Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2009 Review

M P Harvey

ABSTRACT

This report includes descriptions of 32 accidents and incidents involving the transport of radioactive materials from, to, or within the United Kingdom, which occurred in 2009. The number of events in 2009 was less than reported in 2008 (39 events), but more than previous years: 26 events in 2007, 29 events in 2006 and 16 events in 2005. Of the 32 events included in this review 8 involved irradiated nuclear fuel flasks (there were 7 such events in 2008). In 2009 there was 1 event involving the discovery of radioactive material in shipments containing material which was thought to be non-radioactive. None of the events reported resulted in any significant radiation doses to workers or members of the public.

The details of these events have been entered into the RAdioactive Material Transport Event Database (RAMTED), which now contains information on 949 events that are known to have occurred since 1958.

This study was funded by the Department for Transport

Approval: July 2010
Publication: August 2010
£15.00
ISBN 0-978-85951-671-6

This work was undertaken under the Environmental Assessment Department's Quality Management System, which has been approved by Lloyd's Register Quality Assurance to the Quality Management Standards ISO 9001:2000 and TickIT Guide Issue 5, certificate number 956546.

EXECUTIVE SUMMARY

Up to half a million packages containing radioactive materials are transported to, from and within the United Kingdom every year. Accidents and incidents involving these shipments are rare. However, there is always the potential that such an event could lead to the release of the contents of a package or an increase in radiation level caused by damaged shielding and result in radiological consequences for transport workers. Such events could also lead to radiological consequences for the public. The UK Department for Transport (DfT) has supported work to compile, analyse and report accidents and incidents that occurred during the transport of radioactive materials. Annual reports have been produced since 1989 and this report for the year 2009 is the latest in the series. The details of these events are recorded in the RAdioactive Materials Transport Event Database (RAMTED), which is maintained by the Centre for Radiation, Chemical and Environmental Hazards of the Health Protection Agency (HPA-CRCE) on behalf of DfT. The database now contains information on 949 events that are known to have occurred since 1958.

This report includes descriptions of 32 accidents and incidents involving the transport of radioactive materials from, to, or within the United Kingdom, which occurred in 2009. The number of events in 2009 was less than reported in 2008 (39 events*), but more than previous years: 26 events in 2007, 29 events in 2006 and 16 events in 2005. Of the 32 events included in this review 8 involved irradiated nuclear fuel flasks (there were 7 such events in 2008). In 2009 there was 1 event involving the discovery of radioactive material in shipments containing material that was thought to be non-radioactive. None of the events reported resulted in any significant radiation doses to workers or members of the public.

Almost all the events were of a similar type to those occurring in recent years. The 8 events involving irradiated fuel flasks were mainly due to loose lid bolts. Only one of these events involved the discovery of parts that were not of the correct specification. These were relatively minor in terms of the overall safety of the flasks. However, it is essential that these flasks are maintained and operated to the highest quality standards.

* This figure includes the 38 events described in the 2008 review (Harvey, 2009) and the event reported in the 2009 review (see Section 4.2)

CONTENTS

1 INTRODUCTION

Reviews of the accidents and incidents involving the transport of radioactive materials to, from and within the UK have been carried out for the years 1958 to 2008 (Gelder et al, 1986; Shaw et al, 1989; Hughes and Shaw, 1990-1999, 1996b; Hughes et al, 2001a, 2001b, 2006; Warner Jones et al, 2002a, 2002b; Warner Jones and Jones, 2004; Watson and Jones, 2004; Roberts et al, 2005; Hesketh et al, 2006; Hughes and Harvey, 2007; Harvey and Hughes, 2008, Harvey, 2009). The objectives of those reviews were:

- to assess the radiological impact of such accidents and incidents on both workers and members of the public over the period of study;
- to comment on transport practices;
- to provide information pertinent to future legislation and codes of practice;
- to produce and maintain a database of events covering the period of study.

The initial reviews (Gelder et al, 1986; Shaw et al, 1989) were supplemented by annual analyses (Hughes and Shaw, 1990-1999; Hughes et al, 2001a, 2001b; Warner Jones et al, 2002a; Warner Jones and Jones, 2004; Watson and Jones, 2004; Roberts et al, 2005; Hesketh et al, 2006; Hughes and Harvey, 2007, Harvey and Hughes, 2008, Harvey, 2009). A comprehensive review was carried out of events that occurred in the whole period from 1958 to 1994 using an improved event classification system (Hughes and Shaw, 1996b), which has been updated to include events up to and including 2004 (Hughes et al, 2006a). The improved classification system was used to provide a summary and analysis of all events to 2000 that was presented at the Sixth International Conference on Radioactive Materials Transport (Warner Jones et al, 2002b).

Throughout this review accidents and incidents are collectively referred to as events. The information on these events is stored in the RAdioactive Materials Transport Event Database (RAMTED). In 2004, the database was reviewed and revised as the original version was approximately twenty years old and had many limitations compared to typical software and hardware specifications of today (Watson, 2004). The relational format of the current version of the database allows for more efficient recording of the details of an event. The classification systems were reviewed and, though only minor changes were made to the classifications, the change in the database structure now allows for an event to be more efficiently classified with a main category and subsidiary categories if appropriate.

This report describes the events reported during 2009 and analyses these events based on the revised classification system and the main event categories. Some other occurrences of interest that did not meet the criteria for inclusion in the database are also briefly described in Table A1 of Appendix A.

The Glossary (see Section 8) contains descriptions and definitions of a number of technical terms that are associated with the transport of radioactive materials.

2 DATA COLLECTION AND ANALYSIS

For this review, information on accidents and incidents has been mostly obtained from official files at the Department for Transport (DfT) (www.dft.gov.uk). Information was also obtained from other sources, such as the Health and Safety Executive (HSE) (www.hse.gov.uk), the Civil Aviation Authority (CAA) (www.caa.co.uk), the Department of the Environment, Northern Ireland (www.doeni.gov.uk), the Scottish Environmental Protection Agency (SEPA) (www.sepa.org.uk) and from independent Radiation Protection Advisers (RPAs). Other sources of information for these annual reviews include events occasionally reported to the Environment Agency (EA) and records of incidents reported under the National Arrangements for Incidents involving Radioactivity (NAIR). Under the NAIR scheme, the police attending an incident involving radioactive material can summon assistance from a health physics expert in the region. Only occasionally do these NAIR events directly involve the transport of radioactive materials.

2.1 Reporting of events and criteria

The transport of radioactive materials involves a number of activities, such as the preparation of the package by the consignor, its loading onto a vehicle, and finally its shipment carried out by carriers using various modes of transport. The shipment phase may involve a number of loading and unloading operations between different modes of transport before final delivery of the package to the consignee. The reported accidents and incidents included in these reviews come within the scope of these activities, for shipments and transhipments within the United Kingdom. Events involving shipments from the United Kingdom are also included if the event was as a result of a failing in the United Kingdom. However, events occurring on site, i.e. within the premises of consignors and consignees, are not included unless they are relevant to transport in public areas or if they originated from an incident that occurred during transit.

The normal transport of radioactive materials may give rise to small radiation doses to transport workers and in some circumstances members of the public might also receive very low doses. Conditions of transport that are intended to minimise these exposures are given in current national legislation and international agreements, which cover transport by road (UK Parliament, 2009; UNECE, 2007), rail (UK Parliament, 2009; OTIF, 2007), sea (UK Parliament, 1997a; MCA, 2006; IMO, 2006) and air (UK Parliament, 1994, 2007; ICAO, 2006). These conditions include, for example, the specification of segregation distances for packages during stowage. It may be noted that the most significant accidents and incidents that are included in this and previous reviews are those that give rise to increased radiation exposures during transport. In addition, events are included that had the potential for increased radiation exposures. Some events in this group may seem trivial, such as those involving administrative errors; however, experience has shown that in some circumstances such errors can have serious consequences. In practice, all but those reported events that are deemed to be trivial by the Department for Transport, are included in this review.

For transport by road in the United Kingdom, there are two sets of regulations, one for Great Britain (UK Parliament, 2009) and one for Northern Ireland (UK Parliament, 1997b).

For transport by road in Great Britain, the regulations (UK Parliament, 2009) require the driver of a vehicle transporting radioactive material to report a notifiable event to the police, fire brigade and consignor. A notifiable event (UK Parliament, 2009) means:

(i) a radiological emergency;

(ii) the theft or loss of the radioactive material being carried; or

(iii) an occurrence subject to report as construed in accordance with Sub-section 1.8.5.3 (of reference UNECE, 2007). That sub-section includes the release of contents, or risk of loss of contents, environmental damage or personal injury.

Similar criteria are given for Northern Ireland.

Following this, the carrier must report the event to the police and if the driver has not already done so, the consignor and the Secretary of State for Transport. The notification of the latter is fulfilled by informing the Competent Authority that is the Dangerous Goods Division of DfT.

