AECB-1187

ATOMIC ENERGY CONTROL BOARD
Ottawa, Canada

TRANSPORTATION INCIDENTS INVOLVING CANADIAN SHIPMENTS OF RADIOACTIVE MATERIAL 1947 - 1978

by
J.M. Jardine

30 June 1979

04234/80

TRANSPORTATION INCIDENTS INVOLVING CANADIAN SHIPMENTS OF RADIOACTIVE MATERIAL 1947 - 1978

by

J.M. Jardine

INTRODUCTION

This paper gives a brief statement of the legislation governing the transportation of radioactive materials in Canada, reviews the types of shipments made in Canada in 1977, and reviews the transportation incidents which have been reported to the Atomic Energy Control board (AECB) over the period 1947-1978. Some of the more significant incidents are described in some detail. A summary of the incidents is given. The conclusion reached is that the safety record of transportation of radioactive materials has been good.

BACKGROUND

Annual reports of the AECB list the number of shipments of radionuclides year by year. AECB files also contain information on incidents reported since the formation of the Board in 1947 to the present time. Table 1 gives a comparison of shipments with incidents for selected years.

TABLE 1

Year	Number of Shipments*	Reported Incidents M & I*	Reported Incidents ALL**
1948	20	0	0
1950	270	0	0
1955	1 350	0	0
1960	4 730	0	1
1965	8 220	1	3
1970	33 350	1	8
1975	54 750	7	14
1978	93 300 (e)	11	20
****	******	****	****
1947/1978	644 750	60	135

(e) estimated - 10% more than 1977.

* M & I - shipments and incidents for radionuclides used in medicine and instruments.

** All known incidents, including occurrences associated with medical and industrial uses and the nuclear fuel cycle.

The numbers of shipments reported in the annual reports represent only those radionuclides shipped from major suppliers for medical and instrumental (M & I) use. They do not include shipments of uranium, thorium or other materials used in the nuclear fuel cycle, large quantities of radionuclides used industrially, or movements of radiographic devices in private vehicles. The numbers of these latter shipments is not known. Therefore, only the M & I shipments and incidents can be compared directly.

It is evident from Table 1 that transportation of radionuclides for medical and instrumental use has experienced rapid growth from 1947 to 1978. The NRX nuclear reactor at Chalk River became operational in July 1947. The number of shipments of radionuclides from October 30 in that year to March 31st in 1948 was 16. In 1977, 84 800 shipments of medical radionuclides were made.

The growth in production of uranium concentrates also reflects the trend in the nuclear industry. In 1947 production amounted to 238.5 Mg. The estimated production in 1978 was 8 004 Mg.

Radionuclides are finding increasing use in medicine, in industry and in other fields. There has been a large increase in the use of smoke detectors containing small radioactive sources. The increasing use of nuclear energy as a source of electrical power is well known.

It has been estimated that shipments of radionuclides are increasing at the rate of 10% per year. It is logical to conclude that the increasing number of shipments will result in an increasing number of transportation incidents. The incidents which have occurred are discussed in this paper.

LEGISLATION

For the purpose of this paper "transportation" can be broken down into packaging of radioactive materials and the carriage of the material. Although the Atomic Energy Control Act gives the AECB the power to regulate carriage aspects of the transportation of radionuclides, the Board has chosen not to regulate directly but to support and provide advice to transportation mode authorities who issue regulations for the transportation of dangerous goods.

At the present time rail, marine and air transport is governed by separate regulations which are indicated in Table 2. The shipment by post is not permitted. Since there are no comprehensive regulations specially written for carriage

by road transport, the Board, by regulations, has stated that the regulations of the Canadian Transport Commission shall be applicable for road transport.

The packaging requirements for all modes of transport are similar. Board officers are responsible for ensuring that required standards are met for all packages used for the transportation of radioactive materials, and for carrying out technical assessments on all packages, called "Type B", which are required to meet tests which represent accident conditions. The Board officers may authorize shipments of packages which do not meet the "Type B" tests under "special arrangements" which include provisions which result in equivalent safety.

TABLE 2
Regulatory Authorities and Applicable Regulations

Mode	Regulatory Authority	Application
Rail	Director of Operation Railway Transport Committee Canadian Transport Commission	Regulations for the Transportation of Dangerous Commodities by Rail,
Road	Acting Regulatory Authority Atomic Energy Control Board	As above
Air	Director, Aeronautical, Licensing & Inspection Branch, Civil Aeronautics, Transport Canada	International Air Transport Association. IATA Restricted Articles Regulations.
Marine	Director, Ship Safety Branch Canadian Coast Guard Transport Canada	Intergovernmental Maritime Consultative Organization, IMCO International Maritime Dangerous Goods (IMDG)
Post	Post Master General Canada Post Office	Post Office Regulations Section 23, Prohibited Mail Regulations

SHIPMENTS IN CANADA, 1977

A survey of shipments made by licensees indicated that 51,000 packages containing material for the nuclear fuel cycle and 440,000 packages containing other radionuclides were shipped in 1977. A summary of these shipments by mode is given in Table 3. The figures given do not include shipments of heavy water or radioactive wastes.

