Commission of the European Communities

Annual Report 1980

Joint Research Centre Petten Establishment

Contents

Foreword

Annual reports of the Joint Research Centre's Petten Establishment, issued since 1975, were meant for the more specialized reader. This year, we have decided to try and to produce something of interest to a much wider reading public and we hope this volume will prove to be understandable to the general reader interested in research. For the expert, a list of documents has been included at the end of this report to which he is referred for further reading.

The first chapter introduces the work of the Establishment and relates this to technological needs in the European Community. It also briefly introduces the three major programmes executed at Petten.
Chapter two and four briefly sum-up the achievements of 1980 for the scientific divisions. Each of these chapters is followed by a description of highlights from the work of the programmes, chapters three and five.

1980 was characterized by being the first year of a new four-year programme and suffered somewhat from a lengthy discussion on the budget before the final decision by the Council of Ministers in July. Up till that time, emergency financing was made available to cover the Establishment's basic running costs; however, the more important expenditures had to await the availability of the budget.

Detailed information on scientific matters is published regularly both in the scientific press and as topical reports.

P.J. VAN WESTEN
director

I The Petten Establishment of the JRC in 1980

On March 13th, 1980, the Council of Ministers of the European Communities finally reached a decision concerning the new research programme for the period 1980-1983. Although the new programme is a continuation of the programme for the period 1977-1980, the accent has been changed in a number of areas.

The execution of irradiation experiments with the help of the High Flux Reactor (HFR) was continued, both in relation to the research for the further development of reliable and safe nuclear reactors and concerning materials research, the fundamental research of matter and the production of radioactive isotopes.

With reference to the research into the behaviour of materials exposed to high temperatures, the task of the Petten Establishment of the JRC during the previous programme was progressively oriented towards developments falling within the energy sector. High temperatures are characteristic of various conversion processes that will play a great role in the future, in petrochemistry as well as in energy conversion such as coal gasification, MHD and fusion. Some years ago, the JRC made an inventory of requirements for research in the field of high temperature materials in the countries of the Community. Thus the basis was established for a programme entirely directed towards the introduction of new technical methods.
In the process the Petten Establishment was charged with the creation of a meeting centre for European research in this field, where the exchange of information is concentrated.

This line of development, by which the materials research is directed towards the latest innovations in the area of energy conversion, was begun in time to be included in the 1977-1980 programme period and will be further developed during the new programme for the years 1980-1983.
Finally, environmental research is part of the new programme. In the old programme, this type of work was started as part of the programme concerned with research on organic materials. In the new programme, particular attention is paid to carcinogenic and other poisonous materials.

In this chapter, the overall lines of these programme components are set out. In later chapters, more details will be given.

The High Flux Reactor (HFR)

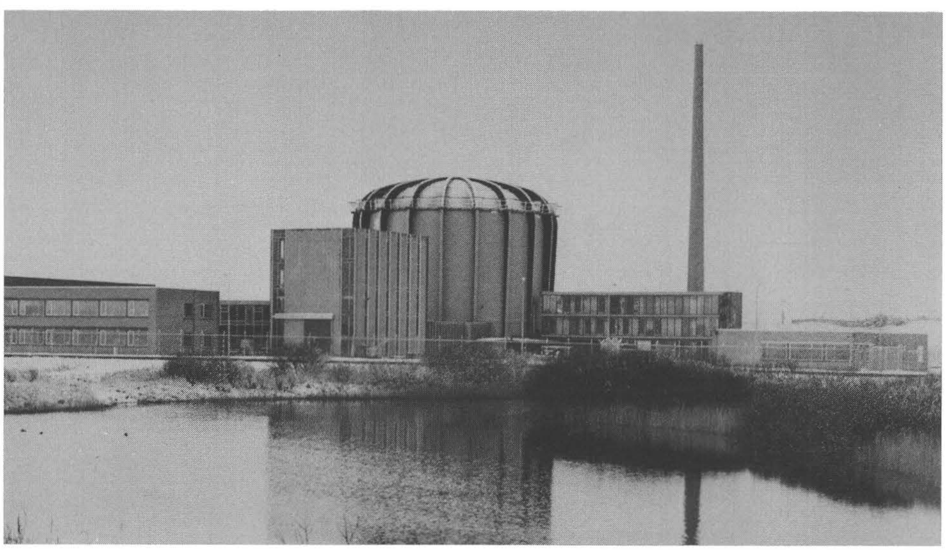
The research carried out in and around the HFR concerns for an important part the development of reliable and safe nuclear reactors for energy production.

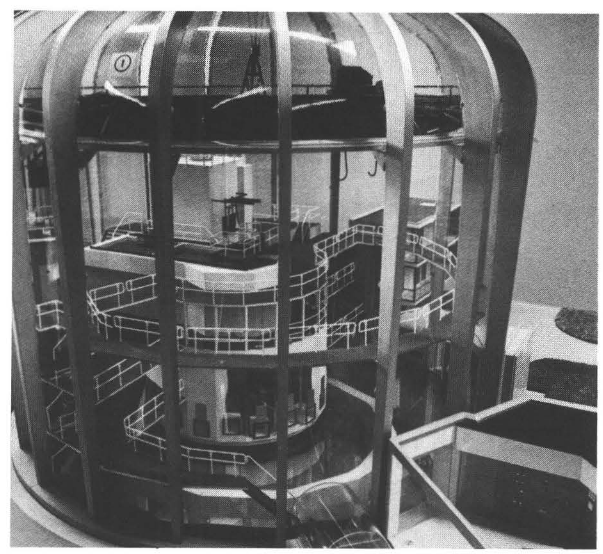
Research on materials and components for both nuclear reactors of the classical type that are used in various countries throughout the world, and advanced reactor types is also undertaken in the HFR. New materials and components are developed and then tested in the reactor under service conditions.

A second group of research activities is made up of experiments in which the radiations in the reactor are used for fundamental scientific research. With the help of neutron radiation, fundamental research can be conducted into the structure of matter. In addition, neutron radiation is also used for the radiography of constructional materials or particular components of technical installations.

Apart from these research activities included in the HFR programme, radioactive materials

The HFR reactor building at the Petten Establishment and a transparent model of the reactor building showing the reactor pool, the various working platforms and the entrance airlocks.





HFR ground-floor. Some experimental set-ups for basic research using the horizontal beam tubes.

are being prepared for use in medical research, for cancer therapy and as radiation sources for technical purposes. The HFR is complemented with a broad spectrum of irradiation facilities which make these various applications of the neutron radiation possible.

In the first place, various spaces are provided in the core of the reactor in which specimens can be introduced for irradiation. In addition, further irradiation positions are located between the reactor core and the wall of the reactor vessel. Situated in the reactor pool is a rectangular space adjacent to the reactor wall in which irradiations can also be performed and finally there is another possibility in using special tubes by which a beam of neutrons can be led to experimental equipment. Easy access to the irradiation positions is assured by means of sophisticated devices. Lead-through passages enable the connection of measuring apparatus to irradiation experiments. All data needed for experiments can be exactly determined for each irradiation position. Nevertheless, the improvement of facilities and measuring apparatus for the precise measurement of radiation and other physical parameters is a constant subject of study.

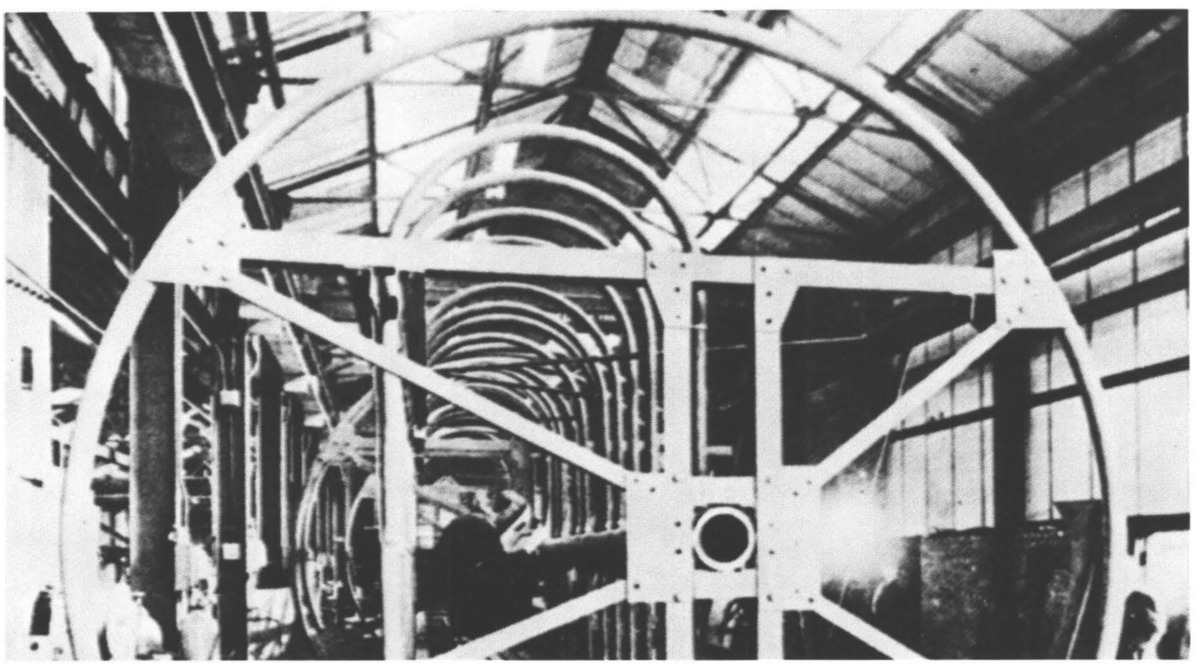
High Temperature Materials Research

The general approach adopted by the Petten Establishment in High Temperature Materials research is first to survey technological and industrial requirements in applications ranging from high temperature petrochemistry to thermonuclear fusion.
The purpose is pinpointing future needs, establishing and performing research projects in selected key areas and building and maintaining multilateral communications with manufaturers, users of these materials and with the research and development sector.

This approach is reflected in three projects (High Temperature Materials Information Centre, Materials and Engineering Studies and Data Bank). These are aimed at the collection and dissemination of information and the encouragement of research in the Community by focussing attention on particular problems.

The activities concerning the exchange and dissemination of information on high temperature materials have been well received and major conferences organised by the Petten Establishment, either alone or in collaboration with national or international bodies have been successful. Instructional courses organised by the Petten Establishment with the collaboration of outside expert lecturers have been well attended.

In the new programme, the information activities on high temperature materials include the compilation of an inventory of current high-temperature research in Europe and the preparation of a computerised information and distribution system. In new fields of research the future requirements are being identified on a large number of important items, such as thermal conversion of energy from biomass



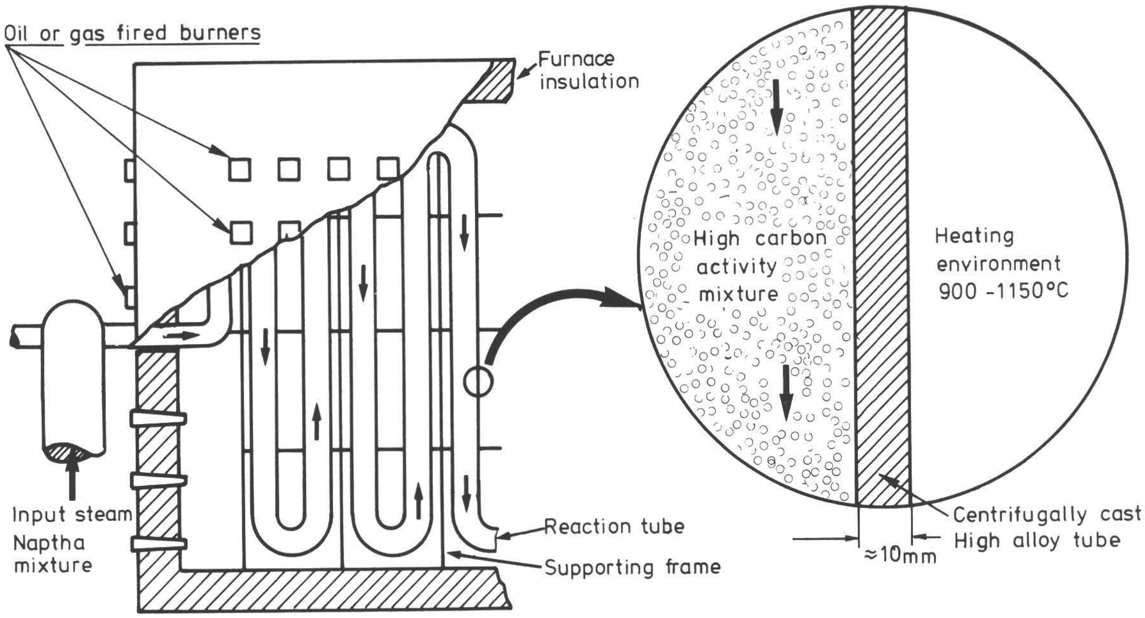
Modern industrial processes require improved high temperature materials: "Pigtails" for petrochemical refining furnace.

and solar sources, the development of materials for nuclear fusion and the development of corrosion resistance coatings for coal conversion plant.

Turning to research, the study of the mechanical properties of materials suitable for high-temperature service in relation to their working environment is one of the highlights in the new programme.
Coal conversion and utilization processes are increasingly emphasized: coal gasification, fluidised bed combustion, power turbines and related technologies. Studies are performed both on corrosion behaviour and the mechanical properties of materials relevant to coal conversion with the types of conditions prevailing in production installations and on the protection against corrosion provided by suitable corrosion-resistant coating materials.

