Development of Type C package for AWE

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Abstract.
The implementation of the new 1996 Regulations for the Safe Transport of Radioactive material TS-R-1, require that materials in a dispersible form and above 3000A_2 transported by air shall be carried in a Type C packaging. The Type C requires greater impact resistance than a Type B and has to withstand a longer thermal test. This paper sets out to detail the work conducted to date and the operating philosophy of the design.

The design brief was to prepare a design which utilised (as far as possible) an existing Type B(U)F packaging, GB3405A. This was designed in the late 1980's and has become an AWE workhorse for transporting RAM in a variety of forms. In addition ideally, the approval of the GB3405A should not be compromised and if modifications to GB3405A were required, then read across from existing data could be made together with reasoned argument to gain approval of the modified GB3405A as a Type B(U)F without performing the Type B tests.

This would give a design that offered maximum flexibility for road transport (using just the modified GB3405A) without the encumbrance of Type C mechanical protection. For air transport compliance with the Type C requirements could be achieved by transferring the modified GB3405A into an outer Container which gives mechanical protection to the containment system from the 90m/s impact test.

The Brief

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The Type C package by definition has to be capable of being transported by air and so must fit onto a standard AML aircraft pallet having dimensions 108″×88″×2.875″ high and a maximum capacity of 4,540 kg or a uniformly distributed load of 68 kg/sq-ft or a concentrated load of 135 kg/sq-in. The maximum height of the pallet and cargo is limited by the size of the aircraft cargo door to 100" high by 140" wide based on a Lockheed Tristar design. The overall dimensions of the Type C package will have to be a compromise between the requirement to protect the GB/3405A containment with an adequate thickness of energy absorbing material and ensuring that the overpack is convenient to handle. The overpack will need to meet normal tiedown and handling requirements. The maximum payload mass is to be taken as 14 kg and to be of similar dimensions to the payload receptacle as currently carried by GB/3405A.

In addition it has been proposed by AWE that a suitable safety factor be incorporated to allow for design and material variations. The design philosophy is to assess the strength of the inner container and design the outer packaging to ensure that the loads imposed on the inner container are within yield with a safety factor of approximately 1.5.

This work was carried out with support from HM Government (DPA.NW)

Determination of the size/impact compromise

The equation of motion indicates that only stopping distance can mitigate mean impact forces which are directly proportional to the deceleration factor G. The majority of commercial energy absorbing materials behave satisfactorily up to a compressive strain of about 50% after which the deceleration is no longer approximately linear and the material may be solid after 50% compression. Therefore, in order to obtain stopping distances similar to theoretical the thickness of energy absorbing material has to be approximately twice the theoretical stopping distance s.

Calculations indicated that approximately 3000g provides a sensible compromise between distance to decelerate and overall size. To select a lower deceleration would result in an unacceptably large overpack, and the law of diminishing returns applies to overall size if a higher deceleration figure is used.

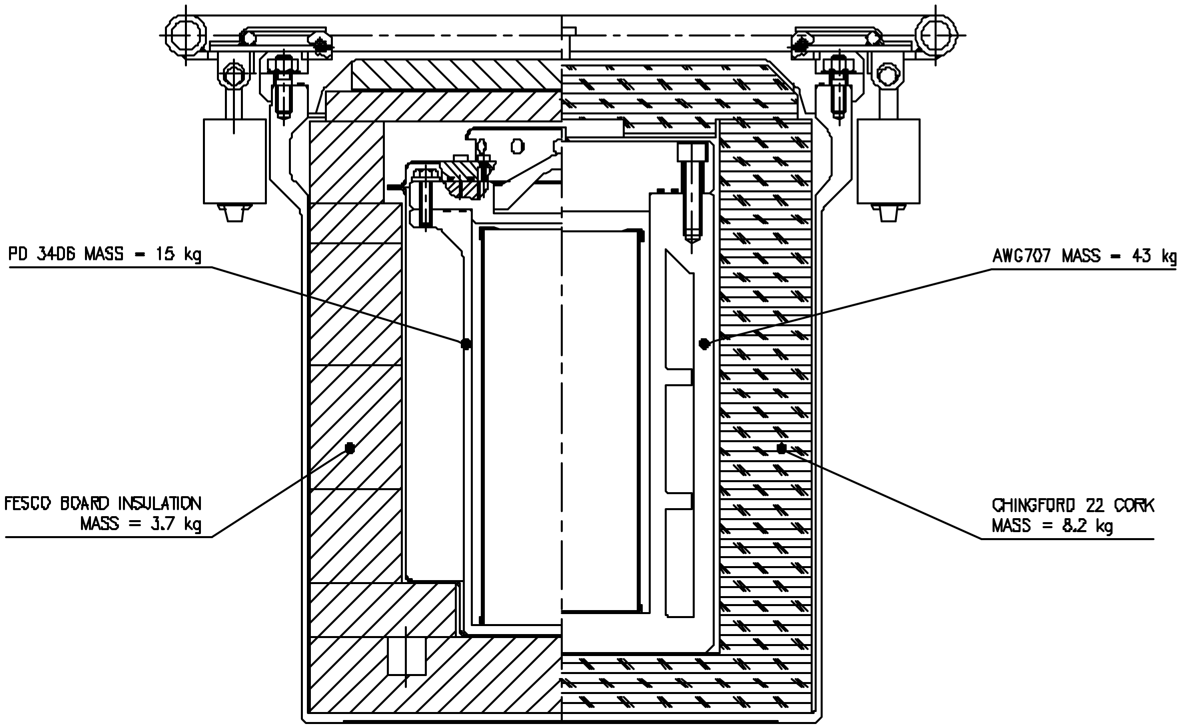
Redesign of the GB3405 Containment System and Insulation

