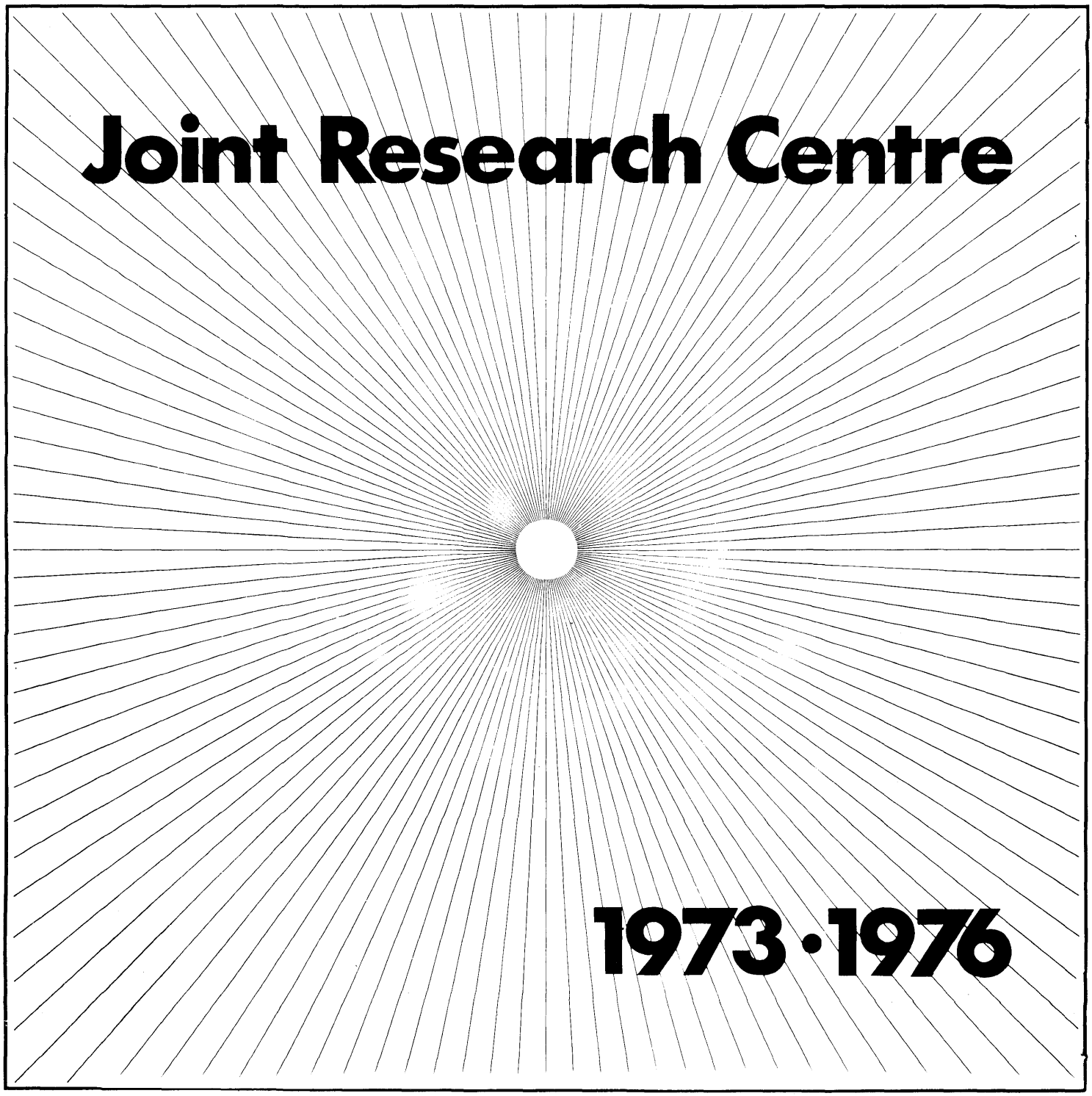
Commission of the European Communities

# Joint Research Centre



## 1973·1976

## Summary Final Report on the Programmes

Preprint

# Contents

# Foreword

*The topics listed in the table of contents show how variegated were the objectives established for the JRC by the Council of Ministers in 1973.*

*First of all, it has to be pointed out that the multi-annual programme 1973-76, summarized in this report, put an end to a long period of uncertainty during which the JRC activity could be planned only on a year-by-year basis.*

*The renewed opportunity to plan the work on a longer time scale did not fail to produce a number of positive results, as can be seen in the present document.*

*I should like to emphasise that one of the new features of the reported programme, as compared to the past, is the extension to non-nuclear fields. Such an evolution can be found indeed in many other nuclear research organisations which occurred more or less in the same period of time.*

*This rather common phenomenon is due, on one hand, to the broadening of the energy issue which often implies the need to compare alternate approaches by using the same type of technical skills, on the other hand, to the emerging evidence that problems connected with energy, environment and resources, are much more entangled and mutually connected than previously foreseen.*

*In the present report, which is in itself a summary, an effort has been made to introduce an even shorter summary at the beginning. In this, of course, only the most prominent parts of the programme could emerge, all the rest being left out.*

*In spite of the problems that a large number of highly differentiated objectives may involve for an efficient use of human resources within the JRC, I believe that the 1973-76 programme has been a fruitful one. This is because, apart from the number of results acquired which are useful in themselves, it made it possible to screen at an early stage a large number of projects, and identify those which are most promising and most fit to be elements of an overall Community research programme.*

Stelio VILLANI

Director-General of the Joint Research Centre

# Summary


## 1. Waste Processing and Storage

Extensive work has been carried on at Ispra in the field of radioactive waste processing and storage, which is currently one of the most important issues of public concern in connection with the large scale use of nuclear energy.

Large part of the effort has been devoted to the two following main aspects of the problem:
The first consists in separating the actinides contained in the wastes (waste processing), since it is due to small quantities of actinides having very long half lives that long term problems arise in waste disposal processes. It is then conceivable that separated actinides are eventually transformed into shorter lived isotopes through processing in nuclear reactors ("burning"). The studies and experiments performed at Ispra allow one to propose potential chemical flow sheets for actinides. Basic data have also been obtained and evaluated as a first step to assess the feasibility of "burning" actinides.

Ispra has made so far a significant contribution to this question by establishing a preliminary model to evaluate the long term hazard of such storage. This type of risk assessment is very useful in providing guidance for choosing between various technical solutions.

## 2. Plutonium and Transplutonium Elements

Burning in nuclear reactors plutonium- the secondary fuel obtained from uranium - greatly increases the overall energy yield of the primary uranium resources.

In comparison with thermal reactors, currently in commercial operation, fast reactors, utilising and breeding plutonium, are those which promise the most efficient utilisation of the primary resources.

The plutonium bearing fuels for fast reactors show, however, some unfavourable phenomena - like fuel swelling and cladding corrosion - which diminish their endurance and therefore their energy yield below the potentially achievable levels.

Control of such phenomena, with the ultimate aim of increasing simultaneously energy yield and safety standards of the fuel, can only be obtained if their basic mechanisms are deeply understood.

One of the main achievements of the JRC activity in this field, carried on at Karlsruhe, is the identification of the mechanisms contributing to the swelling of advanced fuels, particularly carbides, nitrides and carbonitrides.

Investigations on cladding corrosion made it possible to establish a model of the likely mechanism of intergranular attack.

Another important activity at Karlsruhe is basic research on actinides, particularly the study of chemical bonding in actinide metals and compounds. The measurement of a large number of chemical and physical properties of these substances has been performed in collaboration with other European laboratories. In this area it has been no small achievement to have purified multi-gram amounts of americium, gram amounts of protactinium and curium and milligram samples of actinium and californium.

## 3. Materials Science and Basic Research on Materials

The main objective of this activity has been to establish a disciplinary competence in the field of phenomena oriented material research and generic applied material research. These relate, respectively, to the elucidation of natural phenomena in materials and to the demonstration of feasibility within a whole class of new devices, materials or processes.

The activity in the field of materials science has yielded a large number of results of scientific significance. The following are only a few examples:

- Newly developed electron microscopy techniques have allowed one to improve the visualisation of small cavities caused by radiation damage in materials. This was a tool to study the influence of point defect migration on the structure of alloys.

- Wall errosion by energetic impinging particles as well as absorption and desorption of gases have been studied in connection with plasma-wall interactions in fusion devices.
- A number of interesting new materials have been prepared, including aluminium-calcium alloys with oriented structures and materials with extreme properties, such as superplastic alloys.

## 4. Hydrogen Production

An essential objective of the JRC programme at Ispra is to evaluate the potential of new methods to decompose water and produce hydrogen through thermochemical processes in which a nuclear reactor – or a solar concentrator – could be the main heat source.

More than 25 thermochemical cycles have been initially defined as theoretically possible. As result of both laboratory work and preliminary economic analysis performed through a purpose developed computer programme (called OPTIMO), a short list of three thermochemical processes has been selected for further development. These processes are all based on the decomposition of sulphuric acid.

## 5. Reactor Safety

The main objective of the JRC reactor safety programme at Ispra was to carry out experimental and theoretical investigations of outstanding problems for both light water reactors (LWR), which are widely used for commercial power production, and for liquid metal fast breeder reactors (LMFBR), which are being developed as a more advanced concept for future applications.

An important part of the JRC's effort in the field of LWR safety studies has been devoted to the effects of a depressurization accident. A series of tests has been carried out and codes have been assessed and compared to the obtained experimental results. The experience built up in this field, lead to the selection of Ispra for the loop blowdown investigation project (LOBI). This project is underway; the experimental facility is now being erected, and preliminary experiments should start in 1977.

In the field of LMFBR Safety Research, the efforts have been mainly devoted to the setting-up and experimental validation of computational codes. The areas covered include the study of liquid metal boiling conditions, thermohydraulics of core subassemblies under anomalous conditions, dynamic loading and response of the primary containment.

On a more general approach, applicable to both types of reactors, results have been obtained in the development of methodology for probabilistic analysis in reliability and risk assessment of large systems.

## 6. Applied Data Processing

There is an important need for advanced activities in the informatic field, due to its growing impact on practically all disciplines. The JRC Ispra has undertaken developments and provided high level services in this field.

In addition to the development of advanced mathematical tools and of a language processing system, the setting up of the European Computer Programme Institute (EUROCOPI) for promoting software sharing should be mentioned. This service has built up a computerised data base of program-abstracts and is used by some 500 organisations.

## 7. Information Analysis Office

The ever increasing amount of information in technical fields needs to be analysed and filtered for the benefit of users. In such a context this programme has been oriented towards three selected fields of nuclear engineering: radiation shielding (where the European Shielding Information Service, ESIS, assessed computer programs and, during the reporting period, gave technical advice on request from about 80 organisations), nuclear data evaluation (with the Integral Nuclear Data Centre INDAC), and structural mechanics (with the European Structural Mechanics Information Service, ESMIS, which was involved in 7 nuclear projects in 5 Member States).

## 8. Central Bureau for Nuclear Measurements

Very precise measurement of nuclear data and carefully defined nuclear samples are of high importance in the field of nuclear research, industry or medicine. The CBNM programme is organised into three main areas:

- Neutron metrology, where an extensive series of measurements of neutron cross sections and standards has been executed;
- non-neutron nuclear metrology, where half lives of the more important fissile materials and radionuclides have been determined. In this frame, CBNM contributed to three international comparison measurements, organised by the BIPM (Bureau International des Poids et Mesures).
- Preparation and definition of nuclear reference material, where a steady increasing number of characterized samples and targets has been prepared and delivered.

  The CBNM has also provided services in the field of non-nuclear reference materials.

## 9. Technical Assistance to Power Plant Operators

Special studies have been carried out with the aim to solve specific problems encountered generally by nuclear power plant operators. These problems, dealing mainly with water chemistry (corrosion), non-destructive testing or decontamination of components, irradiated fuel examination, have a character of general usefulness and correspond to the mission of public service of the JRC.

An ultrasonic equipment for detection of damaged fuel rods within an subassembly has been designed. Nuclear fueld burn up codes have been improved as a result of measurements carried out on irradiated fuels.

## 10. Training

The JRC is organising courses and seminars with the double aim of contributing to the permanent education system of our society, and to disseminate the knowledge it acquired in the framework of its research activity. Started in 1974, the "Ispra Courses" increased from a total of seven weeks to 20 weeks in 1976, with 50% of the lecturers being members of the Ispra staff.

## 11. Technical Assessment in Support to Commission Activities

This objective covers the activities carried out by the JRC in acting as a specialised Consultant bureau for the benefit of other Directorate-Generals or services of the Commission and has been mainly focussed on the energy field.

In this area, a model for the study of the implications of the siting of power plants has been developed and is used by the Directorate General for Energy.

## 12. European Informatics Network

It is more and more necessary to interconnect data processing centres. The establishment of an experimental computer network connecting computers of different kinds is the aim of the COST 11 project (COST : European cooperation in the field of scientific and technical research).

The Ispra Centre participated actively in the design specification of the telecommunication subnetwork, operational since May 1976, and developed the necessary software and hardware for connecting the Ispra computer centre to the subnetwork.

## 13. Research under Contract

Aimed at promoting the industrial applications of JRC research, the work carried out for this purpose has allowed the commercialisation or selling of several instruments or patents.

## 14. Standards and Reference Materials

A programme of work has been undertaken by the JRC to establish reference methods of strictly controlled accuracy and to produce reference materials for calibration of instruments and

verification of measurement methods. The establishment of references necessitates a large participation of laboratories at a Community level. As a result, the Establishment of Ispra together with those at Geel and Petten and several hundred other laboratories in Member States are associated in an indirect action on reference and standards (Community Bureau of Reference, BCR).

Within this objective, the JRC developed a series of chemical analysis methods and new instrumentation for the study of physical and technological properties.

### 15. Protection of the Environment

Using the expertise acquired so far, the JRC assembled multidisciplinary teams able to deal with a large range of environmental problems. In a first phase it developed highly sophisticated instrumentation and techniques, and started a relatively large number of smaller projects. A streamlining of the programme took place progressively, and gave a compact and homogeneous shape to the current activities, of which only some outstanding parts are noted below.

A study concerning the over-nutrition (eutrophication) of lake water by phosphates and nitrates has been started, utilising experimental measurements and mathematical models of the ecological systems.

A large scale experiment has been initiated to study the environmental pathway of the automotive lead in Italy, an important and timely activity carried out in collaboration with the indirect action programme. Together with this indirect action programme, should also be mentioned the setting-up of the Environmental Chemical Data Information Network (ECDIN). This project which is currently in a demonstration phase at pilot scale, provides already a unique faculty for data concerning toxic chemicals and their properties.

Most of the developed, specialised instrumentation has been already extensively field tested and performed satisfactorily

### 16. Remote Sensing of Earth Resources

Agricultural development is heavily dependent on accurate and timely information. Remote sensing techniques can give such information. In collaboration with the Directorate General for Agriculture, Ispra carried out the AGRESTE project, utilizing data from the LANDSAT-2 satellite, after being selected by NASA amongst several other applicants.

Achievements are reported in the development of methodology, data processing of satellite information and interpretation of digital maps for agricultural purposes.

### 17. Solar Energy

Among the various uses of this alternate energy source, the JRC has essentially concentrated its efforts on the applications in housing, notably high performance flat plate collectors and combined heating and cooling systems It became apparent during the programme that it was very important to improve the elaboration and standardisation of measurement procedures for solar collectors due to the widely dispersed views of European industry in this area. Thus an important effort has been put into this subject. Concentration devices for photovoltaic cells have been also studied and built at Ispra.

### 18. Raw Materials Recycling

A first exploratory study has shown that the JRC should devote rather limited effort to this subject. A system analysis on recycling and substitution of non-ferrous material has been performed, as well as some experimental studies on grinding muds.

### 19. Conceptual Studies on Fusion Reactors

The JRC studies in this field are carried out within the framework of the activities of the Fusion Associations of the Community, and specially in collaboration with the CNEN Establishment at Frascati and the University of Naples. During this collaboration the main parameters of a Tokomak

experimental reactor – designated FINTOR – have been established. The main Ispra-contributions have been in the field of blanket nucleonics, engineering, safety and environmental impact.

