Annual Report 1988

Institutt for energiteknikk

IFE's Board and Management, 1988

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Contents

The front cover image. Photo of a bifurcating cascade of vortex rings of diminishing size generated by submersion of a drop of milk in water. This is a simple example of the development of turbulence. IFE works on fundamental and practical aspects of turbulence.

Account and Balance

The annual account of the Institute with balance sheet and notes to the accounts from Auditor General is published in the Norwegian version of the Institute's Annual Report 1988.

Publications

A representative list of external work reports and publications is included in the Norwegian version of the Annual Report for 1988.

STATEMENT FROM THE BOARD, 1988
Introduction and summary

Institutt for energiteknikk (IFE) finds itself today in a competitive and challenging market environment, where research contracts are increasingly being determined by the laws of supply and demand. Professional excellence and skillful specialization in key areas are IFE's most important assets for establishing collaborative links with industry, commerce and the authorities.

As the central research institute for energy and nuclear technology, having close ties with the Ministry of Petroleum and Energy, IFE is placing emphasis on research directed towards:

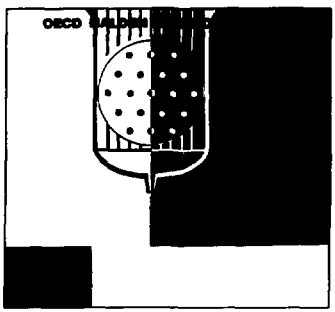
- Producers of oil, gas and electricity
  Energy consumers, particularly energy-intensive industries
  Governmental authorities
  (Ministry of Petroleum and Energy, Norges Vassdrags- og energiverk, the Petroleum Directorate)
  Supply industries
  Users of radioactive isotopes and radiation sources
  Institutes of higher education.

Nuclear power research at the Institute is performed within the international (OECD) Halden Reactor Project. The Halden Project represents an important means of maintaining national competence in handling problems related to nuclear power and nuclear safety (e.g. fuel technology, reactor technology). The project also forms the basis for extensive development work in information technology for Norwegian industry. The main emphasis is on the development of simulator systems, and systems for the control and monitoring of power stations and other complex plants.

IFE's petroleum related activities represent the top level of national expertise in selected areas of exploration and reservoir technology, multiphase technology and gas technology. This is the result of a combination of specialist knowledge of petroleum, flow and materials technologies with advanced mathematical and nuclear-based methods.

In the field of industrial technology, IFE's specialization in mathematical process modelling, process control, instrumentation and systems optimization are united.
An important objective is to increase the efficiency of energy-intensive processes. At IFE a national centre is being built up for industrial energy conservation, which, in cooperation with the authorities, is pioneering the introduction and increased use of energy-conserving process technologies.

IFE has a national function in providing isotope and irradiation services, including supply of established and novel medical isotope products to Norwegian hospitals. These activities are based on the operation of the JEEP-II reactor. The reactor is also the kingpin of IFE's fundamental research in physics, which plays a central role in Norway's research program in the physics of condensed phases. This work is also oriented towards advanced materials research for the petroleum and other industries.



The Institute's nuclear and non-nuclear activities require varying degrees of state involvement. In the nuclear-related areas in which IFE specializes, and which contribute to Scandinavian and international collaboration, the state plays an important part. Consequently, the Ministry of Petroleum and Energy provides annual grants to finance the Halden Project, the operation of the JEEP-II reactor, physics research, and the development of isotope products, together with related support functions (safety, radiation monitoring services, handling of radioactive waste). Further the Ministry of Petroleum and Energy funding supports the building up of apparatus and expertise in petroleum and industry-related areas at Kjeller.

In projects of a non-nuclear nature, that is to say areas where IFE's activities are of a similar nature to those of other research institutes associated with the Royal Norwegian Council for Scientific and Industrial Research system, external project funding at IFE is on par to that found in the other institutions.

The Institute's turnover in 1988 was NOK 240 million, of which NOK 152 million was derived from contract research. For IFE's petroleum- and industry-related activities the proportion of turnover deriving from contract research approaches 80%. The accounts showed a deficit of ca. NOK 2.0 million, which is similar to the profit for 1987. The loss has been covered by capital.

The number of employees at IFE has remained unchanged since last year, at about 520.

The Halden Project

IFE's involvement in the international Halden Project relates to the need for maintaining national competence and awareness in areas related to nuclear power. In the current agreement period, 1988-1990, more than forty organizations in eight European countries, Japan and the USA have joined the project.

The project involves fruitful collaboration with foreign research communities in frontier areas of information technology. The results of this collaboration are put to good use in projects for Norwegian industry.

The technical program of the Halden Project concentrates on two main areas:

- Fuel technology and instrumentation
- Information technology.

Fuel technology and instrumentation

The Halden reactor is internationally recognized as a testing ground for nuclear fuels, with highly advanced instrumentation. The agreed experimental program has been carried out satisfactorily in 1988, and about forty fuel element designs have been tested. The reactor has been in operation for seven months of the year, and has produced about 105,000 tons of steam which has been supplied to local sawmills.

The main objective for the research into reactor fuels at Halden is to discover the basic relations governing fuel reliability under various operating conditions. The operational strategy in modern power stations aims at prolonged fuel lifetime, combined with greater flexibility. A particular *problem in this context is the possibility of* corrosion damage. Corrosion testing is carried out in special test circuits in the Halden reactor. In 1988 a two-year program was completed for investigating the connection between various operational parameters and degree of corrosion in pressurized water reactors, and a new program was started. In addition, a new test circuit was completed to carry out similar experiments in the boiling water reactor environment. Much of the work is being carried out under bilateral direction with member organizations in order to resolve their individual problems.