In practice, many other less serious events are reported voluntarily by consignors, carriers and consignees. Other types of events that are relevant to the transport of radioactive materials may also be reported by others, such as the police, suppliers and manufacturers. There have also been a few instances where members of the public have found lost packages and informed the emergency services.

Events involving undeclared radioactive material discovered in packages, or cargoes of scrap metal are included when they have involved illegal or unauthorised transport after the radioactive material has been discovered or there is evidence that the radioactive material had been deliberately transported. For the purpose of this review, which is concerned with contraventions of the regulations in addition to incidents and accidents, similar considerations are applied to radioactive material discovered at ports and airports by installed radiation detectors. Where such intercepted material was known to be radioactive but was not being transported in accordance with the regulations, this is always recorded as an event. Events involving the discovery of undeclared radioactive material that are notified to DfT but are not included in the database as transport events, because they do not meet the criteria, are briefly described in Section 5.4 and listed in Table A1 of Appendix A.

Incidents involving the transport of dangerous goods by rail are subject to standard reporting procedures. This system can result in quite minor events being reported very efficiently. Each year during the transport of irradiated nuclear fuel (INF) flasks there are a number of incidents where the train has been stopped following the detection of overheated axles or brakes. The detectors activate at temperature levels that do not pose a threat to the integrity of the INF flask. However, on occasions the overheating can result in smoke production and fires in the axle or brake areas. The criterion for including such events in these reviews is whether smoke is apparent.

INF flasks are mainly loaded and unloaded underwater in ponds at nuclear power stations and reprocessing plants. The water in these ponds tends to be contaminated with radioactive material and this contamination may become attached to the flask surfaces. Before transport, the flasks are thoroughly cleaned and monitored. The level of non-fixed contamination by radionuclides must be below the regulatory limit of 4 Bq cm^{-2} for beta emitters and low toxicity alpha emitters and 0.4 Bq cm^{-2} for all other alpha emitters. In the past, operational quantities related to these values, termed derived working levels (DWL), were used. Events involving excess levels of contamination on INF flasks were included in previous reviews if at any point on the surface the level was 10 DWL or above.

As discussed in Harvey, 2009, changes in industry protocols mean that flask contamination is now reported directly in terms of its value in Bq cm^{-2} rather than DWL. Similar pessimistic assumptions are made when calculating the contamination in Bq cm^{-2} as were used in deriving DWL. Therefore, when contamination is reported post-shipment as being just over 4 Bq cm^{-2} the flask is unlikely to have actually been transported with contamination above the regulatory limit. A criterion of 20 Bq cm^{-2} (2 Bq cm^{-2} for alpha) has been applied to the calculated contamination level to separate those events where the regulatory limit is likely to have been exceeded (DfT, 2009).

Similarly to previous reviews this report does not include any events that may still be subject to legal proceedings at the time of publication. Any such events will be reported in later annual reviews.

A system known as the International Nuclear Event Scale (INES) (IAEA and NEA, 2001) has been established for rating events that occur in the nuclear industry, by the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD). This system enables a rating, from Level 0 to Level 7, to be applied to an event to give a prompt and consistent indication of the severity of the event to the media and members of the public. Level 7 refers to the most severe type of accident and Level 0 refers to an event with no safety consequences. The INES scale has been extended to cover other events, including events involving the transport of radioactive materials. Significant events are reported to the IAEA from where the details are distributed and made publicly available. The United Kingdom, in common with most other countries, only reports events that are rated at Level 2 or above.

3 DATABASE OF REPORTED EVENTS

As mentioned in Section 1, details of the reported events have been entered into the RAdioactive Materials Transport Event Database (RAMTED). A comprehensive review of the events in the database was undertaken a few years ago (Hughes et al, 2006) and includes a description of the systems of reporting and scope of the types of events recorded in the database. Some of the information in the database is held in coded form to facilitate analysis. Descriptions of the information stored, including the coding system used to classify events, are given in Appendices B and C.

The database contained information on 916 events up to and including the events in 2008. The earliest reported events are from 1958. During the collection of information for this current review, details were obtained for 32 events in 2009 and for an additional event that occurred in 2008, which brings the total number in the database to 949. The collection of information for this review did not reveal any further events from previous years that were not in the database.

Table1 provides a summary of the main category code for the 32 events reported in 2009 and the additional event for 2008. The essential details of each event are briefly described in Section 4. Brief descriptions of these events are included in the database record of each event. Other details that are entered in the database record for each event are listed in Appendix B, including a broad description of the event as either an accident or incident that occurred during either the transport or handling phase (TI, TA, HI and HA). In addition, events where the main occurrence was radioactive contamination of external surfaces of intact packages, or conveyances, are recorded as category C.

In order to give a better description of the type of event, a classification system has been developed for the RAMTED database that gives more information than the broad descriptive categories noted above. This system enables events to be grouped into logical categories and facilitates analyses. The classification system covers three aspects: a descriptive classification, the effect of the event on the package and the level of radiological consequences. The descriptions of the codes used in this classification system are given in Tables B6, B7 and B8 of Appendix B. The classification codes are listed in the last three columns of Table1 for the 32 events reported in 2009. The first four columns of Table 1 give, respectively, the event identifiers listed in Section 4, the material category code, the transport mode code and the package type. The definitions of the material category codes, the transport mode codes and the package type codes are given in Tables B3, B4 and B5 of Appendix B.

The descriptive classification of the event, given in the fifth column of Table 1, specifies the nature of the event, following the descriptive structure set out in Table B6 in Appendix B. The first character of the code gives the general subject or area under which the event is categorised; that is, administrative (A), general shipment (S) or INF flask (F). Events involving INF flasks are separated from the other general shipments of radioactive materials for other nuclear, industrial and medical uses because of the special circumstances of INF flask movements. The identification of the second character of the code and following numbers are shown in the full coding system which is given in Table B6. The new database structure allows for events to be classified into a number of categories, as seen in Table 1, where some events have more than one entry in the fifth column. In these cases the event classifications are prioritised within the database and are listed in order of priority in Table 1.

The effect of the event on the package integrity, or the package deficiency, is allocated to 12 categories (D03 - D14), as set out in Table B7 in Appendix B. In addition category D01, ’No package’, applies to events in which the radioactive material is not within a package. Category D02 is for contaminated conveyances, with no package involvement.

The radiological consequence of an event is allocated into one of four categories, which are set out in Table B8 in Appendix B. The 'None' category ('N' in Table 1) applies to events where there are no dose rates or contamination above that expected from normal transport, or where there is no evidence that individuals have received any dose. Events in which people received a small excess dose, but not at a level thought to be worth a detailed assessment are categorised in the 'Extremely low, not assessed' ('E' in Table 1) band. Such doses may be received when a worker repackages a poorly packaged item. Events in which workers are exposed to radiation for a significant period and an assessment is carried out of their likely dose fall into either the 'Assessed, lower category' or the 'Assessed, upper category' band, depending on whether their effective dose exceeded 1 mSv, or an extremity dose exceeded 50 mSv.

Table 1. Summary list of events included in the 2009 review

Event ID (Section 4)	Material category (Table B3)	Transport mode (Table B4)	Package type (Table B5)	Event classification (Table B6)	Effect on package (Table B7)	Radiological consequence (Table B8)
Events occurred in 2009						
2009001	7	8	E	SP341	12	E
2009002	7	5	A	AC111 AG111 SC411	3	N
2009003	0	2	E	SP341	7	N
2009004	6	4	IP2	AG211 SC411	3	N
2009005	6	4	IP2FP	SC511	4	N
2009006	7	7	UK	SP241	5	E
2009007	5	1	BM	FP131	3	N
2009008	7	0	A	SP212	5	E
2009009	7	2	A	SP221	4	N
2009010	7	2	A	SP341	7	N
2009011	4	1	BMF	FP131	3	N
2009012	7	2	E	AG221	3	N
2009013	4	1	BMF	FP131	3	N
2009014	4	1	BMF	FP132	3	N
2009015	5	10	AFP	SP171	12	N
2009016	5	1	BMF	FP141	3	N
2009017	7	5	A	SC511	4	N
2009018	0	2	E	AG211	4	N
2009019	4	1	BM	FP141	3	N
2009020	7	2	AP	SP221	4	E
2009021	0	2	UK	AG111	1	N
2009022	6	4	A	SP111	6	E
2009023	9	4	BU	SC411	4	N
2009024	7	10	A	AG211	3	N
2009025	4	1	BMF	FP211	4	N
2009026	10	4	E	SP221	4	N

Table 1. Summary list of events included in the 2009 review

Event ID (Section 4)	Material category (Table B3)	Transport mode (Table B4)	Package type (Table B5)	Event classification (Table B6)	Effect on package (Table B7)	Radiological consequence (Table B8)
2009027	7	4	E	SP141	13	E
2009028	4	1	BMF	FP131	3	N
2009029	10	3	NR	AG241 AP111	3	E
2009030	5	10	UK	SP111 SP171	10	E
2009031	5	10	IP2P	SP171	12	N
2009032	11	7	E	SP121	10	N
Events occurred in previous years						
2008039	7	10	B	SC211	4	N

4 EVENTS RECORDED FOR THIS REVIEW

Brief descriptions of the events reported in 2009 are listed below. The package types used are listed in Appendix B.

