DESIGN & APPROVAL TESTING OF THE DN3705 TYPE-B & DN3726 TYPE-A "NESTED" CONTAINERS

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INTRODUCTION

This paper summarises the design and approval testing of a new family of Type-A and Type-B medium-size container. It also discusses some of their operational features.

Following a review of its packaging operations in the mid-1990s, AEA Technology decided to replace the small-to medium size DN 0399 Type-A design of "nested" containers (Figure 1) which had served the industry for many years. This was to maintain consistency with the latest IAEA regulations for Type-A packagings which require safe operation down to temperatures of -40°C. The opportunity was also taken to upgrade the containers in other ways to make them more versatile units. For example, an adaptation of the new Type-A design includes a drain feature on each container to facilitate drying when used in ponds. The Type-A family has the generic design number DN3726.

To capitalise on this initiative two designs of Type-B "overpack" were also introduced : one to permit operation of the Type-As with gamma-emitting radioactive contents, and the second to permit neutron-source materials to be carried. The Type-B arrangement is designated the DN3705. These containers entered service progressively throughout 1997.

OVERVIEW OF THE TECHNOLOGY

The DN0399 design that was replaced was manufactured largely from mild steel and lead. A complete set comprises three containers each of which provides a nominal 50mm of lead shielding. The inner container may be placed inside the intermediate one, and this assembly placed within the outer in "Russian doll" fashion to provide up to three levels of shielding, although the cavity size in this full arrangement is limited. Figure 2 refers. To meet modern operational and maintenance requirements the DN3726 Type-A containers are fabricated in stainless steel. However, to keep costs at a reasonable level, the DN3705 Type-B "overpacks" are fabricated in a carbon steel which meets the -40 °C toughness criterion. The flexibility of this concept allows for up to six Type-A container configurations to be used. When an incomplete set is required for Type-B operation, steel-clad cork spacers ensure that each inner container is located centrally within the overpack to minimise damage should impact occur.

PACKAGING CONFIGURATIONS & WEIGHTS

Seven configurations for the various assemblies are recommended. These are summarised in the following table:

Table 1 : Type-B configurations for the DN3705 packaging

Designation	Outer Container DN3726A	Intermediate Container DN3726B	Inner Container DN3726C	Neutron Container	Outer Packaging DN3705	Maximum Transport Weight (kg)
DN3705A	•				•	2483
DN3705B		•			•	1789
DN3705C			•		•	1320
DN3705D	•	•			•	3207
DN3705E		•	•		•	2026
DN3705F	•	•	•		•	3444
DN3705G				•	•	4860

Transport of neutron source capsules in a "VIP" can is done by using the DN3705-G variant of Type-B overpack with a special inner container which has a maximum weight of 4860kg. This arrangement provides 100mm of lead shielding in addition to the neutron shielding provided by polythene.

DESIGN FEATURES AND STRUCTURAL ASPECTS

Each of the individual replacement Type-A designs was based on its DN0399 counterpart, but is more robustly designed and easier to inspect, decontaminate and maintain. The three replacements are designated the DN3726-A/B/C and have cavity sizes 735mm x 380mmϕ, 521mm x 235mmϕ and 286mm x 100mmϕ respectively for the outer (A), intermediate (B) and inner (C) containers. As with the replaced design, each packaging provides about 50mm of lead shielding, and can be used separately or in combination. Details of the smallest packaging are shown in Figure 3. A full set has a combined unladen weight of under 3 tonnes.

An important aspect of the design of these containers is that the containment boundary is provided by double o-rings on each of the Type-A designs - the outermost of which is the seal for whichever assembly is used. This seal also provides more than adequate containment for operation of the packagings as Type-A units. Figure 4 refers.

APPROVAL TESTING - CHOICE OF PROTOTYPE

In order to ensure that approval testing of the prototype was rigorous but undertaken within the allowable budget, it was agreed with the Competent

Authority that full-scale testing of the heaviest configuration (the DN3705-G : see Figure 5) would be undertaken as representative for the range, and that approval of the other configurations would be accepted by reasoned argument based upon these results. Finite element analysis was used extensively for the structural and thermal assessment to support this.

