Design Features of the MK A2 Flask

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1.0 INTRODUCTION

GEC Energy Systems Limited were commissioned by CEGB to undertake the design and development of a new AGR Irradiated Fuel Transport Flask. The new flask requirement arose from the enhanced fuel movements attributable to the increasing AGR contribution to the UK power base. Fourteen such reactors will be on-stream by the early 90's and spent fuel requires shipment to the BNFL Sellafield storage/reprocessing plant.

In setting the design specification for a MK A2 Transport Flask account was taken of the service life of the flask fleet (30 plus years). The design brief enveloped all UK, CEGB and International Regulatory requirements with particular reference to fire and impact considerations.

The design brief further placed space and weight constraints to ensure compatibility with the existing AGR stations and fuel handling facilities viz rail/road fleet, PIE facilities and Sellafield.

An early design decision was taken as to whether the new design should be of the "wet" or "dry" type. The wet (water filled) option was chosen after consideration of established operational requirements for normal and accident conditions.

The MK A2 Flask design which emerged and is now in production, is fully compliant with all standards and regulations.

By reappraising the fundamental requirements of flasks, GEC Energy Systems Limited have applied new approaches and concepts to this design. Four specific design areas have been selected to illustrate how this has been achieved. Figure 1 illustrates the new MK A2 Flask design and general descriptive information is given in a companion paper "The MK A2 Irradiated Fuel Transport Flask - a New UK Flask Design".

2.0 THERMAL RESPONSE

The decision was taken to develop a design which effectively desensitized the flask thermal performance from the fire accident.

Two areas are associated with performance limits due to a fire accident. Peak and long-term seal temperatures must be controlled to enable sealing integrity to be assured. For a wet flask design the maximum flask internal pressure is also a design parameter.

In the MK A2 Flask, see Figure 1, the seals have been located as remote from the fire source as possible. This extends the timescale (post fire) at which seal peak temperatures are reached and reduces the magnitude of such peak seal temperatures.

With a wet flask design heat uptake during the fire accident raises the water temperature and hence pressure. The shield wall thickness and consequent large thermal mass of the flask extend the period from fire cessation to the occurrence of maximum internal pressure in the transient to several hours. Since both seal and water temperatures are controlled by the magnitude of heat input to the flask in a fire accident, a solution can be achieved by incorporating thermal insulation on the flask outer surface.

Operational requirements impose limits on water temperature for flask receipt at the reprocessing facility and IAEA Regulations limit surface temperature for normal transport conditions. The location of thermal insulation must be carefully sited to meet these requirements. To achieve Operational and Regulatory compliance for normal transport imposes a requirement to provide an extended surface (fins) to the flask. This ensures adequate heat dissipation. However such surfaces could act unfavorably in a fire accident by providing large heat input sites.

The solution, which has been developed to control heat flows in the MK A2 flask, has been to mount the fins on thin ligaments. Such a ligament arrangement, shown in Figure 2, has been optimised to provide the necessary controls over fire accident heat inputs and normal operation heat outputs. Automatic welding techniques have been developed to provide high integrity weld penetration and attachments which maintain ligament thermal and structural performance.

"Short circuiting" of the ligament by heat transfer between the base of the fin and the flask body is prevented by the application of insulation.

Figures 3 and 4 show in principle how the arrangement achieves the required thermal performance in normal operation and fire accident respectively.

3.0 SEALING INTEGRITY

Fuel transport flasks have to meet stringent leakage requirements under normal operations and accident conditions. This is achieved in the MK A2 flask by twin fluorocarbon elastomer seals.

Sealing performance can only be underwritten if adequate seal compression is maintained.

The MK A2 flask adopts a novel approach to controlling seal face separation by mounting the seals on a flexible sealing member.

The Lid Sealing member (LSM), see Figure 5, consists of a picture frame rim with the centre recessed to form a thin integral membrane. The underside of the rim carries the twin O-ring elastomer seals. Bolt holes are provided outboard of the seals to allow attachment of the LSM to the body seal face by Lid Bolts.

For radiological protection a heavy section Shield Lid is provided which also gives support to the LSM membrane section.

This "Dual Lid" arrangement functionally separates the two major requirements of the flask lid and allows optimisation of each without interaction.

