THE TRANSPORT OF URANIUM SWARF IMMERSED IN OIL

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ABSTRACT

Uranium swarf is considered to be a pyrophoric material liable to spontaneous combustion and is therefore immersed in oil when machined, stored or transported. It is typically packaged in a combination package comprising a plastic drum within a steel outer drum. The oil used is generally a water based emulsion and the material is stored in a non-corroding plastic drum. To avoid further handling of the material the same container is also used for transport.

As a radioactive material, transport is subject to the IAEA Regulations for the Safe Transport of Material. For a package carrying natural or depleted uranium for which the A_2 value is unlimited the IAEA Regulations require transport within an IP-1 Package which is not subject to testing. Consideration must however be given to any other dangerous properties of the material which requires compliance with the packaging requirements of the relevant dangerous goods transport regulations which would normally require the use of a metal package for pyrophoric substances.

This paper will present a justification for the transport of uranium swarf in a plastic drum when the pyrophoricity is suppressed by immersion in oil. It will review the status of the payload by reference to the UN Recommendations on the Transport of Dangerous Goods (UNRTDG) to determine the classification of the material. The paper will review the requirements of the UNRTDG and the modal transport regulations and demonstrate that the proposed package complies with these requirements taking account of the other dangerous properties of the payload.

A further problem is that hydrogen may be produced as a result of radiolysis and corrosion. Since retention of hydrogen would raise further issues due to pressurisation of the package which would then be carrying a flammable gas, the hydrogen is vented. At the same time the oil must be retained to prevent spontaneous combustion of the uranium swarf. The paper will discuss these issues and the features adopted demonstrating compliance with the various regulations.

The paper will conclude by proposing a suitable package design that satisfies the various requirements and summarising the issues raised.

INTRODUCTION

Uranium swarf is considered to be a pyrophoric material liable to spontaneous combustion and is immersed in oil for transport. There is some confusion as to the status of this payload under the various Dangerous Goods Transport Regulations particularly as to whether the payload constitutes a pyrophoric material. This paper reviews the various regulations that apply to the transport of dangerous goods.

Finely divided uranium is a pyrophoric material when clean and dry and since the exact nature of the material cannot be guaranteed uranium swarf may be pyrophoric and would be considered pyrophoric if transported in its raw state. It is immersed in oil when machined, stored and transported and typically packaged in a plastic drum within a steel drum.

As a radioactive material, the transport of uranium is subject to the IAEA Regulations for the Safe Transport of Radioactive Material (reference 1). Paragraph 109 of the IAEA Regulations states that "For radioactive material having subsidiary risks, and for transport of radioactive material with other dangerous goods, the relevant transport regulations for dangerous goods of each of the countries through or into which the material is to be transported shall apply in addition to these Regulations."

Paragraph 507 states "In addition to the radioactive and fissile properties, any other dangerous properties of the contents of the *package*, such as explosiveness, flammability, pyrophoricity, chemical toxicity and corrosiveness, shall be taken into account in the packing, labelling, marking, placarding, storage and transport in order to be in compliance with the relevant transport regulations for dangerous goods of each of the countries through or into which the materials will be transported, and, where applicable, with the regulations of the cognizant transport organizations, as well as these Regulations."

The ADR International Road Transport Regulations (reference 2), paragraph 4.1.9.1.5 state that "Radioactive material with a subsidiary risk shall be carried in packagings, IBCs or tanks fully complying with the requirements of the relevant chapters of Part 6 as appropriate, as well as applicable requirements of Chapters 4.1, 4.2 or 4.3 for that subsidiary risk." ADR Part 6 is titled Requirements for the Construction and Testing of Packagings, IBCs, Large Packagings, Tanks and Bulk Containers and Part 4 deals with Packaging and Tank Provisions. Both the IMDG code (reference 3) for sea transport and the IATA Dangerous Goods Regulations (reference 4) for air transport include similar requirements.

The packaging requirements of the relevant modal transport regulations for any subsidiary risk must therefore be considered along with the requirements of the IAEA Regulations. This is particularly significant when transporting uranium since the A_2 value for natural or depleted uranium is unlimited so the material is classified as LSA-I in accordance with the IAEA Regulations (reference 1) and may be transported in a Type IP-1 transport package which is not subject to testing.

