Marine Transport of Irradiated Nuclear Fuel, Plutonium, and High-Level Wastes

J.H. Mairs, R.R. Rawl
International Atomic Energy Agency

In November 1993, the 18th Assembly of the International Maritime Organization (IMO) adopted a *Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High Level Waste*. This Code was developed by the Joint International Maritime Organization/International Atomic Energy Agency/United Nations Environment Programme Working Group at two meetings held in 1992 and 1993. During these meetings, a broad range of issues were discussed, including several addressing the adequacy in the IAEA Regulations. One of the concerns expressed by some delegations from member states and non-governmental organizations was that accidents on board ships may be more severe than the IAEA regulatory tests account for. Furthermore, there was concern that package failure with subsequent release of radioactive material to the environment may occur.

All the information studied by the Joint Working Group showed very low levels of radiological risk and potential environmental consequences arising from the maritime transport of radioactive material. However, it was agreed that if sound evidence became available to show that a more severe accident environment exists for the sea mode than that encompassed by the IAEA package design requirements and associated regulatory tests, packaging requirements and tests should be strengthened accordingly. In it's ninth meeting, the Standing Advisory Group on the Safe Transport of Radioactive Material recommended that a Coordinated Research Programme (CRP) be established on this topic.

In August, 1994 the IAEA convened a meeting to establish the terms of reference for the CRP and define the scope of the research required for an assessment of the accident environment at sea. It was agreed the objectives were to be "*to assess the severity of accidents on radioactive material packages and their expected frequencies of occurrence for sea transport, specifically to:*

- *conduct and examine new studies on the fire environment on board ships,*
- *consider additional research on sea transport, and*
- *draw conclusions and make recommendations to the continuous regulatory review process, as necessary.*"

In considering the hazards to be evaluated, it was agreed to concentrate on fires but not to exclude studies on impacts, penetration, and immersion. The CRP will take account of the design of the ships used to transport radioactive material, the environment encountered by the package, and fire propagation on board the ship. In studying fires, the CRP will consider temperature, duration, and location. The meeting also established that the first Research Coordination Meeting (RCM) should meet in the autumn of 1995.

In this paper, there is a general introduction to Agency CRPs followed by a summary of the outcome of the first RCM, emphasizing the need for coordination of the ongoing research. The paper also offers some preliminary thoughts on the purpose and presentation of the final report.

IAEA Programmes of Coordinated Research

The aim of an IAEA CRP is to bring together researchers from several countries who are undertaking projects on an identified topic of interest to IAEA member states. Ideally, the number of participating projects should be around six to ten. Limiting the number of included projects ensures that there is sufficient scope and peer review while preventing the project from becoming too unwieldy.

The main purpose of an RCM is to provide an opportunity to exchange information, research results, and opinions. Where appropriate, comparisons of studies and results can be made, emphasis may be shifted, and unnecessary duplication can be identified and prevented at an early stage in the project. If a CRP works well, a synergy between researchers will achieve an overall result that is greater than the sum of the individual research contributions.

A CRP is typically initiated when a technical committee recommends a candidate research topic. The secretariat then submits a proposal to an internal committee for appraisal. If the committee is convinced of its merit, then the CRP is advertized in the IAEA Bulletin, a magazine that is published by the

Division of Public Information and widely distributed among member states. Research proposals are invited for submission through official channels. The secretariat may also send letters of invitation to individual institutes or governments, especially those with a known interest or expertise in the topic.

Incoming research proposals are evaluated by the secretariat, and when found favorable a research agreement is drafted for signature by the research institute or government. In the case of developing member states, a research contract may be prepared. Research contracts make provision for funds to be made available to undertake research in addition to funding the travel and expenses associated with attending RCMs. In addition to identifying participating member states and research institutes, the research agreements cite the names of the main researchers, including the name of the chief scientific investigator who becomes the focal point for interaction with the IAEA. It is the chief scientific investigator, or a designate, who is funded to attend any RCM and is the person with whom the IAEA corresponds.

CRPs are technical programs of research and are not policy forming nor are they used to prepare safety standards or safety guides. They may be used to present information to the IAEA which can be used in other fora to shape policy or draft standards or guides. With this connection in mind, sometimes an individual from a government department may choose to attend an RCM either as the named chief scientific investigator or as an observer to gain first-hand information on progress in the research.