APPROVAL TESTING FOR "NORMAL" CONDITIONS

For "normal" conditions of transport the required tests are : water spray; 0.3m free drop(s) onto a corner or edge; 1.2m free-drop; stacking & penetration. The water spray test was not required because the materials of construction are not susceptible to being degraded by the elements. Also, as the DN3705 packaging was not designed for stacking, but calculations show that it has a safety factor of 6:1 should an equivalent compressive load be applied. Similarly, the strength of the packaging negates the requirement for a penetration test. The 0.3m free drop onto a corner is required for packages transporting fissile material, and in the case of a package undergoing Type-B testing is only intended to address the integrity of safety features affecting control of criticality. Similarly, the effect of "slap-down" is also judged to be minimal given that the packaging is designed to withstand a 9m drop. Hence this test was not undertaken.

The 1.2m free-drop required careful consideration to identify the worst- case attitude. The primary safety feature of the DN3726 packagings is the leak-tightness of their containment seals. This can be compromised only as a result of damage to the sealing surfaces leading to reduced compression of the o-rings. Significant distortion would have to take place in the vicinity of the seals for this to happen. The point of impact and angle of inclination of the 1.2m drop was considered carefully to ensure that maximum cumulative damage was sustained prior to the 9m drop, as separation of the outer packaging lid from the lower body is the most likely event to cause the seals to fail either in the punch test or as a result of exposure to fire.

It was agreed with the approval authority in UKAEA that, as the three designs are similar, the Type-A drop-test performance for each container could be assessed by dropping the outer packaging (with suitable payload) then using these results to assess the performance for the two smaller ones by reasoned argument. For economy, a dummy load was used to help simulate a fully-laden three-container assembly.

The inclusion of the drain feature introduces a leak-path through the base of each Type-A design. It is intended that this will be "permanently" plugged for most operations, but although significant local damage was predicted when dropping onto the base of the non-drained version, the decision was taken to test this and evaluate the worst case.

Summary of the Type-A test results

The 1.2m drop tests confirmed that the basic design met the IAEA regulations. However, the drops onto the drain feature confirmed that sufficient distortion resulted such that containment could not be held to the standard required for general Type-A certification, i.e., approval with does not restrict the contents to non-friable solid materials only. Hence, for this particular design, it was decided to provide a reinforcing ring to protect the base when in service.

APPROVAL TESTING FOR "ACCIDENT" CONDITIONS

For "accident" conditions, the required tests include a 9m free-drop; punch test; thermal test & water immersion. Separation of the outer packaging lid from the lower body is the most likely event to lead to failure of the seals. For this to happen there would have to be a significant reduction in the thickness of, or exposure of, the resin-bonded cork in the vicinity. Separation at the join is most likely to occur from a drop which imposes significant lateral load on either the base or lid flanges. Hence the tests were devised to exploit this. Buckling of the lower tie-down support plate could open-up the base and risk degradation from thermal effects. A bottom-end impact is therefore also of interest because of the potential for buckling the outer shell, or penetration of the steel skin in this region, from loads transmitted by the tie-down features.

The effect of ambient temperature change in the range -40°C to +38°C was considered at length for the various failure modes, but it was determined that the variations in materials properties were small enough to allow testing at the prevailing ambient temperature to be representative. It was also determined that the inner containment vessel would be pressurised to 2 bar gauge (the maximum normal operating pressure {MNOP} limit) for the duration of the tests.

These considerations led to two "worst case" 9m drops being selected in order to ensure that no potential weakness escaped identification. The particular features of the inner containment vessel that were scrutinised for this were the lid bolting and seals, the drainage vent ports and the lifting features.

The first test aimed to impart high impact shear loads to the lid/body joint on the overpack. An attempt to maximise the effects of "slap-down" on the tie-down features was also made in setting the exact orientation of the drop and estimating how the container might bounce before coming to rest. Calculations of material deformation and "knockback" were made for the various configurations, and it was confirmed that testing the DN3705-G configuration was likely to be the most demanding.

The second test - that of dropping the package onto its base with the CoG over the point of impact - aimed to fracture the outer skin (or weld) of the overpack, thereby exposing the cork to degradation when exposed to fire. Throughout this assessment, it was confirmed that the "G" configuration was the most demanding for sustaining damage.

Two "worst cases" were also identified for the punch test by considering how rupture and gross distortion might take place in the vicinity of the seals such that the punch could impact directly upon the flanges of the inner containment vessel.

