TRANSPORTATION OF IMMOBILIZED RADIOACTIVE WASTES: HOW DOES IT FIT IN THE REGULATIONS?

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Abstract

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During the next decade, there will be a large increase in the transport of immobilized radioactive wastes, either in drums or in other larger packages. These packages will be destined for disposal and need to be transported from the sites at which they are produced. An essential requirement for disposal will be that the immobilized waste package should arrive at the repository in a suitable state for disposal, which in practice means that it should not have suffered damage during transport. Radioactive waste packages fall into one of the following categories in the 1985 IAEA Transport Regulations (Safety Series No. 6): (a) Type A (very limited numbers), (b) LSA-III, (c) Type B. The range of wastes which will fall into the LSA-III category will depend upon the interpretation of Safety Series No. 6. All packages which do not fall within either the Type A or LSA-III categories will have to meet the Type B requirements. The paper analyses a number of package proposals currently being developed in the United Kingdom and considers whether the 1985 Transport Regulations are satisfactory for the future transport of immobilized and packaged radioactive wastes.

INTRODUCTION

Since the issue of the first edition of the IAEA Transport Regulations, in 1961, there has been an enormous increase in the transport of irradiated nuclear fuel, isotopes for medical and industrial uses and low level materials, such as uranium ores. During the next decade, there will be a large increase in the transport of a new group of radioactive materials, immobilized radioactive wastes in drums or in other larger packages. These packages will be destined for disposal and will require transport from the sites at which they are produced to the disposal sites.

WASTE PACKAGES

Much attention worldwide has been devoted to the conditioning of low and intermediate level radioactive wastes [1]. These wastes will be immobilized using matrices such as concrete, polymers, bitumen or other materials. Details of waste

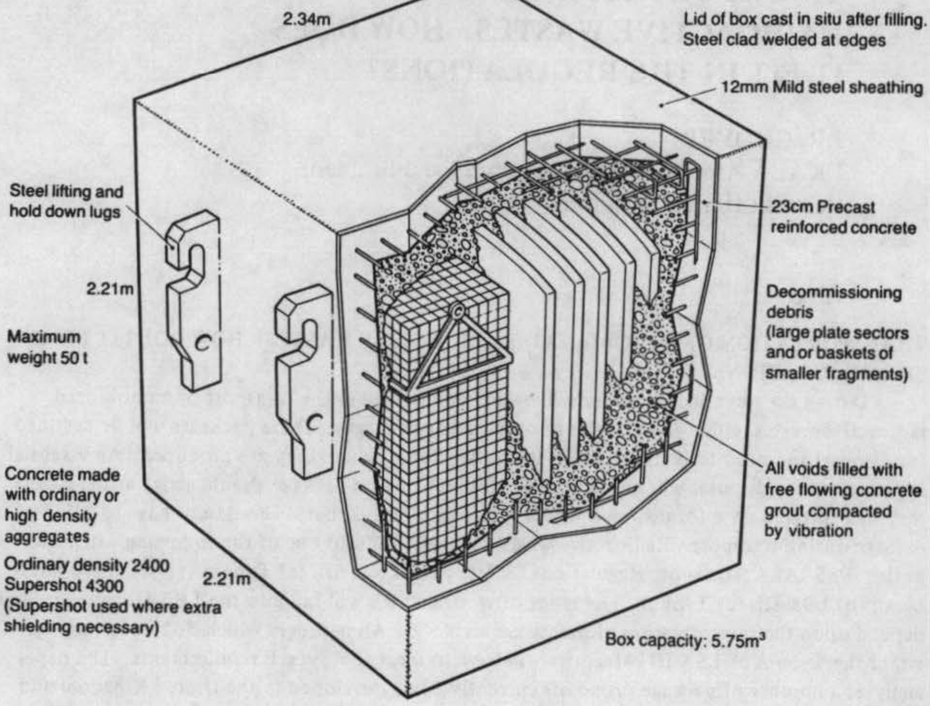

FIG. 1. Waste disposal container.

streams arising in the United Kingdom are available from a number of sources [2–4]. In general, they can be divided into three groups: those, such as sludges and ion exchange resins, which result in a uniform and homogeneous waste form; those, such as fuel element cladding debris, which will result in a heterogeneous, but nevertheless fairly uniform waste form and, finally, miscellaneous plant items of very variable size which will result in a non-uniform waste form.

In the UK, the first two types of wastes will be immobilized, in general using cement [5], but polymer matrices may be used in a few instances. The immobilized waste forms will be prepared in nominally 500 L steel drums approximately 800 mm in diameter and 1285 mm in height.