### 20. High Temperature Materials

The need for high temperature materials is constantly increasing with time. A programme in this field has been decided by the Council of Ministers in July 1975. The Petten Establishment, in charge of this objective, has already compiled a White Book on the state of the art and on the research needs in this area. This book, published in autumn 1976, has been written with the collaboration of acknowledged experts and following an international colloquium where users and producers of high temperature materials were convened.

This work allowed one to draw a detailed working programme, discussed in June 1976 by an ad hoc group of experts.

In parallel, the adaptation of existing laboratory facilities has been undertaken to meet the anticipated demands.

### 21. Safeguards and Fissile Material Control

The JRC has an important activity in this field, where it provides scientific and technical support to the EURATOM Safeguards Directorate of theCommission.

This activity is oriented towards the development and the implementation of techniques and procedures for fissile material control. As an example of achievement, specialized and portable instruments, and special types of seals have been developed and have found practical application by safeguards inspectors and nuclear plant operators.

### 22. Operation of the HFR Reactor

The High Flux Reactor (HFR) is an essential part of the Petten Establishment. The programme covers the operation of the reactor and the planning, execution and supervision of irradiation experiments, as a service available to customers. Major improvements to the HFR facilities have been undertaken during the reported period, which enhance the usefulness of this irradiation tool.

An average of nearly 30 highly instrumented materials testing irradiation services have been loaded per year, and around 12.000 targets have been irradiated for raioisotope production.

# REVIEW OF PROGRAMMES

## 1973-1976

# 1 Waste Processing and Storage

**Scope**

The production of radioactive waste material associated with the large scale use of nuclear energy is one of the most important issues of public concern. The management and disposal of such wastes pose a number of long term problems. However, it is possible to identify the presence of small quantities of actinides in these wastes as the main cause of long-term problems due to their very long half-life.

Work in the field of radioactive waste processing and storage started at Ispra in 1973 and has been concentrated on the problems associated with the actinides. In particular this has involved investigations of possible techniques for separation of actinides from other wastes, better methods for measurement and monitoring of actinides, and assessment of the possibility of transmutation to shorter lived isotopes (sometimes refered to as actinide incineration).

In addition to the actinide studies, evaluation has been carried out on the possible hazards associated with the eventual disposal of solidified wastes in deep geological formations and the long-term stability of the vitrified material of the type proposed for such geological disposal.

Another important activity consists of the collection and evaluation of data on alternative waste management practices.

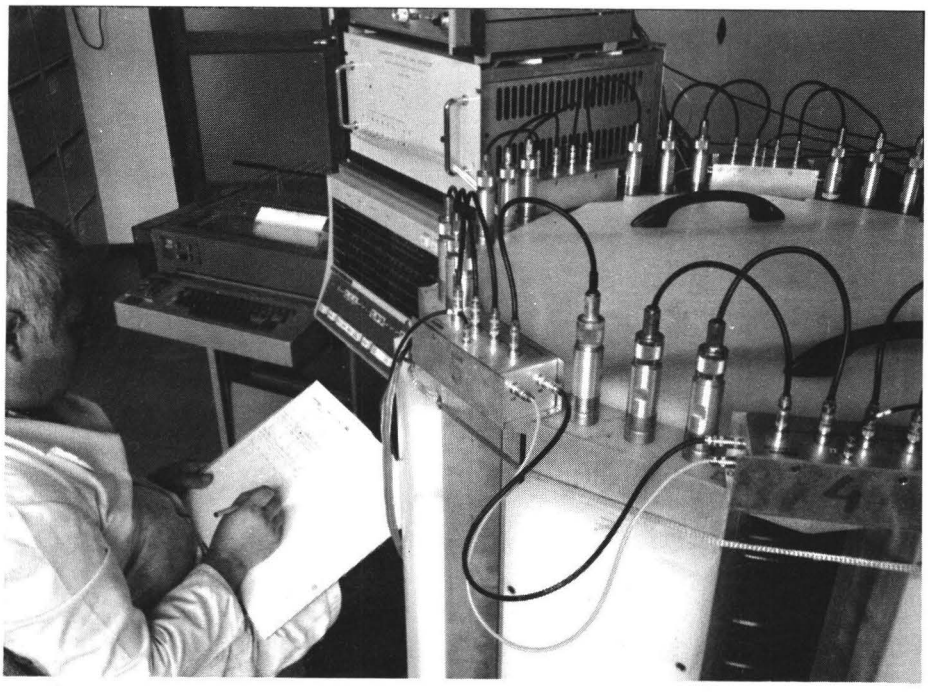
With a view to minimizing the small quantities of plutonium which find their way into the waste materials – rather than being recovered for recycling – studies have been initiated to find improved pyrochemical methods for irradiated fuel treatment in reprocessing plants.

**Achievements**

Solvent extraction and oxalate precipitation has been investigated as the most promising approach to actinide separation and it is now possible to propose potential chemical flow sheets which are the first stage in the development of practical separation plants. The flow sheets are being refined for separation of actinides from high activity wastes and it should be possible to extend the techniques to extraction from medium and low level wastes.

If it can be shown in this way that actinide separation from other fission product wastes is practical, it will open up a number of alternative waste management options in which the disposal of actinides and fission products can be considered separately. One such option which would provide an ultimate solution for actinide wastes is transmutation to short lived isotopes by neutron bombardment. As a first step to assessing the feasibility of "burning" actinides in this way, nuclear data libraries and burnup codes have been set up to evaluate the build up of actinides in different reactors. In one case where the available cross section data has been found to be incomplete, steps have been taken to mount an experiment to make the necessary measurements.

A central laboratory for assessment, calibration and standardisation services in the monitoring of actinide contaminated solid waste streams is being established. The work is focused on the monitoring of plutonium containing solid waste. Guidelines concerning different options for organising monitoring systems have been prepared and a laboratory equipped with apparatus for non-destructive measurement of plutonium by neutron and gamma techniques is being set up.



**Ispra**
**Waste management research. Neutron counting system for waste monitoring.**

A preliminary model for hazard evaluation of radiactive waste disposal in geological formations has been developed. This will provide reference levels for release of alpha emitters and their possible environmental distribution for disposal in a deep subterranean repository. It is also important to know the extent to which alpha damage to vitrified waste over periods of hundreds of thousands of years might permit the release of wastes in such repositories. A techniques for highly accelerated simulation of such damage has been developed using the irradiation of glass loaded with uranium.

A mathematical model has been developed at Ispra for the evaluation of data on waste management procedures and it should allow the optimization of the choice of disposal options from various points of view.

The pyrochemical fuel treatment studies have yielded results on the use of fuel oxidation in molten nitrates for the elimination of plutonium losses normally arising from incomplete dissolution of fuel materials in nitric solutions.

# 2 Plutonium and Transplutonium Elements

**Scope** There is increasing scientific and technical interest – not to mention a growing public awareness – in man-made elements such as plutonium and the other transuranic elements that are being formed in ever increasing amounts in operating nuclear reactors. These exotic elements present both a safety problem and challenging means of further energy supply. Of greatest importance is, of course, the utilisation of plutonium bearing fuels in fast breeder reactors.

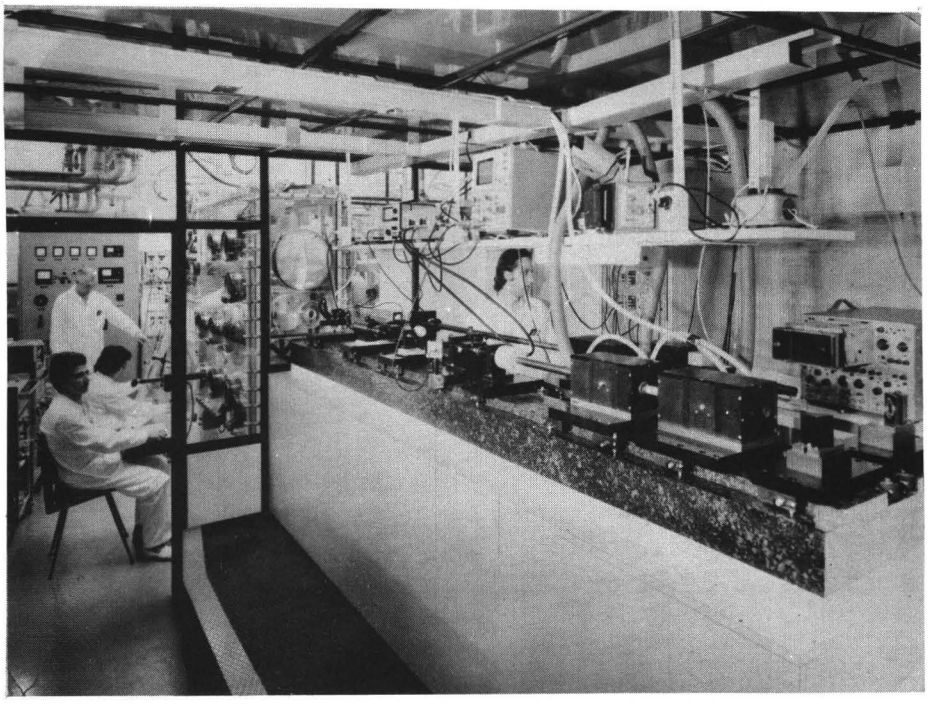
The Commission has centralized its efforts in plutonium and transplutonium research in the European Institute for Transuranium Elements at Karlsruhe. Special facilities have been established for the safe handling of, and experimentation with all sorts of transuranium elements, whether irradiated or non-irradiated.

The work of the Institute falls into two main categories:

- fuel science and technology involving studies of fuel fabrication techniques, investigation of physical and thermodynamic properties of plutonium based fuels, the preparation and execution of irradiation experiments and post irradiation structural and isotope analysis.
- Actinide research in which the Institute is playing a central rôle within the Community both by contributing its own experimental and theoretical work and by coordinating an increasing number of cooperative research efforts from laboratories in various parts of the world.

The main aim of the fuel science and technology program has been to explore the limits of application of plutonium bearing fuels in nuclear reactors. These fuels are oxides, carbides, nitrides and carbonitrides. Of particular interest is the extent to which the filetime of a fuel pin may be limited by volume increases of the fuel during irradiation (swelling). A better understanding of this phenomenon is of particular concern for the more advanced – non-oxide – fuels. Another limitation is presented by the chemical interaction between fuel and cladding material at elevated burn-up and in this case the main interest is in oxide fuel pins. In both instances important parameters which are not sufficiently well known are fuel temperatures, their distribution and evolution with time. These studies have been complemented by detailed investigations of the – hitherto relatively unknown – production rate of fission products in a given neutron flux environment and an extension of previous vapour pressure studies to extreme temperatures (at and above 5000 K) which are of interest for reactor safety studies.

The main aim of the actinide research, which has been carried out at the Institute for the past four years, has been to contribute to the understanding of chemical bonding in actinide metals and compounds. Due to their particular electronic structure, the nature of the chemical bond in these materials gives rise to a number of unusual features in certain thermodynamic and physical properties. To further these studies it has been necessary to produce, separate and purify actinide elements and prepare well characterised samples of metals, alloys and compounds; and to perform physical and thermodynamic property measurements and investigate the possibility of relating the observations to the solid state electronic configuration of these materials.



**Karlsruhe**
**Plutonium and Transplutonium elements. Experimental set-up of state measurements of oxide fuels up to 5,000 degrees Kelvin. The high-energy laser and (in background) the high-vacuum furnace in the glove-box.**

## Achievements

A carefully planned research program has been carried out in order to identify the mechanisms contributing to the swelling of advanced fuels. The swelling is due in part to the precipitation of gaseous fission products and in part to the mechanical interaction between the fuel and its cladding. Laboratory experiments have been performed in order to define fuel properties (mainly mechanical and thermal) of interest for swelling. Fast reactor irradiations were carried out to burn-up of 1,3 and 5% and with linear heat ratings up to 1350 W/cm, both with sodium and helium bonded pins, and the dimensional and structural changes of the pins have been analysed. Models describing the in-pile behaviour of the test pins, in particular their volumetric changes during irradiation, have been designed.

As a result of these efforts it has been possible to build up a relatively complete semiquantitative picture of fission gas release and swelling in advanced fuels and their relation to the detailed structure of the fuel as it varies with burn-up and linear power. For given initial and operating conditions, it is possible to define the operational limit beyond which swelling of advanced fuels should lead to a high probability of cladding failure. Present efforts are aimed at taking into account rapid changes in reactor power and at defining safety criteria for normal and off-normal conditions.

Extensive investigations of the processes leading to cladding corrosion under irradiation have been carried out with a view to finding appropriate means for keeping these processes under control.

As a result some basic aspects of corrosion phenomena have been clarified by sophisticated analytical methods. Post irradiation examination of fast reactor fuel pins revealed how cladding corrosion depends on the initial fuel stoichiometry, on cladding temperature and burn-up. The presence of a ferromagnetic phase (ferrite structure) along the grain boundaries of corroded austenitic steel cladding was detected by interferometry and magnetic etching of the samples. Corrosion simulation experiments with cesium-139 as a tracer revealed that the cesium penetrated into the cladding much deeper than the visible corrosion layer. For the first time, the oxygen potential of milligram samples of mixed oxide fuel was

determined by a newly developed emf-technique, and the rates of bulk and grain boundary diffusion of cesium in steel were measured.

By combining these experimental findings with data and theoretical predictions from the literature, it has been possible for the first time to establish a hypothesis on the likely mechanism of intergranular cladding attack.

Knowledge of the thermal behaviour of fast reactor fuel pins has been improved by thermal conductivity measurements of unirradiated fuel samples with various chemical compositions and mathematical models for thermal fuel pin analysis have been improved.

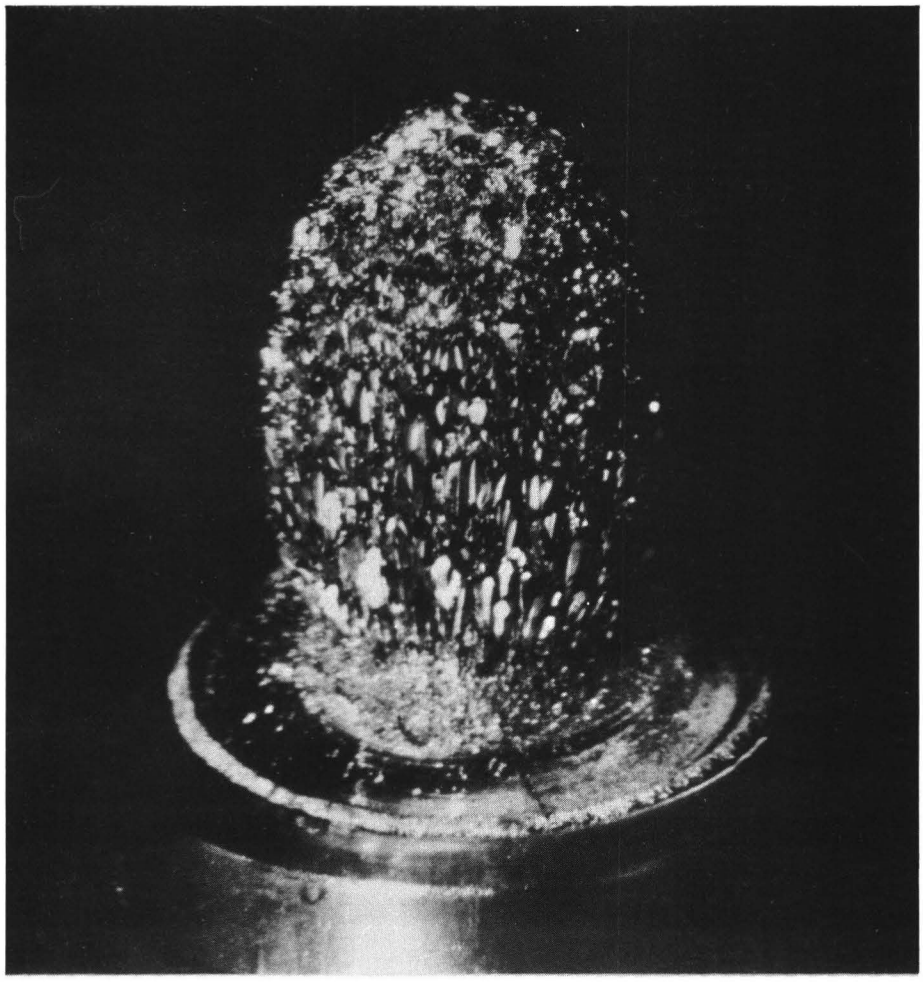
To extend these studies, new methods for the in-pile measurement of fuel temperatures and fuel-to-cladding contact conductance have been prepared. A new type of temperature sensing device, based on the measurement of the temperature dependent velocity of sound in an appropriate sensor, has been developed. This instrument, which is capable of measuring a longitudinal temperature profile at once, operated successfully in the central channel of a mixed oxide fuel pin for more than two hundred hours of irradiation at temperatures above 2350°C which is above the range normally accessible to conventional thermocouples. A new method for gap conductance determinations by a thermal oscillator technique was also tested in the laboratory and is being adapted for in-pile operation.