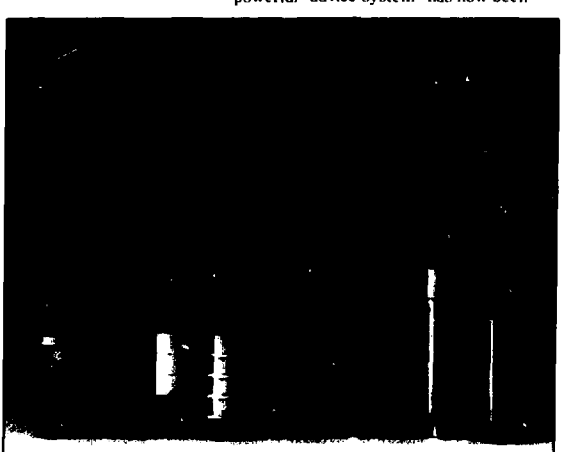
Most of the fuel tested in the Halden reactor is produced in the Kjeller laboratories, and later returned there for post irradiation investigation. This is important as part of the extensive range of long term fuel investigations being carried out at Halden.

There has been increasing interest in exploiting the special expertise in instrumentation technology that has developed through the Halden Project. Some examples of this related to nuclear power include development of methods for measuring flow and coolant level, and, in collaboration with other participants, the development of detectors for studying reactor fuels.

Information technology

The Halden Project research program on *supervision and control* systems has been progressing well. The development work utilizes an advanced experimental control room coupled to a full scale simulator of a pressurized water nuclear power station. During 1988 this laboratory was given additional computing capacity so that the simulator and control room can be used for running experimental information systems at the same time as using the simulator for developing new operator support systems. This laboratory is at the forefront in the development and testing of process monitoring systems.

Extensive testing has been carried out in 1988 of operator support systems, both homegrown and developed in collaboration with partners in the Halden Project. A powerful "advice system" has now been



Through development of specialized detectors and instrumentation for measurement of different reactor fuel parameters during operation, the Halden Project has developed a unique competence in the field of instrumentation technology.

operator tested. This system informs the operator if any of the functions critical to the process are threatened, and advises on remedial action. The tests have clearly shown that this type of advice system gives better operator support in critical situations than conventional alarm systems.

Results from the Halden Project's research activities in the field of computer based supervision and control systems are put to broad use in projects for Norwegian industry. The photo shows the central control room on the Oseberg production platform in the North sea.

A computer-based management system has been developed, and will be supplied to the Italian energy institute ENEA. Norwegian processing industries are also considering introducing this system. It is thought that such systems will gradually replace written procedures.

The development and testing of a monitor system, which identifies faults in a plant before the conventional alarm system is activated, has progressed in 1988. The system, which is based on mathematical modeling of parts of the process, is ready for installation in a Finnish power station in 1989. Further development has also started on an automatic detailed diagnosis system based on expert systems technology.

Work has also been carried out on the development of an integrated monitor and control system, in which individual subsystems such as warning alarms, computer-based procedures, diagnosis etc., are incorporated as modules. This will form the central information system for the operator in all situations: normal operation, operational disturbances and serious emergencies. The system will have an "intelligent" nerve centre which will organize and prioritize the flow of information. The project is being carried out in close collaboration with the Halden Project signatory organizations, and is seen as the prototype for the next generation of computer-based control rooms.

Work on ways of improving software reliability has been carried out in collaboration with Gesellschaft für Reaktorsicherheit (GRS) and Technischer Überwachungs- Verein (TÜV) in Germany, the United Kingdom Atomic Energy Authority (UKAEA) and the Central Electricity Generating Board (CEGB) in Great Britain, and Valtion Teknillinen Tutkimuskeskus (VTT) in Finland. During 1988 programming tools have been developed for the commonest processors.

An important aspect of the development work in information technology in Halden is use of sophisticated tools for programming, database management and information representation. Much of the work has concentrated around use of the powerful UNIX-based workstations, with high resolution colour graphics, for man-machine communication in real time applications such as process control and simulation. The newly developed advanced image generating system, Picasso-2, has played a central role. This system gives the user an effective tool for constructing dynamic flow diagrams, shaping dialog structures and testing the information system against a dynamic base. The system has been received with great interest among many of the signatory organizations in, for example, Great Britain, Italy and Sweden. In Norway the system is being used for simulation of the operating system in the Veslefrikk training simulator, in cooperation with Norcontrol Simulation, Horten.

In collaboration with Statoil, a project has been carried out in 1988 for drawing up general guidelines on the requirements for computer-based control and monitor systems for production platforms. The objective is to increase operational security through optimization of function size and reduction of complexity, investment and maintenance costs. The guidelines and methods that have been developed are also applicable generally in other areas of industry.

In 1988 a large preproject was completed on the specification and planning of the man-machine communication system for the operation planning tool SASIM, designed for the Norwegian electricity supply industry. The system is currently being evaluated by the Norwegian Power Pool. The experience and knowledge accumulated through this work will be valuable for the Norwegian power industry in building up instruments for the optimization and running of Norway's power network. A demonstration system has been completed in Halden, based on Picasso-2, which employs new presentations techniques in a user-friendly way.

Petroleum Technology

In this area, activity is being directed towards the development of methods and apparatus for cost-reduction in all branches of the petroleum industry, and for providing new industrial products. The research strategy is based on interdisciplinary collaboration combining the following elements:

- Advanced mathematical and computing methods
- Nuclear measurement techniques
- Petroleum geology and flow technology.

Reservoir modelling

Most mathematical models for the simulation of petroleum production assume that the reservoir is homogeneous in each block. In the SPOR project "Homogenization of heterogeneous volumes" processes are being studied for the homogenization of reservoir parameters. Programs for this procedure have been developed and tested using data from the Ness Formation in the North Sea.

Under the SPOR program new methods are being developed for the simulation of the movement of trace substances in oil reservoirs. In the tracer project a one dimensional program has been developed for simulation of tracer injection in a two phase fluid flow in porous media. The program builds on newly developed calculation methods that take into account the adsorption of tracers. The program is being tested against laboratory experiments. The next stage will be to extend the program to two dimensions in order to allow simulation of field scale tracer injection.

