A UNIQUE EXPERIMENT

MEASUREMENT OF RADIATION DOSES AT VINCA

A unique scientific undertaking that is likely to make a significant contribution to our knowledge of the effects of radiation on man and to measures to ensure greater protection was recently completed under the auspices of the International Atomic Energy Agency. For the first time in the history of the peaceful applications of atomic energy, an experiment was conducted by an international team of scientists to determine the exact levels of radiation exposure resulting from a reactor incident.

The experiment was made at Vinca, Yugoslavia, where in October 1958 six persons had been subjected to high doses of neutron and gamma radiation during a brief uncontrolled run of a zero-power reactor. One of them died but the other five were successfully treated at the Curie Hospital in Paris under the direction of Dr. Henri Jammet. In the case of four of them, the treatment involved the grafting of healthy bone marrow to counteract the effects of radiation on blood-forming tissues.*

This, it will be recalled, evoked widespread interest in scientific and medical circles. It was immediately recognized that if the effects produced on the irradiated persons, which had been carefully observed before their treatment, could be related to the exact doses of radiation they had received, it would be possible to gain immensely valuable knowledge about the biological consequences of acute and high level radiation exposure on a quantitative basis. For obvious reasons, the effects of radiation on man cannot be determined by direct experiment. At the same time, it is essential that a dependable quantitative relationship be established between levels of radiation and their effects on man. Precise data on this relationship may also help in the development and wider application of the method of treatment adopted at the Curie Hospital.

Here then was a unique opportunity. The effects produced had been closely studied; everything indicated that the doses received by five of the exposed persons were close to or even exceeded those which are usually considered lethal. If the doses could now be established more precisely, it would be possible to correlate them not only with the effects of the radiation exposure but also with the effects of the treatment given.

The Director General of the Agency therefore suggested to the Yugoslav authorities that a dosimetry experiment by an international team of scientists be conducted at Vinca. The Yugoslav authorities agreed to the suggestion and assured the Agency of their active co-operation in the project. A formal agreement was concluded between the Agency and the Federal Nuclear Energy Commission of Yugoslavia on 2 February 1960, under which the Agency assumed the responsibility for organizing and carrying out the experiment by re-starting and operating the reactor with adequate measures of safety and special arrangements for radiation measurements.

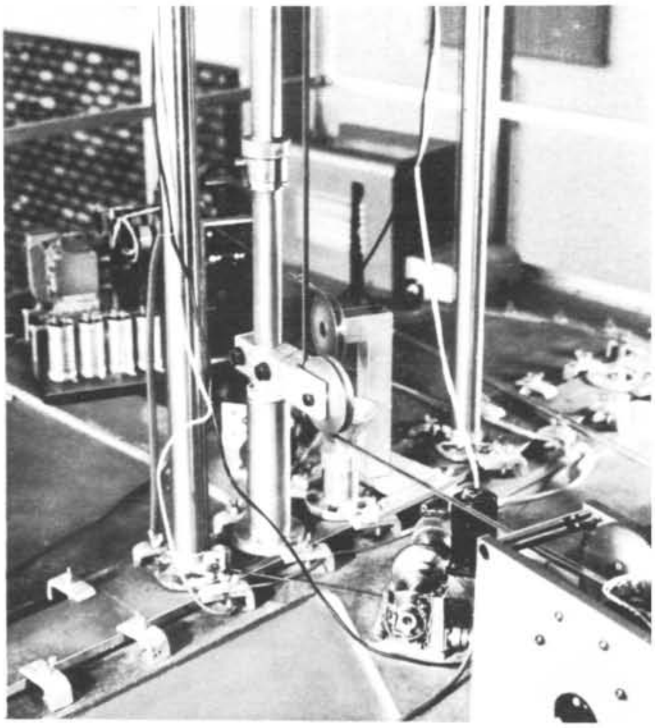
Consultations and Arrangements

The Agency held extensive consultations with the atomic energy authorities of different countries, and numerous countries and groups indicated their willingness to assist in the execution of the project. It was, however, found necessary for the efficient conduct of the experiment to limit the actual participation to as few groups as possible. Yugoslavia agreed to place the reactor and the laboratory premises at the Boris Kidric Institute at Vinca at the disposal of the Agency and to provide consultants, personnel, instruments and services.

