QUALIFICATION OF TYPE IP-2, TYPE IP-3 AND TYPE A PACKAGES FOR RADIOACTIVE LIQUID SHIPMENTS

L. Marcu, G. Sullivan, K.K. Lo

Ontario Power Generation, 700 University Avenue, Toronto, Ontario, M5G 1X6

lidia.marcu@opg.com; gord.sullivan@opg.com; kin.lo@opg.com

ABSTRACT

Commercial products such as pails, drums or bulk containers can be used for radioactive materials transportation if they can be shown to meet the regulatory requirements. Ontario Power Generation (OPG) has successfully tested and qualified several off-the-shelf containers as Type IP-2, Type IP-3 and Type A packages for liquids in accordance with the International and Canadian Regulations. This paper describes the testing and qualification of these commercial products, and discusses the problems encountered and lessons learned during this process.

1.0 Introduction

This paper will describe the designs of the Industrial Packages Type 2 and Type 3 (Type IP-2, Type IP-3) and the Type A packages for Low Specific Activity (LSA-II) and Type A liquids that are part of OPG's radioactive materials transportation package fleet. These packages are mostly off-the-shelf containers. The major benefits of using suitable commercial products are ease of procurement, relatively low costs and immediate availability in desired quantities. The testing and qualification of these packages, and the problems encountered in this process will be discussed.

The Nuclear Waste Management Division (NWMD) of OPG has the responsibility to safely and economically manage all radioactive waste and material generated by OPG and Bruce Power nuclear reactors. Management activities include transportation, processing, storage, and eventually disposal of all low, intermediate and high level waste.

The Radioactive Waste Transportation Design (RWTD) Section of NWMD is responsible for the design, engineering and licensing of OPG's radioactive materials transportation package fleet. This fleet consists of Excepted, Industrial Packaging, Type A and Type B packages. All of these packages have been qualified before first use and conform to the International Atomic Energy Agency (IAEA) and Canadian Nuclear Safety Commission (CNSC) Regulations, [R-1] and [R-2] respectively.

2.0 Description of the Radioactive Contents

The International and Canadian Regulations for the transport of radioactive materials define categories of materials, associated types of packaging, design and operating requirements.

LSA-II liquids are either water with tritium concentration up to 0.8 Terabecquerels/litre and a volume not exceeding 225 litres (45 gallons), or other liquids in which the radioactivity is distributed throughout and the estimated average specific activity does not exceed 10^{-5} A_2/gram. The A_2 value is an activity limit for the relevant radionuclide or mixture of radionuclides

specified in the Regulations [R-1]. LSA-II liquids must be transported in Industrial Packages Type 2 (Type IP-2) or Type 3 (Type IP-3), or higher integrity packages.

Liquids containing radioactivity above the LSA-II limits but not exceeding a total activity of A_2 must be transported in Type A or higher integrity packages. The Regulations do not provide a category name for these liquids. For convenience in this document the term "Type A liquids" will be used.

Typical radioactive liquids that OPG transports are tritiated water or contaminated oils.

3.0 Description of Products Tested

3.1 Drums

OPG has subjected four different drum types to qualification and testing: three closed head drums, each with an approximately 200 liters (45 gallons nominal) capacity; and one open head drum with a nominal 38 liters (10 gallons nominal) capacity. Two of the 45 gallon closed head drums were made of stainless steel, and the other 45 gallon drum was made of carbon steel. The smaller (10 gallon) open head drum was made of carbon steel.

Each of the 45 gallon closed head drums (Figures 1 and 2) has a cylindrical shape body with rolling hoops (bulges on the side-walls) and closures in the top consisting of two bungs with gaskets ? one bung 2 inches in diameter and the other ¾ inches in diameter. The wall thickness of the drums varies from 0.9 mm to 1.6 mm depending on the manufacturer. The gasket materials can be Ethylene Propylene Diene Monomer (EPDM), High Density Polyethylene (HDPE) or Viton.

