Impact Test Qualification of 500-Litre Drums for Long-Term Storage[*]

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INTRODUCTION

This paper describes the results of impact-testing two types of 500-l drums containing different forms of simulated solid intermediate-level waste. The tests were undertaken independent of each other. For clarification, the results, which provide useful benchmarks for designers of waste packagings containing grouted immobilised waste materials, are presented separately.

Test series A : Impact Studies of 500-l Drums Containing Cemented (Simulated) MTR Liquor

REQUIREMENT

It is proposed to immobilize 700m^3 of neutralised MTR liquor (anion deficient aluminium nitrate with trace products of ferrous sulphamate, mercury, calcium, sodium, and fission products) currently stored at the UKAEA site at Dounreay. Immobilization will be achieved by cementation using a mix of Portland Cement and Blast Furnace Slag. Following a development program to improve the long-term properties of the product, it was necessary to evaluate the impact performance of drums containing an inactive simulant of this waste material. This was to support their qualification under both the IAEA transport regulations and also the criteria specified by UK NIREX Ltd who are responsible for the design and development of a fully-integrated system for the deep disposal of low- and intermediate-level radioactive waste in the UK.

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DRUM DESIGN

Features of the immobilised-liquor drum are shown in Fig. 1. The drum is 1190mm tall and has an external diameter of 800mm. It has a capacity of approximately 560 l and contains a paddle to ensure uniform mixing of the cemented product. The lid contains a filler cap, a grout-level sensor and a surface water detector and removal port.

CONTENTS

The drum contains 470 litres of cementitious product (simulating the immobilised ILW material) covered by 90 l of capping grout - a mix of Pulverised Fuel Ash and Portland Cement.

TEST CRITERIA

Three drop-tests were performed on two prototype packages : a 1m drop onto the lid and a 10m drop onto the side of the first drum, and a 10m drop onto the lid of a second drum (Fig. 2).

RESULTS

1m Drop Onto the Lid

The profile of the localised deformation shows that a knockback of 40mm was sustained (Fig. 3). This covered an area of some 500cm^2, with a corresponding volume reduction of about 1 litre. There was no release of contents, and the deformed drum was capable of maintaining a 190mm w/g over-pressure for over 2 hours.

10m Drop Onto the Side

The drum was dropped with its damaged area uppermost. During the final rocking motion after the initial impact, the grout lid became detached because its retaining pins sheared (Fig. 4). This resulted in 0.46 kg of grouted material being ejected. There was no release of simulated MTR product. The drum suffered a knockback of 15mm sustained over a width of around 230mm.

The deformed area was 1,700cm^2 with a corresponding volume change of about 2 l. The metal skin sustained a 2mm x 210mm crack between the lid flange and the drum sidewall. Post-test particulate analysis on the loose debris showed that 43% of the expelled material comprised pieces greater than 50mm and that 99% of the debris had a minimum dimension of greater than 1.7mm.

The drum was cut in half along its principal axis to expose the contents for visual analysis. Approximately 95 l of the matrix had suffered severe cracking and had separated from the main body of material. The "vertical" shear plane followed the line of the mixing paddle : the "horizontal" shear plane remained largely orthogonal to this (Fig. 5). Many of the loose pieces were greater than 250mm minimum dimension, and over 98% were greater than 50mm. Only 0.02 w/o of material was smaller than 300 microns. The remainder of the matrix, although sustaining some cracking, was largely intact.

10m Drop Onto the Lid

On impact, the grout lid broke free and some 0.68 kg of capping grout was released. The drum came to rest in the upright position about 250cm from its point of impact. Knockback was measured at 95mm for a distance of 560mm around the rim. The deformed surface area was 600cm^2 with an associated volume change of 1.5 litres. The surface water detection cap was displaced, but remained attached. Examination of the impact zone revealed two cracks on the welded joint between the lid and the strengthening feature (Fig. 6). One fissure was 0.6mm wide x 195mm long, and the second was 1.7mm (max) x 180mm. Both penetrated by up to 5mm. Subsequent examination showed that the inner surface of the lid sustained a 175mm long crack in this vicinity.