For the special purposes of this experiment, it was arranged that experts from the French atomic centre at Saclay would redesign the control equipment of the reactor and be responsible for its start up and operation. The heavy water (6.5 tons worth approximately $400 000) needed as moderator for the reactor was offered free of charge by the United Kingdom Atomic Energy Authority. Health physics experts of the Oak Ridge National Laboratory, USA, who have specialized in this kind of experiment, offered to undertake the radiation measurements and provide the necessary equipment for the purpose. A British scientist joined the American team with some equipment for radiation measurements. The Boris Kidric Institute at Vinca made many basic preparations on the reactor and the reactor premises and added necessary shielding to the walls of the reactor room to enable the reactor to work at much higher power than originally designed. A higher power level was chosen for the experiment to facilitate the measurements. The Institute made consultants and technicians available for the experiment and provided a great deal of administrative support as well as extensive facilities in matters of organization and physical arrangements, essential for the smooth and efficient conduct of the experiment.

The heavy water from Harwell arrived at Vinca at the end of March. Twelve French experts, led by Dr. Jacky Weill and Mr. Jacques Furet, and the equipment from Saclay arrived at the beginning of

* *Some details of the treatment and the background to the Vinca experiment were contained in an article, entitled* Experiment at Vinca, *in the last issue of this Bulletin (Vol. 2, No. 2, April 1960).*



Part of the control rod mechanism on top of the reactor

April. The American team of seven health physicists, led by Dr. George S. Hurst and Dr. Rufus H. Ritchie, also reached Vinca early in April with their highly specialized equipment, including four phantoms or plastic dummies of men which were then filled with a salt solution.

Start-up and Operation

The control board and the related control equipment for the reactor, which had been designed and constructed at Saclay in five weeks' time, was assembled at Vinca in two weeks. After these preliminary arrangements, the French team completed the tedious task of siphoning 6.5 tons of heavy water from barrels into the reactor system in less than a day. The reactor, which had not been operated since the incident of October 1958, went critical again for the first time at 18:09 hours on 20 April. The critical level of the water in the reactor as well as the operation and efficiency of the control rods and the remote control equipment were checked. Good results were achieved and it was possible to operate the reactor the same evening at a power of 5 watts during eight short periods for the dosimetry experiment. On 22 April it was again operated at a power of 1 kilowatt and on 25 April it was brought to a power level of 5 kilowatts, thus concluding the experiment.

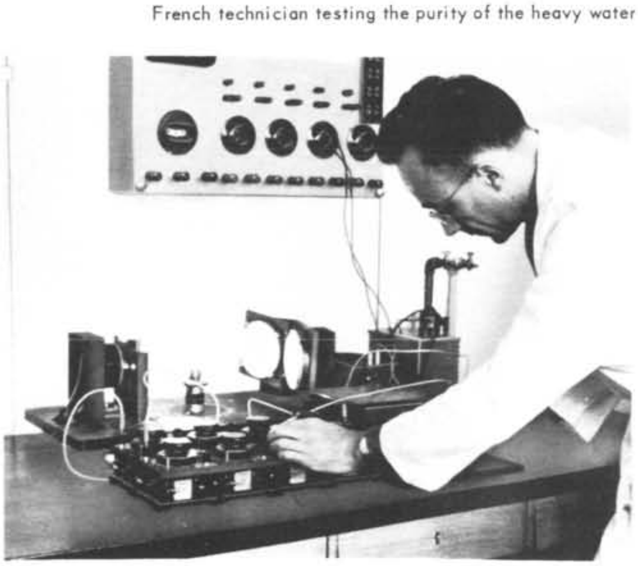
The most accurate modern techniques of dosimetry developed at the Oak Ridge National Laboratory were employed during the experiment. Simultaneous measurements of the neutron and gamma doses were made at points where the people involved in the incident had been located. At these points the effects of the radiation on the salt solution in the phantoms were studied. In particular, the energy distribution of the radiation was investigated, because the biological effects of the neutrons and the gamma rays are different. In fact, it was the ratio between the various components of the radiation that was of special interest in these measurements because this ratio itself would help in determining the exact doses. The dose of one of the components, viz. slow neutrons, had already been determined during the treatment of the patients. If the ratio of the components could now be ascertained, the doses of the fast neutrons and gamma rays could also be established because the ratio would not be affected by the power level at which the reactor was operated.

