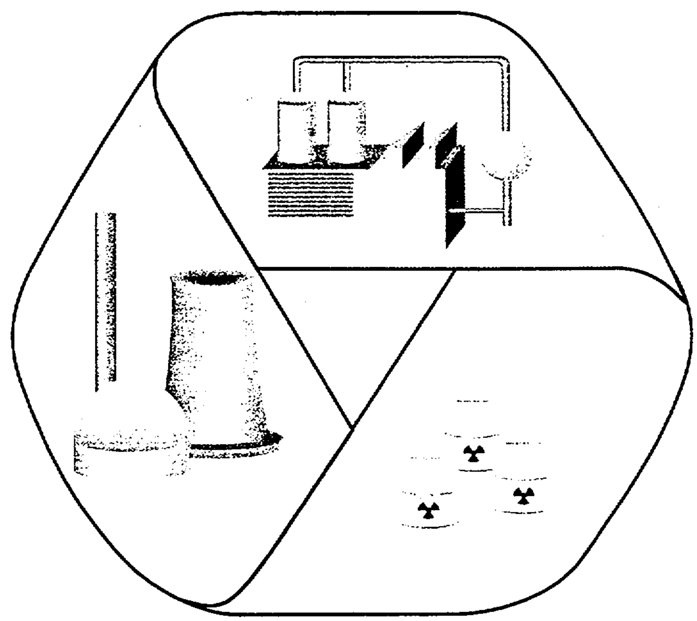
Forschungszentrum Jülich

# Institute for Safety Research and Reactor Technology (ISR)

The rapidly growing world population (expected to almost double by the year 2025) and the need in the Third World to catch up on standards of living will lead to a dramatic increase in the world energy demand. Due to the greenhouse effect, the protection of our environment requires a considerable reduction in $CO_2$ emissions and, in general, the avoidance of further pollution of the biosphere.



The technology applied must fulfil the safety requirements of our society. The technology of the future must now be designed and assessed in the sense of precaution for the future in order to lay the foundations for responsible technology application.

Great significance is therefore attached to application-oriented research for energy technology and the safety of technological facilities.

To this end, ISR is undertaking work in three fields:

## 1. Accidental Risks of Large-Scale Technical Systems

The objectives are to provide methods and data for analysing and assessing risks as well as to draw up safety requirements. Work comprises:

- phenomenological modelling of the accident behaviour of systems and plants,
- event sequence analyses and studies on the reliability of plants and operating staff,
- assessment of accident impacts.

Director: Prof. E. F. Hicken,
also: Ruhr University Bochum,
Chair of Safety Research and Reactor Technology

## 2. Safety Research for Nuclear Installations

Work is directed towards the further development of plant safety so that accidents do not have any damaging effects on the population and environment. Work concerns:

- advanced reactor designs for water- and gas-cooled reactors,
- installations for nuclear waste management,
- facilities for converting radionuclides with a long-term risk.

Director: Prof. K. Kugeler,
also: Technical University of Aachen,
Chair of Reactor Safety and Reactor Technology

## 3. Nuclear Waste Management

The unhazardous recycling or safe final disposal of radioactive substances arising from nuclear engineering is the research goal. Work focuses on:

- characterizing radioactive wastes,
- treatment and storage of radioactive substances,
- radiochemical studies on waste partitioning for isotope transmution,
- development of methods for quality assurance of the wastes to be disposed.

Head: Dr. H. Brücher
(acting)

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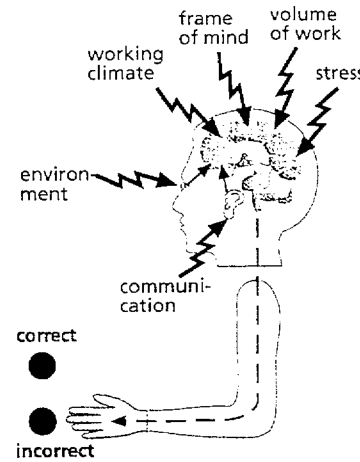
# 1. Accidental Risks of Large-Scale Technical Systems

An acceptable **assessment of the safety and risk of large-scale technical systems** with a high hazard potential is a necessary condition for decisions on their application. Methodologically convincing analyses are required to quantitatively describe the accident behaviour of facilities as exhaustively as possible. Such analyses are the basis for demonstrating the required safety, for achieving further optimizations and for characterizing the residual risks. To this end, data and methods for determining the causes and the frequency of malfunctions as well as for describing accident sequences and their impacts are being compiled and further developed. Failure modes and failure probabilities under operating and accident conditions are being determined experimentally and also computed with the aid of probabilistic structural mechanical methods for safety-relevant large-scale components.

