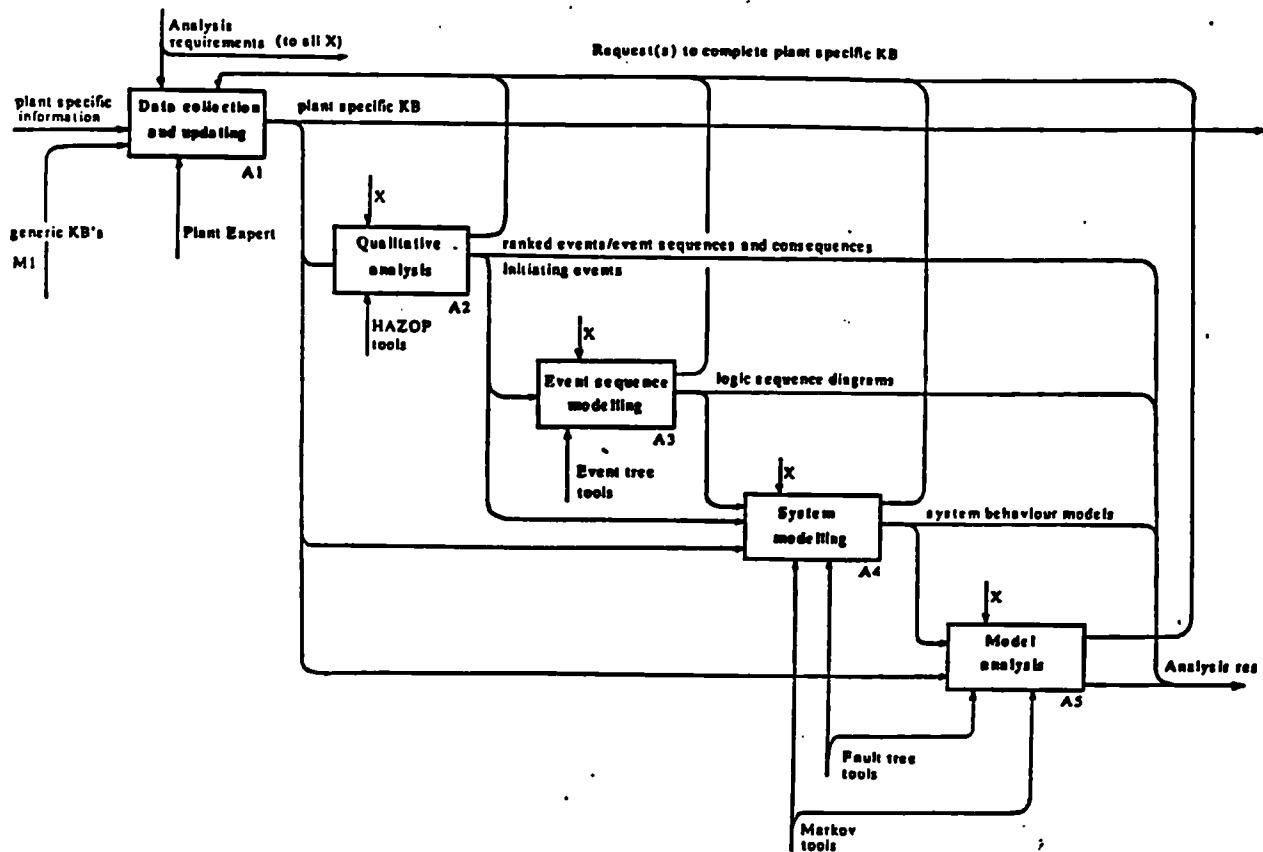3. a reaction matrix KB;
4. a component KB.

Figure 8 - Overview of tasks covered in STARS.

The first three knowledge bases are used for performing HAZOP and consequence ranking. They are pertinent in the safety analysis of process plants. The last knowledge base is used for the construction of logic system models.