TABLE 3
NUMBER OF PACKAGES OF RADIOACTIVE MATERIAL
SHIPPED IN CANADA 1977

(a) Radionuclides other than those used in the nuclear fuel cycle

Description	Total	Road	Rail	Sea	Air
Medical	84 800	26 300	3 400	-	55 100
Instruments and Devices	351 900	249 800	35 200	-	66 900
Industrial	3 040	900	850	100	1 190
Sub-Total	439 740	277 000	39 450	100	123 190
%	100.0	63.0	9.0	0.02	28.0

(b) Radionuclides used in the nuclear fuel cycle

Description	Total	Road	Rail	Sea	Air
Uranium (natural and depleted)	49 340	45 303	2 174	1 848	15
Thorium (natural)	697	5	-	692	-
Uranium (irradiated and enriched)	756	689	64	-	3
Sub-Total	50 793	45 997	2 238	2 540	18
%	100.0	90.6	4.4	5.0	0.04
Total	490 533	322 997	41 688	2 640	123 208
%	100.0	65.9	8.5	0.5	25.1

TRANSPORTATION INCIDENTS 1947-1978

A total of 135 incidents occuring during transportation or at transport terminals have been reported to the Board from 1947 to 1978. The distribution of these incidents by mode is shown in Table 4, and by mode and use in Table 5.

TABLE 4

INCIDENTS BY MODE 1947-1978

Mode	In Transit	At Terminal	Sub-Total
Road	56	19	75
Air	20	18	38
Rail	3	7	10
Sea	7	1	8
Post*	4	0	4
Total	90	45	135

* Incidents by post represent shipments made contrary to Canadian postal regulations.

TABLE 5
TRANSPORT INCIDENTS 1947-1978
INCIDENTS BY MODE AND USE

Use	MODE					
	Road	Rail	Sea	Air	Post	Total
Medical	7		1	19		27
Instruments	19		2	9	3	33
Radiography	24			9		33
Large Industrial	3	2	5			10
Nuclear Fuel Cycle	22	6	2	1	1	32
Total	75	8	10	38	4	135

DAMAGE CLASSIFICATION

The following classification has been used as a measure of damage to the package and, therefore, gives an indication of the consequences which may result from the incident.

Class I	No loss of integrity
Class II	Package damaged; no radioactive material released and radiation level does not increase above 1 rem per hour at one metre. from the package
Class III	Package breached, contents remain in package or vehicle, or radiation level measures greater than 1 rem per hour at one metre.
Class IV	Material released to ground

NOTE: Note that Class IV incidents are not necessarily more serious than the other classes, particularly if material that escapes is of low specific activity.

There were no instances of significant quantities being released to atmosphere (Class V) or released to watercourses (Class VI).

Incidents involving theft, fire, or loss of material are also reported.

A more complete discussion of this classification is contained in a previous paper (1).

A breakdown by class and use is given in Table 6.

---

(1) Transportation incidents involving shipments of radioactive material in Canada, 1957-1973, J.M. Jardine 4th International Symposium on Packaging and Transportation of Radioactive Materials, September 22-27, 1974, Miami, Florida.

TABLE 6
Transport Incidents 1947-1978
Incidents by Class and Use

Use	Class. I	II	III	IV	Theft	Fire	Loss	SUB-TOTAL
Medical	13	10	1	2	1			27
Instruments	20	6	1	1	2	3		33
Radiography	19	1	4	2	7			33
Large Industrial	7	2	1					10
Nuclear Fuel Cycle	10	3	3	12	2	1	1	32
Total	69	22	10	17	12	4	1	135
%	51.1	16.3	7.4	12.6	8.9	3.0	0.7	100.0

The thefts, fires and the loss of a package did not result in increase in radiation levels above Class II criteria. In 108 of 135, or a total of 80% of the incidents, there did not appear to be an increased exposure to any person, other than that exposure which would result from the normal radiation associated with these shipments. The remaining 20% were in damage classification III and IV. Since it is not possible in this abbreviated paper to describe all incidents, the following section will give a brief description of some of the Class III and Class IV incidents.

