IAEA Regulatory Initiatives for the Air Transport of Large Quantities of Radioactive Materials*

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Introduction

The International Atomic Energy Agency (IAEA) has been laboring since 1988 over a far reaching change to its model regulations (IAEA, 1990) for the transport of radioactive materials (RAM). This change could impact the manner in which certain classes of radioactive materials are shipped by air and change some of the basic tenets of radioactive material transport regulations around the world.

The impetus for this effort was spawned in part by the decision of the Japanese government to move large quantities of reprocessed plutonium by air from France to Japan. The exploration of options for overflights of United States and Canadian airspace (among others) and landings in Anchorage, Alaska, generated intense debate in the USA and countries that might have been overflown. The debate centered on general questions of the need to air transport plutonium in large quantities, package survival in an accident, prenotification, emergency response, routing, safeguards and other facets of the proposed operations.

In the USA, which already had the most stringent regulations for packaging of plutonium shipped by air (NUREG-0360), there was immediate additional legislative action to increase the stringency by requiring demonstration that an aircraft carrying plutonium in certified packagings could undergo a severe crash without release of plutonium (the Murkowski amendment). In the United Kingdom there was an official inquiry that resulted in a high visibility report (ACTRAM, 88) and a conclusion that the IAEA should examine regulatory needs in the general area of air transport.

The Japanese program to return plutonium was a triggering event leading to the current IAEA initiative, but, in fact, there had been discussion at many earlier meetings of IAEA's Standing Advisory Group for Safe Transport of Radioactive Materials (SAGSTRAM) concerning the need for specific package qualification standards for the air mode. These discussions stemmed both from unilateral action in the US in the mid-seventies driven by a Congressional requirement and from the realization that the air mode does have the potential to impose more severe accident environments than the truck, rail and water modes for which the IAEA package performance requirements are demonstrably adequate. The main arguments to retain the existing regulatory structure were:

1. the fact that, on a risk per trip basis, air transport was about equivalent to surface modes;

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2. there were relatively few shipments of large quantities of RAM by air; and
3. there was a desire to maintain a relatively simple regulatory structure that was independent transport mode.

Regulatory Process

The ongoing effort to modify the air transport aspects of the IAEA regulations that started in 1988 is scheduled in such a way that if regulation formation is successful, the 1995 edition of the IAEA's "Regulations for the Safe Transport of Radioactive Materials" (also known as Safety Series 6 or SS6) (IAEA, 1990) will include specific provisions for air transport of large quantities of radioactive material. Figure 1 shows the progress and potential result of the regulatory effort.

The December 1991 Technical Committee Meeting (TCM) generated a technical report (IAEA, 92) that contains an account of the work done at the meeting as well as a complete account of the proposed changes to the regulations and their justification as derived from discussions that date to the first SAGSTRAM meeting on the subject.

Regulatory Changes Proposed

The proposed changes to the regulations (see Figure 2) fall into four main categories: Exemption Limits Package Test Standards, Design Requirements, Post-Test Acceptance Standards, and Regulatory Accommodations. All of the first three items engendered significant technical discussion in the process of coming to a decision on the specific features to be sent forward to the Revision panels. Technical data and analyses were provided and argued by a number of member states for the consideration of the TCM's, SAGSTRAM and Consultant Services Meetings. Some continued discussion of technical points is expected to occur in the Revision Panel Working Groups that are charged with the process of integrating realistic changes into the 1995 edition of SS 6

The most visible change to the regulations is in the creation of a new packaging type, termed the Type C package. This is the designator for the package that meets the performance criteria for air shipment of large quantity or high activity RAM. The Type C package must first be shown to meet the requirements of a Type B (u) package including the sequential impact/crush, puncture, fire and immersion tests. Then there are additional design and performance requirements described below that must be met.

Exemption Limits The types and quantities of RAM affected by the change are normal and special forms and fissile materials.

