IAEA MODE-RELATED RESEARCH IN THE SAFE TRANSPORT OF RADIOACTIVE MATERIAL

L. G. Blalock and R. R. Rawl

International Atomic Energy Agency, Transport Safety Unit, Division of Radiation and Waste Safety, P.O. Box 100, A-1400 Vienna, Austria

SUMMARY

The International Atomic Energy Agency sponsors Co-ordinated Research Programmes (CRP) in the safe transport of radioactive material. The CRPs are intended to encourage research by Member States in identified areas and to facilitate co-ordination of exchange of information and resources to reach a common understanding of the problem and alternative solutions. Two of these programmes are: *Accident Severity at Sea During the Transport of Radioactive Material* and *Accident Severity During the Air Transport of Radioactive Material*. This paper will discuss these two programmes and their relationship to the continuing regulatory revision process and interfaces with the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO).

Some Member States and non-governmental organizations in IMO meetings expressed concerns that accidents on board ships may be more severe than the IAEA regulatory tests account for, and that package failure with subsequent release of radioactive material may occur. The CRP on accident severity at sea was established to develop further quantitative information on potential accident severities during the transport of radioactive material by ships. The primary objective of this programme is to collect and evaluate statistical data of marine accidents, perform analyses of potential accident conditions and evaluate the risks resulting from such shipments.

The CRP on air transport was established to make a major international effort to collect relevant frequency and severity data and to analyze it so the accident forces to which a packages of radioactive material might be subjected to in a severe air accident can be more confidently quantified. Several countries have ongoing data collection activities related to aircraft accidents and severity and other sources of statistics for in-flight aircraft accidents will be explored. The International Civil Aviation Organization informed the IAEA of their plans to improve and update the data base for impact velocities resulting from aircraft accidents.

IAEA COORDINATED RESEARCH PROGRAMME ON ACCIDENT SEVERITY AT SEA DURING TRANSPORT OF RADIOACTIVE MATERIAL

Several events occurred in the early 1990s that spotlighted the transport of radioactive material by sea:

- the publication of a report in 1990, commissioned by Greenpeace, which questioned the adequacy of the IAEA Regulations for the Safe Transport of Radioactive Material, the *Regulations* [1],

- the return of about 1.7 tons of plutonium dioxide from France to Japan by sea-going vessel at the end of 1992,

- the US Department of Energy announcement, in 1993, of plans to review the issue of importing foreign research reactor spent nuclear fuel,

- the adoption, in November 1993, by the Assembly of the International Maritime Organization (IMO) of a *Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium, and High-Level Radioactive Wastes in Flasks on Board Ships* which was developed by the Joint International Maritime Organization/International Atomic Energy Agency/United National Environment Programme Working Group (Joint Working Group).

During the Joint Working Group 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 arriving 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 performance tests, packaging requirements and tests should be reviewed accordingly.

The Co-Ordinated Research Programme Participants

In 1994 the IAEA established the CRP and defined 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 concerns that had been expressed and the hazards to be evaluated, it was agreed to concentrate on fires but not to exclude studies on impacts, penetration, and immersion. The CRP was to 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, including temperature, duration, and location.

Research Coordination Meetings (RCMs) were held in 1995 and 1997. The IAEA established research agreements with institutes in France, Germany, Japan, Sweden, United Kingdom, United States and the IMO. The RCMs enabled contributors to:

- review the scope and terms of reference for the programme,
- review and comment on participant studies
- establish a timetable for further effort
- mutually set priorities, and
- consider the structure and purpose of the final CRP report.

Contributions by the participating institutes include:

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 undertaking assessments of the radiological consequences of a release into the marine environment using established computer codes.

Germany

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

Japan - Central Research Institute of Electric Power Industry (CRIEPI)

The CRIEPI effort focuses on calculations and comparisons made for environmental risk assessments for hypothetical submergence of three kinds of radioactive materials packages (high level waste, spent fuel and PuO_2) during sea transport.

Japan - Power Reactor and Nuclear Fuel Development Corporation (PNC)

The PNC investigated typical accident data concerning ocean going cargo vessels to estimate accident environments that packages on board a purpose built ship might encounter during accidents. The objective is to determine the environments and probability of severe accidents during ocean transport of radioactive material.

International Maritime Organization (IMO)

The IMO contribution to the CRP consists of:

- information of the status of the augmentation of the INF Code and the activities within IMO and other organizations concerned, e.g., UNEP;
- implementation of the IAEA Transport Regulations in the sea mode, namely through amendments to, and revision of, the International Maritime Dangerous Goods Code and the INF Code, as appropriate,

- information on casualty statistics being collected by IMO in a casualty data base, and
- other information , e.g., documents submitted to IMO with relevance to this CRP.

Sweden

The Swedish Government is providing the services of AMC, a consulting firm, to assist the IAEA in a co-ordination role and in drafting the reports of the CRP.

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. These reports, and the experience gained in conducting these studies, are available to the CRP.

