prices. The second volume contains similar information on chemical compounds labelled with carbon 14, tritium, iodine 131, phosphorus 43 and sulphur 35.

Health, Safety and Safeguards

Widespread international concern over the possible dangers to health and safety inherent in the peaceful uses of atomic energy has led the Agency to take an increasingly active role in the efforts to minimize these dangers. For example, as indicated earlier, research contracts supported by the Agency have been largely concentrated in this field. In addition, the Agency continued its work in the drafting of regulations, the issue of guides and the evaluation of specific hazards. During the period under review the Agency drafted regulations on the safe transport of radioactive materials and circulated them to Member States for comment.

In October 1959, the Agency completed its first evaluation for a Member State of the safety of an individual reactor, this being the Swiss research reactor, DIORIT. Several further requests and enquiries for such evaluations were received. Work began during the report period on a manual on the safe operation of critical assemblies and research reactors.

The legal problems presented by radiation hazards also received attention. With the aid of a panel of expert advisers, the Agency drafted and submitted to Member States for comment a Draft Convention on Minimum International Standards regarding Civil Liability for Nuclear Damage. A related panel, dealing with liability for nuclear propelled ships, began its work in March.

On the subject of safeguards to prevent diversion of nuclear materials from peaceful to military uses, the report says:

"Some of the questions of an administrative and political character with which the Agency has to deal in this part of its work are as novel as nuclear technology itself and involve long-standing concepts of international relations and sovereignty. Progress is therefore inevitably slow and uncertain. Although divergencies of opinion persist, the Board has been able to give provisional approval to a set of principles and procedures for safeguards to be applied in connection with the Agency's own operations, and also to projects it assists and those to which it is invited by Member States to apply safeguards. The Board is submitting these principles and procedures to the General Conference for its consideration at its fourth regular session."

A Look Ahead

The Board of Governors' report has this comment about the direction of IAEA activities:

"The Board expects that the Agency's operations in the coming year will continue in the main along the lines now established, with some expansion particularly in the domain of technical assistance and scientific information and support. This expansion will however depend partly on the willingness of Member States voluntarily to make available greater resources for the Agency's programs of direct assistance."

SAFE OPERATION OF CRITICAL ASSEMBLIES AND RESEARCH REACTORS

Some 150 research reactors are at present operating in approximately 25 countries and many more are being constructed and planned for operation in the near future. In addition, there are many critical assemblies or zero power reactors in various parts of the world.

Some countries have accumulated considerable experience in the operation of these reactors and have in the process developed safe practices. On the other hand, other countries which have recently acquired, or will soon acquire, such reactors do not have sufficient background of experience with them to have developed full knowledge regarding their safe operation.

In this situation, the International Atomic Energy Agency has considered that it would be useful to make available to all its Member States a set of recommendations on the safe operation of these reactors, based on the accumulated experience and best practices.

The Director General accordingly nominated a Panel on Safe Operation of Critical Assemblies and Research Reactors to assist the Agency's Secretariat in drafting such recommendations. The group, which held its first meeting at IAEA's Vienna headquarters last February and a second meeting in July, was composed of the following experts:

D. W. Jefferson-Loveday, United Kingdom, Chairman
J. Aleksandrowicz, Poland
R. Mello Cabrita, Portugal (first meeting only)
Dr. R. P. de Figueiredo, Portugal (second meeting only)
S. G. Kaufmann, USA
N. Lakshmanachar, India (second meeting only)
N. B. Prasad, India (first meeting only)
E. O. Rexin, Argentina
S. Suguri, Japan
J. F. Tcherniline, USSR

Panel of experts on the safe operation of research reactors and critical assemblies, meeting at IAEA headquarters in Vienna

During the first meeting the Panel reviewed the general form and principal contents of a proposed manual prepared by the Secretariat, and made various suggestions regarding it.

These suggestions were incorporated in a second draft which was then resubmitted to the Panel at the second meeting. From these meetings came an agreed draft manual which, when finally approved, is expected to be published as a document in IAEA's Safety Series.

Scope of the Manual

The draft manual contains seven main sections. The first is an Introduction setting forth the purpose, scope and limitations of the manual, as well as certain definitions. The next section contains suggestions on the safety of design, instrumentation, construction and operation of critical assemblies. A similar section on research reactors follows, but with less emphasis on design and construction. The remaining four sections contain recommendations on personnel qualifications and training; the organization and functioning of safety committees; documentation required for safety; and procedures to be followed in emergencies.