Normal Form - The exemption limit was set at 3000A2, that is, shipments of RAM in quantities less than 3000A2 and more than 1 A2 continue to be allowed to be shipped in a Type B package in the air mode. The decision to set the limit at 3000 A2 was based on two arguments. The first was that it was a level at which shipment notification to competent authorities was required in IAEA rules. In addition, it is a significant level in the US regulations in that it is the lower limit for a Highway Route Controlled Quantity which requires specific routes to be used. Thus there was some recognition that 3000A2 represents a boundary between ordinary shipment operations and large quantities. The second argument was based on some US data (IAEA, 92) that suggested that the release fraction for some Type B packages tested to destruction at typical aircraft crash speeds was in the range of 0.3% to 3%. With 3000A2 in a package this would indicate a release of perhaps 10-100A2 which most participants agreed was a reasonable threshold between serious consequence and high consequence events.

Special Form - Invoking the parallelism between special form and normal forms derived from the Q-system (IAEA, 90a), the exemption level for Special Forms was set at 3000A1, but, because some special form materials contain nuclides with very small A2's , it was decided to limit the total activity content of a Special Form to less than 100,000A2. This value was set under the assumption that the special form encapsulation would limit the release of RAM to the inside of the package to less than 3% as was assumed to be provided by a Type B; so the resultant equivalent normal form content of the package would be 3000A2.

Fissile Materials - Fissile materials presented a particular problem because many fissile materials have large A2 values and as a result shipments would not be affected by the exemption limits indicated above. However, the possibility of a criticality event might be enhanced if ordinary fissile packagings were subjected to an aircraft accident where more massive damage than is ordinarily accounted for in fissile package certification occurred. A special Consultant Services Meeting (Collin, 88) considered the issue. They recommended that existing exemption limits in the regulations also hold for air shipments, but that fissile packages for use in air transport be evaluated in their damaged state as though they had been subjected to the performance tests for a Type C package and that features that would ordinarily be expected to prevent water in-leakage be assumed not to function.

Package Test Standards - It was recognized in defining these standards that there were existing packaging performance standards in place in the US regulations for one specific element, plutonium. It was also recognized that a more general regulatory framework based on the Q-system, was required for fitting all elements and isotopes into a coherent radiological protection scheme. It was also recognized that performance tests must be set to protect against most, not all, possible accident environments. The definition of "most" is that level at which increased capability of the package to resist accident forces would result in little or no increase in the probability of the package remaining competent to retain its contents during an accident. Much effort was expended to determine where the "knee of the curve" is that defines the point of diminishing returns for the impact and fire test requirements. Figure 3 illustrates this point.

Impact - After extensive and largely independent work by several nations, it was clear that the knee of the curve for impact speed was at or about 85m/s. A package built to withstand impacts at higher speeds was likely to be heavier and bulkier and more costly, but provides little additional decrease in risk to the public. As a result the recommended test is specified in the same manner as the existing Type B test, except at a speed of 85m/s into an unyielding target.

Fire - Fire data is notoriously poor with regard to duration and intensity of direct fire exposure over an area which might contain a package (Clarke, 76). The data seemed to suggest that 1 hr duration was about at the knee of the curve (See Fig. 4). In low speed crashes and ground accidents impact damage will not be great, but the fuel is concentrated around the aircraft and can produce a long and intense fire. This situation is the target of the 1 hour fire test for Type C packages. The specification for intensity of fire currently contained in SS6 was adopted for the test because it is judged to be a severe environment that is unlikely to be surpassed in a actual fire event. This is the same intensity and duration required in the US tests.

Puncture - Because it seemed likely that a package in a real accident would encounter a potential puncture probe during an accident's early phases and before any fire had broken out, it was judged necessary to inflict a puncture environment on the package prior to fire exposure. Since the Type B test regime puncture probe seemed untypical of the air mode, the NUREG-0360 (NRC, 1978) puncture test was evaluated and adopted. A 250 kg conical penetrator with 2.5 cm diameter frustum is dropped from a height of 3 metres onto a package with mass less than 250 kg. For package mass greater than 250 kg the package is dropped from 3m onto the probe.

