SELECTING SITES FOR NUCLEAR CENTRES

Choice of site for a nuclear facility, which is often a matter of considerable public interest, must be based on more numerous and varied considerations than are necessary in selecting a site for a conventional industrial plant. In many cases it involves a compromise between conflicting requirements. For example, considerations of safety usually favour the installation of a nuclear reactor away from populated areas, while economic considerations may demand that a nuclear power station be sufficiently near the consumers to minimize the cost of power transmission or organizational or administrative requirements may make it desirable to have a nuclear research centre in close proximity to educational institutions and supporting facilities.

In addition, there are many geological, engineering and other technical considerations that determine the suitability of a site for a nuclear installation. The requirements are often further complicated by local factors and the final choice becomes a complex and delicate task. There is thus a clear need for the formulation of certain general criteria which will not only help in the evaluation of particular sites but also in reassuring public opinion that the selection of a site is not an arbitrary decision but based on a scientific assessment of the balance of advantages and all foreseeable consequences.

One hundred and twenty scientists from twelve countries and five international organizations met at an IAEA symposium in Bombay from 11 to 15 March to discuss criteria for guidance in the selection of sites for the construction of reactors and nuclear research centres. As the Agency's Deputy Director General in charge of Technical Operations, Mr. Pierre Balligand, said in his opening address to the meeting, two principal considerations had determined the organization of this symposium. First, he said, several advanced countries had already had considerable experience with problems of siting nuclear research centres and research reactors, and more recently of nuclear power stations. It was thought that it would be useful to organize an international meeting at which this experience could be compared and ideas exchanged. Secondly, said Mr. Balligand, many of the developing countries were in the process of setting up nuclear research centres and some were also considering the economic and technical aspects of using reactors for the generation of electricity. The choice of site was an important step in this activity and the developing countries could profit from reports on the experience of the more advanced ones and thus avoid a repetition of the difficulties that had been faced in the initial stages.

Mr. Balligand said it was important that public opinion be correctly informed on the implications of siting nuclear centres, because an exaggerated notion of the possible consequences of accidents might lead to the construction of nuclear power stations so far away from power consumption zones as would affect the economics of power generation. At the same time, the requirements of safety must not be overlooked, and the Agency, Mr. Balligand emphasized, attached the first priority to the safety and security of people in atomic energy operations.

This point was also stressed in another opening address to the symposium by Mr. M.S. Kannamwar, Chief Minister of India's Maharashtra State, who said that meetings of this kind played an important part in assuring the public that scientists were not only aware of the existence of hazards of atomic operations but were actively engaged in finding solutions. In fact, he noted, the tradition of safety had been one of the most remarkable features of the nuclear industry from its very early days, and careful siting was an important element in planning for safety in a nuclear enterprise. Referring to the comprehensive list of topics for discussion at the symposium, Mr. Kannamwar said it was clear that nuclear scientists and engineers were considering every conceivable problem posed by the new technology. "Nothing can be more reassuring to the public mind", said Mr. Kannamwar, "than the thoroughness with which they have identified the problems and the seriousness of purpose characterizing their effort to find the solutions."

Papers from a few international organizations concerned with these problems were presented at the first session. The symposium then considered the main factors which have to be taken into account in choosing a site for a nuclear centre. The most obvious of these is the problem of airborne radioactivity that may be released in the course of the normal operation of a nuclear facility or as a result of a nuclear accident. Ground considerations, that is the suitability of the soil for nuclear construction as well as for the disposal of radioactive waste, constitute another important factor. The type of reactor installed, especially the extent and nature of reactor containment, has also a bearing on the suitability of a site. In addition, there are various engineering and administrative factors that may influence the choice of site for a nuclear facility.

After examining these factors, the symposium discussed certain general criteria which could be applied in dealing with the relevant factors in a specific case. Afterwards it heard reports on the experience

A session of the IAEA symposium in Bombay on the selection of sites for nuclear centres

already gained in the selection of sites for nuclear research centres and power stations. The concluding session was devoted to two panel meetings at which some of the participating scientists reviewed the material presented at the symposium and also discussed future trends in site selection criteria, procedure and practice.

Environmental Considerations

The various environmental paths of radiation exposure from a nuclear plant and their potential influence on siting criteria were discussed in a paper by E.C. Watson and C.C. Gamertsfelder (USA). The two main paths are (a) exposure to the released cloud of radioactive contaminants and (b) exposure resulting from the use of land, building and agricultural products contaminated by the passage of the radioactive cloud. In other words, the exposure is to either airborne contaminants or deposited contaminants. Exposure to the former can be through external irradiation or internal deposition (by inhalation). The hazard of deposited contaminants is either from external irradiation as a result of the contamination of ground, buildings and clothing, or from internal deposition through the ingestion of contaminated vegetables, water, milk and other food chain products.