CLASS III AND CLASS IV INCIDENTS

Radionuclides used in Medicine

There were three reported spills of radionuclides used in medical applications, one with a limited (exempt) quantity of carbon-14 which was spilled and lost by evaporation, one with a Type A quantity of radium-226 in which a small amount of contamination occurred as a result of release of radon-222, and one with molybdenum-99, which will be described. There were no indications of radiation exposure beyond permitted limits in any of these cases.

On July 5, 1968, a package (Type A)* containing 200 mCi of molybenum-99 was run over and crushed by a vehicle at an air terminal. The outer cardboard box broke apart and the inner metal can ruptured. Liquid leaked onto cardboard, waybills and generator kit accessories. The measured dose rate on the surface of the metal container was 60 $mrem.h^{-1}$ The contaminated material was buried and the contaminated area was painted.

Radionuclides used in Instruments

There was one Class III and one Class IV incident involving the radionuclide cesium-137 which is used in a number of different instruments. In the Class III incident, a well logging source (0.5 Ci) fell out of a transport container and came to rest under the vehicle deck. There was a small increase in radiation.

---

*A "Type A" package is designed to resist damage which may occur during normal transport. The quantity, i.e., activity, contained is such that if material is released no serious radiation injury should result.

On December 10th 1976, a parked vehicle, carrying a density gauge containing a 0.3 Ci cesium-137 in a sealed capsule, was struck by a vehicle carrying 45 Mg gasoline, which immediately burst into flame. The resultant fire destroyed the parked tractor-trailer, two parked cars and a nearby motel and restaurant.

The density gauge was identified two days later by the radioactive symbol on the package and immediate action was taken to limit exposure of any persons. Military personnel from a nearby air base put out the vehicle fire and later carried out the removal of the density gauge to the base. There were no indicated radiation injuries from this incident.

Radiography Devices

Of six reported incidents in Class III and Class IV, one occurred during air transport from the United States to Canada, the other five were road transport incidents. Of these, one device containing cobalt-60 was involved. The other incidents involved iridium-192. Three incidents are described below.

In 1965, a package containing 56 Ci of iridium-192 was shipped from Philadelphia to Toronto. As a result of impact damage, an extension tube on the unit sheared off and the source was partially withdrawn from its fully shielded position. The unit remained in the airport for eight days, from December 15 to 23rd. High radiation levels were detected when the container reached its destination.

The doses received by various persons were estimated below:

- Three atomic radiation workers received less than 1.1, 0.65 and 0.20 rem.
- Two truck drivers received less than 2.5 and 2.0 rem.
- Airport unloading personnel received less than 2.5 rem.
- Air passengers - New York to Toronto received less than 5 rems each.
- Air terminal workers (60 persons) received less than 14 rem over a posible exposure period of 9 working days.

It is pointed out that the doses of 5 rem and 14 rem to air passengers and air terminal workers, respectively, are maximum estimated values for any individual and therefore the average exposure would be much lower. These doses would not be expected cause (somatic) injury.

This unit failed during handling in the course of normal transport, which indicates that the package would not meet the required Type B test which is required for this activity of the radionuclide, i.e., tests representing accident conditions. When measured at destination, the exposure was found to be 8 rem per hour at one metre from the package. Steps were taken to prohibit this model from being transported in Canada until modifications were made to ensure compliance with Type B tests.

In 1972, a radiographic device containing 100 Ci of cobalt-60 was shipped by road from Montreal, to Leechburg, Penn. During transportation over the period September 7 to 13, the mechanism holding the source in place was broken off

permitting the sealed capsule containing the cobalt-60 to move to a position which resulted in an increase in the dose rate to 10 $rem.h^{-1}$ at surface and 2 $rem.h^{-1}$ at 3 metres.

There were 12 individuals closely connected with the movement of this material. The estimated maximum exposures to four drivers in the U.S.A. were (in rems): 3.0, 0.8, 0.6, and less than 0.6. It was not possible to estimated accurately the exposure time of the eight Canadian workers who had been near the package but blood analyses were carried out on the eight persons. The results indicated that only one person, the driver of the vehicle on the first part of the journey to the U.S.A., may have received a dose of up to 25 rem. The fact that the capsule had moved to a less shielded position was not detected until high radiation alarms were set off at the destination.

Only one of the other four incidents of Class III and IV resulted in significant exposures to individuals. In the most serious case, which occurred on March 13, 1978 estimated exposures to three atomic radiation workers were (in rems): 12, 11 and 6.1 respectively.