Crush - Dynamic crush is an environment that is likely to occur in aircraft accidents. The intensity of the crush environment was subject to discussion that involved considerations of potential mass and stiffness of other cargo and impact angles that control the severity of crush. Since it was impossible to define the crush environment in a meaningful test but possible to control it with stowage requirements, and since it was clear that the structural capability built into a package to meet the impact test was considerable, it was decided that the existing crush test in the Type B test sequence was appropriate for all Type C packagings (not just those with density less than 1000 Kg/m3 and mass less than 500 Kg).

Immersion - Since the air mode is frequently used for intercontinental movements of RAM, it was judged necessary to impose a 200m immersion requirement that reflected the possibility of accidents that resulted in packages submerged in the ocean. To facilitate recovery and to safeguard coastal populations from exposure to released radionuclides, a 200 metre submersion test would be imposed. Using 200 m essentially covers the continental shelf areas where recovery is fairly certain and where there is little opportunity for dilution to minimize impacts on food products from the sea. This requirement parallels current requirements in SS 6 for spent fuel casks.

Sequence of Tests - In the Type B package performance demonstrations the tests are sequential in their application to the same package. The concept behind the sequence of tests is to compound damage as it might occur in actual accident events which could include mechanical insults followed by fire. For Type C testing, only the puncture and fire tests are sequential on the same package. The concept behind this apparent lack of parallelism with the Type B tests results from the fact that high speed aircraft crashes disperse fuel widely such that the fire environment that follows the crash is not extreme. As a result there was no need to concatenate the 85m/s impact and 1 hr fire.

Design Requirements - There was discussion of the need to include specific tests for exposure to fireball environment, burial in near-adiabatic conditions and terminal velocity impacts. It was finally determined that these conditions needed to be brought to the attention of packaging designers in an explicit manner to assure that weaknesses for these mode particular environments don't creep into a design. No tests were proposed in these areas.

Post-Test Acceptance Standards - Considerable discussion of this topic occurred during the Technical Committee Meetings and SAGSTRAM. Two basic positions were taken. The first was that there were existing post-test performance requirements for leakage and radiation levels for Type B packagings that ought to be carried over directly to the new Type C package qualification testing. Consistency and the comfort of not having to justify different values were primary considerations. The second position supported more lenient requirements than the A2/week leakage and 1 rem/hr at 1 metre radiation level post-test currently used for Type B. The basis for the relaxation of requirements was based on two arguments; 1. that the test environments were so much more severe than Type B that using the same requirements would make the packages very expensive or perhaps impossible to build; and, 2. that ICRP guidelines for allowed dose during accident recovery procedures were such that much higher releases and dose rates were justifiable. The result of the Technical Committee activities was to adopt the existing criteria and to note that the position concerning ICRP allowances was a generic problem and could be taken up as part of the overall revision process and apply to all packagings alike.

Regulatory Accommodations - Many modifications in the regulations will need to be evaluated and accommodated in order to bring these changes for the air mode about. Aside from the purely mechanical steps of changing paragraph sequences etc., there are significant issues in marking and labeling packagings to assure that appropriate air packages are identifiable from those not air mode qualified.

Other Issues

Affects on Other Modes - There was significant concern about the effect of these changes on the perception that performance tests for other modes are inadequate. While this is always a danger, the same analysis methods that allowed the lengthy IAEA regulatory process to converge to these proposals fully support the current Type B performance test regime. In fact, the 10 m drop and 30 minute fire are quite representative of the knee of the curve for these same environments in the surface modes (truck, rail, ship/barge). As a result, there should be little impact on other modes from these decisions.