The organisation of a Data Bank for information in the field of high-temperature materials research is in an early stage of development. During the year 1980 attention was centred on data collection methods. The feasibility of data collection from literature was demonstrated and computer-based procedures were further developed at the Petten and Ispra Establishments of the JRC.

The building housing the materials research laboratories.



Organic Materials Research

Within the framework of the new programme for the period 1980-1983, the work of the Organic Laboratory of the Petten Establishment has been orientated towards research in support of environmental protection.

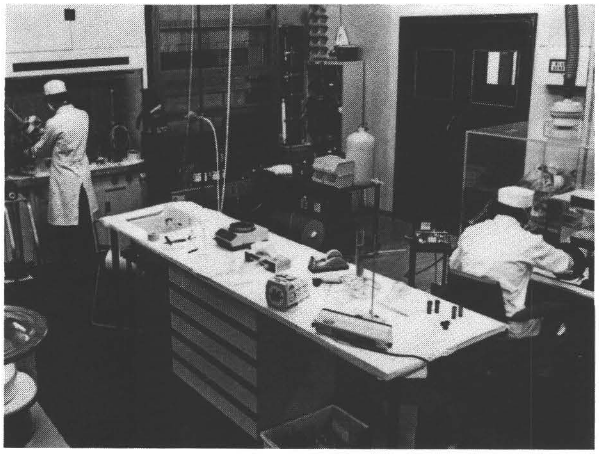
The efficient control of air, water and domestic pollution by organic materials rests on a fundamental requirement: the existance of analytical methods of sufficient sensitivity and precision. A number of these methods are available at Petten. Furthermore, research and development work has been carried out aimed at identifying carcinogenic chemicals in the environment and in working areas, mainly substances originating from fossil fuels used for energy production and transport. These studies seek to promote their analytical detection and control.

In addition, the activities of the Petten Establishment cover analytical research of toxic and hazardous additives or components in plastic materials and cosmetic products for the implementation of Community regulations in this field. Certain reference materials of

Careful handling of potentially dangerous materials in the organic materials laboratories.

known purity have been developed and certified and are now available through the Community Reference Bureau.

From this survey enumerating the tasks of the Petten Establishment of the Joint Research Centre, it may be clear that considerable care has been taken to ensure that the resources available in human competence and in research facilities are applied to technological developments aimed at meeting the requirements of modern society.



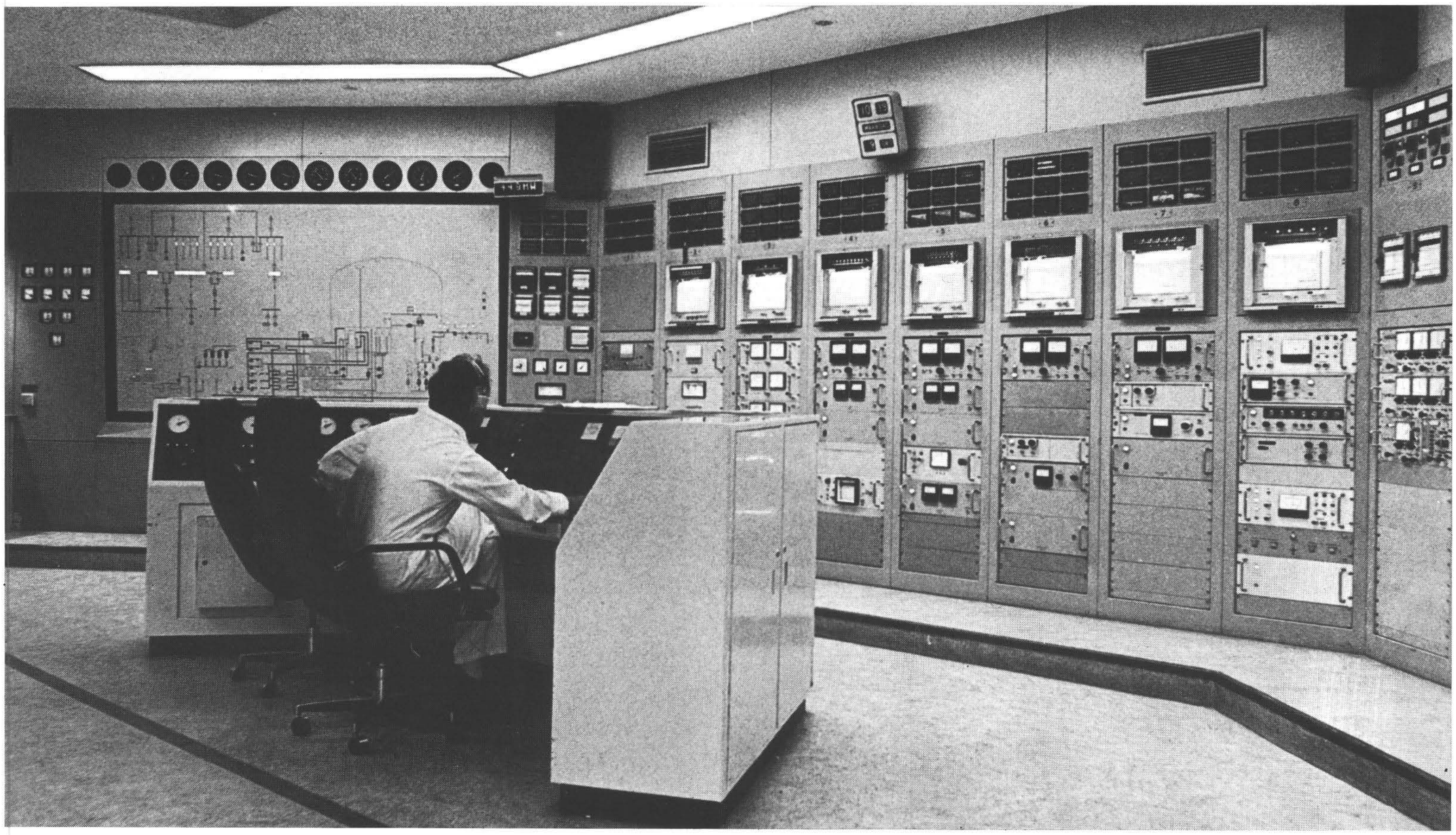
Working on organic materials.

II The High Flux Reactor Research in 1980

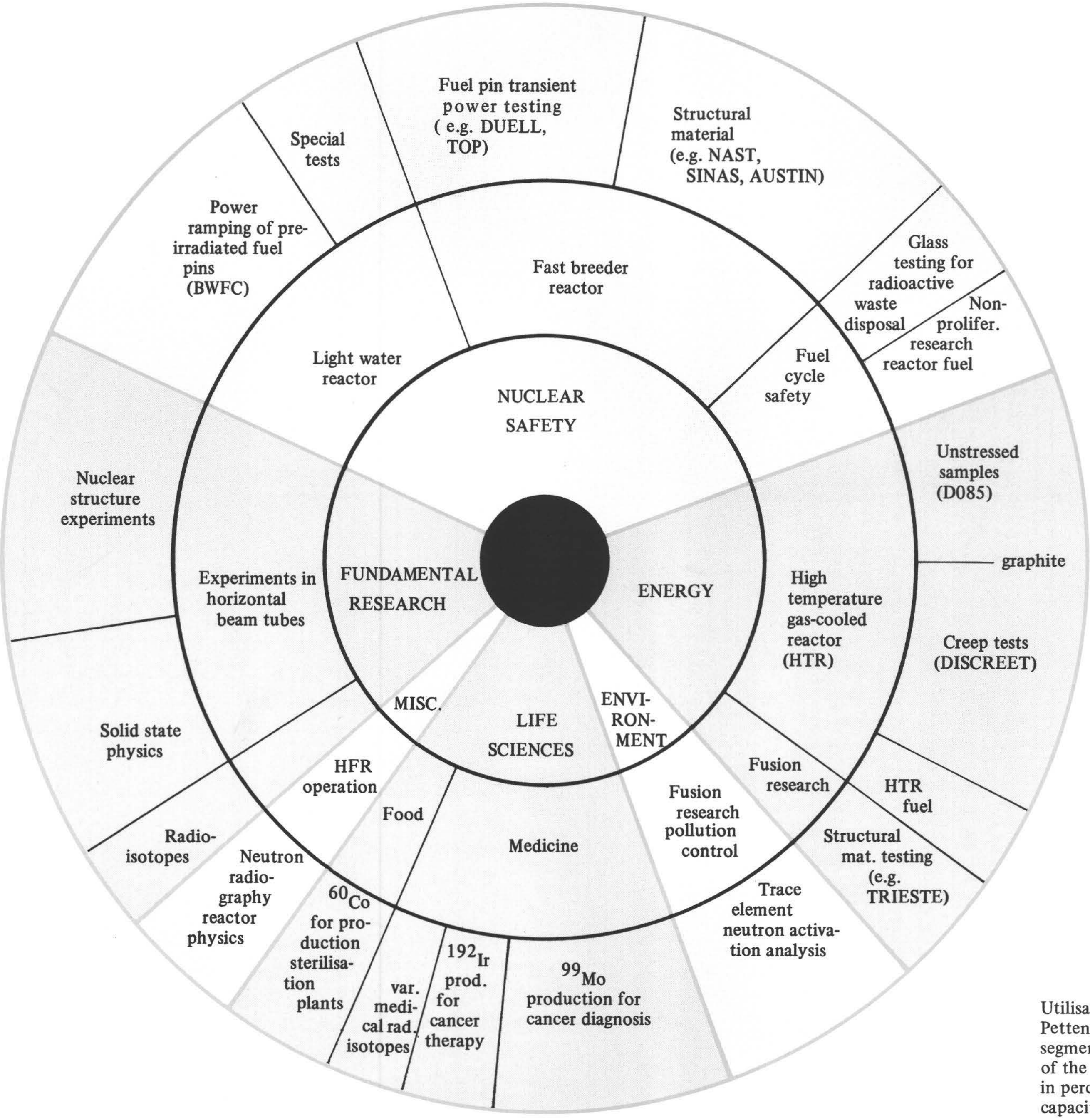
Nuclear Safety

The changed situation in the field of energy supply has had a clear influence on the JRC's research programme and consequently on that of the HFR as well.
Experiments in the nuclear field include those concerned with improvement of the safety of nuclear reactors. Research on methods for limiting the release of radioactive fission products in a nuclear reactor under abnormal operating conditions is an example.

The background of this research is the experience that from time to time the fuel elements in a reactor can be locally exposed, for a short period, to abnormal operating conditions which can be the origin of damage. It is obviously necessary to strive to reduce the risk of the escape of radioactive fission products from fuel elements to an absolute minimum. In practical research, this means that several fuel elements which have already operated for two or three years in light water reactors are submitted to abnormal conditions in the HFR, through their operation in specially developed irradiation capsules. The accurate knowledge of their behaviour allows



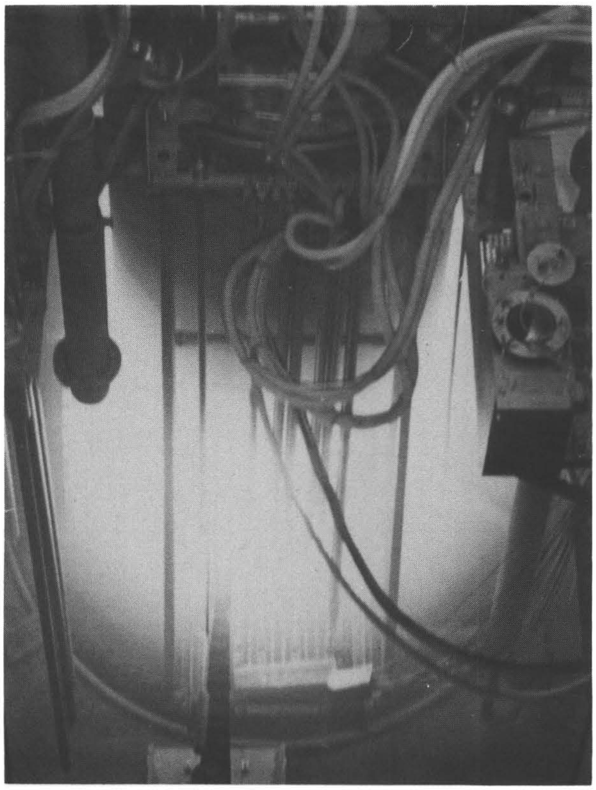
The central control room of the HFR situated adjacent to the reactor hall.



Utilisation scheme of HFR Petten. The angle of the segments gives an indication of the distribution of the use, in percentages of the available capacity.

large power reactors to be operated with a maximum assurance against the release of radioactivity. This work includes non-destructive tests before and after irradiation. It is one of the major parts of the actual HFR-programme.

The development of fast breeder reactors requires similar experiments. An experimental programme has been developed since 1977 for the irradiation of fast breeder reactor fuel pins. These experiments required the translation of the conditions in the HFR into realistic fast breeder reactor conditions. This is achieved by a combination of particular neutron flux measurements and computer calculations. The nuclear characteristics in the fast breeder reactor are sometimes simulated by means of specially developed neutron filters.



View of the reactor pool illuminated by the so-called 'Cerenkov' effect.

The programme also includes irradiation experiments on reactor materials; experiments providing information on the materials' ability to withstand shocks and vibration induced under abnormal conditions.

A field of major interest is the disposal of radioactive fission products. Radioactive wastes can safely be disposed of by transforming them into a corrosion- and erosion-proof glasslike structure which cannot be damaged by its own radiation. The resistance against radiation is studied in the scope of such a programme by simulating the exposure to radiation in the reactor. To this end, boron-silicate pellets containing small amounts of uranium are irradiated in specially developed capsules, thus simulating rather realistically the long-term radiation damage by radioactive waste. The results of these experiments should answer the question how long certain types of waste in glass structures can safely be excluded from the environment.