Increased safety requirements and efforts at restricting as far as achievable the number of possible errors and failures especially in the case of systems of significance for plant safety have led to the current safety philosophy of, as far as possible, **"passive safety"**. Active systems whose functioning depends on the availability of external driving energy (e.g. electricity or steam) or on complex controlling mechanisms should be replaced by passively acting systems whose function is based on simple physical principles (e.g. gravity, convection, heat conduction). A passive system for afterheat removal envisaged for the SWR-1000 innovative boiling water reactor is for example the "emergency condenser". This system is being tested under operating conditions at a large thermohydraulic test facility in ISR.

Risk analyses must also include an assessment of the safety-relevant behaviour of the operating staff. Depending on the degree of automation, **human reliability** influences the safety and thus also the risk of large-scale technical plants. This does not only concern incorrect actions. In the case of beyond-design accidents, appropriate action as trained by accident management techniques can be suitable for reducing the accident risk. In collaboration with industrial and organizational psychologists, the decision-making

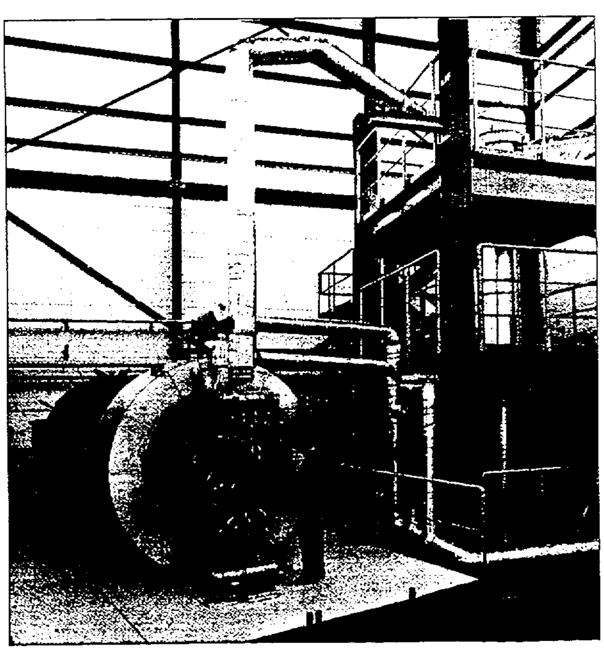



*Influence on operator behaviour by external impacts*

behaviour of operators under stress is being investigated and accidents analysed regarding operating errors.

An energy economy intending to apply the **utilization of hydrogen** on a large scale to satisfy energy requirements will require extensive facilities for storage and distribution. Thoughts of introducing such an energy economy must therefore also include considerations of the risk and studies on the safety of handling, storage and distribution. As an example, safety issues and methods of risk assessment are being investigated in the demonstration project for a complete hydrogen system (PHOEBUS) at the Research Centre Jülich. Furthermore, accidents with the release of liquid hydrogen from a tank at temperatures of minus 250°C were simulated and the spread and evaporation of the ensuing puddle investigated concerning issues of storage or transport risk. For mixtures of hydrogen and air in buildings, the sequence and impact of combustion and explosion processes are being examined.

Finally, ISR is contributing to fusion research at the Research Centre by safety studies on the oxidation of First Wall materials.



*Thermohydraulic test facility for demonstrating the special safety features of water/steam circuits*

## 2. Safety Research for Nuclear Installations

The objective of work at ISR is **catastrophe-free reactor technology.**

The amended Atomic Energy Act requires that, even for events which can be practically excluded, the consequences remain confined to the plant so that, for example, evacuation or relocation is not necessary.