Figure 1. 45 Gallon Carbon Steel Closed Head Drum (#1)

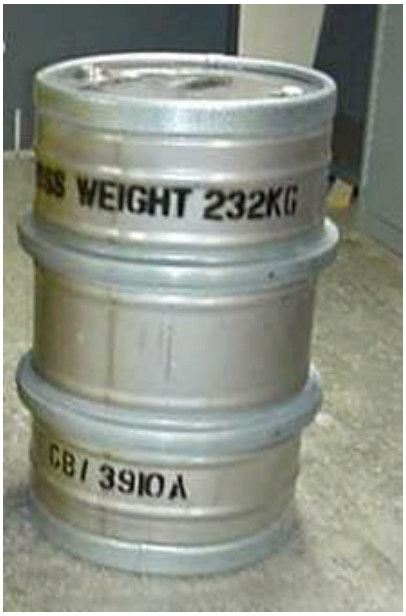

Figure 2. 45 Gallon Stainless Steel Closed Head Drum

The open head drum (Figure 3) has a lid with an EPDM gasket that is closed by a ring secured with a nut and bolt.

Figure 3. 10 Gallon Open Head Drum

Figure 4. Plastic Tote (#2)

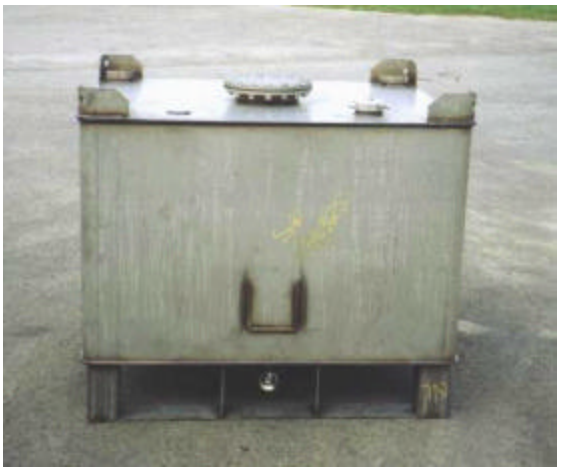

Figure 5. Stainless Steel Tote

3.2 Totes

OPG has subjected three types of bulk containers, typically referred to as "totes", to qualification and testing: two totes with plastic tanks mounted in carbon steel frames (Figure 4); and one stainless steel tote (Figure 5).

Each of the plastic totes has an approximately 1000 liters (270 gallons nominal) capacity tank with a screwed-on plastic cap at the top end of the tank.

The stainless steel tote has a 910 liters (240 gallons nominal) capacity with three openings on the upper surface: a 2 inch nozzle with plug; a 3 inch fusible fill cap; and an 8 inch man-way which is closed with bolts. All the openings have gaskets made of Buna N rubber or Teflon. There is a drain at the bottom of the tote with a 2 inches diameter ball valve with a quick connect adapter.

3.3 Plastic Bottle in Metal Pail

OPG has subjected a package consisting of two commercial products, a 2 liters (0.5 gallons nominal) capacity HDPE Nalgene plastic bottle inside a 20 liters (5 gallons nominal) carbon steel pail, to qualification and testing. The package also uses a foam spacer and absorbent material (Figure 6). The bottle has a screwed-on plastic cap and the pail has a top lid with a gasket secured with a lever lock closing ring.

Figure 6. Bottle/Pail/Absorbent Material (Partially Filled) Configuration

4.0 Compliance Tests

4.1 Compliance Tests for Type IP-2/IP-3 Packages

The Regulations [R-1] permit two alternative sets of tests for Type IP-2 and Type IP-3 packages. One set is defined in the Regulations specifically for radioactive materials transportation packages. The other set of tests is defined by the United Nations (UN) Regulations [R-3] for containers used for the transport of dangerous goods (not necessarily radioactive materials). Several of the containers evaluated by OPG had been qualified by their manufacturers to the UN requirements. However, OPG choose to re-qualify the containers using the tests specified in the IAEA Regulations [R-1]. This decision was made because the CNSC Regulations [R-2] require radioactive materials shipment consignors to have and keep records of any documents demonstrating compliance of packages with the Regulations. The documentation available from the container vendors was judged by OPG to be incomplete and insufficient.

The requirements for the Type IP-2/IP-3 packages are specified in paragraphs 622 and 623, respectively, of the IAEA Regulations [R-1]. These paragraphs call up a set of compliance tests:

- free drop test (paragraph 722)
- stacking test (paragraph 723)

Type IP-2 packages are also required to be able to withstand variations in ambient pressure likely to be encountered during routine conditions of transport (paragraph 615).