The miscellaneous wastes, a large proportion of which will come from plant and reactor decommissionings, would usually be quite large and a larger package is desirable to avoid the problems of significant size reduction. One such package is proposed for the wastes arising from the decommissioning of the Windscale AGR reactor and is illustrated in Fig. 1 (the two figures used in this paper are intended to illustrate the basic principles of the design of the two types of disposal packages and do not necessarily represent final designs), although UK NIREX Limited

(Nuclear Industry Radioactive Waste Executive) is proposing a range of large packages of a more rectangular shape. It is also proposed to use cement as the matrix for these wastes.

PROPERTIES OF IMMOBILIZED WASTE PACKAGES

Immobilized waste forms are usually massive, solid and are generally void-free. If cement is used as the matrix material, the typical leach rates will be:

- For Cs: 10^{-2}–10^{-4} $g \cdot cm^{-2} \cdot d^{-1}$
- For Sr: 10^{-2}–10^{-5} $g \cdot cm^{-2} \cdot d^{-1}$
- For Pu: 10^{-5}–10^{-7} $g \cdot cm^{-2} \cdot d^{-1}$.

Fire tests on cement matrix waste forms in general show minimal effect beyond the outer few millimetres. The mechanical properties of immobilized waste forms using cement are reported in Ref. [6].

REQUIREMENTS OF WASTE PACKAGES FOR DISPOSAL

Much has been written about the multibarrier approach to the long term safety analysis of waste disposal [5]. The barriers being considered in the United Kingdom are:

(1) Wastes immobilized in a cement matrix
(2) An outer steel container
(3) A surrounding layer of cementitious material to grout the packages in the disposal location and to avoid significant voidage
(4) The near and far field geology of the disposal location.

For these multiple barriers to be effective, it is important that each of them be assured at the time of emplacement, i.e. the waste package should arrive at the repository and be emplaced without damage. This implies therefore that in arranging and designing the transportation system, particular emphasis should be given to the protection of the packages against damage, even in the event of minor accidents. (The number of major accidents likely to occur will be low and any packages badly damaged as a result of such an accident could be repackaged for eventual disposal.)

TRANSPORT OF WASTE PACKAGES

From the earlier descriptions of the two typical packages proposed for disposal in the United Kingdom, we can consider two different transport arrangements.

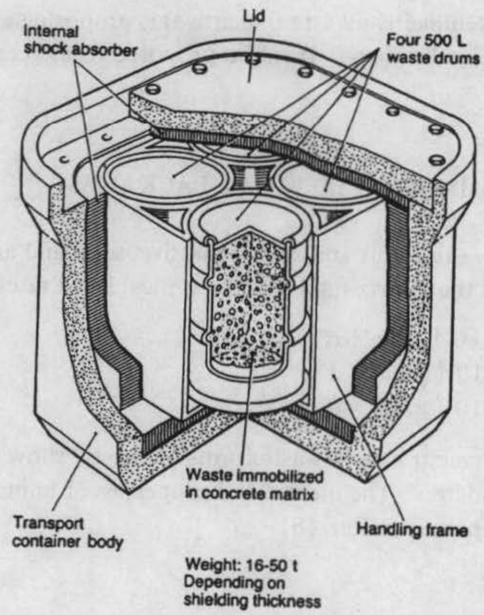

FIG. 2. Transport container for four 500 L drums.

(1) A group of four 500 L drums placed in a handling frame inside a heavy steel, reusable transport container. The space between the handling frame and the transport container is filled with impact absorbing material to protect the steel drums. Additional impact absorbers may be placed on the outside as well. Typical shielding thicknesses of the steel will range from 70 mm to as high as 285 mm. The overall weights of such systems will range from 18–54 t. The designs will ensure no significant loss of shielding in any reasonable accident (see Fig. 2 for an illustration of a possible system).

(2) The large packages illustrated in Fig. 1 are designed to be adequately shielded for transport and so that the entire package, including the shielding, can be disposed of. The construction of the packages with the outer steel box, and also the heavily reinforced concrete shielding layer, result in a very strong package which will withstand minor accidents and prevent significant loss of shielding in more serious accidents.

These two types of packages, with the typical waste streams given in Refs [2–4], will fall into one of the following categories in the 1985 IAEA Transport Regulations:

(a) Type A (very limited numbers)
(b) Industrial package Type 2 (IP-2) for LSA-III
(c) Type B.

