TRANSPORT OF RADIOACTIVE MATERIALS

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Introduction

It is estimated that around 500 million packages of potentially hazardous materials are transported throughout the world each year. This range of materials includes corrosives, flammable gases, flammable liquids, poisons, oxidisers and explosives. Our everyday life depends on the routine transport of these materials and we intuitively accept the small risk associated with their distribution.

Radioactive materials represent one other type of potentially hazardous material. Several tens of millions of packages of radioactive material are transported throughout the world annually. Around 90% of these packages contain only small quantities of radioisotopes, mainly for medical purposes. Most of the remaining 10% contain radioisotopes for industrial and research purposes. Shipments of nuclear fuel cycle materials represent only a few percent of the radioactive packages transported. The number of shipments of radioactive materials will continue to increase by about 10% each year as the medical, industrial and research uses of radioisotopes are more widely applied as a nuclear fuel cycle activities increase.

About 50,000 packages of radioactive materials are transported annually within Australia. Of this number, **Ansto** ships over 20,000 packages each year to all main cities in Australia and to regional countries. The vast majority of these shipments constitute radiopharmaceuticals for medical diagnostic purposes. About 75% of the shipments made by **Ansto** are by air and 25% by road to destinations within the Sydney area.

Regulatory Regime for Transport of Radioactive Materials

The transport of virtually all radioactive materials throughout the world on an international and domestic basis is governed by the provisions of the 'Regulations for the Safe Transport of Radioactive Material' (Safety Series No 6) issued by the International Atomic Energy Agency (IAEA). The IAEA is an organisation established under the aegis of the United Nations. It is based in Vienna and has a membership of 113 countries, including Australia. The IAEA Transport Regulations were first issued in 1961 and have been updated regularly since then. The current edition was issued in February 1985 and revised in December 1988. Australia has played an active role over the years in the development of the IAEA Regulations.

For international shipments of radioactive materials, the IAEA Transport Regulations have been incorporated into all major international conventions and requirements controlling the transport of dangerous materials, including the following:

By sea: The International Maritime Organisation (IMO) Dangerous Goods Code.

By air: The International Air Transport Association (IATA) Dangerous Goods Regulations, and

the International Civil Aviation Organisation (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air.

The IATA Regulations and IMO Code are used to regulate the transport of all dangerous goods, including radioactive materials, by air and sea within and from Australia.

The IAEA Transport Regulations have been widely incorporated into national legislation. In Australia, the IAEA Regulations have been broadly adopted by all Australian States. The IAEA Regulations also form the basis of the Australian Code of Practice for the Safe Transport of Radioactive Substances adopted under the Commonwealth Environment Protection (Nuclear Codes) Act 1978. The Australian Code has recently been updated in terms of the 1985 Edition of the IAEA Transport Regulations.

For the purpose of implementing the IAEA Transport Regulations, each country designates a "competent authority or authorities". The competent authority in Australia for the transport of radioactive materials by sea is the Commonwealth

Department of Transport and Communications and for air is the Civil Aviation Authority. The competent authority for surface transport is the relevant State authority, usually the State Department of Health. Competent authorities are responsible for ensuring that the relevant regulatory requirements are implemented. It should be noted that **Ansto** as a major shipper of radioactive materials has no regulatory role itself in this regard.

The IAEA Transport Regulations contain provisions stating what regulatory requirements need to be met. The IAEA has also published two separate documents named the 'Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material' (Safety Series No 37) containing non-mandatory provisions which advise how each regulatory requirement may be met, and the 'Explanatory Material for the IAEA Regulations for the Safe Transport of Radioactive Material' (Safety Series No 7) explaining why the various regulatory requirements need to be met. In addition, the IAEA has published the 'Schedule of Requirements for the Transport of Specified Types of Radioactive Material Consignments' (Safety Series No 80) which summarises the regulatory requirements. Major revisions of the IAEA Transport Regulations are issued about every ten years; minor amendments are promulgated periodically in the form of Supplements to the Regulations, the last such Supplement being in 1988.