4.1 Events for 2009

January

2009001. An excepted package containing a low activity tritium source was run over by a forklift truck at a UK airport. The primary containment was damaged and measurements showed that the package was contaminated to 1.9 kBq cm^{-2}. The leak was only discovered once the package was back at the consignors. The package contained exempt levels of tritium of 9.25 MBq, which meant that it need not have been transported as radioactive. The package was returned to the consignor, uncontained, i.e without the required salvage container. A salvage container should have been used but the driver sent to collect the damaged package had not been supplied with one hence it was transported without. It is unclear whether the lack of salvage container was deliberate or not.

2009002. A van carrying a troxler moisture density gauge (containing an Am-Be source of 1.48 GBq and a ^{137}Cs source of 300 MBq), was stopped by the police and a prohibition notice was issued. A number of non-compliant items were found including the lack of orange plates on the van, insecure radioactive load and no evidence of the driver's training records.

2009003. During freight checks at an airport, within a consignment of five packages, three were found to be damaged. Two of the damaged packages were found to contain radioactive material. A Radiation Protection Adviser was called and reported that no leakage from the packages had occurred and the surface dose rate was acceptable for an excepted package. It was uncertain where and how the damage occurred, but is was thought that the packages may have been weakened when opened by overseas customs and damaged later in the journey. Notification of the event was sent to the authority from which the consignment was sent. The consignment was repackaged and set onwards to the consignee.

2009004. A shipment of two ISO containers of LLW was transported by road from the low level waste facility to a UK nuclear site without the correct documents or labelling on the vehicle. Also one of the fixings (twist locks) on an ISO container was not fastened properly. The shipment was returned to the consignor and an embargo was made on further shipments pending an investigation. It was found that there were no operator instructions for the driver as this material is normally transported by rail. The consignor reviewed procedures and produced updated procedures which also required checks to be made on the container twist locks before transporting.

2009005. A lorry was transporting encapsulated, low specific activity fissile material in a number of third height ISO containers from a nuclear site to a waste facility, when the trailer carrying the containers de-coupled at a roundabout. This caused the rear of the front trailer section to fall to the ground. The driver of the lorry initiated RADSAFE. It was found that there was no breach of containment and the maximum dose rate close to the container was only 0.2 μSv h^{-1}. The Vehicle and Operator Services Agency (VOSA) took the vehicle and trailer away for inspection and the load was transported back to the consignor. A review of the trailers was made by the consignor before any more material was transported.

2009006. A case was found on a grass verge, where it had been incorrectly disposed of. It was opened by a member of the public and found to contain a radioactive source. The emergency services were contacted, who in turn contacted the stage 1 NAIR respondent in the area. The source was found to be a level gauge containing 18 MBq of ^{137}Cs used for fire extinguisher servicing. No contamination was found. The NAIR respondent transported the source to the nearby hospital for storage awaiting disposal by the Environment Agency.

2009007. During processing of a nuclear fuel flask at a nuclear power station, which had been sent from another nuclear site, it was found that one of the 16 lid bolts was loose. The nuclear site set up an enquiry, prevented dispatch of any fuel flasks and notified DfT. The fuel flask lid tightening procedures were reviewed at all nuclear sites and modifications were made.

February

2009008. A troxler moisture density gauge was stolen overnight from a premise. This contained an Am-Be source of 1.48 GBq and a ^{137}Cs source of 300 MBq. The Health and Safety Executive and the Department for Transport were informed. The stolen gauge was not recovered. The security of the premises was reassessed by the police and the Environment Agency; as a result security was improved.

2009009. Upon arrival at an airport in the UK, a consignment of radioactive medical sources containing about 120 MBq of ^{68}Ge in a Type A package was found to have been misrouted to the UK instead of another European country. It was found that the airport code had been entered incorrectly on the manifest. The consignment was transported to the consignee on the next available flight.

2009010. During handling of freight at a UK airport one of a five piece consignment of radioactive material was found to be damaged. It was concluded that damage had occurred during handling by the consignor, who was informed of the incident. Slight damage had only occurred to the cardboard outer package and readings of dose rates confirmed that the inner package was intact. These showed a dose rate of 45 µSv h^{-1} at 1 m, which meant that there was no increase in dose rate above that expected with a TI of 4.4, as given on the package label. The package was transported onwards to the consignee following advice from a Radiation Protection Adviser.

2009011. A nuclear company discovered that six nuclear fuel flasks had non-compliant lid seal member bolts. These were detected when different checks were made on the flasks. The investigation showed there had been an error in the purchasing documents of the flask spares. Further checks by the consignor showed that there were no more non-compliant bolts used on fuel flasks.

March

2009012. A consignment of sealed sources containing 185 MBq of ^{210}Po, were transported without the correct documents. The company transporting the material had not applied for the standard documents validated by the authority in the European country to which the package was sent. These documents are listed in the council regulation (Euratom) No 1493/93 concerning accountancy of transport of radioactive sealed sources between member states. There was no breach of the transport safety regulations, (DfT, 2010). The sealed sources were to be mounted in an aerosol generator.

2009013. A fuel flask was transported to a nuclear site from a nuclear power station and on arrival was found to have one lid bolt (out of 28) which was not tightened sufficiently, i.e. below the prescribed torque level. All dispatches of flasks from the nuclear power station were suspended pending an enquiry. The cause of this was a trapped lid seal due to debris on the lid face and a faulty torque tool was suspected. A maintenance inspection was carried out for other flasks and before flasks could be transported the inspection report had to be approved.

2009014. During biennial maintenance it was discovered that a fuel flask was non-compliant, because the seal weld related to the flask valve had been incorrectly tested.

2009015. On receipt of a consignment of empty 30B uranium hexafluoride (UF_6) cylinders from a UK fuel fabrication plant, the consignee measured surface contamination marginally above acceptable levels on one of the cylinders. The consignor had checked contamination levels before the cylinders were dispatched and all levels were below the acceptable level of 0.4 Bq cm^{-2}. The consignee was not able to repeat the measurement as the contamination had been removed during measurement.

April

2009016. During processing of a fuel flask, it was found that the blanking plugs for the water valves were only hand tight. The lid chock locking bolts were also only hand tight. This non-conformity was reported and a full investigation was made by the consignor of the fuel flask. Additional checks were made at the consignor's site on other flasks. It was confirmed that the components of the flask were not secure before departure from the consignor's site owing to a fault in the procedures for flask packaging.

2009017. A van carrying a troxler moisture density gauge was involved in a minor head on collision road accident. The gauge contained an Am-Be source of 1.48 GBq and a ^{137}Cs source of 300 MBq. There was no visible damage of the package and a leak test showed that there was no contamination. The package was transported onwards by another vehicle.

May

No events.

June

2009018. A fibreboard box containing radioactive material as an excepted package was loaded ready for transport at an airport by a freight forwarding company. However, this package should not have been loaded as the carrier's policy is not to transport radioactive material. The investigation by the carrier found that one of the reasons that this error occurred was because the air waybill incorrectly did not indicate that radioactive materials were present in the package.

2009019. A nuclear site reported to DfT that a fuel flask was found to have no washers fitted to the four water level valve retaining bolts. This flask had been sent from a nuclear power station in the UK. The same flask, with the missing washers had been transported between sites three times since the beginning of the year. However, the flask passed the leak test on seven occasions. The fuel handling plant was to refit washers to the flask before further onward transit. An investigation was set up and the consigning sites were asked to confirm all fuel flasks had valve bolt washers fitted.

2009020. A package containing a medical source of 5.55 GBq of ^{131}I (TI = 0.7) was misdirected to the wrong country and was therefore assumed lost. After three days it was located and then sent back to the consignor in the UK. It was found that the package was sent with the wrong consignment during loading at the airport. The member of staff responsible was retrained.

July

No events.

August

2009021. A report was made by a previous employer that a consignor was required to complete dangerous goods transport documents for consignments of radioactive material without any training. The consignor responded to the report by setting up a procedure to enable the correct training for completing dangerous goods documents.

September

2009022. A number of packages containing irradiated graphite samples were waiting to be transported under exclusive use, by special arrangement from a nuclear site in the UK. These packages had been withheld from transport since they were waiting DfT approval, as a result of a previous breach of the regulations for transport of radioactive materials. The breach was that over a period of several years numerous packages had been transported without having been maintained under the revised procedures, i.e had been shipped with the wrong seals and without having undergone an annual leak test.

2009023. An empty Type B package was returned to the consignor of irradiation sources on a lorry. On arrival it was found to be insecurely tied down on the lorry. The consignor banned the use of this carrier for transport of further consignments.

2009024. During unloading of a consignment of spent technetium generators it was discovered that documentation was missing for 4 pallets containing the generators. An investigation was set up in the country which sent the material to determine why transport was allowed without the relevant documentation.