At the point of impact the matrix suffered cracking which extended through the 180mm thick grout cap to about 150mm into the simulated immobilised waste material. The secondary impact on the base caused two 450mm-long cracks which penetrated about 180mm into the matrix. The remainder of the matrix was free from cracks.

CONCLUSIONS

Although, inevitably, some structural damage was sustained and containment was breached as a result of these tests, there was no evidence to suggest that any cemented MTR waste would escape such an event. The quantity of ejected material was small, and the amount of radioactivity that would have been released if this had been a real event was within the limits set by UK Nirex Ltd.

RECOMMENDATIONS

Consideration could be given to the design of the inner lid closure features to minimise displacement under impact conditions.

Test series B : Impact Studies of 500-l Drums Containing Supercompacted 220-l Drums

REQUIREMENT

Although supercompaction is a well-established technique for volume-reducing low-level waste in 200-l drums, it is not so well developed for drums containing contact-handleable solid intermediate-level waste. The purposes of these tests were (1) to refine the 500-l overpack drum designs; (2) to assess the package performance under both normal and accident impact conditions; and (3) to address other areas of uncertainty in over-drumming supercompacted waste drums.

DRUM DESIGN

The drum comprises a simple reinforced design (similar in external appearance to the type used above) which has a lid that incorporates a grout-filling point and cover plate. This lid is welded to the body prior to grouting.

CONTENTS

Seven supercompacted 220-l drum pucks were placed in the drum. They contained simulated ILW typical of that expected to arise within the UKAEA. From bottom to top they comprised: (P1) Building Materials* (P2) Combustible Waste*, (P3) Compressible Waste, (P4) Mixed Waste, (P5) Non-ferrous waste, (P6) Combustible Waste*, and (P7) Heavy Waste*, as shown in Fig. 7. Pucks identified thus * contained "Redwop" ultra-violet fluorescent powder which was introduced into the drums prior to supercompaction and found to be on the surface of some pucks present after compression and prior to loading in the 500-l drum. The drum was grouted using a 3:1 mix of PFA/OPC.

TEST CRITERIA

The most severe credible accident was deemed to be a 25m horizontal-axis drop onto a punch. The punch was positioned to cause maximum damage to the drum and its contents. The total mass of the drum and punch, as dropped, was 1,338 kg (Fig 8).

RESULTS

On impact, the punch fully-penetrated the drum side within 40 milliseconds and the drum finally came to rest some 2.5m from the target spot. The punch penetrated to a depth of 230mm, and the drum increased in length along this side by 76mm (Fig. 9). The knockback around the rim was 42mm over a length of 340mm. The deformed surface area was 1,400cm^2 with an associated volume of 1.3 l. On removal of the punch base plate, it was revealed that the punch had "self-sealed" (Fig. 10). There was no sign of damage to the drum base, and no debris appeared to have been expelled. Except for the penetration zone, all surfaces and structural welds remained intact with no signs of tears or cracks. Some of the nonstructural lid-band welds were deformed and torn in the immediate vicinity of the impact zone, but this did not affect drum integrity.

Destructive Examination

The drum was decanned to reveal the impact zone where the capping grout had absorbed most of the impact energy. Cracks were observed in the grout adjacent to the impact zone. The drum skin was also removed from the punch penetration area to expose the condition of the grout. This revealed cracks radiating around the point of penetration, although there was a notable absence of fluorescent powder. The grout was removed to the level of the basket that holds the pucks so that the deformation around the impact zone could be studied in more detail (Figs. 11 and 12). Again, there was no evidence of fluorescent powder.

