the assistance given by the Agency at various stages of the evaluation. They have also requested the Agency to arrange for similar evaluations of power reactor projects in Switzerland; arrangements for these are already under way. In addition, a few other governments have begun enquiries regarding the possibility of Agency assistance in this field, and it is possible that the evaluation of reactor safety will some day become one of the Agency's major activities. A valuable contribution to the efforts to solve the technical problems concerned with reactor safety will be made by expert panels which the Agency plans to convene for discussing questions of siting and containment of reactors.

In the final analysis, the success of these efforts will be largely dependent on recognition by Member States of the importance of an adequate evaluation of reactor safety and their willingness to submit their reactor projects for evaluation by the Agency. Signs of this recognition are already apparent. It is significant to note that the countries which have so far approached the Agency in this connexion are among the more advanced in nuclear technology.

EXPERIMENT AT VINCA

An important experiment to determine the biological effects of acute and high-level radiation exposure is to be carried out under the auspices of the International Atomic Energy Agency at the Boris Kidric Institute at Vinca, near Belgrade, Yugoslavia. The experiment will give more precise information than hitherto available about the doses of neutron and gamma radiation received by some persons during a brief uncontrolled run of the zero-power reactor at Vinca on 15 October 1958. The exposed persons were given long and careful medical attention in Paris and treated by a unique method of counteracting radiation injury. If the levels of their exposure can now be ascertained more precisely, it will be possible to gain a better understanding of the correlation between radiation doses and their effects, and perhaps also to develop the method of treatment for wider application.

The experiment now being arranged will involve the restarting and operation of the reactor at a controlled safe power level. Experts are being called together by the Agency to measure the levels of radiation and to establish more precisely the doses which were received by the exposed persons.

An agreement for the carrying out of the experiment was recently concluded between the Agency and the Federal Nuclear Energy Commission of Yugoslavia. The Commission is placing the facility at the disposal of the Agency to make certain modifications in the reactor and to perform the dosimetry measurements. After the completion of the project, the reactor will be restored to the condition in which it is being made available by the Yugoslav authorities.

The French Atomic Energy Commission is helping the project by providing equipment and experts, and 6.5 tons of heavy water that will be needed as moderator is being obtained as a loan from the United Kingdom free of any charge for its use. The dosimetry measurements have been assigned to a team of experts under the technical direction of the Oak Ridge National Laboratory in the United States. A complete scientific report on the results of the experiment will be published by the Agency.

The incident of 15 October 1958 attracted wide attention, particularly in connexion with the novel medical treatment given to the exposed persons at the Curie Hospital in Paris under the direction of Dr. Henri Jammet. Authentic details of the incident have been published by the Boris Kidric Institute.*

The reactor in which the incident occurred is an unshielded critical assembly fuelled by natural uranium and moderated and cooled by heavy water. Control of the reaction rate was achieved by adjusting the level of the moderator. The accident occurred during an experiment to measure the spontaneous fission rate in the natural uranium fuel at different subcritical moderator levels. Due to a combination of circumstances, the water level reached and exceeded the critical level for a few minutes, resulting in intense emission of neutrons and gamma rays.

Six persons in the immediate vicinity of the unshielded reactor received very large doses of neutron and gamma radiation. Two other persons, who were further away, also received radiation doses above the permissible level.

Treatment in Paris

The irradiated persons received first-aid at the Boris Kidric Institute, and were then transferred to the Centre for Professional Diseases in Belgrade. The same day Dr. Henri Jammet, Head of the Atomic Hygiene and Radiobiology Service of the Curie Foundation in Paris was contacted. He offered to treat the six heavily irradiated patients at his centre. The patients were flown to Paris the following day. Of the six persons transferred to Paris, one was cured

* *See* Journal of the Boris Kidric Institute, *March 1959, and* Nucleonics, *April 1959.*

by conventional treatment, including blood transfusions. It became clear, however, that such treatment would not be adequate for the other five patients who had been subjected to extremely high doses of radiation. The radiation had destroyed the blood-forming tissues in their bone marrow; as a result the number of white cells in the blood fell very sharply. To provide them with new blood-forming tissue, the patients were given transfusions of bone marrow obtained from donors who were matched as closely as possible with the patients by detailed blood tests.

Such a method of treatment had been tried before on an experimental basis but had not proved particularly successful. One difficulty is that bone marrow injected from outside tends to create antibodies; the patient's system refuses to incorporate the foreign substance. In this case, however, the treatment was remarkably successful. Although one patient who had presumably received the highest radiation dose died before the treatment could take effect, the four others were gradually cured. The grafted bone marrow soon began to produce new white corpuscles and the condition of the blood has now returned to nearly normal. According to one theory, the excessive radiation itself had prevented the creation of antibodies and thus facilitated the incorporation of the grafted marrow into the biological system of the patients.

A full and authentic report on the treatment of the Yugoslav patients is not yet available, but enough is known to indicate that the experiment represents a landmark in medical history. It has been widely suggested that bone marrow grafting may now become an invaluable method of counteracting the effects of excessive radiation exposure as a result of nuclear accidents. It may also be useful in the treatment of blood cell disorders caused by diseased bone marrow. Again, it has been suggested that the injection of bone marrow may be able to counteract certain undesirable effects of large doses of X-rays in the treatment of cancer; it follows that this would immensely increase the therapeutic value of X-rays.

Radiation Doses

It is certain that the success of the treatment of the Yugoslav patients will intensify further research and experiments in this field, but the value of the experience gained would be greatly increased if the extent of their radiation exposure were precisely known. If the exact doses can be ascertained, it will be possible to correlate them with the effects observed in the patients in the course of their treatment. And such correlation, apart from its value in general radiobiological investigations, would help further development of the method of treatment of radiation injury as adopted at the Curie Hospital.

According to a report published by the Boris Kidric Institute, it was estimated the irradiated persons received a total average whole-body dose of 683 rems of neutron and gamma radiation. The rem

The reactor building at Vinca (Photo: Yugoslav Nuclear Energy Commission)

is the unit of ionizing radiation which has approximately the same biological effect as one roentgen of X-rays. Since a dose of 400-500 roentgens is considered to be lethal in 50 per cent of cases, the above-mentioned doses would indicate that the outcome would have been lethal, but for the revolutionary treatment given at the Curie Hospital.

While this general conclusion remains valid, further scientific research must be based on more precise data on the radiation doses. The estimates will therefore have to be tested by direct measurements, and it is with the object of carrying out these measurements that the dosimetry experiment is being arranged at Vinca.

The project forms part of the Agency's research programme in the field of health and safety. After signing the agreement for the project, the Director General of the Agency, Mr. Sterling Cole, and the Yugoslav Under Secretary of State for the Federal Nuclear Energy Commission, Mr. Slobodan Nakićenović, in a joint statement said: "The signing of this agreement will make it possible to obtain invaluable data for the studies of the effects of radiation on man and will allow for a better understanding of completely new methods of therapy. The importance to the medical world and to all atomic energy authorities in the Agency's Member States of determining the exact doses received by the persons involved prompted the Director General to suggest some months ago that these experiments be carried out. The Yugoslav authorities, recognizing the value of the experiments to other countries and favouring action through the International Agency, decided to support the Agency initiative and to co-operate fully in the project, although it means a certain disruption of the programme of the zero-power reactor in Vinca. The dosimetry experiment at the Boris Kidric Institute is a good example of international solidarity and joint action in the atomic health and safety field. We are convinced that it will be of great value to all mankind."

(continued on page 12)