TABLE I. PROPERTIES OF TYPICAL WASTE STREAMS IN THE UNITED KINGDOM (IN 500 L DRUMS)

Waste stream	Relationship to 2×10^{-3} A_2/g	Dose rate at 3 m (mSv/h)	Total beta-gamma activity per drum (Ci)[a]
(1) BNFL[b] Magnox floc	0.015	0.002	0.178
(2) BNFL miscellaneous Magnox solids	2.07[c]	61.8[c]	2640
(3) BNFL ion exchange AW500	0.455	138[c]	1440
(4) BNFL Zircaloy cladding	53[c]	26.5[c]	746
(5) BNFL Magnox pond sludge	0.95	11.8[c]	522
(6) BNFL Al/Fe floc	0.5	0.0008	0.052
(7) BNFL miscellaneous solids	0.13	4.2	310
(8) BNFL silo sludge	0.376	11.6[c]	322
(9) CEGB[d] Magnox graphite	2×10^{-5}	0.12	2.07
(10) CEGB AGR fuel element debris miscellaneous activated components	0.06	532[c]	6140
(11) CEGB AGR sludges	0.003	28.4[c]	522
(12) Dounreay low alpha, high beta gamma	0.0014	1.0	2.9
(13) Dounreay MTR liquors	1.3[c]	0.17	7600
(14) Dounreay low level solids	3×10^{-5}	0.0005	0.016
(15) Winfrith ion exchange resins/sludges	3.6×10^{-5}	0.3	0.93
(16) Amersham Co-60 sources	2.01[c]	19 200[c]	50 000

[a] 1 curie (Ci) = 3.70×10^{10} Bq.
[b] British Nuclear Fuels Limited.
[c] Indicates outside limit in IAEA Safety Series No. 6.
[d] Central Electricity Generating Board.

Very few waste packages will fall into the Type A category, so it is first necessary to consider whether they fall in the LSA-III category. A range of waste streams in the United Kingdom is listed in Table I and, based upon currently proposed conditioning factors (i.e. the volume change from raw wastes to immobilized wastes), their specific activities have been compared with the LSA-III limit of 2×10^{-3} A_2/g (para. 131(c), Ref. [7]). (The A_2 value is used, since none of the immobilized waste packages can be considered to be special form.) This is not the only criterion to be considered. For LSA material, it is also necessary to comply with para. 422, i.e. the external radiation level at 3 m from the unshielded material must not exceed 10 mSv/h.

Each of the waste forms in Table I was assessed relative to these two requirements. Seven of the waste streams examined satisfy both of these requirements. Of the remaining nine wastes, eight of them have dose rates at 3 m greater than 10 mSv/h and four of them are above the limit of 2×10^{-3} A_2/g (although with an additional, twofold, dilution, only one would be outside this limit). If the requirement that para. 422 be satisfied is removed, then all but one of the waste streams considered in Table I could be transported as LSA-III, i.e. an industrial package.

DISCUSSION

Industrial packages for LSA materials are not required to withstand accidents, hence the radiation level limitation on the unshielded material of 10 mSv/h at 3 m. However, owing to the total activities in waste packages (see Table I), heavy shielding is essential for the handling and transport of the majority of them and it is clear that they should not significantly lose this shielding during such operations. This aspect is demonstrated particularly by waste streams 5, 7, 8 and 13 in Table I. With a minor dilution for three of them, all four waste streams could satisfy both of the conditions for the LSA-III category, though they would all require significant shielding.

It is highly desirable for the transport of wastes that the majority of waste packages arrive at the repository undamaged. The waste forms are immobilized and are leach resistant to meet the requirements for disposal. Cement matrix waste forms are also unlikely to be damaged in a fire. Fifteen out of the sixteen waste streams listed in Table I could satisfy the LSA-III requirement of being within the limit of 2×10^{-3} A_2/g. However, according to the 1985 IAEA Regulations, only seven of these could be transported in the IP-2 category, while the remainder would have to be transported as Type B packages.

For the large box-type packages which contain miscellaneous items, it will also be necessary to comply with the guidance regarding the interpretation of "essentially uniformly distributed". However, for large miscellaneous items of contaminated plant and equipment, many of which will arise from decommissionings, both cost and operator dose will be minimized if the amount of the size reduction of such large items is also minimized. The large packages being proposed will be ideal for these wastes, but the larger the individual pieces of waste, the greater will be the difficulty in ensuring that the waste is essentially uniformly distributed.

CONCLUSIONS

The requirements given in the IAEA Transport Regulations have been developed over the past 25 years to meet the needs of the industry in safely transporting radioactive materials. It is now time to consider what requirements are necessary for the future transport of immobilized wastes. This paper has identified a number of requirements in the 1985 Regulations which, if they are interpreted correctly, would appear to include much of the radioactive wastes within the Type B category. It is important to examine whether this is necessary or justified in relation to the requirements already placed on waste packages to meet criteria for disposal.

ACKNOWLEDGEMENTS

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