DEFINITIONS

Referring to the United Nations Recommendations on the Transport of Dangerous Goods (reference 5) pyrophoric materials fall within Division 4.2 Substances liable to spontaneous combustion. Paragraph 2.4.3.1.1 states that Division 4.2 includes:

(a) Pyrophoric substances which are substances ... which even in small quantities ignite within five minutes of coming in contact with air.

(b) Self-heating substances, which are substances, other than pyrophoric substances, which in contact with air without energy supply are liable to self-heating. These substances will ignite only when in large amounts (kilograms) and after long periods of time (hours or days).

The UN Manual of Tests and Criteria (reference 6) paragraph 33.3.1.4.3 specifies the test method for pyrophoric solids and requires that "One to two ml of the powdery substance to be tested should be poured from about 1m height onto a non combustible surface and it is observed whether the substance ignites during dropping or within 5 minutes of settling."

The tests for self-heating substances are more involved but basically involve heating a sample at 140^{o}C for 24 hours. If spontaneous combustion or a rise in temperature to over 200^{o}C occurs the substance is self-heating.

CLASSIFICATION

In order to ascertain the regulatory requirements applicable to the transport of uranium swarf immersed in oil, the classification of the material must be determined. The first issue is whether uranium swarf is itself pyrophoric.

Guidance issued by the United States Department of Labor (reference 7), notes that the auto-ignition temperature of uranium depends on the extent to which the metal is subdivided. Reference 7 states that the ignition temperature of uranium metal is 170^{o}C (if oxygen is present); finely divided uranium metal (dust) ignites at room temperature (20^{0}C). Since uranium swarf can take the form of fine chips its ignition temperature would be at the bottom end of the range. A Depleted Uranium Technical Brief issued by the United States Environmental Protection Agency (reference 8) states that "Uranium metal powder or chips will ignite spontaneously in air at ambient temperature". Uranium chips and hence uranium swarf should therefore be considered pyrophoric.

The payload under consideration is however uranium swarf immersed in oil. If a transport incident should result in the release of the contents from a package carrying uranium swarf immersed in oil the material would not ignite for a considerable period (if at all) due to the coating of oil remaining on the uranium. It may ignite if the oil were removed allowing exposure to oxygen in the atmosphere. This would only occur over a prolonged period of time as the oil evaporated. If a sample of the payload were subjected to the test for a pyrophoric substance it would not ignite within 5 minutes because a residual coating of oil would remain on the metal surface.

If subjected to the tests for a self-heating substance, the oil coating would evaporate and the uranium may ignite or increase in temperature. Although such a test has not been undertaken to our knowledge, a reasonable approach is to define uranium swarf immersed in oil as a self-heating substance.

To summarise:

- Dry uranium swarf should be classified as a pyrophoric substance
- Uranium swarf immersed in oil should be classified as a self-heating substance

REGULATORY REQUIREMENTS

Considering the ADR Regulations (reference 2), if the material were not radioactive it would be categorised as:

UN3190 SELF-HEATING SOLID, INORGANIC, N.O.S (reference 2, section 2.2.42.3).

ADR section 3.2.1 indicates that Packing Instruction P410 is applicable to packages carrying UN3190, Packing Group II.

Uranium swarf immersed in oil is typically transported in an HDPE (High Density Polyethylene) plastic inner drum contained within a steel outer drum. The list of packages that are authorised by Packing Instruction P410 (reference 2, section 4.1.4) includes plastic drums (1H1 or 1H2) as single packagings up to a mass of 400kg. The inner HDPE drum is typically a UN approved packaging complying with the requirements of the ADR regulations. The inner drum alone therefore complies with the requirements of the ADR regulations (reference 2) for a package carrying Class 4.2 self-heating substances.

For transport by sea, the IMDG Code applies Packing Instruction P410 which is equivalent to ADR P410, but includes a special packing provision, PP31 which states that packagings shall be hermetically sealed (i.e. air tight). This is not required by ADR.

Packages carrying uranium swarf immersed in oil are typically fitted with a filtered vent to allow the release of any hydrogen that may be produced by corrosion or radiolysis of the oil. They are not therefore hermetically sealed (air tight).

UNRTDG (reference 5) paragraph 6.1.1.2 states that “The requirements for packagings in 6.1.4 are based on packagings currently used. In order to take into account progress in science and technology, there is no objection to the use of packagings having specifications different from those in 6.1.4, provided that they are equally effective, acceptable to the competent authority and able successfully to withstand the tests described in 6.1.1.3 and 6.1.5. Methods of testing other than those described in these Regulations are acceptable, provided they are equivalent.” There are equivalent paragraphs in the ADR Agreement and the IMDG Code.