A three-year project has been started in collaboration with two German research institutes and the Rogaland Research Institute, in order to study the use of polymer flooding technology in the North Sea. The project is funded by Deminex of Germany. IFE has responsibility for the simulation part of the project, including evaluation of existing software, development of new software and simulation of laboratory and field experiments.

Collaboration has been progressing with the Courant Institute, University of New York, on the development and application of their front-tracking program. The program is now running, and has been tested in simulation projects for Statoil and the Continental Shelf Institute (IKU).

Basin modelling

IFE has special expertise in the development of mathematical models for simulation of the processes which lead to the generation and migration of oil and gas in a sedimentary basin. The GEOSIM program embodies knowledge of physical, geological and geochemical effects which are important in the generation and accumulation of petroleum. Production versions of the program are being used by Statoil in the evaluation of new exploration areas.

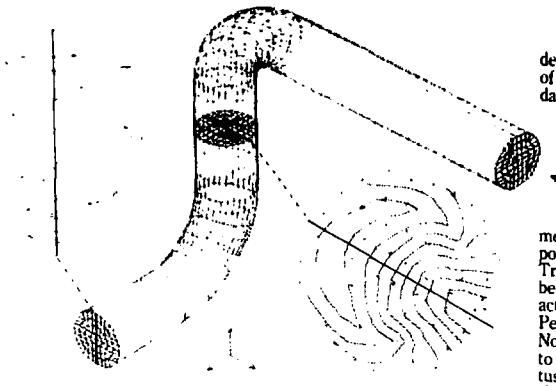
In 1988 the system has been broadened to include a greater number of geological processes, and a more detailed model has been developed for the breakdown of kerogen to oil and gas. Significant progress has been made in 1988 related to migration studies, i.e. modelling the movement of petroleum through sediments after generation. Mathematical treatment (the lithosphere underlying the basin) has also been introduced. This enables better estimation of the temperature history of the basin and therefore the conditions of oil and gas generation.

IFE's basin modelling work is a good example of how research, partly pure research in character, can yield important economic benefits for the oil industry and for society in general. Use of these simulation programs by the oil companies and the authorities will strengthen their basis for making decisions relating to exploration activity, thus contributing to a more efficient exploration strategy and reduced uncertainty in the identification of new oil and gas prospects.

Petroleum geology

Activities related to petroleum geology have mainly been focused on basin evaluation and reservoir characterization. In addition to total basin evaluations from various parts of

Field work in Utah, financed by the SPOR-program, has been basic to the establishment of a database for quantitative geological information.



The simulation of flow through two consecutive 90° bends. Black lines show areas with constant axial velocities. Green arrows are the component of the velocity in the cross section.

the Norwegian continental shelf, work has also been directed towards improving the input parameters to basin models, in particular the refining of temperature indicators.

Increasing use is being made of the strontium isotope ratio $^{87}Sr/^{86}Sr$, as a dating method. The method has good resolution, especially over the last 40 million years of the Cenozoic era, thus making an important contribution to the understanding of basin subsidence on the Norwegian shelf.

The main activity in reservoir characterization has been the establishment of a database for quantitative geological information. Data on the dimensions, shape, orientation and petrophysical properties of various lithologies have been gathered from rock units which are analogs of North Sea reservoir rocks. This has involved fieldwork in Utah, where Cretaceous Ferron sandstone bodies are particularly well suited for this kind of study. This work has been financed by SPOR, and has involved establishing a database specifically designed for use in stochastic reservoir modelling.

The development of geochemical methods for reconstructing the evolutionary history of a reservoir and delineating different hydrodynamic systems has paid off with promising results in 1988. Additionally, the use of trace element geochemistry of authigenic minerals (i.e. minerals formed within the reservoir) and reservoir fluids in combination with isotopic analyses of O,C,H and Sr on the same material has proved to be a powerful tool. IFE has performed the first analyses of uranium and lead isotopes in carbonate cements. Studies of various cement generations from sandstone reservoirs revealed that in some cases the uranium content of carbonate is sufficient to allow direct dating of the time of precipitation by means of the U-Pb system. It also appears that the lead isotope signature of some generations of carbonate cement relates clearly to the dissolution of feldspar. This makes it possible to devise an indirect method for quantification of feldspar dissolution and resultant secondary porosity.

Tracer technology

IFE's tracer studies are giving useful information relating to water and gas injection in North Sea fields. The use of tracers has a strong basis in fundamental laboratory studies of the behaviour of potential tracers under reservoir conditions. Tracer applications are diversifying, and beside work related to the SPOR project, activities are being sponsored by British Petroleum, Phillips Petroleum Company Norge and Statoil. This has made it possible to further upgrade the experimental apparatus. The construction of new types of flow rigs has enabled highly complex flow experiments to be carried out under reservoir conditions.

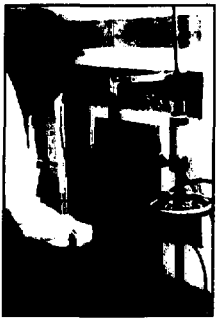
Scaling in pipe systems and production equipment in the oil industry has been found to be slightly radioactive, a situation which has been recognized for some time from the British side of the continental shelf, and more recently in Norwegian installations. Radioactivity from scale is the result of coprecipitation of radium and thorium with barite when injected seawater mixes with formation water. The Institute has been supporting the oil companies with analyses and advice in connection with the treatment of contaminated equipment.

Tracers are also being used in certain types of investigations of industrial processes. Tracers have been shown to be useful for determining residence times, volume measurements and leakage surveys related to process optimization.

Nuclear measuring technology

Collaboration in nuclear geophysics with British Petroleum Norway is proceeding on the development of a technique for measuring the absorption of thermal neutrons in reservoir rocks. Knowledge of this process is important for the correct interpretation of well-log data produced by certain types of nuclear logging tools. Information about water saturation in the reservoir will to a large extent depend on a good understanding of the neutron absorption characteristics of the rock.