Objectives of the IAEA Transport Regulations

The purpose of the IAEA Transport Regulations is "to establish standards of the safety which provide an acceptable level of control of the radiation hazards to persons, property and the environment that are associated with the transport of radioactive material". This protection is achieved by a series of four basic provisions which can be summarised as follows:

- control of the external radiation level. (This concerns the maximum radiation level on the outside surface of a package, the marking of a package with appropriate warning labels, and the safe stowage of a package during transport).

- containment of the radioactive material. (This concerns the design and strength of a package, and the activity and nature of its radioactive contents).

- dissipation of any heat generated. (This concerns the maximum surface temperature of a package and instructions on stowage to provide for the safe dissipation of any heat generated).

- for fissile materials (e.g. reactor fuel), the prevention of criticality.

An important underlying philosophy of the IAEA Transport Regulations is to ensure that to the greatest extent possible, the responsibility for ensuring safety during transport belongs to the shipper and the contribution required from a carrier is minimised. Transport industry workers are expected to treat radioactive consignments with care, but no more than accorded other dangerous goods. The IAEA Regulations are therefore essentially directed to ensuring that levels of safety appropriate to the nature and amount of radioactive material being carried are built-in to the design of the package on the premise that the package could be involved in a severe transport accident. The design requirements for packages are the same for all means of transport e.g. road, rail, sea or air. Operational controls required during transport are therefore kept to a minimum.

Radiation Protection

The radiation protection principles underlying the IAEA Transport Regulations are designed to provide a high safety both for workers engaged in the transport of radioactive materials and members of the public. These radiation protection principles are based on the 'Basic Safety Standards for Radiation Protection' jointly sponsored by the IAEA, the International Labour Organisation, the OECD Nuclear Energy Agency and the World Health Organisation. The IAEA Regulations include the provision that "radiation exposures from the handling, storage and transport of radioactive material shall be kept as low as reasonably achievable, economic and social factors being taken into account".

Types of Packages

There is a wide range in the potential hazard of radioactive materials being transported. The item being transported may range from a luminous watch dial to an irradiated fuel element. To meet this need, the IAEA Regulations provide for four basic types of packages related to the radiotoxicity and the quantity of radioactive material which may be transported in a particular package as follows:

- Excepted packages
- Industrial packages
- Type A packages
- Type B packages

Progressively increasing performance standards are specified for the above types of packages ranging from very basic requirements for excepted packages, which are only permitted to contain minute amounts of radioactivity, to stringent requirements for Type B packages, which may contain quantities of radioactivity having the potential to cause a significant hazard if released.

The vast majority of packages of radioactive material transported within Australia are Type A packages. These packages are typically used to transport radiopharmaceuticals around Australia. Type A packages are permitted to contain only limited quantities of radioactivity. These packages are expected to retain their integrity under conditions of normal transport abuse, e.g. falling from a vehicle, being exposed to rain, being struck by a sharp object or having other cargo stacked on top. It is assumed however that a Type A package may be damaged in a severe accident and that a fraction of its contents may be released. Limits are therefore set in the Regulations for the maximum amount of each radionuclide which is permitted to be transported in a Type A package. These limits ensure that in the event of the package being involved in a severe accident, the risks from external radiation or contamination from the radioactive contents of the package are low.

Larger amounts of radioactive material must be transported in Type B packages. These packages are used for transporting such items as radiography sources or cobalt-60 sources used for cancer therapy in hospitals. A Type B package must be capable of withstanding the effects of a severe accident without releasing its radioactive contents or there being any significant increase in external radiation levels. The design of each Type B package must be approved by the national competent authority of the country in which the packaging is designed.

Excepted packages are required to meet only basic design requirements, but correspondingly the amounts of radioactivity which can be shipped in such packages is extremely low. Examples of such materials are instruments or equipment containing slightly radioactive components, and ore samples.

Industrial packages are used to transport low specific activity material or surface contaminated objects. Low specific activity materials are materials which by their nature have a limited specific activity (or activity per unit mass), or the radioactive material is in a form which is not easily dispersed. This means that independent of the quantity of such materials, they have a high intrinsic level of safety during transport. Uranium and thorium ores are common examples of low specific activity materials. Low specific activity and surface contaminated objects are required to be transported in such a manner that under conditions likely to be encountered in routine transport, there will be no loss of contents from the packages.