The IMDG requirement for a package to be hermetically sealed would prevent the release of suppressant gas within the package and the entry of oxygen. Since the hazard is suppressed by the use of oil this requirement is not relevant. What is required is that the package should be oil tight.

This is achieved by the use of special filters and demonstrated by testing. It is therefore considered that the package used is equally effective in suppressing the hazard presented by the contents. Acceptance of the Competent Authority should however be sought to fully comply with the IMDG Code.

MODAL REGULATIONS

Considering sea transport of uranium swarf immersed in oil, paragraph 4.1.9.1.6 of the IMDG Code (reference 3) states that “Pyrophoric radioactive material shall be packaged in Type A, Type B(U), Type B(M) or Type C packages and shall also be suitably inerted.”

Since it has been determined that uranium swarf immersed in oil is not pyrophoric this would not appear to be applicable. However the statement that packages shall be suitably inerted could be taken to mean that this requirement applies if the raw material is pyrophoric since it is inerted by submerging it in oil. Inerted is not defined in the IMDG Code (reference 3). Although not definitive, inerted is defined on the internet as meaning “filled with an inert gas”. The Code of Federal Regulations, 46 C.F.R (reference 9) §39.10-3 defines inerted as meaning “the oxygen content of the vapor space in a cargo tank is reduced to 8 percent by volume or less in accordance with the inert gas requirements of §32.53 or §153.500 of this chapter”. This definition is in relation to Part 39 Vapor Control Systems and again implies the use of an inert gas.

Since a package carrying uranium swarf in oil does not need to be filled with an inert gas to make it safe for transport it is not considered to be pyrophoric. A package carrying a pyrophoric substance made safe by filling the package with an inert gas would become highly dangerous if the gas should be released. When carrying uranium swarf immersed in oil it would be some time before the contents become dangerous if the oil were released.

When reviewing a specific package used for the transport of uranium swarf immersed in oil by sea, advice was sought from the UK DfT (Department for Transport) (reference 10). The query referred to a package to transport uranium swarf submerged in mineral oil and stated that we are treating the swarf as pyrophoric. Referring to the IMDG Code, the DfT advised that paragraph 2.0.3.5 defines the classification precedence of radioactive material having more than one hazard and that uranium swarf, as LSA-I material, would be classified in Class 7 with class 4.2 as the additional hazard, but with the requirements for Class 7 ruling. As stated in 2.0.3.5 the additional hazard would also need to be identified on the package. Paragraph 2.0.3.5 states “Apart from excepted radioactive material (where the other hazardous properties take precedence), radioactive material having other hazardous properties shall always be classified in class 7, with the greatest of the additional hazards being identified.”

The DfT advice continues - Bearing in mind the above, the ruling paragraph for uranium would be 4.1.9.1.6 as this is specifically stated as applying to pyrophoric radioactive material. Paragraph 2.4.3.3.1 is a more general requirement for pyrophoric solids and liquids. (Paragraph 2.4.3.3.1 states that Packing group I shall be assigned to all pyrophoric solids and liquids). Your proposal to label as "UN 2915 RADIOACTIVE MATERIAL, TYPE A PACKAGE, Non Special Form, non fissile or fissile excepted" would therefore be correct.

It was concluded based on this advice that the package only has to meet the Type A Regulatory requirements to satisfy the requirements of the IMDG code (reference 3). The package was approved for transport on this basis.

This however takes no account of paragraph 4.1.9.1.5 of the IMDG Code which states “Radioactive material with a subsidiary risk shall be transported in packagings, IBCs or tanks fully complying with the provisions of the relevant chapters of Part 6 as appropriate, as well as applicable provisions of chapters 4.1 or 4.2 for that subsidiary risk..”

The DfT advice would appear to consider that the subsequent paragraph 4.1.9.6 which states that “Pyrophoric radioactive material shall be packaged in Type A, Type B(U), Type B(M) or Type C packages and shall also be suitably inerted” takes precedence over paragraph 4.1.9.1.5 such that paragraph 4.1.9.1.5 does not apply to radioactive materials with a pyrophoric subsidiary risk. This would mean that the packaging requirements for pyrophoric materials noted below would not apply although they exceed the Type A Package requirements and would allow the use of plastic packagings which are not permitted for pyrophoric materials.

