Activity Release From ILW Packages in Impact Accident Conditions

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INTRODUCTION

UK Nirex Ltd (Nirex) is owned by the major organisations in the UK nuclear industry. The company is responsible for developing and operating an underground repository for the disposal of solid intermediate-level and low-level radioactive waste (ILW and LLW). Most intermediate level waste will be converted to a cementitious monolithic solid, packaged in thin-walled unshielded waste containers and transported to the repository in reusable shielded transport containers (RSTCs).

The standard unshielded waste containers adopted by Nirex, the 500 litre drum, $3m^3$ box and $3m^3$ drum, have been specified to provide waste producers with a choice of container to suit their needs whilst maintaining common handling features and dimensions (Barlow 1993). Four 500 litre drums in a transport stillage have the same outer envelope dimensions as a $3m^3$ drum or box, so that all these containers can be transported within a standard range of RSTCs having the same cavity sizes and a range of shielding thicknesses.

The 500 litre drum will be the predominant ILW disposal container and is already in use for waste packaging. During transport the 500 litre drum waste package will be afforded protection by the RSTC, which with its contents will form a Type B package as defined by the Transport Regulations (IAEA 1990). On receipt at the repository the RSTC will be unloaded and the unshielded waste packages transferred to disposal vaults.

Previous studies by Nirex (Nirex 1989) have shown that the thin-walled stainless steel 500 litre drum waste package can be designed to be very robust when dropped from 10m, but breaching of the drum walls and release of some radioactive material cannot be discounted. The hazard associated with radioactive material released from a breached package will be determined by a number of factors including:

- The extent to which the matrix breaks up into fine particulate material,
- The performance of the drum in retaining this material, and hence the release fraction from the drum,
- The size distribution of the released material,
- The fraction that becomes airborne,
- The radioactivity associated with the release material, and
- The containment provided by the vaults or the RSTC.

Clearly the performance of the drum and that of the waste matrix are both important parameters for safety case requirements. This paper describes a programme of work to obtain information needed to predict waste container damage, matrix breakup and consequential activity release arising from impact accidents. The work included both full-scale and small-scale inactive impact tests as well as some work using fully active materials. The information obtained will provide the source term for repository safety assessments and for the methodology devised to demonstrate RSTC containment after the IAEA 9 metre drop test.

500 LITRE DRUM DROP TESTS

The purpose of the 500 litre drum drop tests was to determine the fraction and size distribution of the contents of waste packages that are released following an impact resulting in a breach in the waste container.

Test Programme

As it was intended to measure the quantity of released material which became airborne and also that which was subsequently deposited, the test had the following features:

- The drums were dropped onto an aggressive feature so as to ensure that a breach would occur.
- The drums were dropped in an enclosure so that the air could be sampled to measure the aerosol concentrations.

The drop tests were carried out at the facility of International Research and Development Ltd (IRD) in Newcastle. The target comprised a reinforced concrete block measuring 3m x 2m x 1m high, topped by a 200mm thick mild steel plate bolted through the concrete block to a pile cap below, which in turn was supported on piles. For most of the tests the target was a steel punch (0.1 x 0.1 m x 0.2 m high) on top of the steel plate. The target assembly was surrounded by an enclosure 3.27m x 2.00m x 2.65m high. The roof of the enclosure contained a trap door through which the drum fell. This door was closed rapidly after the drum had entered the enclosure (typically within a second).

The test programme examined four inactive simulated wasteforms, chosen to represent the majority of radiologically significant ILW streams:

- solidified magnox sludge,
- solidified reprocessing liquor,
- encapsulated miscellaneous beta gamma materials, and
- encapsulated supercompacted plutonium contaminated material (PCM).

Table 1 lists the drop tests carried out. All drums were dropped from a height of 25 metres. This height was chosen to ensure that the amount of release from the drums would be sufficiently large to obtain meaningful results.

The lid-edge attitude was chosen to inflict maximum damage to the lid-to-body joint, thus maximising the quantity of contents released. The horizontal drop on to a punch was chosen to give a release due to penetration of the drum skin.