Under conditions of normal transport the two assemblies are lightly coupled so that operationally they are handled as a single unit. Under accident conditions (eg impact or fire) these couplings are not required to remain intact but the functional requirements of LSM and Shield Lid remain effective.

Figure 5 shows the essential features of the Dual Lid.

Two accident regimes of operation can be identified for the Dual Lid design.

3.1 Impact

Under impact conditions the heavy Shield Lid inertial forces shear the light coupling bolts. The lid moves outwards to take up clearance at the chocks and pressure loading causes the membrane to displace with the Shield Lid. The special profile of the LSM rim/membrane connection allows the displacement to occur with minimum force transfer to the rim.

Figure 6 shows the end state condition for a typical corner impact. Under such a damaging impact local rotations and displacements of the seal face may occur. Lid bolt preload and stiffness is sufficient to conform the LSM to any reasonable distortion of the body seal face.

3.2 Fire

Within the fire accident period two regimes of stressing of the flask (body and lid) occur.

During the fire thermal stresses are induced which can cause distortions as illustrated in Figure 7.

During the post-fire period significant internal pressure can arise which potentially cause distortions in the same direction, but of reduced magnitude, as the fire.

In each case the lid bolts ensure that the LSM conforms to the local distorted profile of the body seal face.

The design specification required the flask response under impact and fire accident conditions to be considered sequentially.

The LSM approach can cope with such sequential distortion and conformance has been demonstrated by extensive scale model drop testing and by seal face conformance rigs.

The introduction of the Dual Lid assembly has desensitized the MK A2 flask from the consequences of accident conditions whilst maintaining a single lid handling philosophy under normal operating conditions.

4.0 IMPACT DESIGN FEATURES

The MK A2 flask is provided with integral impact limiters (shock absorbers). These are formed as extensions to the flask body material. The provision of integral shock absorbers reduces handling time and requires no storage provision.

The integral shock absorbers, which rely on plastic deformation to absorb impact energy, have had their shapes developed through extensive scale model drop testing trials.

The major body shock absorbing features are at the corners, vertical edges and base. Shield Lid shock absorbers are located at the four corners.

Protection to the lid/body joint is afforded by recessing the lid within the body forging upstand, see Figure 1.

Lid ejection, by inertia forces, is prevented in the MK A2 flask by a chock (shear key) principle, see Figure 1.

Diagonal chocks are trapped between the flask body upstand and the lid within V-shaped grooves. The chocks are positioned at the corners of the flask and enter the groove via a chute slot in the lid. Once the chocks are within the groove the chute section is barriered with a bolted locking block to prevent chock ejection.

The simple loading procedure reduces operator handling time on receipt/dispatch.

Drop tests have shown the reliability of the chock restraint principle of attachment to be tolerant of high inertia loadings in all impact attitudes.

The resistance of the flask fins to both impact and punch damage is of concern since they provide protection to the thermal insulation on the body surface.

Security of the fin/body ligament attachment under impact conditions has been addressed and demonstrated by drop testing. No significant fin/body attachment damage has been noted from drop attitudes where maximum fin impact loading occurs.

Purge and water level valves are recessed well inside the body forging through - wall thickness, maximising resistance to the punch test.

5.0 SHIELDING

Water filling and the robust body and lid structure of the MK A2 design give inherent gamma and neutron compliance with all radiological protection requirements for every condition of transport (normal operations and accident). However, in line with the application of ALARP principles, external dose rates to the operator have been further reduced by incorporating neutron shielding material. This neutron shielding material has been located in the cavity between the fins and body forging, see Figure 2. The placing of the neutron shielding at this location provides valuable structural protection against handling damage.

The neutron shielding material is a castable, self-setting, boron loaded, silicone rubber.

6.0 CONCLUSION

The MK A2 flask design developed by GEC Energy Systems Limited desensitises the flask response to accident conditions. This has been achieved by reappraising fundamental requirements and providing innovative design solutions which have been integrated into the system envelope. The important features of the design have been highlighted in this paper.

The pursuit of a flask design which is relatively insensitive to accident conditions has also taken full account of the normal conditions of spent fuel transport. Detailed design attention has been paid to the total flask transport scenario and in particular the normal functions carried out by operators. The introduction of the Dual Lid design for instance has reduced operator handling time in flask preparation. Close specification of surface finish details and the removal of contamination traps ensures reduced decontamination timescales. Robust guidance systems have been incorporated at specific locations on the flask which reduce handling times by relaxing location alignments.

