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Nuclear Safety Research Department

Annual Progress Report 1992

Edited by B. Majborn, K. Brodersen, C.F. Højerup and
F. Heikel Vinther

Risø National Laboratory, Roskilde, Denmark
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Abstract The report describes the work of the Nuclear Safety Research Department during 1992. The activities cover health physics, reactor physics, operation of the Danish educational reactor DR1, and waste management.

Lists of staff and publications are included together with a summary of the staff's participation in international committees.

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1 Introduction

The Nuclear Safety Research Department is engaged in research and development concerning radiation protection, reactor safety and radioactive waste. The department is organized in three sections: The Health Physics Section, the Reactor Physics Section (with the reactor DR1) and the Waste Management Section.

In addition to its research and development activities, the department is involved in supporting activities related to the safe operation of the nuclear facilities at Risø. The activities include personnel dosimetry, maintenance and calibration of health physics instruments, emergency preparedness, reactor physics support to the reactor DR3, criticality evaluations, and participation in safety committee work. The Waste Management Section is responsible for the safe handling and storage of radioactive waste from Risø as well as from other Danish users of radioactive materials.

The work of the department involves a close collaboration with the Danish nuclear authorities: the Civil Defence Agency and the National Institute of Radiation Hygiene, and also with Danish and foreign universities and research institutes, especially the Technical University of Denmark and partners in research programmes supported by the CEC (Commission of the European Communities) and by NKS (the Nordic Nuclear Safety Research Programme).

The department is involved in the CEC research programmes: Radiation Protection, Radioactive Waste, SCIENCE and TELEMAN, and from December 1992 also in the new concerted action programme: Reactor Safety. In addition, the department is involved in the NKS programmes on emergency preparedness, reactor safety and radioactive waste.

As a part of the co-operation between Risø and the Civil Defence Agency on emergency preparedness, Risø has assisted the Civil Defence Agency during 1992 in preparing a general nuclear emergency preparedness plan for Denmark.

During 1992, a new indoor storage facility for low-level radioactive waste came into operation. It is planned that during the next 2-3 years the waste units which are now stored at an old outdoor storage facility will be transferred to the new building.

This report describes the work of the Nuclear Safety Research Department in 1992 with an emphasis on the results of the research and development activities. Lists of staff and publications are included together with a summary of the staff's participation in international committees.

2 Health Physics

The work in the Health Physics Section includes modelling of atmospheric dispersion of radioactive substances, research and development in dosimetry and instrumentation, as well as radon research. The section also takes care of personnel dosimetry and service on health physics instruments at Risø and contributes to emergency planning and preparedness.

2.1 Dosimetry

2.1.1 Personnel Dosimetry

Risø's personnel dosimetry service covers the individual monitoring of the personnel at Risø and at the Niels Bohr Institute Tandem Accelerator. Only persons actually involved in radiation work are equipped with a personal dosemeter. For controlling the radiation levels in areas where the use of personal dosemeters is not required, an extensive area-monitoring programme using thermoluminescense (TL) dosemeters has been established.

In 1992, 879 persons were monitored. Of these, 205 persons received doses above the registration level for doses from external radiation of 0.2 mSv. The total dose (collective equivalent dose) registered to the monitored personnel was 275 mSv which is nearly the same total dose as registered in 1991. 64 persons received internal doses caused by intake of tritiated water. The contribution to the total dose from internal doses was 38

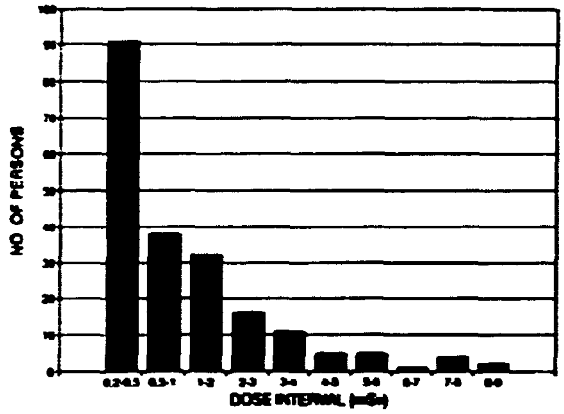

Fig. 2.1. Distribution of whole-body doses (effective doses) in 1992 for the Risø personnel.

mSv. For 1991 the total internal dose was 16 mSv. Figure 2.1. shows the distribution of the registered doses for 1992.

2.1.2 CEC Technical Recommendations on Individual Monitoring

Together with other European laboratories, the dosimetry group assisted the CEC in preparing a document on technical recommendations for monitoring the exposure of individuals to external radiation. The document was further discussed and revised during 1992 and it is expected to be published at the beginning of 1993.

The group evaluated and reported results from a measurement programme aimed at testing the adequacy of the recommendations prescribed in the document. The results confirmed the adequacy of the recommendations.

2.1.3 Dosimetry of Beta and Low-Energy Photon Radiations

In collaboration with seven European laboratories, the group participates in a joint CEC research project aimed at improving the dosimetry of weakly penetrating radiations. The project has been approved for funding by the CEC for a new two-year period. The dosimetry group at Risø co-ordinates the project and contributes by establishing and characterising calibration beams and by developing and studying extrapolation chamber and TL measurement techniques for dosimetry of weakly penetrating radiations. The radiation field from a Ru-106/Rh-106 source was studied for dose rate homogeneity and residual maximum beta particle energy. Furthermore, results were obtained on the radiochemical purity of the source. Agreement with ISO requirements for beta calibration beams was obtained with respect to dose rate homogeneity and residual maximum beta energy. However, it was observed that the source in addition to the Ru-106/Rh-106 radioisotopes also contained a significant amount of another beta emitter with lower beta energies and a longer half-life. The problem has been addressed to the producer of the source with the intention of acquiring a new pure Ru-106/Rh-106 source.

Progress was obtained in the establishment of an automated, computer-controlled extrapolation chamber measurement set-up. This work was carried out with assistance from the Engineering and Computer Department at Risø.

The LiF:Mg,Cu,P TL material has been further studied for application in individual monitoring. Thin detectors were prepared from different products and their dosimetric characteristics were investigated. The results show that the LiF:Mg,Cu,P TL phosphor exhibits good characteristics for application as thin detectors in individual monitoring of weakly penetrating radiations.

Within the framework of EURADOS, studies continued on the determination of dose rates from low-energy beta sources. Results were evaluated for measurements made at four different laboratories of the dose rates from equal Pm-147 sources.

2.1.4 Control of Irradiated Spices

The measurement of TL of dust particles is a reliable method for distinguishing irradiated from non-irradiated spices. The dosimetry group assisted the National Food Agency of Denmark with TL measurements of a number of selected samples of spices for irradiation control purposes.

2.2 Radon Research

A model of radon transport in soil and entry into houses has been further developed and tested. It is a two-dimensional numerical model of the finite-difference type. The calculations are performed in two steps. Firstly, the movement of soil gas is determined in response to an indoor-outdoor pressure difference. Secondly, the model solves the radon transport equation that involves generation, decay, combined advective and diffusive transport, and partitioning of radon between the gas and aqueous phases. The model is flexible and can be used for the Risø test structure, for real houses, and for soil probes. The model has been implemented on a personal computer and on a VAX-8700. On a personal computer, the model can handle grids with up to 10000 nodes. It has been subjected to a number of tests concerning the mathematical correctness. The verifications have focused on the ability of the model to solve two-dimensional heat-flow problems and one-dimensional radon-transport problems for which solutions are known. In addition, the model has been tested against other numerical models.

The model was used to calculate soil-gas and radon entry rates at the radon test structure established at a field site at Risø. The heart of the structure is a 40 litre stainless-steel cylinder placed in a 0.52 m deep quadratic excavation with a side length of 2.4 m. The excavation is lined with an airtight membrane, and soil gas enters the cylinder through a changeable interface in the bottom. A number of probes have been installed in the soil around the structure, so that the pressure and radon fields in the soil can be mapped. Experimental results obtained at the structure were compared with results of model calculations based on measured soil parameters. The measured and calculated values of the pressure couplings, the normalized radon concentration fields under diffusive and advective conditions, and the degree of radon depletion were in reasonable agreement for most of the probe locations. This verifies the ability of the model to describe the combined diffusive and advective radon transport which is a key element of the model. However, the model significantly underestimated the soil-gas and radon entry rates. Even if the soil was assumed to be homogeneous and to have a permeability equal to the highest of the measured values, the predicted soil-gas entry rate was still a factor of two lower than measured. This indicates that even a rather extensive characterization of the soil may be insufficient for correctly predicting soil-gas and radon entry rates in the common case of inhomogeneous soils.