Another question of great concern is the proliferation of nuclear weapons. The use of highly enriched uranium from research reactors for military purposes is very difficult from a technical point of view. In order to minimize even this small risk, the International Nuclear Fuel Cycle Evaluation (INFCE) recommended the development of proliferation-proof fuel for research reactors, using a considerably lower degree of enrichment (20 °/o) than the high enrichment used at present. Studies of this issue have been carried out in Petten since the year 1977. In 1980, preparations were made for test irradiations to be carried out in the near future. Together with non-destructive and destructive tests after irradiation, they will provide the necessary technological basis for future conversion of research reactors to the use of still more proliferation-resistant fuel.

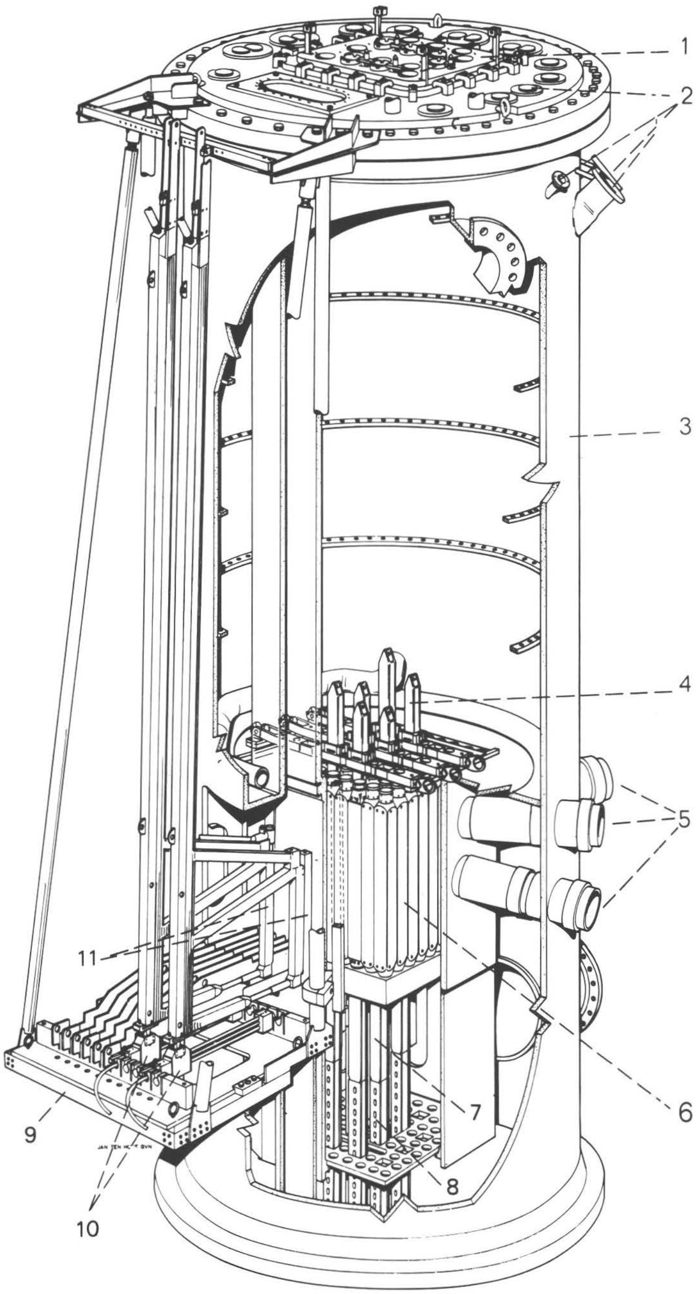
Energy

The choice between the different reactor concepts for energy production has got a new emphasis: the success of the light water reactor was due to a large extent to economic factors. This choice has to be reconsidered in the light of an improved utilization of resources, a greater degree of safety and an extension of the contribution of nuclear reactors to the saving of fossil fuels by using reactors as a source of process heat.

The high-temperature gas-cooled reactor, commonly named HTGR or HTR, originally excluded by the light water reactor for economic reasons, offers a number of advantages such as a higher thermal efficiency, a larger possibility of using proliferation-resistant fuel and the possibility of utilising it for high temperature chemical processes, including coal gasification and liquefaction as an alternative to the use of natural gas and oil. Another feature of the HTR is the so-called inherent safety of this reactor type. This means that in case of abnormal conditions such as sudden rises of temperature in the reactor, it slows down without any intervention from the reactor operator and stops functioning.

The HFR programme includes test irradiations for two materials which are typical of the high temperature gas-cooled reactor: graphite as a predominant core structural material and coated particle fuel elements. A large new facility was installed and taken into operation at the end of 1980 in order to study the release of radioactive fission products from HTR fuel.

Schematic drawing of the reactor



1. Cover (see a)
2. Penetrations
3. Reactor vessel
4. Control member absorber section
5. Horizontal beam tubes
6. Reactor core with fuel and reflector elements
7. Control member fuel section
8. Control member connection to drive mechanism
9. Pool side facility (PSF) with support table
10. PSF trolley
11. PSF rigs

Protection of the Environment

The increased utilization of coal as a replacement for oil and natural gas might be a threat to the environment, if not enough attention is paid to research with respect to the impurities contained in coal. Analysis of the contents of coal and other substances can be realised using the neutron activation analysis method. The analysis of samples after irradiation gives detailed information with respect to the content of dangerous impurities and contaminants like arsenic, mercury, cadmium and uranium. Several facilities have been developed for the activation analysis over a wide range of irradiation times and sample types.

Fundamental Research

From the beginning, the HFR has been used for fundamental research related to the structure of matter. When a sample is irradiated by neutrons, certain interactions occur: the neutrons are scattered or the irradiated material reacts to the irradiation by the emission of gamma-rays. The analysis of these effects of irradiation provides information with respect to the way in which the material in question is physically built up.

Thus, the HFR is an important tool for fundamental research on crystal structures of solids and the fine structure of the nuclei of matter.

Radio-isotopes for Medical Applications

Last but not least, the HFR is used for the production and development of irradiation sources both for diagnosis and therapy of cancer and other medical applications. A recent development, to which HFR contributes to a large extent, is the use of the short-lived radioisotope called technetium-99m. This isotope can be produced in high purity by radioactive decay of another isotope, called molybdenum-99. This is produced in the HFR applying two different techniques, viz. by irradiating normal molybdenum and by irradiating highly enriched uranium.

III Highlights of HFR Research in 1980

The main lines of the research programme for the HFR were sketched in Chapter two. The importance of this research to the development of techniques in the field of nuclear energy was also explained.

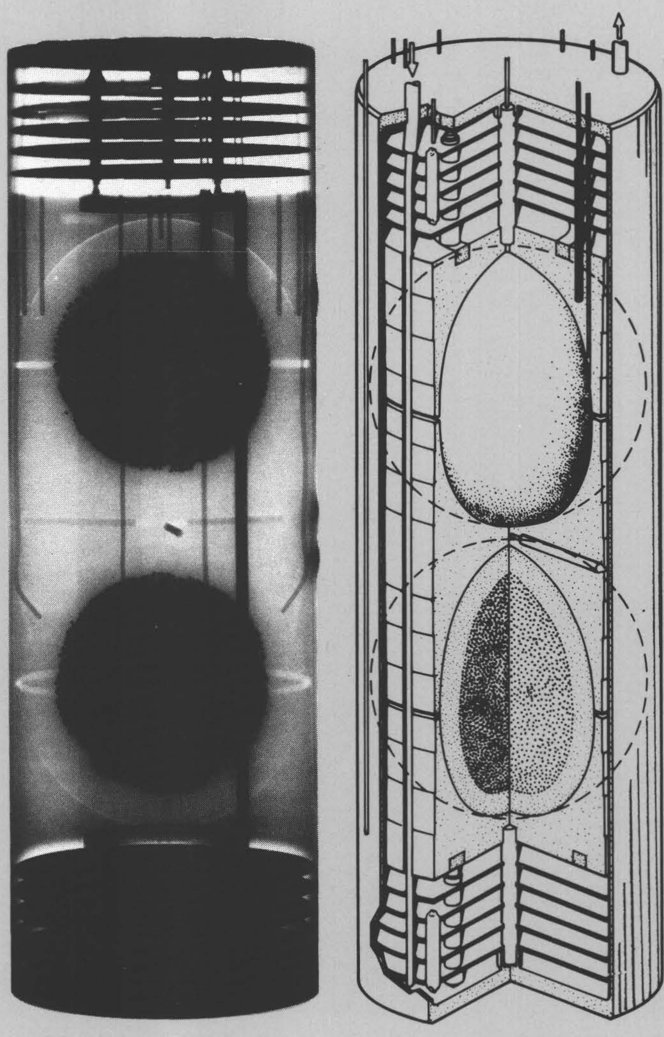
The main goal is a further improvement of the reliability and safety of the usual reactor types, the light water reactors, and the development of the high temperature reactor (the HTR).

This reactor has a high reliability, and through having a high efficiency it can make better use of the available fissile material reserves than the other current types.
Furthermore, the development of new fuels for research reactors, using low enriched uranium proved important. Some highlights from this research will be discussed in this chapter. The emphasis will be placed on work that was done in the year 1980.

Fuel for the High Temperature Gas-Cooled Reactor (HTR)

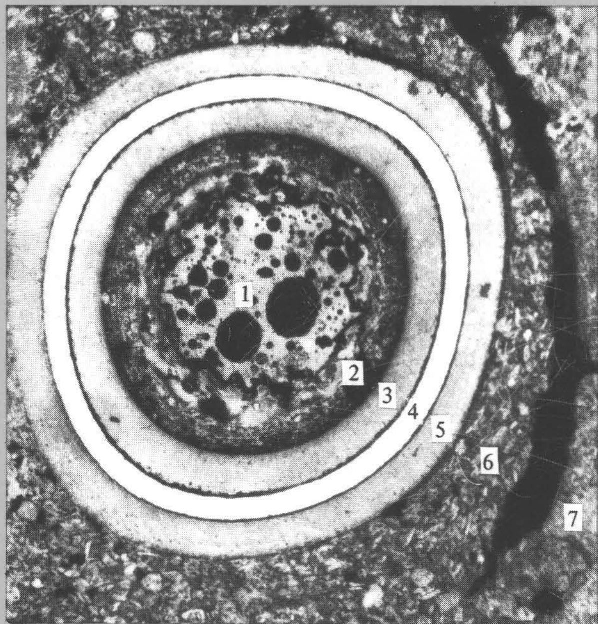
One of the special areas of the HTR concerns the form of the fuel. In the light water reactor, the fuel appears in the form of uranium oxide, contained in metal fuel elements. For the fuel to resist the higher temperatures which are necessary to increase the efficiency, a choice is made, in the case of the HTR, of a special kind of fuel in the form of small balls, which can withstand temperatures above 1500 °C. These balls, with a diameter of 1 mm, are coated with a layer of carbon that can contain the fission products. These particles are then sintered together to form spherical fuel elements with a diameter of a few centimeters. Use of this system can lead to a reactor with a high efficiency and a low neutron loss, as well as a cheaper fuel reprocessing method. Moreover, this form of reactor offers a perspective into a state of development which includes the use of gas-turbines.

The production of the HTR fuel in this special form, and its behaviour in the reactor, requires thorough research. The carbon used must come up to high specifications, so that as few neutrons as possible are absorbed and the fuel balls are able to withstand the conditions within the reactor. Impurities in the coolant,



HTR fuel testing. X-radiograph and schematic drawing of an irradiation capsule containing two spherical fuel elements.

Coated fuel particle irradiations. This figure shows a particle of the type with Al_2O_3 getters.



1. kernel material, UO_2 - Al_2O_3
2. buffer layer
3. inner PyC-layer
4. SiC layer
5. outer PyC layer
6. compacted graphite
7. coupon

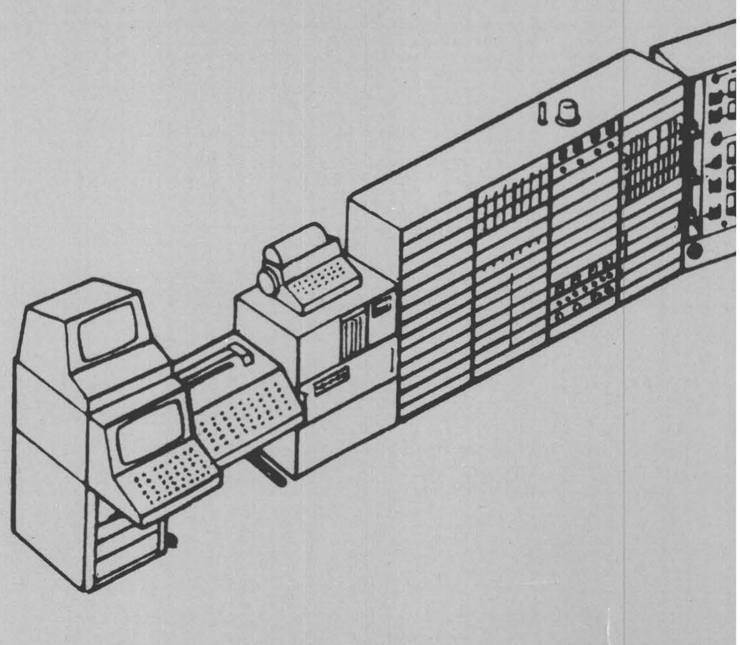
for instance, have proved to cause damage to the carbon, while under irradiation.

At present a group of new coated particles is examined in the HFR, specially designed for use in reactors where the heat produced is used as process heat. In 1980, the activities were concentrated on the irradiation and the analysis after irradiation of these specially developed coated particles and on the design and commissioning of new irradiation devices. A series of ten fuel varieties of coated particles was irradiated in a special test facility and subsequently analysed by ceramographical examination.