Once the IAEA has received a few signed research agreements, perhaps within a year of the CRP being initiated, an RCM is convened. An RCM is particularly effective if it can be located at a site of technical interest and relevance, for example, where an experimental facility can be visited. Host institutes are sought as volunteers, and the IAEA enters into communication with the government of the member state to cement the agreement. A CRP usually includes three RCMs which normally take place at intervals of about 18 months. This means that a CRP is usually concluded in a period of about 3 years from the first RCM. The interval between RCMs is not fixed and should be dictated by progress being made in the research program to ensure that there is sufficient new material to discuss, while maintaining the momentum of the program.

The IAEA CRP on Accident Severity at Sea

This CRP was initiated in August 1994, and the first RCM was held in Vienna, Austria, in November 1995. At that time the IAEA had received five signed research agreements with institutes in France, Germany, Sweden, UK, and the United States. In addition, Japan provided an observer to the RCM. This RCM was useful in enabling contributors to comment on CRP studies that are envisaged, on-going or complete. It provided the opportunity to review the scope and terms of reference for the program, establish a timetable for further

effort, set priorities, and consider the structure and purpose of the final CRP report.

The following section summarizes the contributions being made by the participating institutes:

France

Commissariat a l'Energy Atomique/Institut de Protection et de Sûreté Nucléaire (CEA/IPSN) have analyzed historical data on accidents at sea and are ready to undertake assessments of the radiological consequences of a release into the marine environment using established computer codes.

Germany

Gesellschaft für Reaktorsicherheit (GRS) envisage a specific risk assessment for the transport of nuclear fuel from the UK and France to Germany. Part of this study would be relevant to the CRP, in particular, the option of sea transport from the UK to the continent of Europe. GRS are interested in analyses of the probability of accidents and the assessment of radiological consequences of airborne releases.

Sweden

AMC, a consulting firm, have offered to assist the IAEA in a co-ordinating role and in drafting the report of the CRP. A similar role has been assumed to good effect in previous CRPs.

United Kingdom

Both British Nuclear Fuels plc (BNFL) and Nuclear Transport Limited (NTL) are contributing studies to this CRP. These companies are able to offer useful information on the design of ships used to transport nuclear fuel and details of the package environment. Both companies have undertaken studies that demonstrate a high level of safety associated with their own operations. These reports, and the experience gained in conducting these studies, are available to the CRP.

United States

Sandia National Laboratories (SNL) with sponsorship from the Department of Energy are conducting a number of studies that are relevant to the CRP. These include an analysis of the historical data on ship fires and collisions, a computer simulation of a collision between two vessels and a series of fire experiments on board a test vessel.

Aspects of Study in the CRP

When the different studies are drawn together it becomes clear that there are common aspects, and the benefit of coordinating the research efforts becomes equally clear. In summary, there are four areas of research: a study of the probabilities of ship accidents, ship fires, ship collisions, and radiological consequences. The RCM agreed that the emphasis of further effort at this stage should be placed on studies relating to the probabilities of accidents at sea and concluding the series of fire experiments on board the test vessel. The importance of studying radiological consequences would be determined later on the basis of the results of the experimental results, analyses, and probability data.

Probability studies

Ideally, the CRP will provide probability data to be used as input to risk assessments. The studies made to-date using historical records show that the analysis of the available data is fraught with difficulties. Nevertheless, France, the United Kingdom and the United States have all made studies, and it was agreed that the CRP would benefit from an informal meeting dedicated to obtaining the best information from the available data. Topics to be discussed include definitions of events, units of measure; size, age, and type of vessel, and temporal and spacial analyses of the data. The CRP should report on the importance of factors that affect probabilities derived from historical records. Where possible the meeting should reach agreement on the factors to be studied and methods of analysis so that the CRP moves towards the goal of providing definitive information on the probability of occurrence of accidents at sea. The RCM welcomed the initial offer of GRS to host this special meeting in April 1996.

Participants at the RCM suggested that account be taken of improvements in vessel safety in recent years resulting from the development of more sophisticated navigation and collision prevention systems. It was necessary to review the data bearing in mind the age of the vessel and the date of the occurrence. When considering data on impact speeds, the type of hull was an important parameter; only war ships have both high speeds and mass, whereas reefer hulls, while attaining high speeds, are a feature of smaller vessels.