Construction of a new test structure was initiated in the latter half of 1992. The new structure simulates a slab-on-grade foundation more closely than the previous one. Houses with slab-on-grade foundations are the most common type of single-family houses in Denmark, and they have the highest average indoor radon concentrations in the living areas.

The numerical model has been used to study the importance of soil and building related factors on radon entry rates. For a slab-on-grade house with a 3 mm perimeter crack along the floor-wall joint, the entry was found mainly to be determined by the soil permeability and by building related factors such as house depressurization and the presence of a capillary breaking layer of gravel below the slab. For a house with a bare soil floor, the diffusivity of the soil was found to be of principal importance for the entry rate even for moderate permeabilities.

This work is carried out in collaboration with six other European laboratories in a joint CEC research project on Radon Sources, Models and Countermeasures.

2.3 Development of Instruments and Methods

2.3.1 Optically Stimulated Luminescence (OSL)

A system allowing for optical stimulation of luminescence in quartz and feldspar has been described previously. It is based on a tungsten halogen lamp and a filter system. Powers of 16 mW/cm^2 were recorded for the broad wavelength band 420-550 nm using a 75W source.

A new ultra-compact module was developed, which - when attached to the above system - allows for monochromatic illumination of samples in the wavelength range from 380 to 1020 nm. Fast optics, highly efficient wavelength dispersal and low stray-light levels were the prime requirements of the design, since the built-in excitation lamp of the system is of relatively low power. We have thus chosen to use linearly variable interference filters for monochromatic dispersal (typical transmission efficiency of 30-60%) in conjunction with linearly variable glass filters for stray-light rejection, and f-2 optics for high light throughput. When coupled to the standard OSL module, output powers of between 0.02 mW/cm^2/nm (at 400 nm) and 0.6 mW/cm^2/nm (at 1000 nm) are measured. The use of a variable slit (0-10mm) allows the resolution of the system to be continuously adjustable from 0 to 80 nm. Continuous wavelength scanning is provided via a stepper-motor system with running speeds of between 0 and 30 nm/s (at 0.14 nm per step).

Additionally, the small dimensions of the unit (it adds only 4 cm to the size of the original OSL system) means that it is easily installed between sample and photomultiplier, allowing for wavelength dispersal of the luminescence signal.

In 1992, Risø delivered TL/OSL systems to the following research laboratories: 1) Bergakademie Freiberg, Germany, 2) Max-Planck Institute, Heidelberg, Germany, 3) University of Cologne, Germany, 4) University of London (Royal Holloway), UK, 5) University of Sussex, UK, and 6) Nordic Laboratory for Luminescence Dating, Denmark.

2.3.2 Low-level Beta Multicounters

The five-sample anticoincidence multicounter system, model Risø GM-25-5, for low-level beta counting applications was modified with the aim of improving the lower detection level by reducing the counter background. The physical dimensions of the mechanical counter unit were changed to achieve an optimal guard/sample counter geometry and thereby reducing the background arising from the cosmic radiation. The inherent instrument background was determined by testing the multicounter over a prolonged time in the Asse salt mine facility in Germany. This facility has an ultra-low ambient dose rate of less than 1 nGy/h, which is approximately 100 times less than that at the ground surface.

The measurement programme in the Asse underground laboratory further comprised counting of ultra-low-active Tc-99 samples extracted from sea water collected in the Greenland Sea and the Baltic Sea. The samples with activities as low as a few mBq were counted over a week and calibrated against samples with known Tc-99 activities.

The modification of the counter geometry generally improved the background from approximately 0.20 cpm obtained with the previous model to about 0.15 cpm obtained with the new 50 mm model in a normal laboratory environment. By inserting the sample slide with sample holders mounted with 0.7 mm thick non-active steel plates as blanks, the background was lowered by about 30% resulting in a zero value of typically 0.11 cpm for the new 50 mm counter. The latter effect may be ascribed to attenuation of beta particles generated from contamination of the surrounding material. The background measured in the Asse salt mine was typically 0.05 cpm and thus about three times less than that obtained in a normal laboratory.

The use of an extra external guard counter on top of the lead shielding was found to further reduce the background by about 20% to a value of typically 0.09 cpm in a normal laboratory environment. The effect obtained with external guard counters is ascribed to the elimination of secondary gamma radiation produced in the passive lead shield. A further reduction of the background may thus be achieved by covering a greater part of the surface of the lead shield with external guard counters. However, a cost-benefit analysis must consider the increased gas consumption by using several external large-area gas-flow counters.

Earlier, the use of the five-sample beta multicounter resulted in a detection level of about 2 mBq when counting Tc-99 samples for 24 hours. Now, with a counting efficiency of 41% and a typical counter background of 0.05 cpm, a detection level of about 0.8 mBq is obtained when counting Tc-99 for 48 hours. A schematical diagram of the new five-sample beta multicounter is shown in Fig. 2.2 and the experimental set-up with external guard counter is shown in Fig. 2.3.

Risø beta multicounters were delivered to 1) The University of Faroe Islands, 2) Institute of Radiation Hygiene, Norway and 3) Institute of Energy Techniques, Norway.

2.3.3 Measurement of Environmental Gamma Radiation

The instrument group co-ordinates a CEC research project aimed at testing different detector types for environmental photon radiation and the establishment of calibration procedures.

Continuous measurements of the air kerma rate at the Hinkley Point Power Station in the UK were successfully completed using four different designs of active monitoring systems in addition to passive integrating TL dosemeters. The work was carried out under a Risø subcontract with Dr. I.M.G. Thompson (UK). Details are given in a paper submitted for publication in Radiation Protection Dosimetry.

Comparison of results from the four active detectors shows that although they all very closely followed the variations in air kerma rate with time, they did not agree in the measured values of the different radiation components. Figure 2.4 shows an example of the air kerma rate variations as measured by the high-pressure ionisation chamber provided by Risø National Laboratory

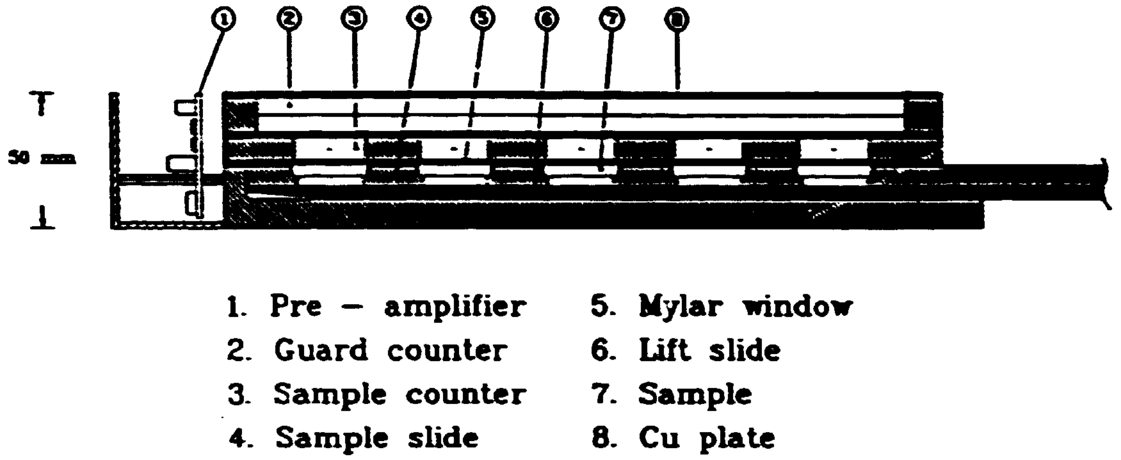

Fig. 2.2. Schematic diagram of the new five-sample beta multicounter

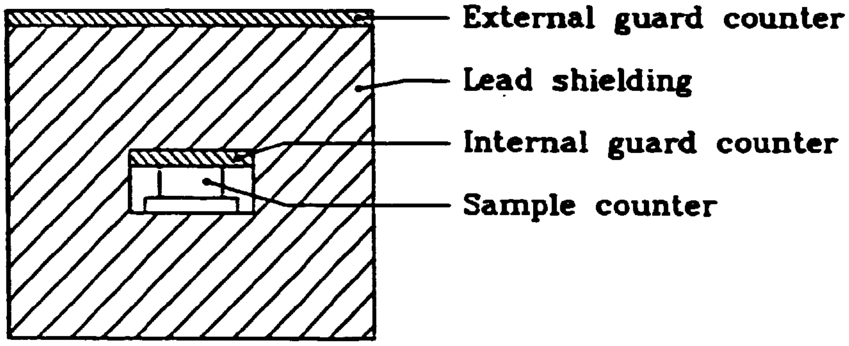

Fig. 2.3. Schematic diagram of the beta multicounter set-up with external guard counter.

