CENTRAL ELECTRICITY GENERATING BOARD

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Overseas Service

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Division of Fuel Cycle and
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Safety and Safeguards
United States Nuclear Regulatory
Commission
WASHINGTON DC 20555, U.S.A.

Our ref SS.SE.28.70.1/DAO Your ref

Date 4 May 1984

Dear Mr. MacDonald

Visit of Mr. R. E. Cunningham
Thursday, 24 May 1984

--- Further to your letter and subsequent telex I enclose two press releases issued by the Board on our programme of full scale flask tests.

We will of course be delighted to receive a visit from Mr. Cunningham and I will be in touch again shortly with full details of the arrangements. In the meantime if you have any further queries do not hesitate to contact me.

Yours sincerely

John Martin

J.P.T. Martin
Head of Overseas Service

A-3

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WITH COMPLIMENTS

J. D. Hart

A-4

CENTRAL ELECTRICITY GENERATING BOARD

Nuclear Fuel Flask Train Crash: 17 July 1984

British Rail Test Track, Old Dalby, near Melton Mowbray

Today's train crash has been arranged by the CEGB to demonstrate its confidence in the transport of spent nuclear fuel. The crash is part of a four year programme costing the Board £4 million.

This brochure gives details of today's crash, the timetable, on-site arrangements and the background to the transport of nuclear fuel.

The demonstration is necessarily — for technical and safety reasons — subject to an inflexible timetable and mandatory safety arrangements. All guests are asked to ensure that all arrangements are complied with. Should you encounter any problems during the day, please do not hesitate to contact any of the CEGB officials who can be identified by their white badges.

ON-SITE ARRANGEMENTS

By car: Coaches will transport car passengers between Wymeswold airfield and the Old Dalby site. Please rejoin a coach at the entrance gate.

By train: The departure point is *not* the arrival point. Please check the map for details or ask CEGB officials for directions.

Listen for reboarding announcements and CHECK-IN for TRAIN B at 14.30 hours CHECK-IN for TRAIN A at 15.30 hours.

Please check your CEGB rail travel voucher to ensure you join the correct train as seating arrangements are limited. At the departure point please present your voucher before joining the train.

The trains will depart to schedule and arrive at St. Pancras approximately 2 hours 30 minutes later.

Name badge: Please wear this at all times while on site. Green and blue badges ensure admittance to the EAST side; yellow badges to the WEST side. A cross-over point on the track will be opened *after* the crash once the site is declared safe.

Facilities: Toilets and St. John Ambulance Brigade vehicles are situated on both sides of the track.

Refreshments: Box lunches are available from 11.30 hours from the refreshment marquees. Tea, coffee and soft drinks are available throughout the day.

Stands: Viewing stands are positioned on either side of the railway line in a safety zone some 100 metres behind the point of impact.

Radio-controlled devices:

No radio-controlled devices such as cameras or communications equipment can be used UNLESS prior clearance has been arranged with the CEGB.

Audio/visual commentary:

Peter Fairley will be giving a running commentary on the event and other announcements. Television monitors will be showing various aspects of the event.

Exhibition; empty fuel flasks:

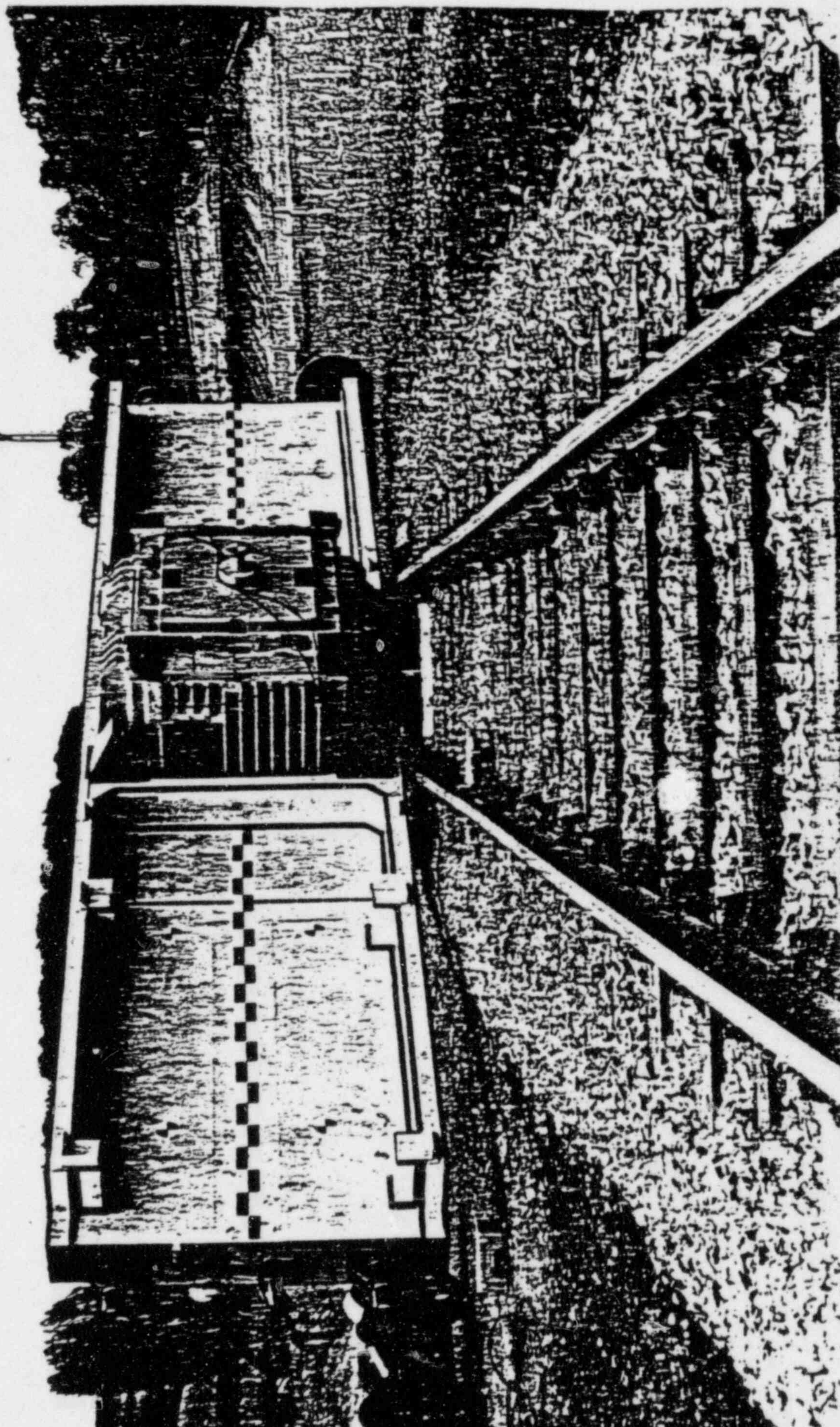
On both sides of the track there will be displays on the transport of nuclear fuel. Full size and scale model fuel flasks are available for inspection.

Inspection of the flask after the crash:

You will be able to inspect the crash site once the wreckage has been declared safe. Please keep to the marked route for your own safety.

