
Mk A2 AGR Irradiated Fuel Transport Flask—A New UK Flask Design

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INTRODUCTION

The transport of irradiated fuel from the UK's Advanced Gas Cooled Reactors to the reprocessing plant at Sellafield has, up to now, been undertaken using a composite lead in steel cuboid flask fitted with a detachable aluminium shock absorber.

The commissioning of further AGR power stations necessitated the procurement of additional transport flasks and the opportunity was taken, by the CEGB, in line with their policy of continuous review to reassess the existing design against the need to produce a flask which would be acceptable for continued operation for the next 25-30 years.

The design philosophy adopted was to meet the 1985 IAEA Regulations with the inclusion of cost effective margins as an insurance against possible changes in the Regulations which might occur during the lifetime of the design. Additionally, the response of the flask to possible real accident scenarios applicable to the method of transport used in the UK, provided an input to the design concept as did the need to adopt the ALARP concept applicable to radiation dose rates experienced during on site handling.

Additional design considerations embraced the need to retro fit existing AGR Power Stations and the reprocessing facility at Sellafield with minimum interruption to Station operation and at minimum cost. The design concept was to be based on the use of monolithic forged construction and embody an integral shock absorber. GEC Energy Systems were commissioned to undertake the design and development of the new

design in 1981.

Optimisation work at the beginning of the design phase was aimed at maximising the performance. It became clear during the design phase that in order to meet the specification it was necessary to reduce the sensitivity of the flask to impact and fire under accident conditions without adversely influencing, to any significant extent, normal operating capability. The concept adopted was to depart from the traditional approach of locating the main flask seals in a single heavy lid, the dimensions and mass of which are determined by radiation shielding requirements, and introduce a second flexible inner lid which performs only the sealing duty.