A large amount of work has been carried out on improving measuring techniques for the spectroscopic determination of natural radiation in core samples. The work involves development of instrumentation and intercalibration of nuclear data from cores and wireline logs. During 1988 a system was developed for Reservoir Laboratories in Trondheim for the automatic recording of saturation profiles for use in a rig for measuring relative permeability.



Tracer testing at reservoir conditions.

1. *Sample preparation of genuine formation material.*
2. *Assembly of a core-plug in a shrinktube of inert material.*
3. *Experimental simulation of tracer behaviour in dynamic systems.*
4. *Results, dispersion profiles of tracers*

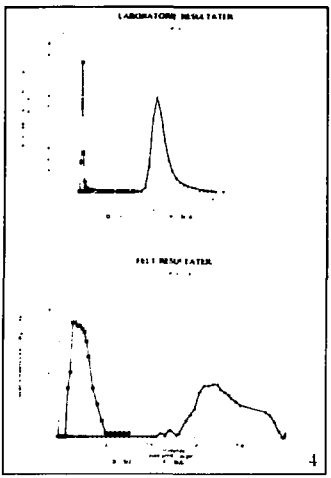
The use of fractal theory is a new area where IFE is engaged in basic research projects related to petrophysical reservoir description. Work commissioned by Fina Exploration Norway has been started, including extensive experimental and theoretical studies aimed at using fractal theory to aid reservoir characterization.

Environmental concerns have led to an increased interest in activation analysis for identifying and quantifying pollutants in, for example, industrial waste. During 1988 about 200 samples were analysed. Although the emphasis of most of the project is environmental, projects have also been carried out related to prospecting, medical and biological research, and quality control of products and other analytical methods.

During the year a number of chemical analysis projects have been carried out related to geochemistry, tracer applications, certification of uranium fuel and quality control of rare earth element products. IFE's laboratories for chemical analyses are well equipped for the analysis of small sample size and low concentrations. Laboratory equipment includes X-ray fluorescence and diffractometry, atomic absorption spectrometry and mass spectrometry, the latter being used in combination with laser technology for in situ analysis of carbon and oxygen isotopes in geological materials.

Multiphase technology

Multiphase technology is playing an essential part in the development of cost-reducing procedures for future offshore field developments. Increased use of multiphase technology will make it possible to utilize simpler and cheaper development strategies than are used today, for example allowing exploitation of existing platforms and pipelines for the development of new small fields. In the longer term, development could lead to direct transport to land of unprocessed well streams. In order to realize such goals continued development work is needed in IFE's specialist fields: flow technology, materials technology, instrumentation and process control. IFE today comprises the mainspring of Norwegian multiphase research.



The collaborative project with SINTEF on multiphase flow has advanced through a new two-year program which ends in 1989. The main objective of this project is to develop a new physical and numerical method for tracking "slugs" in pipelines. In close collaboration with SINTEF, IFE has also developed a plan for marketing and commercialization of the program OLGA under the direction of a Norwegian consultancy firm.

The development of integrated systems for control and monitoring of multiphase transport systems has progressed well in 1988, in close collaboration with the oil industry. IFE has been contracted to provide the software for a monitor and simulation system for two phase flow conditions in the TOGI pipeline, which will transport gas from the Troll field to Oseberg for gas reinjection. The system is programmed on two powerful UNIX-based work stations, and can raise alarms based on both real time simulations using on-line measurements, and on prediction of future conditions. IFE has also had the main responsibility for multiphase thermo-hydraulic calculations for the Gamma-Nord installation in the Oseberg field. Further development work has produced a VAX version of the program PIPPS (Pipeline Simulator Station) for the French Petroleum Institute (IFP). The system estimates and monitors two phase flow in a pipeline.

IFE has played a central role in setting up a national program for multiphase transport technology (PROFF), under the direction of NTNF. Of the four subdivisions of the program, IFE has been given responsibility for coordination of multiphase technology and choice of materials, erosion and corrosion.

Collaboration with the University of Oslo has been strengthened in 1988 by the appointment of two adjunct professors, one in flow technology, one in materials science. The Institute has four such positions, and this is giving a solid contribution to teaching and research at the university. Collaboration with the University of Pisa has been cemented by a doctoral studentship in the field of slug flow.

Gas measurement technology

Work in this field has involved development work for the measurement technology laboratory at Karsto (K-LAB). This relates to simulation of flow conditions in complicated pipeline geometries, and verification of calculations using modelling experiments. The aim is to achieve a simulator which, by using successive calculations for individual geometries, can compute the range of velocities in a pipe system constructed using standard geometries. During 1988 a computer program for four standard geometries was established, and progress has been made towards a flexible integration of the models. Laboratory experiments have confirmed the accuracy of the simulations. IFE has ongoing collaboration with the industry in observing and influencing work on international standardization which is relevant to quantitative measurement of natural gas.

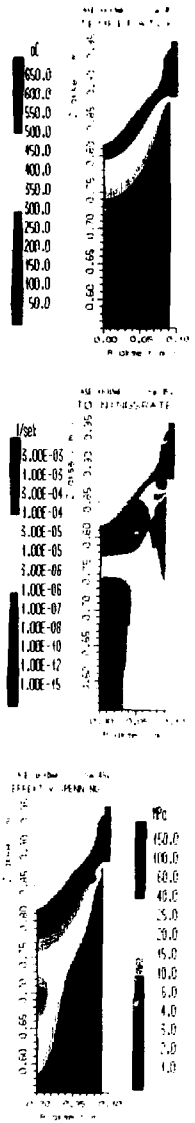
Gas technology

In early 1988, a methanol splitting system, rented from Norsk Hydro Elektrolysorer, was installed at IFE's gas laboratory. The system, originally built for the production of hydrogen by the restructuring of methanol, has been modified by Norsk Hydro for the production of synteses gases which will be used in experiments on separation technology.