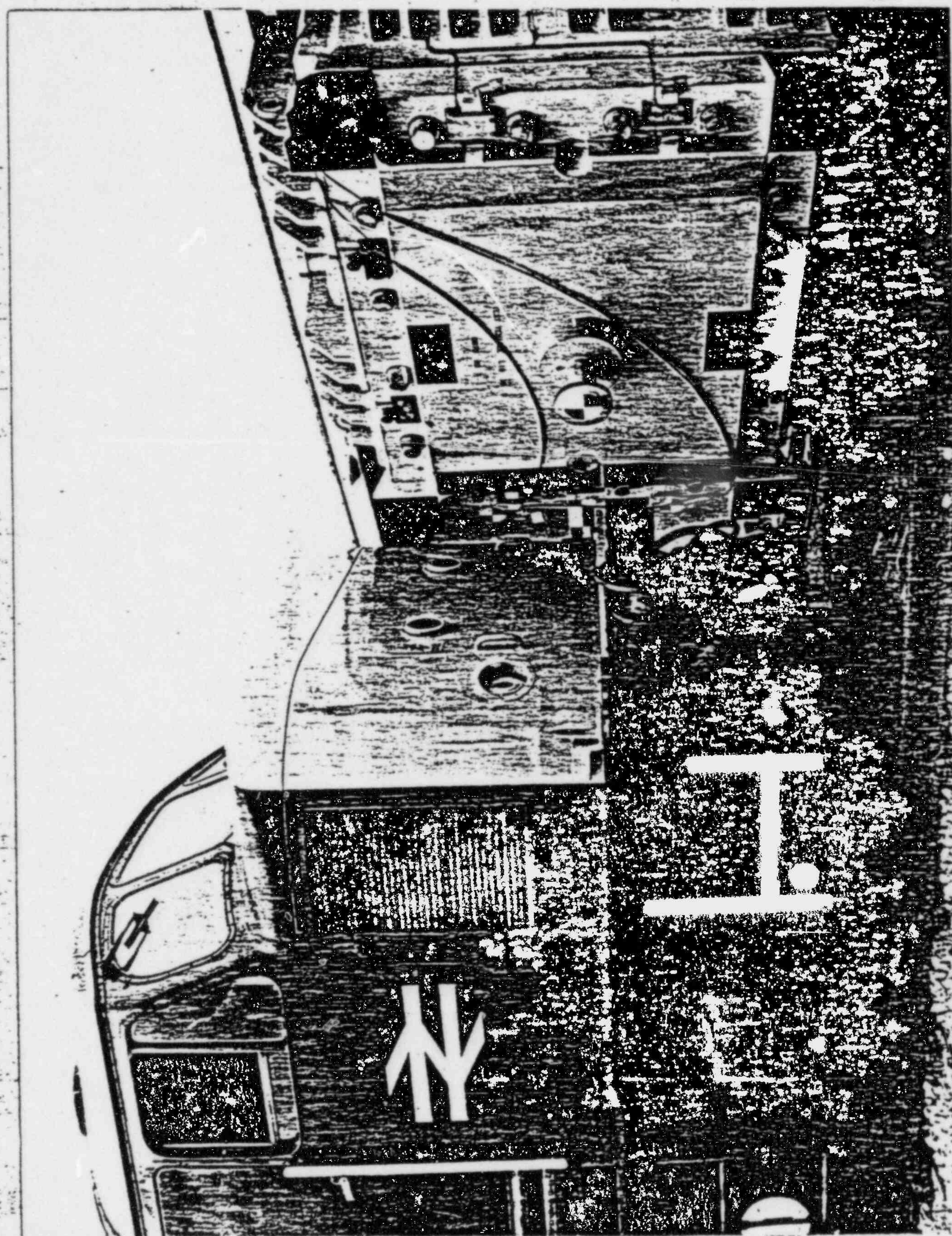
CAUTION

Your personal safety is paramount during this crash. There are clearly marked safety zones and it is imperative you remain within them, before and after the crash.



A 48-tonne Central Electricity Generating Board nuclear fuel flask is lined up on the track in preparation for a 100 mph rail crash - an event at Old Dalby, Leicestershire on 17th July to demonstrate the strength of the flask.

The steel flask straddles the track in the worst-possible attitude for a 140 tonne locomotive - the heaviest in service with BR - to run into it.



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For further information contact CEGB Press Office:

Telephone: 01 634 5111.

CENTRAL ELECTRICITY GENERATING BOARD

NUCLEAR FUEL FLASK TRAIN CRASH: 17 JULY 1984

TECHNICAL DATA PACK

Today's train crash has been arranged by the CEGB to demonstrate its confidence in the transport of spent nuclear fuel. The crash is part of a four year programme costing the Board £4 million.

This data pack gives further technical details to supplement the background information given in the guests brochure.

It contains technical data sheets and predictions regarding today's crash, some information on ther international regulations covering flasks, and an article on the full scale drop test demonstration which the Board conducted earlier this year.