When fissile materials are transported, such as reactor fuel elements, the IAEA Transport Regulations specify additional requirements to ensure that criticality cannot occur.

Identification of Packages

All packages of radioactive materials other than excepted packages are required to be labelled with a distinctive radioactive warning label with a trefoil on two opposite sides. Information on this label indicates the name of the radionuclide contained in the package, the activity of the radioactive contents and the transport index. In most cases, the transport index is determined from the radiation level at 1 metre from the external surface of the package. Freight containers carrying radioactive materials are required to have both the above label and also a 25cm x 25cm placard on all four sides, similar to the placard used when any other class of dangerous goods is transported.

Additionally, Type A packages are required to be legibly and durably marked on the outside of the packaging with the words 'TYPE A'. Type B packages designed for fissile materials are required to be legibly and durably marked on the outside of the packaging with:

- an identification mark allocated to each design by the competent authority

- a serial number to uniquely identify each packaging
- for Type B packages, the wording 'TYPE B(U)' or 'TYPE B(M)'
- for Type B packages, a radioactive warning trefoil symbol which is resistant to the effects of fire and water.

Package Test Requirements

In order to demonstrate the safety of each new package design, the IAEA Transport Regulations require prototypes of each package design to be subjected to a series of very rigorous test without loss of contents or significant increase in external radiation levels. These tests are not intended to represent directly any specific transport accident scenario, but are intended to simulate the damage to a package which would result from normal transport conditions or a severe transport accident as appropriate. A description of the test requirements is attached.

The efficacy of this test regime in simulating the transport environment and accident conditions has been verified by a series of full scale tests held mainly in the United States and the United Kingdom. For instance, in 1977 and 1978 a series of five tests were conducted by the Sandia National Laboratories in the United States involving a spent-fuel cask mounted on a trailer being struck by a 120 ton locomotive travelling at 130 km/hour, a rail-type spent-fuel cask striking a 690 tonne concrete block at 130 km/hour, and a rail-type spent-fuel cask being subjected to a fire from jet-aviation fuel for over two hours. The United Kingdom held a similar test in July 1984 where a spent-fuel cask was hit head-on by a diesel locomotive weighing 140 tonnes, coupled to three 35 tonne coaches and moving at 160 km/hour. In the above tests, the casks received only minor damage and there would have been no significant release of radioactive material to the atmosphere had the casks been carrying actual spent fuel. These tests provide convincing evidence that the requirements specified in the IAEA Transport Regulations are more severe than those encountered in actual highway and rail crashes. The tests also corroborate the analyses techniques used in the design of packages.

Accident Experience

No matter how much care is taken, accidents do happen, and accidents in the transport of dangerous materials are no exception. In the case of radioactive materials, it can be seen from the above discussion that the provisions of the IAEA Transport Regulations are designed to ensure that the possibility of any harm resulting from a package of radioactive material being involved in an accident is remote. This has resulted in radioactive materials having a much better safety record than other hazardous materials. One need only think of petrochemicals which are flammable and can disperse quickly over a wide area when the container is damaged. Probably the worst example of this occurred in 1978 when a truck carrying propylene ran off the road near a camping site in Spain and the resulting explosion killed more than 200 holidaymakers. The transport of oil is also hazardous not only to people, but the environment; for instance, when the Amoco Cadiz ran aground off the coast of France in 1978, some 220,000 tonnes of oil were spilled into the ocean, and when the Exxon Valdez ran aground in Alaska's Prince William Sound in March 1989, some 40,000 tonnes of oil were released into a unique environment. In 1979, a train accident near Toronto in Canada prompted the evacuation of about 250,000 people due to the possible rupture of tankers carrying liquid fuels, petrochemicals and chlorine. The list could go on.

Packages carrying radioactive materials have been involved in a number of severe transport accidents involving all transport modes. There has however been no recorded case when a Type B package has released its radioactive contents. Many Type A packages have also withstood severe accidents, although not required to do so. In the 40 years experience of transporting high-level radioactive materials throughout the world, there have been no deaths or injuries incurred as a result of the radioactive nature of the materials of any kind. This position contrasts markedly with the experience in transporting other hazardous materials.