Newly developed highly automated equipment has been used for isotope analysis of heavy nuclides and certain fission products during irradiation of fuel rods. The techniques are used for evaluation of burn-up and also provide information on integral cross sections and fission yields in fuel subjected to a fast neutron environment. The accuracy of the data obtained from these measurement techniques is well within the more demanding requirements of present day nuclear technology. In the case of some plutonium and americium nuclides the measurements have provided important new data pertinent to the spectrum of fast reactors and some of the results obtained deviate considerably from theoretical expectations. Results of determinations of isotope ratios and certain fuel parameters have been applied to fuel management problems and procedures for supervising the flow of fissile materials through fabrication plants, reactors and reprocessing installations.

An entirely new technique has made it possible to measure vapour pressures of fuel materials at temperatures up to 5000°K. This information is used in the establishment of the equation of state of the materials which is important in reactor safety studies. The new measurement technique makes use of a high-energy solid state laser operating in the milli- to microsecond pulse range and producing power densities of the order of $10^7$ W/cm$^2$ at the fuel sample surface. The first quantitative results were obtained for uranium oxide and mixed uranium-plutonium oxides in 1974. A special double intensity pulse technique allowed later extension of these measurements to temperatures below 4000°K.

A new equation of state for $UO_2$ was derived from the data obtained from these measurements, with a critical temperature of 2560°K, a critical pressure of 1210 at and a critical density of 1.60 g/cm$^3$. In addition the melting points of ternary U, Pu oxides and carbides were measured as a function of composition. As a first step towards the future work on the equation of state of mixed carbides, the evaporation behaviour of these fuels has been measured up to 2500°K.

The actinide research work is devoted more to the basic properties of the lesser known nuclides beyond plutonium. In this area it has been no small achievement since 1973 to have purified multi-gram amounts of americium, gram amounts of protactinium and curium and milligram samples of actinium and californium. These precious quantities of materials are produced in the form of metals and compounds and are used for a wide range of experimental measurements.



**Karlsruhe**
**Plutonium and Transplutonium elements. Americium metal (2 grams of $^{241}$Am) condensed from the vapour phase.**

Partly in collaboration with other laboratories, it has been possible: to determine the crystal structures of actinium, protactinium, americium and curium metal phases; to measure the vapour pressure and the heat of dissolution of certain actinide metals; to determine the specific heat and elctrical resistivity of americium and curium; to investigate the magnetic properties of protactinium, americium and curium, and to study the optical spectra of metals and oxide systems at wavelengths ranging from the ultraviolet to near infrared. These investigations have clarified the role of 5f electrons in chemical bonding of actinides. Optical spectroscopy has recently been complemented by photoelectron spectroscopy techniques which yield directly electron configurations and bond energies.

# 3 Materials Science and Basic Research on Materials

**Scope** Since its origin the Joint Research Centre has been involved in basic materials research work in support of advanced technology throughout the Community. In 1973 this program of work, previously designated the "Physics of Condensed Matter Program" was reoriented to stress those problems in materials science of a long term character. The main areas of research are now:

- radiation damage studies
- surface reactions on advanced materials
- mechanical properties of metals and composites
- physical properties at high temperature
- transport processes and structural behaviour of metals and polymers
- effect of structural changes and lattice imperfections on the physical properties of materials
- neutron physics studies carried out in collaboration with the Laue Langevin Institute in Grenoble.

The research and development activities have been organized with the intention of providing general technical support for the current and longer range development of advanced materials. Efforts have been made to establish an infrastructure of technical, scientific and instrumental competence which will respond effectively to real materials requirements and which is well integrated with existing industrial and governmental activities within the Coommunity. Each area of research is to some extent related to the project oriented objectives of the JRC. The main objective has been to establish a disciplinary competence in the field of phenomena oriented materials research and generic applied materials research. These relate, respectively, to the elucidation of natural phenomena in materials and to the demonstration of feasibility within a whole class of new devices, materials or processes.

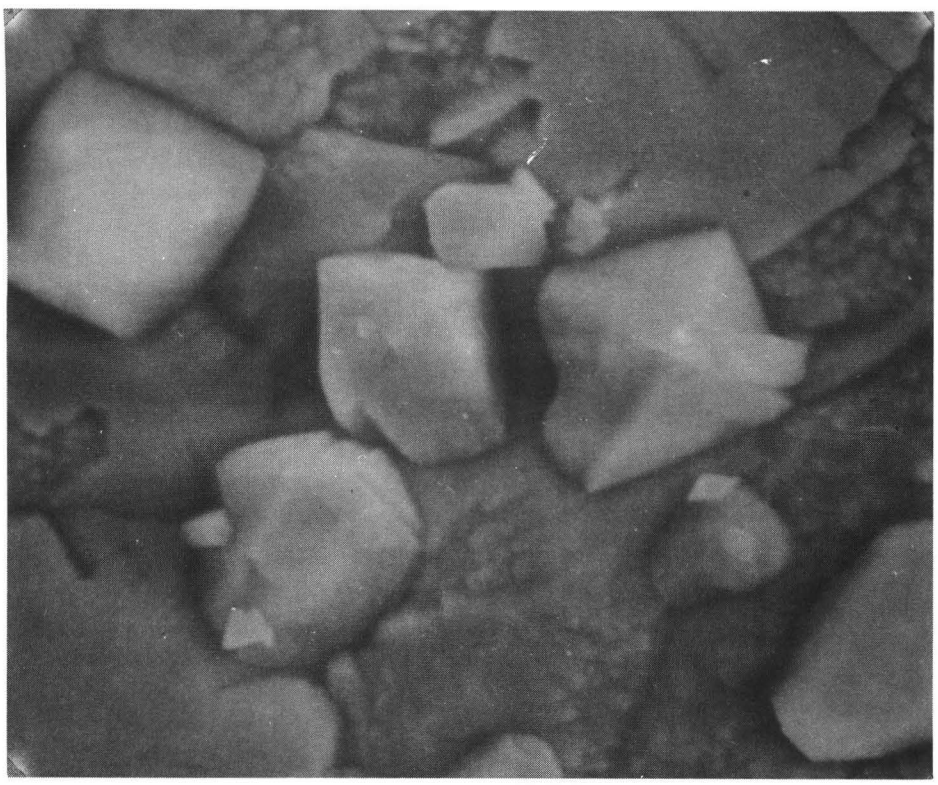
**Achievements** Electron microscope work has yielded further insight into the image-forming of small holes and bubbles and has demonstrated the best way to visualize the small cavities caused by radiation damage. Diffusion of point defects and the influence of their migration on the structure of alloys has become a strong point of the programme. Self-diffusion in nickel, the ordering and structure of gold-silver alloys, the precipitation of iron in copper and the behaviour of point defects in copper-gold alloys, are some of the problems that have been resolved.

Plasma-wall interactions in fusion devices has provided many problems for the surface reactions studies on advanced materials. Experimental techniques for measuring the erosion due to energetic particles emitted from plasmas have been developed and are currently in use. The measurement of adsorption and desorption of gases on transition metals has been carried out using specially developed apparatus.

The ion implantation laboratory has investigated arsenic ions in silicon and has started, in collaboration with other activities in the materials programme, the study of oxide grown on silicon carbide.

With a better understanding of the mechanical properties of metals and in particular insight into the mechanisms which play a role in plastic behaviour, it has been possible to prepare a number of interesting new materials. Work concerned with the preparation of metallic composites

from eutectics furnished a fairly complete picture of the growth mechanisms of aluminium-calcium alloys with oriented structure, obtained by unidirectional solidification. The field has been constantly extended and materials with extreme properties — such as superplastic alloys — can now be prepared. In a parallel study hardening of nickel-base alloys by dispersion has been investigated. With the new method employed it has been possible to produce a wide variation of the composition and dimensions of the second phase particle resulting in high temperature stable materials.



**Ispra**
**Basic research on materials. Scanning electron micrograph of Ni-foil containing octahedral-shaped precipitates of NiO.**

In the course of making measurements of the mechanical strength of materials three interesting new techniques have been envolved to supplement the classical tests. These are: the measurement of density of deformed materials which makes it possible to follow the formation and growth of microinfrastructures; acoustic stress wave emission which has been very successful in the identification of stress wave sources; and dynamic experiments in a scanning electron microscope.

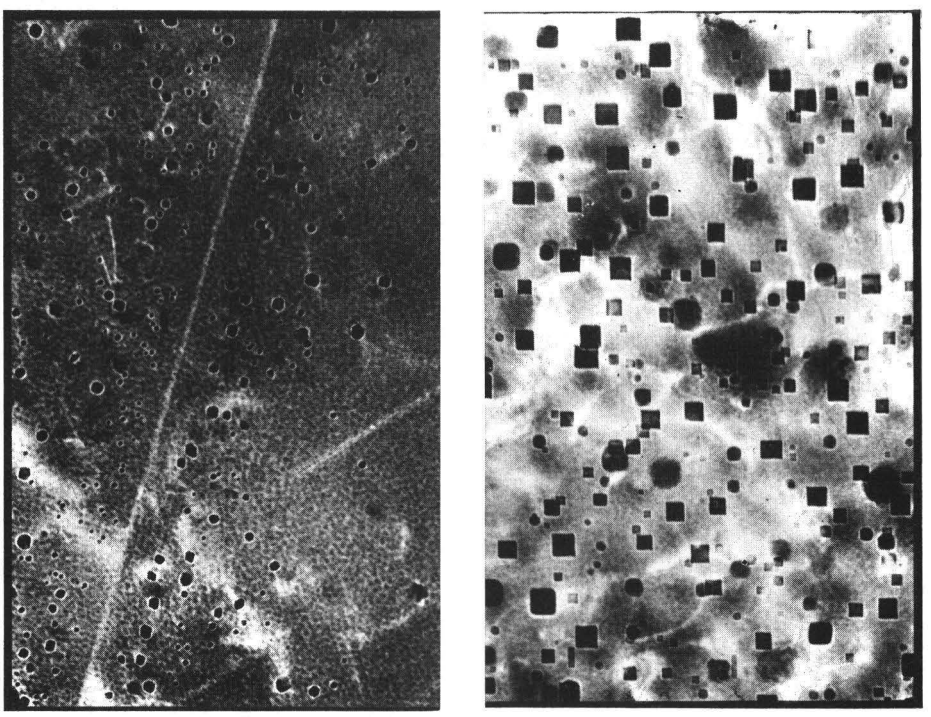
In a continuing programme of work on the performance of heat pipes a number of problems associated with their operation at high temperatures have been solved. Wetting studies of liquid sodium on various metals have been carried out using a specially developed heat pipe device.

The studies of transport processes and structural behaviour of metals and polymers have been helped by greatly improved instrumental capacity for electron spin and nuclear magnetic resonance measurements. This has yielded original results on the vanadium-hydrogen system and on polymorphic liquid crystals. New reseach lines in biophysics have been opened up in collaboration with the Biology Group at Ispra (General Directorate Research Science and Education).

In studying the effects of structural changes and lattice imperfections on the physical properties of materials emphasis has been given to phase transformations in metals, alloys and ionic solids. A large spectrum of scattering techniques have been developed for this work.

A high resolution neutron diffractometer has been designed by the neutron optics team at Grenoble. In connection with this design work assessments have been made of neutron monochromators and some studies were also developed to neutron topography and neutron scattering in liquid crystals. Another group planning to carry out fission fragment experiments, has been preparing a multisection ionization chamber and associated data collection equipment for use with the Lohengrin spectrometer at Grenoble.

Part of the programme was executed in 1973-74 at the Petten Establishment, where the well-established competence in the field of preparation of high-purity vanadium was used to start systematic studies of the influence of impurities on the mechanical properties of single crystals, on the recrystallisation of deformed vanadium and on the formation of voids and gas bubbles in the irradiated metal.



**Petten**
**Basic research on materials. Transmission electron micrographs of vanadium, neutron irradiated at 600°C to a dose of about $3x10^{21}$ n/cm$^2$ (energy of neutrons over 0.1 MeV). On the left, high purity vanadium; on the right, high purity vanadium pre-injected with 10 atomic parts per million of helium (50,000 x)**

# Hydrogen Production 4

**Scope**

There is considerable interest in extending the application of nuclear energy to uses which do not involve the generation of electricity. Such applications could, in the long term, help to reduce the Community's dependence on oil and natural gas as primary sources of energy. The production of synthetic fuels using nuclear heat is one of the alternatives and hydrogen seems to be the most promising synthetic material to produce. Hydrogen can be produced by decomposing water; it is an important chemical feedstock; it can be stored easily and economically; and it can be used as a fuel for a large number of energy needs which can not conveniently be met by electricity.

The objective of the JRC programme at Ispra is to evaluate the potential of possible new methods for decomposition of water. Thermochemical processes, in which closed cycle chemical reactions are used to reduce the heat input needed to split water into its constitutent parts, are being investigated. The work involves: the defining of potential thermochemical processes and criteria for comparing them; the collection of as much theoretical and experimental information as possible on candidate processes; and selection of the most promising processes. It is also necessary to compare potential thermochemical processes with electrolysis of water – both with the present state of the art and with potential developments in electrolysis.

The JRC has a leading organisation role in the cooperative action on hydrogen initiated by the International Energy Agency and also has individual cooperation agreements in this field with German and French research centres.

**Achievements**

More than 25 thermochemical cycles, using different elements, have been defined as theoretically possible on the basis of available physico-chemical and thermodynamic data. These cycles involve, for the most part, only chemical reactions but in some hybrid cycles one electrolytic step is included.

Detailed data and information based on experimental tests and calculations has been gathered for about a dozen of the more promising chemical cycles in three different families – the mercury-bromine family, the iron-chlorine cycles, and the sulphur cycles. For the key reactions in these cycles (numbering about 30) experimental tests have been made to measure kinetic data under practical conditions and to determine the influence of the more important parameters such as temperature, pressure and concentrations. This is the first step in evaluating the practical feasibility of the processes but work has also been started on associated corrosion tests and the screening of potential plant construction materials that can make or break the economics of a commercial process.

With all the candidate processes it has been important to establish criteria for selection of the most promising at an early stage of evaluation. A computer program called OPTIMO has been prepared for this purpose and is used for the definition and optimization of flow sheets. The program also provides parametric analysis and by highlighting the more critical characteristics plays an important part in orienting experimental tests.

Preliminary economic analysis provided by the OPTIMO program indicates that, with present values of heat and energy costs, the most promising thermochemical cycles could give hydrogen production costs which are competitive with those anticipated from the most advanced electrolytic cells.

As a result of these evaluations a short list of three thermochemical processes has been selected for further development in bench scale demonstration plants. These processes are all of the sulphur family which is based on the decomposition of sulphuric acid and involves also other elements such as iodine or bromine.

# Reactor Safety 5

**Scope**

The main objective of the JRC reactor safety programme at Ispra is to carry out experimental and theoretical investigations of outstanding reactor safety problems for light water reactors (LWR) and liquid metal fast breeder reactors (LMFBR). The increasing activity of the JRC in this field has been stimulated by different European and international committees involved in reactor safety research. Reactor constructors, licensing authorities, national laboratories and utilities are represented on these commnittees.

The Advisory Committee for the Management of the Safety Programme has set up five ad hoc specialist working groups: one for each major orientation of the work carried out at the JRC.