and by the UK GM counter. Constant dose rates of different heights are caused by the natural background and the high-energy N-16 radiation at different power steps of the reactor. The peak shaped variations riding on the constant dose rates have their origin in the directional changes of the wind blowing the Ar-41 plume across the dose rate meters. The Hinkley Point experiments clearly demonstrated that dose measurements in the environment of a nuclear facility can only be accurate if continuous measurements are made and the detectors respond accurately to the different radiation components.

2.4 Modelling of Atmospheric Dispersion

The main projects in 1992 concerned development of on-line models in close co-operation with the Meteorology and Wind Energy Department at Risø and numerous national and international groups. The co-operation partners include the Danish Inspectorate of Nuclear Installations, the Danish Meteorological Institute, Kernforschungscentrum Karlsruhe, Naval Postgraduate School, Monterey, Laboratorie de Mècanique des Transferts Turbulents et Diphasiques, Nantes (LMTTD), and Central Research Institute for Physics, Budapest (CRIP). The main purpose of the work is to improve the models in respect to their application in emergency preparedness both for conventional and nuclear releases.

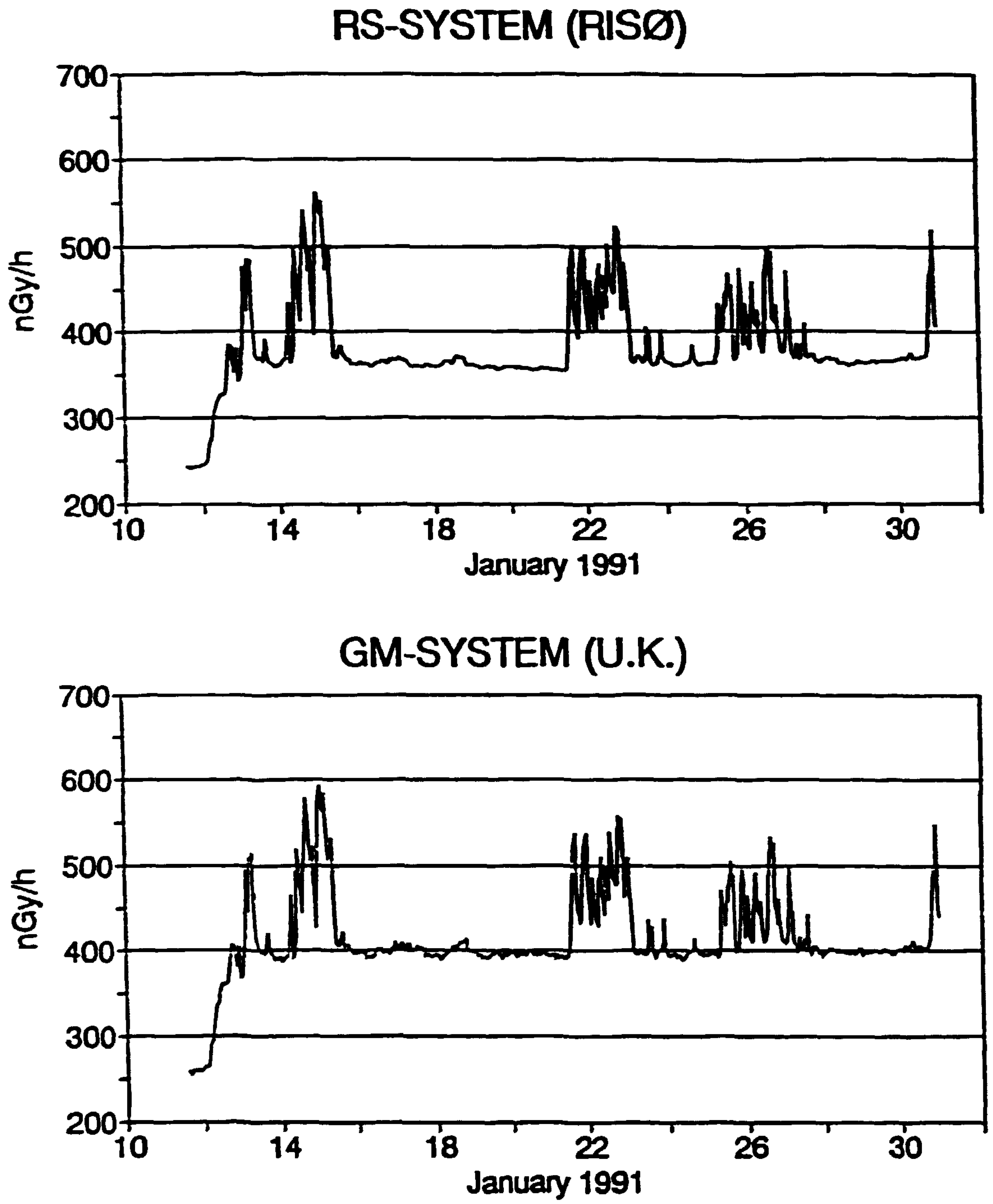

Fig. 2.4. The air kerma rate variations at the Hinkley Point Power Station in January 1991 as measured by a Reuter Stokes high-pressure ionisation chamber (RS-system) and a GEC GM counter(GM-system).

The on-line dispersion model developed within this context, RIMPUFF (RIsø Mesoscale PUFF-model), was enhanced with a fast model for calculation of gamma doses from puffs developed in co-operation with CRIP. Computer programs displaying time series of calculated and measured dispersion data were developed. This work is done within the framework of a contract with the CEC concerning the implementation of RIMPUFF within a harmonized European system for real-time calculation of the consequences of nuclear accidents (RODOS). RIMPUFF is now being implemented as a near mesoscale atmospheric dispersion module in RODOS.

The wind field calculated by a fluid-equation-based flow model is normally based on one upwind and unperturbated observation. However, for natural conditions, a procedure has been set up to calculate a wind field, which gives the best fit to a network of simultaneous observations at multiple stations. This fitting procedure was implemented in RIMPUFF.

Several field experiments with Risø's mini-LIDAR show that RIMPUFF is able to simulate short-time concentration fluctuations very realistically.

The risk of infection of pigs by the so-called Aujeszky's disease was evaluated using RIMPUFF and data from meteorological stations in southern Jutland.

A series of full-scale dispersion experiments are being analysed. The experiments were carried out over complex terrain at Guardo in northern Spain in 1990. Actual wind and turbulence measurements taken during the experiment are used as input data for a series of simulations made with Risø's combined flow and diffusion model (LINCOM/RIMPUFF). The results are compared with actual observed mean dispersion data, and the uncertainty associated with the modelling is analysed.

In co-operation with LMTTD and Centre Scientifique et Technique du Batiment in Nantes, work started on development of an on-line system for use in connection with accidents on oil-refineries, chemical factories etc. within the municipality of Nantes.

2.5 Emergency Preparedness

Under the Nordic Nuclear Safety Research Programme 1990-1993, the Health Physics Section is entrusted with the management of the BER-3 project entitled: Evaluation and Harmonization of the Planning of Countermeasures and the Use of Intervention Levels.