Large Industrial Shipments

One serious Class III incident occurred in 1962 with a road shipment of 4 425 curies of iridium-192 from Ottawa, Ontario to Hoboken, New Jersey. The shipment was in transport for 14 days, from May 11 to 25th, during which time the shipment was loaded or unloaded 16 times. Sometime during the journey, the screw top of an inner container came undone, releasing radioactive metal pellets, which rolled

down a drain tube and came to rest against a screw plug. The resultant cone of radiation, which was detected at the end of the journey gave a dose rate of 40 $rem.h^{-1}$ at 2 metres from one side of the package.

Approximately 66 persons may have been exposed to the radiation from the package.

The incident was the result of faulty packaging procedures and vibration during transportation. There was no evidence of external damage and the high radiation levels were not discovered until the package reached its destination. Steps were taken by the Board to insure that deficiencies in procedures were corrected by the shippers.

Nuclear Fuel Cycle

There were 15 incidents involving spillage, 3 Class III and 12 Class IV. None resulted in to radiation doses to persons other than that normally encountered in transport of these materials.

Seven cases of spillage occurred with uranium chemical concentrates. Two occurred when drums in rail cars broke open during transport. The five other cases were the result of drums falling from vehicles and breaking open. One case occurred in the harbour area in Quebec city on March 30, 1970. Two freight containers fell from a road vehicle and twelve drums broke open. Contamination in the harbour area resulted from poor procedures used in transferring the spilled material. Procedures have been revised to prevent further occurrences of this nature.

Spillage of a large quantity of material of low specific activity occurred on March 30, 1976, when waste residues from a uranium extraction process were being transported by dump truck to a waste disposal area near Port Hope, Ontario. Several tonnes of residue containing a small amount of radionuclides were spilled over a kilometre section of a major highway. The road was closed for two days while cleanup and decontamination was carried out.

Most of the other incidents occurred with low specific activity materials. However, in one rail shipment (1960 May 31 - June 6), of irradiated nuclear fuel from Chalk River, Ontario, to Dumbarton Oaks, South Carolina, some contaminated water escaped from a container as a result of a chemical reaction causing pressure build-up. Cleanup of a small quantity spilled on the ground was arranged by escort personnel.

SUMMARY

There were 135 transportation incidents reported to the Atomic Energy Control Board since the inception in 1947 of the nuclear industry in Canada. During this time there were 645,000 reported shipments of radionuclides and instruments and a large number of other radioactive materials. Of these, only 27 incidents or 20% resulted in spillage of radioactive material or increase in radiation level above one rem per hour at a distance of one metre from the package. There were no indications of radiation injuries in any of these incidents. A further breakdown is given below.

Radionuclides for Medical Use or in Instruments

Sixty incidents were reported in the course of transportation of 645,000 shipments of radionuclides used in medicine or in instruments. There were no known exposures to any persons as a result of these incidents in excess of that allowed under the regulations. Some exposure to individuals result from the radiation emitted from these packages during their transport by air and road, the usual methods used, but this exposure is also controlled by regulation.

Radiography Devices

There were 33 transportation incidents reported for devices used in radiography, 32 of which contained iridium-192 and one contained cobalt-60. Of these, seven were serious but only three resulted in estimated individual doses greater than 0.5 rem, the annual maximum dose permitted for members of the public. The increased radiation levels were not detected in these three cases until the packages had reached their destination. These cases were discussed in the body of the report.

Industrial Radionuclides in Large Quantities

Of 10 incidents reported for transportation of large quantities of radionuclides for industrial use, there was only one case of serious increase in radiation level. As in the cases noted in the previous section, the failure of the containment system was not detected until the package had arrived at its destination. There was no evidence to indicate that drivers or other personnel connected with this movement had received excessive doses of radiation.

Nuclear Fuel Cycle

Of the 32 incidents which involved shipments in the nuclear fuel cycle, the most significant occurences were spillages of material of which there were 15 cases. Most of the incidents occurred with material of low specific activity which resulted in contamination of the ground, but there were no indications of injuries to individuals from exposures resulting from this contamination.

CONCLUSIONS

The safety record achieved in the transportation of radioactive materials in Canada over a period of more than 30 years has been very good. Of 135 reported incidents, in 645,000 reported shipments of radionuclides used in medicine and in instruments and a large number (undetermined) of other radioactive materials, only 27, or 20%, resulted in spillage of material or increase in the radiation level above one rem per hour at a distance of one metre from the package. Most cases of spillage involved material of low specific activity. Insignificant amounts of material were released into the environment in any instances involving spillage. There were only four cases of exposure to radiation where members of the public received whole body doses in excess of the permissable annual dose of 0.5 rem.

There was only one instance where an individual received a dose which may have been as high as 25 rem. No detectable harmful effects are expected to occur as a result of a single exposure of this magnitude.