Reactor safety research includes the use of experimental rigs in which various types of hypothetical accident conditions can be simulated. Experimental measurements are compared with computer predictions and where necessary the computer codes are refined. These computer codes can then be used in the assessment of the adequacy of safety features to deal with the hypothetical accidents in real nuclear power plants. The LWR investigations at Ispra have been mainly concerned with depressurization of reactor systems and have involved a number of blow down rigs and experiments. Experimental studies have been carried out on the fuel coolant interaction. The LMFBR work has been mainly concerned with the boiling of the metal coolant that might result from localised blockages, the adequacy of primary containment to deal with accidents, and again, the interaction of fuel with the coolant in the event of a partial melting of the core.

Work has also started at Ispra on the application of probability analysis to the reliability of all the components and sub-systems that make up a nuclear power plant.

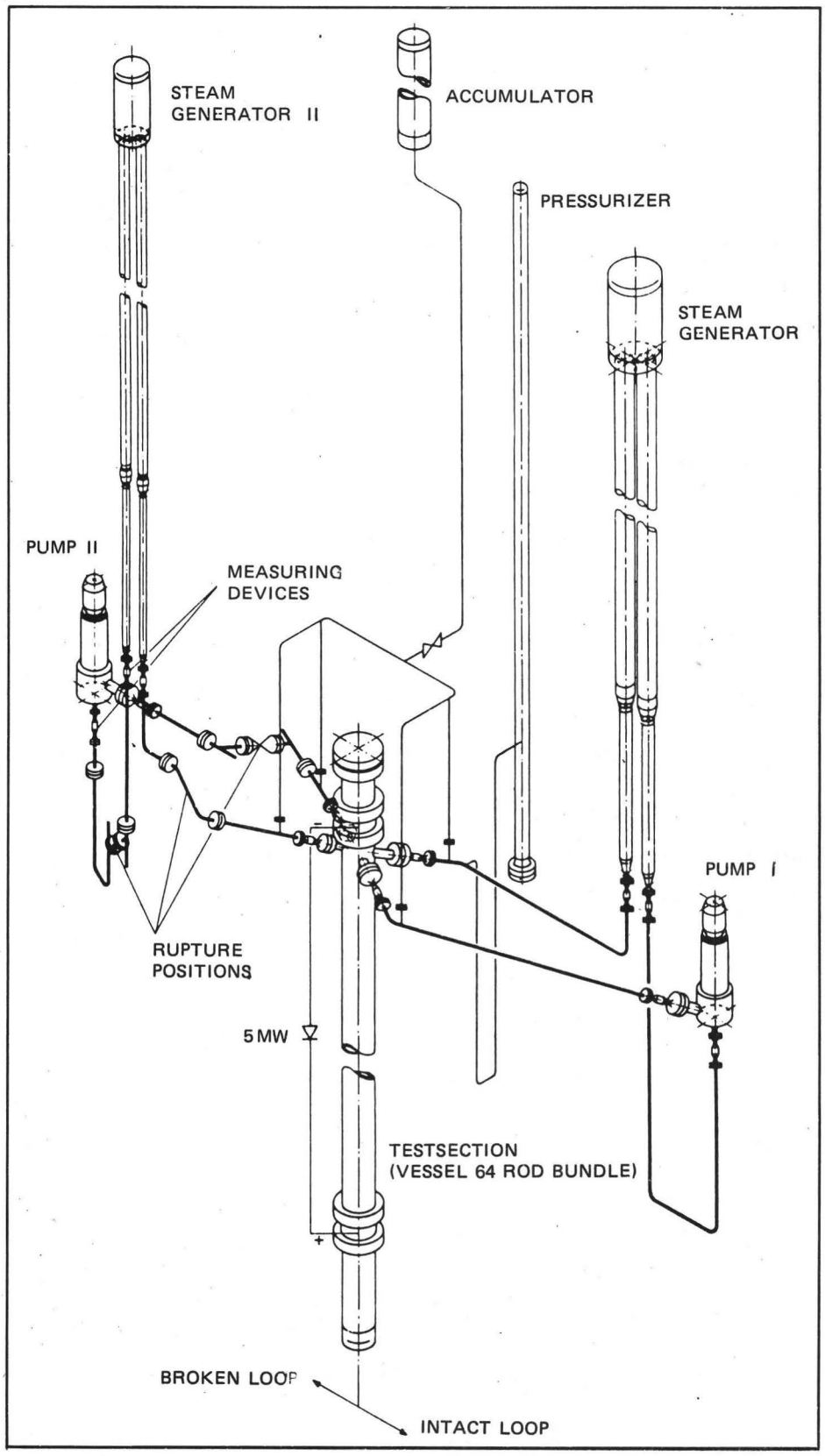
To ensure that the research in the reactor safety field is always related to the real problems of nuclear plant designers and licensing bodies it is important to work closely with the national programmes. This is ensured by the work of the Advisory Committee and of the ad hoc specialist working groups on one side and by collaboration contracts on the other side: 30 contracts have been negotiated and executed from which an important financial contribution is also derived.

**Achievements**

A series of depressurization studies have been carried out to simulate the effects of a rupture in the cold leg of a pressurized water reactor (PWR) primary circuit and the effects of combined ruptures in both the cold and hot legs. The experimental results have been compared with the blowdown code "KAPCOR" and showed a good agreement. Further investigations of the thermodynamic equilibrium which will occur in the primary circuit during accident conditions have been completed. The half-value times of return to equilibrium have been found to lie between 10 and 150 milliseconds for the flashing tests and at about 0,5 seconds for the cold water injection tests. These results can now be introduced into the blowdown code "BRUCH".

Based in no small part on the success of this series of tests, the JRC were asked by the German Federal Ministry for Research and Technology (BMFT) to make a proposal for a loop blowdown investigation project

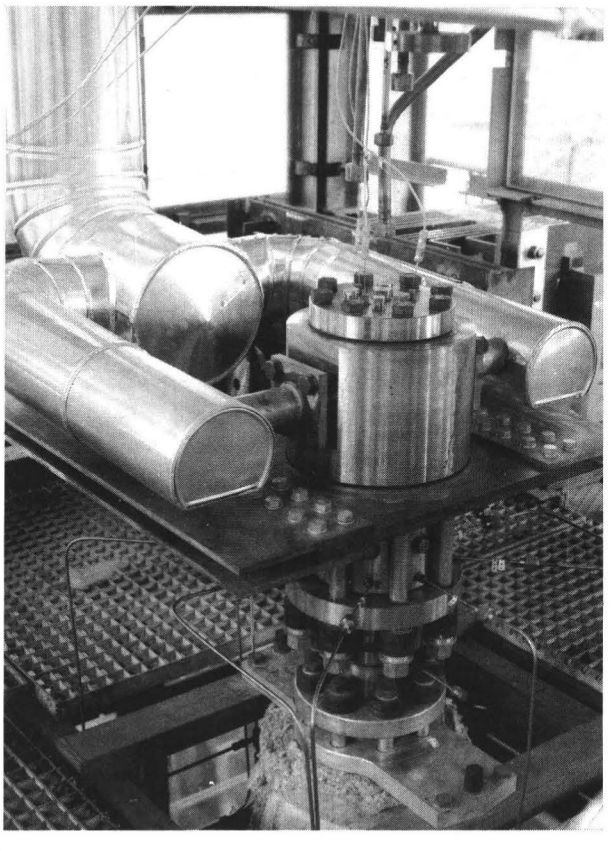
(LOBI) and has finally been selected to carry out the work. Parallel to the German part of the programme, a Community programme has been elaborated which will be executed on the same loop. Progress has already been made on the comparison, modification and development of existing codes for this new project. The experimental facility, a two loop test facility simulating the four loop primary coolant system of a 1300 MWe PWR reference plant, is being erected and preliminary experiments should start in 1977.




**Ispra**
**Reactor safety**
**Blowdown loop system**

Basic transient heat transfer measurements for emergency core cooling conditions were completed in 1976 and the point of departure from film boiling (DFB) – or quenching point – has been determined. This is essential for the layout of emergency core cooling systems. A physical model is now being developed to describe the film boiling heat transfer in subcooled conditions prior to the DFB point for all realistic emergency core cooling conditions. Together with another series of experiments that have been carried out by the JRC on heat removal by radiation, these investigations have made an important contribution to a fuller understanding of emergency core cooling in the LWR.

A further series of experiments has been mounted on the 4 MW BOWAL test loop in collaboration with the German BMFT and the Italian CNEN. The experiments are designed to determine the boiling mixing effect between subchannels in PWR and BWR type sixteen-rod cluster geometries. Under steady state conditions these experiments should provide more precise information about the departure from film boiling margin while the mixing process under transient conditions will help to determine the initial blow down phase.



**Ispra**

**Reactor safety. The boiling Water Loop (BOWAL)**
**Left: a view of the loop**
**Right: the head of the 16-rod bundle for mixing test**

A new test facility has been built for the study of the interaction between molten $UO_2$ fuel and water. The first experiments showed only slight fragmentation and consequently the pressure rises were small.

Viscosity and surface tension measurements have been made for $UO_2$, stainless steel, Zircaloy 4, and possible compositions of these materials that might arise during the melt down of an LWR core. Preliminary measurements are currently being evaluated and it is envisaged that these measurements could be extended to melt compositions that might result from an LMFBR core.

Extensive studies have been carried out on forced convection liquid metal boiling to provide the basic information on the flow redistribution during the transient from a single phase coolant flow to a two-phase boiling

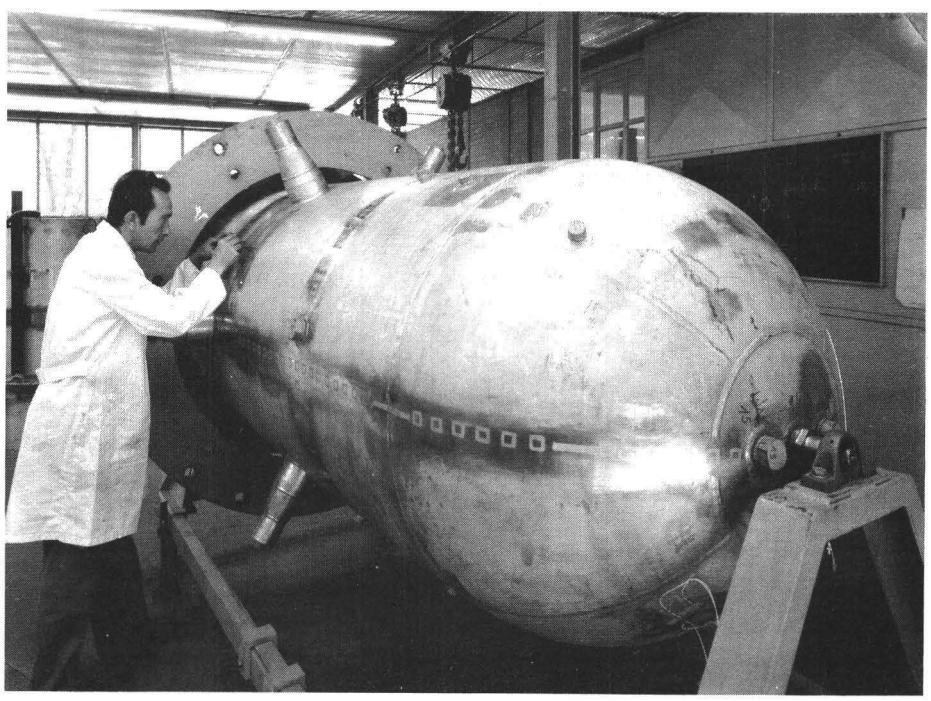
regime in an LMFBR. As a result of these studies it has been possible to develop a computation code to predict the pressure drop, dry-out and heat flux under two-phase boiling conditions.

As a result of preliminary experiments of liquid metal boiling behaviour in porous blockages, it has been possible to establish a further test programme which will give a more realistic representation of likely channel blockage in LMFBR cores.

New computational codes have been developed to describe the thermo-hydraulic behaviour of LMFBR core subassemblies under anomalous conditions such as: a cooling deficiency inside the subassembly due to a geometrical anomaly or a thermohydraulic transient due to a sudden deterioration of cooling or rapid change of power.

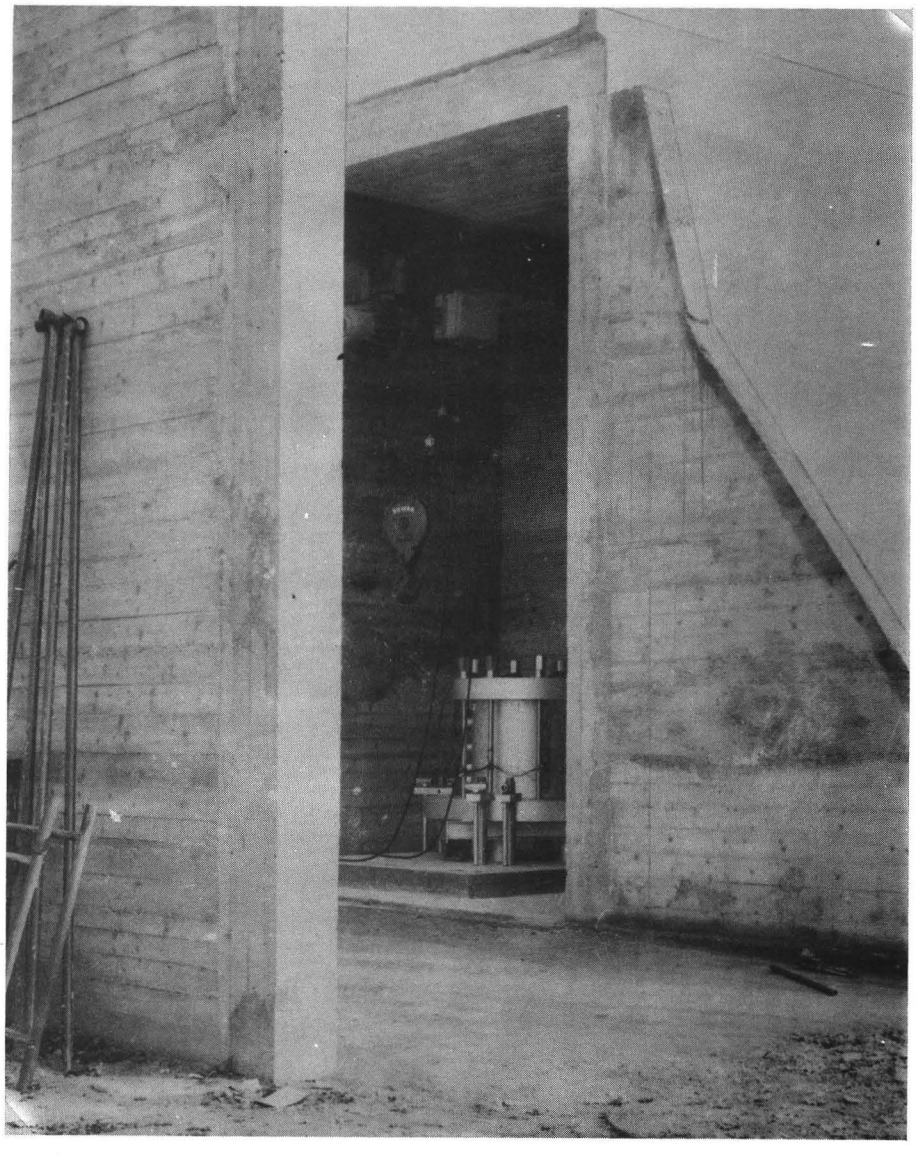
New methods have been developed to compute the transient temperature distribution in fuel rods and the coolant temperature transients in a single fuel channel of an LMFBR. These computational methods, which are essential for the prediction of thermal response of LMFBR subassemblies to loss of coolant transients, have been validated by experiment.

Special early detection systems have been developed for the location and assessment of size of blockage in LMFBR subassemblies. The detection method makes use of thermohydraulic noise analysis.