The working group published a report on methodology for justification and optimization of protective measures including as a case study an analysis of the »Exercise Sievert«-release. Furthermore, a chapter on »Psychological Factors to be Considered in Deciding on Intervention Measures« was finished as a pre-print to the final BER-3 report.

On December 8-9, 1992, decision makers and radiation experts from the five Nordic countries gathered in Denmark for participation in a Decision Conferencing Exercise.

The objectives were threefold:

1. To achieve a common understanding between decision makers and local government officials on the one hand, and the radiation protection community on the other, of the issues that arise in decisions in the aftermath of a major nuclear accident.
2. To identify issues which need to be considered in preparing guidance on intervention levels.
3. To explore the use of decision conferencing as a format for major decision making.

An updated version of International Intervention Policy and Nordic Status on Intervention has been published.

Risø, the Danish Meteorological Institute (DMI), and the Swedish Meteorological and Hydrological Institute (SMHI) are studying the methods for coupling RIMPUFF into a system for calculating the dispersion of toxic materials over long (1000 km) and medium ranges. This work is part of the program BER 1.1, Real-time Dispersion Modelling.

The present status of the Nordic Chernobyl Data Bank (NCDB) was presented at the Nordic Radioecology Seminar at Tórshavn in June 1992.

The C-base system forming the support of the NCDB was documented.

As the A6 computer at Risø was finally closed at the end of 1992, a conversion project has been carried out to replace old, but daily-used programs for handling of gamma spectrometry measurements and general data by a new set of programs based on the C-base system. The project continues in 1993.

A new nationwide emergency plan for handling of nuclear accidents has been prepared by the Danish Civil Defence Agency (from January 1, 1993, the Emergency Management Agency). Risø plays an important role in this plan and has assisted in preparing it. The local organization at Risø has been adapted to the new plan. A system for monitoring potential radioactive contamination is operated by Risø. The system is working satisfactorily after correction of some problems in the software and strengthening of the communication system.

2.6 Publications

2.6.1 Publications in International Journals, Proceedings and Reports

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3 Reactor Physics

The work in the Reactor Physics Section falls into three categories:

1) Reactor Physics
2) Reactor Safety
3) Activities at the DR1 Reactor

3.1 Reactor Physics

Further development and use of the system of LWR codes, which has been generated during many years, is the basis for the reactor physics work.

- Collision probability routines for elementary cells of LWRs have been developed for use in an interface current flux routine (3.1.1)
- The conversion to FORTRAN of some older computer programs written in ALGOL, is completed (3.1.2).
- Calculations of the radioactivity of some construction elements (top grid, injection systems) of the Swedish Ringhals 1 boiling water reactor have been performed (3.1.3).
- For the Danish Civil Defence Agency a dynamic simulator model of the Barsebäck reactor has been developed for use on a personal computer (3.1.4).
- Irradiation of silicon in DR3 takes place in increasing quantities. Calculations have been made for securing the uniformity of the neutron doses in all parts of the crystals (3.1.5).

3.1.1 Nodal Collision Probability Theory

Plans have been worked out and programming is in progress for an LWR fuel assembly code under development. The multigroup neutron flux distribution is based on collision probability theory within the individual cells (cf. Fig. 3.1), while the coupling between cells is provided by the well-established interface current technique (in the uniform, isotropic flux approximation).

Subroutines have been developed for the evaluation of first-flight collision, escape, and transmission probabilities for fuel pin cells with an arbitrary number of annular fuel and cladding regions. The water may either be a single region or subdivided into four segments as shown in Fig. 3.1. The numerical ray tracing technique is a 2-D extension of the well-known »Flurig« scheme employing Gaussian quadrature in both the radial and the angular direction. The efficiency is further improved by utilizing the symmetry properties as well as the reciprocity and conservation relations to the maximum possible extent. The same principles are going to be applied to the third cell type in Fig. 3.1, representing a section of the water gap and the flow box of a BWR assembly. As for the cross-shaped BWR control rods, an infinite-lattice approximation will be applied for the row of control rods embedded in a control blade.

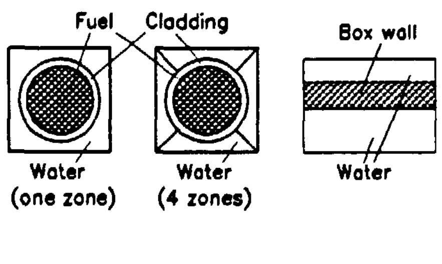
The most commonly occurring LWR assemblies can be composed of these »building bricks«. The general grid layout is designed so as to accommodate checkerboard and colour set patterns of four assemblies with utilization of possible symmetries. The contemplated boundary conditions may be either reflective or periodic (at option) and the respective albedo or transmission coefficient may be used as the criticality parameter.

The solution technique is based on separation of the flux from the interface current equations, which thus become a set of nodal equations with coefficients being multiple-flight transmission probabilities and with the interface currents as nodal variables. This method is expected to lead to a very efficient iterative solution scheme.

3.1.2 Computer Code Conversion

The A6 computer at Risø was closed at the end of 1992. Most of the reactor physics programmes developed at Risø during the last twenty years have been implemented on this computer in the programming language ALGOL. This language cannot be applied on the modern computers. Therefore, a programme conversion from ALGOL to FORTRAN was initiated two years ago.

Fig. 3.1. Cell types for nodal interface current code. Common LWR fuel assemblies may be composed of the elementary cells shown.



During 1992 the fuel element programme CCCMO and the fuel depletion programme CDB have been converted from ALGOL to FORTRAN.

Thus, the Reactor Physics Section has finished in due time its programme conversion from ALGOL to FORTRAN.

Furthermore, the programmes have recently been implemented on Risø's CONVEX computer which is a UNIX platform.

3.1.3 Ringhals Calculations

The Swedish utility Vattenfall, who owns and operates the Ringhals nuclear power station, requested a calculation of the neutron induced activities of some reactor components situated above the core of the Ringhals 1 BWR.

The calculation was made in a number of steps:

1. The LEWARD assembly programme was used to calculate diffusion cross sections for the core and the various materials. This was done in 20 energy groups with the emphasis put on the high-energy end of the spectrum.
2. The RINGHALS 1 reactor was modelled in (r-z) geometry and calculations with the DIFF2D programme and the above-mentioned cross sections were performed.
3. By means of an ad hoc programme the 20 group fluxes were expanded into 100 groups.
4. Activation calculations with the ACTIVA programme in 100 groups were made.

An example of the results is shown in Fig. 3.2 where selected isotopic activities of the stainless-steel top grid are shown as functions of cooling time.

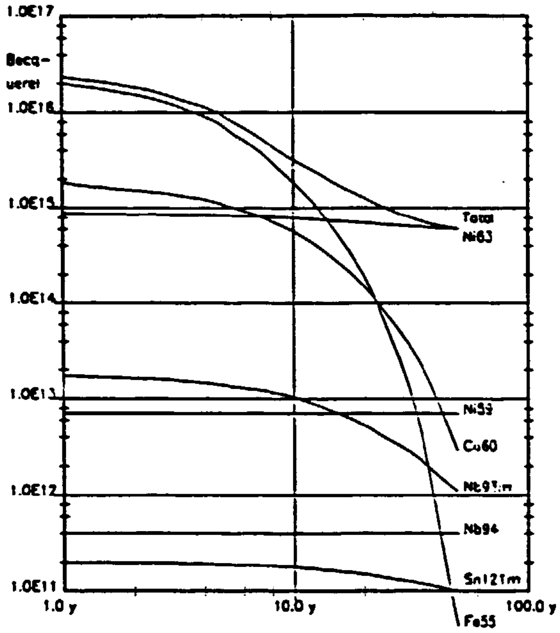


Fig. 3.2 Activities in the top grid of the Ringhals 1 BWR as function of time after end of irradiation. Irradiation time: 75500 full power hours.

3.1.4 Barsebäck Simulator

A one-dimensional dynamic computer simulator of the Barsebäck nuclear power plant has been developed in co-operation with the Section of Risk Analysis at Risø.