Table 1. Details of Full-Scale Inactive Drop Test Programme

Test	Contents	Age at Test (days)	Weight (kg)	Drop height (m)	Impact orientation
A1	Supercompacted PCM	113	1268	25	Lid edge
A2	Supercompacted PCM	116	1259	25	Horiz. on punch
A3	Miscellaneous Beta Gamma Materials	112	1641	25	Horiz. on punch
A4	Miscellaneous Beta Gamma Materials	116	1678	25	Horiz. on punch
A5	Magnox Sludge	113	1003	25	Horiz. on punch
A6	Magnox Sludge	115	985	25	Horiz. on punch
A7	Reprocessing Liquor	106	1146	25	Horiz. on punch
A8	Reprocessing Liquor	105	1147	25	Horiz. on punch

Test Measurements

Airborne material within the enclosure was measured by extracting air through sampling heads fitted with filters to collect the airborne material. Two arrays of four samplers were positioned along opposite walls of the enclosure. Each sampler had its own pump, operating at 8 litres/min with a calibrated flowmeter. Samples were operated in pairs, one on each side of the enclosure, to average local variations in the density of airborne material.

The first pair of samplers operated for the first 15 minutes after impact. The weight of material collected during that period was taken to represent the immediately airborne material. In undisturbed air, particles of 100μm diameter settle at a velocity of 0.3 m/s and would thus take less than 100 seconds to fall from the enclosure roof to the floor. Particles of 10μm diameter settle at 0.003 m/s in undisturbed air and would remain airborne for at least 15 minutes. Further pairs of samplers were operated for 15 to 30 minutes, 30 to 60 minutes and 60 to 90 minutes after impact. The results from these samplers determined the variation of airborne material with time.

Two further pumps were also activated immediately after impact. These drew air at a lower flow rate (1 litre/min) through impingers filled with isotonic electrolyte solution. These were positioned on the cross-walls between the main sampler arrays. One operated for 30 minutes after the impact while the other operated for the full 90 minutes of the sampling period. The suspensions of particles drawn into the isotonic solution were later analysed using a Coulter electronic particle counter to determine the size distribution of the airborne material down to less than 1μm diameter.

As a volume of $1.56m^3$ of air was extracted during the test, it was necessary to provide a route for make-up air to enter the enclosure. Three apertures were provided near the top of the enclosure. The inlets were filtered to ensure that dust was not drawn in. The results were later corrected to allow for the introduction of clean air during the sampling period.

Before each test, all enclosure surfaces were cleaned and the perspex windows were sprayed with anti-static fluid to prevent them attracting dust. A background run was then carried out to determine the dust level in the enclosure prior to testing.

After each test the filters and impingers were removed for analysis and the material deposited in the enclosure was collected for weighing and particle size analysis. Material falling out when the drum was removed from the punch was collected separately for weighing. Table 2 summarises the principal results of the tests.

Table 2. Summary of 500 Litre Drum Drop Test Results

Test	Contents	Mass escaping (g)	Mass <105μm (g)	Mass <32μm (g)	Initial Aerosol Density in the Enclosure (mg/m^3)
A1	Supercompacted PCM	37	3.7	1.48	10
A2	Supercompacted PCM	47.2	8.17	2.70	1.8
A3	Miscellaneous Beta Gamma Materials	273.9(1)	14.25	1.37	1.8
A4	Miscellaneous Beta Gamma Materials	7.0	0.49	0.15	2.1
A5	Magnox sludge	11.1	0.92	0.27	0.9
A6	Magnox sludge	5.9	0.67	0.18	2.2
A7	Reprocessing liquor	6.0	0.606	0.16	1.4
A8	Reprocessing liquor	229.3(1)	2.98	0.69	3.3

(1) In these tests the drum rebounded releasing additional material.

These results were processed to provide data for releases from a 500 litre drum, weighing 2 tonnes and dropped from 25m. These results can be applied to different weights and drop heights by presenting the results in terms of grams of material released per MJ of impact energy. The results for all the samples are shown in Table 3.

Table 3. Release Fractions for 500 litre Drum Drop Tests

Description	Size Range	Mass per unit Impact Energy (g/MJ)
respirable, promptly airborne	< 32μm	0.1 - 0.50
non-respirable suspendible and promptly airborne	32 to 100μm	0.013 - 0.015
respirable, deposited	< 32μm	2.4 - 4.5
non-respirable suspendible and deposited	32 to 100μm	8.1 - 9.3

SMALL-SCALE INACTIVE AND ACTIVE TESTS

Small-scale impact tests have been carried out in the past by Nirex (Nirex 1989) and others (Wallace 1976, Ramo 1979) to measure the relationship between impact energy and the quantity of fine particulate material generated in solidified wasteforms. In the previous work by Nirex it was shown that the quantity of fine particulate material generated is proportional to the impact energy. Based on this finding a method had been proposed to estimate the quantity of particulate material generated in a full-scale test from the results of a small-scale test. The method was shown to be conservative (i.e. the quantity at full-scale was overestimated by up to a factor of 10).