2009025. While loading a fuel flask onto a flatrol at a nuclear power station, the flask was slightly tilted causing the crane to stop. There was no evidence of any flask damage.

October

2009026. A consignment containing three excepted packages of smoke detectors were sent for recycling and failed to arrive, as they had been misdirected. The consignment contained 185 smoke detectors with a total activity of 6.8 MBq. After four weeks the consignments were located and sent on to the recycling works.

2009027. A UK company notified DfT about a discrepancy in dose measurements on an excepted package containing ^{85}Kr, received from a customer, consigned from overseas. The surface dose rate measured at the UK premises was 10 μSv h^{-1}, greater than the maximum surface dose rate allowed for this type of package of 5 μSv h^{-1}. The customer recorded a dose rate of only 1-2 μSv h^{-1}. An investigation with the customer about the discrepancy in doses concluded that the highest surface dose rate had not been identified.

2009028. A flask was transported from a nuclear power station to a reprocessing facility and on arrival was found to have a lid bolt which was not tightened sufficiently, i.e. below the prescribed torque level. All dispatches of flasks from the nuclear power station were suspended pending an enquiry. This was similar to event 2009013, which occurred in March.

November

2009029. A 40 foot container triggered radiation detectors at a seaport in the UK. The container was found to contain 32,000 thoriated gas mantles with incorrect or absent labelling. The surface dose rate on the surface of the packages was 8.4 μSv h^{-1}, which was greater than that allowed for an excepted package. It was proposed that the mantles were repackaged as smaller consignments, so then they could be transported in excepted or exempt packages.

2009030. A lorry transporting drill pipes containing scale and sand incorporating naturally occurring radioactive material from an offshore facility was found to contain spilled material on the lorry floor on arrival at the decontamination plant. The sections of pipe had been cut into sections and placed into plastic bags and during transport the bags had ruptured. The lorry was unloaded and rewashed at the decontamination plant and returned to service. The company investigated the incident and proposed to use a more robust packaging rather than plastic bags.

December

2009031. On receipt of a consignment of 48Y cylinders at a UK nuclear site containing uranium hexafluoride (UF_6) residues, the surface contamination was measured above acceptable levels for non-fixed contamination on one of the cylinders. This was measured at between 7 and 8 Bq cm^{-2} on an area of the flask below the valve, where the contamination was visible. The consignor had measured fixed contamination levels before the cylinders were dispatched, but since this was fixed contamination it was assumed there would be no breach of the transport regulations. Transport of this cylinder was halted, pending an investigation by the consignor.

2009032. Three crates of UN2910, excepted packages carrying lead bricks and lead shot were dispatched from a hospital. On arrival the lead shot was found to be leaking from the bags within the wooden crates. The vehicle carrying the crates was withheld from service and remonitored before it could be used for transporting materials again. No contamination was found.

4.2 Events for previous years

An event was reported to the Department for Transport in October 2008, but was still ongoing when the review for events occurred in 2008 was published (Harvey, 2009). This event has been included in the summary table for the current review (Table 1) and has been added to RAMTED database but has not been considered in the discussion of events given in Section 5 or included in any of Tables 2 to 6 of this report, as Section 5 and Tables 2 to 6 only refer to events which occurred in 2009. A brief description of the event is given below. It should be noted that there were no radiological consequences to workers or members of the public as a result of this event.

October 2008

2008039. A package containing an industrial irradiation source of 3.25 PBq of ^{60}Co was inspected by DfT, before being transported abroad from a UK seaport. The package was non-conforming, because the annual leak test of the container was not up to date and it was uncertain that a leak test carried out within the previous 12 months was an acceptable test.

5 DISCUSSION OF 2009 EVENTS

5.1 General

There were 32 events reported during 2009, not including any events that are still subject to legal proceedings at the time of publication.

The numbers of events in each of the descriptive classifications that occurred in 2009 are given in Table 2. Using primary classification in the three broad categories, 7 (22%) were administrative events, 17 (53%) general shipment events and 8 (25%) INF flask shipment events. The numbers of events in these three categories in the period 1958 to 2004, expressed as a percentage of the total, were 16%, 61% and 23%, respectively (Hughes et al, 2006). Four events were given more than one event classification. Considering the primary event classifications only, the most numerous type of event involved four instances involving INF flasks, where the flask lid was defective or lid bolts were loose. For the INF events, there were seven events involving flask components that were either missing or not of the correct specification or with loose bolts plus one event involving a flask being lifted incorrectly. The problems identified for these events and those reported previously (Harvey, 2009) affected both AGR and Magnox flasks and led to several temporary suspensions of flask shipments. Other problems involving flask components not meeting the required specification were reported to DfT; most were discovered prior to dispatch and did not lead to a non-compliant shipment and consequently do not meet the criteria for inclusion in this report. The organisations involved in consigning INF flasks have produced a comprehensive report identifying root causes which has been presented to the DfT who are working with industry to develop a programme of remedial action.

The number of events in 2009 was less than in 2008, but more than reported before that: there were 39 events in 2008[*], 26 events reported in 2007, 29 events in 2006 and 16 events in 2005. The average annual number of recorded events during the period 1958 to 2004 was approximately 17 (Hughes et al, 2006), although in the first decade of

[*] This figure includes the 38 events described in the 2008 review (Harvey, 2009) and the event reported in the 2009 review (see Section 4.2)

that period events were probably under-reported. Over the past 20 years the annual number of events has fluctuated between 11 and 44 with an average of 26 events. The number of events in 2009 was therefore slightly higher than this long-term average, maybe as a result of the increased number of INF flask events identified, which also occurred in 2008.

In 2009 there was 1 event involving the discovery of radioactive material in shipments containing material which was thought to be non-radioactive.

Table 3 shows an analysis of the events by material category. During 2009, the largest group of events (11 events) involved the transport of medical and industrial radioisotopes. The percentage of events (34%) involving medical and industrial isotopes was lower than the annual average (47%) for events in the period 1958 to 2004 (Hughes et al, 2006). There were 3 events (9%) involving transport of material which was in an undefined category. Eight events involved irradiated nuclear fuel flasks: seven involving faulty flasks and one which was lifted incorrectly. Of these eight fuel flasks, six contained irradiated nuclear fuel and two contained fuel residues. Three further events involved residues, two of these were contaminated uranium hexafluoride (UF_6) containers and one involved NORM material.

Three events (9%) involved transport of radioactive waste, 2 of which were a result of conveyance and package problems. Only 2 events (3%) involved transport of consumer products. A single event involved transport of an empty package and the remaining event (3%) involved the transport of lead shielding.

Table 4 gives an analysis of the events by mode of transport: 8 events involved shipments by rail (25%), 7 by air (22%), 5 by sea/road and sea (16%), 10 by road (31%). The proportion of sea events (16%) was higher than the long-term annual average (7%). For rail the proportion of events in 2009 (25%) is similar to the long-term annual average (24%). The number of road and rail events in 2009 (18) is higher than the average annual number (approximately 10) during the period 1958 to 2004 (Hughes et al, 2006). There was one event (3%) where a package was damaged by a fork-lift truck, which was lower than the long-term annual average of 22%. There were a large number of these events during the 1970s, but they now occur infrequently due to better handling techniques.

Table 2. Numbers of 2009 events in each classification

Event classification	Event classification code (see Table B6)	First classification	Second classification	Third classification
Administrative	AC111	1	0	0
	AG111	1	1	0
	AG211	3	0	0
	AG221	1	0	0
	AG241	1	0	0
	AP111	0	1	0
Total		7	2	0
General (non-INF) Shipments	SC411	1	1	1
	SC511	2	0	0
	SP111	2	0	0
	SP121	1	0	0
	SP141	1	0	0
	SP171	2	1	0
	SP212	1	0	0
	SP221	3	0	0
	SP241	1	0	0
	SP341	3	0	0
Total		17	2	1
INF Flask shipments	FP131	4	0	0
	FP132	1	0	0
	FP141	2	0	0
	FP211	1	0	0
Total		8	0	0

Table 3. Classification* of 2009 events by material category

Material		Administrative			General (non-INF) Shipments		INF Flask shipments			Percentage	
Code	Category	General	Conveyance	Package	Conveyance	Package	Conveyance	Package	Total	2009†	1958-2004
M00	Unknown	2	0	0	0	1	0	0	3	9	N/A‡
M01	Uranium ore concentrate	0	0	0	0	0	0	0	0	0	4
M02	Pre-fuel material	0	0	0	0	0	0	0	0	0	3
M03	New fuel	0	0	0	0	0	0	0	0	0	<1
M04	Irradiated fuel	0	0	0	0	0	0	6	6	19	13
M05	Residues	0	0	0	0	3	0	2	5	16	14
M06	Radioactive wastes	1	0	0	1	1	0	0	3	9	8
M07	Medical & industrial radioisotopes	2	1	0	1	7	0	0	11	34	47
M08	Radiography sources	0	0	0	0	0	0	0	0	0	10
M09	No radioactive material	0	0	0	1	0	0	0	1	3	<1
M10	Consumer products	1	0	0	0	1	0	0	2	6	1
M11	Other	0	0	0	0	1	0	0	1	3	<1
Total		6	1	0	3	14	0	8	32	100	100

Notes

*: First classifications only (see Table B6 for descriptions of event classifications).