The work was done on request from the Danish Civil Defence Agency who wanted the simulator to study different power transients, basically for educational purposes.

The computer model is based on the modular simulating system called DYSIM, developed at Risø some years ago.

The model comprises reactor core, steam line, turbines, reheater, moisture separator, condenser, feedwater line, feedwater heater, feedwater and condenser pumps, and control systems.

Several transients can be simulated, e.g. loss of electric load, turbine trip, loss of feedwater, loss of one or more feedwater heaters etc.

The model is running on a 386-PC and contains several graphic flow charts of the main components of the nuclear power plant. As a simulation progresses the values of different system parameters (power, pressure, temperature, flow etc.) are displayed at the graphic screen.

3.1.5 DR3 Reactor Physics

At Risø's research reactor DR3 a new horizontal facility for nuclear transmutation of silicon has been installed. In this process a silicon crystal is irradiated while it is moved slowly from one side of the reactor to the other to obtain a uniform irradiation.

During the test period some of the crystals got stuck in the horizontal irradiation tube and received a non-uniform irradiation profile.

A computer programme was made, which simulates the course of the failed crystal and calculates a re-irradiation procedure by which the crystal can fulfil the specifications.

Comparisons with measurements have shown good agreement with the calculations and several stuck crystals have been »saved« by the re-irradiation suggested by the programme.

3.2 Reactor Safety

The work consists of

- Studies of hydrogen deflagration in containment under accident conditions (3.2.1).
- Participation in the SIK projects conducted by the Nordic Committee on Safety Research (NKS):
- SIK-2, which addresses »Severe Accidents« (3.2.2)
- SIK-3, where safety-related data for reactors in neighbouring countries are collected (3.2.3).
- Participation in the CEC project ENTOREL, in which the reliability of robots is evaluated (3.2.4).
- Participation in the work of the Risø Study Group for Nuclear Preparedness, which has been concentrated on advanced reactor systems:
- Descriptions of a number of advanced reactor types have been made (3.2.5).
- The stability of the PIUS reactor against Xe oscillations has been examined (3.2.6).

3.2.1 Hydrogen Deflagration

Intermediate scale combustion experiments have been performed in the Containment Test Facility at Whiteshell Laboratory, Canada, for studying the combustion behaviour of dry hydrogen-air mixtures with simultaneous multipoint ignition. Flame speeds and pressure histories have been measured and compared with results for single ignition.

For numerical simulation, an adapted version of the AECL-program VENT has been used.

A computing model for calculation of the pressure waves and Chapman-Jouguet detonation effects has been implemented in the computer code CONTAIN. Further development of CONTAIN for simulating the multi-point ignition in a non-homogeneous atmosphere is under way.

3.2.2 SIK-2

SIK-2.6, Assessment of Aerosol Modelling, is a task in the Nordic SIK-2 project on Nuclear Reactor Accident Analysis. The codes considered are primary system codes and containment codes. Reporting is in progress.

3.2.3 SIK-3, Safety Related Data for Neighbour Reactors

The objective of the SIK-3 project is to collect, systematize and evaluate safety related data of nuclear installations within and close to the Nordic borders. The data include design features and operational practices significant for the plant safety. The data collected and the expertise gained in the project have two main applications:

- Based on the data, the safety authorities can respond to general safety related questions concerning a particular design. Such questions can come from politicians, the public, or the media.
- In case of an emergency situation at a plant located in a neighbouring country, the data can help the Nordic safety authorities to assess the severity and course of the accident, potential external consequences and necessary emergency response actions.

The data are presented in reports of about 100 pages for each nuclear power plant or installation.

Risø has the project management of SIK-3, which was started in 1990 and will continue until the end of 1993.

During 1992 reports on the following nuclear installations have been finished:

- Kola I-IV
- Brunsbüttel
- Krümmel.

3.2.4 ENTOREL

ENTOREL (ENvironmental TOlerance and RELiability) is part of a CEC cost-shared action programme named TELEMAN. The objective of this programme is to develop remotely operated robots to be used in nuclear power plants, reprocessing facilities etc.

ENTOREL is headed by the Risk Analysis Group at Risø and is conducted in collaboration with CEN, Belgium, Harwell, UK, and Interatom, Germany.

A qualitative reliability analysis has been carried out for a gantry-type of machine based on a

Failure Mode and Effects Analysis and a Fault Tree Analysis.

The analysis assists in identifying components and systems with an especially great impact on the reliability of the overall system. Furthermore, it will serve as the basis for a quantitative analysis, when »hard« reliability data are available.

Finally, an outline of a failure strategy was set up. The strategy, based on the above-mentioned reliability model, takes into account the functional characteristics of the robot as well as the relevant tasks and environmental conditions. The strategy is divided into two parts:

- Preventive measures.
- Consequence mitigating measures.

The first part concerns design, operation, and repair, while the second part concerns only operation.

3.2.5 Advanced Reactors

The new generation of advanced reactors being developed in several countries offers simpler and more robust safety features than the rather complex engineered safety systems of present reactors. Thus, they will probably be introduced in the electricity supply systems in a number of countries.

Such reactor types constitute an interesting study object for the Nuclear Preparedness Study Group. After an introductory overview of the many innovative designs put forward, the studies have been concentrated on the 5 reactor types, which seem to be most promising.

Detailed reports describing the reactor systems have been prepared. The 5 reactor types are:

- ALMR, the Advanced, Liquid-Metal-cooled, fast Reactor
- SBWR, the Simplified BWR with natural circulation
- AP-600, an Advanced PWR with some novel safety features
- SIR, the Safe, Integral Reactor combining many passive safety systems with existing technology
- PIUS, the radically new PWR design with Inherent Ultimate Safety and several completely new construction details.

3.2.6 Xenon Oscillations in PIUS

Due to the dynamics of the generation and elimination of the strongly neutron-absorbing fission product Xe-135, power oscillations may occur in large reactors, unless preventive measures are taken by control-rod movements.

In the advanced reactor PIUS there are no control rods (the reactor is controlled solely by dissolved boron in the water), and therefore it may be potentially unstable.

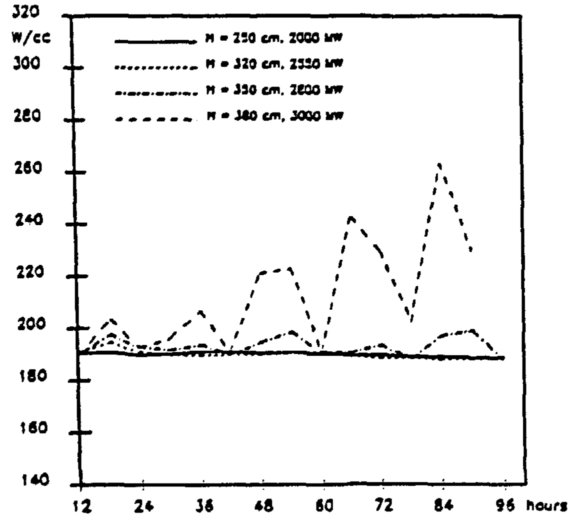
Preliminary calculations have been done indicating that the reactor is stable with its proposed size. However, neither height nor radius can be increased significantly without the risk of destructive power oscillations. In Fig. 3.3 the peak power density (W/cm^3) is shown as a function of time for various core heights. The stability with the proposed height, 250 cm, and the growing inclination for diverging power oscillations when the core height is increased, is notable.

3.3 Activities at the DR1 Reactor

Activities at the DR1 reactor have comprised

- Courses on experimental reactor physics for high-school classes and students (3.3.1).
- Irradiation of computer memories with fast neutrons to examine bit error frequencies (3.3.2).

Fig. 3.3 Peak power densities vs. time for the PIUS reactor for different core heights. The design height is 250 cm. The average power density is kept constant. The position of the peak oscillates between the upper and the lower half of the reactor core.



3.3.1 Education

The reactor has been used almost exclusively for educational purposes. 50 high-school classes have carried out one-day or half-a-day experiments at the reactor. The total number of students in 1992 was more than 900.

A number of students from the Technical University of Denmark have carried out experiments at the reactor over a period of three weeks.