Advanced reactor concepts therefore should satisfy three basic requirements for all cases of accidents:

- **self-acting limitation of nuclear power** and fuel element temperatures,
- **self-acting removal of afterheat** from the reactor system and
- **self-acting maintenance of fission product barriers:** fuel element, reactor pressure vessel and reactor containment.

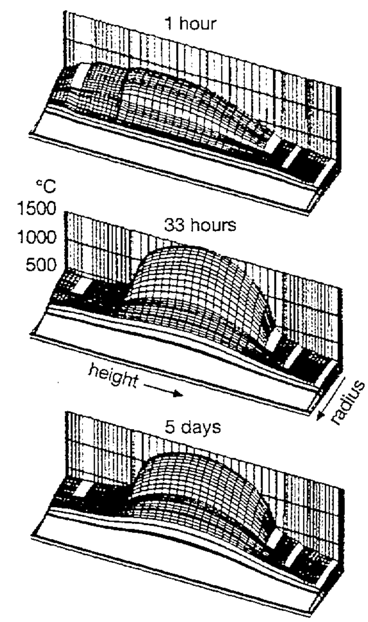
Self-acting is a key concept here, for this is the best protection against damage resulting from the failure of active safety devices. As an illustration, heat transfer between a hot and a cold body is a self-acting process which cannot fail.

Theoretical and experimental studies are being carried out at ISR on solutions for ensuring compliance with the required criteria. It is being examined whether this can be realized for high-temperature reactors as well as innovative water-cooled reactor designs.

Two examples from our current work will be described in more detail here.

- For the **prevention of core meltdown:**

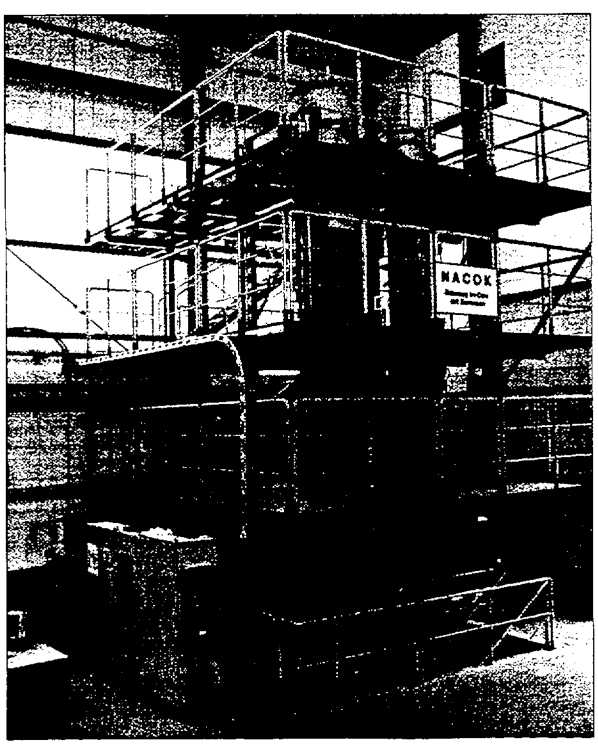
In the HTR-Modul reactor, the fuel elements cannot melt because the afterheat is removed to the outside in a self-acting manner thus ensuring a self-acting limitation on fuel-element temperatures so that fission products can practically not be released. The temperature transient over time in the HTR core is investigated in detail by a computer program. The illustration on the right shows the temperature limitation. This is a computer result which has also been tested in the SANA (German acronym for self-acting removal of afterheat) experimental facility illustrating a principle of catastrophe-free reactor technology.