†: With a sample size of 38 events, interpretation of these rounded percentages must be made with care. The total of 100% is of the unrounded values.

‡: This material category is a new addition to the database; no comparison can be made with previous data.

Table 4. Classification* of 2009 events by mode of transport

Mode of transport		Administrative			General (non-INF) Shipments		INF Flask shipments			Percentage	
Code	Category	General	Conveyance	Package	Conveyance	Package	Conveyance	Package	Total	2009†	1958-2004
V00	Unknown	0	0	0	0	1	0	0	1	3	N/A‡
V01	Rail	0	0	0	0	0	0	8	8	25	24
V02	Air	3	0	0	0	4	0	0	7	22	13
V03	Sea	1	0	0	0	0	0	0	1	3	7
V04	Road > 1.5 t (lorry)	1	0	0	2	3	0	0	6	19	15
V05	Road < 1.5 t (van)	0	1	0	1	0	0	0	2	6	13
V06	Road Car	0	0	0	0	0	0	0	0	0	3
V07	Road Unknown	0	0	0	0	2	0	0	2	6	<1
V08	Fork-lift truck	0	0	0	0	1	0	0	1	3	22
V09	Other	0	0	0	0	0	0	0	0	0	<1
V10	Road and sea	1	0	0	0	3	0	0	4	13	<1
V11	Road and rail	0	0	0	0	0	0	0	0	0	<1
V12	Road and air	0	0	0	0	0	0	0	0	0	<1
Total		6	1	0	3	14	0	8	32	100	100

Notes

*: First classifications only (see Table B6 for a description of event classifications).

†: With a sample size of 38 events, interpretation of these rounded percentages must be made with care. The total of 100% is of the unrounded values.

‡: This material category is a new addition to the database; no comparison can be made with previous data.

5.2 Effects on packages

Table 5 shows an analysis of the events in terms of the package condition. A list of types of packages considered in the database is given in Table B5; definitions of the codes used to identify package conditions are given in Table B7 of Appendix B. For one event there was no package. In 12 of the 32 events there was no damage or threat of damage to the packages involved. For 8 events there was no report of damage to the package or increase in dose rate, but there was a minor potential to cause damage. For 2 events there was no report of damage to the package or increase in dose rate, but there was a high potential to cause damage. For one event there was defective or poor condition of the package, but without increase in dose rate or loss of containment. Two events had a package with minor damage without increase in dose rate; two events involved package damage with loss of containment; 3 events involved the discovery of contamination outside of the package and one event involved improper packaging with loss of shielding or containment.

Table 5. Nature of package deficiency by type of package

Package deficiency or damage		Type of package (as specified or assumed)							
Code	Description	Excepted	A	BU	BM	BMF	IP2	Others	Total
D01	No package	0	0	0	0	0	0	1	1
D03	No damage or threat of damage to package	1	2	0	2	5	1	1	12
D04	No report of damage or increase in dose rate, but potential to cause damage to the package (lower category)	2	2	1	0	1	0	2	8
D05	No report of damage or increase in dose rate, but potential to cause damage to the package (upper category).	0	1	0	0	0	0	1	2
D06	Defective or poor condition, without increase in dose rate or loss of containment	0	1	0	0	0	0	0	1
D07	Minor damage without increase in dose rate or loss of containment	1	1	0	0	0	0	0	2
D10	Damage with loss of containment	1	0	0	0	0	0	1	2
D12	Contamination outside package	1	0	0	0	0	0	2	3
D13	Improper package with loss of shielding or containment – inappropriate contents	1	0	0	0	0	0	0	1
Total		7	7	1	2	6	1	8	32

5.3 Radiological consequences

Table 6 shows the likely radiological consequences for the events in 2009, analysed by material category. Table B8 in Appendix B provides a description of the categories for radiological consequences. Of the 32 events, 24 were categorised as 'None', indicating no radiological consequences for those events and 8 were categorised as 'Extremely low, not assessed'. Within this latter category, four events involved exposure to medical sources, one of which had been damaged, one which had been found by a member of the public and had the potential to cause exposure, one which had been misrouted and had a TI of 0.7 and therefore had the potential to cause exposure and one source which had a discrepancy in dose rate measurement. One event involved handling NORM material which had leaked out of the package; one event involved a stolen density gauge, which had the potential for exposure if it was taken apart; one event where waste material was being transported by exclusive use without being leak tested; one event involving a shipment of consumer products in the wrong package. The doses from these events would be less than a few microsieverts to the workers involved and to the public.

There were no events categorised as 'Assessed, lower category' involving effective doses below 1 mSv or in the 'Assessed, upper category' involving effective doses above 1 mSv or extremity doses over 50 mSv.

Table 6. Radiological consequences by material category

Material		Radiological consequences				
Code	Category	None	Not assessed, extremely low	Assessed, lower category (< 1mSv)	Assessed, upper category (> 1mSv)	Total
M00	Unknown	3	0	0	0	3
M04	Irradiated fuel	6	0	0	0	6
M05	Residues (inc. discharged INF flasks)	4	1	0	0	5
M06	Radioactive wastes	2	1	0	0	3
M07	Medical and industrial radioisotopes	6	5	0	0	11
M09	Non radioactive material	1	0	0	0	1
M10	Consumer products	1	1	0	0	2
M11	Other	1	0	0	0	1
Total		24	8	0	0	32

5.4 Other occurrences

During 2009 some occurrences were notified to the Department for Transport that have not been included in the database as transport events, since they do not meet the criteria for inclusion. Although they were not transport events for the purposes of this report, they are briefly noted here for completeness (see Table A1 of Appendix A for detailed descriptions).

An operation called Project Cyclamen was set up in April 2003 to provide the capability to routinely screen all forms of traffic at points of entry to the United Kingdom for the illicit movement of radioactive materials.

In 2009 there were a number of consignments which triggered the Cyclamen radiation detector alarms at UK airports and ports. Advice from DfT was sought for seven of these events. Six of these were due to radioactively contaminated steel. These involved consignments of items contaminated with ^{60}Co, such as metal flanges, steel needle valves and anchor bolts for plaster board. In recent years such items have been returned to the consignor. Even though the plaster board bolts had a high surface dose rate of 2 mSv h^{-1}, it is likely that the transport workers were only exposed to the container holding the bolts resulting in a dose of less than a few microsieverts. However, such items have the potential to cause higher doses if member of the public are exposed to the radioactivity in them and care should be taken that none of these items are in the public domain. An estimate of the dose from such items in a typical domestic scenario showed that members of the public would receive an annual dose of less than 1 mSv y^{-1}. This estimate assumes that an individual erects a mirror with 4 plaster bolts and is exposed for 8 hours a day at a distance of 1 m.

The remaining event involved a consignment containing a mineral sample, which did not have the correct labelling to indicate that it contained radioactive material. The maximum dose rates outside the packages was about 15 µSv h^{-1}, which would give a dose to the workers handling the packages of less than a few microsieverts.

6 CONCLUSIONS

During 2009 there were 32 accidents and incidents, involving the transport of radioactive materials from, to, or within the United Kingdom and this report includes descriptions of each event. The number of events in 2009 was less than those reported in 2008 (39 events), but more than previous years: there were 25 events reported in 2007, 27 events in 2006 and 16 events in 2005.

The number of events in 2009 was slightly higher than the annual average over the past 20 years (26 events). This variation can be attributed to statistical fluctuation and is not indicative of any long-term trend. The events reported for 2009 are in general similar to those reported in recent years.

Project Cyclamen has resulted in the discovery of radioactive material and has partially contributed to the increase in the overall number of events compared to previous years. There were also 8 events involving fuel flasks, mainly due to loose lid bolts. Only one of these events involved the discovery of parts that were not of the correct specification. In terms of the overall safety of the flasks these errors were relatively minor. However, it is essential that these flasks are maintained and operated to the highest quality standards.

None of the events that occurred in 2009 resulted in any significant radiation doses to workers or members of the public. There were three events involving potentially high dose rates from medical sources one of which was damaged. An event involving a stolen density gauge had also the potential of giving relatively high dose rates if it was taken apart. However, the maximum dose to workers or members of the public from these events is likely to be only a few microsieverts.

This report also provides details of an event reported to the Department for Transport in 2008, which was not included in the review for 2008 (Harvey, 2009). This event resulted in no radiological consequences to workers or members of the public.

Most of the cyclamen events which are discussed in Appendix A, are related to steel items contaminated with ^{60}Co, being imported into the United Kingdom without the consignor's knowledge that they are contaminated. Some of these items have high surface dose rates, but the doses would be below 1 mSv y^{-1} if they were allowed to be distributed in the public domain.