United States

The Department of Energy, through its Sandia National Laboratories (SNL), is conducting a number of studies relevant to the CRP. These include an analysis of the historical data on ship fires and collisions, frequencies of maritime accidents world-wide, a computer simulation of a collision between two vessels and a series of fire experiments on board a test vessel to better understand heat transfer mechanisms in the holds of ships.

Aspects of Study in the CRP

When the different studies are drawn together there are certain common aspects that illustrate the benefits of coordinating the research efforts. There are four main areas of research: severity and probability of ship accidents, ship fires, ship collisions, and radiological consequences. The participants 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 and severity 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 difficult. Nevertheless, it was agreed that the CRP would benefit from obtaining the best possible information from the available data. Specific information includes definitions of events, units of measure, size, age, and type of vessel, and temporal and spacial analyses of the data. The CRP participants reached agreement on the factors to be studied and methods of analysis, thus moving the CRP towards providing definitive information on the probability and severity of occurrence of accidents at sea.

Participants of the CRP 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. It is important that the analysis of the data not be distorted by the inclusion of irrelevant types of vessel, such as small fishing vessels; however, to increase the number of eligible records in the study, the limit of 100 gross tones was used to provide a reasonable cutoff.

In considering fires on board ships, the CRP participants 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.

Port call data was studied to establish the relationship between distances sailed and accident probabilities. Initial findings suggest that the outbreak of fires on general cargo ships is proportional to time rather than location. On the other hand, collisions are a function of ship congestion which is related to its location.

The historical records can be analyzed to provide a reasonable estimate of the probability of an initiating event such as a ship collision or fire. However, the data provides very limited information on the severity of the event in terms of whether the integrity of a package might be challenged. The severity of a fire is proportional to the heat input to the package which is a function of fire location, temperature, and duration. It was agreed that nuisance fires occurring in accommodation areas and small galley fires should be filtered-out from the study. If a fire is co-located with a package, three factors are influential:

- the amount of combustible material in the cargo hold
- the ventilation rate (air ingress to the hold)
- the efficacy of fire fighting provisions.

In considering these factors the CRP participants noted that fighting fires aboard ships in ports is more effective than at sea due to the proximity of shore based emergency services and the efficacy of simple measures such as pouring water into an open hold. At sea, although the fire fighting capability will be reduced, the ventilation rate of a hold will be low when the hull is intact because the hatches will be closed.

Experimental Fire Studies

A series of experiments of fires on board a test vessel were conducted by the US Department of Energy with cooperation from the US Coast Guard. The results of the tests were reported and are being used in conjunction with computer codes to analyze the heat transfer mechanisms of fires in ship holds. 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 will be to comment on the relevance of the experiments to actual fires on board ships. Preliminary results of these experiments indicate that the severity of ship hold fires are enveloped by the IAEA Transport Regulations design criteria.

Impact Studies

In considering impacts, the event of interest is a ship carrying the radioactive material being struck by another vessel. In groundings, the package will be protected by the hull while the

prow of the vessel will provide protection in the event of the carrying ship striking an object. Low speed collisions, such as those occurring in ports, do not cause the hull to be penetrated. Only penetrating collisions that are co-located with the package are considered to be potentially threatening to the package integrity.

The main work in this area is computer simulation of a collision between two vessels. Analysis conducted by the US simulated ship masses, construction, speed and package placement conditions that were conservative for a radioactive material shipment. While refinements to the model are possible, the preliminary results presented to the first RCM 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(U) and Type B(M) packages.

Assessment of Radiological Consequences

The CRP participants are aware that established codes to study nominal releases of radioactivity in both the marine environment and the atmosphere. Participants were able to cite specific reports where such types of release had been studied. Furthermore, they recalled that even with upper value nominal releases the impacts on the environment and health were small or negligible.

IAEA Advisory Group Meeting

In November 1996, the IAEA hosted an Advisory Group Meeting (AGM) on Modal Issues to provide Member States and international organizations with a forum to identify any issues they foresee as causing difficulties in implementing the provisions of the *Regulations* for one or more modes of transport. The Sea Mode Working Group reviewed and considered a letter from the IMO to the IAEA dated 26 July 1996 which provided *Extracts From the Report of the Maritime Safety Committee (MSC66/24)* [2]. The letter advised the IAEA of activities undertaken by the IMO and requested that the IAEA consider:

- specific hazards associated with maritime transport of flasks and consequences of severe accident scenarios,
- adequacy of existing liability regimes covering accidents with INF materials, and
- adequacy of flask design and tests.

Additionally, the Working Group considered the following issues which are being discussed at IMO:

- route planning/notification to coastal States and availability of information on the type of cargo being carried, including its hazards and
- adequacy of existing emergency response arrangements.

The AGM considered these points with the following conclusions:

- the issue of hazards and consequences was viewed as being appropriately covered by the ongoing CRP,
- flask designs and tests are still considered adequate in the event of sea transport related accidents and the studies to date indicate very low consequences even in postulated cases of package failure.