CENTRAL ELECTRICITY GENERATING BOARD

NUCLEAR FUEL FLASK TRAIN CRASH: 17 JULY 1984

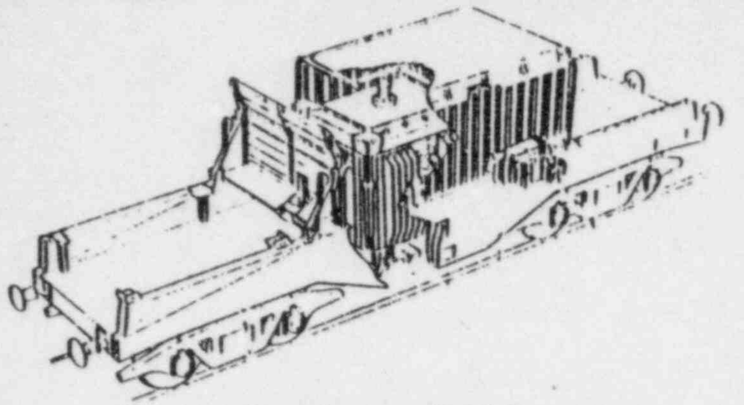
TECHNICAL DATA SHEET

Flask	Magnox Mark M2c	
	Overall dimensions	2.18 x 2.56 x 2.21 metres
	Weight of flask body, bolts, valves, etc.	37 tonnes
	Weight of flask lid	7 tonnes
	Weight of skip and simulated fuel (steel bars)	3 tonnes
	Weight of water	1 tonne
	Overall weight	48 tonnes
Flatrol	Specially made for the crash following the service unit design XK 003B	
	Length over buffers	12.49 metres
	Weight, unloaded & without bogies	13 tonnes
	Major changes from service unit design	i) sliding cover deleted ii) mild steel instead of stainless cladding iii) braking system deleted iv) bogies removed
Locomotive	Number 46 009 (Class 46)	
	Length over buffers	21 metres
	Weight	140 tonnes
	Major changes	i) remote starting switch added ii) batteries and CO2 bottles removed for safety

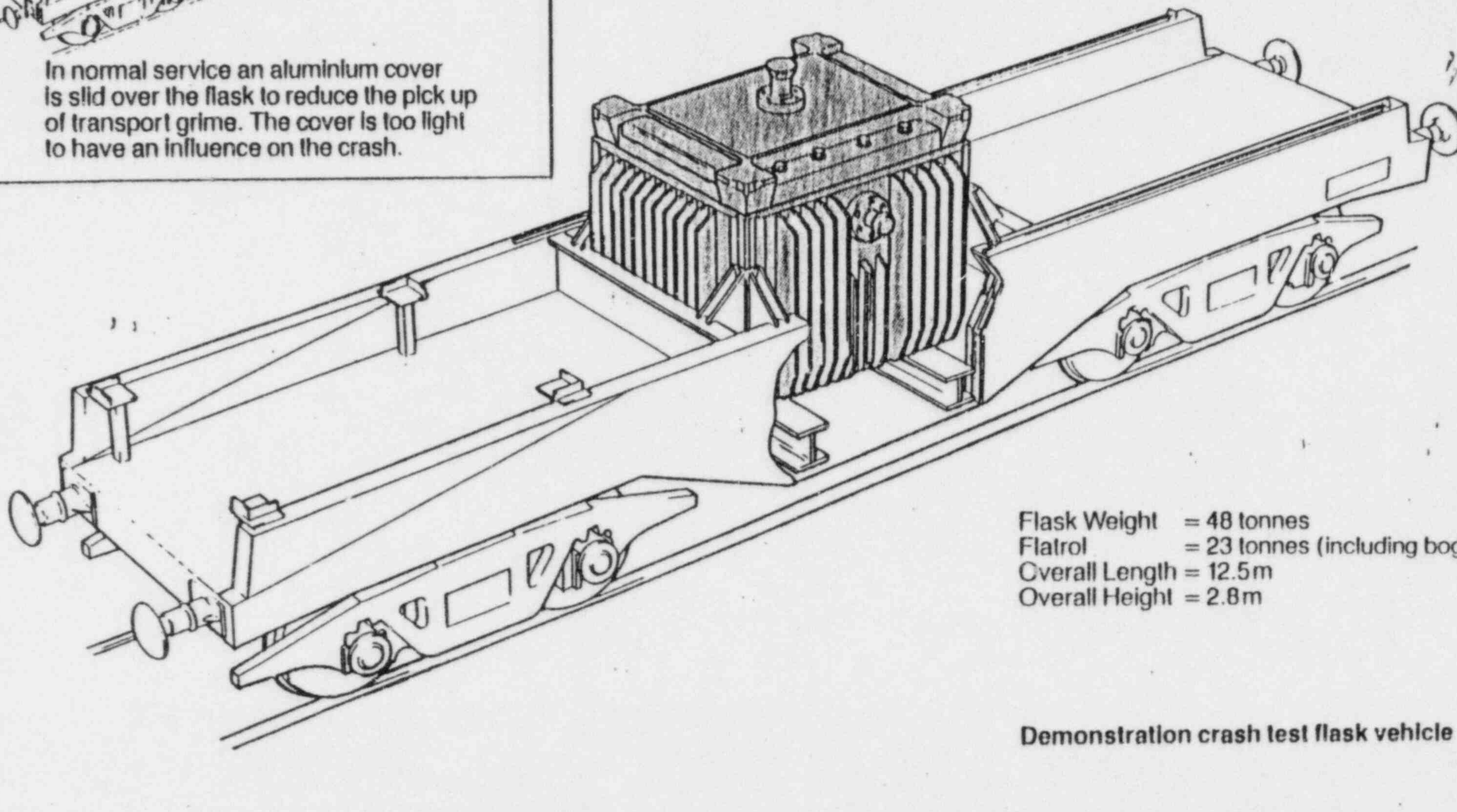
Carriages (3)	Mark 1 Passenger Coach	
	Length over buffers	20 metres
	Weight (each)	33 tonnes
Crash details	Impact velocity	90-100 mph (40-45 m/s)
	Flask impact attitude	Short lid edge centre of gravity of flask on centre line of the train
	Flask internal pressure	100 psig (0.69 N/mm2) pounds per square inch guage (0.69 Neutons per millometre square)
Instrumentation	i) on the flask	24 channels of information collected by 4 solid state recorders (one per side) carried on the flask 12 Accelerometers 1 Pressure Transducer 3 Lid Displacement Transducers 8 strain gauged lid bolts
	ii) on the locomotive	6 channels of information collected by 1 solid state recorder 3 Accelerometers (Engine block and leading drive motors) 3 Strain gauges (Chassis beam and leading bogie side