The production of electricity from natural gas can occur in an efficient and environment-friendly way in fuel cells. By establishing a "Norwegian Fuel Cell Forum", IFE has contributed to the increased interest in fuel cells in Norway. The Forum has the participation of several research institutes, together with industry, energy supply and governmental agencies.

The program ALSPEN calculates thermal stress development during aluminium casting.

The figure shows the distribution of temperature, strain and effective stress in a radial section through an aluminium extrusion billet.



Industrial Energy Technology

IFE's activity in this field is based mainly on:

- Advanced research specialization in mathematical modelling, control, instrumentation and optimization of energy-intensive industrial processes
- Broad research links over many years with the Norwegian energy-intensive industries, especially the electrometallurgical industry
- Multifaceted and well established energy conservation activities, and close interaction with the Ministry of Petroleum and Energy.

Material modelling/process simulation

The program ALSPEN, which describes thermal stress during aluminium casting, achieved a breakthrough in 1988 with the development of a unique algorithm covering the entire temperature range. ALSIM3, which computes thermal relationships, has been modified and will soon be ready for use. New formulae for boundary conditions have been developed and incorporated into ALSIM2 and ALSIM3.

The STEELTEMP model is finding an increasing range of applications in the Scandinavian steel industry, and the model has been installed in five steelworks in Sweden and one in Finland. This dynamic model has, in the course of the year, been extended to cover substances in the furnace with variable dimensions and temperatures.

Activity in process simulation has mainly been concentrated on modelling of electrolytic aluminium furnaces and simulation of large processing projects. A model has been developed to represent the coating on furnace walls. It is important to be able to predict the shape and size of the coating when designing and constructing electrolytic furnaces. This program makes it possible for the first time to make a relatively accurate estimation of the shape of the coating. The program employs a dynamic element distribution, which tracks the shape of the coatings as they change shape during a run.

Aluminium furnaces can display instability due to the relationship between the flow of liquid aluminium in the furnace and the strong electromagnetic fields involved. In 1988 special attention has been paid to the horizontal component of the external magnetic field.

1988 saw the beginning of the EUREKA project PROSIM. This is a collaborative project with Norcontrol Simulation and the British organization SAST. The objective is to develop an advanced system for the construction

of modular simulators. IFE has developed an automatic network solver, which actually builds up the structure of the process system to be simulated, and coordinates the integration of pressure and flow calculations between the different unit of the process system. The network solver has been used for integration of the training simulator for Veslefrikk. IFE has also been involved in modelling aspects of the Veslefrikk project, using various node, pipe and valve models.

Under the direction of the Nordic Council of Ministers, a project related to energy consumption mapping in the foodstuff industry has been carried out.

The photo is from one of the participating companies – Henning-Olsen ice-cream factory in Kristiansand.

Prosess control

The project "Monitoring of vulnerable production equipment in the ferrous alloy industry" was completed in 1988. The project was part of the NTNF program "Automization of the processing industry", and has been running for three years. A comprehensive monitoring system has been developed in collaboration with Elkem, and has been installed in a FeSi furnace at Salten Verk.

Progress has been made with the control and monitoring of aluminium furnaces in collaboration with Hydro Aluminium. During the year a state estimator, based on an extended Kalman filter, has been put into trial use in two furnaces. Development has begun on a regulator which uses the estimates of state. A preliminary study has also been carried out on the possibility of using an expert system for monitoring furnaces. A simple demonstration prototype is under development.

The simulator OPPSIM, for operator training in aluminium foundries, has been sold to ENEA in Italy. ENEA will use OPPSIM in projects for the Italian aluminium producers Aluminia.

In the project "System for optimal economic control" a study has been carried out on material flow and material administration, mainly in the paper and metallurgical industries. In the project "Regulation of processes which are difficult to represent" the use of expert systems has been studied in relation to other types of regulation and monitoring methods.

Energy conservation

The project "Optimal running of industrial drying plants" is concerned with problems related to drying technology. So far the drying of grain and wood has been examined. The project is supported by NTNF, regional energy authorities and industrial partners. Another project, under the direction of the Nordic Council of Ministers, has been carried out in order to survey energy consumption in various branches of industry. IFE has studied two companies in the foodstuffs industry.

Within the Norwegian wind power program, the building of 10-15 wind power stations along the Norwegian coast is being considered for the near future. IFE is carrying out wind measurements at the proposed sites, and thus calculating expected output. IFE is also developing tools for the collection and processing of such data.

The prototype demonstration program "Energy in industry" will come to a finish in 1989. The results from the first projects can now be documented. Eight final reports were completed in 1988. The results from these have been distributed by the Norwegian Centre for Energy Information (NSEI) to interested parties. At the end of 1988 the project had, in total, contact with 83 companies. Government funding (ca. NOK 12 million) has resulted in investment of about NOK 7 million in energy conservation. The expected energy saving is almost 70 GWh, and the average repayment time is 2.5 years.

In collaboration with Pentech A/S energy measurement packages have been developed and produced, including equipment and software.

Five reports have been prepared for the Ministry of Petroleum and Energy (the trade network, the consultancy program, quality assurance, action plan, the energy conservation potential for Norwegian industry), in connection with the preparation of the parliamentary report on "Energy conservation and renewable energy resources".

Acting as the national center for energy information (NSEI), IFE is actively spreading energy information in Norway. The main objective for NSEI is to be the Norwegian contact for various energy databases, including the new IEA database CADDET (Centre for the Analysis and Dissemination of Demonstrated Energy Technologies). Four Norwegian projects have been submitted to CADDET in 1988.

In 1988 IFE conducted parts of the The Ministry of Petroleum and Energy training program for industrial and consultancy trades. A complete training program has been developed with three levels: Introduction course, Foundation course and Specialist course. The entire program is directed towards more effective use of energy.

Materials Technology

IFE's activities in this area are based on well established specializations in corrosion, "exotic" or special metals and welding technology.