Some of the experiments were:

- Determination of the reactor's temperature-, power-, and bubble -coefficients
- Neutron activation analysis
- Measurements of neutron cross sections
- Neutron radiography
- Health physics
- Core flux distribution measurements.

3.3.2 Neutron-Induced Bit Errors in Computer Memories

In 1991, a Danish software house experienced problems with bit errors (Single Event Upsets or SEUs) in small computers used on long-distance passenger flights.

The characteristics of the error patterns were readily reproduced by exposure to a neutron source available at DR1, whereas conventional causes (vibrations, extreme temperatures etc.) were ruled out by tests performed by the manufacturer.

Fast neutrons are produced at flight altitudes when cosmic ray particles (mainly protons) hit oxygen or nitrogen nuclei. When the fast neutrons in turn hit silicon nuclei, recoils and in some cases protons or alpha particles are produced. The ionization generated by the recoiling nuclei causes the majority of the SEUs.

In the laboratory tests, both the original version of the computer and a newer one were irradiated with fast neutrons and a total of 176 SEUs were observed. The newer version proved to be considerably more resistant to neutron irradiation than the original one.

Also, the ability of the software to recover from SEUs has been successfully tested.

3.4 Publications

3.4.1 Publications in International Journals, Proceedings and Reports

Bujor, A.; Koroll, G.W., Intermediate-scale hydrogen combustion experiments with simultaneous multipoint ignition. Trans. Am. Nucl. Soc. (1992) v. 66 p. 329-332.

Nonbøl, E., Reactors in nearby countries. In: The Nordic research programme on nuclear safety. Summary of projects in the fourth NKS-programme 1990-93. NKS-92-7 (1992) SIK-3.

3.4.2 Risø Reports

Fynbo, P.B., Advanced reactors. SBWR. Natural convection boiling water reactors. Risø-I-602 (1992) 17 p.

Fynbo, P.B., Implementering af CORAN. Risø-I-553 (1992) 10 p.

Fynbo, P.B., Uranressourcer. Risø-I-611 (1992) 6 p.

Højerup, C.F., Calculation of neutron induced activation of construction elements in Ringhals 1. Risø-I-622 (1992) 40 p.

Højerup, C.F., Investigation of Xe-instability of the advanced reactor PIUS. Risø-I-640 (1992) 10 p.

Johansson, T., Advanced reactors PIUS (Process Inherent Ultimate Safe reactor). A technical description. Risø-I-639 (1992) 24 p.

Lauridsen, K.; Kongsø, H.E.; Becher, P.E.; Petersen, K.E., Reliability assessment of the TELEMAN machine. Qualitive analysis. Risø-I-630(EN) (1992) 70 p.

Majborn, B.; Brodersen, K.; Højerup, C.F.; Heikel Vinther, F. (eds.), Nuclear Safety Research Department annual progress report 1991. Risø-R-625(EN) (1992) 23 p

Nonbøl, E., Advanced reactors. AP600 (Advanced Passive 600MWe). A technical description. Risø-I-610 (1992) 15 p.

Olsen, J., Reaktorkursus DR1. Januar 1992. Risø-Dok-189 (1992) vp.

Olsen, J., Driftsrapport for DR1. Risø RP-04-92 (1992).

Olsen, J., Beregninger af bit-fejl fra neutroner. Risø RP-07-92 (1992).

Quist, J.; Nonbøl, E., Intermediate fuel element storage facility at reactor DR3. Risø-I-657 (1992) 8 p.

Thomsen, K.L., Pin-cell routines for collision, escape, and transmission probability calculations. Risø-I-636 (1992) 35 p.

Thomsen, K.L., Representation of boundary nodes and symmetries in LWR fuel assembly code. Risø-I-662 (1992) 20 p.

3.4.3 Other Publications

Olsen, J., Einstein-Podolsky-Rosen-paradokset og Aspects forsøg. Nat. Verden (1992) (no.3) p. 97-102.

3.5 Lectures at Conferences and Meetings

Bujor, A., Multiple ignition experiments in H2-air mixtures. AECL-CANDU, Sheridan Park, Mississauga, Ontario (CA), 19 May 1992. Unpublished. Abstract available.

Fynbo, P.B., Assessment of aerosol modelling in computer codes. SIK-2 seminar, Halden (NO), 17-18 Nov 1992. Unpublished. Abstract available.

Højerup, C.F., Comments on the Danish contributions to PDWA benchmark. Benchmark calculations of power distributions within assemblies, Paris (FR), 22-23 Oct 1992. Unpublished. Abstract available.

Nonbøl, E., Design and safety features of nuclear installations in neighbouring countries. NKS-sommermøde, Helsingør (DK), 31 Aug - 3 Sep 1992. Unpublished. Abstract available.

4 Waste Management

The main task of the Waste Management Section is to collect, to concentrate, to condition and to store radioactive waste from the use of the nuclear installations or laboratory work at Risø. In 1992, a relatively large amount of waste arised from the decommissioning of the Risø Hot Cell facilities.

The Waste Management Section also functions as a centre for handling and storage of radioactive waste from other Danish users of radioisotopes, primarily hospitals, industry, and research and service laboratories. It is not intended to dispose of the radioactive waste stored at Risø in the nearer future, but the Waste Management Section contributes to the international discussions and to research concerned with the safety of disposal systems. The experimental work and modelling efforts are mainly focused on the long-term behaviour of bituminized waste and cementitious materials used as barriers or in interaction with soil.

4.1 Practical Waste Management

The inactive waste-water treatment plant, the collection of chemically toxic waste, and the decontamination and laundry facilities, were operated as usual. This was also the case for the compaction of low-level solid waste, and for the purification of radioactive waste water by distillation and the bituminization of the resulting evaporator concentrates. The 'new' control system for the bitumen plant is still not operating satisfactorily, so the plant had to be operated using the old system.

The release of tritiated water with the distillate was 1260 GBq. In addition some further 128 MBq of mixed ß-activity was released with waste water to the recipient. It is about 1% of the permitted amount. About 19 GBq C-14 (carbon dioxide) were released to the atmosphere with off-gas from the bituminization plant during treatment of used ion-exchange resins from DR3. The environmental effects of this release were discussed and compared with other sources of C-14 in the atmosphere by the Risø Safety Committee for Waste, and it was concluded that a change in procedure was not motivated.

Considerable amounts of unconditioned α-contaminated waste from the Hot Cell decommissioning was received and stored at the Risø facility for this purpose: 'Centralvejslageret'. For 1992 it consisted of 30 standard drums and some 19 m^3 packed in steel boxes, etc.

The normal radioactive-waste treatment procedures resulted in a total of 98 drums containing bituminized evaporator concentrate or compacted low-level solid waste.

Construction of a new storage building for low-level waste near the Waste Management Plant was finished medio 1992 and an operation permission was applied for. However, the Nuclear Regulatory Authorities requiered additional information about the type of waste in the drums, the expected sensitivity for external γ-measurements of radioisotopes in the drums, the handling procedures for corroded drums, and the plan for transfer of the drums from the old storage area ('Betonrørslageret'). This documentation was supplied in July and a partial permission for use of the new building was given in September. A total of 350 drums from the running production and from 'Centralvejslageret' were then moved to the new building. Permission for transfer from the old storage area ('Betonrørslageret') was not received in 1992, but it is expected early in 1993. Transfer of the 3350 drums from the old to the new storage facility will then be carried out within the next 2 to 3 years.

One of the requirements in the Nuclear Authorities' permission for use of the new storage facility is that external γ-measurements of radioisotopes should be made on all drums, where the content is not known from administrative information or other measurements. This requirement has resulted in considerable practical difficulties which are now more or less overcome. However, because of the unavoidable geometrical uncertainties in such measurements, it is doubtful whether much additional information will be forthcoming from this procedure, compared with that obtained from the much simpler measurements of total external radiation.

Permission for external disposal as inactive material of the very weakly radioactively-contaminated sludge from the biological waste-water purification plant at Risø was applied for in 1991, but a permission has still not been received from the Nuclear Authorities. Another application for declassification of some weakly-activated construction materials is underway. Hopefully, international efforts within the very important area of 'below regulatory control' will lead to a more easy handling of such cases. It will be important e.g. for all stage-3 decommissioning cases where nuclear facilities are completely demolished.

