

NORA: AN INTERNATIONAL PROJECT IN REACTOR PHYSICS

By Viking Olver Eriksen, Kjeller, Norway

The NORA project has been in existence for about five years and one may ask what has been the experience so far from the operation of the project, what results have been obtained and what is going on at present?

Let us first recall the origin of the NORA project. In June 1959 the Norwegian Government proposed to IAEA that this organization should promote a scientific programme for measurement, collection, evaluation, and distribution of integral nuclear data. As a first step the Norwegian Government offered to the IAEA to make available for a joint programme in reactor physics between IAEA and the Norwegian Institutt for Atomenergi, the zero-power reactor NORA, with accompanying facilities and scientific staff. It was proposed that the joint programme should be implemented by an international scientific staff. The Agency was to play an important role in providing this scientific staff, reactor fuel and general services. The Agency should act as a catalyst in promoting such a programme also in other countries. The Board of Governors of IAEA approved the Norwegian offer in February 1961 and an agreement was signed in April 1961.

The main features of the agreement are that Norway provides the reactor NORA and the services of the permanent operating and scientific staff, meets the expenses necessary for the operation and maintenance of the reactor, and is responsible for safe operation. The Agency on its side assists in obtaining from the United States Atomic Energy Commission a fuel charge of enriched uranium dioxide fuel, supplies the services of additional scientific staff from its Member States, and otherwise provides advisory assistance on scientific matters, health and safety questions and the like. A research contract sponsored by USAEC was granted in support of the programme.

The project is supervised by a committee consisting of members from the Institute and IAEA. Dr. R. Ramanna from India has been chairman of the project committee since the start. The NORA reactor is situated at Kjeller, which is about 20 km east of Oslo. It was brought critical in June 1961.

THE SCIENTIFIC PROGRAMME

There has been a tremendous development in the field of reactor physics during the last decade. On the theoretical side the development of fast, large computers has raised reactor calculation techniques to a level and degree of sophistication undreamt of 10 years ago. On the experimental side, vast amounts of experimental information have been accumulated for various fuel and moderator systems. Experimental techniques have been developed and improved. There seems, however, to be a lack of precise experimental data which can offer sufficiently good test cases for the complex and very detailed computer programmes now being used.

One main objective of the NORA Programme was to improve the understanding of the physics of light water/heavy water-moderated, slightly enriched uranium dioxide fuelled cores by accumulation of experimental information on such systems, by developing experimental techniques which could extend the experimental knowledge and by developing theoretical methods to analyse the experimental data. The research programme of the NORA project was originally formulated with emphasis on providing experimental arrangements suitable for theoretical analysis. Later on, this emphasis shifted towards study of effects also appearing in power reactor cores.

The supporting facilities which the NORA project could use for this programme were, on the experimental side, the NORA critical facility and the JEEPNIK sub-critical facility, and for theoretical work, a Ferranti Mercury computer, later replaced by a Control Data Corporation CDC-3600 computer. The actual programme as it was conceived and implemented in the subsequent work can be grouped under four headings: (1) experimental programme (reactor statics), (2) theoretical analysis, (3) development of experimental techniques, and (4) reactor kinetics.