In this project the previous work was used to examine the sensitivity of breakup to variations in parameters such as compressive strength, water content, age and cracking. The work was also extended to encompass a wider variety of wasteforms.

Test Description

The impact test apparatus used in the programme consisted of an impactor, a delivery tube for the impactor, an anvil for locating the specimen and an enclosure for the debris.

The specimen was seated on an anvil located directly below the delivery tube and mounted securely on a steel plate bolted to the concrete floor. The anvil was a mild steel fabrication which supported a specimen snugly on its base and on its cylindrical face away from the impact, at an orientation such that the specimen's geometric centre of gravity was vertically below the impact point, and aligned with the axis of the delivery tube.

The impactor was a solid mild steel cylinder 80mm diameter 280mm long, with a flat impacting end and weighing approximately 14kg. The specimens were all of a standard size of 100mm diameter by 150 mm long. A combination of hand sieving, airjet sieving, and laser diffractometry was employed to obtain the particle size distribution of the debris generated.

Test Programme

Table 4 provides details of the tests carried out. In order to minimise the effect of scatter in the results, three specimens were tested for each test condition. Specimens were subjected to the equivalent energy of a 10 metre or 25 metre drop.

Table 4. Summary of small-scale tests carried out

Age	Drop height	magnox sludge1	magnox sludge2	reproc liquor	sludge cores	swarf cores	floc	sludge 1	sludge 2	poly-mer	PFA OPC
7 days	10m	✓	✓	✓							
	25m	✓	✓	✓							
90 days	10m	✓	✓	✓			✓	✓	✓		✓
	25m	✓	✓	✓							
90 days plus	10m	✓	✓	✓							
	25m	✓	✓	✓							
11 mths	10m									✓	
7 yrs	10m				✓	✓					

In addition to impact tests, static compressive strength tests were carried out on specimens of the same age as the impact test specimens.

The specimens tested ranged in age from 7 days to 7 years; from 0.6 N/mm^2 to 40.7 N/mm^2 compressive strength; and from 10.1% to 54.6% free water content (measured as loss of weight when heated to 105°C). Both homogeneous and heterogeneous wasteforms were tested.

Test Results

Figure 1 shows a typical result. It shows that for magnox sludge type 1, the extent of breakup decreases with age up to about 90 days. Thereafter there is a modest reduction in breakup. During the curing period a wasteform increases in strength. Hence from Figure 1 it might be expected that the breakup of a strong waste might be less than that of a weak waste. For fully cured wastes however (>90 days old), this is not the case. Figure 2 shows the variation in breakup with compressive strength for all the wastes tested, and shows no trend for breakup to vary with compressive strength. Similarly Figure 3 suggests that breakup is independent of water content. Seven-year-old magnox swarf cores and magnox sludge cores can be seen to have provided similar results to other wasteforms which were only about 90 days old. The heterogeneous magnox swarf produced similar results to the other wasteforms.

The main conclusion to be drawn from the series of small-scale inactive tests is that the amount of breakup obtained from the fully cured specimens was similar for all wasteforms (allowing for experimental scatter) regardless of compressive strength, free water content, chemical composition or even homogeneity.

The small-scale impact test programme was completed by additional tests involving fully radioactive magnox sludge, immobilised and cast to form standard test pieces. The test equipment and procedure were identical to that described previously except that test had to be carried out in a shielded facility. Comparison of particle size distribution for active and inactive tests shows good agreement giving confidence in the breakup properties of the magnox sludge simulant.