Mr. Watson and Mr. Gamertsfelder stated that for the normal operation of chemical processing facilities and for the accidental release of radioactivity from power reactors, ingestion was the most important path of environmental exposure. They said: "Depending upon the meteorology of any particular site, land activities at distances as far as 10 to 15 kilometers may be affected. Generally, the distance at which land use restrictions may be required are such as to preclude eliminating the problem by site selection. Distances cannot be considered as a major factor in reducing environmental exposures from radioactive contaminants released to the atmosphere during their normal operations or major incidents. The emphasis must be placed on confinement of the radioactivity within the facility."

One of the problems of siting is the long-term average exposures which result from routine environmental releases of small quantities of radioactive material. F.T. Binford (USA) presented an analysis aimed at developing a method of estimating the upper bound of the radiation dose received by inhalation from routine releases.

A French paper (A. Menoux and others) suggested that a network of monitoring stations should be set up to obtain information on background radiation at a nuclear site before the start-up of a plant. The measurements carried out through this monitoring network would make it possible to draw up a map of the background radioactivity at the site under consideration, and the map would include not only the radioactivity from natural sources, but also that due to nuclear test fall-out. Such a map would be useful if any question arose over the share of responsibility of atomic plants in the event of any damage due to radioactivity in the neighbourhood. "In principle," the authors said, "the fact that such a document is available will make it easier to verify that the peaceful use of atomic energy has not caused any danger to the population."

A few papers on ground considerations for site selection were presented by French scientists. One of them (F. Duhamel) stated that the transport, storage and disposal of radioactive wastes had to be taken into consideration in deciding upon the suitability of a site. Another French scientist, J. Bourrier, pointed out that one of the ways of processing radioactive effluents from a nuclear centre was to fix the radioactive ions by filtration through a column of soil; he discussed some technical questions arising from this method which have a bearing on site selection.

In a general discussion on the location of nuclear power plants from the point of view of environmental safety, J.M. Smith (USA) pointed out that two decades of experience had shown that nuclear facilities could be constructed and operated with a very high degree of assurance of public safety. The containment barriers of the plant, he said, were expected to provide essentially complete protection, even in the event of serious failure of the reactor system. It was only in the multiple contingency of failure of the containment barriers, in addition to failure of the reactor system, that plant location could affect environmental safety. Mr. Smith suggested a "site rating index" method, aimed at providing a numerical measure of the contribution to safety which the plant location could provide. The method was expected to be an improvement on the existing ones, as it took into account the importance of "meteorological probabili-

ties", such as wind directions and atmospheric diffusion conditions.

Containment and Engineering

In a paper on reactor containment and siting, V.V. Shirvaikar and A.K. Ganguly (India) pointed out that the possibility of contamination by air-borne radioactivity as well as by water sources which receive radioactive effluents from a nuclear plant made it usually necessary that a reactor be located at some distance from a thickly populated area. This difficulty, however, could be overcome to a large extent by providing for proper reactor containment. The authors concluded that:

(a) The safety criteria must finally depend on the amount of probable release and the local meteorological and hydrological factors which govern their dispersion; a general population/distance criterion cannot, therefore, always be set;

(b) Suitable containment, if economically feasible, can be provided in order to locate reactors in places of comparatively high population density, when a site is otherwise suitable; and

(c) Micro-meteorological data for sites under consideration are not generally available and have to be collected when the site is considered suitable from preliminary investigations; a margin in the containment requirements should, therefore, be provided so that specific requirements can be incorporated in the design when the data are available.

In a review of containment schemes for water cooled reactors, R. O'Neil and A.R. Edwards (UK) said that it was usually not possible to provide leak-proof containment for the air-borne fission products and means must be provided to minimize leakage as soon as possible. This could be done by immobilizing the fission products or by removing the driving pressure that produced the leakage or by both. Present knowledge favoured the conclusion that the removal of the pressure differential might be preferred in the initial stages of an accident. The use of a double shell containment provided a hold-up and delayed the release of significant quantities of radioactivity to the site, and this allowed time for emergency measures to be taken.