It could be argued that both paragraphs 4.1.9.1.5 and 4.1.9.1.6 apply with paragraph 4.1.9.1.6 imposing an additional requirement.

REQUIREMENTS FOR PYROPHORIC MATERIALS

If a material is pyrophoric the packaging requirements of the regulations applicable to pyrophoric materials would apply. The applicable UN number would be:

UN1383 PYROPHORIC METAL N.O.S

According to the ADR Agreement (reference 2) and the IMDG Code (reference 3) Packing Instruction P404 would apply. This is the same for both ADR and IMDG and permits the use of :

(1) Combination Packagings comprising an outer packaging (1A2, 1B2, 1N2, 1H2, 1D, 4A, 4C1, 4C2, 4D, 4F or 4H2) with metal inner packagings with a maximum net mass of 15kg each which shall be hermetically sealed and have threaded closures.

(2) Metal Packagings (1A1, 1A2, 1B1, 1N1, 1N2, 3A1, 3B1 and 3B2) with a maximum gross mass of 150kg.

(3) Composite Packagings comprising a plastic receptacle in a steel or aluminium drum (6HA1 or 6HB1.

The IMDG Code (reference 3) includes a special packing provision, PP31 which states that packagings shall be hermetically sealed. This is not required by ADR.

According to the IMDG Code “Composite packagings means packagings consisting of an outer packaging and an inner receptacle so constructed that the inner receptacle and the outer packaging form an integral packaging. Once assembled, it remains thereafter an integrated single unit; it is

filled, stored, transported and emptied as such." The use of a standard plastic drum within a standard steel drum would not therefore constitute a Composite Packaging.

The use of plastic packagings is not permitted – if a single packaging is used it must be metal. We have however determined that the payload is not pyrophoric so this requirement does not apply. This section demonstrates however that if the extremely conservative assumption were made that the payload is pyrophoric, the proposed packaging would not be acceptable.

RETENTION OF OIL

The safe transport of uranium swarf immersed in oil relies on the continuing presence of the oil to prevent the swarf drying out and igniting. Open head plastic and steel drums are typically UN approved for the transport of solids so are not guaranteed to retain liquids. Testing of packages comprising a plastic inner drum within a steel outer drum at Gravatom has however demonstrated that although there may be a small transient release of liquid from the inner drum at impact, this release is retained by the outer drum and the inner drum subsequently remains leak tight.

CONCLUSIONS

- Uranium swarf is classified as LSA-I radioactive material (Class 7) and should be transported in a Type IP-1 package.
- The package design must take account of any subsidiary risks associated with the material.
- Uranium swarf is considered pyrophoric in its clean (oil free) and dry state.
- Uranium swarf is normally immersed in oil when transported. A payload of uranium swarf immersed in oil is not pyrophoric. It is classified as a self-heating substance within Class 4.2. The packaging must comply with the requirements for a self-heating substance which are more stringent than IP-1 requirements.
- Uranium swarf immersed in oil can be transported in a Type IP-1 Package comprising of a UN approved plastic inner drum in a steel outer drum. The UN approved plastic inner drum satisfies the requirements for transporting a self-heating substance. Testing has demonstrated that this design will retain oil under normal conditions of transport.
- A plastic inner drum is preferred as it does not corrode and is suitable for long term storage. Transfer into a different package for transport is not good radiological practice
- The package should be fitted with a special filter to prevent the build up of hydrogen resulting from corrosion and radiolysis while retaining the oil. Since this does not comply with the special packing provision of the IMDG Code that packages for self-heating substances should be hermetically sealed, the agreement of the Competent Authority should be sought. Since the hazard is suppressed by the use of oil rather than a suppressant gas it is considered that the use of an oil tight package is appropriate.
- The use of a Type A Package for transport by sea has been considered since the raw material (uranium swarf) is considered to be pyrophoric and given the advice that no consideration of the pyrophoric nature of the contents would be needed. This takes no account of the general requirement of the various regulations that the relevant transport regulations for any hazard are

complied with. If the payload were considered to be pyrophoric a plastic inner drum would not be suitable although such a design could satisfy Type A requirements.

- This raises the more general issue as to whether radioactive material packages carrying materials with subsidiary risks need to comply with all the requirements applicable to the subsidiary risk (which would usually require a UN approved package) or whether the radioactive material package testing is sufficient, but that is different subject which is not considered in this paper.

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