**Ispra**
**Reactor safety. Reactor vessel mock-up scale 1:6) being prepared for explosive test**

An extensive experimental code validation program (COVA) for the dynamic loading and response of the primary containments for LMFBRs has been agreed with national experts. This makes a substantial contribution to the assessment of containments for both pool-type and loop-type LMFBRs. Tests were performed in 1 : 6 and 1 : 10 scale mock ups to investigate the behaviour of important safety structures such as shield tanks, perforated plates and bursting plugs. The existing codes in this area (ASTARDE, SURBOUM, and REXCO) have been improved and the calculations have been checked against the experimental results of the COVA tests. New codes (EURDYN 1, 2 & 3) have been developed for the non-linear dynamic response of structural components and will be validated with the respective experimental tests. These activities have been



**Ispra**
**Reactor safety.**
**Mock-up component ready for explosive test in concrete bunker**

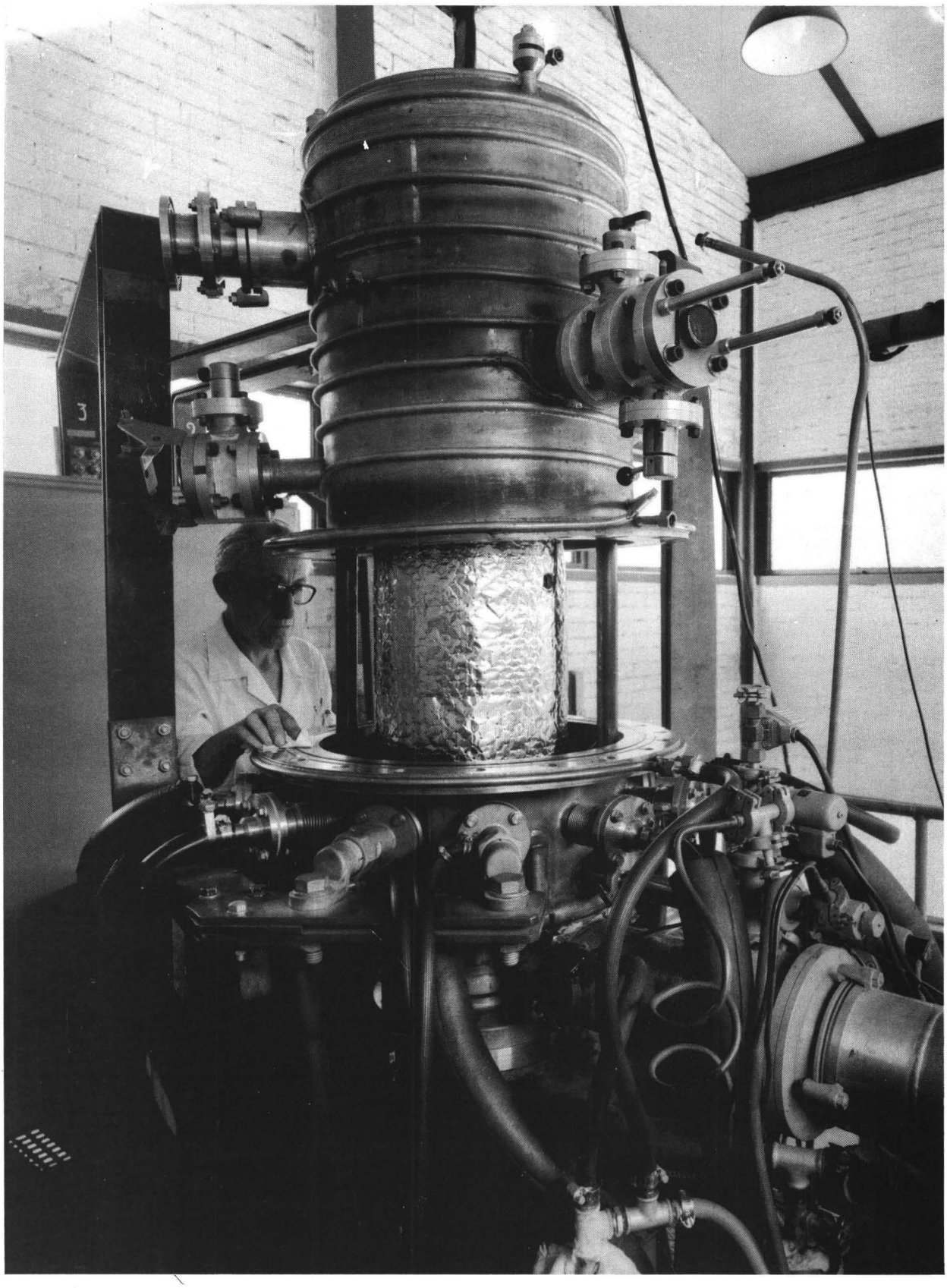
accompanied by experiments aimed at the determination of the dynamic behaviour of structural and vessel materials for the different dynamic loading which may arise in the event of a disruptive accident and long term creep-fatigue behaviour of reactor materials under realistic conditions.

The interaction between molten $UO_2$ fuel and liquid metal has been investigated in a number of experiments and has provided the necessary information for the assessment of the impact of an LMFBR core meltdown on the inner structures of the reactor and the pressure increase in the primary vessel. The analysis of the results shows that the assumptions made in the parametric calculation codes are pessimistic and that more realistic models of the mixing and fuel fragmentation procedures are needed in order to explain the experimental results.

Extensive theoretical effort has been devoted to he development of methodology for probabilistic analysis in reliability and risk assessments of large systems and to the development of suitable models for the assessment of the probability of failure of mechanical structures. A method has been developed which combines the probability transient paths with a deterministic analysis to define the consequence of each path. A detailed application of the method was carried out to determine the overpressure distribution in a PWR and two further pilot studies have been successfully executed.

**Ispra**

Reactor safety
Furnace for $UO_2$ melting
The interaction between molten $UO_2$ fuel and liquid metal takes place in a special loop placed below the furnace



# Applied Data Processing 6

**Scope**

The objective of the JRC Applied Data Processing programme is to provide high level services and to undertake development activities in selected field of informatics within a Community framework. The programme consists of three projects, interrelated to a certain degree, and chosen for their priority impact on the overall aim.

- The European Computer Program Institute (EUROCOPI), which evolved from a library of advanced computer programs used in JRC research activities, has now developed into a service for promoting the sharing of computer software within the Community.
- An Information Science project is charged with the objective of development and experimental evaluation of an integrated system for automatic documentation which provides, amongst other things, automatic indexing and key word construction.
- Methods and systems of computing are developed in order to provide the means for facilitating the interaction between users and computers and to allow users an optimal benefit of available resources.

**Achievements**

EUROCOPI has collected information on more than 10.000 computer programs of which about 2000 are processed by using a computerized interactive storage and retrieval system specially developed under the project. A service is provided to about 500 institutions with the publication of Computer Program Indexes and the Program Description series. EUROCOPI is also acting as a European distribution agency of non-European libraries. A recent initiative has been taken to establish closer collaboration amongst organizations interested in computer program dissemination and meaningful software transfer.

The first part of the information science activities have been devoted to the provision of the necessary informatics tools. A generalized system for language processing known as SLG-II (Simulated Linguistic Computer), is now fully operational. As a first large-scale pilot application of automatic indexing in a real-life environment, the International Nuclear Information System (INIS) of the IAEA was chosen. The work is being performed in cooperation with the Directorate General for Scientific and Technical Information and Management in Luxembourg.

A modular calculation system, known as CARONTE, has been developed and has found application both at Ispra and at six outside institutions. An on going activity of producing and improving modern mathematical tools for systems modelling, numerical analysis and statistical methods in a research environment has found many applications.

# 7 Information Analysis Office

**Scope** The JRC Information Analysis Service provides high level services and support activities in special fields of nuclear engineering. The programme consists of three projects which were selected because of their incisive impact on the scientific community engaged in these areas of activity.

- The European Shielding Information Service (ESIS) has, since 1972, been providing a technical support for those sectors of the international scientific community engaged in research, development and design of radiation shielding. The service personnel collects, organizes, analyses, evaluates and disseminates shielding information.
- The International Nuclear Data Center (INDAC) has worked mainly on nuclear data evaluation, nuclear data processing and sensitivity analysis for radiation shielding applications.
- The European Structural Mechanics Information Service (ESMIS) provides a service in the field of computerised structural mechanics. It acts as a support to both licensing authorities and the nuclear industry.

**Achievements** Eight highly sophisticated computer programs for shielding calculations have been assessed and distributed by ESIS. The supporting technical advice service has been expanding and over a four year period more than 600 consultations have been dealt with. Valuable exchange of shielding information is maintained with contacts that have been established with more than 85 shielding groups and institutions.

The output of INDAC has included: an elaborate study for the evaluation of important shielding cross sections; the establishment of a series of standard and special purpose cross section libraries and distribution of the information to all the European nuclear research laboratories; and the development of a computer program for three dimensional sensitivity analysis for the study of real shielding configurations.

The ESMIS group has dealt with structural mechanics studies ranging from pressure vessel stress analysis to anti-missile and anti-earthquake structural design for seven nuclear projects in five different member states. More recently the activities have been directed towards the safety aspects concerned with the integrity of primary components.

# Central Bureau for Nuclear Measurements 8

**Scope**

The Central Bureau for Nuclear Measurements (CBNM) is concerned with the development and application of high precision nuclear measurement techniques. The resulting nuclear data are primarily applied in the fields of reactor development and the industrial and medical uses of isotopes, but they also lead to a better understanding of the properties of nuclei.

Another important activity of the CBNM is the preparation of carefully defined nuclear samples which are distributed to national laboratories for nuclear measurements and for the calibration of analytical techniques.

The work of the CBNM is organized into three main areas:

- Neutron metrology for the measurement of neutron cross-sections and standards.
- Nuclear metrology, other than neutronic, for the measurement of standards and constants associated with the decay of radionuclides, dosimetry and measurement of isotopic composition.
- Preparation and definition of reference materials required for nuclear measurements.

Some slight changes in the emphasis of the work have taken place to meet new demands, notably the application of the available skills to the problems of safeguarding nuclear fuel and to the preparation and characterisation of some reference materials for non-nuclear applications.

Improvements to the major facilities are providing the CBNM with extended measurement capability. The electron energy from the Linac has been increased from 85 MeV to 160 MeV, the beam power has been doubled and the pulse width has been reduced from 10 to 4 nanoseconds. The improved machine, which should be ready for experiments by the end of 1976, will extend the range of the so-called white source neutron cross section measurments from the thermal-keV region to the thermal-MeV region. The Van de Graaff facilities are being extended with a new 7 MV generator fitted with a facility to supply either direct current or pulsed output. This modernisation, in addition to extending, the ranges of neutron energy available, gives more flexibility in the machine operation and usage. Two new surface ionisation mass spectrometers have been purchased and existing machines have been subjected to a programme of improvement and modernisation. This will help to meet the increased demand for elemental and isotopic analysis particularly for samples of fissionable material.

**Achievements**

A more consistent set of measurements has been made of the cross--sections of uranium-235 and plutonium-239 and 241 extending into the resonance region but normalised to accepted values at thermal energy.

In the resonance region an extensive programme of measurements of total and various partial cross-sections of fissionable and other reactor materials has been carried out. This allows the establishment of accurate values for the parameters associated with the numerous resonance has involved as well as the examination and correlation of statistical effects with the predictions of nuclear theory. Twelve isotopes of particular interest have been studied in this programme of cross-section measurements and in some cases the capture gamma-ray spectra have also been investigated to yield more information about the nuclear levels involved. Some fundamental

studies on the phenomenology of fission have also been carried out and amongst other things have shown that the variations of the kinetic energies of the fission fragments from resonance to resonance in uranium-235 are not statistically significant – a result which seems to contradict findings in the USA.

In the fast neutron region measurements have been completed on four important neutron induced reactions which have convenient threshold characteristics for use in neutron dosimetry and additional work is in progress on two further reactions. Some important evaluations of the data relating to neutron producing reactions in deuterium, tritium and lithium have also been carried out. Valuable contributions have been made in the continuing effort to fill the gaps in neutron cross-section data and to resolve various anomalies. In view of the importance of absolute measurement of neutron cross-sections, the problems associated with the measurement of neutron flux have been studied. In order to try to resolve differences in measurements at various laboratories the CBNM has participated in the first round of an international comparison of a measurement of fast neutron flux.

Surprisingly perhaps, the half lives of the important fissile materials are still not known to the required degree of accuracy. Accordingly work has been completed on an extensive series of measurements on the half life of uranium-233 and the results are in good agreement with coincident measurements made elsewhere. A similar series of measurements on plutonium-239 is well under way and work has started on plutonium-241. Half lives and other decay parameters of ten non-fissile radionuclides have also been measured.

In connection with the metrology of the radionuclides, an important activity has been to contribute to three international comparison measurements organized by BIPM (Bureau International des Poids et Mesures) with the objective of overall improvement of accuracy.

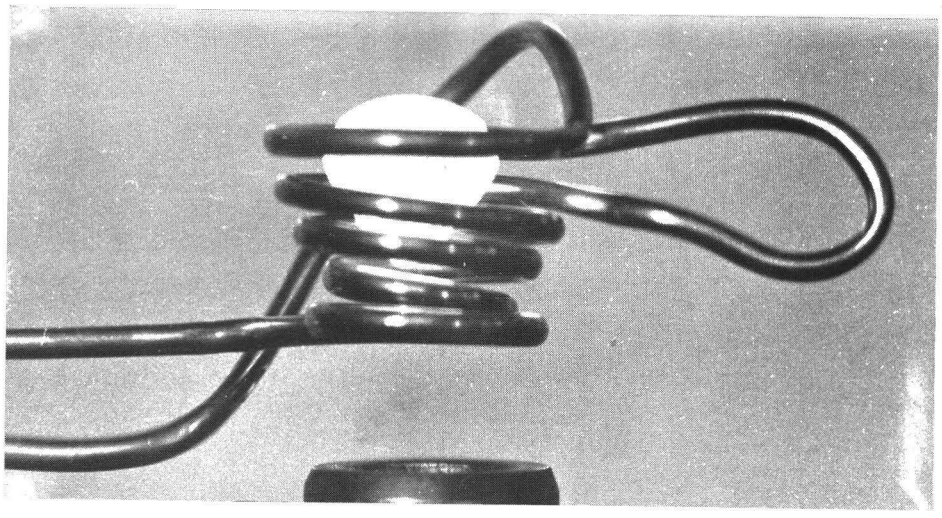
Measurements of some atomic constants have also been performed and a compilation of measurements and best estimates of isotopic abundances of the natural elements has been made.

There has been a steady increase in the number of orders for carefully characterised samples and targets fabricated by CBNM for use in nuclear measurements. Many of these samples were in the form of thin films and were prepared by special electrospray and evaporation techniques. Others were alloys with certified composition or bulk samples requiring more conventional fabrication and in some cases canning techniques. A large fraction were samples of fissionable material.

To improve the characterisation of the thin film samples new methods for determination of film thickness and in some cases film uniformity were developed.

There has also been much activity in the preparation and characterisation of nuclear reference materials required for calibration purposes in the measurement of fissionable materials by destructive methods. Three batches of uranium hexafluoride, with natural, depleted and enriched uranium, have been characterised with the uranium-235 abundances certified to 0.15%. Solutions of uranium-233 and plutonium-242 that can be used as added spikes in isotope dilution mass spectrometry, have been calibrated and the isotopic compositions of the primary chemical uranium standards supplied by the US National Bureau of Standards have been measured. A series of reference alloys of uranium-plutonium, aluminium-uranium, uranium-molibdenum, and aluminium-plutonium have been

prepared by quantitative levitation alloying and the compositions have been confirmed by isotope dilution mass spectrometry. Work is in progress on further alloys of thorium-uranium, aluminium-thorium and aluminium-uranium.



**Geel**
**Preparation of nuclear reference materials. Levitation melting**

The CBNM has participated in international programmes organized by the US Energy Research and Development Agency (ERDA) to evaluate and compare methods used to analyse fissionable materials.

A reliable method has been developed for estimating the Pu 238 abundance in isotopic Pu mixture based on alpha spectroscopy.

As an important service to the Directorate of Safeguards of the Commission, work has been undertaken on the analysis of samples taken from nuclear power plants in the Community by Safeguards inspectors. Destructive methods based on isotope dilution spectrometry have been used to give fissile material content and the same time isotopic compositions. This service has developed to the point where coordination of similar analyses made by other JRC laboratories is made from the CBNM, which gives also help in evaluating the data and deciding whether there are statistically significant departures from the declared values.