STARSis conceived primarily for assessing plant safety and reliability but its capability can be considered in a more comprehensive way. Some possible and new type of exploitations are: the use as "real time" decision supporting tool for reliability and safety optimization under different design alternatives and/or maintenance policies and the use as supporting tool for a living PSA management of specific plants.

The progress made on the STARS project can be summarised as follows:

1. The specification of the project has been completed. This resulted in the definition of about 50 work packages: 27 kernel work packages to be carried out by the partners and 23 optional work packages to be undertaken by possible affiliates to the project.

2. The work packages concerning the conceptual studies of the HAZOP tool and related knowledge base development were initiated.

3. The work packages related with conceptual study of the knowledge base management system (KBMS) were completed and a start was made with the implementation of the KBMS.

4. The work packages dealing with the conceptual study of the fault tree construction expert system were initiated and a start was made with the development of a demonstrator for the concept. This demonstrator includes an ad-hoc CAD system for describing system Piping and Instrumentation Diagrams (P&I D's).

References

[1] Poucet A. and Guagnini E. (1989. STARS: Software Tools for Analysis of Reliability and Safety. Proc. PSA 89 Int. Topical Meeting on Probability, Reliability and Safety Assessment. Pittsburgh, April 2-7, 1989.

[2] Guagnini E. and Poucet A. (1989). Knowledge based tools for reliability and safety analysis. DECHEMA-Monographs Vol. 116.

[3] Poucet A. (1989). Automated fault tree construction and expert systems. Proc. Post SMIRT-10 seminar to be published in Reliability Engineering and System Safety.

6.2 LASER HOLOGRAPHIC INTERFEROMETRIC MEASUREMENT FOR THE ANALYSIS OF RESIDUAL STRESSES IN WELDED JOINTS (Activity carried out in collaboration with Politecnico di Milano)

Successful tests have been performed on low carbon steel specimens or various thicknesses (2 to 10 mm).

6.3 INTEREST CLUB

Aim: development of an expert system (ARTIC) for damage assessment and lifetime prediction of pressurized steam headers of conventional power plants.

Collaborting Institutes: CEGB-UK, ENEL-I, Laborelec-B, MPA-D, ISE Ispra, JRC Petten.

ARTIC is envisaged as a "procedural expert system" mainly based on expert knowledge and operation experience.

The prototype version of ARTIC has been implemented. A schematic view of its functionality is shown in Figure 9.
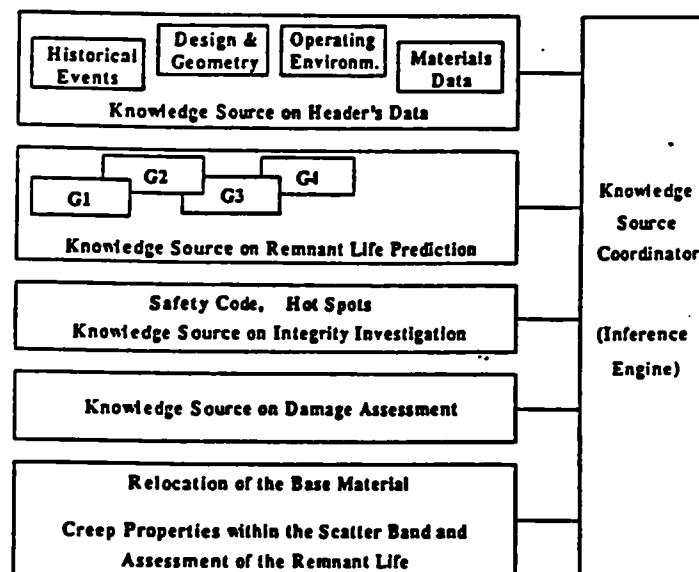

Figure 9 - Schematic view of the ARTIC functionality.

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7. ISE's Large Installations

7.1 ESTI (EUROPEAN SOLAR TEST INSTALLATION)

The Facilities of ESTI are used to develop equipment and methods for tests on photovoltaic devices. These tests are executed mainly on request by industry and other laboratories. In 1989, main efforts went into assessment, calibration and qualification of both prototype and commercial photovoltaic products.