It was recognised early in the design process that the Fesco insulation used would not be likely to withstand the deceleration forces and would need replacing. Additionally the containment system required assessing to determine if it would withstand a notional deceleration of 3000g multiplied by a factor of 1.5.

An FE analysis was performed on the GB3405 with the Fesco replaced with cork. This demonstrated that the GB3405 was not able on its own to survive a 90m/s impact (this was suspected, but needed conclusive demonstration). All that could be deduced from the model was that the containment system would withstand a 54g deceleration. It was demonstrated by modelling that the unmodified GB3405A would withstand the crush test, the burial and the one hour thermal test. It was established therefore that the GB3405A provided a sound basis from which the Type C could be developed to meet the brief.

To this end it was decided to redesign the containment system. The result is shown below, additionally, the cork was reconfigured again as shown below. Analysis has shown that the redesigned containment system would withstand 3000g applied axially or radially.

The mass of this redesigned GB3405 was kept in region of 100kg. This was so that data from its sister variants GB3405B, C and D could be used to validate the design and give confidence that it would, on its own, meet the Type B requirements thereby allowing it to transported by road without the Type C overpack. For comparison the revised GB3405 is shown against the GB3405A below.



Identification of a suitable impact absorber

The 90m/s impact is the most influential factor in the package design since its mass, impact absorbing properties, size and cost are driven by it. Several options were considered. Historically, RAM transport packages have been produced utilising materials whose mechanical properties are well known. Use of such materials as carbon/stainless steel, aluminium etc. in producing an impact absorbing protective outer frame or structure for the package is one option to be considered for the Type C package design. In order to give multi-directional protection, the outer frame or structure would, by necessity, be complex. Justification of its performance under test conditions would be difficult by any means other than testing. The Type C series of tests will be expensive to perform and a high degree of confidence in the frame or structure prior to testing is a prerequisite.

A product search to identify other possible impact absorbing materials was considered essential in the development of a Type C package design. The use of polyurethane foams and aluminium honeycomb in shock absorbing applications is relatively common and has been used for many years. However, owing to the extreme Type C impact energy it was not immediately apparent that they would be suitable and may have been superseded by a next generation of materials.

A detailed product search was conducted using a variety of information sources. Finally three materials were considered for further detailed study and analysis. These were;

a) Hexcell cross core
b) General plastics Last-a-foam
c) ERG Duocel®aluminium foam

Conclusions following detailed investigation of selected impact absorbers

DuocelÒ Aluminium Foam This material provided a solution according to the manufacturer, however, data from ERG was incomplete and does not include extreme temperature conditions. GESL has attempted an analysis based on the available data without success. GESL found that the density of the absorber and hence the impact energy of the package outstripped the ability of the foam to absorb the impact energy. GESL has a number of reservations regarding the results and would require more design information from the manufacturer before being able to make a recommendation, hence within the timescales required we were not able to pursue this material. Additionally the cost per unit volume was an order of magnitude greater than the Crosscore or Last a foam.

Last-a-Foam FR-3730 The package dimensions used in the analysis did not provide a solution. The results showed that the effect of temperature on the performance of the foam is significant, and ultimately critical to the solution. The deceleration factors proved reasonable in all orientations apart from the side impact. At higher temperatures the foam was unable to absorb sufficient energy in the side impact and this caused the inner container to bottom out such that the peak deceleration was not quantifiable. It is necessary to increase the diameter of the package in order to provide extra cushioning in the side impact. Further investigations by GESL proved unsuccessful. GESL concludes that Last-a-Foam is unsuitable for a Type C package because if a theoretical solution can be found it would preclude the use of the re-designed 3405A and/or be so massive as to be impractical and financially unviable.

Hexcel Cross-Core This material provided the best technical solution and the most compact design. G factors in all orientations were within the design criteria for the re-designed 3405A.