Materials and corrosion

A third phase of an international project on stress corrosion in storage tanks for ammonia was started in 1988. The aim of the project is to determine fracture propagation rates at low temperatures -33 C. The importance of this problem has been emphasized by the unexpected discovery of fractures in refrigerated storage tanks. The results of IFE's research will be important for current safety evaluations of this kind of tank. The project is being funded by industry and the authorities in Europe and the USA.

There has been increasing activity at the Institute related to advanced metals, especially titanium. Two large consecutive projects have been carried out on the offshore and on-land industrial uses of titanium for Phillips Petroleum Norway and CNEN, Italy. IFE is also participating in a three year EEC funded EURAM project on the use of titanium in offshore installations. The project is being carried out in collaboration with industry and research institutions in Finland, England and Spain, and is focused on hydrogen brittleness in titanium. It may be advantageous in future submarine installations to use titanium coupled to less noble metals which are cathodically protected. Under such conditions and in adverse circumstances, titanium may absorb hydrogen, which can then initiate brittle failure in the metal. The aim of the project is to assess the limits for safe use of titanium in submarine installations in the light of this phenomenon.

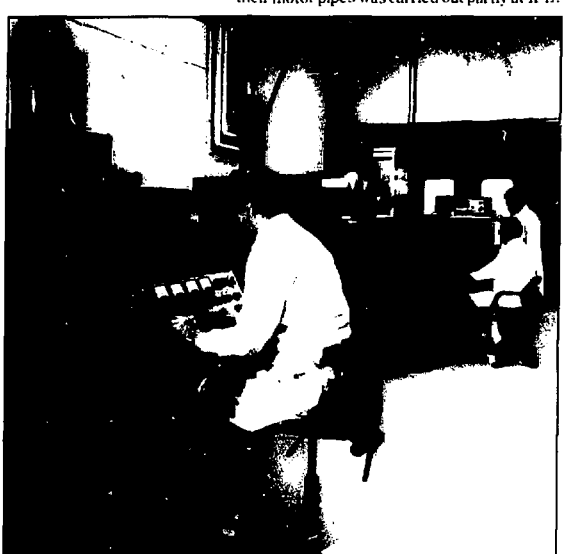
Work related to materials selection and the corrosion of steel in submarine petroleum production and transport has progressed in 1988. Materials for development of the Snorre field have been evaluated for Saga Petroleum, together with the corrosion behaviour of various steel alternatives. Experimental work related to internal corrosion has progressed on several fronts. Five oil companies are funding a project on CO_2 corrosion of steel under strictly controlled conditions (Kjeller Sweet Corrosion II). Fundamental studies have been carried out on the galvanic effects between different grades of steel, and between bare metal and metal covered by corrosion film. The conditions under which such effects are likely to cause problems have been evaluated.

The oil corrosion laboratory has been extended with two new test circuits. In one of these it is possible to study corrosion in the gas phase in pipes which are half filled with oil. This type of corrosion is difficult to combat by conventional methods such as use of inhibitors. Experiments in this test circuit have been funded by Statoil.

Another test circuit for studying sand erosion has been used to study the effects of the amount of sand, grain size and flow geometry on internal abrasion in steel pipe. This project also has oil company sponsorship.

Metallurgy and welding technology

In 1988 numerous projects have been carried out for Norwegian industry involving electron beam welding techniques, for example welding of airplane engine components for civil and military planes (for Norske Jetmotor A/S). Work for Luftforsvarets Forsyningskommando has also been started on the use of electron beam welding for the modification of Norwegian F-16 jet engines. Norsk Forsvarsteknologi has supplied a series of Penguin missiles to the USA. Electron beam welding of their motor pipes was carried out partly at IFE.



In 1988 IFE doubled its electron beam welding capacity. IFE is now operating two 6 kW electron beam welding machines. This gives an improved flexibility and security for the customers. The electron beam welding workshop is an offer to the industry where they can get development work as well as production welding done.

Nuclear fuel

A new fuel charge for the JEEP reactor was produced in 1988, together with standard fuel elements and new experimental fuels for the Halden reactor. The metallurgical hotlab completed at the end of the year a large post irradiation investigation of an irradiated fuel rig for Power Reactor and Nuclear Fuel Development Corporation (PNC), Japan.

Isotope and Irradiation Services

Isotope supply

IFE's current supply service of isotopes includes manufacturing, control and distribution of radiopharmaceuticals, chemicals and irradiation sources. Most of these radioactive products go to nuclear medical departments in hospitals and to research laboratories at Norwegian universities and colleges. Radiopharmaceuticals are used mainly for organ imaging and organ function studies.

More than 200 tons of spices and other food additives are now being irradiated at IFE each year.

The development of new radiopharmaceuticals and the improvement of existing products is being carried out in close collaboration with the hospitals and pharmaceutical companies. Work on one existing compound in 1988 aimed to modify it so that it could be used in the diagnosis of a wider range of illnesses. The majority of the research has been carried out in liaison with Nycomed A/S on the development of new radiopharmaceuticals based on raw materials which can be manufactured using new biotechnological methods. Work has been concentrated on finding specific "homing" molecules which, after marking with radioactive isotopes, can be injected into the body and actively targeted at and concentrated in cancerous tissue or other anomalous areas. IFE's role has centred on the problem of marking the new molecules with suitable radioactive isotopes, development of analytical methods and the design of biological models.

In a project initiated by the Scandinavian Medical Committee, IFE, in collaboration with the State Medical Control, has contributed to the drawing up of guidelines for the approval of radioactive medicines. The cooperation is continuing with the aim of creating a code of practice for the handling and control of radiopharmaceuticals in hospitals.

Quality control of radiopharmaceuticals, radiochemicals and their raw materials is an ongoing activity, together with providing documentation of these for the European Pharmacopoeia.