Output in 1989:
- Calibration of 37 radiation sensors by indoor and outdoor methods and issue of certificates.
- Issue of qualification certificates according to EUR Spec. 502 for 8 types of photovoltaic modules.
- Electrical performance tests on 270 devices.
- Assessment of prototypes by special measurement procedures and stress-test sequences.

New facilities:
- Upgrading of existing large facilities for the implementation of the light soaking test for amorpous devices, developed at ESTI (LS-1/a).
- Installation of a new climatic simulation system for humidity-freeze and thermal cycle tests in line with proposed IEC Standards (International Electrotechnical Commission).

7.2 STRIKE LABORATORY

Structural Reliability Investigation by Knowledge Engineering

- Automatic testing facilities for mechanical and thermal fatigue, thermal shocks, burst tests.
- Two control rooms and data collecting units.
- Automatic scanning devices for UT inspection.
- Automatic continuous monitoring by UT.
- Multichannel Acoustic Emission system with transient recorder and pattern recognition software.
- Laser holography facility.
- Measurement of residual stresses.

The activities on the test rigs are mainly aimed at the experimental validation, on complex structures, of:
- Damage models, lifetime prediction models etc.
- Inspection and monitoring procedures and techniques.

The experimental activity is supported by a theoretical activity on modelling and prediction of physical system evolution, information pooling, data analysis, decision making and operation management, uncertainty modelling, expert system development.

7.3 PULSED WAVE LASER

It is part of the instrumentations and facilities of the LAO (Laser and Applied Optics) Laboratory: power 3 joules; possibilities of two synchronized pulses with a time lag up to 800 us;

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repetition rate 4 pulses per minute; recording by thermoplastic camera; computer control and parameter setting.

The laser is essentially used for structural diagnostic by holographic interferometry (deformation measurement and strain analysis; vibration analysis; surface state identification, etc.).

The analysis of the interferograms is performed by a software running on a PC (with transputers).

7.4 B.E.G. - GENERAL DESIGN OFFICE

The S.E.R. Division includes also one sector (B.E.G.), the main task of which is to carry out drawings, projects, posters, etc. for the laboratories of the Centre.

B.E.G. is also equipped to execute calculations and solve problems of a mechanical character (stress analysis) and thermodynamics in complex devices.

For the laboratories of the Centre the work of B.E.G. has been centered principally on projects related to Reactor Safety, Industrial Risk and Alternative Energy.

B.E.G. has carried out a work for third parties (ABB Tecnomasio) concerning studies related to the High Field Tokamak IGNITOR.
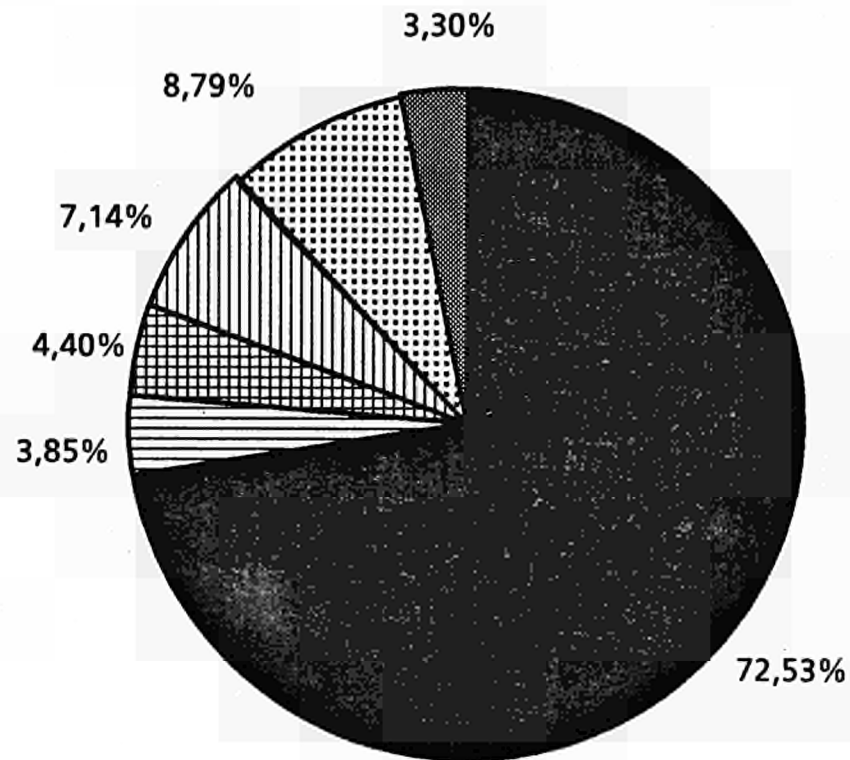
The requested work was as follows:
1. Technical advice on the flowsheet of the hybrid cooling plant (Helium gas plus liquid Nitrogen).
2. Optimization study of the cooling of the transformer coil, in relation to the temperatures and stresses developped.
3. Stress verification of the row of conductors of the transformer coil adjacent to the equatorial plane of the machine.