There are also three appendices. Appendix 1 is a selected list of references. Appendix 2 contains typical examples of some of the administrative orders and instructions advocated in the manual. Appendix 3 is a suggested course of study associated with the section on personnel qualifications and training.

The introduction makes it clear that the manual is intended to be particularly useful "to those users who have no direct access to other collected sources of information", including administrative authorities as well as scientists and technicians. It is not, however, "a set of rules or a code of practice" so much as "a series of recommendations which must be interpreted with scientific judgment in their application to any particular problem".

The research reactors to which the draft manual applies are primarily "small and medium sized research reactors which are mainly used by physicists". High flux reactors used for large scale engineering experiments are not covered, nor are reactors of the type used in fast kinetic experiments.

The draft manual also deliberately excludes questions regarding the location and containment of reactors, stating that practices on these matters vary widely among States and that much work remains to be done before international recommendations can be produced.

Also outside the scope of the manual are the subjects of permissible levels of radiation exposure for personnel, and the details of radiological protection.

Critical Assemblies - Design

The draft manual lists certain essential dangers inherent in critical assemblies which are not found in research reactors. These are "the element of uncertainty of the critical parameters, the large excess reactivities which may be possible and the frequent direct access to fuel elements".

Accordingly, a first problem in the safe design of critical assemblies is to ensure that reactivity additions and the rates at which reactivity is added do not exceed safe limits. In these respects the draft manual suggests certain values which should not be exceeded.

The designer must also ensure that the assembly can be shut down under all circumstances. To accomplish this, the manual recommends that there be at least two systems of independently operated shut-down devices. It suggests also the amount of reactivity each group of devices should control and their maximum time of operation.

It is stated that the main items of equipment which govern the operation of a critical assembly should be designed on a "failure to safety" philosophy. This means, for example, that should any essential incoming supply of electricity, compressed air or water be interrupted at any time during the operation of the assembly, the interruption itself will automatically trigger a safe shut down of the assembly. The same result should follow failure of any equipment if such failure could result in dangerous conditions.

Without giving elaborate instructions, the draft manual makes it clear that the designer must consider a fairly large number of additional factors in order to achieve a safe design. Among the factors mentioned are control mechanisms, speed of withdrawal of safety rods, interlock systems, coefficients of reactivity, shielding, materials of construction, and ventilation.

In addition, the designer is asked to study the possible consequences of an accident and to consider, if it is not too costly, the incorporation of special features to restore or dispose of equipment following such an event.

The section on the design of critical assemblies concludes with this advice:

"At the conclusion of the design it must be critically reviewed to ensure that no hazards remain and also that no additional hazards have been created by a portion of the design itself".

Critical Assemblies - Instrumentation

Instrumentation is required in a critical assembly to supply information on the operating conditions inside the assembly. The basic means employed is a detector located in the core, from which information is transmitted to the control desk. On the basis of this information actions to control operating conditions can be taken either by the operator or automatically by control devices.

The manual recommends that two independent instrument channels should be used to convey certain vital measurements, and provision should be made, preferably by "fail-safe" design features, for shut down of the assembly if any part of the basic control instrumentation is not working properly. A list of situations which should activate such a shut-down is given.

A system of interlock circuitry connecting signals received through the control instrumentation to the central system is recommended as a means of ensuring that operating steps are taken in proper sequence. Such interlocks must ensure, for example, that no reactivity can be added to the assembly unless safety rods are withdrawn. Cut-outs of interlocks may be needed to permit the assembly to be operated under special conditions, but their number should be minimized and very strict procedures employed to prevent dangerous situations.

Suggestions are made regarding basic instruments needed for the purpose of radiological protection. These are applicable to both critical assemblies and research reactors.

Critical Assemblies - Operation

The draft manual lays great stress on proper staff organization and procedures. It states: "Experience to date has shown that most reactor accidents have been the result either of lack of written procedures or of failure to carry such procedures out". Accordingly, written procedures and instructions for each member of the operating team are strongly recommended. Staff members should know the instructions applicable not only to themselves but also to those superior and subordinate to them.

Further procedural recommendations include a log book in which all significant events are recorded, and prominently displayed "core certificates" to acquaint personnel with the state of the assembly at all times and the operations which may be performed with it in that state. These core certificates are described in some detail, along with procedures for their use.

A form of organization recommended is one in which responsibilities are very clearly divided. The functions of operators and experimenters should be separated, with operators having the final authority on matters of safety.

The manual urges that prior to initial start-up thorough testing of equipment be carried out. Further tests and checks are recommended before each day's operation. These should be performed according to detailed check lists.