The basket was removed, along with some grout, to reveal the condition of the supercompacted pucks (Fig. 13). Details of the punch penetration showed that pucks P1 and P2 had been forced apart and some tearing of the skin was found on P2. The only fluorescent powder observed was that previously seen on puck P6, when the puck was loaded into the 500-l drum. Removal of the base and bottom puck showed that the punch had penetrated 120mm between this puck and the adjacent one. Although there were tears in the skins of both pucks, there was no evidence of fluorescent powder having been released as a result of the impact..

CONCLUSIONS

The drum survived a 25m drop onto a punch with a breach of structural containment only at the point of punch penetration. There was no observed release of particulate matter. The integrity of the drum was not affected by failure of certain non-structural welds.

The drum remained in a retrievable and handleable condition providing the punch was left in place. Detection powder that was present on the puck surface before encapsulation in the 500-l drum did not spread beyond the puck / grout interface during impact.

RECOMMENDATIONS

Although this design meets the containment criteria that were applied. a future post-impact retrieval strategy may need to be developed to deal with real impact scenarios as the degree of containment achieved depends upon the penetrating feature acting as the seal.

ACKNOWLEDGMENTS

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REFERENCES

This paper was compiled from unpublished work undertaken by AEA Technology staff as part of a substantial programme of R&D supporting the handling, transport and disposal of radioactive wastes within the UKAEA.