GENERAL DESCRIPTION OF FLASK

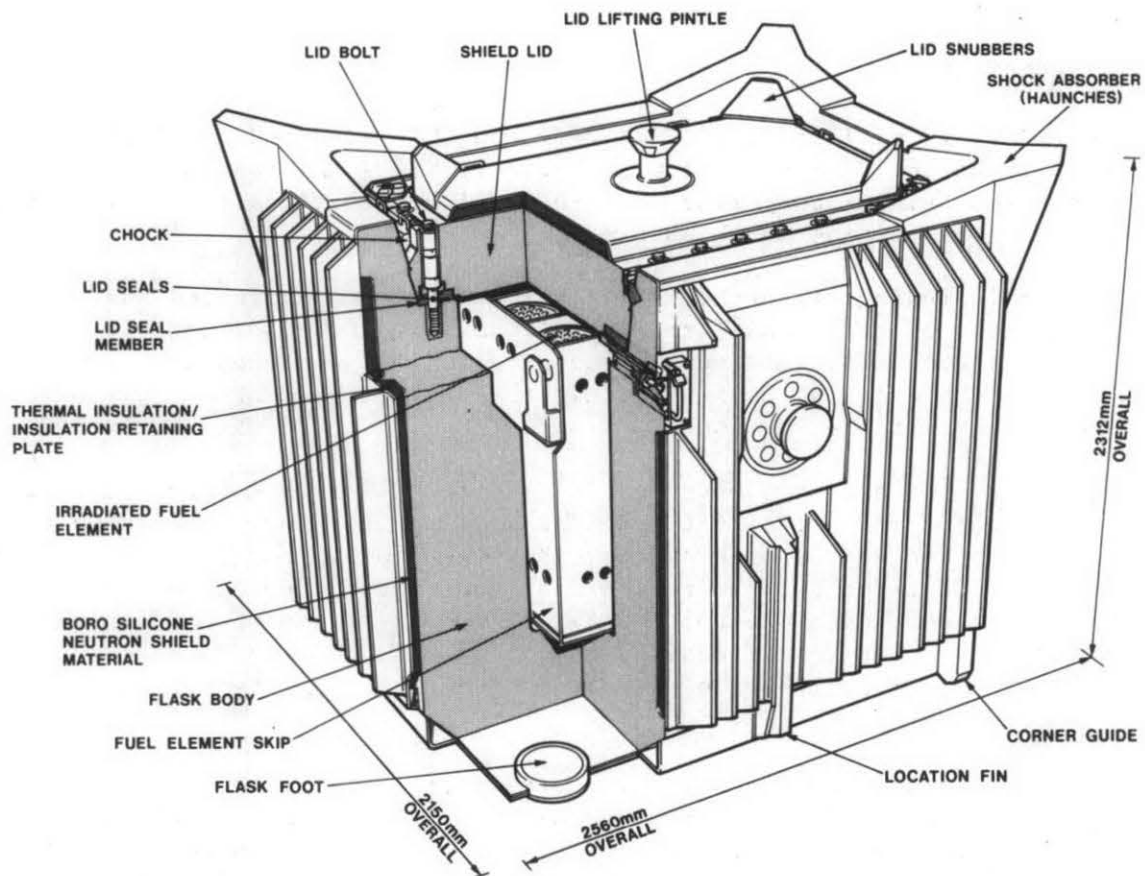


FIGURE 1 AGR A2 TRANSPORT FLASK

The body of the flask is of thick walled monolithic construction with cooling fins on the external vertical surfaces. Between the flask walls and the cooling fins there is a sealed, pocketed, cavity filled with borosilicon material which affords additional neutron shielding, and thermal insulation.

The flask lid, which is recessed into the body, comprises two parts; the shielding lid and the lid seal member. The shielding lid is formed from a thick steel forging on top of which is a sealed cavity filled with borosilicon material and thermal insulation. The lid seal member (LSM), which is not normally removed from the lid in service, carries the main flask O-ring seals.

Twenty-eight lid bolts pass through the shielding lid to clamp the LSM against the flask body. The shielding lid is retained in the recess in the flask body by sixteen removable chocks.

Two valves, of identical construction, are fitted into the flask body side walls. The lower of these valves controls the water level in the flask and the upper valve is used for purging the flask ullage space with Nitrogen. Near the purge valve passing through the flask wall are two interseal test points which facilitate testing of the effectiveness of the flask sealing.

The interior and exterior surfaces of the flask, with the exception of the rubbing surfaces, are finished with a paint coating; the rubbing surfaces are uncoated stainless steel. Different paint compounds are used for the inside and outside of the flask.

The irradiated fuel elements are placed in the flask either unbottled in a fifteen compartment skip or bottled (in the case of failed fuel) in an eight compartment skip and are submerged under water at all times when they are in the flask.

The 15 compartment skips are fabricated from 304 type stainless steel for the outer structural base and side members. The grids forming the individual element compartments are of welded comb joint construction using a Stainless Steel containing 0.7% boron.

The flask, the maximum all up weight of which is 52 te, is lifted by means of two trunnions, one on each of the longer vertical sides and the lid assembly is lifted by means of a single central pintle.

The body and lid are produced from single piece vacuum degassed Ni/Mn steel forgings. Both the material and the forging route were originally developed for the manufacture of the CEGB flasks used in conjunction with the Magnox nuclear stations and, consequently, the production technique and metallurgical properties were well validated.

FLASK SEALING - THE LID SEAL MEMBER

Flask sealing is achieved by twin O-ring elastomer (fluorocarbon) seals located in grooves with the associated interspace used for predespatch leak testing.

The major requirement for high sealing integrity is close conformance of the sealed faces and in this context both impact and fire accidents are potentially disruptive events.

The design philosophy adopted was to desensitize the sealing arrangement from such events by functionally separating the requirements of the lid. The arrangement would separately address the requirements of sealing and shielding. This fundamental separation gives rise to the "dual flask lid" design incorporated on the Mk A2 flask. Although the lid is dual in function it has been designed to act and be handled as a single unit under normal operating conditions - only under abnormal conditions does separation occur.

