scientific co-operation, exchange of knowledge and co-ordination of research in peaceful uses of atomic energy. He hoped that the sustained and dedicated commitment to international co-operation of these three men would inspire similar efforts by scientists, engineers and statesmen throughout the world.

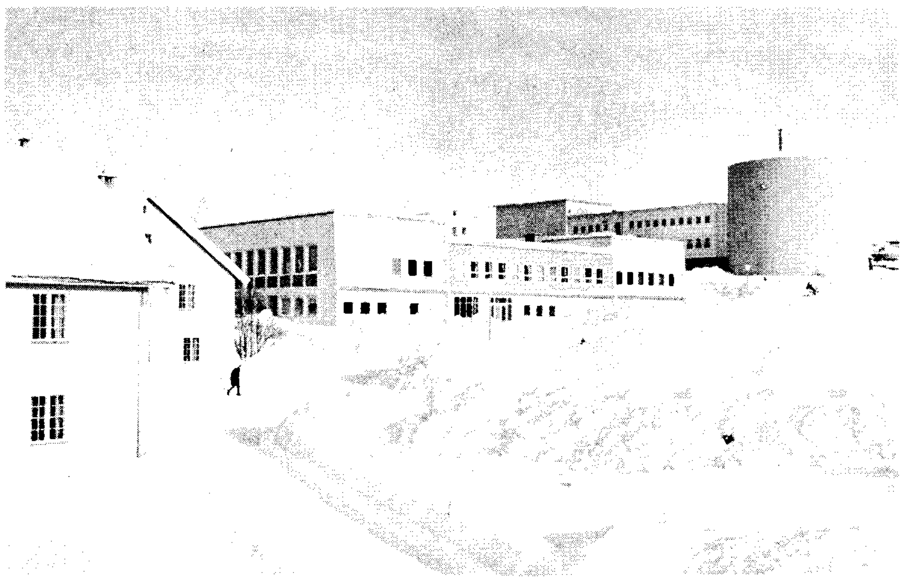
NPY - A THREE-NATION ATOMIC PROGRAMME

Norway, Poland and Yugoslavia have provided the initials for the NPY programme, an Agency-guided collaborative effort which since 1964 has been making important contributions to knowledge in reactor physics, has strengthened the research effort of each of the three countries and has assisted work in other countries. An idea of the happy way in which the programme has worked, and of its possible assistance in preparing other co-operative ventures between nations, is given in this article.

Although the agreement signed with the Agency by the three countries officially came into force in April 1964, parts of it had already been put into operation the previous year. It was for a three-year period, but the whole operation was so successful that in 1967 an extension agreement for a further three years was signed. The broad outlines were the subject of Paper No. 596 at the 1964 Geneva Conference on the Peaceful Uses of Atomic Energy.

INTRODUCTION

The aim was to bring about coordination of some parts of the national programmes in reactor physics in the signatory countries. These programmes included many similar items, and coordination was expected to strengthen each of them.



Part of the Institutt for Atomenergi at Kjeller, Norway, with buildings containing the research reactors NORA (to the left) and JEEP II, which also produces isotopes.

The work is conducted in national laboratories: the Institutt for Atomenergi, Kjeller, Norway; the Institute of Nuclear Research, Swierk, Poland; the Institute Boris Kidric, Vinca, and, partially, the Institute Josef Stefan, Ljubljana, Yugoslavia.

The basic scientific theme is the study of the reactor physics of thermal reactor lattices. Both experimental and theoretical work is included. The experimental work has been performed in critical and subcritical assemblies in the three countries: NORA, in Norway, an assembly of slightly-enriched uranium in light and heavy water; in Poland, ANNA, a water and graphite moderated, graphite reflected, enriched uranium fueled critical assembly, and HELENA, a natural uranium-graphite subcritical assembly; and RB, in Yugoslavia, a heavy-water moderated assembly. The computing facilities in the three countries have all been used for the theoretical studies, that in Norway being the largest and fastest.

The cooperative arrangements provided each group with better knowledge of the others' results and plans, reducing unnecessary duplication of work. In addition, it made available to all three countries the exchange of experts and special equipment.