Neutron and gamma irradiation

Neutron and gamma irradiation is performed by IFE for numerous clients in Norway and abroad. The irradiation takes place in the JEEP-II reactor and the gamma irradiation facility. The most important tasks are:

- Manufacture of radioactive substances
- "Transmutation", i.e. neutron doping of semiconductors for the electronics industry
- Sterilization of medicines and medical equipment
- Antibacterial treatment of packaging for foodstuffs
- Sterilizing spices and other food ingredients to prevent infection of industrially produced foods.

Neutron irradiation creates radioactive isotope in the material. This is the basis for the manufacturing of suitable starting materials for the production of radioactive medicines and chemicals. Radiation sources are also made for industrial use (as tracers in various industrial processes) and research. Another application of radiation sources is in the training of personnel in the use of measuring equipment for radioactivity, or the control of such equipment.

Super pure silicon in monocrystalline chromium is irradiated with neutrons in order to alter its electrical conductivity, in that some of the silicon atoms are converted to phosphor. This produces a very evenly doped material which has special applications in the electrical and electronics industries.

In the gamma irradiation facility, ionizing radiation is used from ^{60}Co, a highly radioactive source. This radiation does not cause radioactivity in the irradiated material, while organic substances and microorganisms in the materials are affected by the radiation. At sufficiently high radiation doses, microorganisms (e.g. bacteria) are destroyed. This is exploited as a means of sterilization, e.g. for disposable medical equipment. For some products it is sufficient merely to reduce the number of microorganisms to an acceptably low level. This would apply to spices and flavourings for industrially produced food-

stuffs and the packaging of foods designed for a long storage life. This kind of irradiation service is carried out at IFE for a long list of Norwegian companies.

Over 200 tons of spices and other food additives are now irradiated at IFE each year for the foodstuffs industry. Gamma irradiated packaging is used mainly for dairy products with a long storage life, but also for some medical products.

Operation of the JEEP-II reactor

The research reactor *JEEP-II* is Norway's only facility for irradiation with high neutron doses. It represents a national resource for research, development and production in a variety of areas. JEEP-II is necessary for IFE's basic research activities in neutron physics, irradiation activities, isotope supply and neutron activation analysis. Excess heat from the reactor is used to heat eight buildings at IFE. *JEEP-II* has been in continuous operation in 1988, apart from three down periods for maintenance, fuel adjustment and inspection.

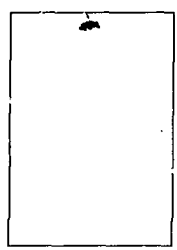
Basic Research in Physics

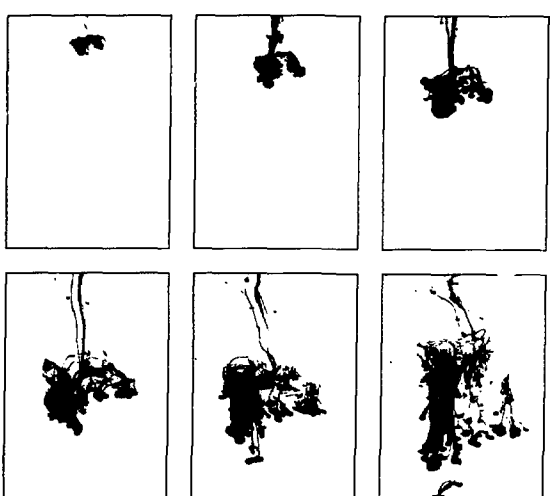
This activity has a broad interface with Norwegian and foreign research communities, and is directed towards areas which are important for other research and higher education in Norway.

Neutron radiation from the JEEP-II reactor is used for research in condensed phase physics. The neutron radiation is an invaluable aid for, e.g., crystallographic analysis of magnetic materials and of bonding between light and heavy elements. Researchers at the Institute are thus collaborating with other research groups on the investigation of high temperature superconducting oxides.

Monodisperse microspheres in water or ferrofluids are being used as model systems for studying various fundamental processes such as crystallization, melting, aggregation and fracture generation. This work is funded by Dyno Industrier A/S.

Non-linear phenomena related to chaos and turbulence are being studied with neutron diffraction and optical microscopy respectively in convecting liquids and in paramagnetically rotating monodisperse particles.





Development of turbulence. The photo-series illustrates the time development of a bifurcating cascade of vortex rings generated by submersion of a drop of ink in water. The tree like structure may be described mathematically as a fractal set illustrated by a cascade of line segments with diminishing length.

Special IFE Functions

A number of activities are a consequence of the Institute's national responsibility in nuclear affairs. This includes, for example, advisory projects for the authorities, the library for atomic energy literature, fuel services for the Halden program and the Scandinavian program for reactor safety. The extent and content of work in the areas of radiation safety and radioactive waste are determined largely by IFE's own nuclear activities in the reactor plants and laboratories. IFE has Norway's only system for the handling and storage of radioactive waste, and thus accepts such waste from external users of radioactive substances. IFE also has the expertise and equipment to carry out external projects related to radiation safety.

Library and literature services

IFE's library represents not only the scientific library for the Institute, but also the national reference library for nuclear technology and research oriented energy literature. Consequently the library serves a range of external users.

In an initiative organized by the International Energy Agency (IEA), and under an agreement between the Scandinavian authorities and the USA relating to exchange of energy information, Norwegian energy literature and publicly financed Norwegian energy research reports are referenced and fed into an energy database. The same reporting is used in the compilation of the Nordic Council of Ministers' catalogue of Scandinavian energy projects. Norwegian literature on nuclear power and related areas of physics are referenced in the INIS database of the International Atomic Energy Agency (IAEA).

National and international nuclear power liaison

In compliance with the Non-Proliferation Treaty, all nuclear materials in Norway are subject to security inspection by the IAEA. IFE carries out the practical steps demanded by the safety inspection agreement between Norway and the IAEA. IFE thus maintains the required national registration and inspection system for nuclear substances. Through constant contact with IAEA's safety inspectorate, including routine reporting of stocks and stock changes, IFE has, as in previous years, arranged for IAEA's safety control in Norway.