*The transient over time of the fuel element temperature in a pressureless high-temperature reactor after failure of all active cooling devices: the core does not melt, the temperature is limited in a self-acting manner.*

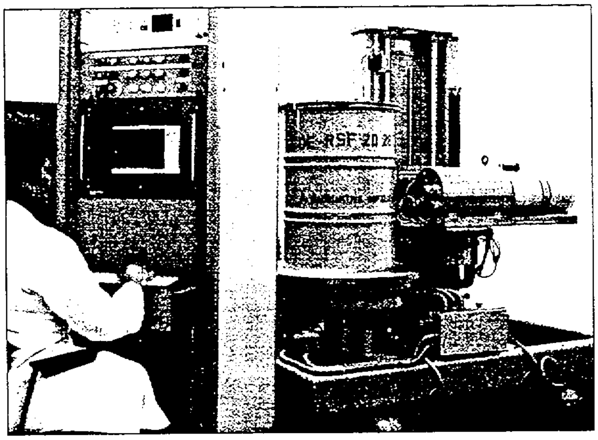
- For the investigation of **corrosion due to air ingress:**

Natural convection is a universally known phenomenon. If it causes air to flow through a hot graphitic core structure then damage occurs due to corrosion. However, natural convection can also have a positive effect if increased cooling occurs. The NACOK (German acronym for natural convection in the core with corrosion) experimental facility is used for the investigation of these coupled phenomena. NACOK essentially consists of an experimental channel which can be heated to 1000° C and through which air flows in a natural draught. The action of this natural convection has now largely been investigated and subsequent studies will be concerned with corrosion.




*NACOK (natural convection in the core with corrosion) detection device for studying corrosion due to air ingress.*

# 3. Nuclear Waste Management



*Examination of a 200-litre drum for gamma radiation*

The safe and environmentally compatible **storage of radioactive wastes** must satisfy stringent requirements. To this end, efficient methods for characterizing radioactive wastes have been developed at ISR. Today, conventional analyses are complemented by the direct measurement of gamma- or neutron-emitting radioactive residues from reactors. The results are exact data on the type and extent of radioactive isotopes as well as their constituents. Only in this way can the wastes be classified according to their properties thus creating the necessary prerequisite for their safe disposal.

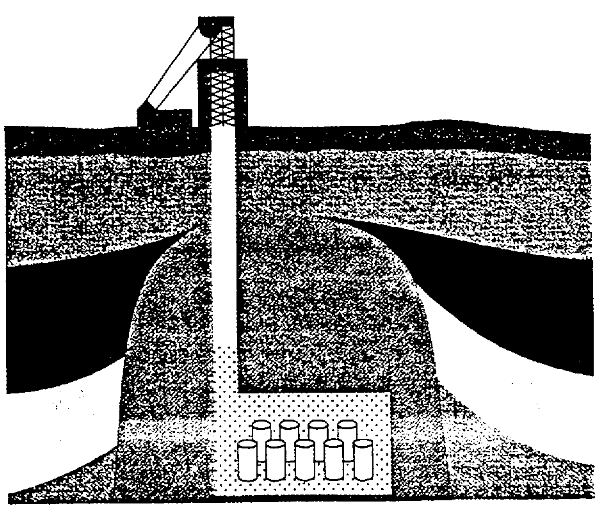
At present, radioactive waste still contains the entire spectrum of more than 40 chemical elements. Efficient **separation methods for long-lived isotopes** are therefore being developed. Short-lived radionuclides whose radioactivity already decays after a relatively short time are left behind. The separated long-lived isotopes can, in principle, be transformed in a reactor or particle accelerator into short-lived or stable elements (transmutation). If this transformation does not achieve the desired aim then the few long-lived radionuclides can be permanently fixed in **tailor-made ceramics** developed at ISR.

The **safe final disposal** of radioactive wastes is one of the key issues in nuclear engineering. In Germany, deep-seated geological formations are being investigated as repositories, e.g. the salt dome at Gorleben or the Konrad iron mine near Salzgitter. In salt domes, heat-generating wastes will be stored for millennia in deep boreholes or in horizontal drifts. The cavities are backfilled with coarse-grained crushed salt.

With the aid of computer models and laboratory experiments, the **pressure distribution within the salt backfilling**, amongst other aspects, is being investigated in ISR at different temperatures and with different arrangements of waste drums.

*Crushed salt in the repository: investigating the pressure distribution*

No water has penetrated into the salt domes for about 250 million years. Nevertheless, investigations on the **behaviour of waste packages in brines** are being performed at ISR. As yet, there has been no indication of a risk to the biosphere.



*Schematic representation of a mined geological repository*