Methods of multiple containment were discussed in detail by W.K. Ergen (USA), who stated that United States criteria for power reactor sites were dominated by concern over atmospheric pollution by radioiodine in the event of the maximum credible accident (i.e. the worst kind of accident that can be reasonably conceived). In the Consolidated Edison Thorium Reactor the usual high-integrity containment vessel was surrounded by an additional concrete shell. The air space between the vessel and the outer shell could be kept at negative pressure by exhausting the air through filters, thus reducing the release of iodine and delaying the passage of radioactive rare gases. This multiple containment made it possible to use twice the reactor power that standard containment would permit at the same site. Similarly, the air space could be filled with porous concrete and the exhaust could be pumped into the inner containment vessel, thus eliminating - in principle - any release into the environment until radioactive decay and filtering allowed such release. Multiple containment could also be achieved by surrounding a pressure-suppression system by a further containment shell.

There was also some discussion on the influence of engineering problems on site selection. Two Indian scientists (V.N. Meckoni and R.P. Mehta) pointed out that apart from the basic consideration of power demand in a given region, a nuclear power station should be so located as to permit interconnection to an integrated grid system with a minimum of new transmission lines. Availability of adequate water for reactor cooling was another important consideration. Other requirements included good foundation conditions, low sub-soil water level, availability of construction power supply and proximity to sources of construction materials.

Some Criteria for Evaluation

In a paper on safety principles for low and medium powered research reactors, G. D. Bell and J.C. Chicken (UK) listed a set of criteria and stated that provided these criteria were satisfied there was no safety reason why reactors of up to 3 MW could not be built on suitable sites near urban districts. These criteria are:

(1) The design should be such that rapid additions of reactivity are virtually impossible;

(2) The reactor should withstand coolant accidents;

(3) It should be impossible to move central fuel elements until outer fuel elements have been removed, and fuel elements should be locked firmly in position;

(4) All fuel elements should be manufactured to fine dimensional limits. Bonding of the cladding to the fuel should be good and fissile material should be uniformly distributed throughout the fuel;

(5) The control system should have adequate diversity and redundancy to ensure that it can shut the reactor down under all conditions;

(6) The instrumentation must cover the whole range of reactor operation with adequate overlap;

(7) The building to house the reactor must be such that it provides adequate resistance to the escape of radioactivity, fire resistance and ease of decontamination.

In another paper, G. D. Bell and F. R. Charlesworth described the method of evaluating sites for power reactors in the United Kingdom. The considerations underlying the method are as follows:

By taking into account the likely composition of the fission product release and the maximum emergency exposures, it is possible to calculate the relative distances to which the various hazards may extend. Inhalation of radioiodine presents the greatest hazard for immediate control and contamination of milk is the most widespread hazard. It is not possible to determine an absolute scale of hazard for individuals living at different distances around a reactor site. What can be done is to rate sites on a relative scale, taking account of the composition of the possible release, the nature of the hazard and the general argument that people living close to the reactor may be affected by fission product releases of large or moderate size under a variety of weather conditions. At greater distances adverse consequences could only arise from large releases during unfavourable weather conditions. It is therefore reasonable to give greater weight in the assessment of hazards to populations living near reactor sites.

This can be done by deriving a weighting factor for population which varies with distance as the square of the air-borne concentration. The rating of a site is then determined by evaluating the sums of the population multiplied by the appropriate weighting factor. The population around the reactor site is considered in 30^{o} sectors divided into areas formed by drawing arcs at, say, one-mile intervals. The population in each division is then multiplied by the mean weighting factor for that division and the total summed for each 30^{o} sector. The highest total obtained for any 30^{o} sector is regarded as the site rating. (Special consideration must be given to the area immediately adjacent to the site and population residing within one mile of the site is therefore treated separately.)

Mr. Bell and Mr. Charlesworth, however, pointed out that rating by this method could not be the sole criterion in the safety evaluation of a site. A number of other factors, which could not be readily expressed in numerical terms, would influence the assessment, e.g. unusual features of population distribution, land utilization, local geography and meteorology.

Siting Experience

The experience gained in the selection of sites for nuclear research centres and power stations was reported by scientists from different countries at the last two general sessions of the symposium.

On research centres, papers were given by scientists from Japan, the Netherlands and the USA. Evaluation of the site at Tokai-mura for the research reactors in Japan and the criteria for radiation control established for the purpose were described by I. Miyanaga and T. Aoki (Japan). J. Pelser and M. Bustraan (Netherlands) gave an account of the studies that led to the selection of Petten as the site for the research centre of the Reactor Centrum Nederland. A paper on experience in site selection at the National Reactor Testing Station in the USA was given by three American scientists (J. R. Horan and others), and a description of the Los Alamos Scientific Laboratory - especially in the context of its isolated location - was given by N. E. Bradbury, also from the USA.