The IAEA regulation punch of 150mm diameter was used for the punch test, a length of 600mm being determined as necessary for ensuring that maximum penetration would occur.

The ability of the package to withstand the IAEA regulation fire test was assessed by finite element analysis. At the time of writing, the cability of the package to withstand the IAEA regulation fire test was being assessed by finite element analysis. The results to date show that the package meets these requirements in its undamaged state, and there is no reasons to believe that it will not meet these requirements when the damaged states are analysed. (An update of this will be given at the conference.)

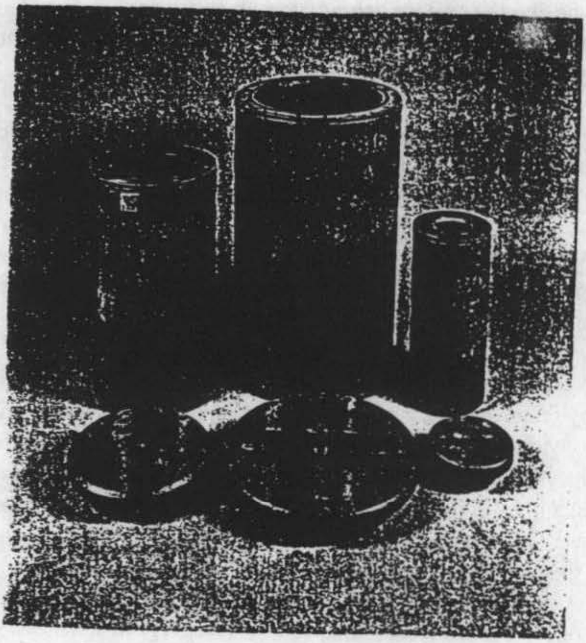
Summary of the Type-B test results

The package was subjected first to a 9m drop on the lid "corner" and then a 9m drop flat onto the base. The damage suffered by the lid showed that the ability to withstand the thermal test could be marginal, and so further reinforcing in the form of a 3mm flat plate placed diametrically across the dome-end at "shoulder" height was incorporated. This was successful, although re-testing by dropping onto the uprated lid then led to the failure of a number of bolts securing the lid to the body through cumulative damage. As a result of this the base was also reinforced by also including a plate as a precautionary measure to negate this.

Although the original design of packaging lid and base required reinforcing as a result of experience gained with the cumulative testing, the design was deemed fit-for-purpose after these simple modifications had been introduced.

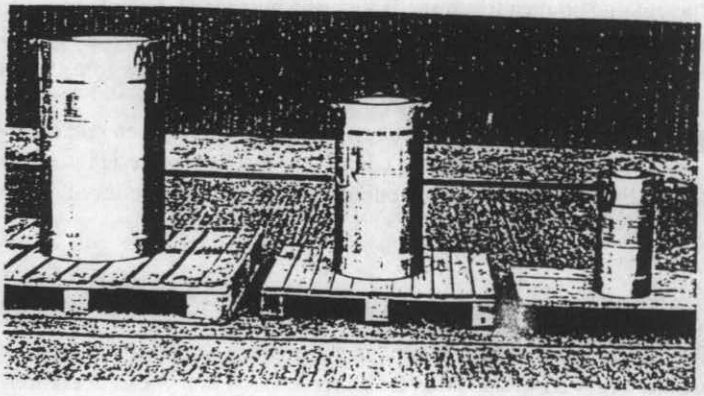
SUMMARY

The DN3705/DN3726 family of containers provides a versatile set of packagings designed to IAEA ST-1 standards for either Type-A or Type-B operation. Maintenance is minimal as a result of using modern materials of construction and fabrication techniques. The Type-A packagings entered service in October 1997 1997 and the Type-B's are due early in 1998.



