EVALUATION OF REACTOR SAFETY

Although the operation of nuclear reactors has a remarkably good record of safety, the prevention of possible reactor accidents is one of the major factors that atomic planners have to contend with. This, perhaps, is just as well, because it would be folly not to profit from the errors of the early days of industrial development, and if we were to err again it would be wiser to do so on the side of caution.

At the same time, excessive caution may breed an attitude that hampers progress, either by resisting new development or by demanding unnecessarily elaborate and expensive precautions out of proportion to the actual hazards involved. The best course obviously is to determine the possible dangers and adopt adequate measures for their prevention, providing, of course, for a reasonable margin of error in judging the hazards and the effectiveness of the measures. The greater the expert understanding and thoroughness with which this is done, the narrower need the margin be.

This is the basic idea behind the evaluation of reactor safety. If atomic reactors were to be installed without a careful examination of the safety features, the consequences might be catastrophic. Besides, even if no accidents took place, there would always be serious misgivings in the public mind, and any steps to allay these misgivings would be unfounded in the absence of a basis of judgment in regard to the safety of the plant.

Different Conditions

Quite often this point tends to be overlooked. The designs of the common reactor types today are well tested, but there is seldom any guarantee that a reactor of a proven type is safe under different operating conditions, and it is well known that these conditions vary in significant respects. Besides, some of the effects of the operation of a reactor which are perfectly harmless in one situation may constitute a serious hazard to health and safety in another. It is essential, therefore, that the safety requirements of a reactor and the arrangements to meet these requirements are examined for each individual case in relation to the specific conditions under which it is to be operated.

Many States have already introduced measures requiring that the installation of a reactor is to be permitted only after a proper certification of safety by a competent authority. While the competent authority may be an administrative body, the certification has necessarily to be based on the judgement of experts. This is a field in which the pooling of expert knowledge can be a great advantage, particularly because of the special features of the various reactor types which have been developed in different countries. Besides, the safety of a reactor has often an international significance and many advanced countries would prefer an international opinion.

Role of International Agency

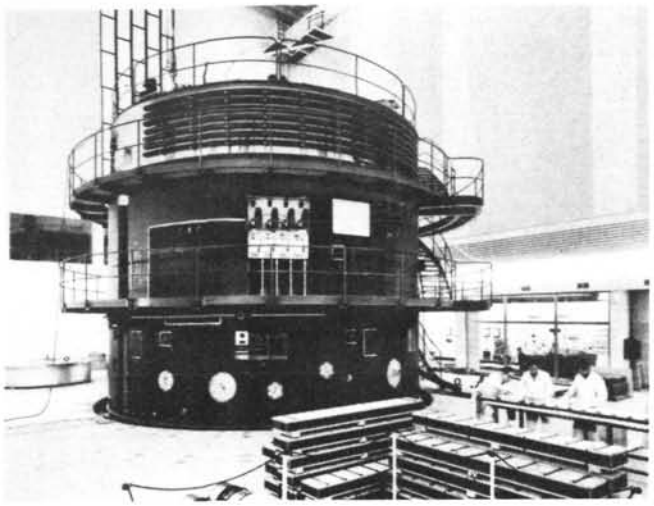
The role that an international technical agency can play in this respect has received increasingly wider recognition during the last few years. If the evaluation of reactor safety could be performed by an international body whose objectivity and technical judgement would be universally acceptable, all countries could turn to it for the safety reviews of their reactor projects according to an established set of principles and procedures. Apart from the technical advantages involved, such a practice would be of considerable value in creating public confidence in the rapidly growing atomic industry.

The International Atomic Energy Agency has already taken steps to establish this service. Certain general procedures have been worked out for carrying out assignments of this type. At the request of a Member State to undertake a reactor safety review, an evaluation group, consisting of members of the Agency's scientific staff, would first examine a detailed report, dealing with all aspects that might have a bearing on safety, prepared by those in charge of the design and construction of the reactor. On the basis of this evaluation, the report would be revised as necessary by the designer and prepared for presentation to an advisory panel on reactor safety. On the basis of the verdict of this panel of experts of international repute, the national authorities would decide on the safety certification of the reactor. This procedure should be performed not only before the construction of the reactor but also again before the actual operation.

Evaluation of "Diorit"

The procedures, of course, will vary to some extent according to the needs of individual cases, but a good working model was established in the course of the first reactor safety evaluation carried out by the Agency. This was done at the request of the Swiss Government for the Swiss reactor project, "Diorit". The Agency not only obtained the services of the experts for the final evaluation but also advised the reactor staff on the preparation of the report on the safety analysis and on its presentation to the experts.