Recommendations and actual regulatory work within the field of radioactive waste are made in many international contexts. Risø participates together with representatives of the Danish Regulatory Authorities in the ACPM for 'the Plan of Action' concerned with management of radioactive waste in the European Communities. The mandate for this CEC advisory body has recently been extended to the year 2000. A major motivation for participation in this type of work is to maintain good personal contacts between the responsible managers in the various countries and to reach a reasonable degree of consensus within the field of radioactive waste management. This is also one of the major motivations for continuation of Nordic cooperative studies within the area.

4.2 Waste Materials Research

The research efforts of the Waste Management Section are mainly concerned with disposal problems, exemplified by the long-term behaviour of products prepared from two of the most important materials in waste management: bitumen and cement. In this context the interaction between waste components, steel, cement, bitumen and the surrounding soil or the geology in general is very important. For a disposal facility it is desirable to be able to predict the behaviour of the involved materials over very long time spans. This calls for long-term experiments and/or experiments designed to elucidate the more fundamental aspects of the chemistry and physics of the materials.

4.2.1 Properties of Bituminized Materials

A new CEC contract on »Characteristics of Bituminized Waste« has been running since december 1991 as a co-operative project between CEN Cadarache, France, CEN/SCK Mol, Belgium, and Risø. The annual report 1992 is in preparation.

Results from the first sets of experiments done at Risø confirm previous experience. Data for diffusivites of tritiated water (vapour) and for leaching, water uptake and swelling of bituminized materials containing soluble salts are obtained as functions of bitumen type and the amounts and type of the soluble and/or insoluble fill materials. The development of swelling pressure is also followed for confined samples. Swelling pressure is important because it may crack external barriers. An individual experiment takes from one month to a year, but they are normally run in series using four individual systems and with some overlap in time.

A model describing the swelling and leaching behaviour of bituminized materials containing soluble salts have been under development since 1991. The work has mainly been done outside the CEC contract, but it is met with considerable interest in this context, because it is the only available model which attempts to describe the development of the porosity in the swelling materials. Preliminary results were presented at working meetings in Jülich and in Paris.

4.2.2 Properties of Cementitious Materials

A paper based on earlier experimental work and describing some peculiar safety aspects of cemented waste containing soluble salts has been published.

A CEC contract on »The Performance of Cementitious Barriers in Repositories« has been running since May 1991 as a co-operative project between AEA Technology, Harwell, and Risø. The first annual report is available, and the second covering 1992 is in preparation.

Four series with crack filling in artificially cracked cementmortar samples exposed to a slow flow of calcium bicarbonate solution (simulating ground water) or deionized water have so far been run within the contract. Each series consists of 4 samples and lasts from 2 to 5 months. Much analytical work is involved. A characteristic example of the composition of the outflowing water from an nonclosing crack is shown in Fig. 4.1. The filling of the crack with precipitated $CaCO_3$ is found to occur somewhat erratically, but there is no doubt that thin cracks (< 0.1 mm) tend to close, while thicker cracks (> 0.2 mm) are not closed but covered on the surface walls with a relatively impermeable layer of calcium carbonate crystals. The last phenomenon is a negative aspect seen from a safety point of view because the pH in the flowing water is not buffered by contact with the concrete, i.e. the pH remains low and the concentrations of carbonate species relatively high. This will increase the risk of migration of α-emitters with the flow of water.

The crack-filling materials have been characterized using scanning electron microscopy (with assistance from the Materials Research Department at Risø) and micro-tomography performed by BAM (Bundesanstalt für Material Forschung and Prüfung), Berlin. Cracks and features down to 0.03 mm can be seen, but it is too early to evaluate the use of this method.

The work done at the Chemistry Section at Risø using SANS (small angle neutron scattering) to characterize the microstructure of cement paste degraded by leaching was brought to a preliminary end. The method is now well documented, but the results are of limited interest, partly because the coarser pores dominate the behaviour of cementitious materials, and SANS gives mainly information about the smaller pores.

The crack-filling experiments are supplemented with development of a numerical model of the formation of calcium carbonate precipitates on the surface and within the pore structure of a cracked sample of cementitious material.

This gives rise to many interesting problems connected with the diffusive movement of the macro-ions in the pore solution within the pore structure and the precipitate.

Results from the studies were presented at working group meetings in Jülich and in Paris.

The crack-filling experiments and other types of experimental studies of cementitious materials performed at Risø are of interest also for the use of concrete as an ordinary building material. Advises were given in connection with experiments on diffusion of organic vapours through concrete floors, work performed by the Danish Geotechnical Institute for the Danish Ministry for Housing and Building.

The migration of chloride into concrete is important for the corrosion rate of embedded reinforcement. Results from some early Risø experiments using Cl-36 were presented at a workshop arranged by the Danish Technological Institute (DTI) and was later rewritten for presentation at a Nordic Mini-Seminar on Chlorides in Concrete arranged in Januar 1993 by Chalmers Technical

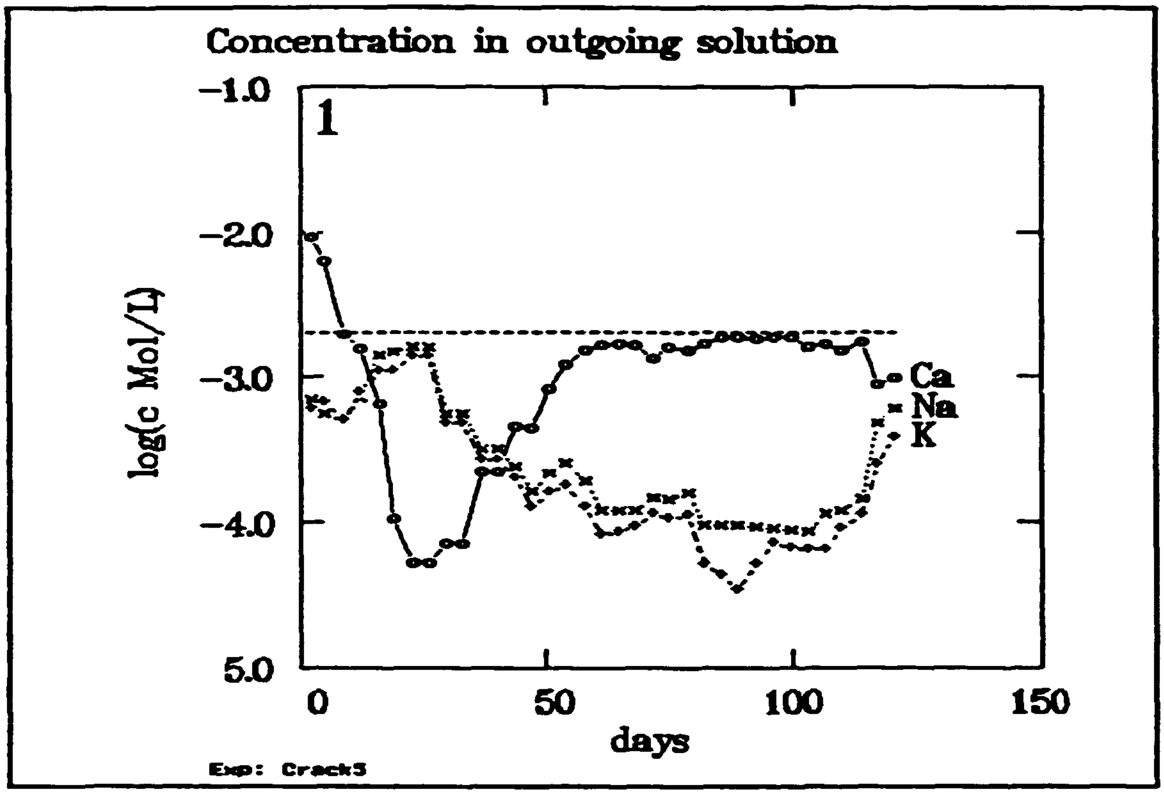


Fig. 4.1. Concentrations in the outflowing solution from an experiment with crack filling in concrete. The horizontal line represents Ca in the slow flow of incoming calcium-bicarbonate solution. The crack was partially closed between 20 and 30 days and again after 100 days. The low flow in these periods explains the increase in the concentration of K and Na leached from the concrete. Note that the Ca concentration approach the values in the incoming solution after 60 days. This is due to the formation of an impermeable layer of calcium carbonate on the inner surfaces of the crack.