Photography	i) ground mounted:-	16 mm: 4 @ 1000 frames per second 9 @ 400 frames per second 9 @ 24 frames per second 35 mm or 70 mm: 6 @ 8 frames per second Video: 2
	ii) helicopter mounted:-	16 mm: 1 @ 400 frames per second 35 mm: 1 @ 24 frames per second
	iii) light aircraft mounted:-	Aerial survey before and after impact
Figures	Demonstration flask riding on its Flatrol Demonstration Crash Attitude	

Nuclear fuel flask
train crash 17 July 1984



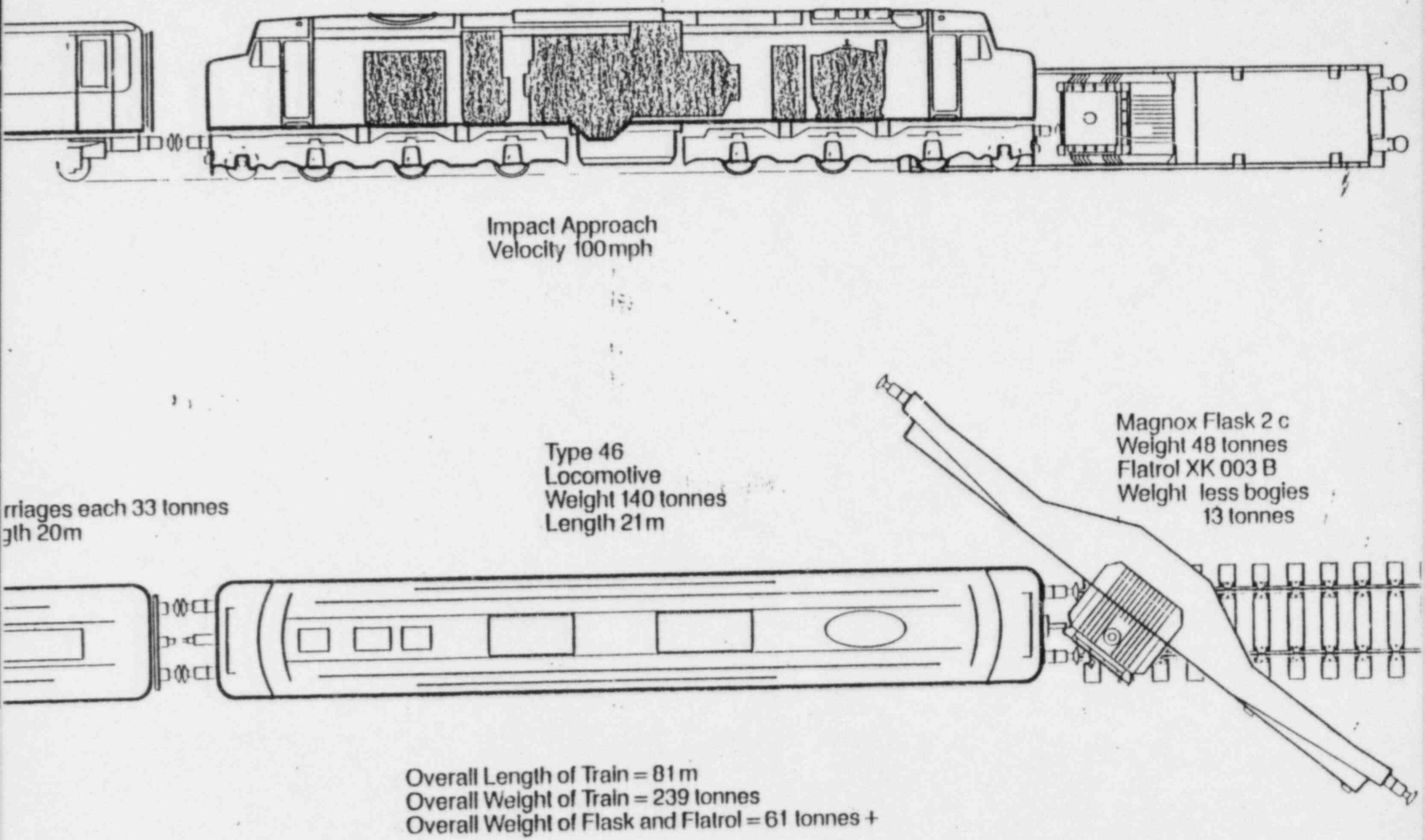
In normal service an aluminium cover is slid over the flask to reduce the pick up of transport grime. The cover is too light to have an influence on the crash.