Type IP-3 packages are required to meet the same requirements as Type IP-2 packages plus additional requirements and tests:

- ambient pressure reduction to 60 kPa (paragraph 643)
- water spray test (paragraph 721)
- free drop test (paragraph 722)
- stacking test (paragraph723)
- penetration test (paragraph 724)

Details of the tests and the results are described in the following sections.

4.1.1 Free Drop Test

To pass the free drop test the package must prevent the loss or dispersal of the radioactive contents after the drop. The free drop test consists of dropping the package onto a target so as to suffer maximum damage in respect to the safety features to be tested. For a package with a mass less than 5000 kg the height of the drop, from the lowest point of the specimen to the upper surface of the target, shall be not less than 1.2 m. The target is a flat, horizontal essentially unyielding surface. Typically this means a massive reinforced concrete slab topped with thick steel plates.

All OPG packages for liquids are qualified to carry liquids with a specific gravity up to 1.2. For the drop test the contents must simulate the maximum weight of the package payload. Frequently a mixture or water and salt or sand is used for this purpose, or plain water can be used but an increased drop height is necessary to achieve the same potential energy for the drop.

The closed and open head drums were each dropped in two different orientations. One drop was on the side weld seam, and the other was an inverted drop on the chime or rim with the centre of gravity over the point of impact.

It was planned to drop the plastic totes in multiple orientations, but both types of totes leaked due to cracking of the plastic tanks, in the initial inverted top drops.

The stainless steel tote was dropped in five different orientations, inverted top flat and corner, bottom flat and corner, and side drop on the weld seam.

The drums and stainless steel tote passed the drop tests successfully with no loss or dispersal of the contents (for pre- and post-drop pictures see Figure 7 for the 45 gallon carbon steel closed head drum and Figure 8 for the 10 gallon open head drum).

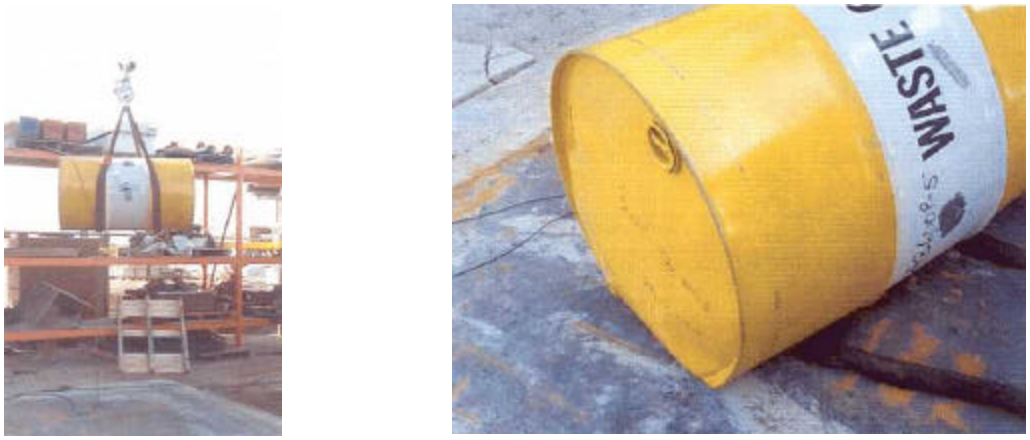

Figure 7. Side Drop Test for the 45 Gallon Carbon Steel Closed Head Drum (#1)

Figure 8. Corner Drop Test for the 10 Gallon Drum

4.1.2 Pressure Requirement

The ambient pressure variation for the Type IP-2 and the 60 kPa external pressure reduction requirement for the Type IP-3 packages can be considered as the same test condition. That is, the IAEA Advisory Material [R-4] suggests that the minimum ambient pressure for Type IP-2 packages should be 60 kPa. However, for packages moved solely in specific countries or regions, it is allowable to use other values for the ambient pressure conditions provided that they

are justified, and adequate controls are in place to limit the use of the package to the relevant regions or countries (paragraph 615, [R-4]).