For the calculations and simulations mentioned above, the following software packages were used:
a) PATRAN: a CAE (Computer Aided Engineering) software that is used as pre and post processor.
b) ABAQUS: a FEA (Finite Element Analysis) software package with extended nonlinear capabilities for structural and thermomechanical (conduction) analysis.
c) P-Thermal: a FEA package that permits also convective calculations.

8. Human Resources 1989

Total staff 182

3,30%

8,79%

7,14%

4,40%

3,85%

72,53%

■	Permanent staff 132
☰	Auxiliary agents 7
▦	Visiting scientists 8
▥	Grant holders 13
▦	Stagiaires 16
■	External firms 6
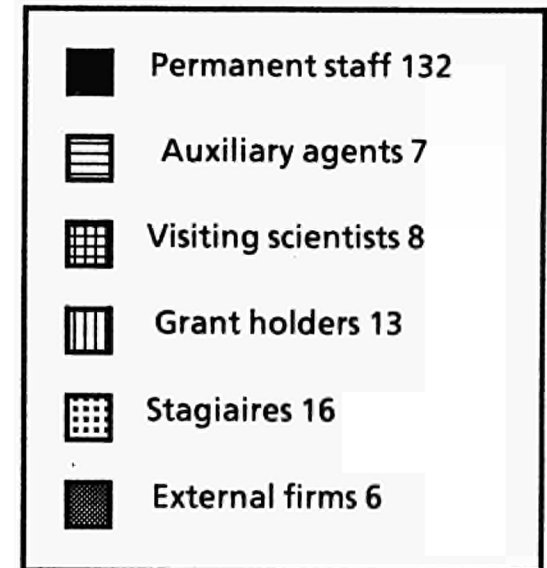
9. INSTITUTE FOR SYSTEMS ENGINEERING
Specific Credits 1989

Legend:
- Fram. Programme
- Administration ISEI
- Supp. to Comm.
- 3rd Party Work
- Special Projects
- Expl. Research