These shortened operator handling time cycles, coupled with the low surface dose rates, reduce operator radiological burden under all normal transport modes.

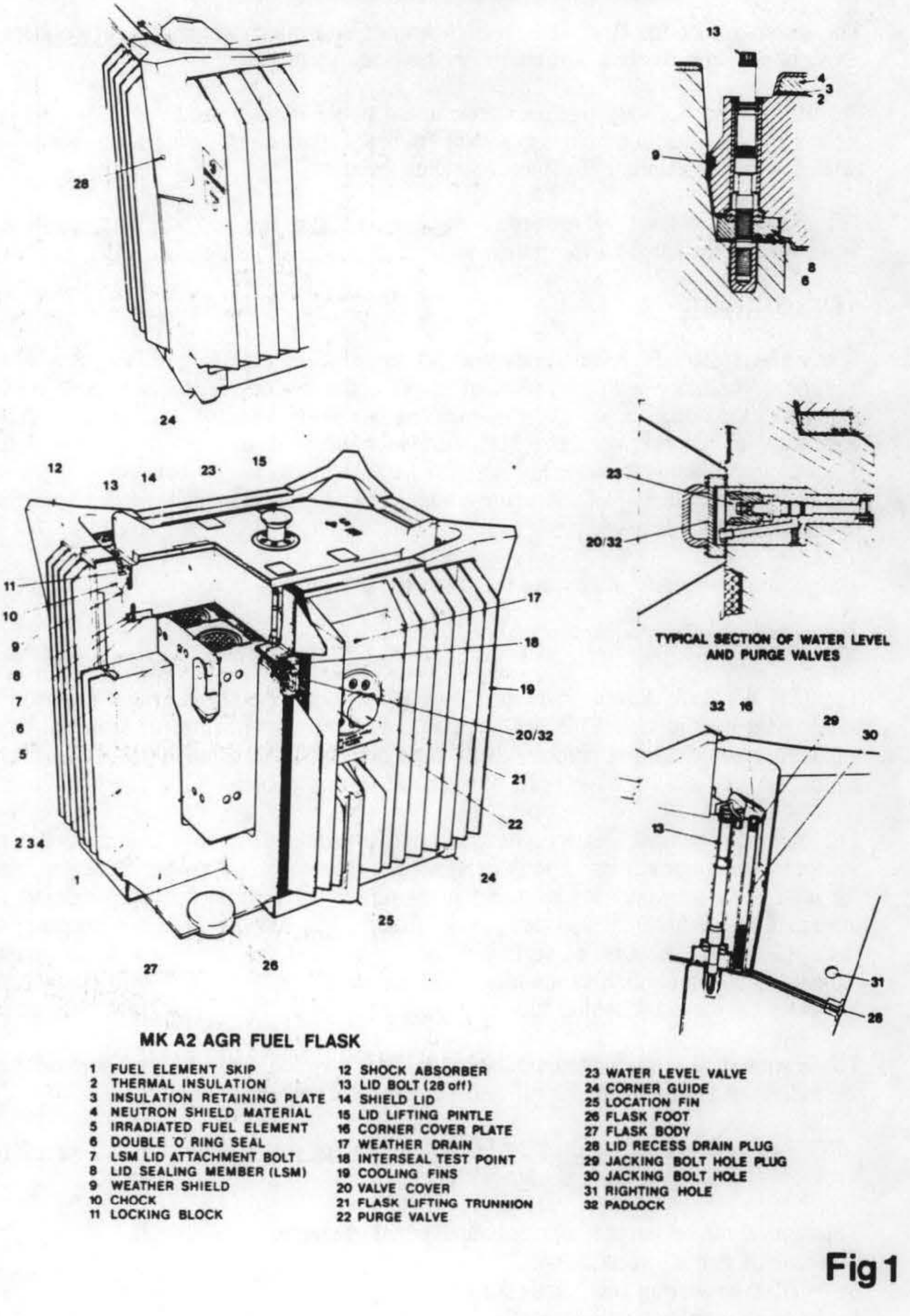
GEC Energy Systems Limited's MK A2 design for the Transport Flask has fulfilled CEGB's objectives by producing a flask design which is:

Tolerant of major impact accidents and punch damage.
Tolerant of major fire accidents.
Insensitive to sealing face distortions.
Inherently compliant radiologically.