Additional Data Needs- It became clear in the deliberations that there are problems associated with data needed to support these kinds of regulatory decisions. Of particular importance here were data for fire and crush environments. Fire data is rather poorly reported and is confused regarding total duration and duration of involvement of aircraft structure or cargo. Improved standard forms for reporting and training of responders in observing and reporting of accident events will provide a much more useful and reliable database. From the standpoint of crush environments, data needs relate to surveys of cargo and interactions of packagings and aircraft structure as a function of impact angle and speed. There is a need for data on mass and stiffness of cargo in typical cargo flights and those that might contain large quantity RAM shipments. Many such shipments occur in Exclusive Use where loading and other cargo are controlled, but surveys could provide useful information for the design of a relevant crush test. Some additional detail on aircraft crash phenomenology may indicate the relative importance of impact and crush environments and allow some fine tuning and, perhaps, liberalization of these requirements.

Implementation - When there is a change in regulations affecting packagings, there is usually a period of 2 to 5 years in which use of old designs are "grandfathered." Because this change puts an entirely new type of packaging in the regulations, the TCM's have taken the position that the only time needed is that to design and build a package. It was believed that, given the duration of the studies reported here, the short time before requiring use of the Type C package should be (1 or 2 years).

Conclusion

Few technical issues remain in determining the shape of the IAEA's revision of its regulations to accommodate air transport of large quantities of radioactive material. In the next two years the detailed wording of the regulations will be fully worked out and proposed for inclusion in SS 6. Considering the breadth of the member state participation in the process, it seems likely that the approved version of the 1995 revision of SS 6 will contain air mode revisions that move away from the predominantly mode independent character that characterized their first 30 years.

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Figure 1: IAEA Air Transport Regulation Development Process

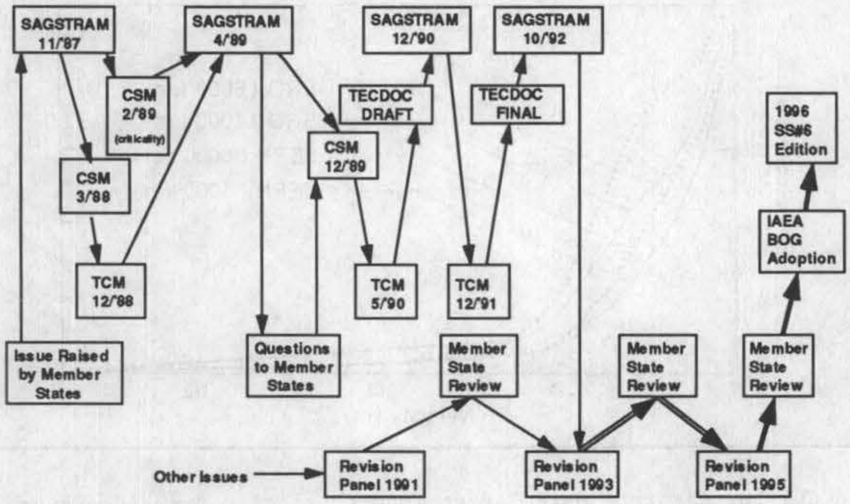

Figure 2: Issues Considered in New Air Transport Regulations

- Nuclide / Isotope Application
- Exemption Levels
  Normal Form
  Special Form
- Candidate Performance Requirements
- Test Pass Criteria
- Non-Dispersible Forms
- Fissile Materials
- Operational Features
- Applicability of Risk Assessment
- Bleed Over into Other Mode Requirements
- Phase in Period