Thermal Considerations

A comparative thermal analysis was performed using data obtained from the half hour thermal test of GB3405B. This is similar to the GB3405A as modified in that it uses cork as an insulator and has a higher mass containment system. A comparison of containment heat capacity and an extrapolation of the thermal data from half an hour to an hour indicates that if the modified GB3405A were subjected to a thermal test without an overpack then the temperature rise would be approximately 80^{o}C

Similarly, the presence of an insulator around a containment system will result in a rise in temperature of the contents and containment. Using data from self heat trials on GB3405A it is anticipated that the temperature rise of the containment will be approximately 60 ^{o}C. The presence of the overpack will increase this slightly and a trial will be conducted to determine this.

Insolation, will be considered at a later date but is not expected to significantly add to these values.

Design Description

Having identified the key elements/components of the design, i.e.:

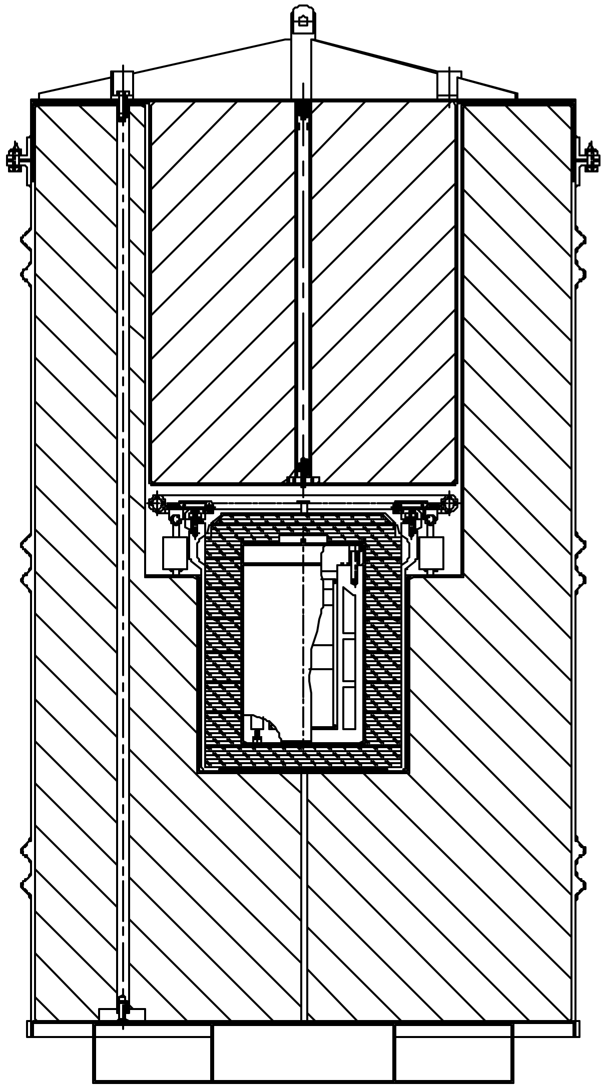
containment
impact absorber
thermal insulation

and proved that the brief was practical it was necessary to bring these elements together in a design.

The main premise is to retain the impact absorber around the modified GB34405A in an impact attitudes. Additionally, the retention method must allow the impact absorber to crush and dissipate the impact energy.

It was therefore decided that a light drum structure should surround the impact absorber. This structure must allow the Type C to be handled by fork lift, palletised and tied down. Additionally it must be robust enough to resist routine handling.

The cross section is shown below.



The modified GB3405A is shown centrally positioned within the impact absorber. One difficulty with such a design is to be able to access the item that is packed with minimal loss of impact absorber effectiveness. This is always a compromise. After several design iterations it was decided that a 'body and plug' design offered the optimum compromise. This ensures that the split line between the plug and body is minimised.

The cross core has also been configured to minimise horizontal split lines.

Access to the interior is via a high mounted lid secured (stitched almost) by many bolts. The lid incorporates a spider which is designed to support the impact absorber in a top corner impact. The lid is through bolted using bonded in tie-rods. These should buckle during an impact.

Status

Three prototypes have been manufactured and handling trials completed (see photo below). Manufacture went well apart from difficulty in obtaining the cross core to the agreed schedule.

The project was completed start to finish in 14 months, and having achieved project milestones .

What would we do differently?

Or the benefits of hindsight. Having built and seen the design in the metal our major concern is the rod which secures the plug to the lid. This currently is solid and we will probably change this to either a tensioned wire or a thick wall tube. This will minimise its punching effect in a flat lid impact.

The following photographs show some aspects of the design in the metal.

View of the drum as presented for transport

Detail view of the lid

Please note this is an abridged version of the full paper. The full paper can be found on our our website at www.gravatom.com