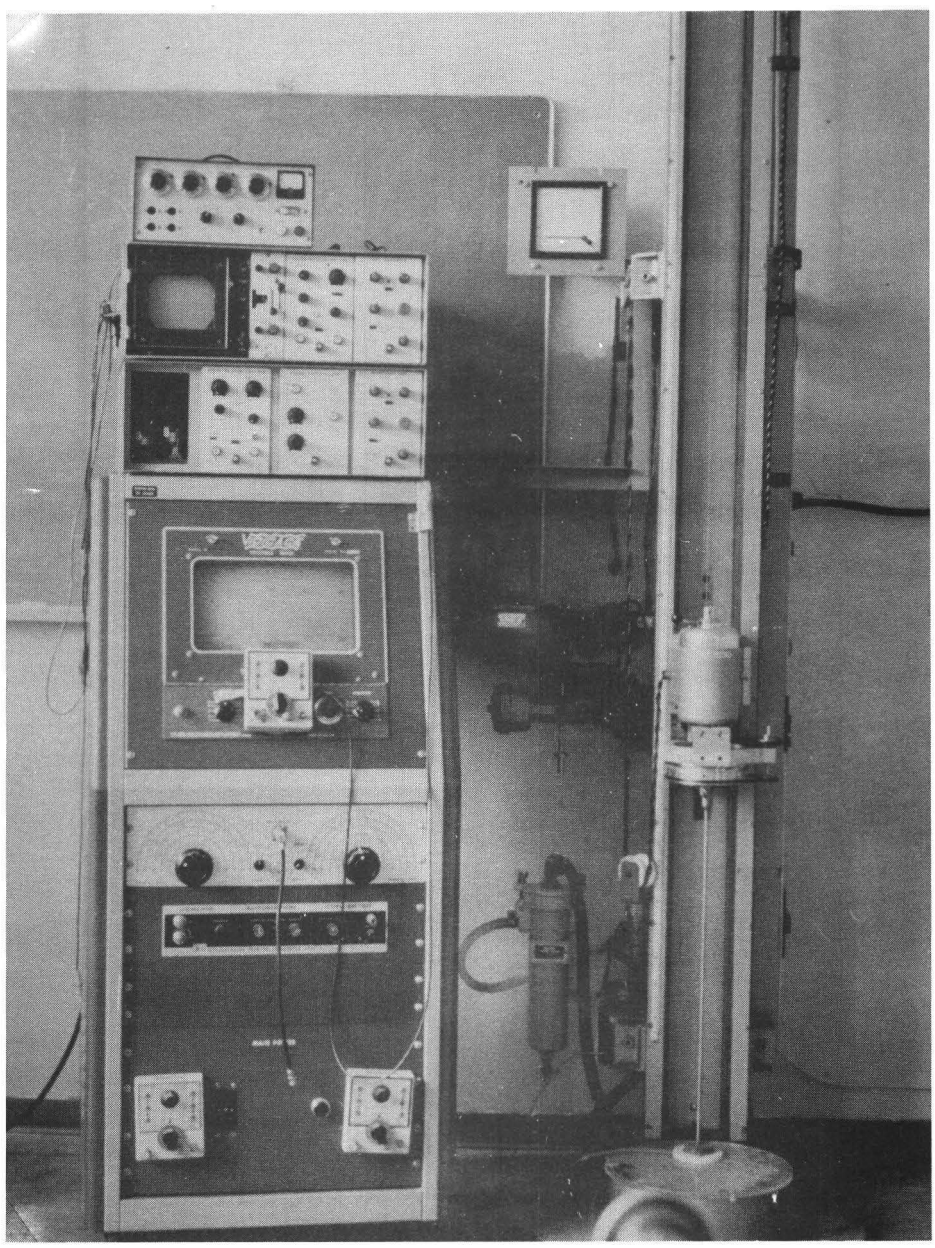
The CBNM has also provided services in the field of non-nuclear reference materials. In addition to giving advice, the preparation and analytical techniques available at CBNM have been used to give positive laboratory support to some indirect action programmes of the Community. In connection with the programme to improve methods of determining traces of noble metals in metals, reference samples of copper containing various trace quantities of plutonium and palladium have been prepared and distributed to measuring laboratories while samples with known quantities of silver and gold are being prepared.

Some development of nuclear methods for sensitive analysis of trace materials is in progress using the radiations available from the CBNM accelerators. A method based on resonance neutron capture has been investigated and studies of gamma-ray activation using bremsstrahlung from the Linac and Rutherford backscattering, ion-induced X-ray fluorescence using the Van de Graaff, have been started. The possibility of using a method based on beta-ray absorption to measure the real density of dust collected on a filter, is also being investigated.

# 9 Technical Assistance to Power Plant Operators

**Scope** The JRC has undertaken studies in various fields where it possesses the necessary competences, in order to find solutions to some of the specific problems encountered by operators of nuclear power plants. This work was started in 1973. There have been three main areas of activity and one important new activity has recently been started.

- Water chemistry experiments to study the generation, transport and deposition of corrosion products in the primary circuits of light water reactors.
- Post irradiation examinations both for the study of mechanisms responsible for fuel rod failure and to produce information, by radiochemical analysis, on burn-up and isotopic composition of irradiated fuels.
- Development of improved techniques for quality control of reactor components, in particular better methods and apparatus for non-destructive tests in power stations.



**Ispra**
**Assistance to nuclear power plant operators. Ultrasonic apparatus for the detection of fuel rod damage**

- Investigation of techniques for decomposition of reactor components, a new study started in 1976 in response to strong interest from the operators of nuclear power plants.

**Achievements**

Experiments carried out in laboratory test circuits have provided a better understanding of the phenomena of corrosion product production, mobility and deposition, and can contribute to practical solutions of problems that have been encountered in operating nuclear reactors. This work is carried out in collaboration with the Water Chemistry Group sponsored by the Commission as a platform for discussion between power station operators and research centres.

Fuels irradiated in the Trino Vercellese and Garigliano reactors in Italy and the Gundremmingen and Obrigheim reactors in Germany have been examined in post irradiation facilities of the JRC. As a result of this work it has been possible to supply power station operators and fuel management groups of the Community with data which allows them to verify and improve their nuclear fuel burnup codes.

In the development of non-destructive test equipment for quality control, ultrasonic equipment has been designed which makes it possible to detect damaged fuel rods without having to dismantle the fuel assemblies.

# 10 Training

**Scope** The JRC set up a Training and Education programme in 1973 in recognition of the growing importance of permanent education systems in the modern technological society and of the interest of a European contribution in this field. Essentially the programme is aimed at the dissemination of knowledge acquired at JRC in the framework on its research activities. This has been achieved by organizing courses and seminars for external people.

As this type of activity was quite new in Ispra, the first year was mainly devoted to the setting up of a team, the development of the organizational procedures and the identification of possible subjects for courses and seminars. In order to offer a real and complete educational service and to complement the disciplinary skills available at Ispra, it was recognised at the outset that some of the courses would profit from the contribution of external specialists and guest lecturers. This outside contribution is also thought to stimulate exchanges which will be of benefit to the course participants.

**Achievements** The courses, in English and Italian, were started in 1974 and have increased from a total of seven weeks of courses in that year to 12 weeks in 1975 and 20 weeks for 1976. The number of participants was 66 in 1974 and 229 in 1975. Ispra staff members acted as scientific coordinators and provided some 50% of the lecturers.

The subjects covered include : protection of the environment (two courses), Safeguards and fissile material control (two courses), Engineering science (three courses), Radioprotection and shielding (four courses), Material science (one course), and various other subjects (three courses).

# Technical Assesments in Support of Commission Activities

# 11

**Scope**

The JRC has undertaken a number of evaluation studies in order to provide technical information support to the Commission services in elaborating the various sectoral policies for the Community. The majority of the work undertaken by the JRC in this context has been focused on the energy field and some attention has also been devoted to transport problems related to energy consumption and transmission.

All the studies were explicitly requested by the Commission services and the priorities were established by an inter-General Directorate Committee. The main subjects covered are as follows:

- Analysis of the installation policy of power plants for electricity production,
- Studies of the perspectives for high temperature gas-cooled reactors (HTR) and of liquid metal fast breeder reactors (LMFBR),
- Other studies concerning energy or energy-related transport problems,
- Consultative studies on the evolution of electronic components for computers.

**Achievements**

Computer methods capable of describing the consequences of various alternative policies on the energy system have been elaborated. The JRC at Ispra is now able to offer an advanced tool in this field. Using similar computational techniques to those of the energy studies, a specific analysis has been made to clarify the advantages and disadvantages of the HTR and the LMFBR and their possible penetration of the energy market.

Other assessments have been made of the possible utilization of waste heat; the use of methanol as an alternative energy carrier; the energy balance of advanced high speed transport systems; the future transport system for radioactive materials; and the transport of oil to Europe from the Middle East including the prospects for nuclear ships.

# 12 European Informatics Network

**Scope** A project to establish an experimental computer network was put forward in 1971 by the COST group (Co-Operation Européenne dans le Domaine de la Recherche Scientific et Technique) at the initiative of the Commission and a number of European countries. The project — also known as the COST 11 Project — is being used to explore the problems related to telecommunications networks connecting data processing centres and to the logical connection of computers of different kinds into a heterogeneous network.

The project, which came into force in February 1973, involves the participation of the Federal Republic of Germany, France, Italy, Yugoslavia, the Netherlands, Portugal, Sweden, Switzerland, the United Kingdom, and the Commission.

In the first phase the network consists of five nodal centres situated at the Politecnico of Milan, the Institut de Recherches en Informatique et Automatique (IRIA) in Paris, the National Physical Laboratory at Teddington near London, the Eidgenössische Technische Hochschule Zürich, and the JRC at Ispra.

The Ispra staff has participated actively in the design specification of the telecommunications subnetwork and in the choice of the contractor — the Consortium SESA-LOGICA.

**Achievements** The subnetwork has been installed and became operational in May 1976. Information is conveyed in the form of packets which are switched at the nodal centres until they reach their destination.

In parallel the JRC has developed the necessary hardware and software for connecting the local computers to the network and has participated with teams at the other nodal centres in order to define standard protocols for exchanges between computers. These protocols are now being tested and will allow specialists to communicate with each other using special programs conceived for this purpose.

The JRC has also developed software to test the subnetwork under various conditions of load and errors. The testing of this software should be completed by the end of the year when it will be made available to the other participants.

# Research under Contract 13

**Scope**

This programme is intended to promote the industrial valorization of the JRC research. It should lead to the diffusion of ideas processes or patents originating from JRC research activities. Work in this direction includes: the carrying out of special tests on apparatus patented by JRC; the organization of stands at scientific exhibitions; the development of ideas and processes which have a good chance of leading to contracts or for which contracts have already been drawn up.

**Achievements**

Activities have been successfully undertaken by this programme in the following fields: development of MET-X seals and welding techniques; development of a patented gas depurator; systems reliability analysis; applications of X-ray diffractometry to lattice parameters; technical support for the preparation of exhibition displays; development of ultrasonic instrumentation; studies of hydrogen diffusion mechanisms.

# 14 Standards and Reference Materials

**Scope** A programme of work has been undertaken by the JRC to establish reference methods of strictly controlled accuracy and to produce reference materials for calibration of instruments and verification of measurement methods. This activity provides a basic tool for a community system of references, contributes to the quality of products, and allows harmonization of the standards and regulations that facilitate commercial exchanges. Efforts in this direction are considered to have an immediate effect on environmental policy, consumer protection and public health.

The establishment of references necessitates a large participation of laboratories at a Community level. As a result the Establishment of Ispra together with those at Geel and Petten and several hundred other laboratories in Member States are associated in an indirect action on reference and standards (Community Bureau of Reference, BCR).

Some 60 groups of experts have been set up to deal with the various problems encountered in this field and half of them are strongly supported by specialists from JRC. The contribution from Ispra has been in three general directions: support of the BCR Secretariat; support for services of the Commission; and development of reference materials and methods.

**Achievements** About 1500 organizations have been questioned about the need and the availability of reference materials and a guide book with addresses of the producers of reference materials and high purity products has been published. A computer data bank on reference materials and high purity products has also been established. Selected documents concerning reference materials have been published. Statistical methods have been established and applied to the treatment of measurement data and information courses on the application of statistical methods have been launched. A computerized classified file has been established for CBR operations and contacts.

Experience acquired in the field of measurement and the interpretation of results is a constant support to the Commission Services in charge of establishing and managing the common Customs Tariff. Special analytical methods have been developed for residues of pesticides in foodstuffs, fertilizers, surfactants and cosmetics, and further experiments are being undertaken to define methods for characterizing the risks of alimentary pollution by lead and cadmium from the enamel on crockery.

To help in the preparation of reference materials of certified composition or attested purity, a series of analytical methods have been developed or improved. These analytical techniques cover such materials as cokes, coals, vegetable and animal matrices, mineral and non-ferrous metals, atmospheric dusts, etc. Certain products (oxygen in metals and minerals) have been certified on a European basis while others (potassium, nitrate, coal, and cholesterol) have been cp-certified with the US National Bureau of Standards (NBS).

In the setting up of instrumentation for standard measurement of important physical properties the following has been achieved: an absolute viscosimeter has been constructed; heat pipe thermostats have been set up and their performance tested; two thermal conductimeters for

liquids and solids have been set-up and tested; a device for measurement of fixed points has been developed; and a simple method for measurement of thermal conductivity in non-conductive solids has been published.

Work on the instrumentation and preparation techniques for reference samples has resulted in: the realisation of reference tribometers; fabrication and characterization of 500 couples for friction tests; fabrication of 5000 reference specimens for impact tests; modification and metrology of impact test machines; instrumentation for the characterization of gauges for control of defects by ultrasonics; and technology for the fabrication of reference artificial defects.

Progress has been made at Petten on four new projects, in collaboration with various national laboratories, covering a range of organic reference materials and analytical methods in the field of petroleum products, plastics, rubbers and environmental protection. This is in response to a new programme of the Commission approved in August 1975 and aimed at making a contribution to the harmonization and calibration of analytical techniques within the Community in the field of organo-chemical products.

# 15 Protection of the Environment

**Scope** A Community programme of action in the field of environment has been decided in November 1973 and is intended to provide the Commission with technical and scientific support especially in the establishment and evaluation of scientifically based criteria for the most relevant pollutants in air, water and soil. In this way support is offered to the decision makers in legislating for proper environmental measures. Another important task is the building up of an information system for the dissemination of knowledge on environmental problems throughout the Community.

A JRC research programme on environmental protection (direct action) has been started at Ispra in 1973 and at the same time the Council of Ministers agreed in the same field on a three year programme of indirect action, which was extended by a second programme early in 1976. Both the direct and the indirect programmes are strongly interdependent and are supervised by the same Advisory Committee.

At the beginning of the programme there were at the JRC no interdisciplinary teams, able to deal with a large range of environmental problems. On the other hand there was a broad expertise from the previous nuclear programmes in areas such as analytical chemistry for trace elements, systems analysis, instrumentation, radiobiology and radioecology. Due to this the programme started with a relatively large number of smaller projects and emphasis was placed on the development of higly sophisticated measuring techniques and instrumentation of a kind that was not available on the market at that time.

Other activities such as the development of aerosol counters, the build-up of a thermal pollution demonstration model of a river and the investigation of aerosol absorption of organic materials (work performed at the Petten Establishment) were concluded during 1974. Studies on biotelemetry with laboratory animals and on water purification by catalytic oxidation gave interesting preliminary results but have nevertheless been concluded as they do not fit into the general lines of the overall programme.

It is now considered that the overall programme has a compact and homogeneous shape and forms a sound basis for the treatment of more ambitious projects in the future.