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Annex A : List of Publications
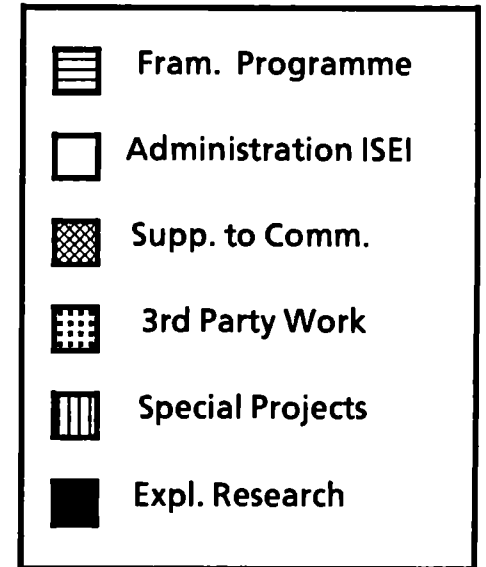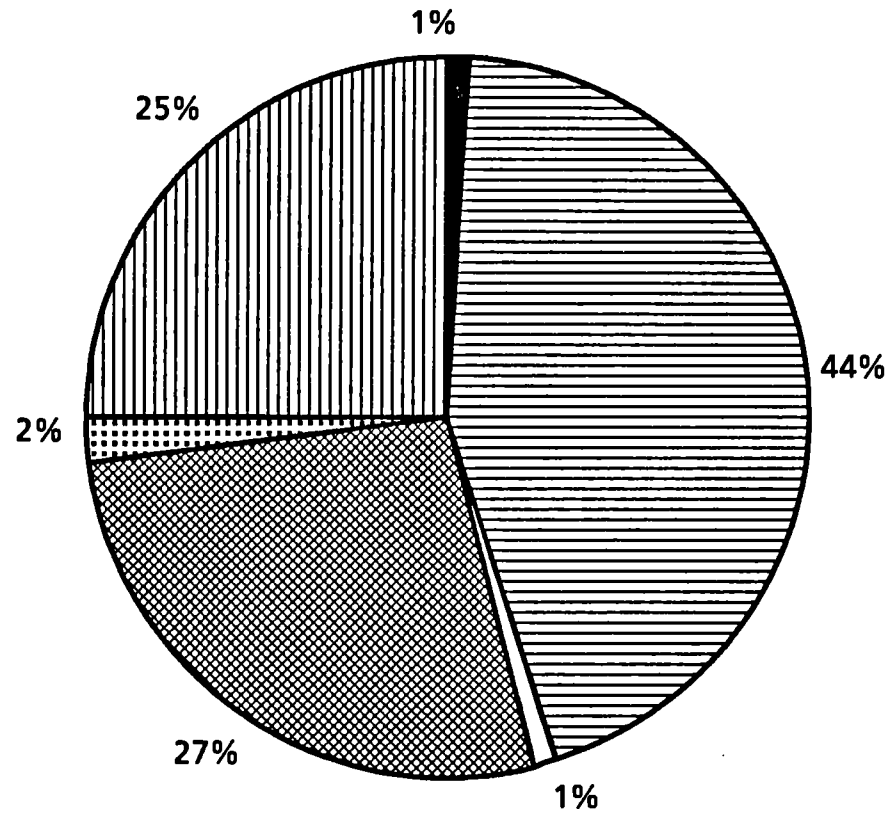
Specific Research Programmes

Industrial Hazards

CONTRIBUTIONS TO PERIODICALS AND MONOGRAPHS

OTWAY, H., WYNNE, B.* — Risk Communication and the Paradigm of Paradox. Risk Analysis, Vol. 9, No. 2 (1989) 141-145 — ART 28344

OTWAY, H. — Deaths vs Survival. A Comment on Munera's Letter. Risk Analysis. Vol. 9, No. 1 (1989) 23-24 — ART 28483

HAASTRUP, P., STYHR PETERSEN, H.*, JOERGENSEN, N.* — New Development in Transportation Risk Assessment. ESRA Newsletter, Vol. 6, No. 2 (1989) p.16 — ART 28755

OTWAY, H. — Book Review on 'In Search of Safety: Chemicals and Cancer Risk', by John D. Graham, Laura C. Green and Marc J. Roberts, Harvard University Press, Cambridge, Ma. and London, England. 1988. Intern. Digest of Health Legislation (WHO) — ART 28811