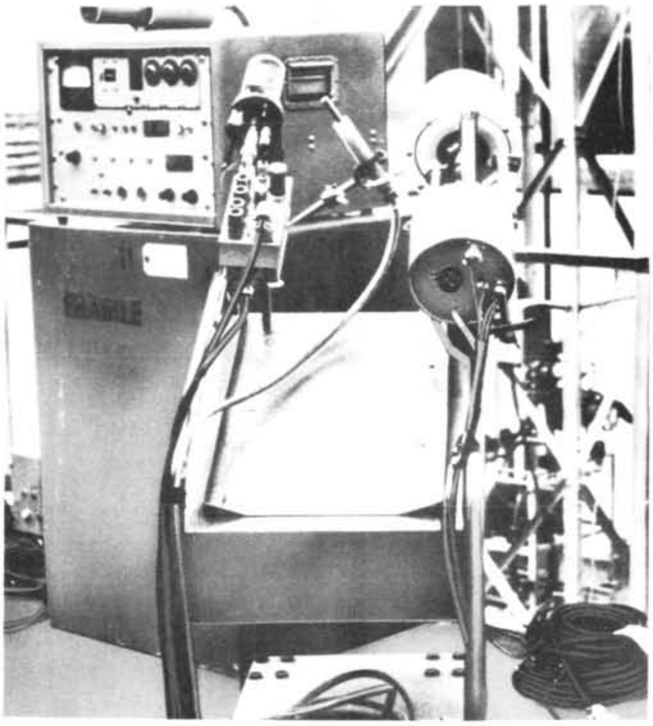
International Co-operation

Details of the experiment were given at a press conference held at Vinca on 27 April by the scientists responsible for its organization and execution. Dr. Henri Jammet was also present. Mr. G. W. C. Tait, Director of IAEA's Division of Health and Safety, opened the press conference with a general account of the experiment. Describing some of its unique features, he said: "It has demonstrated international solidarity in an extremely delicate field in which this work is a pioneering step. It promises to be of very real benefit to science and the results will be made known to all countries which are members of the International Agency and the United Nations. Harwell, Saclay and Oak Ridge have now been linked even closer than before to the Boris Kidric Institute and the International Agency has completed one of its first major projects, a project which did not at all times seem easy to carry through."

In reply to a question, Mr. Tait said that the situation at Vinca had been unique in the opportunity it provided for acquiring useful information. Dr. Hurst

French technician testing the purity of the heavy water





Radiation monitor, part of the dosimetry instruments brought from Oak Ridge, USA

said that some other accidents had been investigated in part and in some cases it had not been possible to obtain enough information to make a detailed investigation feasible. He, however, added that there was one accident in the United States in which investigations comparable to those at Vinca were possible, and that was the accident which occurred at Oak Ridge in June 1958.

Describing the modifications carried out on the reactor by the French team, Dr. Weill said that before the experiment the reactor was not designed to be operated at the power level necessary for the dosimetry work to be undertaken. Two things were important for this experiment: to increase the safety of operation and to install the necessary control mechanism to operate the reactor at power levels many times higher than that for which it had been designed.

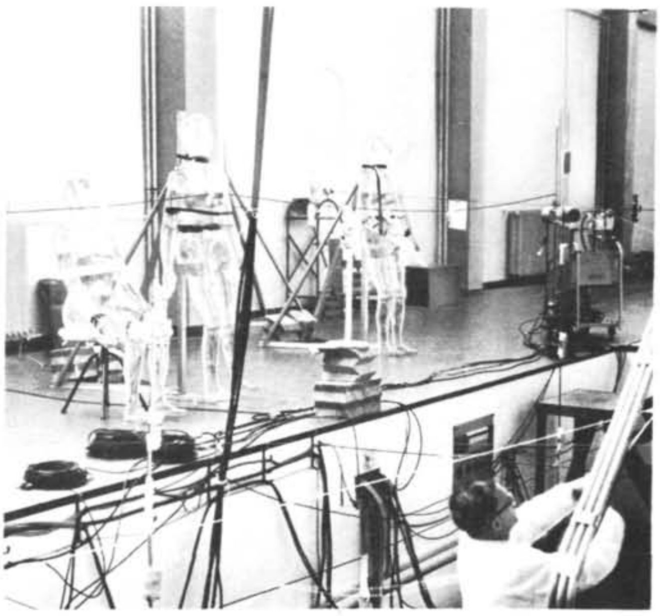
A correspondent asked whether the conditions under which the experiment had been made were exactly similar to those at the time of the incident of October 1958. Dr. Hurst explained that it was not necessary to reconstruct the exact conditions of the accident because the techniques of dosimetry did not depend on this. Besides, it probably would have been impossible to reconstruct the exact situation because of certain unknown factors, particularly those associated with the exact location of the affected persons at the time of the accident. Dr. Weill said that what was interesting was to determine the nature or composition of the radiation, i.e. the relationship between the neutrons and the gamma rays. Mr. Tait added that the experiment was designed to obtain specific scientific data and even if it had been possible to reproduce the physical conditions of the accident, he doubted whether it would have been desirable to do so. At the same time, Mr. Ritchie pointed out, it was important to ensure that the configuration of the reactor room was exactly the same as it was during the accident, because scattering on the walls, floor and objects of the room influences the distribution of thermal (slow) neutrons and this might alter the relationship to the dose already determined during the treatment of the patients.