University, Göteborg. Co-operation between DTI, The Technical University of Denmark, Risø, and possibly the Force Institutes on a joint proposal for the coming CEC Materials Research Programme is a possibility.

4.2.3 Soil/Cement Interactions

The Waste Management Section has for some years contributed to the Nordic KAN projects (Kärnavfal och Nerlägning) under NKS with experimental studies on cement solidification of soil. The outcome of the studies were partly negative because the retention of Cs- and to some degree Sr-isotopes was not improved by the procedure. However, the experiments have given considerable insight into the chemical interactions between soils and concrete in general, and the studies made in 1992 were mainly concerned with such aspects. The project as such is finished and a final report is available in draft form awaiting some late-coming results from long-term experiments.

The study is part of the KAN2 project concerned with the possibilities for handling of waste from nuclear accidents. In this context a few column experiments with contaminated soil without cement, but containing decaying organic materials, were also performed. This simulates a typical disposal situation in connection with large accidents. The experiments are too few for any serious conclusions but illustrates some practical problems with soil-column experiments involving radioactivity, which could be of interest for the planned new Risø research facility RE-RAF.

4.3 Soil Chemistry

A general knowledge of soil chemistry is important in connection with waste management but is also interesting in itself. As a part of a long historical development this has led to studies of general soil chemistry in the unsaturated zone of agricultural and forest areas.

In continuation of studies concerned with soil chemistry and element turnover in a forest area (carried out in co-operation with the Danish Forest and Landscape Research Institute and the National Environmental Research Institute) the Waste Management Section is expected to contribute to a contract under the NECO project (Nitrogen Deposition, Turnover and Effects in Coniferous Forests Ecosystems) financed by the Danish Strategic Environmental Research Programme. The work is carried out in co-operation with the Ecology Section at Risø and will mainly consist in modelling of elemental turnover in soils and plants at a selected forest area. A modified version of the SAMUS model (based on the previous ECCES model developed at Risø) will be employed. However, the contract was only signed late in December 1992, and, except for some slight modifications of the SAMUS model, no actual work was carried out in 1992.

4.4 Publications

4.4.1 Publications in International Journals, Proceedings and Reports

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4.4.2 Risø Reports

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4.4.3 Other Publications

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4.5 Lectures at Conferences and Meetings

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Unpublished. Abstract available.

Brodersen, K., Swelling due to water uptake in bituminized waste. 3. Progress meeting of the EC research programme on radioactive waste management, Jülich (DE), 5-7 Oct 1992.
Unpublished. Abstract available.

Brodersen, K., Behandling og oplagring af radioaktivt affald i Danmark. Helsefysisk kontaktforum. Helsefysik-dag på Forskningscenter Risø, Risø (DK), 14 Oct 1992.
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Brodersen, K., Modelling of swelling and leaching of bituminized waste. Working Group Meeting of Task 3 of the EC Research Programme on Radioactive Waste Management, Saclay, Paris (FR), Dec. 1992.

Appendix 1

STAFF of the Department 1992

Head of Department

Benny Majborn

Office Staff

Inge Blyitgen
Margit Nielsen
Lis Rasmussen

Health Physics Section

Scientific Staff

Frits Heikel Vinther (head of section)
Claus Erik Andersen
Lars Bøtter-Jensen
Poul Christensen
H.L. Gjørup (consultant)
Jørgen Lippert
Uffe Lyngbæk (temporary, from September 22)
Flemming K. Nielsen
Nigel Poolton (post doc. fellow, from October 1)
Søren Thykier-Nielsen
Ole Walmod-Larsen
Mette Øhlenschlæger (temporary)

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Per Brøns
Henrik E. Christiansen
Lissi Sture Hansen
Jørgen Jakobsen
Nina Jensen
Johannes Jepsen
Finn Jørgensen
Frode Lund (temporary, from September 28)
Finn Pedersen
Lis Sørensen
Finn Willumsen

Guest Scientists

Geoff A.T. Duller (April 2 - May 14), University College of Wales
Högne Jungner (February 2 - March 8), University of Helsinki, Finland
Igor Luiz Bacelar Leao (August 17 - September 25), Commissao Nacional de Energia Nuclear, Rio de Janeiro, Brasil

M.Sc. Students

Torben Nilsson (until January 31)
Arvid Olsen (until January 31)

Apprentices

Michael Guldager (until October 31)
Sonny Rasmussen

Reactor Physics Section

Scientific Staff

C.F. Højerup (head of section)
P.E. Becher
A. Bujor (Ph.D.student)
Peter Bille Fynbo
Erik Nonbøl
Jørgen Olsen (until July 31)
Knud Ladekarl Thomsen

Technical Staff

Benny Andreasen (temporary, from November 17)

M.Sc. Students

Kirsten H. Nielsen (from September 7)

Waste Management Section

Scientific Staff

Knud Brodersen (head of section)
Massimo Steen Carugati

Technical Staff

Birthe Andersen
Winnie Andersen
Mogens Christiansen (from March 1)
Birthe Hansen
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Jørgen Larsen
Knud Larsen
Bent Nielsen
Palle Olsson
Jesper Bohn Rasmussen
Nina Thomsen
Bent Willumsen
Arne Vinther
Ruth Aagesen

Appendix 2

Participation in International Committees.

IAEA, The International Atomic Energy Agency

Co-ordinated Research Programme on Intercomparison for Individual Monitoring (Christensen).
INES Users Group (Becher).
Nuclear Regulators Working Group (Becher).

ICRP, International Commission on Radiological Protection

Committee 4, Application of the Recommendations (Gjørup).

OECD, Nuclear Energy Agency

CSNI, Steering Committee (Højerup).
CSNI-PWG4, Confinement of Accidental Radioactive Releases (Fynbo).
CSNI-PWG4, Subgroup of Experts on Accident Consequences (Thykier-Nielsen).
NEA-NSC, Nuclear Science Committee (Højerup).
NEA-Data Bank Executive Group (Højerup).

CEC, Commission of the European Communities

CGC 6 Nuclear Fuel Cycle (Brodersen).
ACPM for Plan of Action (Brodersen).
Task 3 of the Waste Research Programme (Brodersen).
Reactor Safety Working Group (Becher).
LWR Safety Research Index Group (Nonbøl)
Working Group on Reactor Dosimetry (Olsen).
Working Party on Criteria for Recycling Materials from the Dismantling of Nuclear Installations (Heikel Vinther).
Group of National Experts on Assistance in the Event of a Nuclear Accident or Radiological Emergency (Heikel Vinther).
Article 37 Group of Experts (Walmod-Larsen).
Expert Group on Transfrontier Emergency Planning (Walmod-Larsen).
Expert Group on Environmental Gamma Monitors (Bøtter-Jensen).
Group of Technical Experts on Radiation Protection Dosimetry (Christensen).
EURADOS, Skin Dosimetry (Christensen).
EURADOS, Criticality Accident Dosimetry (Majborn).

EAES, European Atomic Energy Society

Public Relations Correspondents Group (Walmod-Larsen).

Nordic Co-operation

Steering Committee for NKS Projects (Heikel Vinther).
Reference Group on KAN Projects (Brodersen).
NKS/SIK-3 Project Group (Nonbøl).
NKS/BER-3 Project Group (Walmod-Larsen)

Editorial Boards

Radiation Protection Dosimetry (Bøtter-Jensen).
Nuclear Europe Worldscan (Fynbo).

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The report describes the work of the Nuclear Safety Research Department during 1992. The activities cover health physics, reactor physics, operation of the Danish educational reactor DR1, and waste management.

Lists of staff and publications are included together with a summary of the staff's participation in international committees.

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