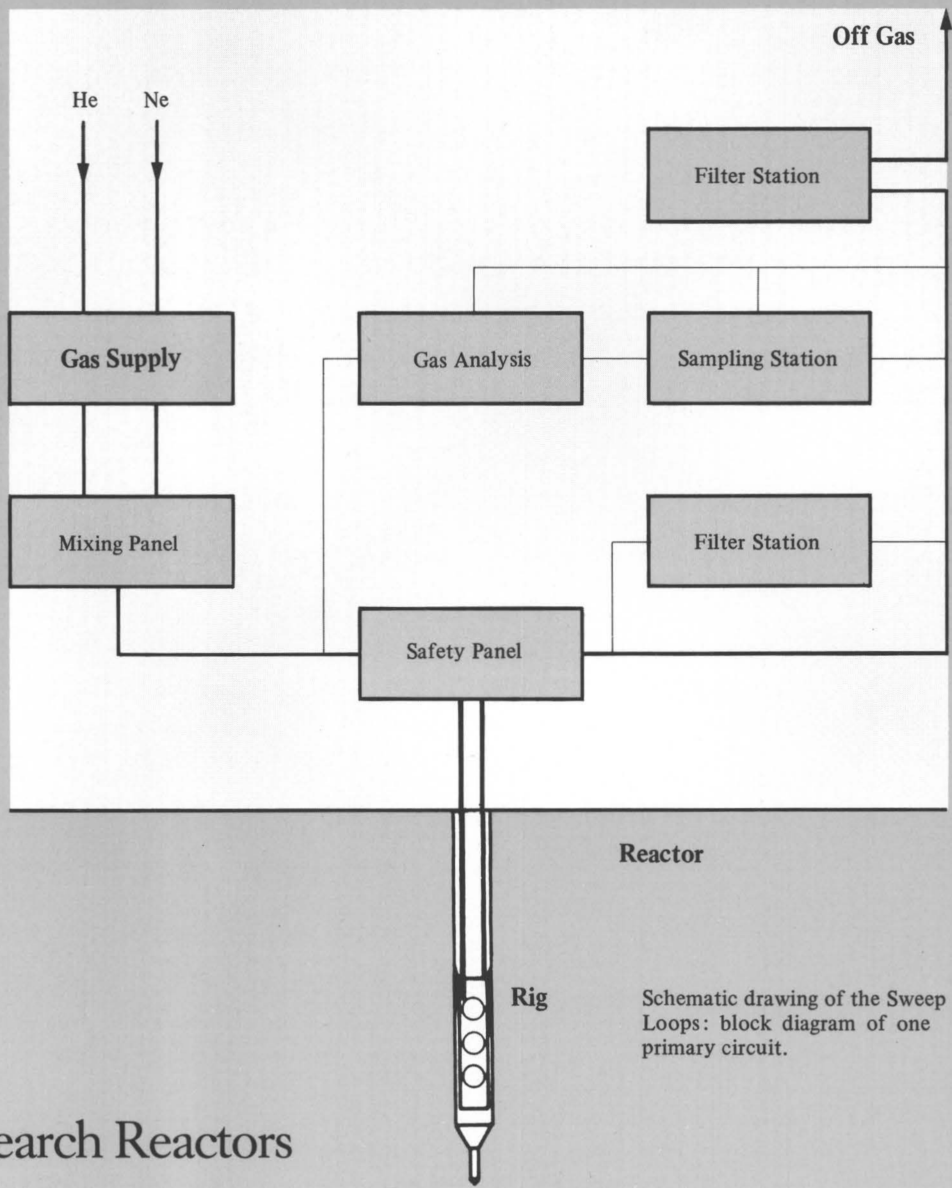
A most significant result has been obtained in the improvement of the irradiation performance of coated particle fuel. The coating, consisting of a layer of silicon carbide (SiC) between two layers of carbon, can be seriously damaged by the action of fission products.

This damage has to be avoided. This can be achieved by mixing the fuel mass with so-called fission product getters, chemical compounds like aluminium oxide, which prevent the migration of fission products towards the coating. Analysis has taken place of coated particles, irradiated under different temperature conditions and up to different levels of irradiation. The picture shows the cross section of an irradiated particle, demonstrating that the effect of mixing the fuel mass with getters is extremely satisfactory.
This experiment has been explained in some detail to illustrate the execution of development work in order to produce long living fuel kernels for High Temperature Reactor fuel elements.

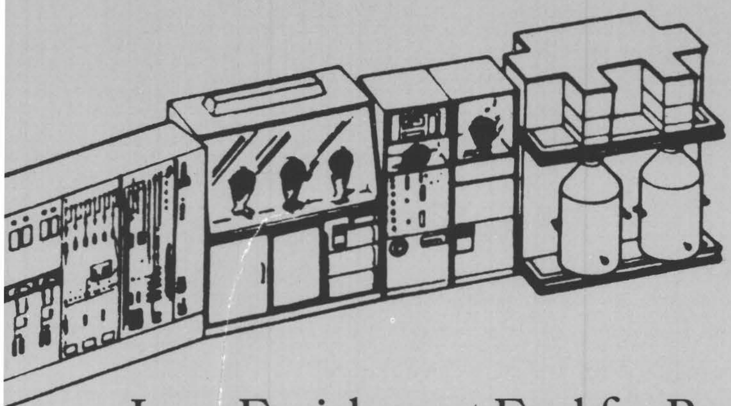
As mentioned above, research is also being carried out on spherical fuel elements. These fuel balls have a diameter of around 60 mm, they are loaded with a large number of the above-mentioned coated particles.



An important part of this work is the design and production of sweep loops used in the irradiation of fuel elements. A sweep loop is an installation for the continuous transport of fission products, and their quantitative analysis, from the fuel elements under irradiation. This is illustrated in the flow-chart.
The sweep loop was taken into operation by the end of 1980. The installation can operate and independently control six fuel samples. It is equipped with a central programable microprocessor controller and with a computer-controlled gamma spectrometer. The gamma-spectrometer is a device with the aid of which it is possible to measure and analyse gamma-rays, emitted by the samples after irradiation in the reactor. The analysis of the gamma-radiation is a means of obtaining the composition of the irradiated fuel.



Schematic drawing of the Sweep Loops: block diagram of one primary circuit.

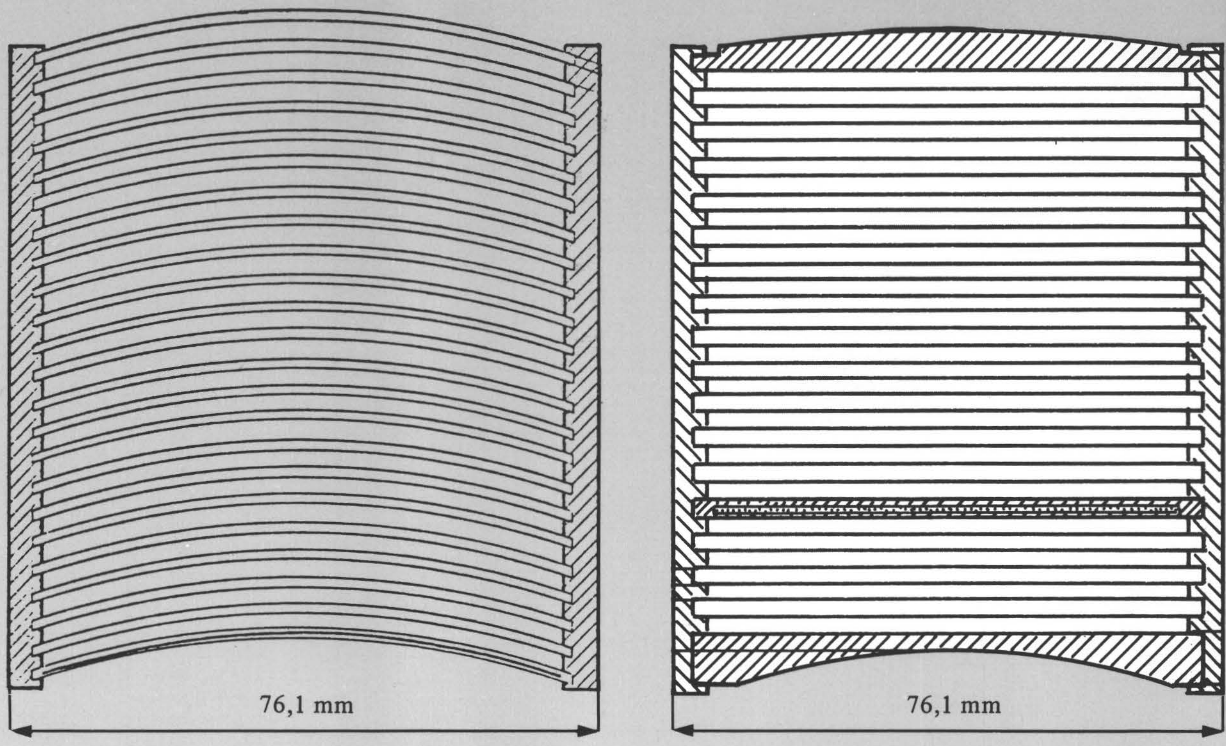


Low Enrichment Fuel for Research Reactors

A research reactor must be able to realise a certain radiation exposure much faster than under normal conditions.

It is therefore of importance to have research reactors with a high neutron flux. Therefore, the means of construction of fuel elements must be chosen to achieve the greatest possible production of neutrons as opposed to the smallest possible absorption of neutrons by the construction material.
These are the reasons why, up to now, it has been normal to choose high enrichment uranium (90 $^{o}/o$) in order to obtain optimum conditions, and a high neutron production. In general, the fuel elements consist of flat plates of a uranium-aluminium alloy, covered on both sides by aluminium cladding.

Cross-section of a conventional HFR fuel element (high enriched uranium) and a reference "LEU" fuel element (low enriched uranium).



The production of enriched uranium for nuclear reactors used for energy production carries little risk in view of its extremely low enrichment of about five percent. The enrichment percentage for research reactors is considerably higher but this does not mean that there is a great risk of misuse: fuel elements containing aluminium with ninety percent enriched uranium are equally unsuitable for weapon production and, once used in a reactor become so contaminated as to be unusable for military purposes.

Nevertheless, caution remains essential and for the sake of maximum safety, one strives to develop fuel for research reactors containing uranium of markedly lower enrichment; around twenty percent. One of the problems this presents is that a higher concentration of the uranium (now weaker in fissile atoms) is needed to realize the same results as obtained from the use of the ninety percent enriched material and this creates certain difficulties with fuel element fabrication.

As already pointed out in chapter II, during the year 1980 preparations were made for test irradiations to be carried out in the near future to provide the necessary basis for the future conversion of research reactors to the use of proliferation resistant fuel with an enrichment of about 20 °/o. This project is covered by a large international collaboration, involving the ECN in Petten, charged with the management of the programme, and the Argonne National Laboratory in the USA, CERCA in Romans, France, Nukem in Hanau in the Federal Republic and the International Atomic Energy Agency in Vienna, Austria.

The figure shows a section of the Petten Reference LEU (Low Enrichment Uranium) fuel element, designed for irradiation in the HFR in 1981.

This experiment was prepared during the year 1980 and discussed during a meeting at the Argonne National Laboratory in November 980. The preparations in Petten consisted of e discussion and final approval of the design the experimental elements.

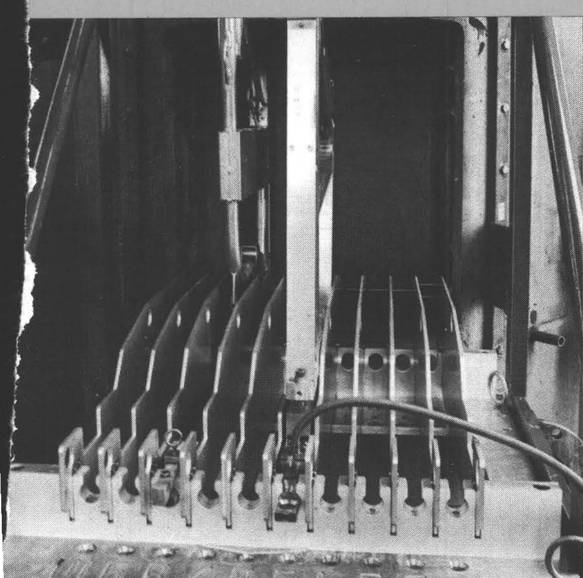
A special feature of the design is a relatively high content of uranium, because of the necessity to arrive at approximately the same concentration of fissile material as obtained with the standard fuel elements with highly enriched fuel.

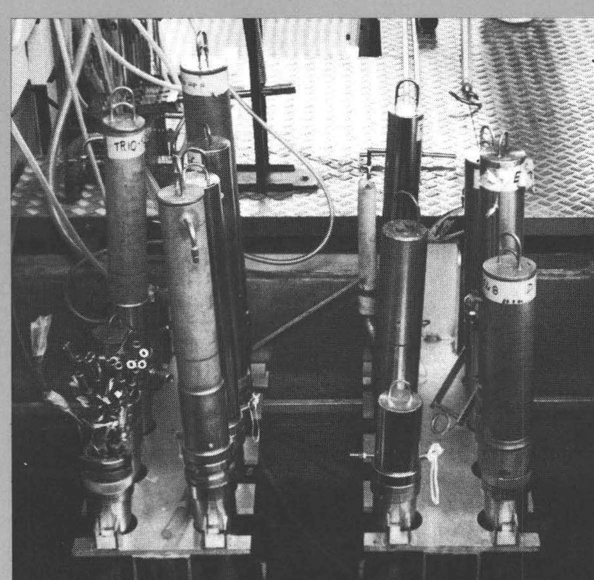
ther Activities

ailed information on the achievements ng the year 1980 are published in technical rts and other publications.
eneral, the facts and features of this year be summarized as follows.