**Achievements** A highly sophisticated device has been developed for trace analysis of volatile pollutants in samples of air, water and soil. It is composed of sample enrichment columns, a gas chromatograph for the separation of the samples and a mass spectrometer as a detector. The spectra of unknown substances are automatically compared and interpreted by a computer aided comparison with a library of 25.000 known compounds. This unit allows the semi-quantitative analysis of any unknown pollutant rather than dealing only with those preselected for their real or possible hazardous nature, as was the case in the past. Early in 1976 this instrument was used successfully for the first exploratory measurements of micropollutants at the part-per-billion level in air. This work is also providing an important contribution to the COST project concerned with the analysis of micropollutants in water and aimed at the establishment of drinking water quality criteria.

In collaboration with the indirect action programme, a pilot project has

been set up an Environmental Chemical Data Information Network (ECDIN). In this project both numerical and text data are collected for more than 100 characteristics of the chemical of interest. This information includes: identification, structure codification, physical constants and anlytical data; supply, use and transport information; environmental dispersion and degradation data; and toxicity and regulatory information. For the demonstration phase of the project the number of compounds considered has been restricted to some 3000.

Studies of the decomposition of tetraethyl lead under environmental conditions have been completed and have shown that it decomposes with a half life of five hours in sunshine and is stable in the dark. This work is now being extended to study the photochemical reactions of natural and anthropogenic organic compounds.

Studies of the uptake of sulphur dioxide by plants and soils have made an important contribution to the COST Project concerned with physico-chemical behaviour of $SO_2$ in the atmosphere. A knowledge of the absorption behaviour of different standardised European soils and forest trees is important because they act as a sink for sulphur dioxide which is the most important atmospheric pollutant. Absorption studies for soils have been completed and preliminary results are available for beans at different humidity and pollution levels.

Long term and low doses experiments have been carried out to study the transport and metabolic mechanism of cadmium in laboratory animals and are being extended with similar studies using selenium and vanadium. This is part of an investigation of the transfer of heavy metals in environmental systems and is of special importance because heavy metal pollution deriving from the soil-water-food chain is one of the most serious risks to man's health (Cadmium is fixed by the ad hoc biosynthesized proteine metallo-thionine). Other studies were carried out to learn about the heavy metal transfer mechanism from polluted water to edible fish, to soil and to rice. Major results were gained in: the knowledge on zinc metabolism and its alternation by cadmium and mercury in fish; the effect of cadmium and iron on vitamin $B_{12}$ storage in fish; and the experimental transfer of zinc and cadmium from lake water to soil and rice.

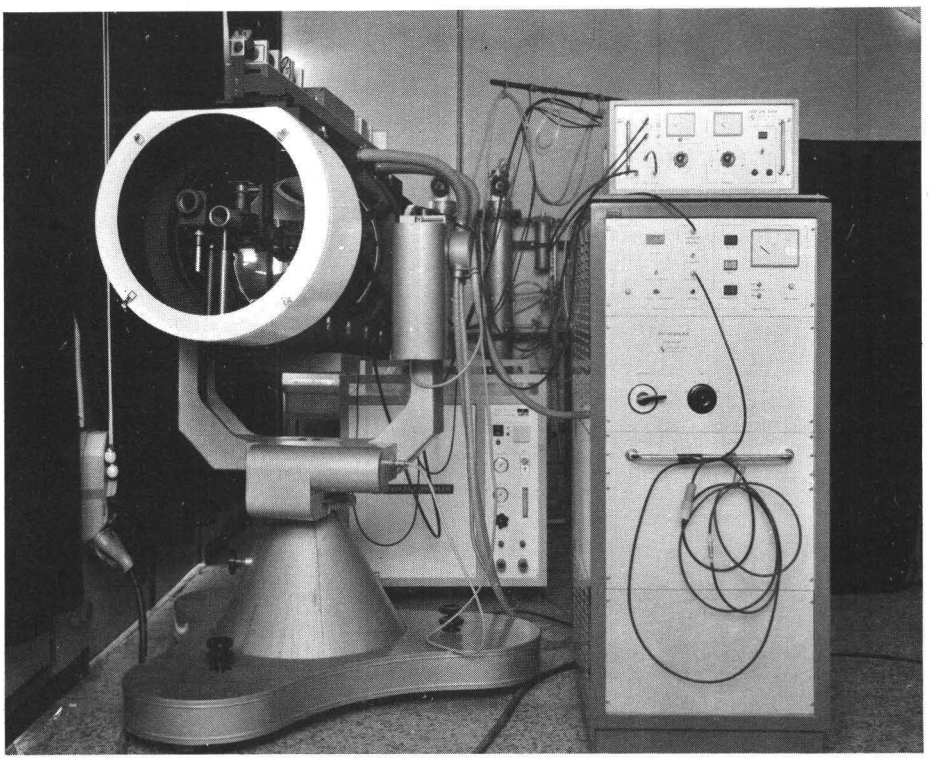
A large scale experiment has been initiated, in collaboration with the indirect programme, to study the environmental pathway of automotive lead. Use is being made of a particular isotopic composition of lead as a natural tracer. For two years all the gasoline sold in Italy will contain anti-knock lead of an isotropic ratio 206/207, of 1.04, which will distinguish it from the background values of 1.16. The analysis campaign is concentrated on the Turin and Cagliari regions. A total of 24.000 samples will be taken from aerosols, vegetation, water, food and human blood. A considerable improvement in analytical procedures was called for in order to provide the necessary precision in mass ratio determinations.

A study has been started to investigate the over-nutrition (or eutrophication) of lake water by phosphates and nitrates. In particular the eutrophic state of Lake Lugano has been extensively investigated as a new water purification plant that went into operation in 1976 will allow the study of successive improvements in the water quality. Mathematical models describing the ecological system biomass-nutrients-water have been developed. An instrumented buoy for the monitoring of relevant physical and chemical parameters was installed in 1976 and is now operating.

A big effort on instrumental development for air pollution studies was made due to the relative lack of suitable commercial instruments at the

beginning of the programme. Some of the results are as follows:

- A Raman Lidar instrument to measure gaseous pollutants, temperatures and humidity of air has been developed and is going to be used in a lorry mounted version.



**Ispra**
**Environmental research. Raman Lidar for the measurement of gaseous pollutants, temperatures and humidity of air**

- An assessment has been made of the technique of long path absorption of tunable infrared laser light for measurement of carbon monoxide and organic pollutants.
- The performance of a BARRINGER correlation spectrometer for long path absorption measurements of $SO_2$ and $NO_2$ in the part per billion range over 10 km distances was verified.
- An acoustic sounder (SODAR) for the study of inversion layers of the atmosphere was successfully applied in field measurements.

The Barrington and Sodar instruments were used in large scale intercomparison compaigns for remote sensing techniques. organized as part of the indirect action programme, at Lacq in France and Drax in the UK.

For air quality monitoring of urban areas, mathematical prediction models have been developed and tested by means of tracer techniques.

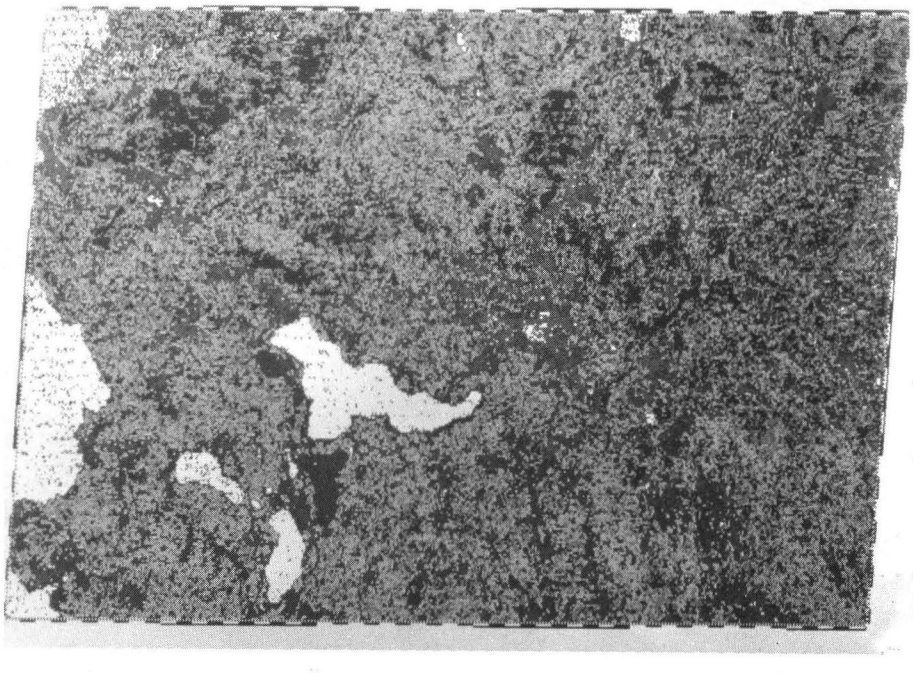
In this field Ispra is collaborating with regional projects around Frankfurt in the Federal Republic of Germany and Venice in Italy.

# Remote Sensing of Earth Resources

# 16

## Scope

Programmes of agricultural and agronomic development are heavily dependent on having accurate and timely survey information for wise decision making. This is important for the proper management of renewable resources and for the achievement of desired increases in food and wood production. Remote sensing techniques can greatly accelerate and expand data collection and processing operations. With this in mind a pilot project known as AGRESTE has been carried out by the JRC at Ispra. The three Commission Directorates General for Agriculture, for Development and Cooperation and for Research, Science and Education have been involved together with the Commission's Statistical Office and several national institutes. Use is made of data from the LANDSAT – 2 satellite in the frame of an agreement with the US National Aeronautics and Space Agency (NASA), concluded after a severe selection among several applicants. The aim of this pilot project was the evaluation of satellites and associated aircraft facilities in a typical context of European agricultural conditions ranging from artificial closed ecosystems – such as irrigated rice crops and poplar plantations – to natural ecosystems – such as beech forests and conifer afforested areas.



**Ispra**
**Remote sensing. Thematic map of land use of the Ispra area established from satellite data. The Lago Maggiore is the white area at the left of the photo. The city of Varese is near the centre.**

## Achievements

Work carried out prior to the satellite launch included: laboratory identification of spectral signatures; feasibility evaluation of poplar inventory in different plantation productivity classes; identification and outline aerial radiometric and photographic monitoring of rice areas affected by disease; preparation of software for data processing of satellite information; and correction of satellite digital data from atmospheric masking effects.

The post-launch and on-going studies include: large scale systematic acquisition of radiometric, photographic, meteorological and ground-level agronomic data; correlation of optical properties with vegetation characteristics for rice by means of greenhouse, lysimeter and open-field

radiometric and agronomic measurements; and automatic digital classification and inventory of rice cultivated areas, poplar plantations and natural forests.

A multidisciplinary team has been created at the JRC Ispra and use is currently being made of aircraft, helicopters and terrestrial platforms equiped with advanced instrumentation. A computer program has been developed and a correct classification and interpretation is possible for the main agricultural subjects on digital maps.

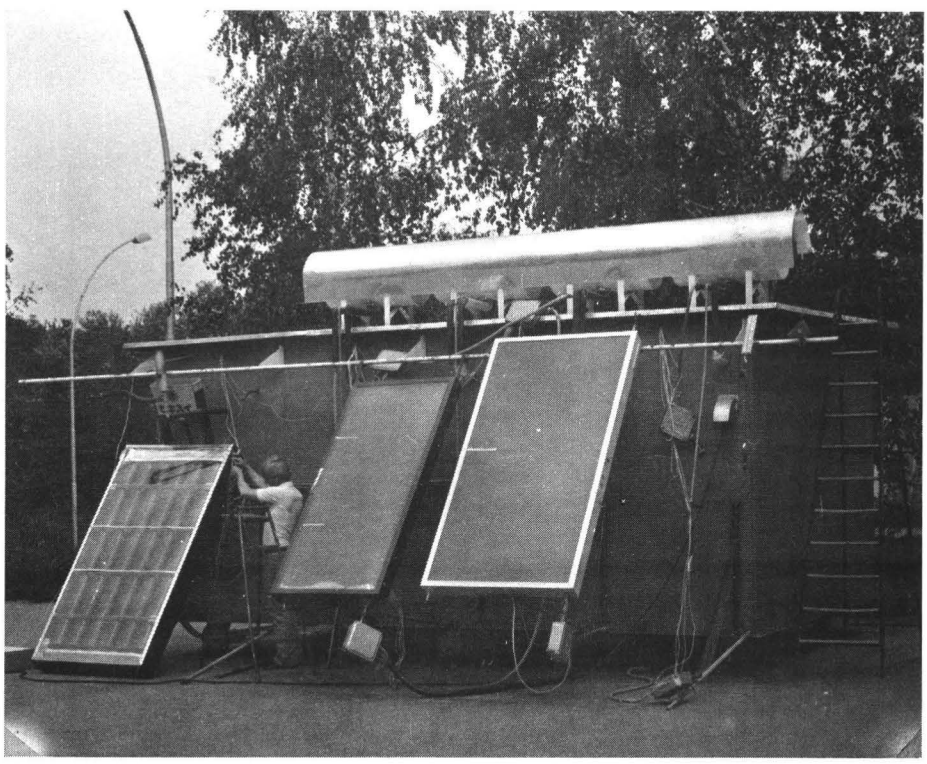
# Solar Energy

# 17

**Scope**

Under a programme of new technologies the JRC has been looking at alternative energy sources – other than nuclear energy – since 1970 and this work was intensified after the oil crisis in 1973. In January 1973 a four years programme on solar energy thermal conversion, direct conversion and basic research was started.

The main objective was the design of high performance flat plate collectors for house heating (and cooling) and to develop standards of test procedures for European industry. Basic studies were undertaken on the direct conversion of solar energy into electricity and the possibility of using solar energy to produce chemical fuels such as hydrogen.



**Ispra**
**Solar energy research. Flat plate collectors being installed for heating**

**Achievements**

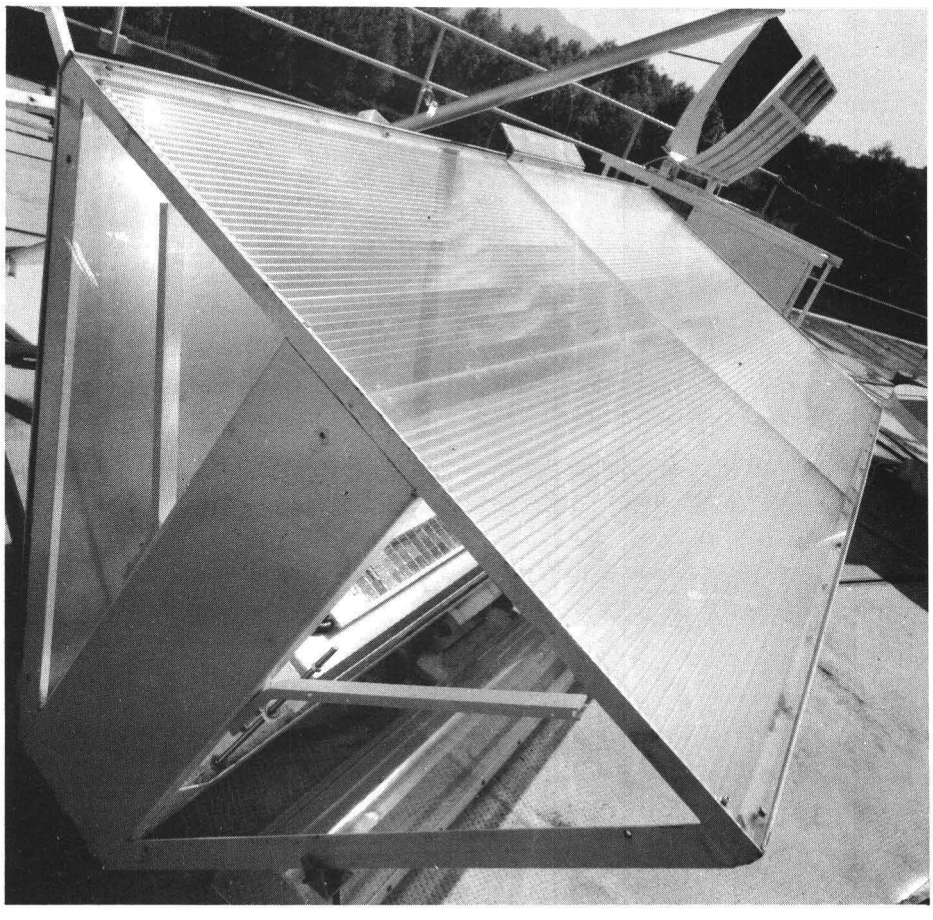
It become apparent during the programme that it was vitally important to improve the elaboration and standardisation of measurement procedures for solar collectors due to the widely dispersed views of European industry in this area. Accordingly a considerable effort was put into this subject.