The design, development, testing and provision of documentation for the MK A2 Flask has taken 3½ years elapsed time and 45 man years of effort to achieve.

The MK A2 Flask design is now being manufactured by three major UK engineering fabricators.

General Arrangement of MK A2 Spent Fuel Transport Flask



MK A2 AGR FUEL FLASK

1 FUEL ELEMENT SKIP
2 THERMAL INSULATION
3 INSULATION RETAINING PLATE
4 NEUTRON SHIELD MATERIAL
5 IRRADIATED FUEL ELEMENT
6 DOUBLE 'O' RING SEAL
7 LSM LID ATTACHMENT BOLT
8 LID SEALING MEMBER (LSM)
9 WEATHER SHIELD
10 CHOCK
11 LOCKING BLOCK
12 SHOCK ABSORBER
13 LID BOLT (28 off)
14 SHIELD LID
15 LID LIFTING PINTLE
16 CORNER COVER PLATE
17 WEATHER DRAIN
18 INTERSEAL TEST POINT
19 COOLING FINS
20 VALVE COVER
21 FLASK LIFTING TRUNNION
22 PURGE VALVE
23 WATER LEVEL VALVE
24 CORNER GUIDE
25 LOCATION FIN
26 FLASK FOOT
27 FLASK BODY
28 LID RECESS DRAIN PLUG
29 JACKING BOLT HOLE PLUG
30 JACKING BOLT HOLE
31 RIGHTING HOLE
32 PADLOCK