980, the regular operation of the HFR tinued according to the planning and hout major problems. In line with the itional policy of upgrading and modernisa-, a large number of minor components e replaced during the year. Major develop-nts have been the complete replacement of pool side support table with its drive mechanisms, bringing about an important improvement for the operation of experiments, notably related to nuclear safety.

A series of new devices for testing fast reactor fuel elements was installed and new facilities, ranging from several computer installations and their software to a full range of post-irradiation facilities, were extended and ameliorated. With respect to nuclear safety, a large number of tests on light water reactor fuel pins and on stainless steel samples for the investigation of mechanical properties under irradiation were completed.

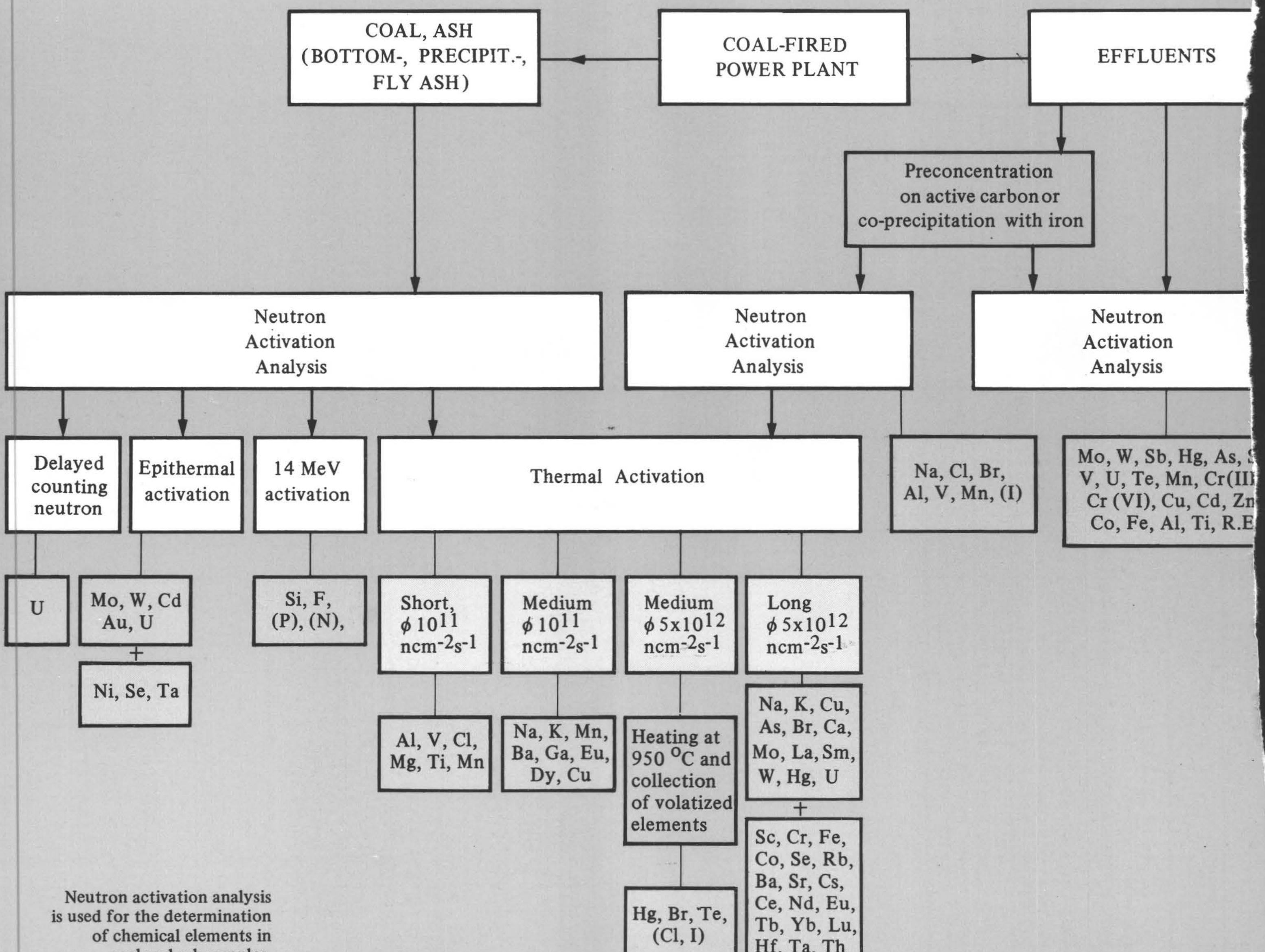




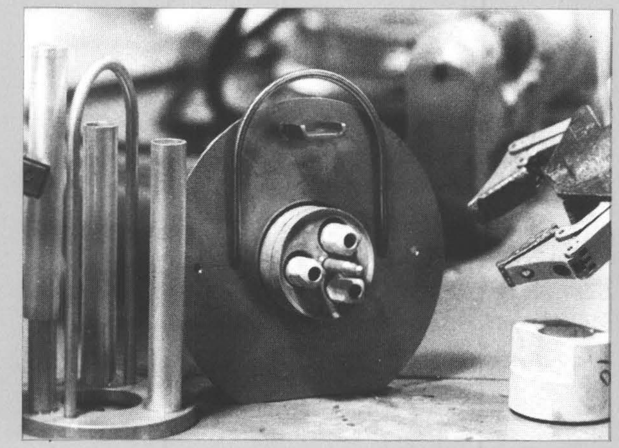
Irradiation facility development.
To the left: the new pool side facility support table before installation.
To the right: the enlarged active storage facility for irradiated capsules.

As to the research related to the protection of the environment, mentioned in the previous chapters, regular analysis of coal and ashes has become routine practice. About twenty chemical elements are routinely determinated in coal and ash samples by instrumental methods.

Recognition of the country of origin of coal samples was shown by the determination of the the concentration of seventeen trace elements. Trace element concentration in coal ashes and leach solutions of fly ash were determined for environmental studies. As a contribution to geological studies, a large number of trace element determinations were carried out on rock samples.



Neutron activation analysis is used for the determination of chemical elements in coal and ash samples.



Last but not least, the production of radio-isotopes for medical applications was developed and extended during the year 1980. Several facilities were developed to satisfy the increasing demand for molybdenum-99, already mentioned in chapter two.
In 1980, the frequency with which transports of this important isotope leave Petten increased to once a week.
Most of the other isotopes produced in the HFR in 1980 were equally destined for medical applications. In total, 1700 samples were irradiated. Studies for the production of cobalt-60 in quantities required for the use of this isotope in food-stuff sterilisation plants were started.

To the left: capsule for isotope production being handled at the hot cell.
To the right: handling the container for the transport of isotopes.

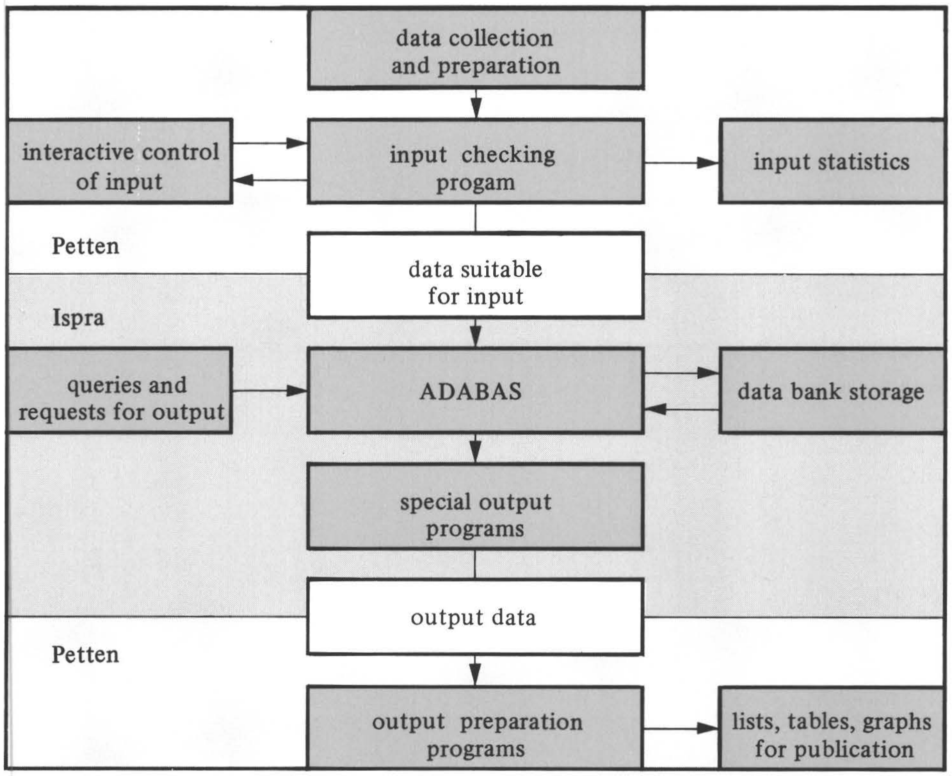
IV Materials Research in 1980

Research and Development in the field of materials for service at high temperatures is one of the keys to advances in energy technology.
The knowledge of the effect of organic materials on the human body and the environment is a precondition for the protection of the population and serves to avoid risks and dangers as a by-product of technological development in this field.

High Temperature Materials

In the high temperature (HTM) programme there is a close relationship between research and development and the dissemination of knowledge. Experimental research on the one hand is concentrated on corrosion and creep of alloys exposed to the environments of the energy and chemical process technologies.
On the other hand much effort is devoted to the provision of information services to the European Community. Promising results have been obtained from this work, which was intensified during the present programme period. Conferences, colloquia and courses have been organized on the problems of structure stability, creep-fatigue and corrosion of high temperature materials commonly used in turbines, installations for the petrochemical industries, heat exchangers and energy process installations.

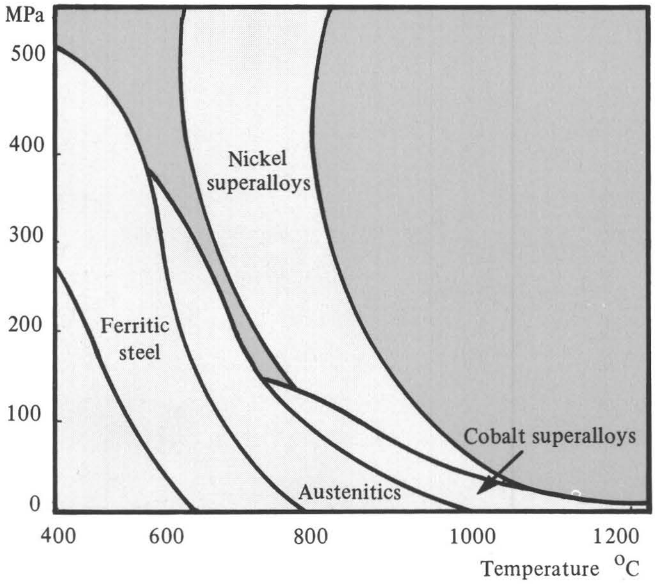
HTM Data Bank, system plan.

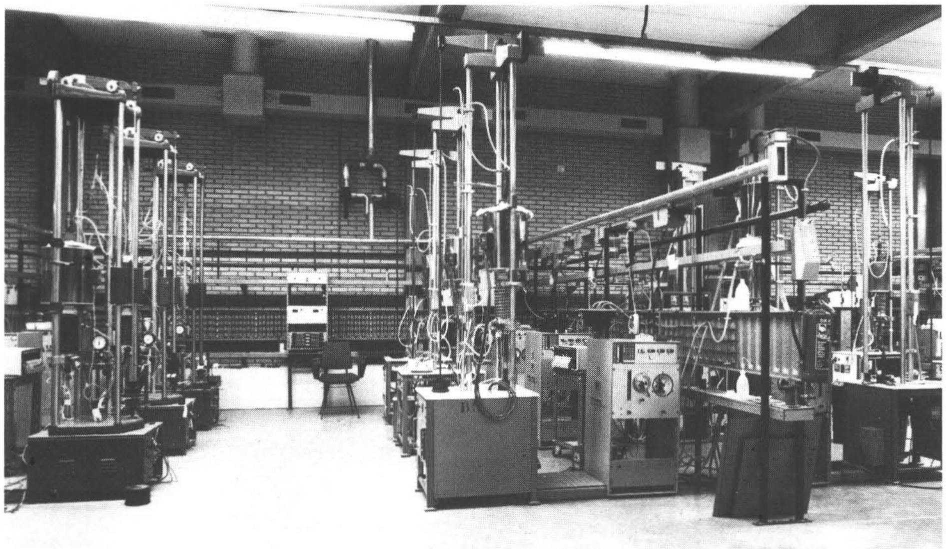


The European interest in a HTM data bank was investigated; it appeared appropriate to use the research capacity of the JRC as a scientific base for the establishment of an information system meeting European needs. Preparations have been made to realise a pilot scheme for a data bank in the near future.

The goal of the operational data bank is both the provision of an instrument for the identification of areas where research in data generation requires stimulation and the provision of a service to the users of data on high temperature materials. In the preliminary demonstration phase, the activity concentrates on the identification of data sources, initiation of the data collection activity and publication of a Demonstration Hand Book.

The definition of the scope of contents and the analysis of the data structure are available. A first data collection trial has been completed.





To the left: stress to cause failure by creep in 10 000 hrs for various superalloys.
To the right: creep testing units in the environmental testing laboratory (ETL).