SUMMARY

The aim of the work described in this paper was to obtain estimates of activity release from waste packages in an accidental impact situation. It was not feasible to obtain this directly by carrying out drop tests on full-size packages containing the real radioactive waste. Instead the relevant information was obtained indirectly through a combination of full-scale inactive tests, small-scale inactive tests and small-scale active tests

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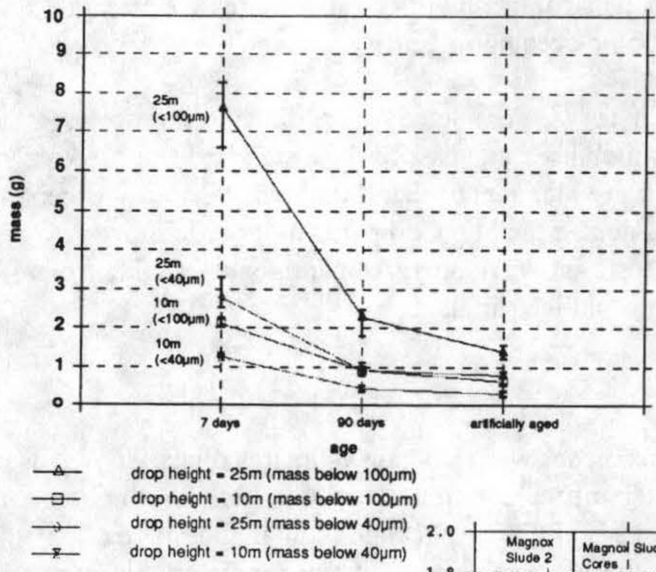

Figure 1
VARIATION OF MASS BELOW 100µm AND 40µm WITH AGE: MAGNOX SLUDGE 1

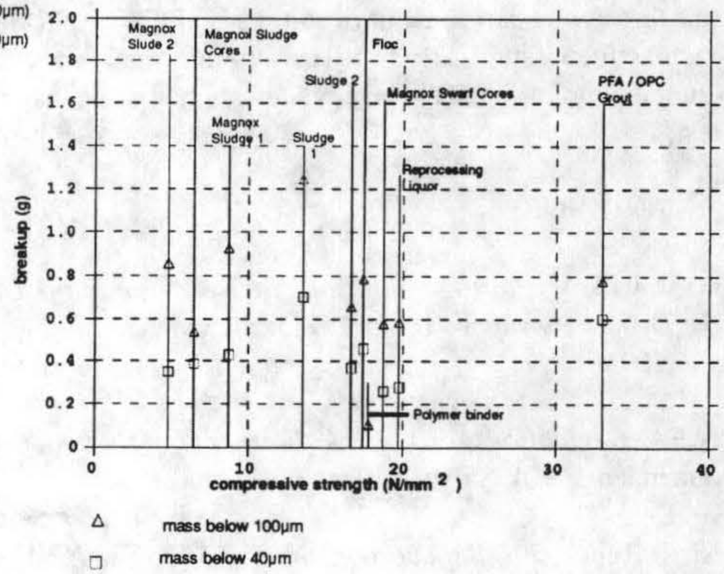

Figure 2
VARIATION OF BREAKUP FROM 10m WITH COMPRESSIVE STRENGTH

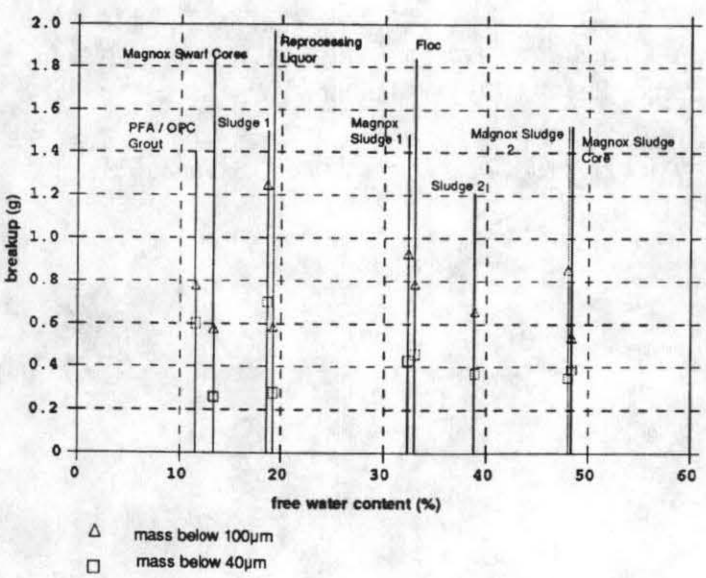

Figure 3
VARIATION OF BREAKUP FROM 10m WITH FREE WATER CONTENT