MANAGEMENT

The programme is managed by a Joint Committee, consisting of one representative from each of the three countries, and two members from the Agency, meeting about twice a year. Each of the parties also has a separate Programme Supervisor responsible for the implementation of the national contribution to the programme, and the Supervisors also participate in the committee meetings. Typical Agenda for committee meetings include:

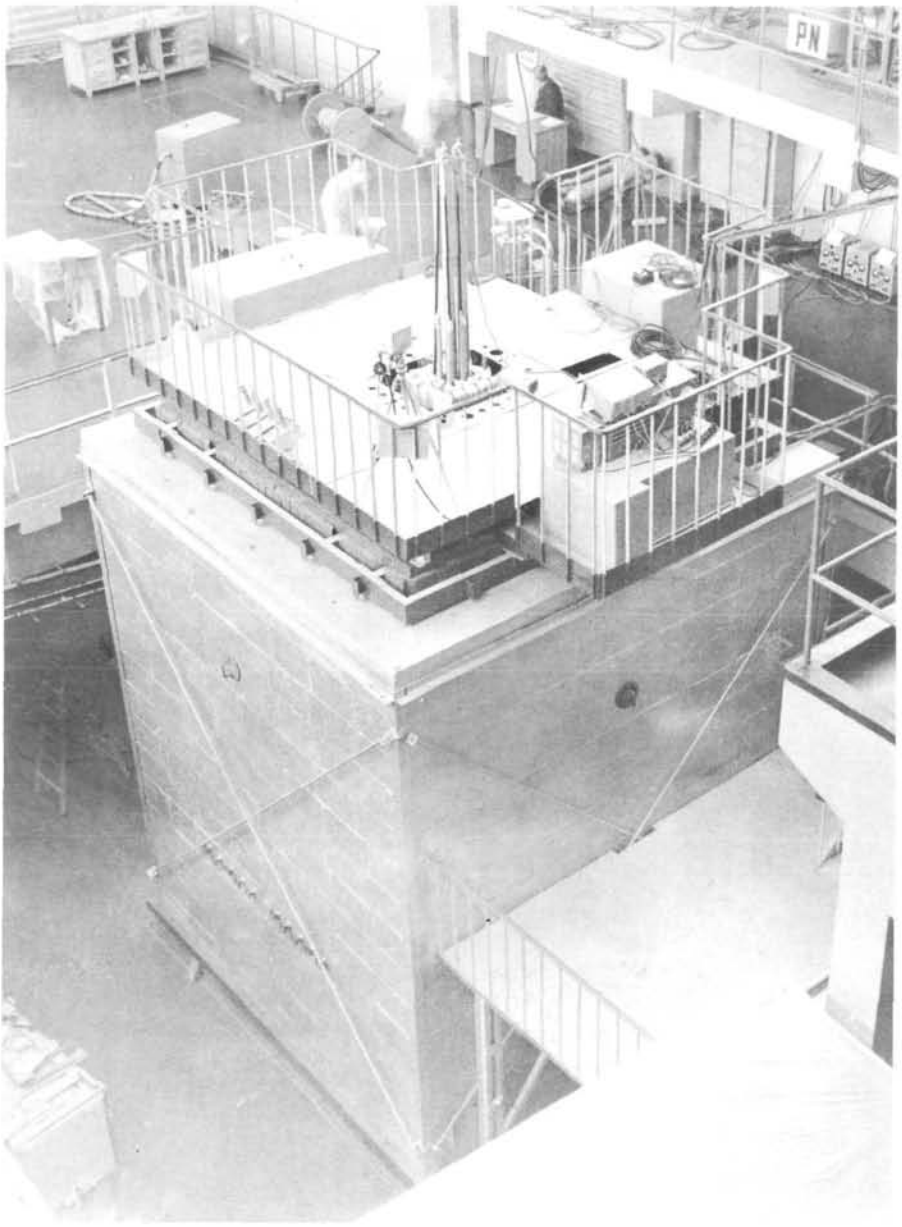
- Staff problems, such as seconding personnel from one centre to another and selecting Agency Fellows;
- Status of each of the scientific tasks which have been selected;
- Planning of detailed activities for the next period of time;
- Possible seminars, meetings and monographs;
- Technical presentations by the staff members at the centre in which the meeting is held;

The role of the Agency has covered several aspects. Through the Technical Assistance Fellowship Programme, it has been possible to provide useful talents to the signatory centres, while at the same time increasing their value as training centres for the Fellows assigned. Some Secretariat services have been provided to make the agreement run smoothly. The participation of IAEA staff members in the technical discussions has occasionally helped bring new information to the technical subjects at hand. Finally, the firsthand knowledge of the programme has made it possible to sponsor peripheral activities, such as summer schools, which have been held in conjunction with the project.