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Annex B : List of Figures

Annex C : Glossary of Acronyms and Abbreviations

AE-source	Acustic Emission Source
AORS	Abnormal Occurrences Reporting System
ARIMA	Autoregressive integrated moving average
ARMA	Autoregressive moving average
ASTUS	Reading Equipment for TITUS Ultrasonic Seals
ATM	Asynchronous Transfer Mode
BE	Benchmark Exercise
BEG	Bureau d'étude général (General Design Office)
BWR	Boiling Water Reactor
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CCITT	Comité Consultatif International pour Télégraphie et Téléphonie
CDCIR	Community Documentation Centre on Industrial Risk
CEA	Commissariat à l'Energie Atomique
CENELEC	Comité Européen de Normalisation Electrotechnique
CEDB	Component Event Data Base
CEPT	Comité Européen des Postes et Télégraphes
CFC	Carbon Fibre Composite
CISE	Centro Italiano Studi ed Esperienze
COD	Crack Opening Displacement
COGEMA	Compagnie Général des Matières Nucléaires
COSIMO	Cognitive Simulation Model
COST	European Cooperation in Science and Technology
COVASTOL	Numerical Code for Fatigue Life Assessment
C/S	Containment and Surveillance
DAM	Damage Assessment Model
DYLAM	Dynamic Logical Analytical Methodology
EDF	Electricité de France
EDSES	European Data System for Energy Saving
ELCA	Electronique du Capitole (Toulouse)
EMAT	Electromagnetic Acoustic Transducer
ENEA	Comitato Nazionale per la Ricerca e per lo Sviluppo dell'Energia Nucleare e delle Energie Alternative
EPRI	Electric Power Research Institute
ERDS	European Reliable Data System
ESARDA	European Safeguards Research and Development Association
ES-RBE	Event Sequence Reliability Benchmark Exercise
ESTI	European Solar Energy Testing Installation
ETSI	European Telecommunication Standards Institute
EUROSTAT	European Statistical Office

FCG	Fatigue Crack Growth
FEA	Finite Element Analysis
FMEA	Failure Mode and Effect Analysis
FRAP	FRont end for Abaqus finite element Programme
GIP	Global Information Pooling
.HELP	Decision Support System for Hazardous Transportations
HAZOP	Hazardous Operability Analysis
IAEA	International Atomic Energy Agency
IEC	International Electrotechnical Commission
ISE	Institute for Systems Engineering
ISES	International Solar Energy Society
ISO	International Standard Organization
ITER	International Thermal Nuclear Experimental Reactor
JRC	Joint Research Centre
KB	Knowledge Base
KBMS	Knowledge Based Management System
KE	Knowledge Engineering
LASCO	LAboratory for Surveillance and COntainment
LEU	Low Enriched Uranium
MoU	Memorandum of Understanding
MOX	Mixed Oxide Fuel
MPA	Materialpruefungsanstalt
NDE	Non Distructive Evaluation
NET	Next European Torus
PASSYS	Passive Solar Energy System
PRA	Probabilistic Reliability Assessment
PTS	Pressurized Thermal Shock
PURPLE	Package for Urban Refuse Plant Location
PV	Photovoltaics
PWR	Pressurized Water Reactor
RAMINO	Reliability Assessment for Maintenance and Ispection Optimization
RASCAL	Laser Technique for the Identification of Surface Textures
RELIEF	Residual Lifetime Estimation for Fatigue Loading
RPES	Reliable Parameter Estimation System

SCA	Shared Cost Action
SER	Systems Engineering and Reliability
SESAME	Databank on European Community's Energy Research and Development Projects
SNL	Sandia National Laboratories (USA)
SRDF	Système de Recueil des Données de Fiabilité
STARS	Software Tools for Analysis of Reliability and Safety
STRIKE	Structural Reliability Investigation by Knowledge Engineering
TCT	Technical Committee on Telecommunications
TITUS	Low Cost Multipurpose Ultrasonic Seal
TRIM	Transportation Risk Management
UNCTAD	United Nations Conference on Trade and Development
UT	Ultrasonic Techniques
VAK III	Ultrasonic Sealing System for Nuclear Underwater Applications
XR	X-Ray