Both impact and fire have markedly different modes of seal face separation. Under impact conditions seal face separation is governed by inertia loading separating the faces. In fire accidents differential thermal movements of the seal faces occurs in both longitudinal and transverse directions. The solution is, therefore, to provide a low mass, highly flexible, sealing member. This philosophy is embodied in the Lid Seal Member (LSM).

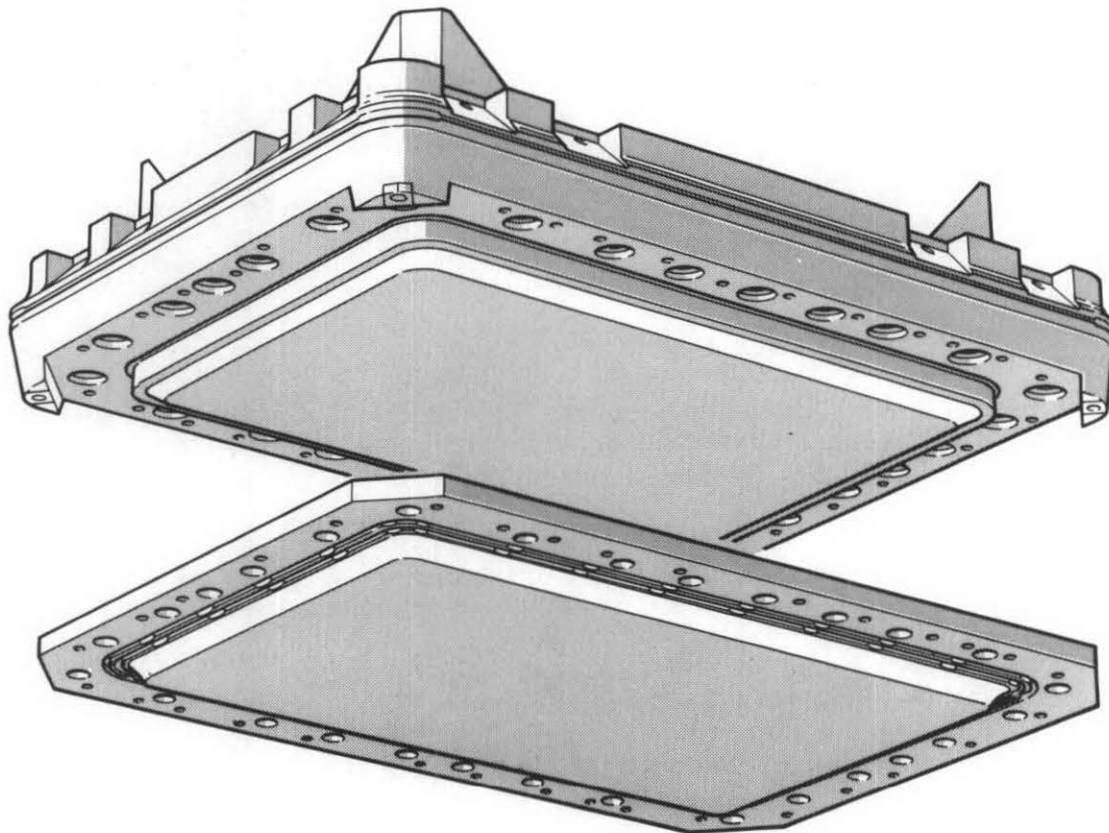


FIGURE 2 LID SEAL MEMBER

The LSM consists of a picture frame outer rim, carrying the seals, and a continuous thin diaphragm centre. The diaphragm to rim connection is profiled, by pressing, to give a continuous curve. The shape of the profile has been developed such that it acts as a rolling hinge allowing the diaphragm edged to move, with respect to the rim, under controlled force application for impact induced loading.