The AGM recommended that the IAEA may need to take steps to ensure the CRP, or alternative efforts adequately address all important issues (e.g., duration and severity of fire accidents based on credible accident events).

Interim Conclusions of CRP Participant Studies

The interim conclusions presented by CRP participants are:

- the probability of a robust radioactive material package being damaged due to crush force experienced during a ship-to-ship collision is small and the strength and flexibility of the ship structure limits the magnitude of the crush forces,
- the probability of a fire starting somewhere on a ship and spreading to a hold containing a radioactive material package is very small; a fire starting in a hold containing a radioactive material package is unlikely,
- collisions depend on traffic density, fires do not, and
- most material released to a cask interior will deposit on interior cask surfaces; so cask retention fractions are large and cask-to-environment release fractions are small;

consequently, calculated risks from maritime of radioactive material remain small.

IAEA Future Activities in this CRP and Application for Final Report

The CRP will be completed in 1998. The final product of the CRP is expected to be a technical report that contains a summary of results with the details of the research undertaken presented in a series of annexes. The CRP will be considered in the IAEA continuous regulatory review process which 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. The report, will be used in addressing concerns about the adequacy of the IAEA package performance requirements. The use of the CRP results to address issues raised through the modal organizations is a good example of how this element of the IAEA technical programme can be brought to bear on current issues.

IAEA CO-ORDINATED RESEARCH PROGRAMME ON ACCIDENT SEVERITY DURING AIR TRANSPORT OF RADIOACTIVE MATERIAL

Air transport of radioactive material has attracted considerable attention in recent years. The 1996 Edition of the Agency's *Regulations for the Safe Transport of Radioactive Material* introduced limitations on the quantity of radioactive material that may be transported by air in Type B(U) and Type B(M) packages, provisions for low dispersible material and Type C package requirements. These provisions will undoubtedly work to continue the excellent safety record of radioactive material transported by air. However, during the development of the 1996 Edition it was recognized that additional data collection and accident analyses could be helpful in the continued development of the regulations.

The Transport Safety Standards Advisory Committee [3] has recommended the establishment of a Coordinated Research Programme (CRP) dealing with issues arising from the air-mode. The Advisory Group Meeting on Modal Issues in the Safe Transport of Radioactive Material [4] recommended the CRP consider research on aircraft accident frequency and severities.

The Transport Safety Standards Advisory Committee [5] recommended that ICAO be invited to participate in this effort, particularly with regard to making available additional information

on accident severities and frequencies and that the CRP be initiated as soon as possible. The ICAO has confirmed their intent to participate in this CRP.

The Agency is initiating a CRP entitled "Accident Severity During Air Transport of Radioactive Material". The overall objective of the CRP is to further study the issues related to air accident forces. Data on aircraft accidents are available from several sources; however, much of that data is collected for purposes other than the study of accident scenarios and severities, which means the data to be analyzed and evaluated carefully to provide sufficiently reliable information on which to make transport safety decisions. This CRP should make a major international effort to collect additional relevant data and to analyze it so the accident forces to which a package of radioactive material might be subjected can be further quantified.

We anticipate the information to be collected and analyzed is to include frequency and severity information related to:

- Impact - aircraft velocity; orientation of aircraft on impact; angle of impact target hardness; rotation of aircraft on impact; etc.,
- Fire - duration; temperature; effect of impact velocity on fire characteristics; etc.,
- Crush forces from aircraft structure and other cargo; and
- Other relevant environmental forces which may be imparted to packages.

Probabilities of accident should be determined on a per-flight or per-kilometer basis.

The outcomes/products of this CRP will be used in the regulatory development process to evaluate the level of protection provided in the event of severe aircraft accidents.

In order to accomplish this, we hope to conclude a number of "Research Agreements" with selected institutes under which each institute would agree to transmit to the Agency two copies of a complete technical report containing publishable information, including a full description of the research carried out, the results obtained, and the full conclusion reached, also make a presentation at each research co-ordination meeting held under the CRP. The report may be in the form of a pre-print, re-print, or of a report prepared for other purposes. In return for this, each institute would participate in all exchanges of information between the participants in the programme.

REFERENCES

[1] IAEA, Safe Transport No. 1, Regulations for the Safe Transport of Radioactive Material, 1996.

[2] IMO letter, dated 26 July 1996, and enclosure, Extracts from the Report of the Maritime Safety Committee (MSC66/24).

[3] Transport Safety Standards Advisory Committee Meeting, 26 February - 1 March 1996, Vienna, Austria, TRANSSAC I.

[4] Advisory Group Meeting on Modal Issues in the Safe Transport of Radioactive Material, 4-8 November 1996, Vienna, Austria, AG-940.

[5] Transport Safety Standards Advisory Committee Meeting, 2-6 June 1997, Vienna, Austria, TRANSSAC II.