The selective surfaces playing an important part in achieving high performance from collectors, several new surfaces have been produced and are undergoing endurance tests.

Systems investigations on combined heating/cooling systems were carried out for habitat and a field test facility is under construction.

Although electricity can be produced directly from sunlight by photovoltaic cells, the cost is extremely high for the current systems. Concentration devices can decrease the costs and several concepts of mirrors and lenses have been studied and executed at Ispra.

**Ispra**
**Solar energy research. A row of photoelectric cells receives sunlight concentrated by a large plate-type Fresnel lens**



The theoretical thermodynamic limits have been determined for the production of hydrogen and other chemical products via photoelectrochemical processes or quantum conversion.

Experiments to demostrate the possibility of creating electrical energy from the action of direct sunlight on a titanium oxide plate were conducted successfully.

# Raw Material Recycling

# 18

**Scope**

Although a programme of study of recycling of raw materials was approved as part of the New Technologies activities in 1973, an exploratory study lead to the conclusion that only a very limited JRC activity was at present possible in this field.

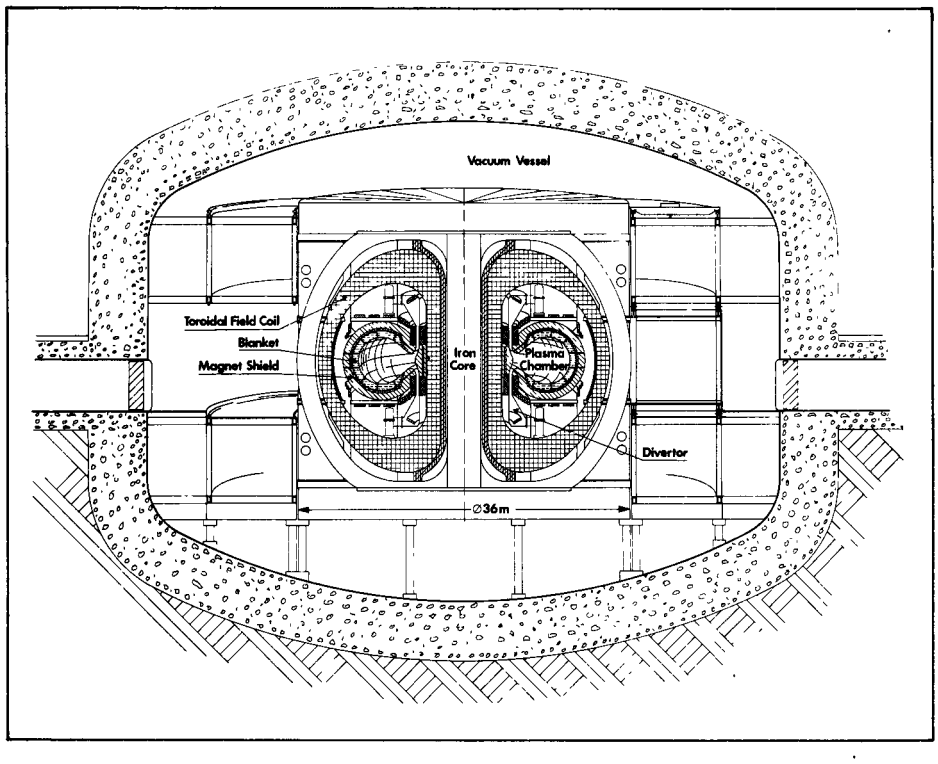
**Achievements**

A systems analysis has been performed to determine the consequences of various degrees of recycling and the substitution for a number of non-ferrous materials on the availability of resources and on the energy balance.

An experimental study on the feasibility of recycling muds arising from grinding operations was carried out. An original procedure for recycling molybdenum muds was evolved and a patent has been deposited.

# 19 Conceptual Studies on Fusion Reactors

**Scope** Conceptual studies on fusion reactors are being pursued at Ispra within the framework of the activities of the Fusion Associations of the Community. Ispra is contributing to the assessment of a Tokamak experimental power reactor concept in collaboration with the CNEN Establishment at Frascati and the University of Naples.




**Ispra**
**FINTOR 1 - A conceptual design of a Tokamak DT experimental power reactor. Schematic cross section of the nuclear island**

**Achievements** The cooperative work carried out by Frascati, Ispra and Naples University on a Tokamak reactor – designated FINTOR – has now reached the stage where the main physics and engineering constraints for a minimum size Tokamak experimental reactor have been classified. The main parameters for the reactor (FINTOR-1) would be: plasma radius – 2.25 m; major radius – 9 m; toroidal magnetic field on the axis – 3.5 T; thermal power – 90 MW. A parametric analysis has lead to the conclusion that, without important changes in the technical assumptions made in the study, the reactor dimensions cannot be appreciably reduced.

The main contributions of the JRC to the FINTOR conceptual study have been in the following areas blanket nucleonics; heat transfer and energy conversion systems; stress analysis; safety and environmental impact; general reactor layout; handling and repairs of reactor components.

The concept of transfering the vacuum boundary outside the reactor has been shown in these studies to be attractive. It would remove the need for high temperature vacuum joints, ease maintenance and repair operations.

The structural arrangements of the blanket modules and their maximum dimensions have been evaluated by three dimensional thermo-mechanical calculations (finite element methods). Severe restrictions on the space between the plasma region and the inner magnets has lead to the concept of a D-shaped blanket. The inner shield and the outer blanket/shield have been evaluated by a multi-group one dimensional "discrete ordinates" code chain set up at Ispra.

# High Temperature Materials 20

**Scope**

Rapidly expanding interest in new energy technologies has created a need for better understanding of the behaviour of materials at very high temperatures. In particular process heat applications with their attended operation of plant for long periods under hostile conditions pose many severe materials problems. Several other industrial needs are also of importance.

A programme of work on high temperature materials was agreed by the Council of Ministers in July 1975 to be formally effective from the beginning of that year. The work is being carried out at the Petten establishment.

The programme has been defined in the following terms:

- Expert evaluation to assess industry requirements for advanced refractory materials and review of the research and development programmes already in hand in the Member States and elsewhere in the world.
- Basic research as an extension of work already in progress in the JRC; the directions of this research to be reviewed later in the light of priorities emerging from the survey work.
- Applied research centred on industry-oriented subjects to be defined in the light of the survey results.

Owing to the importanceof the survey in selecting suitable topics for research by the Petten team, work was put in hand immediately following the programme decision. In parallel, the adaption of existing laboratory facilities was undertaken to meet the anticipated demands of the new programme.

**Achievements**

Users and producers of high temperature materials participated in a colloquium in January 1976 and contributed to the clarification of research needs in this area. A White Book has also been compiled on the present position of the application and technology of these materials with contributions from acknowledged experts in the field.

A detailed working programme has been developed from the analysis of the survey results and was discussed by an ad hoc group of experts in June 1976. Two main objectives have been characterized: the need to understand the mechanisms governing the high temperature behaviour of materials in practical applications; and the application of the knowledge so gained to industrial technology.

The survey reveals that there is a particular need for research and development in the following fields:

- the effects of operational environments on mechanical properties
- the study of modes of failure of materials operating at high temperatures in plant or equipment.
- investigation into the relationship between the structure of materials and their properties together with the study of the fundamental processes involved.

- the testing of materials and components under operating conditions in a large test facility.
- evaluation of engineering codes and practices for high temperature materials.

In addition the need for a number of software activities has been identified. These include: the setting up of a forum for the efficient exchange of information and ideas between research and industry; and the organization of various information services such as newsletters, data banks, etc.

# Safeguards and Fissile Material Control 21

## Scope

Since 1969 the JRC has taken an active part in the development of techniques and procedures for fissile material control with the main objective of providing scientific and technical support to the Safeguards Directorate of the Commission and with the further aim of suggesting methods for more efficient and economic fuel management within the nuclear industry.

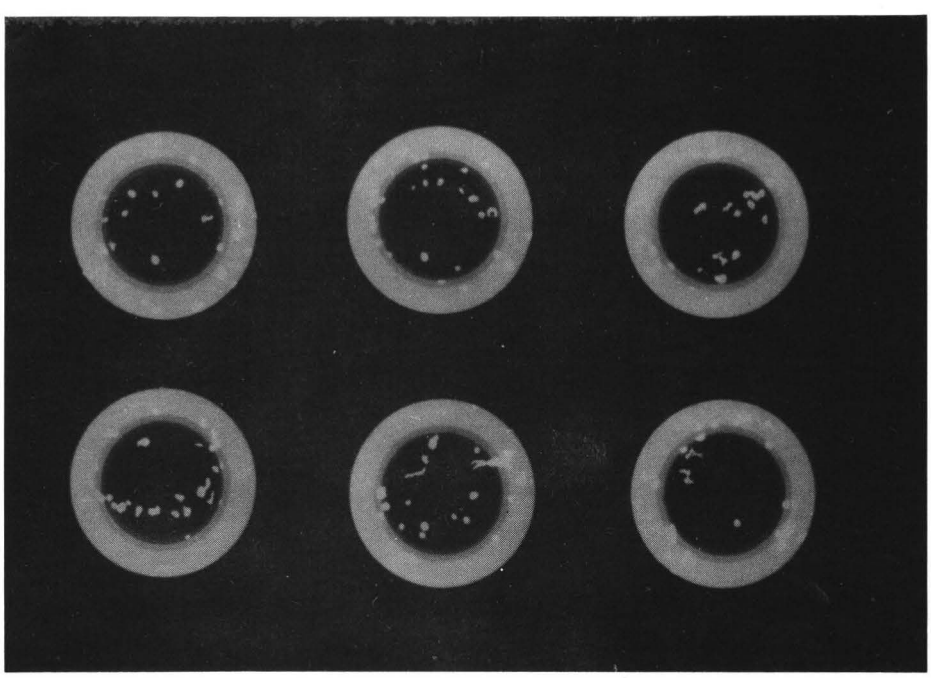
The research activity of the JRC in this direction is coordinated within similar activities carried out by other research groups in the Community in the framework of the European Safeguards Research and Development Association (ESARDA). Apart from this, direct collaboration in special fields has been established between the JRC and industrial firms. In this connection it is worth mentioning the work done with Nukem in Germany, Eurochemic in Belgium, ENEL in Italy, and Belgonuclèaire in Belgium.

The main actions of the present programme include: systems analysis of accountancy procedures; theoretical and experimental isotope correlations; non-destructive assay of fissile materials; and development of techniques for sealing and identification of fissile material containers.

## Achievements

The systems analysis work directed towards the optimization of the procedures and techniques used in accountancy of fissile materials for safeguards and fuel management purposes, provided special support to the Commission in the 1969-1973 period during the negotiations with the International Atomic Energy Agency concerning the application of the Non-Proliferation Treaty. Since the signature of the agreement in 1973, the activity has been directed to the practical implementation of the safeguards systems in nuclear plants.

The results of the isotope correlation studies carried out at Ispra and Karlsruhe have important applications in the control of plutonium at the input end of reprocessing plants.



**Ispra**
**Fissile material control. Radiography of seals containing randomly dispersed inclusions of different materials (bronze, tungsten, etc.). These seals, having tamperproof unique identities, are used for safeguarding fissile materials, and their examination is made by an ultrasonic method. The reflection of an ultrasonic wave by the inclusions results in a unique and perfectly identifiable pattern, which can be regarded as the inimitable "finger print" of the seal.**

Several instruments developed at Ispra for the non-destructive assay of fissile material have been tested at nuclear plants and are at present utilized by safeguards inspectors and plant operators. These instruments include: gamma scanners, counters of spontaneous fission neutrons; instruments based on the neutron interrogation techniques; and portable instrumentation for gamma ray spectrometry.

**Ispra**
**Fissile material control. A portable, complete seal identification system has been developed for use by fissile material inspectors. The system, complete with an automatic calibration device, is composed of a mechanism for the mechanical exploration of the seal, an ultrasonic instrument and a recorder. A digital output is optionally available.**

Different types of seals have been developed for both sealing and identification of vessels containing fissile materials or different types of fuel elements from materials testing reactors, light water reactors and fast breeder reactors. Some of these seals have already found practical applications by safeguards authorities and it is believed that they could play an important part in reducing inspection effort.

# Operation of the HFR Reactor

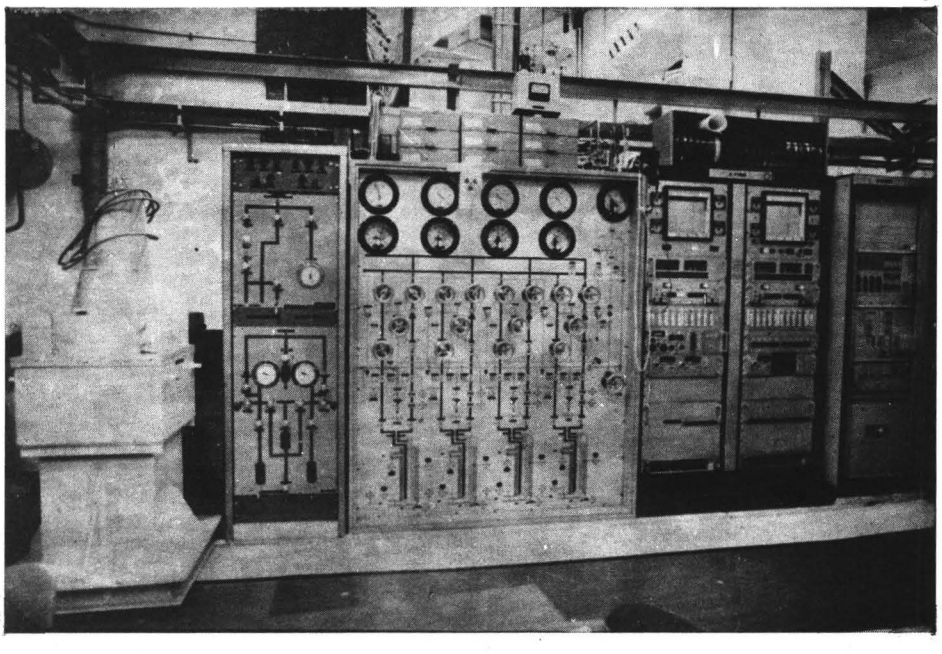
# 22

**Scope**

The High Flux Reactor (HFR) is part of the JRC at Petten. The programme covers the operation of the reactor and the planning, execution and supervision of irradiation experiments as a service available to reactor development projects, research programmes and ro radioisotope production.

Major improvements to the facilities of the HFR during the four year period have included:

- a change over to burnable poison fuel elements.
- a new reactor top cover and core configuration allowing increased irradiation possibilities and improved fuel element life.
- development of several computer codes for fuel management and for accurate assessment of irradiation conditions.
- modernisation of the electronic systems
- decontamination and resumed operation of the reactor dismantling cell.
- visual and dimensional control of all in-core components.



**Petten**
**Operation of the HFR reactor. The complete out-of-pile facility for simultaneous operation of 8 irradiation devices (Boiling Water Fuel Capsules) for studying the behaviour of fuel pins under pressurized water reactor conditions.**

**Achievements**

Due to a strict schedule of regular maintenance and renewal the HFR plant has been maintained in a perfect state of health.

New general purpose facilities have been made available comprising: central supply and control circuits for noble gases and cooling water, digital data loggers, and standard reloadable irradiation capsule.

A total of 114 major irradiation experiments have been undertaken during the 1973-76 period representing an average loading of about 30 highly instrumented materials testing irradiation devices per year. In practice, the reactor loading measured in irradiation units varied from 50 to 75% and turned out to be limited more by a lack personnel than by a lack of projects.

In addition there has been a consistently high utilization of the eight horizontal beam tubes equipped for nuclear and solid state physics experiments, and some 12,000 individual targets have been irradiated in eight special facilities for radioisotope production.