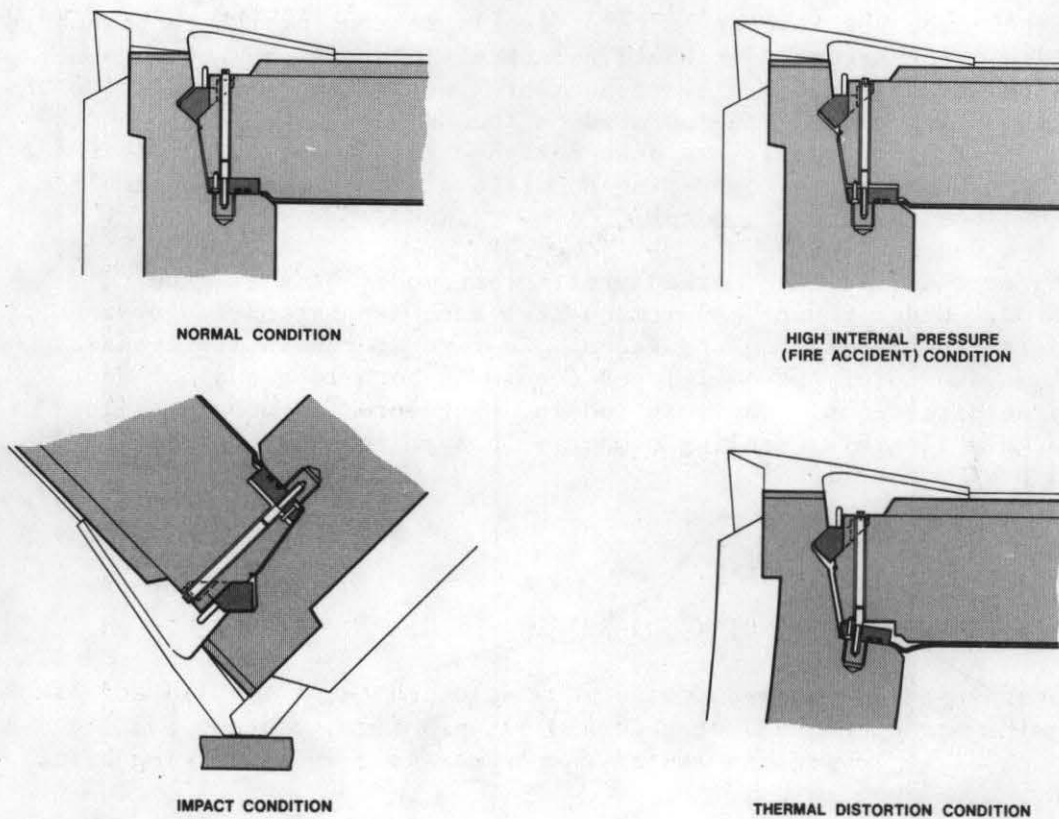


FIGURE 3 DOUBLE LID ARRANGEMENTS

The rim of the LSM is securely anchored to the flask sealing face by (28) relatively small clamping bolts sized to elastically accommodate inertia loading plus the forces transferred from the diaphragm rolling hinge.

Under fire accident thermal distortion conditions the clamping bolts provide sufficient stiffness to maintain conformance between the rim and the flask sealing face.

The system has been fully demonstrated to show compliance, under impact testing from 36 metres, at 1/8 and 1/4 scale.

Analytical and experimental testing has also shown that the LSM is specification compliant for seal face movements and distortions 2 to 3 times greater than those which occur during design target fires.

SHIELDING LID - RETENTION SYSTEM

Since there is functional separation of sealing and shielding the flask is no longer constrained to the traditional sealing lid attachment philosophy of multiple bolts of large size to maintain elastic, or limited plastic, response under impact conditions - separation of the shielding lid from the LSM is of no consequence.

This fact allows consideration of non bolted shielding lid retention systems and the one finally adopted was the use of captive shear keys (chocks) inserted between the lid and flask upstand.