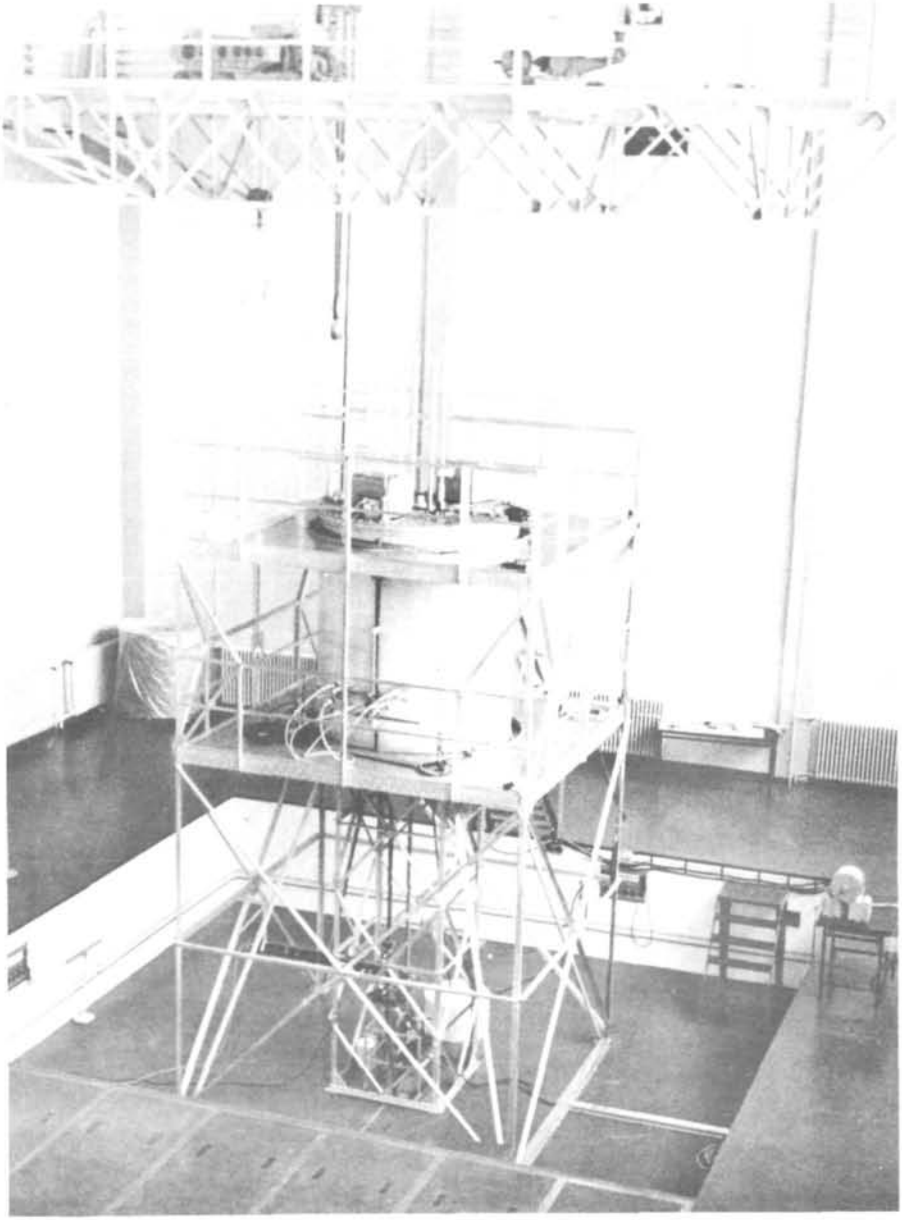
The bulk of the finance has been provided by the countries concerned. It is believed that the expenses of scientist exchange, committee meetings and so on are not greater than the ad-hoc expenses which would be necessary simply to keep each of the laboratories aware of developments at the other locations. By regularising the exchange agreements, the most efficient work can be done, both for the joint programme and for the related national programmes. Since the programme is a synthesis of national efforts, it is furthermore not necessary to draw upon other resources except for activities already mentioned as sponsored by IAEA: Fellowships, international meetings, monographs, and schools.

Among the most useful benefits has been the expediting of the supply of special materials and equipment as loans among the signatory countries. All three have been both suppliers and recipients of specially prepared foils and samples. Instrumental techniques were developed in all three countries and either the instruments themselves or assistance in building equivalent instruments provided to the others.

This critical assembly at Swierk, Poland, using enriched uranium in water and graphite, is named ANNA. A sub-critical assembly, HELENA, is also used for the NPY project.



RB, the heavy water moderated assembly in Yugoslavia.



NPY TASKS

The Joint Committee, in consensus, formulates "tasks" consisting of areas of work which are being actively pursued in at least two of the three countries and where some cooperation is considered useful.

Thermalisation and Thermal Neutron Distribution. The major activity under this task has been the measurement and interpretation of the distribution of thermal neutrons in the critical assemblies. Since the critical assemblies in the three countries are different, it has been very useful to see how a theory which works from one sort of system can be used for another type. The results of measurements were made available to theorists in all three countries and served to test calculations of a number of theoretical models. The preliminary results were reported in a joint paper in the 1964 Geneva Conference and the final results have been reported in a monograph *. It is believed that this work has resolved the long standing discrepancy between experiments and advanced theoretical predictions of the thermal neutron spectral and spatial distribution in single fuel element lattice cells.