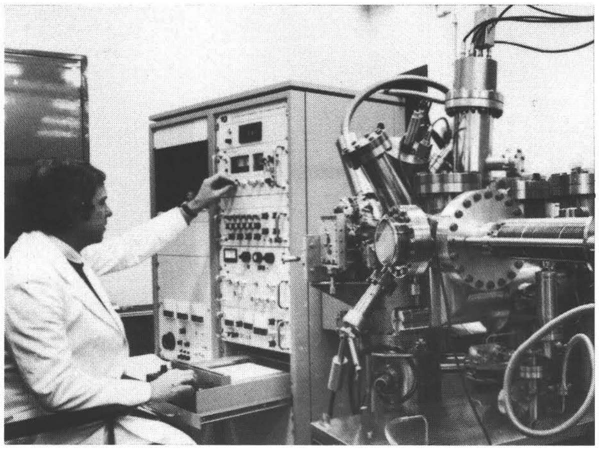
It showed the problems involved in extracting factual data from literature and converting them to systematic input and storage. The design and implementation of the pilot data bank is made in collaboration with the computing centre of the Establishment of the JRC in Ispra (Italy).

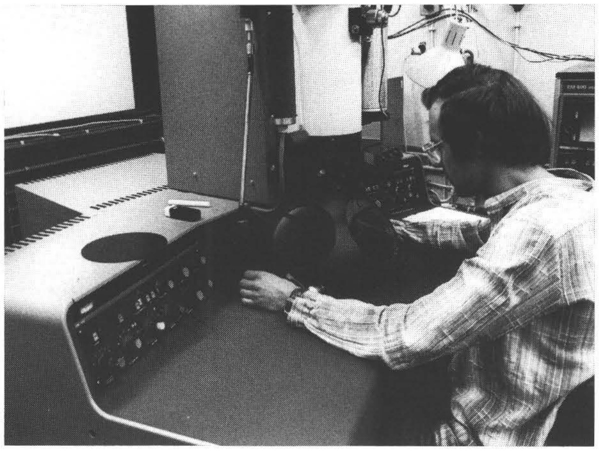
With respect to research, the 1977-1980 programme established a valuable point of departure for the new programme, aimed at understanding the mechanisms governing the behaviour of selected metallic alloys in certain types of corrosive environments at high temperature.

Many plant components in the various energy conversion processes referred to in the Introduction, share a requirement to operate at temperatures in the range 700 - 1100 °C for long periods under stress in aggressive environments. At present, design techniques for preventing failure of these components are based on rules which place an upper limit on the load and deformation allowed. Assessment of expected performance in comparison with these rules requires knowledge of the behaviour of the material under conditions typical of the application, but in very many cases there is little knowledge as far as the actual situation is concerned.
Therefore information on both the mechanical properties and the corrosion resulting from exposure to the aggressive atmospheres is needed. To this end tests have been performed on high temperature materials up to temperatures as high as 1100 °C in aggressive atmospheres, causing chemical and physical changes which influence the structural qualities of the material. To accommodate all these creep, corrosion and other related experiments in aggressive environments, a special facility, the Environmental Testing Laboratory (ETL) has been built.

This testing has shown that the aggressive environments found in petrochemical or coal conversion processes and in gas turbines bring about important changes in the mechanical properties of the heat resistant steels under consideration. Work on this question will be described in Chapter five. In

Metallographic examination is carried out with various electron microscope systems. Scanning electron microscopy (left) for studying surfaces, and Transmission electron microscopy (right) for studying microstructures of thin samples.

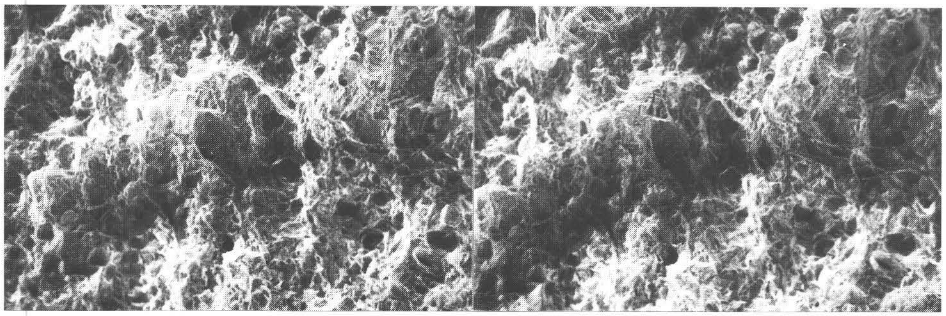




some situations, however, the level of stress is low and corrosion resistance is the dominant property. In others, knowledge of corrosion mechanisms and the way in which kinetics vary with alloy composition can assist the selection, or development, of materials which may have promising mechanical properties in the aggressive atmosphere.

Corrosion work during 1980 has related the kinetics of carburisation to the proportions of the main alloying elements in the material. The importance of minor elements and of surface condition on the severity of carburisation in the presence of very small amounts of oxygen have also been illustrated. Other experiments have explored the extent to which a range of alloys is attacked in moderately severe sulphidising atmospheres.

Stereographic SEM micrograph of a fracture surface.



When all mechanically suitable materials suffer unacceptible changes due to corrosion it is necessary to protect the surface of the alloy with a specially applied coating. During 1980 the work in this area concerned the changes that take place with time at high temperature along the interface between the coating and the alloy which is being protected. These particular experiments concerned gas turbine alloys.
This work and also all the mechanical property evaluations on gas turbine alloys have been integrated with related studies taking place in other European Laboratories through a "concerted action", COST 50.

To make the information gained from tests on laboratory samples more directly applicable for design engineers and plant operators, a range of engineering studies is being carried out. The stage reached in experimental work is described in Chapter five, but a more complete study will require the construction of new facilities, which have reached the final stage of design.
The feasibility study and specification of a possible European test facility for the evaluation of long term high temperature properties of welded tubular components has equally reached an advanced stage.

Organic Materials

As pointed out in Chapter one, the work of the Organic Laboratory of the Establishment in Petten has been reorientated towards research in support of environmental protection. Emphasis was laid on the development of sensitive analytical methods and the creation of suitable reference materials. Here again, the reorientation towards topical problems is obvious.

During the year 1980, progress has been made on a number of subjects. In the field of health protection against environmental carcinogens, attention was especially focussed on the identification and testing of cancer suspect environmental chemicals and on the highly accurate determination, evaluation and collection of certain data on cancer suspect agents.

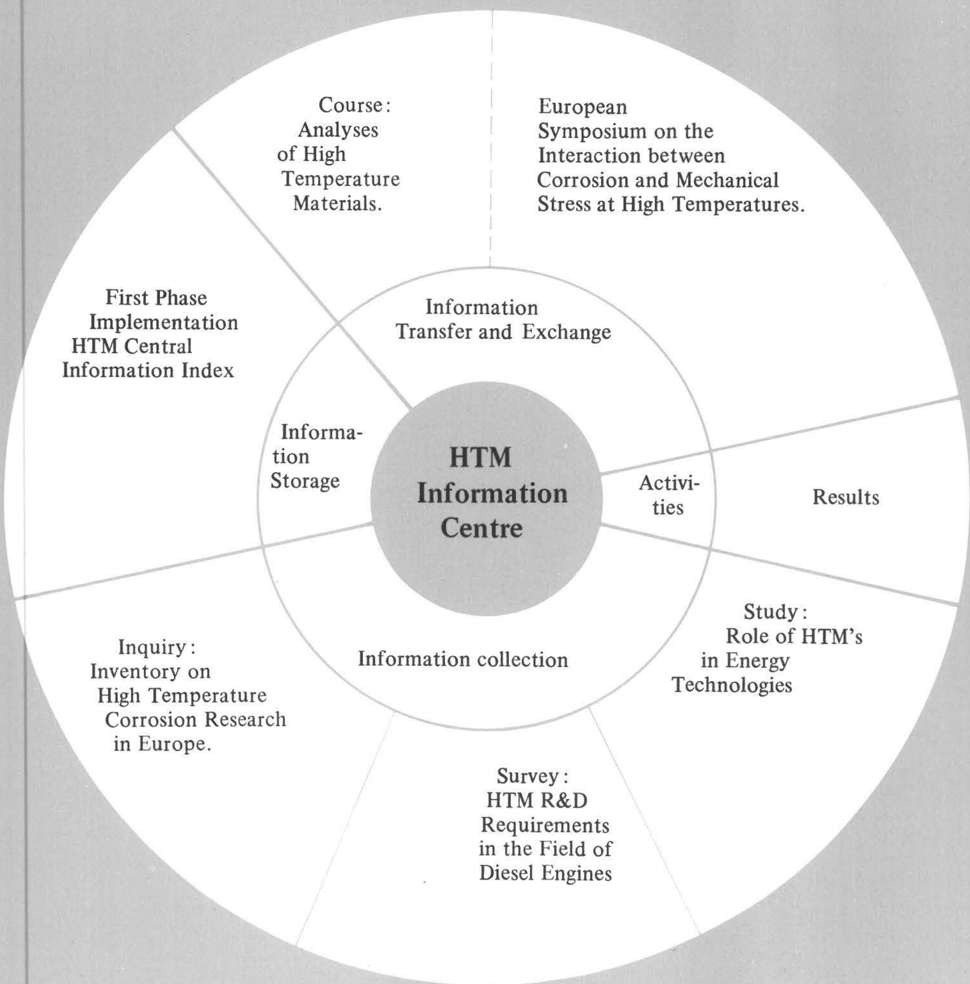
As to occupational carcinogens and toxic chemicals, research centered on carcinogenic substances and toxic additives in plastic materials and on hazardous colorants and dyes.

Besides these research activities, work on organic materials included experimental support to Commission services for the characterization and certification of purity and properties of hazardous organic materials. Further, technical assistance was given to the Community Bureau of Reference (secreteriat of expert and subworking groups, storage and distribution of high purity reference materials).

V Highlights of Materials Research in 1980

HTM Information Centre

The purpose of this project is the provision of an information service to the European high-temperature materials community and the encouragement of cooperative actions. The scope envisaged for the information service ranges from the organisation of small informal discussion meetings for verbal information exchange to the establishment of comprehensive, fully computerised data acquisition, processing and documentation systems; while the promotion of research cooperation within Europe requires a detailed understanding of the relevant scientific factors governing the HTM research activities of the Community as a whole.



Four important items can be mentioned in order to illustrate the working procedure of the Information Centre.

1 The behaviour of high temperature alloys in aggressive environments in general is an important factor in the development of modern energy transformation techniques. It was the theme of a conference held in October 1979 in Petten. The proceedings of this important conference give a clear picture of the state of affairs; they were published by The Metals Society, U.K.

2 In May 1980, a European symposium on the relationship between corrosion and mechanical stress at high temperatures was held; it included a panel discussion which reached conclusions on various aspects of future research opportunities. The results of this symposium will be published by Applied Science Publishers, Ltd., U.K.

3 The analysis of high temperature materials is a typical subject of which the collected knowledge has to be disseminated in an appropriate way. In April 1980, a course was organised in order to give a survey of the techniques both for bulk chemical analysis and for crystallographic analysis with the aid of the electron microscope or X-ray diffraction as applied to high temperature materials and microprobe methods.

4 The future development of high efficiency Diesel-engines will provide a contribution to the saving of fuels. In this development operation at high temperatures is necessary. Therefore, much attention was paid to the

development of research techniques in the field of high temperature materials for Diesel engines. A round table discussion among invited European experts in this field took place in April 1980.
The materials research and development requirements resulting from the need for these fuel savings in future engines have been discussed and identified.

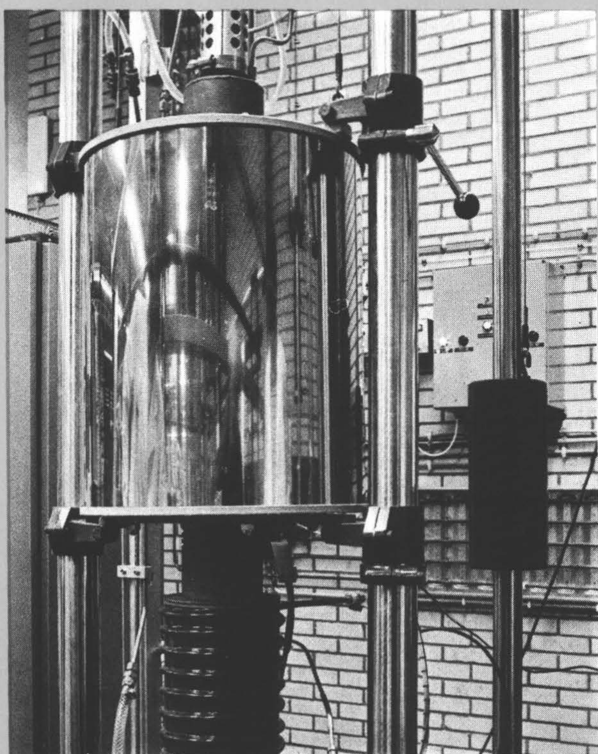
Further activities in progress are the termination of a study on the role of high temperature materials in energy technology, the preparation of an inventory of research in the field of mechanical properties of high temperature materials, the preparation of an inquiry into advanced ceramics research and a survey of high temperature materials research and development in solar power generation plants.

High Temperature Alloys in Corrosive Environments

The central theme of the research work being conducted in the High Temperature Materials Programme is the understanding of the mechanical behaviour of heat resistant steels and other superalloys in corrosive atmospheres. The mechanical properties under investigation include creep, fatigue and thermal fatigue. The critical importance of the components whose properties are being determined was mentioned in Chapter four.