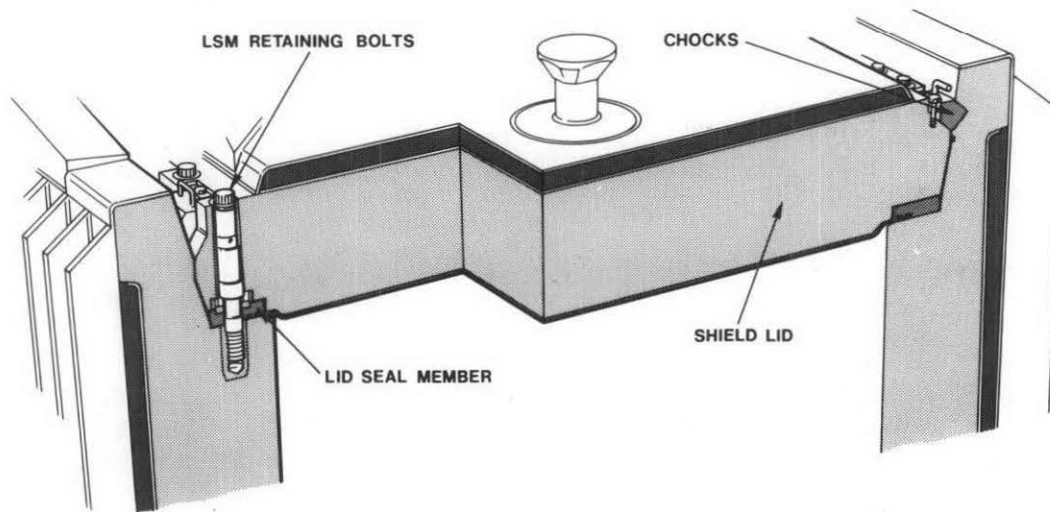


FIGURE 4 SHIELDING LID RETENTION SYSTEM

The shear keys are lowered down a local slot chute on the lid and are moved sideways within a slot machined between flask upstand and lid. A second chock is lowered in behind the first and a small locking block closes the chute opening.

Sixteen chocks in total provide lid restraint for the flask. The fitting clearances provided in production allow easy placement of the chocks and dramatically reduce operator contact time in dispatch and receipt.

IMPACT CONSIDERATIONS

The CEGB has experience of both detachable and integral shock absorbers, detachable in the case of the predecessor of the A2 flask and integral in the case of flasks used to service the Magnox reactors. A considerable amount of development work has been undertaken by the CEGB on shock absorber design and the conclusion reached that the integral type is preferable. The method by which the integral steel shock absorber absorbs energy is consistent, predictable and scalable. Additionally, its performance under "real accident" impacts involving targets softer than that defined by the Regulations can often be superior to the detachable type. A further benefit is that operationally it is more convenient. Consequently, the integral type was specified for the A2 flask.

The shapes associated with each absorber have been derived and supported by extensive drop testing. The design of each was developed from both impacted scale details and geometrically scaled flask models. Performance was shown to be consistent and scalable.

The trunnion side (long side) of the flask has been given special design consideration in the trunnion area. The material forming the trunnion boss area has been profiled such as to present a crushable area thereby limiting the impact force on the unsupported wall.

Base drop shock absorbers are provided to act in a two stage fashion. Initial contact takes place on the foot. The foot is designed as a hollow ring and collapses in a controlled manner. After 10 mm collapse the corner base sections are brought into play developing additional collapse stiffness.

36 metre drops onto the Regulatory target have produced peak acceleration on inverted drops on the lid area of approx. 500 g and for flat bottomed base drops 1,000 g.

In addition to the tests carried out against the Regulatory target a considerable amount of testing was undertaken against non regulatory target anvils (e.g. reinforced concrete) to assess the performance against "real target" materials.

FIRE ACCIDENT CONSIDERATIONS

The major consideration of thermal design, certainly in the case of a water filled flask, is the compromise to be made between normal operating temperatures and the consequences of the fire accident. In normal operation surface temperatures must not exceed 85°C and flask water temperature has, for obvious reasons, been limited to 100°C. In the fire accident, loss of ullage volume by flask water expansion, seal temperatures and thermal distortion of the flask body are of importance.

Increasing the fire accident scenarios from the Regulatory conditions to 925°C for 1 hour with enhanced convection coefficients suggested that it would be prudent to set the thermal design parameters against accident conditions and consequently considerable emphasis has been placed on reducing heat input during the fire at the expense of allowing peak water temperatures under normal operation to rise to 100°C.