The details of the 32 events occurred in 2009 and of the additional event occurred in 2008 described in this review have been added to the RAdioactive Materials Transport Event Database (RAMTED), bringing the total number of reported events since 1958 to 949.

7 REFERENCES

DfT (2009). Personal communication, DfT.

DfT (2010). Personal communication, DfT.

Gelder R, Mairs JH and Shaw KB (1986). Radiological impact of transport accidents and incidents in the United Kingdom over a twenty-year period. IN Proceedings of the International Symposium on the Packaging and Transportation of Radioactive Materials, PATRAM '86, Davos, June 1986.

Harvey MP (2009). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2008 Review. Chilton, HPA-RPD-056.

Harvey MP and Hughes JS (2008). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2007 Review. Chilton, HPA-RPD-048.

Hesketh N, Watson SJ, Jones AL and Hughes JS (2006). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2005 Review. Chilton, HPA-RPD-021.

Hughes JS and Shaw KB (1990). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1989 Review. Chilton, NRPB-M230.

Hughes JS and Shaw KB (1991). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1990 Review. Chilton, NRPB-M310.

Hughes JS and Shaw KB (1992). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1991 Review. Chilton, NRPB-M364.

Hughes JS and Shaw KB (1993). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1992 Review. Chilton, NRPB-M437.

Hughes JS and Shaw KB (1994). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1993 Review. Chilton, NRPB-M475.

Hughes JS and Shaw KB (1995). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1994 Review. Chilton, NRPB-M549.

Hughes JS and Shaw KB (1996a). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1995 Review. Chilton, NRPB-M662.

Hughes JS and Shaw KB (1996b). Accidents and Incidents Involving the Transport of Radioactive Materials in the UK, from 1958 to 1994, and their Radiological Consequences. Chilton, NRPB-R282.

Hughes JS and Shaw KB (1997). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1996 Review. Chilton, NRPB-M862.

Hughes JS and Shaw KB (1998). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1997 Review. Chilton, NRPB-M964.

Hughes JS and Shaw KB (1999). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1998 Review. Chilton, NRPB-M1082.

Hughes JS, Warner Jones SM and Shaw KB (2001a). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 1999 Review. Chilton, NRPB-M1256.

Hughes JS, Warner Jones SM and Shaw KB (2001b). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2000 Review. Chilton, NRPB-M1320.

Hughes JS, Roberts D and Watson SJ (2006). Review of Events Involving the Transport of Radioactive Materials in the UK, from 1958 to 2004, and their Radiological Consequences. Chilton, HPA-RPD-014.

Hughes JS and Harvey MP (2007). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2006 Review. Chilton, HPA-RPD-034.

IAEA and NEA (2001). The International Nuclear Event Scale (INES). User's Manual, 2001 Edition. IAEA and OECD/NEA. IAEA-INES-2001.

ICAO (2006). International Civil Aviation Organisation. Technical Instructions for the Safe Transport of Dangerous Goods by Air (Class 7) (2007-2008 Edition).

IMO (2006). International Maritime Organisation. Dangerous Goods Code (IMDG Code) (Class 7).

MCA (2006). Maritime and Coastguard Agency. The Carriage of Dangerous Goods and Marine Pollutants in Packaged Form - Amendment 33-06 to the International Maritime Dangerous Goods Code. Merchant Shipping Notice MSN 1806 (M) (2006).

OTIF (2007). Intergovernmental Organisation for International Carriage by Rail. Convention concerning the International Carriage of Dangerous Goods by Rail (COTIF) Appendix B. Uniform rules concerning the contract for the International Carriage of Goods by Rail (CIM) Annex 1, Regulations concerning the International Carriage of Dangerous Goods by Rail (RID) (Class 7) (2007), JERID.

Roberts D, Watson SJ, Jones AL and Hughes JS (2005). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2004 Review. Chilton, HPA-RPD-007.

Shaw KB, Hughes JS, Gooding TD and McDonough L (1989). Review of the Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK from 1964 to 1988. Chilton, NRPB-M206.

UK Parliament (1994). The Air Navigation (Dangerous Goods) Regulations, 1994, SI 1994 No 3187. London, TSO.

UK Parliament (1997a). The Merchant Shipping (Dangerous Goods and Maritime Pollutants) Regulations 1997, SI 1997 No 2367. London, TSO.

UK Parliament (1997b). The Carriage of Dangerous Goods by Road Regulations (Northern Ireland) 1997, SI 1997 No 248. London, TSO.

UK Parliament (2007). The Air Navigation (Dangerous Goods) Amendment Regulations 2007, SI 2007 No28. London, TSO.

UK Parliament (2009). The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009, SI 2009 No 1348. London, TSO.

UNECE (2007). United Nations Economic Commission for Europe. European Agreement concerning the international carriage of dangerous Goods by Road (ADR) (Class 7) (2007-2008 Edition).

Warner Jones SM, Hughes JS and Shaw KB (2002a). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2001 Review. Chilton, NRPB-W29.

Warner Jones SM, Hughes JS and Shaw KB (2002b). Experience in the Analysis of Accidents and Incidents involving the Transport of Radioactive Materials. *RAMTRANS*, **13** (3-4), 371-376.

Warner Jones SM and Jones AL (2004). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2002 Review. Chilton, NRPB-W53.

Watson S (2004). Review of the Content and Structure of the RAMTED Database. Chilton, NRPB-EA/1/2004.

Watson SJ and Jones AL (2004). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2003 Review. Chilton, NRPB-W64.

8 GLOSSARY

Term	Description
Absorbed Dose	Measured in Grays (Gy), it is the amount of energy absorbed per kilogram of matter, for example tissue, as a result of exposure to ionising radiation.
Activity	The number of radioactive decays per unit time in a given material. Normally measured in disintegrations per second (Bq).
AGR	Advanced Gas-cooled Reactor. Used in the UK's second generation of gas-cooled nuclear power stations.
Alpha emitter	A radionuclide that decays emitting an alpha particle.
Alpha particle	A particle emitted by a radionuclide consisting of two protons and two neutrons (i.e. the nucleus of a helium atom).
Beta emitter	A radionuclide that decays emitting a beta particle.
Beta particle	An electron or positron emitted by a radionuclide.
Category	Packages other than excepted packages and overpacks must be assigned to either category I-White, II-Yellow or III-Yellow, depending on the maximum dose rate at the surface and at 1 m from the surface and must be labelled accordingly.
Committed Effective Dose	A measure of the total lifetime radiation exposure of an individual from intakes of radioactive material. The effective dose received across the life-time of an individual (taken up to the age of 70 for members of the public), from an ingestion or inhalation of radionuclides.
Effective Dose	Measured in Sieverts (Sv), it is a measure of the overall exposure of an individual from ionising radiation. It is dependent on the absorbed dose, type of radiation and regions of the body affected. Since the Sievert is a large unit, doses are more commonly expressed in millisieverts (mSv) or microsieverts (μSv).
Effective dose rate (or Dose rate)	The rate at which effective dose from external radiation is received, measured in units of Sv h^{-1}, or mSv h^{-1}.
Flatrol	A type of rail wagon used to carry INF flasks.
Irradiated Nuclear Fuel (INF) Flask	A Type B package used to transport irradiated nuclear fuel (see packages).
Ionising Radiation	Radiation capable of breaking chemical bonds, causing ionisation and damage to biological tissue.
Label	Apart from excepted packages all packages must be labelled with a diamond shaped warning label which gives information on the contents of the package.
Low toxicity alpha emitters	Natural uranium, depleted uranium, natural thorium, ^{235}U, ^{238}U, ^{232}Th, ^{228}Th and ^{230}Th when contained in ores or physical and chemical concentrates; or alpha emitters with a half-life of less than 10 days.
Magnox	The first generation of the UK's gas-cooled nuclear power stations.
NAIR (National Arrangements for Incidents involving Radioactivity)	A scheme designed to provide assistance to the police when dealing with an incident which involves, or is suspected to involve, radioactive material.
NORM	Naturally Occurring Radioactive Material.
Nuclide	A species of atom characterised by a nucleus with a specific number of protons and neutrons.
Overpack	An enclosure such as a box or bag which is used by a consignor to transport a number of packages as a single unit.

Term	Description
Package	There are five main types of packages used to carry radioactive material: • Industrial Packages are industrial containers, such as drums, used to carry bulky low activity materials, or contaminated items. • Excepted packages are simple packages used to carry low activity materials and sources. They are mainly used to transport low activity diagnostic test materials to hospitals. • Type A packages are used to transport medium activity material such as medical or industrial isotopes. They must withstand normal conditions of transport including minor mishaps. • Type B packages are used to transport high activity sources and materials, such as Irradiated Nuclear Fuel (INF). They provide shielding from high radiation levels even under extreme circumstances. They must meet severe mechanical and thermal test requirements, which simulate accident conditions. • Type C packages are for the transport by air of greater quantities of radioactive material than is allowed to be transported by air in Type B packages. They must be designed to withstand very serious accidents such as aircraft crashes.
Radionuclide	A nuclide which spontaneously loses energy or disintegrates into another nuclide, resulting in the emission of ionising radiation.
RADSAFE	An emergency response plan operated by the main carriers of radioactive materials.
Special form radioactive material	An indispersible solid radioactive material or a sealed capsule containing radioactive material.
Transport Index	A number equal to the maximum dose rate, at 1 m from the surface of the package, overpack or freight container, measured in mSv h^{-1} multiplied by 100. This number is used to control radiation exposure from a group of packages during transport.