Medical Significance

Several questions were addressed to Dr. Jammet about the significance of the experiment from the medical point of view. He explained that the medical consequences had been closely studied in the persons affected by the Vinca accident; it was now a question of ascertaining the actual radiation doses that they had received. He, however, pointed out that from the medical point of view it was also a question of deciding on a method of treatment that would suit an individual case. In the case of the Yugoslav patients, all had not received the same kind of treatment, nor had the results been identical. The public should not be led to believe that the therapy adopted by him could be used as a positive cure in all cases. There were always some unknown factors in specific cases and and the problem was to make the treatment correspond to the specific needs of a case. However, the experiment at Vinca was certainly a great contribution, "another stone, I would say, in the edifice of our research in the medical field".

Asked whether the Curie Foundation had any plans for treating similar cases in the future, Dr. Jammet

The phantoms placed in position for the experiment



said he hoped he would not have too much opportunity to exercise his talents in this field; it was to be hoped cases of radiation injury would not be frequent or numerous. In any event, all cases were not identical and the treatment would have to vary. Besides, there were cases which did not require any treatment and others in which treatment would be of no avail. The Curie Hospital, therefore, had no fixed programme of treatment. Dr. Hurst said that the method of treatment employed in the case of the Yugoslav patients had not been attempted in any other case of this type. In the case of the Oak Ridge accident, the people affected had received a somewhat lower dose and it was not thought desirable to try treatment of this type. In other cases in the United States the exposure had been so large that such treatment would have been useless.

Commenting on the significance of the experiment in general, Dr. Hurst said that since the advent of atomic energy there had been considerable concern about the effects of radiation on man but so far there had been little opportunity to establish a quantitative relationship between amounts of radiation and their consequences. Every opportunity should be taken to ascertain this relationship so that one could determine the levels of tolerance that would govern various operations in the field of atomic energy.

RADIATION SAFETY MEASURES

Safety in atomic operations has an exceptional significance because the hazards involved are of a rather special character. While normal industrial hazards may well be catastrophic, their nature is well known and they can be controlled by methods which are relatively simple to formulate and enforce. The hazards of nuclear radiation which are inherent in most atomic energy activities are much more complex; not only their effects but their very presence are sometimes likely to remain unnoticed until harm has been done. Adequate insurance against these hazards can be secured only be a set of special measures of safety.

The International Atomic Energy Agency has, from the very outset, regarded radiation safety as one of its primary responsibilities. The potential contribution of atomic energy to human welfare is now universally recognized, and it is inevitable that there will be a steady expansion of activities to derive its benefits. But it would be a sad irony if this progress were attained at the cost of human health and safety. While assisting the development of the uses of atomic energy for economic and social progress, the Agency must, therefore, also try to ensure that it does not constitute a threat to man's health and heredity.

While this may be too wide an objective to be fulfilled by the efforts of any single organization, the Agency must at least see to it that the activities to which it lends its assistance are carried out without causing any avoidable damage to life and property. And the important thing to remember is that however insidious the dangers of nuclear radiation, much of the possible damage is avoidable through the adoption of appropriate measures of safety.

The sources of danger, of course, cannot be eliminated. The emission of ionizing radiations is governed by an unalterable natural law; the substances which emit them are indispensable in atomic operations; and there is as yet not a great deal that one can do to reduce or substantially modify the effects of the radiations. But what one can, and must, do is to ensure that people are not exposed to these radiations in a manner or to a degree that is likely to be harmful.

This is the basic purpose of radiation safety regulations. The precise formulation and enforcement of these regulations, however, depend upon a large complex of technical and organizational considerations. From the technical point of view, it is necessary to study the behaviour of various radioactive substances, to determine the levels above which the radiations are likely to be harmful, and to devise measures to keep the levels of exposure with an adequate margin of safety below the threshold of danger. On the organizational side, however, one must not only ensure that the technical regulations are adequately observed but also see to it that in so doing, an undue restriction is not placed on the development of peaceful atomic energy work. After all, if atomic energy is to be put to any practical use, radioactive substances cannot be isolated from the arena of human activity, and some kind of contact is inevitable at every stage of production, storage and use. The aim, therefore, is to evolve a system under which these operations can be carried out effectively with a minimum of direct contact, keeping the levels of exposure as far below the threshold of danger as possible.

Special Responsibilities

Many national and international organizations are concerned with this problem, but inevitably IAEA must assume certain special responsibilities in this field. Under its Statute the Agency is authorized to establish or adopt standards of safety for the protection of life and property and to provide for their application to operations to which assistance is rendered by it or at its request. The Agency may also, if so requested,