Under normal operation the maximum thermal load the flask will carry is 12.4 KW and in order to maintain the 85°C surface/100°C water temperature it was necessary to use cooling fins. However, to prevent excessive heat input via the fins during the fire, a fin attachment system was used which produced, effectively, a thermal resistor.

Attachment of the fins to the body is by welding the fin to local upstands machined in the body forging. The size of the body ligament has been optimised by analysis.

Thermal response of the system is now dictated by the conduction route between bulk flask material and the fin. The ligament size is such that the connection provides optimum heat flow control.

Thermal insulation has been applied to the flask body surfaces and secured against loss by mechanical means. Generally insulation takes the form of a compressed insulation blanket, nominally 12 mm thickness compressed to 5 mm. Within the fin cavity the ligament section has been recessed and the insulation retained by a profiled retaining plate secured to the body by screws.

To protect the insulation against the punch test the pitching and recess depth are chosen to prevent insulation/punch interaction. Thus under adverse punch orientation only limited damage to the fins can occur whilst the integrity of the thermal insulation is unaffected.

Insulation has also been used on non-finned areas and in these instances over cladding is used to provide external protection against insulation damage.

In the case of the flask base, to preclude excess removal of insulation by a punch, the base is divided into sections which do not exceed 1 square metre in area. The base division takes the form of substantial machined upstands cross connected by welded T section. The upstands provide structural attachment and a means of arresting punch damage. Cladding sheets are secured by full penetration welds.

In performing the thermal analysis of the flask, loss of insulation was assumed. Although no mechanism can be shown by which other than local damage can be sustained from either impact or punch, analysis has considered the effect of an arbitrary removal of 1 square metre of insulation.

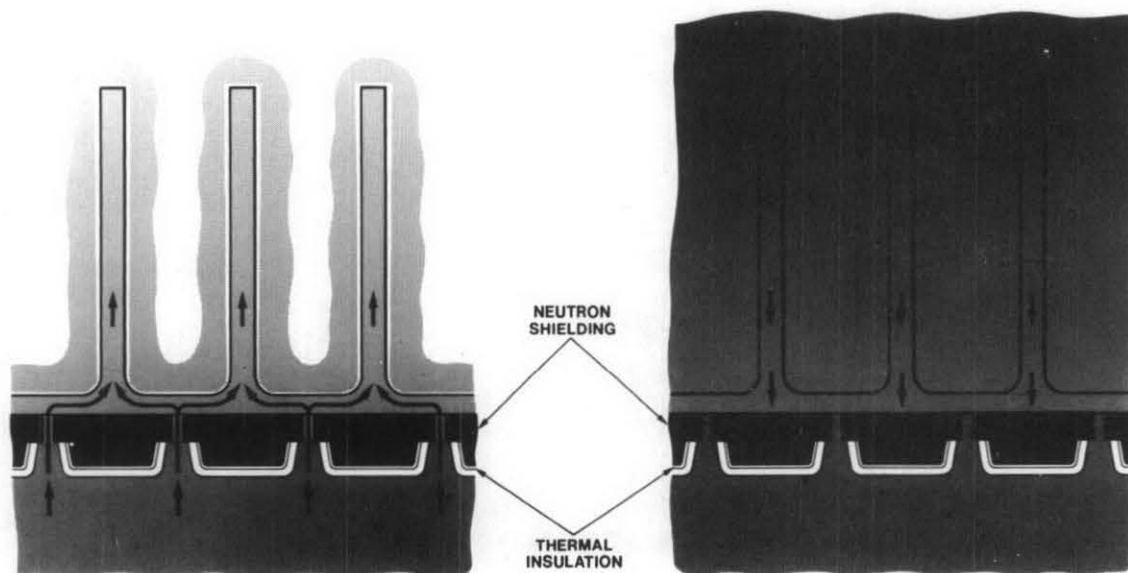


FIGURE 5 FIN ATTACHMENT