APPENDIX A Summary of Cyclamen events not included as transport events

In all these cases the consignor could not be reasonably expected to recognise these as radioactive material and they were therefore not classified as transport events.

Table A1. Summary of Cyclamen events not included in RAMTED database

General information on Cyclamen event category	Additional information on event
Contaminated metal	
A number of consignments were detected at UK seaports and one at a UK airport, containing radioactively contaminated steel. All six consignments contained manufactured steel parts contaminated with ^{60}Co. The dose to workers from handling these packages range to a few µSv to a few 10's of µSv for the consignments where higher dose rates were measured out side the packages In most cases the manufactured steel parts were sent back to the consignor, or released in the UK if they were below the exemption level.	A container arrived at a seaport in the UK and was found to contain a package with 25 metal flanges which had been contaminated with ^{60}Co. The dose rate outside the transported container was 1.5 µSv h^{-1}.
	A container arrived at a seaport in the UK and was found to contain a package with steel needle valves which had been contaminated with ^{60}Co. The dose rate was 0.5 µSv h^{-1} at 1 m and 20-30 µSv h^{-1} in contact with the valves. A dose estimate of 50 µSv was made for workers shipping the package. The consignment was transported from the UK port to the consignee and then sent back to the consignor by air freight. A similar package was also transported to New Zealand from the consignor later in 2009.
	A 40 foot container arrived at a seaport in the UK and found to contain a mixture of goods from a number of companies, including two boxes contained stainless steel needle valves which had been contaminated with ^{60}Co. The dose rate on the surface of the package was 8.5 µSv h^{-1} and the total activity of these items was 10 MBq. These items were repackaged in excepted packages and returned to the consignor.
	A container arrived at a seaport in the UK and found to contain packages of steel plaster board anchor bolts contaminated with ^{60}Co. The peak dose rate close to the bolts was 2mSv h^{-1}, while the dose rate at the rear if the container 7.5 µSv h^{-1}.
	A container arrived at a seaport in the UK and was found to contain a package containing 13 boxes with metal flanges which had been contaminated with ^{60}Co, giving a surface dose rate of about 1 µSv h^{-1}. All but one boxes had activity concentrations below the exemption levels and were returned to the consignor by sea. The remaining box had activity concentrations of up to 27 Bq g^{-1}. This box was sent back to the consignor by air.
	A package arrived at an airport in the UK and was found to contain a wooden box with metal flanges contaminated with ^{60}Co. The activity levels were required to be checked to see if they were below the exemption activity.
Other	
	A package containing mineral samples was detected at a UK seaport within a passenger vehicle, driving from a ferry. The surface dose rate outside the package was 15 µSv h^{-1}. The mineral samples were over packed to reduce the surface dose rate to 3.4 µSv h^{-1} and labelled an excepted package. The vehicle and package were allowed to continue their onward journey

APPENDIX B Information System Used in the RAdioactive Materials Transport Event Database (RAMTED)

The details of each event are stored in a computer database by the use of descriptive text and alphanumeric coding systems that are described in Table B1 below.

Table B1. Information on transport events recorded in the RAMTED database

Information	Description
Event ID	The events are numbered using a 7 digit identifier with the format YYYYXXX, where YYYY is the year of the event and XXX is a sequential figure.
Date	The date is recorded in the format DD/MM/YYYY
Source	Information regarding events is obtained from the following sources: Civil Aviation Authority, Dangerous Goods Division of the Department for Transport, Health Protection Agency Radiation Protection Division, National Arrangements for Incidents involving Radioactivity, Environment Agency, Health & Safety Executive and others. The source of the information is given for each event, together with the event identifier used by the source organisation.
Type of event	This coding gives the broad type of event, classified as occurring either during the moving phase of transport operations or during handling before or after movement. Furthermore, events occurring during either the moving or handling phases are categorised either as accidents or as incidents. Alternatively, events may be classified as contamination events. More information on the types of event is given in Table B2
Regional location of event	The location at which the event occurred is given, if known, together with a code assigning the location to one of a number of defined geographical regions.
Mode of transport	A code is given to identify the mode of transport for each event. Codes and their definitions are given in Table B4.
Category of material	A code is given to identify the type of material for each event. Codes and their definitions are given in Table B3
Consignor	The name and address of the company/organisation that despatched the shipment is given for each event, if known.
Consignee	The name and address of the destination company/organisation is given for each event, if known.
Carrier	The name and address of the carrier (and sub-carrier, if appropriate) is given for each event, if known.
Description of event	A brief description of the event is given in words.
Activity release	The activity, in TBq, of any radioactive material released into the environment is given for each event.
Worker doses	The maximum dose received by workers from an event is given in mSv, if known.
Public doses	The maximum dose received by the public from an event is given in mSv, if known.
INES ratings	The INES rating assigned to each event is given, if known.
INES Conditions	The INES rating is partly dependent on whether certain conditions applied to the event. A record is made of whether these conditions did apply for the event, if known.
Event implications	Implications such as worker or public safety implications, or environmental implications are given, if known.
Nuclear industry and airport events	It is recorded for each event if the event involved the nuclear industry or damage to a package at an airport, if known.
Emergency action	It is recorded for each event if emergency action was taken, if known.
Additional information	Any additional information, including photos if appropriate, is recorded for each event.
Description of packages	A description of each package is given, if known.
Package type	For each package, a package type is given, using the codes given in Table B5.

Table B1. Information on transport events recorded in the RAMTED database

Information	Description
Transport Index	For each package the Transport Index (TI) is given, if known (see Glossary for a definition of Transport Index)
Radionuclides	The radionuclides contained in each package are listed by their chemical symbol and mass number, with a record of whether or not each nuclide is a sealed source or a fission product.
Activity	The activity of each radionuclide is given, in TBq, if known.

Table B2. Codes used to identify types of events in the RAMTED database

Code	Definition	Description
TA	Transport accidents	A transport accident is defined as any event during the carriage of a consignment of radioactive material that causes damage to the consignment or significant damage to the conveyance so that the conveyance could not continue its journey.
TI	Transport incidents	A transport incident is defined as any event, other than an accident, occurring before or during the carriage of a consignment of radioactive material which caused, or might have caused, damage to or loss of the consignment or unforeseen radiation exposure of workers or members of the public.
HA	Handling accidents	A handling accident is defined as an event during the loading, trans-shipping, storing or unloading of a consignment of radioactive material and which caused damage to the consignment, eg a package falling from a fork-lift truck and subsequently being run over or a package being dropped owing to crane failure during handling.
HI	Handling incidents	A handling incident is defined as an event, other than an accident, during the loading, trans-shipping, storing or unloading of a consignment of radioactive material which caused, or could have caused, damage to or loss of the consignment or unforeseen exposure of workers or members of the public.
C	Contamination	A contamination event is defined as an event where radioactive contamination is found on the surface of the package or conveyance in excess of the regulatory limit.

Table B3. Codes used to identify the type of material of an event in the RAMTED database

Code	Definition
M00	Unknown
M01	Uranium ore concentrate (UOC)
M02	Pre-fuel material
M03	New fuel
M04	Irradiated fuel
M05	Residues including discharged nuclear fuel flasks
M06	Radioactive wastes
M07	Medical and industrial radioisotopes
M08	Radiography sources
M09	No radioactive material
M10	Consumer products
M11	Other

Table B4. Codes used to identify modes of transport of an event in the RAMTED database

Code	Definition
V00	Unknown
V01	Rail
V02	Air
V03	Sea
V04	Road – lorry > 1.5 t
V05	Road – van < 1.5 t
V06	Road – car
V07	Road – unknown
V08	Fork-lift truck
V09	Other (including crane)
V10	Road and sea
V11	Road and rail
V12	Road and air

Table B5. Codes used to identify the type of package in an event in the RAMTED database

Code	Definition
Type A Package Codes	
A	Type A
AP	Presumed to be Type A
AF	Type A, with fissile material
AFP	Presumed to be Type A, with fissile material
Type B Package Codes	
B	Type B
BP	Presumed to be Type B
BF	Type B, with fissile material
BFP	Presumed to be Type B, with fissile material
BM	Type B(M)
BMP	Presumed to be Type B(M)
BMF	Type B(M), with fissile material
BMFP	Presumed to be Type B(M), with fissile material
BU	Type B(U)
BUP	Presumed to be Type B(U)
BUF	Type B(U), with fissile material
BUFP	Presumed to be Type B(U), with fissile material
Type C Package Codes	
C	Type C
CP	Presumed to be Type C
CF	Type C, with fissile material
CFP	Presumed to be Type C, with fissile material
Excepted Package Codes	
E	Excepted
EP	Presumed to be Excepted