Flask Weight = 48 tonnes
Flatrol = 23 tonnes (including bogies)
Overall Length = 12.5m
Overall Height = 2.8m

Demonstration crash test flask vehicle

Nuclear fuel flask train crash 17 July 1984



CENTRAL ELECTRICITY GENERATING BOARD

NUCLEAR FUEL FLASK TRAIN CRASH: 17 JULY 1984

THE IAEA REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIALS

The statutory provisions for spent fuel transport in the UK stem from regulations and guidance laid down by the International Atomic Energy Agency (IAEA). A fundamental concept of the IAEA Regulations is that each member state shall assign the responsibility for ensuring that each different flask design complies with the Regulations to a Competent Authority. In this country the Competent Authority is the Minister for Transport for whom the executive function is exercised by the Radioactive Materials Transport Division of his Department.

The standards to be achieved are described in the IAEA Regulations and cover normal use and accident conditions. The Regulations have been prepared by engineers and scientists drawn from member states of the IAEA and are subject to regular reviews (a major review is currently nearing completion).

The IAEA Regulations have international applicability such that a flask design carrying the approval of one Competent Authority can be accepted by another. To achieve this it was necessary to set the standards by specifying simply defined test conditions which are considered to be as damaging to the flask as the conditions experienced in normal transport and as might be experienced in an extremely severe accident. The regulatory accident tests make no attempt at reproducing real accidents.

Thus the IAEA accident test conditions comprise:-

* Punch test - flask dropped from 1 metre onto 150 mm diameter steel bar.
* Drop test - flask dropped from 9 metres onto a flat horizontal unyielding target.
* Thermal test - flask fully engulfed for 30 minutes in an $800^{\circ}C$ environment with no artifical cooling for at least 3 hours.
* Immersion test - flask immersed under a head of 15 metres of water for 8 hours.

The worst cumulative effects of the punch and drop tests followed by the thermal tests have to be assessed. The acceptance standard is expressed in terms of maximum radioactivity releases and in determining these it has to be assumed that the flask is carrying its maximum payload in the specified hotest ambient conditions for the whole of the specified maximum journey duration. In deriving the maximum permitted releases a generous margin is allowed relative to the recommendations of the International Committee for Radiological Protection. The IAEA Regulations state that compliance with the test conditions can be accomplished by:-

* performance tests on prototypes or a regular production unit
* reference to other previous similar demonstrations
* performance tests on scale models
* calculation or reasoned argument

or by a combination of these.

The CEGB, in common with the majority of applicants, demonstrates compliance with the accident conditions by scaling the impact performance obtained with models (usually half scale) and then calculating the additional thermal effects and subsequent radioactive release.

The validity of using information derived from tests on models has been demonstrated by comparing results obtained at different scales and by way of public reassurance a full scale regulatory drop test was performed in March of this year.

CENTRAL ELECTRICITY GENERATING BOARD

NUCLEAR FUEL FLASK TRAIN CRASH: 17 JULY 1984

CRASH PREDICTIONS

The predictions are based upon both calculations and scale model testing.

Preliminary calculations were conducted using a one dimensional computer program (SHOCK) which Sandia Laboratories used in the analysis of the crash tests performed in the USA. For these studies a BR high speed train was assumed to run into a stationary flask at 125 mph. The major conclusions drawn from these studies were:-

* the peak force on the flask was about one half the peak force exerted in the IAEA regulatory 9m drop test.