IFE has also given support to the authorities in connection with other international nuclear energy issues, especially in IAEA and OECD's nuclear energy agency (NEA). In 1988 IFE has acted in an advisory capacity in connection with problems that have arisen related to previous Norwegian exports of heavy water.

IFE contributed towards national preparations in readiness for the possible crash of the satelite COSMOS 1900.

IFE is today the national center for reception, management, treatment and storage of radioactive waste. The photo shows control of low-active "scale" (internal deposition of radioactive material) in a component from an oilproduction system.

Safety and environmental services

Security aspects of the operation of the Institute's reactors and laboratories are monitored by the Safety Committee and its sub-committees. The Safety Committee undertakes safety clearance of experiments, changes in operating personnel and procedures, and alterations to and running of the nuclear and non-nuclear facilities. The Safety Committee is an advisory body for IFE's management in safety related issues, and it ensures that safety measures set by the State Atomic Inspectorate (SAT), the State Institute for Radiation Hygiene (SIS) and the Works Inspectorate are fulfilled. The Institute places great importance on protection against industrial espionage, and has a committee for computer security.

The radiation protection service carries out routine control of radiation resulting from IFE's activities. During 1988 there have been no incidents in which safety has been compromised. Monitoring has shown that the average radiation dose to the approx. 20% of the Institute's staff which has been exposed to radiation at work in 1988 lies well below 10% of the current limits for occupational exposure. The radiation thus does not represent any significant occupational hazard.

The recorded emissions of radioactive substances from the Institute have, as in previous years, been very small, and represent no threat to the environment.

Two types of service are being offered in association with SIS: finger dosimetry, mainly for Norway's larger hospitals, and calibration for hand-held instruments for the measurement of radioactivity.

As part of IAEA's safety evalutaion of IFE's nuclear facilities, the radiation protection set-up was also assessed. IAEA concluded that the standard of radiation protection work at IFE was very high, despite the scanty resources allocated for radiation protection.

IFE has had a number of projects for local authorities, housing corporations and private individuals related to the measurement of radon concentrations in soil, bedrock, drinking water, building materials, houses and other buildings. In collaboration with the Norwegian Geological Survey (NGU), IFE can now offer to local authorities and other housing developers a complete service for the assessment of the radon hazards in, for example, planned housing estates.

The laboratory for environmental monitoring is specially equipped for the measurement of small amounts of radioactive pollution, and carries out the statutory controls on IFE's releases to the surroundings. The laboratory is collaborating with institutions in Norway and abroad, and is participating in Scandinavian radioecological initiative, presently focused on Chernobyl fallout. The laboratory also carries out a number of external projects in 1988, including the nationwide monitoring of radioactive fallout, which IFE has performed since 1982 under contract from the Norwegian Defence Research Establishment (NDRE). This involves monitoring samples of air, precipitation and milk from stations in Kjeller, Bergen, Stjordal and Tromsø. Under recommendation of the Fretheim committee for a national plan of action for nuclear power accidents, IFE was given several tasks, including monitoring of the marine environment in collaboration with the Institute of Marine Research. IFE is one of the very few organizations in Norway which is able to analyse "difficult" radioactive substances such as strontium and plutonium.

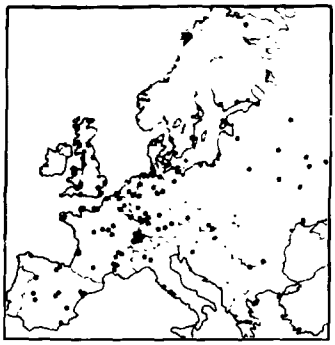
Nordic safety program

The reactor safety work at IFE includes contributions to Nordic collaborative projects directed by the Nordic Liaison Committee for Atomic Energy (NKA). These projects are funded by the Nordic Council of Ministers, and include the refining of data and methods related to risk analysis, and the analysis of consequences and remedial action in the event of a reactor accident. The Chernobyl incident has demonstrated the importance of maintaining knowledge and expertise in such subjects at a national level, even in a country without its own nuclear power stations. These collaborative research projects are thus of vital importance for maintaining know-how and expertise.

Radioactive waste

A new encapsulation system for medium level waste from the Halden reactor was started up in 1988. The system was commissioned at the beginning of 1988, and encapsulation of radioactive ion exchange resins from the water cleaning circuits has been an important activity during the year. In addition, routine work is continuing relating to the collection, handling and storage of radioactive waste from IFE's own activities and from other users of radioactive substances such as industry, hospitals, defence and research institutes.

Collaboration with the other Nordic countries on waste from reactor decommissioning has progressed, and work on low level radiation in scale in pipelines and equipment has been carried out in collaboration with oil companies. Optimal volume reduction will be an important aspect of long term disposal plans for low level waste.



Questions related to accident preparedness play a major role in the Nordic cooperation in the nuclear power safety field.

The figure shows location of European nuclear power plants (each dot indicates 1 to 4 reactors).

Economy

The Institute's gross turnover for 1988 was NOK 237.0 million, of which NOK 149.8 million relates to activities at Kjeller, and NOK 87.2 million to work at Halden. The accounts showed a loss of NOK 2.1 million, which will be covered by capital. The loss mainly relates to the activities at Halden. IFE's income from contract research in 1988 comprised 64% of the total income, a reduction of 3% from the previous year as a result of tighter market conditions. The level of income from contract research is nevertheless still regarded as high, especially considering the unusual overheads incumbent upon IFE with the operation of reactors and nuclear laboratories (safety, radiation protection, security and control of nuclear substances, handling and storage of nuclear waste).

Personnel

At the end of 1988 IFE had 521 permanent employees, of which 321 work at Kjeller, 200 in Halden. The total is similar to the previous year. There was 7% staff turnover. 178 employees have university or college education, and 136 have technical college qualifications. During the year 7 of the Institute's scientists have been pursuing doctoral studies in Norway or abroad, and 5 have been given leave for other forms of higher education.

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