Table B5. Codes used to identify the type of package in an event in the RAMTED database

Code	Definition
Exempt Package Codes	
X	Exempt
XP	Presumed to be Exempt
Industrial Package Codes	
IP	Industrial Package, any type
IPP	Presumed to be an Industrial Package, any type
IPF	Industrial Package, any type, with fissile material
IPFP	Presumed to be an Industrial Package, any type, with fissile material
IP1	Industrial Package, Type 1 (IP-1)
IP1P	Presumed to be an Industrial Package, Type 1
IP1F	Industrial Package, Type 1, with fissile material
IP1FP	Presumed to be an Industrial Package, Type I, with fissile material
IP2	Industrial Package, Type 2 (IP-2)
IP2P	Presumed to be an Industrial Package, Type 2
IP2F	Industrial Package, Type 2, with fissile material
IP2FP	Presumed to be an Industrial Package, Type 2, with fissile material
IP3	Industrial Package, Type 3 (IP-3)
IP3P	Presumed to be an Industrial Package, Type 3
IP3F	Industrial Package, Type 3, with fissile material
IP3FP	Presumed to be an Industrial Package, Type 3, with fissile material
Other Codes	
CV	Contaminated conveyance only
NIL	No radioactive material carried
NR	Packaged item, but not in recognised package type
SC	Item carried within load of scrap
UK	Unknown packaging status
UPX	Unpackaged item, which should be packaged
UPY	Unpackaged item, which is OK to be unpackaged

B1 EVENT CLASSIFICATION SYSTEM

The analysis of the database of events is facilitated by the use of classification systems that define the description of the event, the type of package damage or deficiency and the extent of any radiological consequence. These three classification systems are set out in Tables B6, B7 and B8. Each event is characterised by the allocation of the alphanumeric codes shown in Table B6 and each package is characterised for damage or deficiency by the codes shown in Table B7. The radiological consequences of each event are characterised by the allocation of the codes shown in Table B8.

Table B6. Classification of reported transport events

Area/Subject	Item	Sub-item		Description
A – Administrative (all packages)				
G – General	1 – Training	1	1	Insufficient worker training
	2 – Documents	1	1	Consignor's certificate incorrect or absent normally the "Dangerous goods transport document"
		2	1	Other shipment documents incorrect or absent, normally the "Instructions in Writing"
		3	1	Correct contents but wrongly described in documents
		4	1	Material undeclared as being radioactive
		5	1	Accounting error, ie apparent loss of package
	3 – Delivery	1	1	Administrative difficulty or error, returned to consignor or re-consigned
	4 – False alarm	1	1	Suspected incident but none found
C – Conveyance	1 – Placards	1	1	Correct vehicle placards not displayed
		1	2	Placards displayed but no sources carried
	2 – Excessive TI	1	1	Excessive TI on conveyance or in stowage hold
P – Package	1 – Labels	1	1	Insufficient or incorrect package labels
		1	2	Labels on empty package
		2	1	Incorrect TI on package label
		3	1	Incorrect radionuclide or activity on package label
	2 – Marking	1	1	Package type unmarked or wrongly marked
S – Shipments, general (not irradiated nuclear fuel flasks)				
C – Conveyance	1 – Load	1	1	Excessive load on conveyance
	2 – Mechanical	1	1	Faulty conveyance, or mechanical failure
	3 – Security	1	1	Locks or security devices: insecure, insufficient or defective
	4 – Tie-downs	1	1	Tie-downs or similar devices: insufficient or defective
	5 – Accidents	1	1	Collisions and other accidents, without fire
	6 – Accident/fire	1	1	Collisions and other accidents, with fire
	7 – Fire	1	1	Spontaneous fire on conveyance
	7 – Stowage	1	1	Inappropriate stowage conditions
P – Package	1 – Preparation	1	1	Poor standard of packaging or containment
		2	1	Incomplete package, insecure inner container
		3	1	Incomplete package, insufficient shielding
		4	1	Incorrect contents or package type
		5	1	Material in supposedly empty package
		6	1	Contamination inside package
		7	1	Contamination outside package
	2 – Loss/disposal	1	1	Stolen and recovered
		1	2	Stolen, not recovered
		2	1	Lost, found, temporary loss, wrong destination or wrong conveyance
		2	2	Lost, not recovered
		3	1	Lost at sea and recovered
		3	2	Lost at sea, not recovered
		4	1	Inappropriate disposal
		5	1	Radioactive material in scrap metal

Table B6. Classification of reported transport events

Area/Subject	Item	Sub-item		Description
P – Package	3 – Damage	1	1	Spontaneous mechanical failure of package, including leakage
		2	1	Deliberate damage or interference
		3	1	Damaged by falling from or within conveyance, or by falling object, or by external object
		4	1	Damaged during cargo handling
		5	1	Damaged due to broken or loose tie-downs
F – Irradiated nuclear fuel flasks				
C – Conveyance	1 – Flatrol/ HGV	1	1	Flatrol or HGV problem eg buffers, brakes, canopy not correct, including significant overheating of wheel or axle
	2 – Accident	1	1	Collision
		2	1	Derailment during low speed marshalling
		3	1	Inadvertent decoupling
		4	1	Fire on the conveyance
	3 – Contamination	1	1	Flatrol or HGV contaminated above regulatory limits.
		2	1	Fixed-contamination above 5 μSv h^{-1}
P – Package	1 – Preparation	1	1	Shock absorber damaged or unsatisfactory
		2	1	Tie-down bolts insufficient or defective
		3	1	Lid, defective or loose bolts
		3	2	Lid seal unapproved or obsolete
		4	1	Water level valve defective
		5	1	Discharged flask containing fuel rod, excessive deposit, or other incorrect contents
		6	1	Faulty test procedures
		7	1	Fuel not fully covered by water
		8	1	Other minor preparation error
	2 – Mechanical	1	1	Mishandled during loading or unloading
		2	1	Venting system or valve problem
	3 – Contamination	1	1	Contamination of surface above regulatory limits.
		2	1	Other: poor standard of decontamination

Table B7. Classification of package deficiency associated with the transport event

Deficiency Code	Deficiency	Examples/Comments
D01	No package	No package involved in event.
D02	Contaminated conveyance	Contaminated conveyance only with no package involved.
D03	No damage to package or threat of damage	Administrative errors and false alarms. Inadequate locks and security devices. Inappropriate or wrong contents. Obsolete lid seals.
D04	No report of damage or increase in dose rate, but potential to cause damage to the package. Lower category	Package temporarily lost or mislaid, or wrong destination, or put on wrong conveyance. Low speed derailments and collisions. Flatrol decoupling. Faulty conveyance or tie-downs.

Table B7. Classification of package deficiency associated with the transport event

Deficiency Code	Deficiency	Examples/Comments
D05	No report of damage or increase in dose rate, but potential to cause damage to the package. Upper category	Stolen source. Unretrieved lost package. Inappropriate disposal. Severe collision. Fire on the conveyance.
D06	Defective or poor condition, without increase in dose rate or loss of containment	Package of generally poor standard, corroded or other deterioration. Parts missing or mechanical defect.
D07	Minor damage without increase in dose rate or loss of containment	Damage to outer packaging: knocked, dropped or dented. Conveyance overturned.
D08	Severe damage without increase in dose rate or loss of containment	Severely damaged: crushed. Scorched by fire. Part of container, eg lid, knocked off.
D09	Damaged with increase in dose rate but without loss of containment	Increased dose rate outside package caused by damage or fire en route. Includes internal leakage and other mechanical failure. No loss of material outside package.
D10	Damaged with loss of containment	Leakage out of package caused by damage or fire en route. Includes material or source(s) released from package. Usually accompanied by some increase in dose rate.
D11	Contamination inside package	Unexpected contamination or other residual material found inside package.
D12	Contamination outside package	Fuel flask contamination above regulatory limits. Any other contamination above IAEA limits.
D13	Improper package with loss of shielding or containment – inappropriate contents	Activity unexpectedly high for package, leading to dose rates higher than expected.
D14	Improper package with loss of shielding or containment – inadequate shielding	Package shipped with poor, ineffective or damaged shielding, or source exposed en route.

Table B8. Radiological consequences resulting from transport events

Code	Definition	Circumstances
N	None	No dose rates or contamination above those expected during routine transport. No evidence of exposures having been received.
E	Extremely low, not assessed	Some increased exposure above that associated with routine transport but considered to be so low that an assessment was of little value.
L	Assessed and below 1 mSv*	Some increased exposure above that associated with routine transport and considered to be of a magnitude worth investigating, but found to be low.
U	Assessed and above 1 mSv* or exposure to significant contamination	Some increased exposure above that associated with routine transport and considered to be of a magnitude worth investigating. Some exposures found to be appreciable.

Note:

*: An effective dose of 1 mSv or an extremity dose of 50 mSv.