FIGURES

Fig 1. Immobilized Liquor Drum Schematic

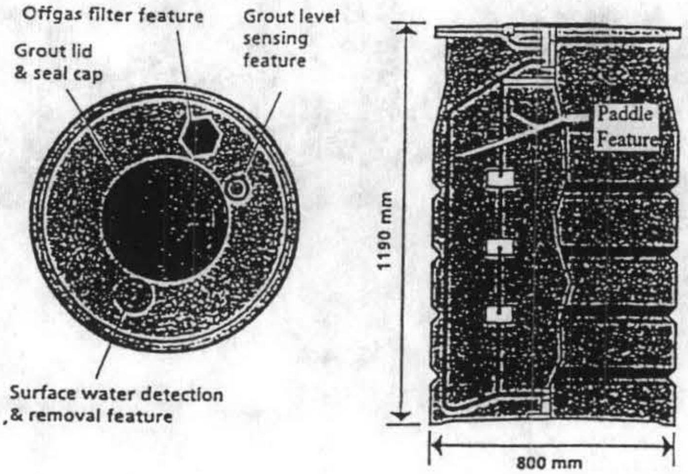

Fig 2. Lid drop attitude

Fig 3. Lid knockback

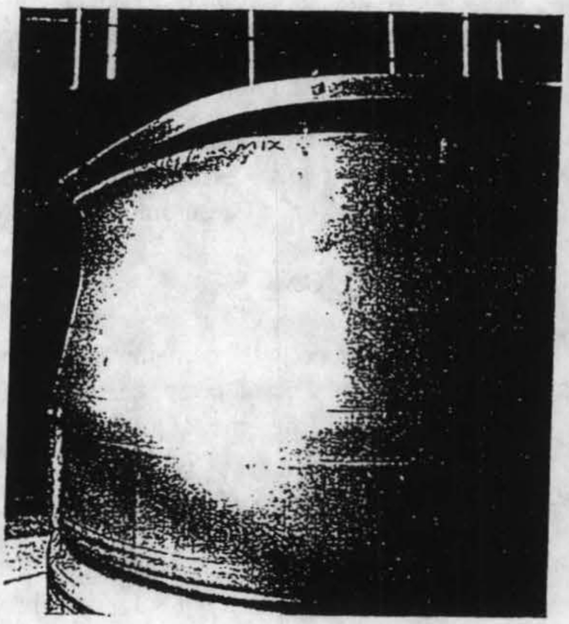

Fig 4. Grout lid detachment

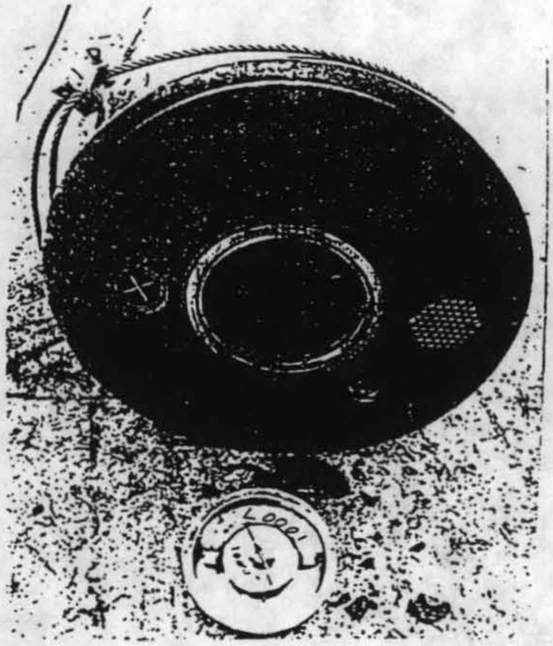

Fig 5. Grout fracture planes

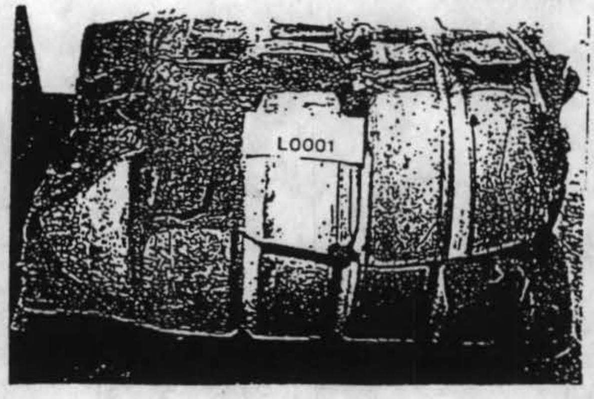

Fig 6. Lid area weld fractures

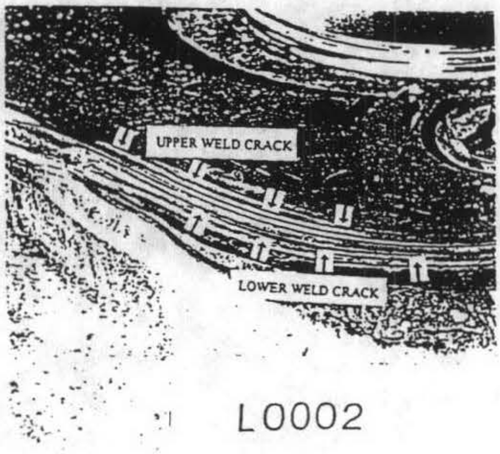