Fig 1

Fin/Body Ligament Attachment Arrangement

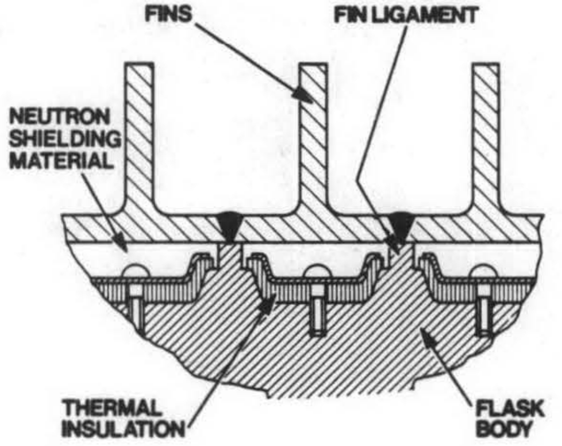


Fig 2

Ligament Effect on Normal Operation Heat Flow

SCHEMATIC REPRESENTATION

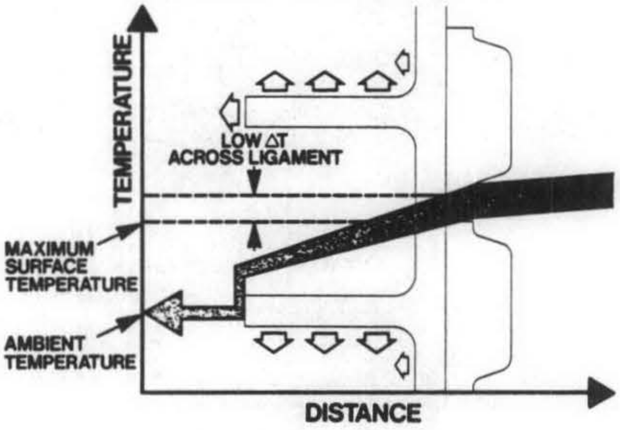


Fig 3

Ligament Effect on Fire Accident Condition Heat Flow

SCHEMATIC REPRESENTATION

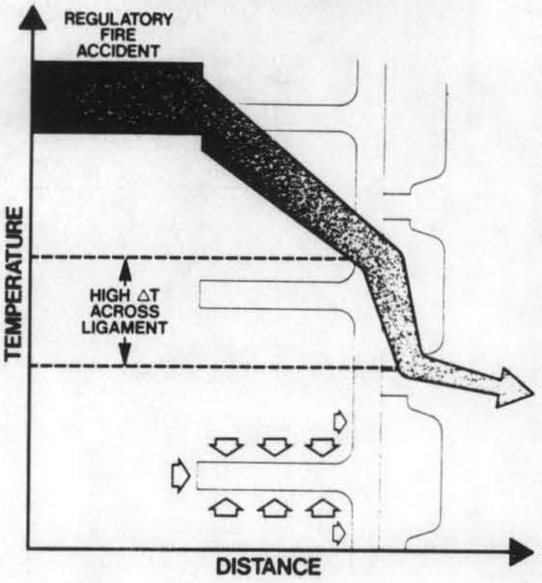


Fig 4

Section through "Dual Lid" in normal operation

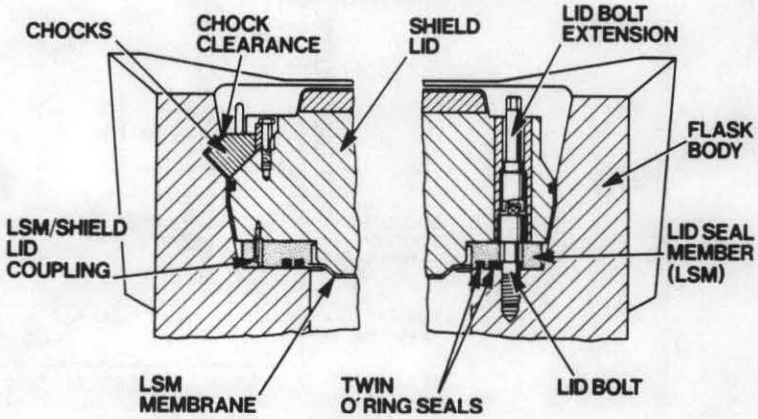


Fig 5

Typical Impact Accident

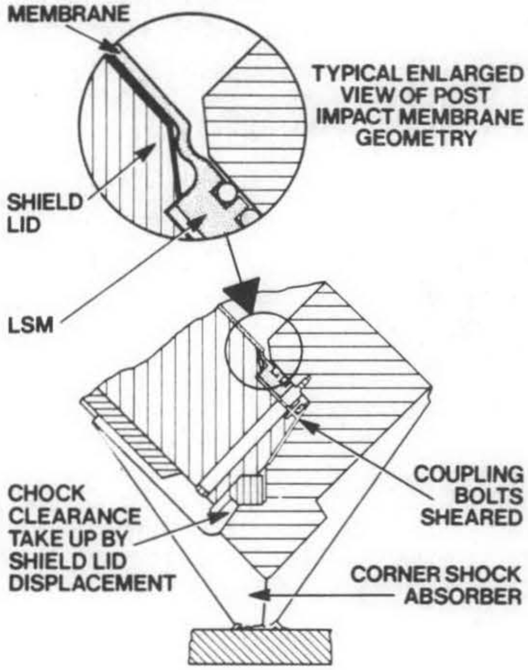


Fig 6

Thermal/Pressure Distortion of the Flask under Fire Accident Conditions

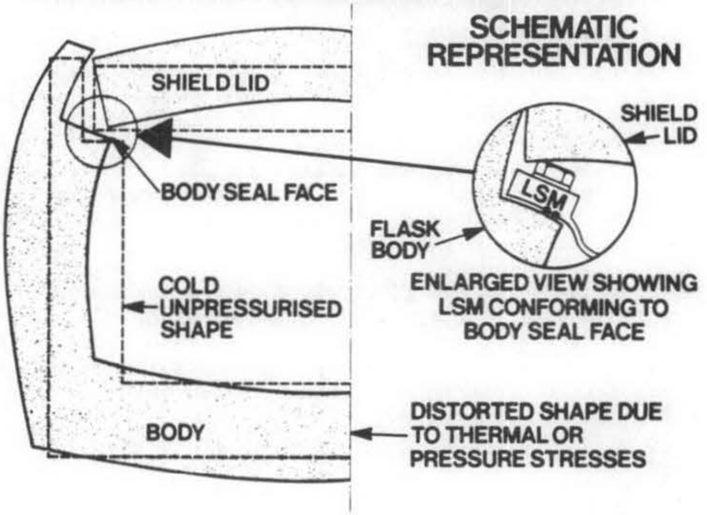


Fig 7