* the peak force occurred within the first 1/10 second and was the same irrespective of how many coaches were coupled to the power car.

For reasons of engine power and availability the heavier Class 46 locomotive was chosen for the demonstration, it having been shown in studies using a two dimensional computer program (AMP-2D) that at only 90 mph the Class 46 locomotive exerted the same peak force on the flask as the HST at 125 mph. The additional conclusions from these more detailed studies were:-

* forces are applied to the flask during an initial primary impact phase lasting less than 2/10 second at the end of which the flask and train are travelling at the same speed i.e. less than 70 mph (30 metres per second).

* the presence of the flatrol for which allowance was made by increasing the mass of the flask and raising the centre of gravity increases the duration of the primary impact phase and the tendency to rotate, but it has little effect upon the peak force on the flask.

* the carriages are decelerated by the collapse of their own structures and apply forces to the locomotive, but not before the flask has reached a common velocity with it; the carriages do not, therefore, affect the forces on the flask but increase the time required for the train to come to rest.

* the collapse of the leading bogie frame on the locomotive represents the major source of loading applied to the flask.

The following diagram illustrates the way in which the force on the flask changes over the primary impact period as the locomotive structure crushes.

For the computer calculations it is necessary to stylise the train into a number of large solid masses linked together with springs which represent the stiffnesses of the structures between the masses. An example of the way this is done is shown in a following diagram.

With the knowledge that the locomotive, in particular its leading bogie, was the main generator of force on the flask, it was not necessary to produce finely detailed scale models of the train for the model tests. Instead, Ove Arup & Partners, the Board's main contractor, designed a simple wheeled test vehicle in which the appropriate locomotive masses and deforming structures were represented, at ½ scale, by steel blocks, interspaced with packs of aluminium honeycomb. These 'masses' and 'springs' were free to slide within the vehicle framework which reproduced the important features of the front end of the leading locomotive bogie. The vehicle was designed to produce, on impact at 100 mph with a ½ scale flask and flatrol, scaled forces which were equal to or greater than those calculated for the full scale event.

The following conclusions were drawn from the model tests:-

* good agreement was found between the deformation of the test vehicles after impact and that estimated by computer calculation.

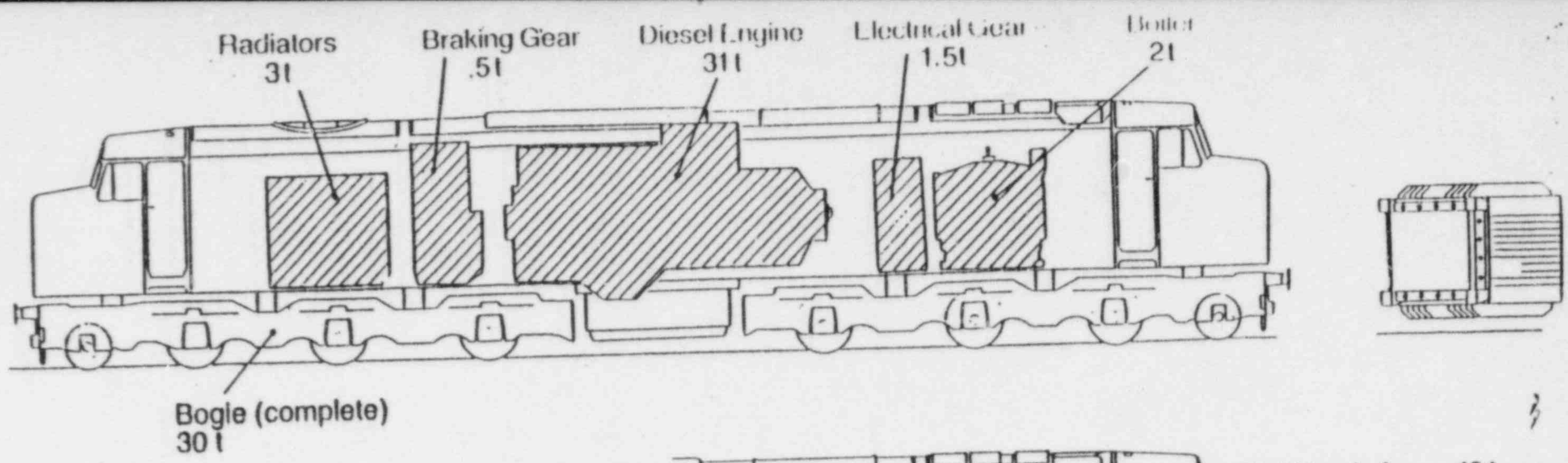
* in every test the flask containment remained intact and there was no water leakage.