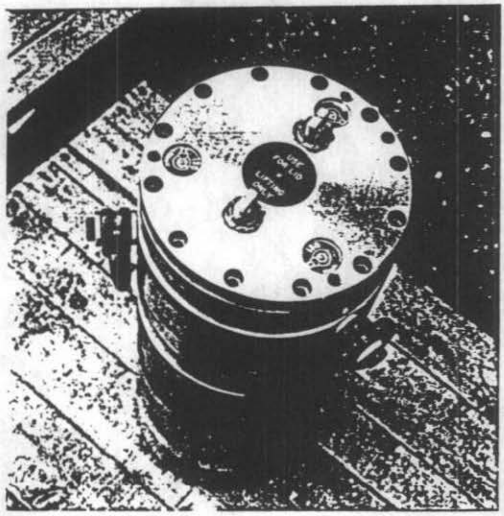
The DN0399 containers which were replaced by the new designs

Figure 1



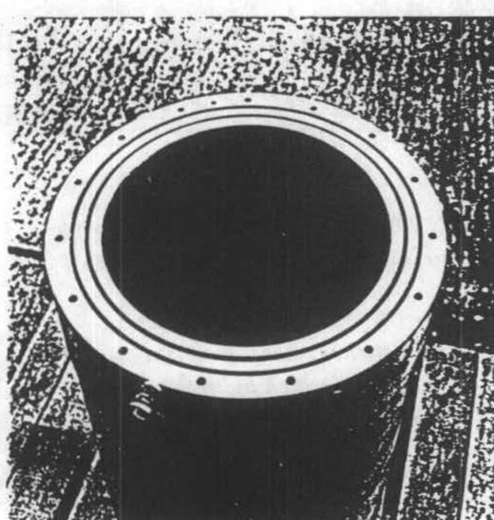
The DN3726 packaging family

Figure 2



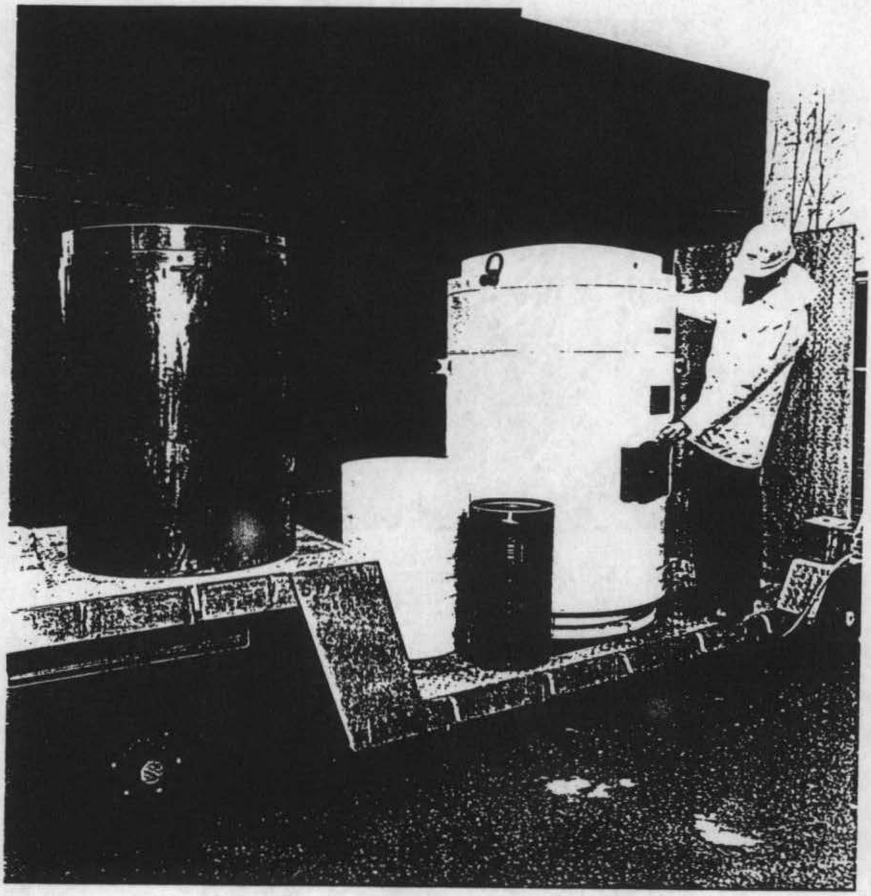
The DN3726C "inner" container
with lid attached

Figure 3



The DN3726A "outer" with lid removed
showing the double o-ring seals

Figure 4



The DN3705G assembly for used carrying neutron sources comprising (left to right) :

the DN3730 spacer container
the polythene neutron shield
the "VIP" can which holds the source
the DN3705 Type-B outer packaging

Figure 5