Fig 7. Supercompacted puck stacking

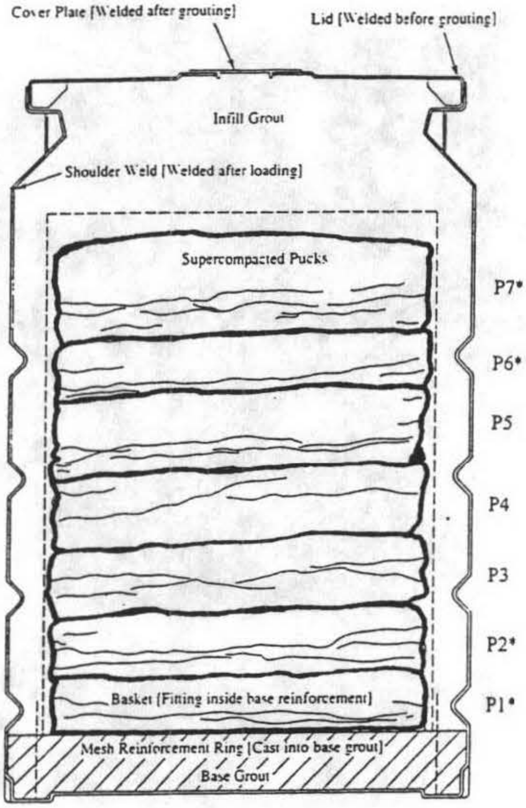

Fig 8. Punch confuguration

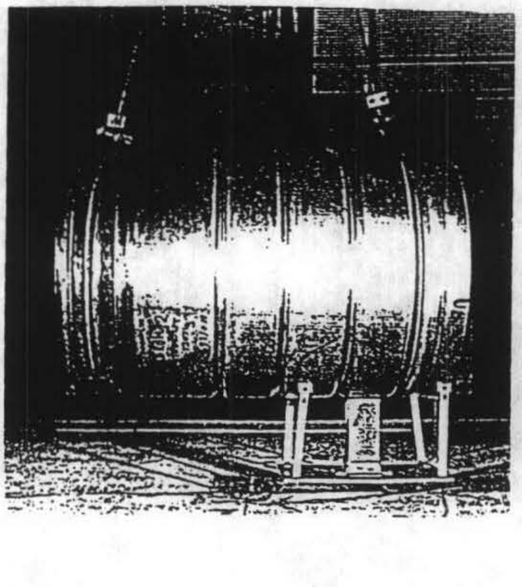

Fig 9. Punch penetration

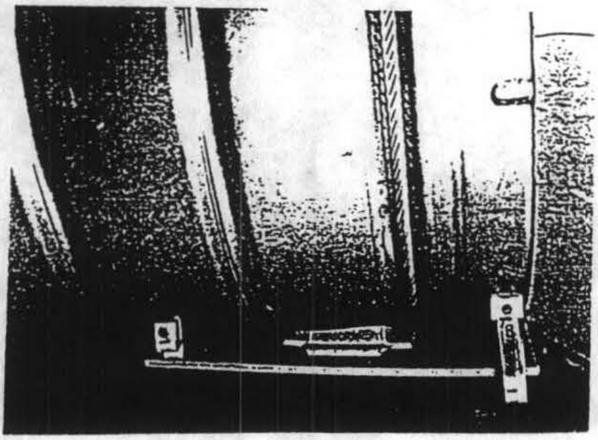

Fig 10. Impact zone

Fig 11. Impact zone after decanning

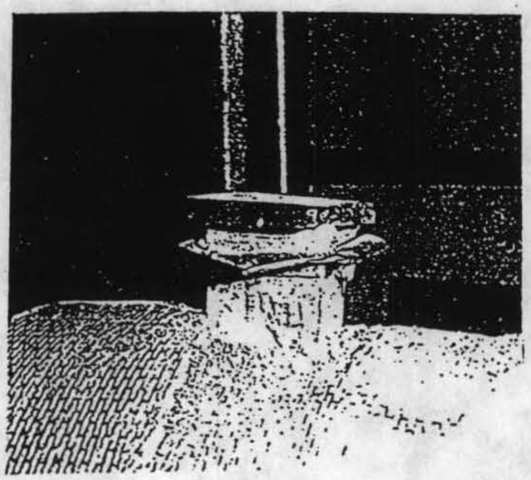

Fig 12. Impact zone basket deformation

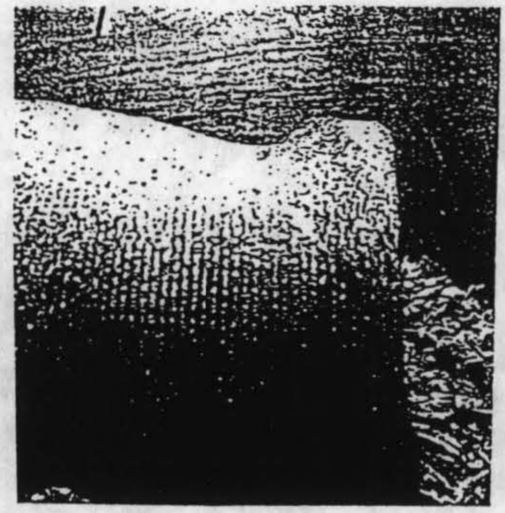

Fig 13. Impact zone puck deformation