To pass this test, the package must contain its radioactive content under the change in ambient pressure.

For each of the closed head drums and the stainless steel tote the pressure reduction test was performed by pressurizing the interior, via a test manifold connected to one of the top openings, to an absolute pressure of 142 kPa to simulate a drop of the external ambient pressure to 60 kPa. The pressure gage reading was monitored for 10 minutes to detect any variation. All of the closed head drums and the stainless steel tote passed the pressure reduction test.

The 10 gallon open head drum did not have a suitable test opening. Therefore a hole was made in the lid to accommodate the test manifold. The test was performed in the same manner as described for the other packages above. The drum started to leak at the closure at an absolute pressure of 117 kPa. It was concluded that the drum could withstand a differential pressure of 16 kPa.

The RWTD Section contacted Environment Canada to determine the maximum pressure variation that could be encountered under routine transport conditions in Ontario. The data obtained from Environment Canada was the minimum and maximum pressure readings at weather stations located throughout Ontario. The data was the result of hourly measurements over the past 10 years. During this period a minimum ambient absolute pressure of 91.16 kPa was encountered in Mount Forest (latitude 43.98° north, longitude 80.75° west) and a maximum pressure of 105.27 kPa was encountered in Moosonee (latitude 51.27° north and longitude 80.65° west). It was concluded that for transport in Ontario the maximum variation in the environmental pressure would be less than 15 kPa.

Since the 10 gallon drum withstood a pressure differential of 16 kPa, the RWTD Section accepted the drum for the transport of radioactive liquids within Ontario only. The drums will bear the label “FOR USE IN ONTARIO ONLY”.

4.1.3 Water Spray Test

The water spray test is a requirement for Type IP-3 packages that simulates at least one hour of exposure to rainfall. Typically this test is only a concern for packages made of materials that absorb or are softened by water. This test was not performed on any of the drums or the tote because these packages are made of steel (stainless or painted carbon) and engineering judgment was sufficient to conclude that they would not be affected by water spray test.

4.1.4 Stacking Test

To pass the stacking test a Type IP-2 and Type IP-3 packages must prevent the loss or dispersal of the contents when subjected for 24 hours to a compressive load equal to the greater of the following:

- the equivalent of the 5 times the mass of the actual package, or
- the equivalent of 13 kPa multiplied by the vertical projection area of the package.

The load must be applied uniformly to the top and bottom of the specimen.

The drums and the stainless steel tote were each subjected to a load equal to 5 times the actual mass of the fully loaded package. Each package was filled to 98% of their capacity with water and the stacking load, consisting of steel plates and/or containers of steel shot, was placed on top (see Figure 9). Measurements of the height of the each package at various locations were taken before and after the test. No deformations of the packages and no leakage or spillage were observed.

All of the packages have passed the stacking tests.

Figure 9. Stacking Test (10 Gallon Drums)

4.1.5 Penetration Test for Type IP-3

The penetration test was required for qualification of the stainless steel tote and one of the carbon steel 45 gallon drums as Type IP-3 packages. To pass the test the package must prevent the loss or dispersal of the radioactive content when a steel bar of 3.2 cm diameter with a hemispherical end, and a mass of 6 kg is dropped from 1 m directly onto the centre of the weakest part of the package.

For each test the specimen package was filled to 98% of its capacity with water. The bar was dropped in two locations on the specimens: onto the centre of the side weld seam; and onto the largest closure bung.

Both packages have passed the test successfully.

4.2 Compliance Tests for the Type A Packages for Liquids

The requirements for Type A packages containing liquids are specified in paragraphs 633 to 648 of the Regulations [R-1]. These paragraphs call up a series of compliance tests:

- water spray test (paragraph 721)
- free drop test (paragraph 722)
- stacking test (paragraph723)
- penetration test (paragraph 724)
- an enhanced free drop test or enhanced penetration test, whichever is more severe (paragraph 725)

Type A packages are also required to be able to withstand an ambient pressure reduction to 60 kPa (paragraph 643)

The water spray, stacking and regular free drop and penetration tests are identical with the tests for qualification of Type IP-2/Type IP-3 packages. Only the pressure reduction requirement and the enhanced free drop and penetration tests for the Nalgene bottle/metal pail package will be discussed in the following sections. Because it was not possible in advance to determine whether the enhanced drop test or enhanced penetration test would cause more damage, the package was subjected to both tests.