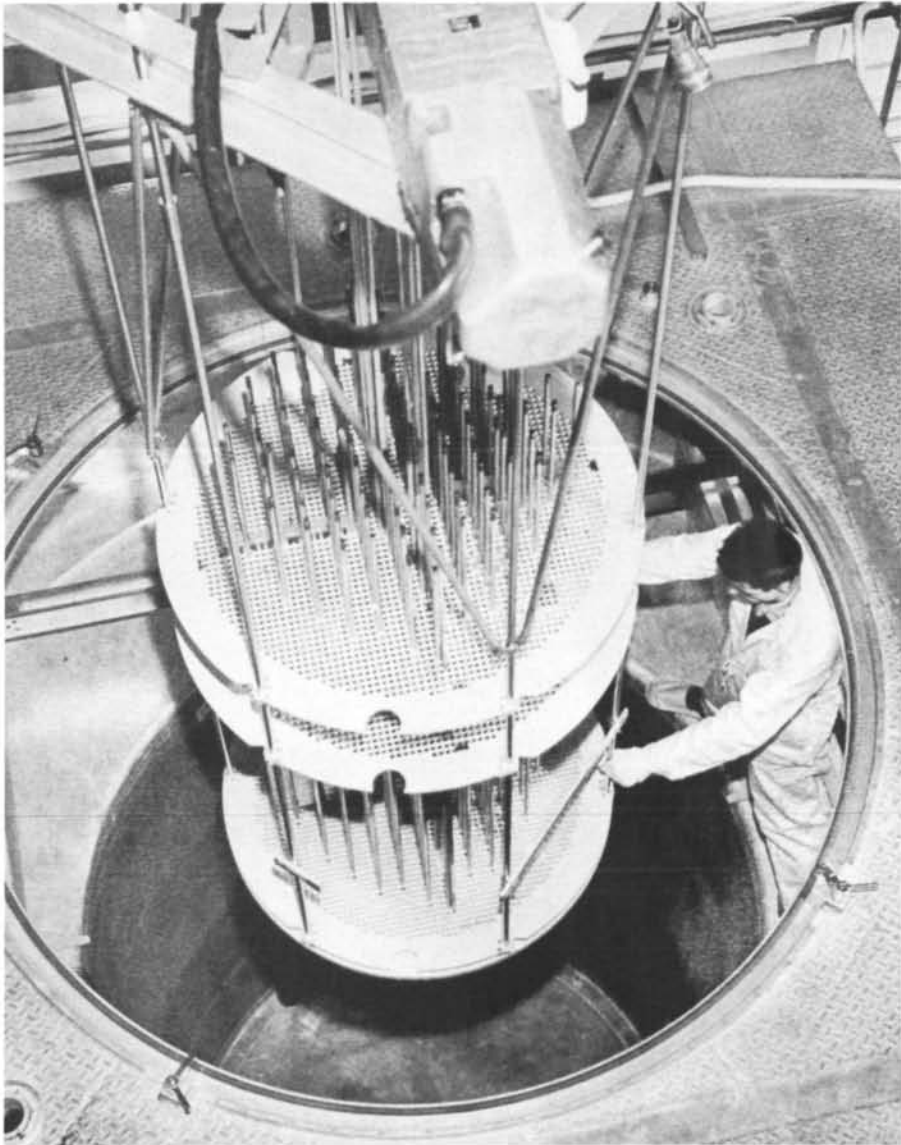
THE EXPERIMENTAL PROGRAMME

Two series of experiments only will be mentioned here. The first series consisted of a study of 16 lattices of 3 per cent enriched uranium dioxide fuel in mixed heavy water/light water moderators. Heavy water concentrations were 99.4 per cent, 81 per cent and 55 per cent respectively. The second series concerns a 3.4 per cent enriched uranium dioxide charge in light water. Regarding the first series of experiments, it is known that changes of the neutron spectrum in a reactor core influence core reactivity and a varying deuterium hydrogen ratio can therefore be used for reactivity control. This principle is the basis for the spectral shift reactor concept.

Very few experimental data existed on such lattices. The NORA project has provided an important part of basic information for such cores. The NORA programme was, however, more general and covered a study of well-moderated cores as well as the strongly under-moderated cores relevant for spectral shift reactor designs. Volume ratios of moderator to fuel ranged from 100 to 1.5.

The experiments involved the measurement of a number of important parameters relating to the reactor, and in more detail, to the reactor cells. Thus, much work was devoted to a careful mapping of neutron flux distribution within the cell, using conventional experimental techniques such as foil irradiation. Some cell parameters were measured applying radiochemical separation techniques developed within the NORA project.