New experimental techniques and theoretical computation methods, involving both hand calculation and the use of digital codes, were freely exchanged. Some of the experiments were performed using a pulsed neutron generator supplied by IAEA.

In connection with this task, a Seminar on the subject of neutron thermalisation was held in Warsaw in December 1965. It consisted of ten hours of lectures by Dr. Paul Michael (Brookhaven, USA) and ten hours of discussions. It was attended by 26 participants from five countries.

Slowing Down and Resonance Absorption Effects. Major work was done on chemical measurement of resonance absorption in natural uranium, using a rapid separation technique for isolating the neptunium 239 formed. It is important to know how many neutrons are lost to the chain reaction by this resonance absorption, which captures the neutrons while they are being slowed down, and before they have much of a chance to cause fission. In addition, a number of other materials were studied. Resonance capture of silver (a control material) and zirconium and zircalloy (reactor structure material) are reported. In 1964 a Seminar on resonance absorption under the leadership of Dr. Robert Hellene (Brookhaven, USA) was held in Belgrade. Six lectures led to many hours of discussion of advanced topics.

Buckling Measurements and Interpretation. This task concerns the concept of buckling, which is a generalised parameter closely related to the critical size of a reactor. Theoretical work consisted both of programming for digital computer some of the standard techniques used to predict buckling, and also the development of new approaches to the criticality problem (in

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* R.J.J. Stamm'ler, S.M. Takac, Z.J. Weiser, "Neutron Thermalisation in Reactor Lattice Cells: An NPY Project Report", Technical Reports Series No. 68, IAEA, Vienna (1968).

reactors the "buckling", together with the reactor geometry, completely determines whether a simple system is critical and, if so, what the shape of its power distribution will be).

Reactor Kinetics. These were investigated by three methods: Neutron noise (i. e., the fluctuation in neutron population due to natural fluctuation in fission rate); reactor modulation (the way in which neutron population follows a variation in criticality); and pulsed sources (the way a pulse of neutrons transforms into a steady, or slowly varying neutron population).

As this work progressed, it required accompanying theoretical activity. It became apparent that standard descriptions of reactivity, covering a range of critical, supercritical and subcritical states of a reactor are either not entirely correct or lack definition. Work was performed to achieve correct definitions of reactivity for application under specific experimental circumstances. Other theoretical problems concerned the effects of spatial migration of neutrons on their variations with time.

Two seminars on reactor kinetics were held in Norway: one general one in May 1965 and another, specifically on reactor noise, in March 1966. Invited speakers for the first of these were Dr. Henri Smets (ENEA) and Dr. N.G. Sjøstrand (Chalmers Institute of Technology, Sweden). The Seminar on Reactor Noise featured presentations by Dr. D. Stegeman (Karlsruhe, Germany) and Dr. W. Mattes (Ispra, Euratom). It included participants from the Netherlands and was very helpful for providing suggestions for NPY programmes in this area of research.

Development of a Nuclear Design Code. This is a correlation of many of the other tasks, being an attempt to develop a modular code system (i.e., a master computing code consisting of independent "blocks" for each of the auxiliary problems) which would correctly predict the properties of all assemblies measured in all the centres, as well as similar assemblies reported from other sources. The activity was initially centred in Norway and Poland who work cooperatively on both the analytical and computer operations. More recently, the expansion of the computer available to the Yugoslav party is making it possible for all three countries to participate.

SUMMER SCHOOLS

In addition to the seminars in support of the tasks, one of the most productive results of the project was the holding of advanced summer schools in reactor physics. These were sponsored [as Technical Assistance activities] by the IAEA with the support of the three countries and thus took on a world character while at the same time permitting the NPY signatories both to present their results and to contribute to the total literature. Lectures and seminars at the schools have been given by some of the world's foremost reactor physicists. An auxiliary benefit was the assistance provided by the expert discussions to the planning and implementation of the programme.

The first advanced summer school in reactor physics took place in Zakopane, Poland, in September 1964, with 67 participants and 19 observers from 28 countries. It resulted in a series of lecture notes on reactor physics which were widely circulated.

The second took place in Sandefjord, Norway, in September 1966, when 122 participants from 31 countries took part. Notes were prepared by the Norwegian hosts (Kjeller Report KR-117, 1967) and a limited number of copies are available from IAEA.

PUBLICATIONS

The NPY project has resulted in a large internal report literature. The reports have been circulated freely among the parties and are used as the basis for more formal reporting. Copies of the documents and reports lists are obtainable from the originating centre and a collected list of reports is available on enquiry to the Division of Nuclear Power and Reactors, IAEA.

The monograph, previously mentioned, on neutron thermalisation has enriched the world literature, and was widely circulated by IAEA. It has become a standard reference on the topic.