4.2.1 Pressure Reduction Requirement

To comply with the pressure reduction requirement, the package containment system must prevent loss or dispersal of the contents under a reduction of ambient absolute pressure to 60 kPa.

To demonstrate compliance with the pressure reduction requirement the RWTD Section usually specifies a test which subjects the package to an equivalent differential pressure. This test is very conservative ? it demonstrates the ability of the package to retain air even though the actual contents will be solids or liquids.

In the case of the package consisting of the Nalgene bottle, metal pail and absorbent material, the typical pressure test was determined to be inappropriate since it would involve separately testing the bottle and pail rather the combined ability of the packaging components to retain the contents.

The guidance material for the IAEA Regulations (paragraphs 643.2 and 646.4, [R-4]) state that "for solid, granular and liquid contents, one way of satisfying the requirements for "no loss or dispersal" would be to monitor the package (containing a non-active control material) on completion of a vacuum test or other appropriate tests to determine visually whether any of the content escaped". This approach was used for testing the Nalgene bottle/metal pail package. The bottle was filled with water and placed inside the pail with sufficient absorbent material (a specific type of vermiculite) to absorb twice the volume of the contents. Fluorescent powder was mixed with the absorbent material. The pail was closed; the package was inverted and placed into a chamber connected to a vacuum pump. The absolute pressure in the test chamber was reduced to 60 kPa and maintained and monitored for 10 minutes. The pressure differential was then relieved, the package was removed from the chamber and a check was made for traces of water and fluorescent powder using an ultraviolet light source. No evidence of leakage was found on the package exterior.

The Nalgene bottle/metal pail package satisfied the pressure reduction requirement.

4.2.2 Enhanced Free Drop Test

The Regulations require a Type A package for liquids to prevent the loss or dispersal of its content when dropped from a height of 9 m onto an unyielding target. This is a much more severe test than the 1.2m drop required for Type IP-2 /IP-3 packages of this size, as described in Section 4.1.1.

For the test the metal pail was loaded with a 2 liters Nalgene bottle containing a test liquid, the spacer and the absorbent material. The liquid had a specific gravity of 1.2 and also had fluorescent powder mixed-in. The assembled package was dropped from 9 m in three different

orientations as to suffer maximum damage (side drop on the weld seam, top flat drop, and top corner drop with the centre of gravity over the closing lever and point of impact).

The pail has passed the free drop tests ? no liquid or fluorescent powder was observed outside the pail (see Figure 10).

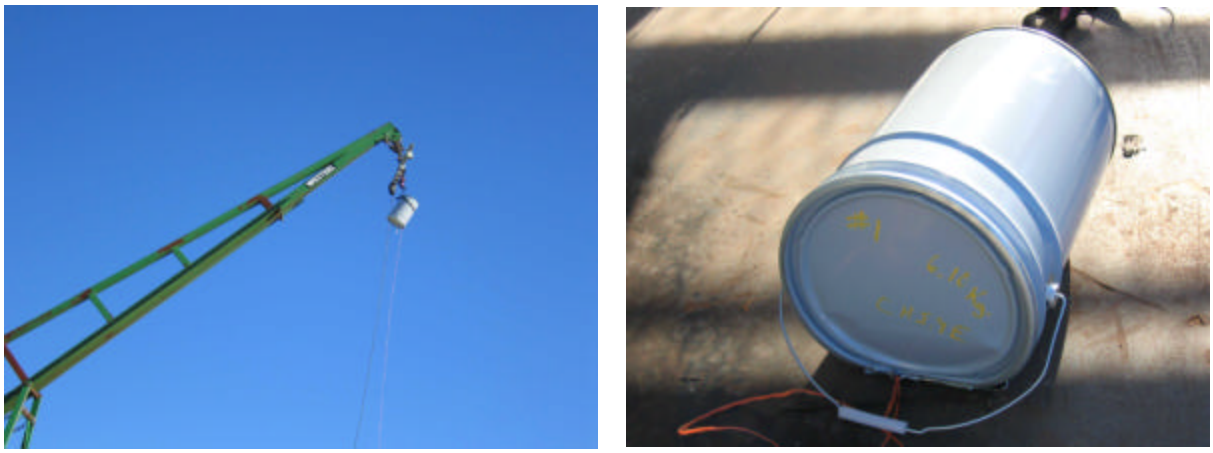

Figure 10. Drop Test of Metal Pail (Nalgene Bottle Inside) from 9 m.