The second series of experiments, which started last year, employs a fuel charge of 3.4 per cent enriched uranium dioxide in a light water moderator. This series is a natural sequel to the previous experiments. The same parameters are measured, and the objective is again to provide experimental information and to develop further calculation techniques. There is a distinct difference in approach, however. The experiments will be



Core loading of the NORA reactor

undertaken also for more complicated lattices which conform more closely to those of power reactors. A study of a simulated power reactor core with water gaps, control rods, temperature effects and simulated voids will be a main task. The scope of this series of experiments is therefore one of more engineering interest.

THEORETICAL ANALYSIS

Development of theoretical methods and possible improvements of existing theories have been considered an important part of the NORA research programme. The theoretical work related to the NORA project has therefore been dealing partly with the application of existing methods and recipes for the interpretation of experimental results, partly with intercomparison of such methods to determine their relative merits, and partly with development of more refined theoretical models based upon fundamental data.

Considerable effort has been devoted to the development of methods for calculating the lattice parameters of the cells. These have resulted in two computer codes, known as K-7 THERMOS and BIGG. The intercomparison of different computer codes has yielded interesting results also.

The problem of calculating neutron thermalisation (the final stage in the process of slowing down fast neutrons) and neutron density distributions inside reactor cells, is important for reactor calculations and has attracted interest in many countries. This part of the NORA project is also a task in a joint effort in reactor physics between Norway, Poland and Yugoslavia (the NPY project, also under the auspices of IAEA). In this task quite different core lattices, studied in the respective national critical facilities, are jointly analysed by using different theoretical models originating from the three countries. This work is still going on.