Creep investigations can illustrate our approach. Creep is the occurrence of permanent deformation of a material subject to a constant but low load. This deformation or strain is permanent in the sense that it remains when the loading is removed. As long as the material is loaded, creep goes on until fracture (rupture) occurs. The speed at which the material creeps is dependent upon the temperature and, of course, upon the load imposed.
In constructions operating at high temperatures creep is generally a phenomenon of major importance. One simple practical example of uniaxial creep can be found in the rods used to suspend a heat exchanger tube bundle from a supporting structure; multiaxial creep is found in the high pressure tubes which make up the bundle.

Generally speaking, information exists on creep and rupture properties for tests conducted in air, but in that atmosphere there is usually little effect of the environment on properties either as a result of oxidation or even nitridation. However, in service applications such as



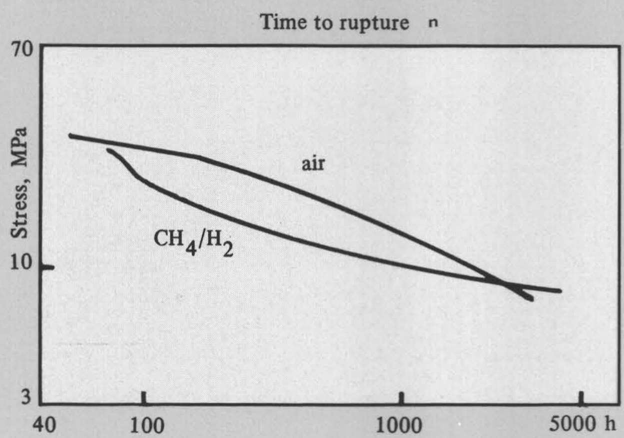
Materials and Engineering studies. Machine for the testing of creep specimens at high temperatures.

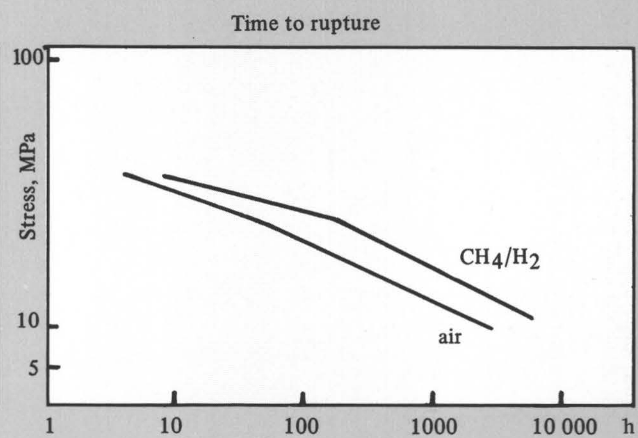
petrochemical, coal conversion, gas turbine, etc., corrosion attack can be much severer than in air; in some cases dominating the materials' behaviour.
Besides direct corrosive attack, which reduces the cross section of a component and thus weakens it, the composition of apparently sound components can be changed by the uptake of foreign elements coming from the environment, such as oxygen, sulphur, carbon, resulting in an undesirable change in mechanical properties.

Frequently oxidation leads to a self healing protective oxide layer on an alloy, but carburisation, on the other hand, progressively affects more and more of the cross section of a sample and hence has a significant effect on mechanical behaviour. Carburisation is the principle form of corrosion found in the "cracking tubes" used to obtain light oils (petrol) or gases from heavy oils, whether natural or derived from coal liquefaction. Carburisation can also occur in coal gasification units or gas turbine components if there is the necessary combination of operating conditions. Thus, this widely relevant mode of attack will be used for illustration.

Special purpose creep test machines developed in this laboratory, were used to obtain creep curves on materials while they are being exposed to a carburising atmosphere at 1000 °C. This was shown to give the most suitable and severe environmental conditions for changes in the creep behaviour. At the same time tests were performed to obtain similar data on the same material samples in air at temperatures between 900 °C and 1100 °C. This forms the basis for assessment of environmental effects on creep and rupture properties.

Two alloys were selected for detailed study following consideration of the industrial situation and the corrosion behaviour. They represent commonly used tubes made by casting (HK40 in low and high carbon version) and forging (Alloy 800H). For HK40 the creep rupture strength is reduced by testing in corrosive gas. At long testing times, however, the test piece used becomes through-carburised during testing and the creep rupture strength is raised progressively relative to the air data. In In the graph on the left the strength is halved in the most critical conditions, but for test durations over 2500 h the carburised material has the better life. The trend to show improved life is related to the increase that takes place in rupture ductility which in turn is the result of microstructural changes that take place during carburisation. At long



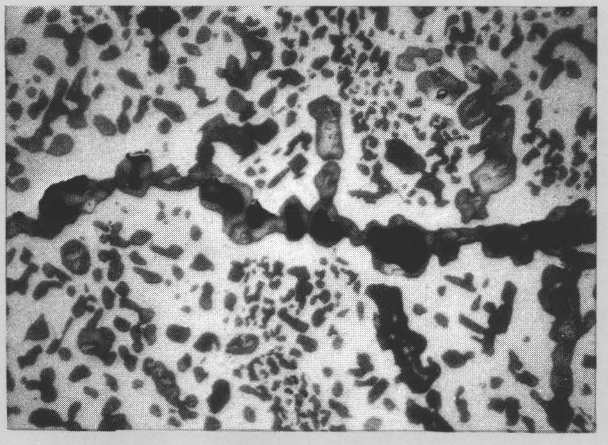


Creep rupture strength of HK40 (left) and Alloy 800H (right) tested in air and carburising environment at 1000 °C.

testing times the increase in rupture ductility is threefold (3 °/o to 10 °/o).
In contrast, the creep rupture strength of the other major material, Alloy 800H, is increased at all applied stress levels as a result of progressive carburisation. This is particularly noticeable at lower stress levels (longer life tests, greater carburisation). The rupture ductility remains high at all times; the maximum test duration in the test series being 4000 h.

An important observation has been that during testing of HK40 with progressive carburisation, large cavities and cracks can form in the uncarburised core at an early stage. These cracks remain stable when the carbon front reaches and engulfs them. Failure only occurs after subsequent advancement of the creep process. This pattern of behaviour is consistent with the observations made on failed thermal cracker tubes.
It can be concluded that no effects which would be detrimental to life at about 1000 °C should be noticed in long life components as a results of their exposure to a carburising environment at this temperature.

In contrast with the above effects, the embrittlement occurring at room temperature should not be neglected.
In most engineering situations, components are stressed in a multiaxial fashion rather than in the simple uniaxial manner that is standard in laboratory testing. In practice it is sometimes difficult to analyse these complex stress patterns sufficiently thoroughly to allow uniaxial data to be used with a high degree of confidence and for this reason it is planned to perform multiaxial creep experiments on tube shaped specimens in corrosive environments at high temperatures. Such complex high pressure tests require sophisticated

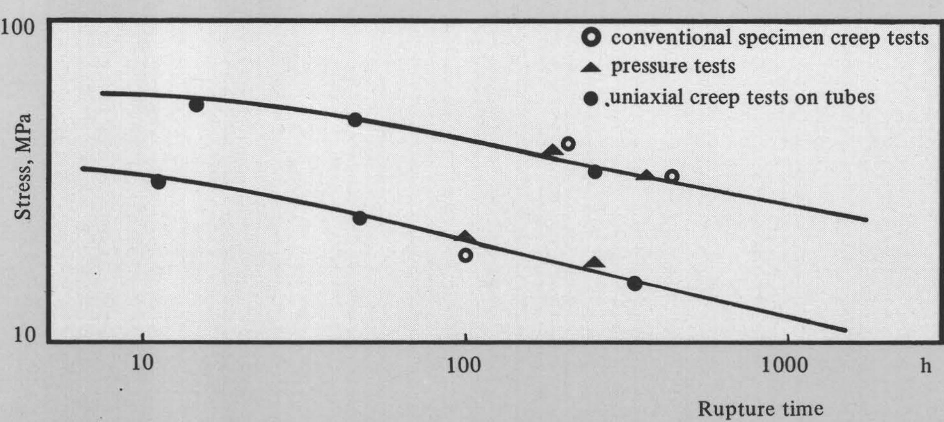


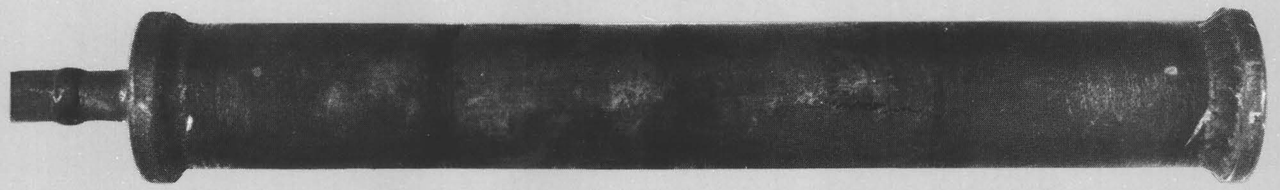
Carburised intergranular voids in HK40 creep tested at 1000°C in hydrogen/methane gas.

experimental equipment and infrastructural facilities.

In the Environmental Testing Laboratory Alloy 800H tubes with 4.5 mm wall thickness and 33 mm outside diameter were tested in uniaxial creep, to compare their behaviour with that of the standard creep testpieces described above. As a first step towards multiaxial stress testing, tubes with the same cross-section were internally pressurised. Results are compared in the graph below and show that for this simple case the time to rupture was relatively unaffected by the different test arrangements, as might be expected for a homogeneous wrought material.

Stress rupture data for conventional and tubular alloy 800H creep specimens.





Alloy 800H tube, pressurized at 100 bar at 900 °C, showing creep failure.

The photograph shows the type of failure observed in the internal pressure tests in which a lower rupture ductility was demonstrated.

All the above testing took place in air; argon was used as the internal pressurising medium. This work provides a base from which non-homogeneous samples, welded specimens for example, and simultaneous corrosive attack will be introduced.
The information and experience gained from these prototype tests has provided an additional input to the design of an installation to house a few tube testing units which will be able to apply longitudinal loads to tubular specimens and sub-components under internal pressure from a corrosive gas at high temperature. This multiaxial corrosive creep testing facility will provide, for small diameter tubes, a realistic simulation of component behaviour in various high temperature industrial processes.

Organic Materials as Environmental Polluants

A group of chemical compounds, called polycyclic aromatic hydrocarbons (PAH compounds) frequently occurs in environmental samples: air particulates, factory stacks and car exhausts, waste and surface waters and tobacco smoke. They equally occur in certain working areas like coke ovens, aluminium smelters and coal conversion plants. In order to contribute to an assessment of the risk caused through release of such agents into the environment, the Petten laboratory has undertaken a systematic study to isolate cancer suspect agents from environmental sources in order to investigate their properties.
During 1980, a number of compounds of the type mentioned above were detected in specimens of fossil origin and their structure was defined. Attention was focussed on a frequently occurring group of PAH-compounds, so-called thiophene derivates.

Several representatives of this group of sulphur containing organic chemicals were analysed in order to determine the degree to which they are capable of causing cancer by testing their mutagenic activity. Of special interest was the identification of a compound with a strong mutagenic activity, a sulphur analogue of benzo-a-pyrene, which may be one of the chemicals occurring in coal conversion processes.

Another highlight concerns the study of the migration of toxic components from plastic packaging materials into food.

Plastics are synthetic macromolecular substances (polymers) which contain unpolymerised monomers and certain additives necessary for plastic processing. These two groups of small molecules, not linked to the polymer matrix, have a tendency to migrate out of the plastic into the foodstuff. Community regulations are in preparation concerned with the avoidance of contamination and therefore analytical methods have been developed for the quantification of small amounts of these contaminants in food.

The influence of different parameters (time, temperature) on migration is another subject of this research as well as the development of new types of plastic additives with very specific properties to reduce mobility. This last feature is of considerable practical interest since it could provide the means of reducing pollution risks of packed goods, especially in food packaging applications, and of limiting the release of toxic additives into the environment after use.