Perhaps the most recent incident receiving wide international publicity where a consignment of radioactive material was involved in a transport accident was the collision and subsequent sinking of the cargo-ship Mont Louis in the North Sea in August 1984. This vessel was carrying 350 tonnes of natural, slightly enriched and slightly depleted uranium hexafluoride in 30 containers. Because of its low specific activity, the uranium hexafluoride was being shipped as a "low specific activity material". All 30 containers were subsequently recovered intact, except for one container where a very small leak was found in a closure valve due to buffeting by the storm. The Mont Louis incident had no public health consequences and caused no detriment either to the health of the salvage team or the environment. The incident provided added evidence as to the effectiveness of the regulatory requirements for transporting such materials as uranium hexafluoride. The Mont Louis accident has however contributed to moves to ensure that the IAEA Transport Regulations specifically address radioactive materials having high subsidiary risks such as uranium hexafluoride with its dual radiological and chemical hazards. Additional guidance for the transport requirements for such materials will be issued by the IAEA shortly.

The most common type of accident involving packages of radioactive materials in virtually every country in the world, including Australia, is damage to the outer packaging of Type A packages during their handling at airports. About 3 or 4 such incidents occur each year at Sydney Airport. In only very rare occasions however is there any loss of radioactive contents from the package. In no case at Sydney Airport has any significant health hazard been caused as a result of damage to a package of radioactive material.

Physical Protection During Transport

Regulations for the safe transport of radioactive materials are designed to afford adequate protection from hazards associated with a package under normal handling and accident conditions. They do not provide for physical protection, which consists of security measures designed to protect against wilful acts such as theft, sabotage, or unlawful removal and use of nuclear materials. The responsibility for physical protection of nuclear material, indeed as for all hazardous materials, under the jurisdiction of a country rests entirely with the government of that country. The IAEA has nevertheless issued a set of recommendations under the title 'The Physical Protection of Nuclear Material' (INFCIRC/225 Rev 2) which provide guidelines for the physical protection of nuclear materials in use, storage and transit. Australia has adopted these recommendations as minimum requirements. With regard to international shipments of nuclear material, a Convention on the Physical Protection of Nuclear Material was negotiated in 1979 under the auspices of the

IAEA; Australia ratified this Convention in 1987. The responsibility in Australia for formulating detailed physical security requirements for nuclear material rests with the Australian Safeguards Office.

Emergency Arrangements

Again, the responsibility for responding to an accident involving radioactive material rests with the relevant authorities in each country. In essence, the kind of emergency planning and preparedness that is needed for responding to transport accidents involving radioactive materials is very similar to that required for responding to accidents involving non-radioactive hazardous materials such as flammables, explosives, poisonous gases and toxic chemicals. As indicated earlier, many of these non-radioactive hazardous materials pose significantly greater threats to public health and safety than do radioactive materials. To assist public authorities in their emergency planning, the IAEA has recently issued the documents 'Emergency Response Planning and Preparedness for Transport Accidents involving Radioactive Material' (Safety Series No 87) and 'Emergency Planning and Preparedness for Accidents involving Radioactive Materials used in Medicine, Industry, Research and Teaching' (Safety Series No. 91). In Australia, the responsibility for emergency response for transport accidents involving radioactive materials rests primarily with the Department of Health in each State, except on Commonwealth establishments such as airports.

Sydney Airport is by far the busiest airport in Australia for movements of radioactive material. The Department of Transport and Communications Aerodrome Emergency Procedure specify detailed procedures to be followed in the event of a situation involving damaged radioactive cargo at Sydney Airport. These procedures provide inter alia for an **Ansto** safety officer who is on call to be notified and to provide any necessary specialist assistance. **Ansto** has a set of emergency monitoring equipment stored at the Airport for use as necessary. **Ansto** officers also participate in emergency exercises at Sydney Airport.