For an approach to criticality or for assembly start-up the manual urges that a neutron source be always used unless there is sufficient spontaneous neutron generation.

Special caution is advised for the first approach to criticality with any new lattice. The different steps involved in this process are described and the number and identity of persons who should agree to basic decisions or be present during specified parts of the operation are given.

Routine maintenance should be performed on strict schedules and be recorded, along with any faults found or corrected, in a log book.

Research Reactors

The draft manual takes note of a danger inherent in research reactors, but not usually in critical assemblies, namely "accidental release of fission products during an excursion, since generally the integrated flux will be much greater".

The manual contains much less detail on the design of research reactors than on the design of critical assemblies. The reason given is as follows: "The design and construction of a research reactor is necessarily a complex procedure requiring a large and highly experienced design organization, together with well developed manufacturing facilities. The details of design and construction of research reactors are felt, therefore, to be beyond the scope of this manual." General principles to be followed in design are given, however.

The manual states that, since research reactors can achieve considerable size, it is important to take precautions against severe accidents which might affect the surrounding area. Such a possibility can be greatly reduced by ensuring that the reactivity available within the system is less than that required to cause an accident which might rupture the fuel cladding.

A further recommendation is that there should be a minimum of two safety systems either of which must be capable of shutting down the reactor under all circumstances.

External dangers, such as from fire, crashing aircraft and earthquakes, should not be overlooked in the design of research reactors, particularly the shielding.

The manual urges that provision be made for adequate cooling at all times, for the safe removal and storage of fuel elements, for the storage and subsequent disposal of any radioactive reactor wastes, and for shielding adequate to protect the surroundings.

Recommendations given on instrumentation for research reactors are in the main similar to those given for critical assemblies.

Operating procedures and organization recommended for research reactors in general follow those recommended for critical assemblies. An important difference is that, for research reactors, the manual urges the use of separate teams for operation and for experimental use. The need to prevent unsuitable material from being inserted into the reactor for irradiation and the potential hazards involved in refuelling and in start-up after refuelling are discussed.

The manual contains a brief section dealing with the design of experiments in research reactors and with the design and manufacture of equipment for such experiments. The recommendations in this section deal with problems similar to those considered in sections on the reactors themselves.

Personnel Qualifications and Training

Consistent with the draft manual's emphasis on the importance of human factors in achieving safe operation of reactors is a section devoted to the qualifications, experience and training desirable for reactor personnel.

The inculcation of discipline in the strict observance of instructions is emphasized as an object of the training period to ward off any complacency that may arise from the fact that accidents occur very rarely.

The manual recommends prior training in reactor technology and, if possible, in reactor operation for senior staff members. If facilities for such training do not exist in the country concerned, it should be arranged elsewhere either through an international organization or through agreements with other States. In the case of research reactors, a period of orientation by the supplier is desirable.

The manual recommends that minimum health, education and experience requirements be established for staff at various levels. A short course of on-site training is recommended for junior staff and the desirable content of such training is indicated. A more complete reactor training course is suggested as another possibility, and a syllabus for such a course, involving 95 hours of lectures, is presented in Appendix 3. Periodic emergency exercises and examinations on matters related to safety are suggested for all staff.

Safety Committees

A further manifestation of the draft manual's emphasis on administrative matters is the devotion of a major section to recommendations regarding establishment and operation of safety committees. The purpose is to make available to the director of the establishment the independent scrutiny and advice of a group of people skilled in the arts on which reactor safety depends.

While the function of the committees is stated to be advisory and not regulatory, it is emphasized that obtaining their advice at various stages in the process of building and utilizing a nuclear installation should be obligatory. The stages at which obtaining committee advice is recommended include conception, design, inactive testing, commissioning, utilization, at periodical intervals after commissioning, and any time when significant modifications are made.

Besides reviewing technical aspects of design, manufacture, and commissioning of installations, the committee may also be asked to examine operating procedures, training standards and staff organization and selection.

While it will not be obligatory to follow the advice given, it is expected that proposers will alter any plan which the committee disapproves. If they did not do so, the committee would withhold its clearance certificate which enables the proposers to proceed without further reference to the director of the establishment.

It is suggested that, even in the smallest establishment, there should be an establishment safety committee, appointed by the director of the establishment, and an operations review sub-committee appointed by the establishment safety committee for each research reactor or critical assembly within the establishment.

It is recommended that members devote only part of their time to committee work except that in a larger establishment a full-time secretary may be justified. It is also recommended that members should not be directly connected with the matters they review.