In considering fires on board ships, the RCM agreed that data from oil tankers and LPG tankers were not relevant to vessels used to carry radioactive cargo. The probability of fires involving these vessels with radioactive cargo would have to take into account the chance of a collision between such vessels, leading to vanishingly small probabilities. However, the RCM was unable to agree upon a probability that was so low as to be irrelevant to the study, although it was agreed there was merit in the concept.

In analyzing historical records of fires on ships, it was noted that sometimes the fire had been allowed to burn, in a controlled manner, because that was the best option for saving the ship or minimizing risk of life.

Fire studies

The series of experiments of fires on board a test vessel is ongoing and the United States reported the results of the first two tests to the RCM. The results of the experiments are being used in conjunction with computer codes used to analyze fires. The dissemination of information from the experiments is welcome, since the data will be available for use with other computer codes. It is recognized that the experiments are being conducted on a test vessel and the modifications needed to ensure adequate ventilation of the fire for safety reasons must be judged for their significance. A useful role of the CRP in reviewing the experiments conducted in the United States will be to comment on the relevance of the experiments to actual fires on board ships.

Impact studies

The main work in this area to simulate a collision between two vessels using a computer as reported to the RCM by the United States. While refinements to the model are possible, the results already support the findings of previous studies, which have shown that the stresses and strains borne by the package are less severe than when subjected to the IAEA tests for Type B packages. The report to be made to the CRP will detail some of the most sophisticated work undertaken in this field. Whether any future experiments are conducted as part of the CRP to provide further validation of the code remains a question of funding for the research.

Assessment of radiological consequences

The RCM participants were aware that established codes are available to study nominal releases of radioactivity in both the marine environment and the atmosphere. Participants were able to cite specific studies where such types of release had been studied. Furthermore, they recalled that even with large nominal releases the impacts on the environment and health were small or negligible. For the CRP report it was felt useful to review the literature on this subject. The second RCM will decide whether further effort to study radiological consequences is necessary. If further work is undertaken, the derivation of reasonable release fractions from packages will be one of the important aspects of the study.

The Product of the CRP

The product of the CRP will be a technical report that contains the details of the research undertaken in a series of annexes. It is envisioned that there will be a summary report covering the annexes. This summary should be capable of

standing alone and contain a much reduced technical content. It would also be a document that is acceptable to each of the Chief Scientific Investigators. The document is expected to be an authoritative international study of accident severities at sea aimed at an interested lay audience. The information should be presented in a way that supports an evaluation of the adequacy of the design and performance requirements of the IAEA Regulations.

Use of the CRP Report

The CRP report will be considered in the IAEA continuous regulatory review process. This is a series of technical meetings that considers the adequacy of the IAEA Regulations for all types of radioactive material and all modes of transport. One of the aims of the review process is to keep to a minimum the modal differences in the Regulations and provisions that are specific to certain types of radioactive material. In the historical development of the Regulations it has been necessary to introduce a limited number of these types of provisions. To date, the most significant modal differences lie with the air mode. In the revision leading to the 1996 edition of the Regulations it was acknowledged that accidents in the air mode could be more severe than accounted for by the Type B tests. This led to the introduction of Type C packages. In making this judgment and determining the performance standards for Type C packages, probability data from aircraft accidents was analyzed. It was determined that the performance standards for Type C packages should be chosen such that the package would be expected to survive most accidents. The IAEA strives to be consistent in its approach between the modes, and the CRP will consider presenting its results in a way that would allow a parallel to be drawn with other modes. The outcome might be that the current Regulations are shown to cover an adequate percentage of accidents at sea.

At the 19th meeting of the IMO Assembly, a resolution was adopted that stressed the importance of making progress toward resolving several identified issues. Among these issues is concern about the adequacy of the IAEA performance requirements applicable to materials subject to the "Irradiated Nuclear Fuel Code," namely, Type B packaging requirements. The information produced by the CRP will be instrumental in addressing this concern using reliable technical data and analyses. The use of the CRP results to address issues raised by the modal organizations is a good example of how this element of the IAEA technical program can be brought to bear on current issues.