SAGSTRAM

This overview of the transport regulatory scene would not be complete without mentioning SAGSTRAM, the IAEA's Standing Advisory Group on the Safe Transport of Radioactive Material. This body was founded in 1978 with the function of advising the Agency on all aspects of its work on transport safety. SAGSTRAM has met seven times to date; most recently in April 1989. Although it has advised on many transport issues in the transport safety programme work, its most significant work to date has been to guide the review of the IAEA Transport Regulations which gave rise to the 1985 Edition. Furthermore its advice, based on the experience of that review, has now resulted in a newly-adopted concept of a continuous regulatory review.

In terms of the further development of the Regulations, there are three main issues which have been considered at some length by SAGSTRAM. The first is the matter of mode-related aspects of the Regulations and in particular the transport by air of large quantities of radioactive material, including plutonium. There are proposals being developed for more stringent package test requirements for such materials to take account of so-called low-probability/high-consequence accidents. The second is guidance material on the transport of uranium hexafluoride as mentioned earlier. The third is the extent to which probabilistic risk assessment techniques and/or criteria should be implemented in the IAEA Transport Regulations. The above three issues will be considered in detail during the process of the next major revision of the IAEA Transport Regulations due to be published in 1995.

Conclusion

The transport of radioactive materials has been conducted around the world for the last 40 years with an excellent safety record. The millions of packages which are transported each year contribute to the benefit of mankind in many fields of daily life. With due care in meeting regulatory requirements, there is no reason why this level of safety should not be maintained in the future.

ATTACHMENT

SUMMARY OF TEST REQUIREMENTS FOR PACKAGES OF RADIOACTIVE MATERIAL AS SPECIFIED IN THE 1985 EDITION OF THE IAEA TRANSPORT REGULATIONS

There are two sets of tests. The first set of tests simulates the damage arising under "normal" conditions of transport which packages may experience such as exposure to rain, rough handling and minor mishaps. Both Type A and Type B packages are subjected to these tests. The second set of tests simulate accident conditions in transport. Only Type B packages are subjected to these tests. In order to meet the test requirements, a package must retain its radioactive contents and have no significant increase in external radiation levels following the applicable tests.

Tests for Normal Conditions of Transport

Water spray test:

The package is subjected to a water spray which is approximately equivalent to a rainfall rate of 5 centimetres per hour for a duration of one hour.

Free drop test:

The package is dropped onto a hard target (e.g. a concrete block) so as to suffer maximum damage to the safety features to be tested. The height of the drop measured from the lowest point of the package to the upper surface of the target is 1.2 metres for most packages. Heavier packages, i.e. over 5 tonnes, are dropped from a lower height. For packages which contain liquid or gaseous contents the drop height is 9 metres.

Stacking test:

The package is subjected for a period of 24 hours to a compressive load equal to the greater of 5 times the weight of the actual package or the equivalent of 1300 kg/m^2 multiplied by the vertically projected area of the package.

Penetration test:

The package is placed on a rigid, flat, horizontal surface, and a bar of 3.2 centimetres diameter with a hemispherical end and weighing 6 kilograms is dropped from a height of one metre (1.7 metres in the case of packages which contain a liquid or a gas), with its longitudinal axis vertical, so that it falls onto the centre of the weakest part of the package.

Tests for Accident Conditions in Transport

Mechanical test:

The package is subjected to two different drop tests which must be carried out in such a way that the damage the package suffers in the drop test will lead to the maximum damage in the thermal test. In the first drop test, the package is either dropped from a height of 9 metres onto a flat horizontal, unyielding surface, or alternatively in the case of certain types of light-weight packages, a solid mild steel plate weighing 500 kg is dropped from a height of 9 metres in a horizontal attitude onto the package. In the second drop test, the package is dropped from a height of 1 metre onto a solid mild steel bar of 15 cm diameter and at least 20 cm in length mounted vertically.

Thermal test:

The package is exposed to a temperature of at least 800°C for 30 minutes in a fire or a furnace.

Water immersion test:

The package is immersed in water with a head equivalent to at least 15 metres for a period of not less than 8 hours, except for packages containing irradiated nuclear fuel, where the package is immersed in water with a head equivalent to at least 200 metres for a period of not less than one hour.