A minimum of four members, representing diverse skills, is recommended for both establishment safety committees and operating sub-committees. Circumstances may require larger committees with additional skills. The use of members from other establishments and, indeed, other countries, is recommended to provide diverse experience, and it is suggested that international organizations be called on for help if recruiting difficulties are encountered.

Under the manual's proposals, the essential operation of establishment safety committees is based on two documents. One is a safety report which proposers submit to the committee. The other is a clearance certificate which the committee issues stating that in their opinion the proposal is safe provided that it is operated in the manner laid down in the safety report. This certificate is included in a final copy of the safety report which incorporates the committee's suggestions and is distributed to all interested people. The clearance certificate is to be valid for a limited period - one year is suggested - after which time the safety report, brought fully up to date, must be re-submitted for a new appraisal.

Operations review sub-committees act in their narrower fields of interest in generally the same manner as establishment safety committees. Their meetings need to be more frequent, however, and in the case of small projects they can register their approval with less formality and documentation.

Safety Documents

The documents referred to in the section on safety committees are considered at length in the next part of

the draft manual. Circumstances requiring safety reports and the timing of their presentation are reviewed. Recommendations are made as to the topics which should be covered in the safety reports. These provide an exhaustive description of the project, including its physics, engineering and administrative aspects.

An example is also given of a critical assembly core certificate, referred to above as a device to acquaint all personnel with the current condition of the assembly.

Emergency Procedure

The concluding part of the draft manual deals with plans which should be made to cope with any accidents which may arise. Possible accidents are divided according to severity into three classes - local incidents, site emergencies, and public emergencies - each of which calls for a different type of planning.

Local incidents are considered to be those involving only a limited number of personnel, most likely being confined to one room or a small part of a building.

Site emergencies would involve some release of radiation to the surroundings of the reactor but not beyond the area under control by the establishment.

A public emergency would involve release or threat of release of undesirable amounts of radioactive materials outside the confines of the establishment.

In preparing for both local incidents and site emergencies it is essential to designate clearly in advance the persons who will be responsible and their precise tasks. The manual makes various suggestions along these lines. Means and lines of communications must also be clearly established.

A public emergency will involve participation and control by public authorities, but the site emergency staff must be prepared to deal with it in its initial stages. Radiation monitoring would become particularly crucial at such times and the manual specifies the equipment which should be provided for this function and suggests procedures which should be followed.

It also suggests arrangements which should be worked out in advance with public authorities.

Conclusion

The procedures proposed by the manual for achieving safety in critical assemblies and research reactors are thorough and leave very little to chance. Indeed, prospective reactor owners or operators may be somewhat surprised at how much should be done. It must be stressed, however, that similar procedures to those outlined have been evolved in many Member States as a result of experience, that they have been shown to function with little interference to the experimental programs, and that their use has contributed to the remarkably good safety record which critical assemblies and research reactors have achieved.

AN OUTLINE OF 1961 PROGRAM

The program of work for 1961 which the International Atomic Energy Agency's Board of Governors has presented to the Agency's General Conference for final approval provides for steady amplification of its work in technical assistance to specific projects, training of scientific personnel and scientific research. These activities and certain others are of special interest to those areas of the world that are less advanced in the utilization of atomic energy. This is in accord with the Agency's Statute which requires that it bear in mind "the special needs of the under-developed areas of the world". At the same time, the Board indicated that the 1961 program "provides for activities intended to create a basis for general progress in the safe utilization of atomic energy for peaceful purposes which is of concern to all Member States. Thus the delay in the advent of generally economic nuclear power is used to build up the necessary technological infrastructure in the less-developed countries and to establish an international framework of norms and regulations which an orderly and safe development of widespread nuclear industries will require."

Some highlights of the 1961 program are presented below.

Technical Assistance

The Agency has followed a policy of sending missions of experts to Member States which are in a relatively early stage in the development of atomic energy for peaceful purposes in order to make broad initial assessments of requirements and potentialities. It is expected that there will be two more such missions in 1961, one to survey the situation of newly independent countries in Africa and the other to visit countries in Latin America which are establishing atomic energy operations for the first time.

Except for these two areas, the need for preliminary missions appears largely to have been met, and emphasis in technical assistance work has begun to shift towards the support of specific projects in Member States. Accordingly, it is expected that in 1961 there will be more experts in the field for more man-months than in 1960.

Requests for scientific and technical supplies and equipment as an integral part of technical assistance projects have increased considerably during 1960 and are expected to increase further in 1961.

It is also anticipated "that the Agency will be increasingly concerned with the supply of fissionable