4.2.3 Enhanced Penetration Test

The penetration test for a Type A package for liquids requires that the package prevent the loss or dispersal of the contents when a steel bar (same size and mass as the Type IP-3 penetration test bar) is dropped from 1.7 m (rather than 1 m for the Type IP-3 test) directly onto the centre of the weakest part of the package.

In the case of the Nalgene bottle/metal pail package only the pail was subjected to the penetration test because if the bar did not penetrate the pail it would not affect the bottle. For the test the pail was filled with sand and fluorescent powder. The bar was dropped onto the centre of the side weld seam.

The pail passed the test. The bar indented but did not penetrate the pail and no traces of fluorescent powder were observed when the pail was inspected after the test.

4.2.4 Summary of Qualification Results

The results of the package tests and evaluations are summarized below.

Package	Qualification
45 gallon stainless steel closed head drum (#1)	Type IP-2 & Type IP-3
45 gallon stainless steel closed head drum (#2)	Type IP-2
45 gallon carbon steel closed head drum	Type IP-2
10 gallon carbon steel open head drum	Type IP-2
Plastic tank tote (#1)	Leaked following Type IP-2 free drop test
Plastic tank tote (#2)	Leaked following Type IP-2 free drop test
Stainless steel tote	Type IP-2
Nalgene bottle/metal pail	Type A for liquids

5.0 Operating Requirements

In addition to the performance and test requirements, the Regulations (paragraph 310 of [R-1]), require that all packages be periodically inspected, maintained in good condition, and, as necessary, repaired such that they continue to comply with all relevant requirements and specifications, even after repeated use. The RWTD Section has found that this last requirement is a concern with off-the-shelf containers, particularly drums.

5.1 Operating Requirements for the Type IP-2/IP-3 and Type A Packages

The RWTD Section has had discussions with drum manufacturers about appropriate service lives for drums. There is no explicit limit for the drum service life in the Regulations or from manufacturers. However one manufacturer suggested for drums that are frequently used to carry dangerous goods a limit of 6 months of service would be prudent unless they were re-tested. The drums in OPG's inventory (at various sites) are infrequently used for transport and they are often stored unloaded or loaded for extended periods. The RWTD Section has therefore imposed a service life limit of 5 years and 15 years (starting from the vendor assigned date of manufacture) on re-usable carbon and stainless steel drums, respectively, with the following requirements for each use:

1. Pre-shipment visual inspection
2. Replacement of the closure gaskets before shipment,
3. Closed head drums must pass a pre-shipment air pressure test.

The inspection and tests are to be performed by the users at each OPG station or site ? not by the Nuclear Waste Management Division.

The requirements apply to the three types of qualified 45 gallon drums. The stainless steel totes are inspected and maintained by the Nuclear Waste Management Division on a periodic basis.

The 10 gallon open head drum and Nalgene bottle/metal pail package are single use items because it is not practical to re-test them. These packages are visually inspected prior to first use and cannot be used if they are damaged or older than 5 years (based on the manufacturing date).

5.2 Use of Overpacks for Type IP-2/IP-3 Packages

OPG Nuclear Waste Management Division governance requires the use of a secondary container (also called an overpack) to contain a Type IP-2/IP-3 package when shipping radioactive liquids. This precaution, above the requirements under the Regulations, reduces the risk of an unrecoverable spill to the environment, protects conveyances against contamination and demonstrates due diligence.

The value of this precaution was proven to OPG a few years ago when a shipment of radioactive liquid waste was made from Ontario to an American disposal facility. At the destination it was discovered that during transport three brand-new drums had leaked due to interaction between the contents (acidic) and the drum material (stainless steel). No release of the contents to the environment occurred because the drums were shipped in overpacks which retained the liquid.