A senior member of the Agency's scientific staff worked in close collaboration for several weeks with the staff of Reactor A.G. which designed, built and will operate "Diorit". After the preliminary review had been made and a report prepared, an advisory



"Diorit" under construction, December 1959 (Photo: Reaktor A.G.)

panel called together by the Agency, consisting of Dr. J. Bourgeois (France), Dr. G. C. Laurence (Canada), Dr. R. L. Dean (USA) and Dr. V. O. Eriksen (Norway) - all of whom are leading authorities in reactor safety in their respective countries, visited the site of the reactor at Würenlingen, Aargau. The experts were given a detailed report on the reactor installation after which they inspected the plant and examined the arrangements at first hand. This was followed by long sessions at which they questioned the reactor staff on various points in the safety report and asked them to justify the arrangements. At the end of their examination, the experts concluded that the reactor could be operated without undue risk to the health and safety of the public and submitted a report accordingly to the Federal Council of Switzerland.

The purpose of safety evaluation is to ensure that in all aspects of planning and construction every possible hazard is taken fully into account. That is why the panel of experts interrogated the designer on many points of detail and asked them to defend the plans from the point of view of safety.

Nature of Review

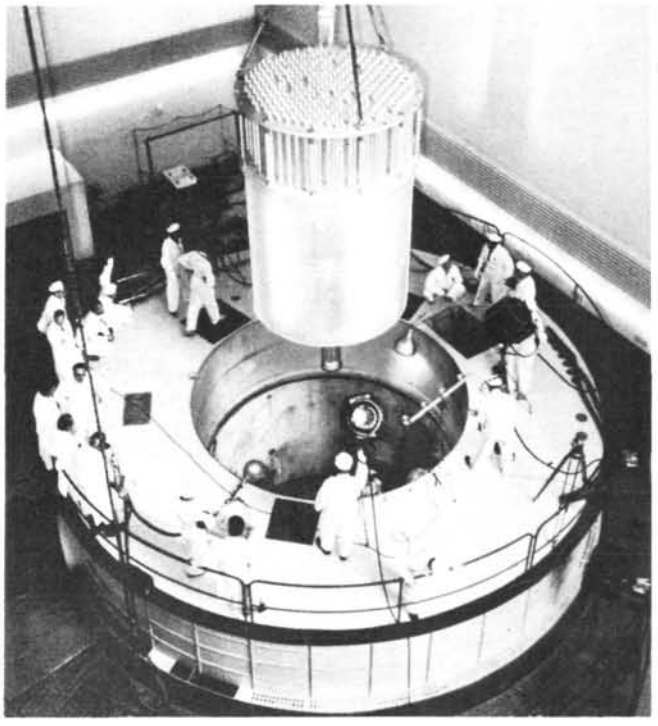
"Diorit" is a research and materials testing reactor, fuelled by natural uranium and moderated and cooled by heavy water, with a power output of 20 MW. One of the first questions asked by the experts related to its programme of experiments; whether a reactor would operate safely would depend largely on the kind of work that is done with its aid. Another point of consideration was the precise method of making the reactor critical. A number of important questions related to the arrangements for controlling the rate at which the fission reaction would proceed; control of the reaction rate is usually achieved by the insertion, in the form of movable rods, of material that can absorb neutrons and reduce the reaction rate or by adjusting the level of the moderator. The arrangements for the insertion and removal of these rods or for adjusting moderator levels form a complex control mechanism, every aspect of which has to be examined carefully to avoid any failure in its working. Furthermore, the design and construction must provide for adequate arrangements for dealing with emergencies.

The arrangements for reactor safety must provide for the prevention of any hazardous release of radioactive material. While the safety of the reactor staff would be ensured by normal health physics regulations, the evaluation of reactor safety has to take into account the wider problem of contamination affecting the general public. Some amount of radioactive material has to be disposed of as waste and some will always be released in routine operation. It is important to ensure that any resultant contamination is so controlled as not to constitute a health hazard to the public. After examining "Diorit" the panel of experts pointed out that the small quantities of radioactive material that might be released from time to time would not be hazardous. It was also emphasized that as the design and the mode of operation of the reactor developed, it would be necessary to review its safety at periodic intervals to ensure that the original standards had been maintained.

Further Projects

The Swiss authorities have expressed their appreciation of the work done by the experts and of

The reactor tank being lowered into the shield (Photo: Reaktor A.G.)



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.*