At the session on power stations, F. Faux and G. N. Stone (UK) gave an account of experience in planning and siting nuclear power stations for the Central Electricity Generating Board of the United Kingdom. They said that at present these stations were being sited in areas remote from the major coal fields, and all but one of them were on estuaries or the sea coast. The choice was further limited by engineering requirements and by the policy to select sites relatively remote from population.

Studies leading to the selection of Tarapur for locating India's first atomic power station were described by M. N. Chakravarti and M. R. Srinivasan (India), and some of the data bearing on the choice of site for the Chinon power station in France were summarized in a paper by two French scientists (G. Lamiral and A. Combe).

L. Carlbohm (Sweden) reported that while the general site selection criteria in Sweden were similar to those used in other countries they had had to be applied to certain special and somewhat unusual situations. These arose from the use of a reactor for district heating purposes and the use of underground reactor buildings.

View of International Bodies

Earlier, representatives of three international organizations had presented papers on certain aspects of the siting problem.

S. Halter (WHO) maintained that all tasks which aimed at the protection of public health should be placed under the supervision of "such existing organizations as are by their nature responsible for public health", and listed the tasks in the selection of nuclear centre sites with which health authorities should be concerned. He said: "WHO hopes that in those countries that undertake nuclear programmes health authorities are allowed to participate in such activities from the very beginning of the implementation of these programmes."

G. Wortley (FAO), in a paper on the impact on agriculture of the siting of atomic energy establishments, said that while in certain areas it was practicable to select a site that was not used for agricultural purposes, in many countries it was impossible to avoid the siting of atomic establishments near to agricultural land. It was therefore important to con-

sider what steps should be taken to protect agricultural interests against any adverse effects. Referring to the record of safety achieved so far, Mr. Wortley concluded that agriculture had little to fear and much to gain from the successful development of an atomic energy industry if the well-laid plans of the present continued to be followed.

In a paper on the waste management implications of nuclear site selection, J. F. Honstead and J. Beranek (IAEA) said that while in general site selection would ultimately be guided by criteria other than waste management, the decision could have considerable influence on the waste problem, including the cost of waste management operations. "The concern for keeping the cost of waste handling problems to a minimum", they said, "requires that one maintains an awareness of how site characteristics affect the budget." Each of the three main approaches to the waste problem - absolute containment, delay storage to permit radioactive decay and dispersion of low-level waste in the environment - was affected to some degree by site characteristics, and the appropriate waste management system must be based on a study of these characteristics.

At the final session Mr. Balligand, in a closing speech, said that the meeting had confirmed the impression that the security of nuclear sites from the point of view of public health was extremely well supervised all over the world. The symposium had provided an opportunity not only for the pooling of information on past experience and current practice but also for an exchange of ideas for the formulation of more widely applicable criteria than existed at present. After the proceedings had been carefully studied it would be possible for IAEA to formulate recommendations, which would be submitted to a small working group of experts and later published as an Agency document. Mr. Balligand emphasized, however, that before universal rules could be framed the main task was to collect the maximum possible information and study individual cases with the help of small groups of experts. The Agency, he pointed out, had already provided such expert groups to advise on specific problems at the request of Member States.

NUCLEAR ENERGY AGAINST INSECT PESTS

Twice within just over two and a half years, the International Atomic Energy Agency has convened scientific symposia on the use of nuclear energy to combat insect pests. The second of these - on the Use and Application of Radioisotopes and Radiation in the Control of Plant and Animal Insect Pests, held in Athens last April and jointly organized by IAEA and FAO with the co-operation of the Greek Government - confirmed even more clearly than the first meeting (Bombay, December 1960) that nuclear energy is a fully established tool in the struggle for the protection of human food resources.

In this struggle, nuclear energy in the form of radioisotopes is fulfilling a number of different, but altogether complementary, roles.

A prerequisite for any effective control, or possibly eradication, of harmful insects is knowledge of their ecology, of their breeding and feeding habits, their dispersal and migration, and of insect-plant relationships. Radioisotope techniques, in particular tagging, have provided an effective means for these studies.

Among striking illustrations of the usefulness of tagging given during the symposium in Athens were those described by C. Courtois and J. Lecomte

At the opening session of the Athens symposium: (left to right) Dr. C. Logothetis (FAO); Mr. D. Vourdoubas, Greek Minister of Agriculture; Prof. A.N. Rylov, IAEA Deputy Director General in charge of Training and Technical Information; Prof. G. Pantazis, Vice-President of the Greek Atomic Energy Commission; and Dr. M. Fried (IAEA)