VI Administration and Personnel

The distribution of the staff authorized for 1980 by programme and by category (scientific and administrative) was as follows:

Programme	Scientific staff	Staff for technical support	Staff for general and administrative support *)	Totals
HFR	41	27	18,2	86,2
High temperature materials	37	4	18,5	59,5
Protection of the environment	8	0,8	3,3	12,1
BCR support	2	0,2	0,8	3
Totals	88	32	41	161

*) Directorate, administration, finance, infrastructure and administrative support to the scientific divisions

Staff present at the end of the year (situation on 31.12.1980) totalled 159. Distribution by category of posts and by service (scientific/technical or administrative) was as follows :

Category of posts	Scientific and technical staff	Staff for general and administrative support	Totals
A	33	3	36
B	64	10	74
C	28	14	42
D	3	4	7
Totals	128	31	159

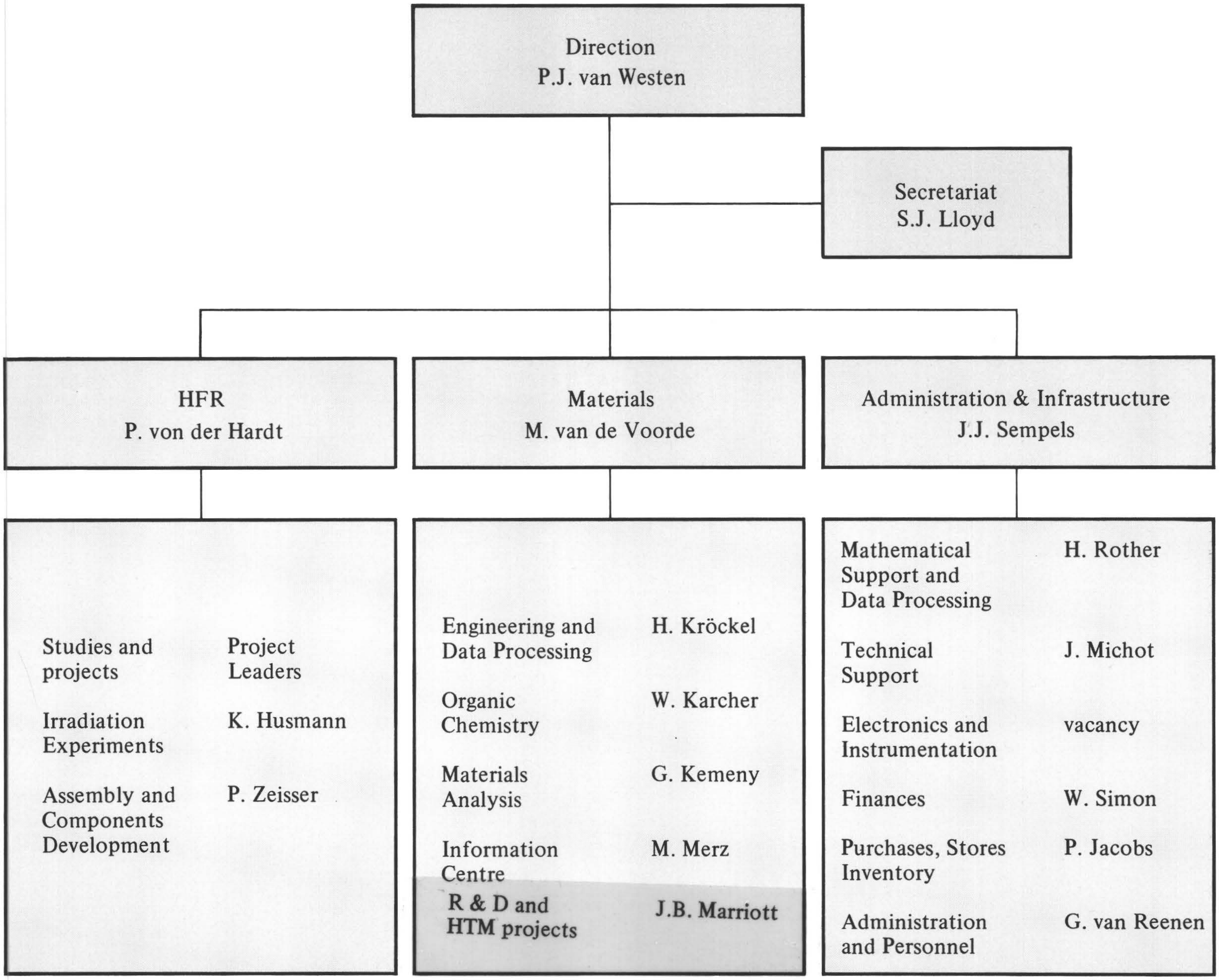
On an average, the number of auxiliary staff totalled 3. A further 6 students and research fellows working in the framework of irradiation technology and materials science, stayed at Petten for the preparation of their doctorate. Moreover, a visiting scientist and some staff detached from institutes using irradiation services in the HFR worked at the Petten Establishment during 1980.

The distribution of the personnel by nationality is stated in the next summary :

Category	German	British	Belgian	French	Italian	Luxemb.	Irish	Danish	Dutch	Total
A	15	8	8	3	--	--	--	--	2	36
B	26	7	13	5	5	1	2	1	14	74
C	1	1	4	2	2	--	--	--	32	42
D	--	--	1	1	--	--	--	--	5	7
General totals	42	16	26	11	7	1	2	1	53	159

VII Functional Organisation

Functional organisation chart of the Petten Establishment at 31.12.1980.



VIII Finance

For 1980 the credits allocated to the Petten Establishment amounted to 16.630.909 European Accounting Units (ECU's).

Distribution between the various activities was as follows:

Summary of the 1980 Budget Distribution

	HFR	High.Temp. Materials	Environment	Support to BCR	Total
Direct Expenditures (Running costs, investments and study contracts)	7.906.991	609.000	142.000	23.000	8.680.991
Indirect Expenditures (Staff, Technical and Administrative support)	4.141.009	3.000.629	646.623	161.657	7.949.918
Total	12.048.000	3.609.629	788.623	184.657	16.630.909

Contribution to HFR exploitation by common research programmes using the facilities	717.000
Specific credits for the account of common research programmes and other clients	490.000

IX Scientific Publications

J. Adelus (formerly research fellow at JRC Petten, now at AWRE, Aldermaston), V. Guttmann (JRC Petten), V.D. Scott (Univ. of Bath) :
Effect of Prior Cold Work on Creep of 314 Alloy Steel.
J. Mat. Sci. Eng. Vol. 44, No.2 (1980), pp 195 - 204.

J. Bressers :
Creep and Fatigue in High Temperature Materials.
EUR 6844 en.

J. Bressers :
Creep Techniques.
In: Creep of Engineering Materials and Structures. C. Bernasconi, G. Piatti (Eds.), Applied Science Publ., 1979.

E. Bullock, P.D. Frampton, J.F. Norton :
Structural Aspects of Gaseous Carburisation of Austenitic Steels.
Paper presented at the 13th Annual Technical Meeting of the International Metallographic Society, Brighton, 18 - 22nd August 1980.

M.R. Cundy (JRC Petten), M.F. O'Connor, G. Kleist (both KFA Jülich) :
High Fluence Creep Behaviour of near Isotropic Pitch Coke Graphite.
Paper presented at Carbon '80 Conf., Baden-Baden, June 1980.

V. Guttmann, R. Bürgel :
The Creep Behaviour of HK40 and Alloy 800H in a Carburising Environment.
Paper presented at European Symp. on the Interaction between Corrosion and Mechanical Stress at High Temperatures, Petten, May 13 - 14, 1980.

R. Krefeld (Coordinator) :
High Temperature Corrosion Research in Europe, An Interim Survey.
EUR 6919 en FS.

E. Lang, E. Bullock :
The Effect of Coatings on the High-Temperature Mechanical Properties of Nickel-base Superalloys.
COST 50 Project CCR-1, Progress Report 1.1.

J.B. Marriott, V. Guttmann :
The Effects of Corrosion Atmospheres on Time Dependent Mechanical Properties.
Paper presented at International Conference on Environmental Degradation of High Temperature Materials, Isle of Man, March 31 - April 3, 1980.

J.F. Norton :
Factors Affecting the Corrosion Behaviour of High Chromium-Nickel Alloys in High Temperature Gaseous Carburising Environments.
Paper presented at 21st Corrosion Science Symposium, Univ. of Oxford, 16 - 19 Sept. 1980.

H. Penkalla (formerly research fellow at JRC Petten, now at KFA Jülich), V. Guttmann and J. Timm (both at JRC Petten) :
Interaction between Creep Deformation and Carburisation.
Paper presented at European Symp. on the Interaction between Corrosion and Mechanical Stress at High Temperature, Petten, May 13 - 14, 1980.

M.F. O'Connor (KFA Jülich), G.B. Engle, L.A. Beavan, R.D. Burnette (General Atomic Company, San Diego), W.P. Eatherly (Oak Ridge Nat. Lab.), M.R. Cundy (JRC Petten) :
FRG/US-Zusammenarbeit bei der Charakterisierung von Reaktorgraphiten.

Paper presented at Carbon '80 Conf., Baden-Baden, June 1980.

H. Röttger (Ed.) :
Proceedings of the Third ASTM-Euratom Symposium on Reactor Dosimetry.
EUR 6813 en FS.

O. van der Biest, G. von Birgelen, G. Kemeny :
Study of the Early Stages of Gas-Metal Reactions in a H-C-) atmosphere using AES and ESCA.
Paper presented at European Congress on Electron Microscopy, The Hague, 24 - 29 Aug., 1980.

O. van der Biest, G. von Birgelen :
AES Studie van Korrelgrenssegregaties in Nikkel-basis Legeringen.
Paper presented at meeting 'Analyse van Dunne Lagen en Grensvlakken', Amsterdam, 7 Nov., 1980.

M. van de Voorde, O. van der Biest and R. Fordham (Editors) :
Materials Division, Facilities and Equipment.
EUR 7036 en (revised edition, Oct. 1980).

High Temperature Materials Programme 1980 - 1983. Technical Description.
COM 3739 (Nov. 1980).

Special issues :

H. Röttger (Ed.) :
Newsletter on Reactor Radiation Metrology, No. 13, Febr. 1980 and No. 14, Nov. 1980.

R. Fordham, W. Karcher, L. Haemers :
The certification of the limiting viscosity number of a polystyrene materials by solution viscosimetry. EUR 6966.

G. Haesen, B. LeGoff :
Determination of phenolic plastic additives in edible oils by thin-layer chromatography. Paper presented at 13th Intern. Symposium on Chromatography, Cannes, June 30 - July 4, 1980.

G. Haesen, B. LeGoff, P. Glaude :
Separation and determination of trace amounts of unintentional additives in plastic packaged dairy products. Paper presented at 8th Intern. Microchemical Symposium, Graz (Austria), August 25 - 30, 1980.

W. Karcher :
Safety practices for handling carcinogenic substances in the laboratory. Paper presented at "Carcinogenic Materials", Amsterdam, Febr. 27, 1980.

W. Karcher, J. Dubois, R. Fordham, P. Glaude, J. Jacob :
High purity materials and reference spectra for the analytical and carcinogenicity control of hazardous organic chemicals in the environment. Paper presented at Symp. on Environmental Pollution, Atlanta, (USA), Oct. 16 - 17, 1980.

W. Karcher, G. Haesen, B. LeGoff, A. Schwarze, K. Figge :
The concept of acceptor-donor complex formation between additives and polymers. Paper presented at 3rd International Symposium on Migration, Hamburg (D.), Oct. 22 - 24, 1980.

W. Karcher, A. Nelen, R. Depaus, J. van Eijk, P. Glaude, J. Jacob :
New results in the detection, identification and mutagenic testing of heterocyclic aromatic hydrocarbons. Paper presented at 5th Intern. PAH-Symposium, Columbus, Ohio (USA), Oct. 27 - 30, 1980.

W. Karcher, J. Jacob, L. Haemers :
The certification of eight polycyclic aromatic hydrocarbons. EUR 6967.

X International Conferences

Survey of International Conferences, attended by members of the JRC Petten staff in 1980.

o Prediction of Plant Performance from Laboratory Corrosion Experiments	Cranfield, U.K., 3 - 4 Jan. '80
o Informationstagung "Die Kernenergie vor dem Hintergrund der Weltenergielage"	Mainz, D., 21 - 22 Jan. '80
o Reaktortagung 1980	Berlin, D., 25 - 27 Mar. '80
o Environmental Degradation of High Temperature Materials	Douglas, U.K., 31 Mar. - 3 Apr. '80
o Plasma Surface Interaction	Garmisch-P., D., 21 - 25 Apr. '80
o International Liquid Chromatography Symposium	Amsterdam, NL, 27 - 29 Apr. '80
o Konferenz "Strahltechnik"	Essen, D., 7 - 8 May '80
o International Conference on Post-Irradiation Examination	Grange-over-Sands, U.K., 12 - 15 May '80
o Symposium on "The Interaction between Corrosion and Mechanical Stress at High Temperatures"	Petten, NL, 13 - 14 May '80
o International Symposium on Chromatography	Cannes, F., 30 Jun. - 4 Jul. '80
o Carbon '80	Baden-Baden, CH., 30 Jun. - 4 Jul. '80
o Corrosion Conference	New London, USA, 23 - 27 Jul. '80
o Annual Technical Meeting of the International Metallographic Society	Brighton, U.K., 18 - 22 Aug. '80
o European Congress on Electron Miscroscopy	Den Haag, NL, 25 - 29 Aug. '80
o International Microchemical Symposium	Graz, A., 25 - 30 Aug. '80
o Conference on Engineering Aspects of Creep	Sheffield, U.K., 15 - 19 Sept. '80
o Corrosion Science Symposium	Oxford, U.K., 16 - 19 Sept. '80
o Cosmetics, Chemistry and the EEC Directive	Teddington, U.K., 7 Oct. '80
o INTERKAMA	Düsseldorf, D., 13 - 14 Oct. '80
o International Symposium on Environmental Pollution	Atlanta, USA, 16 - 17 Oct. '80
o Third International Symposium on Migration	Hamburg, D., 22 - 24 Oct. '80
o Symposium on Polynuclear Aromatic Hydrocarbons	Columbus, USA, 27 - 30 Oct. '80
o Packaging and Transportation of Radioactive Materials	Berlin, D., 10 - 14 Oct. '80
o Energy from Biomass	Brighton, U.K., 4 - 7 Nov. '80
o Kongress "Mikroelektronik"	München, D., 11 - 12 Nov. '80
o MHD-Onderzoek in Nederland	Eindhoven, NL, 9 Dec. '80

Glossary

BCR	Community Reference Bureau
BWFC	Boiling Water Fuel-element Capsule
COST	Cooperation avec des pays tiers Européens dans le domaine de la recherche Scientifique et Technique
CRM	Certified Reference Material
ECN	Energieonderzoek Centrum Nederland
EEC	European Economic Community
ETL	Environmental Test Laboratory
HFR	High Flux Reactor
HT	High Temperature
HTM	High Temperature Material
HTR	(HTGR) High Temperature (Gas-cooled) Reactor
IAEA	International Atomic Energy Agency
JRC	Joint Research Centre
LWR	Light Water Reactor
MTR	Materials Testing Reactor
PAH	Polyaromatic Hydrocarbons
PSF	Pool Side Facility
R & D	Research and Development
RM	Reference Material
SEM	Scanning Electron Microscope
STEM	Scanning Transmission Electron Microscope
TEM	Transmission Electron Microscope

Colophon

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