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NUCLEAR SAFETY RESEARCH AT THE JOINT RESEARCH CENTRE OF THE COMMISSION OF THE EUROPEAN COMMUNITIES.

Within the framework of the 1977-1980 research programme entrusted to the Joint Research Centre by the Council of Ministers, an important part (about 40%) of the activities are devoted to the problems posed by nuclear safety. The Joint Research Centre of the Commission of the European Communities, with its four Establishments at Ispra (Italy), Geel (Belgium), Karlsruhe (Federal Republic of Germany), and Petten (the Netherlands), is carrying out the Commission's own "direct action" in the field of scientific research. Other Community research activities are implemented through the Commission's "indirect action", that is in cooperation with organizations and institutions, public and private, in member countries.

The "nuclear safety" part of the JRC programme has been drawn up and is being carried out taking into account Community needs in this field and the work underway in member countries. For this purpose, the Commission avails itself in particular of the advice of Advisory Committees composed of national experts.

Under the "Nuclear safety" heading, the JRC is investigating three different research areas :

- Reactor safety;
- Plutonium fuels and actinide research;and
- Management of nuclear materials and radioactive waste.

A short description is given here below of what the JRC is now doing in these fields of nuclear safety research.

Reactor safety

Reactor safety activities of the JRC are among the measures taken by the Commission to improve the safety of nuclear installations, as required by a decision of the Council of Ministers. They include three types of studies:

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- Overall Analysis of safety concepts;
- Theoretical and experimental studies of possible accidents; and
- Prevention of component failure.

The overall analysis of different reactor safety concepts will permit the comparison and synthesis of methods of risk evaluation used in the Community as well as in the US. The reactor safety programme is carried out mainly at the Ispra Establishment of the JRC, with a contribution by the Karlsruhe Establishment.
The main aim of the JRC research programme on reactor safety is the study of the probability, the sequence and the consequences of hypothetical reactor accidents. The JRC work is closely coordinated with the national programmes in the same field and is mainly concerned with problems of general interest.

The programme concerns both light water reactors (LWRs) and liquid metal cooled fast breeder reactors (LMFBRs). While most of today's nuclear power programmes in Community countries are based on LWRs, LMFBRs are in the advanced development stage and, with their capability of producing more nuclear fuel than they consume, may represent the future prevailing technology of nuclear power utilization.

As far as light water reactors are concerned, the worst possible accident which can theoretically occur is the rupture of the primary cooling loops followed by a rapid loss of the cooling water which assures the removal of the heat generated in the reactor core. The investigation of such hypothetical accident implies research on a number of areas, such as :

- necessary margins of tolerance for reduced cooling in the reactor core, and behaviour of fuel cladding temperature;
- reliability of emergency core cooling systems (ECCS);
- consequences of reactor core melting, in case of ECCS failure; and
- relevance of rupture size and position in the cooling circuit.

The main contribution of the JRC to these studies is centered around an experimental facility, the largest of its kind in Europe, which simulates circuit rupture in a four-loop primary cooling system of a 1.300 electrical megawatt pressurized water reactor (PWR) and subsequent blowdown conditions. "Blowdown conditions" are those caused by a sudden and total loss of the cooling water from the primary circuit, and may lead to melt-down in the reactor core. Theoretical and experimental studies are provided for by this research programme. These experiments are partially covered by a research and development contract between the European Commission and the Federal Ministry for Research and Technology (BMFT) of the Federal Republic of Germany. Existing "blowdown" codes should be compared, critically analyzed and validated by experimental results.

A further contribution to the analysis of the accident chain are the studies on fuel-coolant interactions which may occur as a result of a hypothetical accident. These studies concern both LWRs and LMFBRs. They propose to define, by experimental tests and theoretical analysis, the conditions under which violent interactions may occur between molten core materials (nuclear fuel and structural materials) and the coolant (water or sodium). Various highly advanced facilities are used, where molten core materials and cooling fluids are brought together and the resulting conditions are thoroughly analyzed.

Another important field of LWR safety research included in the JRC programme is aiming at the setting up of a European Reliability Data System, to collect all available data on the reliability of commercial LWR components. Moreover, a probabilistic analysis of LWR core accidents is planned, with emphasis on the study of some initiating events (such as failure of pressure vessel, primary pipings, etc.), effects of blowdown conditions in the core, models of various accidental paths, etc.

As far as liquid metal fast breeder reactors are concerned, the JRC programme provides for both theoretical and experimental studies on sodium thermohydraulics, fuel-coolant interaction and associated problems, and dynamic loading and response of reactor structures (primary containment and core internals) following a hypothetical explosive accident.

Thermohydraulics studies on the heat transfer from the fuel assemblies to the sodium primary coolant (under accident conditions) propose to contribute to the development of adequate computer models describing such situations. Theoretical analyses and experimental tests are performed on the consequences of a number of initiating events.

The work on fuel-coolant interaction has already been mentioned above, in connection with LWR safety research. A particular problem concerning LMFBRs is that of the removal of heat from a molten core after a hypothetical accident. In this field the JRC is starting experimental and theoretical work aiming at the development of physical models and calculation codes to serve as a basis for the design of post-accident core cooling systems.

The studies on the mechanical behaviour of reactor components under normal and off-normal conditions, as well as after an explosive accident (that is, of their dynamic loading and response) aim at developing and validating computer codes. The experimental programme includes a series of explosive tests on reduced-scale models of LMFBRs: these tests will be used to validate mathematical models and codes developed in structural materials and components are also investigated as part of the programme .