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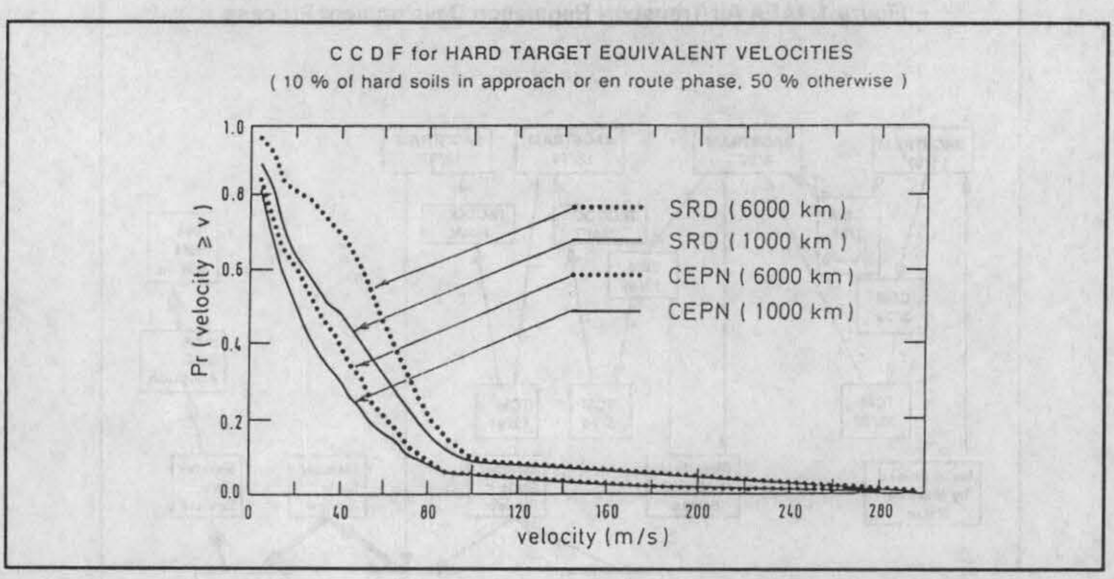

Figure 3: CCDF for Aircraft Hard Target Impact Velocity from (Degrange, 89)

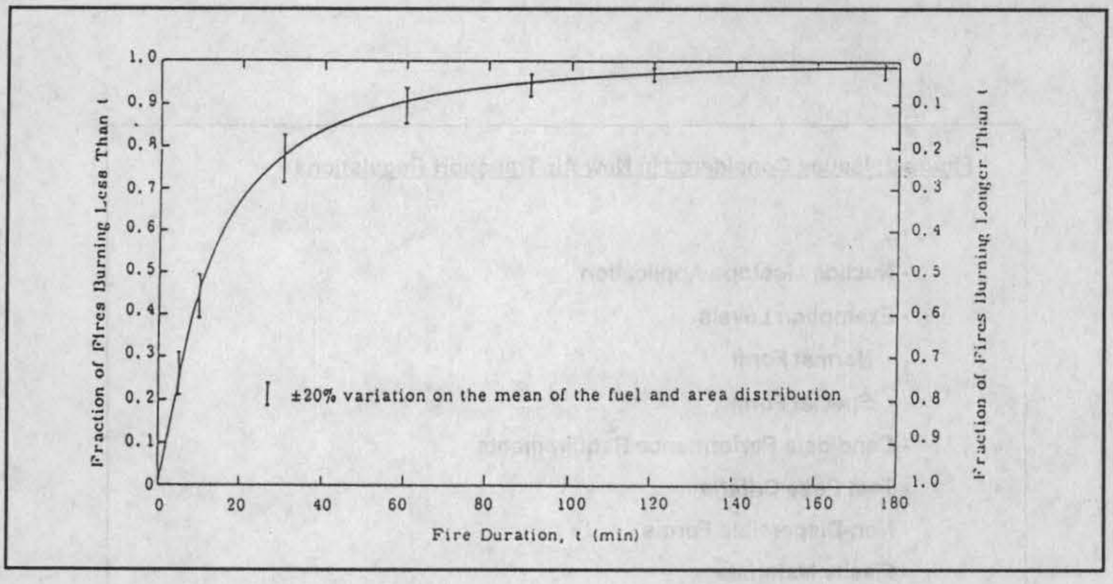

Figure 4: CDF for Aircraft Fire Duration from (Clarke, 76)

PACKAGING TECHNOLOGY

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