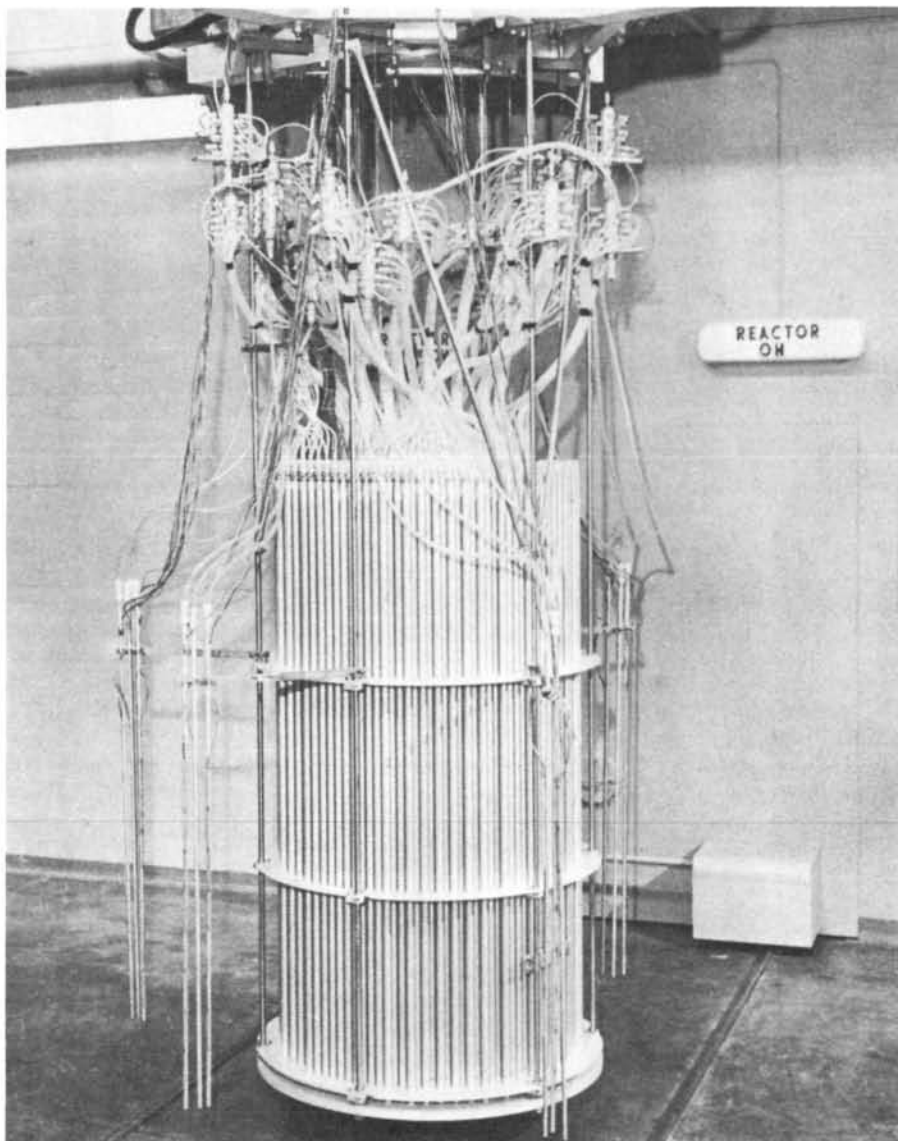
DEVELOPMENT OF EXPERIMENTAL TECHNIQUES

Improvement of existing experimental techniques and development of new ones was considered an essential part of the NORA research programme. Development of new techniques is time-consuming and expensive. Only in a few cases, where a good idea was available, could such work be initiated.

Radiochemistry techniques were used to determine detailed parameters within the cell, such information was obtained by measurements based on neutron capture in uranium-238 or fission in uranium-235. Neptunium-239 and the fission product molybdenum-99 are, respectively, indicators of these reactions. Again, reactor control rods were developed which move in and out of the reactor periodically, thus modulating the reactivity and hence the power response of the reactor. A further instance is the use of neutron pulses to study reactor kinetics.

REACTOR KINETICS

Two different rotating modulator rods have been built and used to vary the neutron absorption in the core as a function of time. The resulting time variation of the neutron flux has been measured in a variety of cores, comprising heavy water, light water, as well as spectral shift cores. The results have been used to test our ability to predict the kinetic behaviour of these cores through theoretical methods. Of special interest was the study of spatial kinetic effects in heavy water moderated cores, which are so important for large power reactor cores.



Core equipped for void reactivity experiments in NORA

A study of reactor noise - the statistical variations in the neutron density - was taken up in 1963. Introductory measurements using standard techniques gave results that could not be readily explained by the current theories. The experimental equipment was next improved, and a comprehensive series of measurements was carried out in 1965, using several complementary methods. The new results substantiated the former findings. Theoretical work carried out in parallel to the experimental efforts has since led to a re-formulation of the theory.

In addition to some further work in the noise field, pulsed neutron work will also be taken up in 1966. A neutron pulse generator will shortly be installed in the NORA reactor, with the primary purpose of developing a method for measuring accurately the reactivity value of control rods.

SOME RESULTS

A proper assessment of the results of the NORA project can only be made by consulting the numerous reports and publications emerging from the work. It is the opinion of the author that important contributions have been made in the field of mixed moderator lattices, both with respect to the theoretical analysis of such systems and to development of experimental techniques related to this work. Similarly, the investigations in spatial reactor kinetics and reactor noise have yielded results of novelty and of considerable interest.

The success of the NORA project is in a large measure due to the generous assistance of the United States Atomic Energy Commission which has helped through provision of fuel charges, scientific personnel and research grants. The high scientific level is in a large measure due to the enthusiastic support both from the permanent scientific and operating staff and from the guest scientists from IAEA Member States. Brazil, Canada, Czechoslovakia, Hungary, India, Japan, the Netherlands, Pakistan, Poland, the United States, and Yugoslavia have provided scientists for the project.

The importance and usefulness of establishing an international centre of this type has been realized throughout the project period. The centre provides opportunities for young physicists to enter an active and progressive milieu, and fruitful contacts have been established between the respective national laboratories through the project.

The helpful assistance of the IAEA secretariat is gratefully acknowledged.