Within the general framework of reliability and risk assessment studies, the development of a European fast reactor accident code is also planned, according to the recommendations made by an Expert Group to the European Commission. The new code will provide a flexible system for module interaction and code organization, capable of receiving modules selected from national computer programmes; The final goal is the setting up of a modular code including the most advanced modules describing the sequences of whole core accidents in fast reactors.

All the activities described so far are essentially oriented towards the study of the initiating events which may lead to a reactor accident and their consequences. Another part of the JRC safety programme deals with the prevention and the early detection of possible failures. The long term behaviour of LMFBR materials is analyzed, in order to develop and validate non-destructive testing techniques for the surveillance of nuclear power plants. Issues under investigation include fracture mechanics in stainless steel structures; fatigue and creep crack growth in the same structures; the applicability of ultrasonic emission techniques for early failure detection; and the reliability of these techniques for the surveillance of operating reactors.

Plutonium fuels and actinide research

The best utilization of plutonium as a fuel is for fast breeder reactors (which can produce more fresh plutonium in the uranium blanket than is burnt in the reactor core), but it can also be put to use in today's uranium fuelled, commercial power reactors. Here plutonium can either be burnt within the same uranium elements where it is generated (thus contributing to the increase in the life-time of the element), or be recovered from spent fuel and recycled into new, plutonium-enriched fuel.

What is the subject-matter of research on plutonium and the heavier elements formed in nuclear reactors?

Apart from the solution of the scientific and technological problems standing in the way of the development of economically and technically satisfactory plutonium fuel, major safety problems stem from the alpha radioactivity and the toxicity of plutonium and the other elements forming the 14-member group called the "actinides", because of their common atomic properties. The acquisition of a full knowledge of the conditions for the safe handling of increasing quantities of these elements up to the final disposal of radioactive wastes is therefore an absolute necessity.

The unity of this research, which includes technological development and human and environmental protection research, is based on the dangerous properties (radioactivity and toxicity) of plutonium and the other actinides. Because of these properties, research activities can only be conducted in very specialized installations. The Karlsruhe Establishment of the JRC has been constructed to concentrate Community activities in this field, and this is where most of the programme is carried out, with a contribution by the Ispra Establishment.

In this programme, development-oriented research is intimately linked with safety research, also in the studies on the utilization limits of plutonium fuels (mostly for fast breeder reactors). The work in this field includes the volume increase ("Swelling") of advanced fuels submitted to high power density and to long periods of operation in a reactor under varying conditions; the compatibility between mixed uranium-plutonium oxide fuels and stainless steel cladding materials under severe conditions; the thermal behavour of fuel rods under irridiation; and the evaporation of nuclear materials above their melting point.

The studies conducted on the plutonium and actinide aspects of the nuclear fuel cycle are closely related with the two other JRC nuclear safety programmes, concerning nuclear reactors and radioactive waste management. Basic safety problems of the nuclear fuel cycle are investigated from the standpoint of the handling of large amounts of plutonium compounds during reprocessing and refabrication, etc.
A substantial amount of basic research work on the actinides completes this JRC programme. The actinide research is by itself a long term activity being carried out in a web of interconnections between various European research institutes, in a spirit of truly European cooperation.

Management of nuclear materials and radioactive waste.

The industrial exploitation of nuclear energy involves the production of substantial quantities of radioactive wastes, which are quite different in chemical composition, physical constitution, quantity and level of radioactivity. Among these wastes, the elements heavier than uranium (or transuranium elements) are the main cause for concern, since they couple very long radioactive lives (up to millions of years) with very high radioactive toxicity. The JRC research programme in this field is mainly carried out at the Ispra Establishment, with a contribution by the Karlsruhe Establishment.

Two different approaches exist for the solution of the problem :

a) the permanent disposal of wastes in well chosen geological sites, where the definite assurance can be reached that no disrupting factors will affect the long term safe containment of the wastes and their separation from the biosphere; and
b) The development of new techniques by which the elements responsible for long term hazard would be eliminated. Such new techniques can be oriented toward their transmutation into different, non-toxic elements.

The assessment of long term hazards of radioactive waste storage is one of the research lines pursued by the JRC, within the framework of the first approach to the solution of the problem. The analysis includes the theoretical evaluation of the risks of waste disposal and the comparison of the various options and strategies for the optimization of the choice of geological sites. Other studies concern the long term behaviour and stability of glass- and bitumen - conditioned high activity waste; and the techniques for the detection and measurement of the actinides contained in solid wastes.

In addition to the JRC programme in this field, the Commission of the European Communities started in 1975 an "indirect action" on waste management.

Various aspects of waste conditioning technologies are studied by this programme and a large coordinated action has been launched for **the** study of waste disposal in various types of geological formations.

The separation and nuclear transmutation of actinides is the alternate, second approach solution of the waste problem being studied at the JRC. The idea is of chemically separating the actinides from the other wastes and transforming them, by exposure to neutron bombardment, into short-lived elements , thus altogether eliminating the long term hazard. Theoretical assessment studies and experimental actions are being carried out for a better understanding of the feasibility, advantages and disadvantages of the proposed method.

Apart from nuclear waste, other safety problems arise from the accumulation of radioactive corrosion products in various circuit components of water cooled reactors : radioactive materials originated by irradiation in the reactor primary cooling circuit are corroded and carried away by the cooling water. Over the years they may gradually accumulate in primary circuit sections outside the reactor core. The solution of the problems brought about by this phenomenon would be useful for the safety of procedures for nuclear plant maintenance, repair and decommissioning. This programme particularly deals with contamination mechanisms in high temperature water circuits, the study of contaminated surface layers and the actions of decontaminating agents.