The use of overpacks is an appropriate precaution when using commercial products where the quality assurance is controlled by the manufacturer and where there is a relatively thin containment structure that could be vulnerable to handling damage and material degradation.

OPG has a variety of overpacks that are specific to the packages carried. The overpack for the 45 gallon drum is an off-the-shelf 85 gallon salvage drum (Figure 11). The overpack for the stainless steel tote is a metal case (Figure 12).

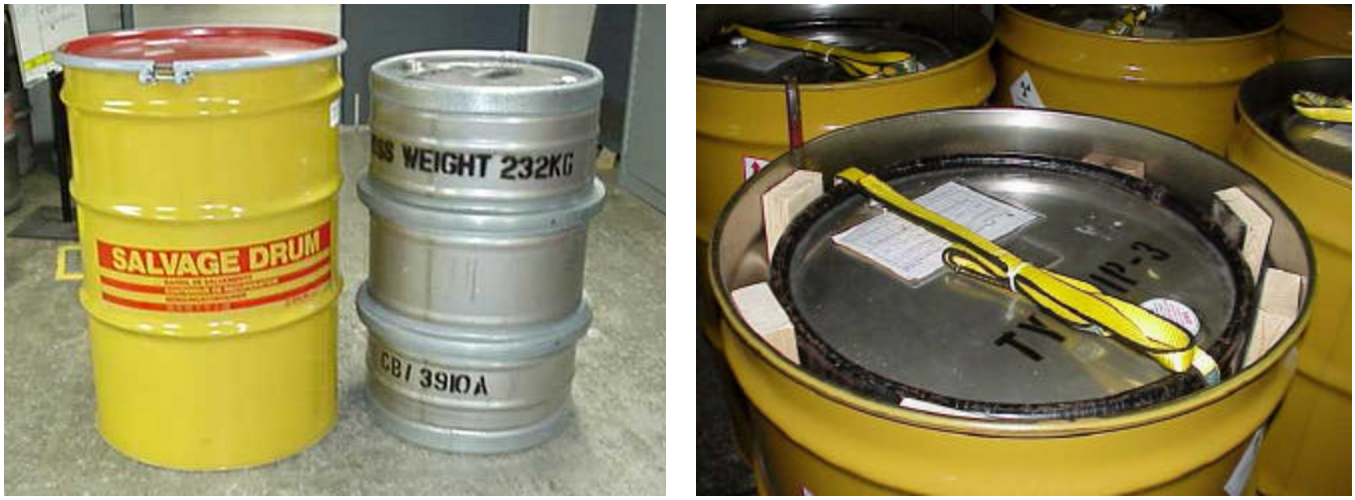

Figure 11. 45 Gallon Carbon Steel Closed Head Drum (#2) and Overpack (85 Gallon Salvage Drum)

Figure 12. Stainless Steel Tote and Tote Overpack

6.0 Lessons Learned

It was discovered through the testing of the plastic totes that dangerous goods containers qualified by vendors in accordance with UN tests may not offer the same degree of robustness as radioactive materials transportation packages qualified using the test procedures described in the IAEA Regulations [R-1].

7.0 Conclusions and Recommendations

Through its independent qualification process, OPG has obtained a high degree of confidence that the off-the-shelf products it is using as radioactive materials transportation packages meet the requirements of the International and Canadian Regulations.

It is recommended that these products be periodically re-evaluated and re-tested as manufacturers may occasionally change production processes which could affect the performance of the products as radioactive materials transportation packages.

8.0 References

[R-1] IAEA Safety Standards, "Regulations for the Safe Transport of Radioactive Material", 1996 Edition (Revised), No. TS-R-1 (ST-1 Revised), International Atomic Energy Agency, Vienna 2000.

[R-2] Canadian Nuclear Safety Commission (CNSC), "Packaging and Transport of Nuclear Substances Regulations", SOR/2000-208, 31 May, 2000, and SOR/2003-405, 3 December, 2003.

[R-3] United Nations, "Recommendations on the Transport of Dangerous Goods", Model Regulations, Eleventh revised edition, United Nations: New York and Geneva, 1999

[R-4] IAEA Safety Standards, "Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material", No. TS-G-1.1 (ST-2), International Atomic Energy Agency, Vienna 2002.