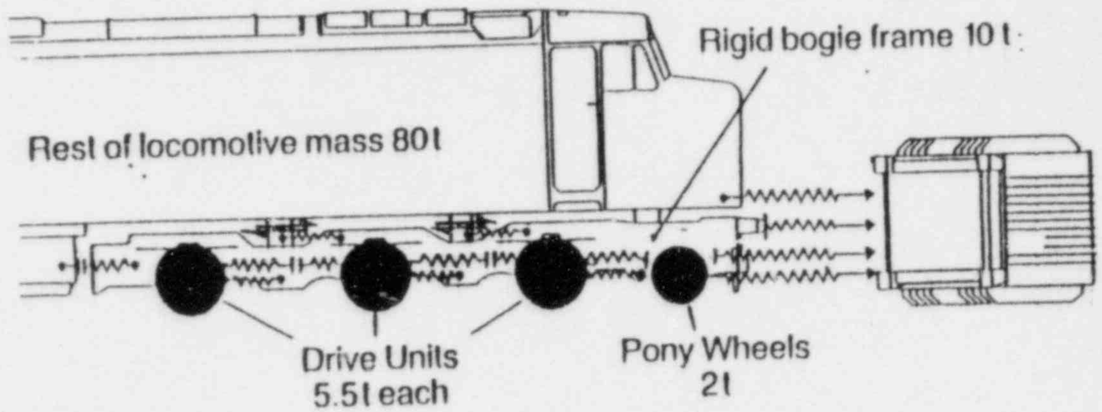
* in most tests the lid lifting pintle was sheared off and in some tests the head of a lid bolt was removed.

* debris from the impacts was propelled up to 200 metres, the flask was propelled about 130 metres from the impact point.

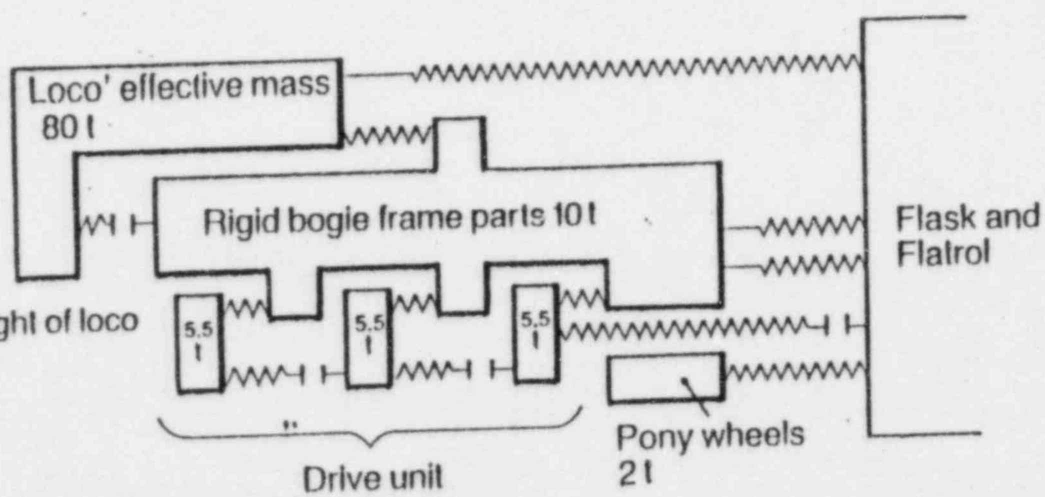
Combining the results from the computer calculations and the model tests and taking account of such information that exists in BRB accident reports, the following prediction is derived for the course of the crash:-

Time (Seconds)	Event
0	Draw hook impacts lid/body joint Cab impacts flask fins and flatrol. Buffer impacts lid pintle.
$\frac{20}{1000}$	Pony wheels impact flask.
$\frac{50}{1000}$	Maximum force on flask. Trailing deck of flatrol hits ground.
$\frac{1}{10}$	Train and flask reach common speed (less than 70 mph).
$\frac{2}{10}$	Boiler inside locomotive imparts final primary force on flask.
$\frac{3}{10}$	Locomotive runs off the end of the track and carriages may begin to snake.
2	Flask and flatrol might drop away from the train.
5	All components at rest.



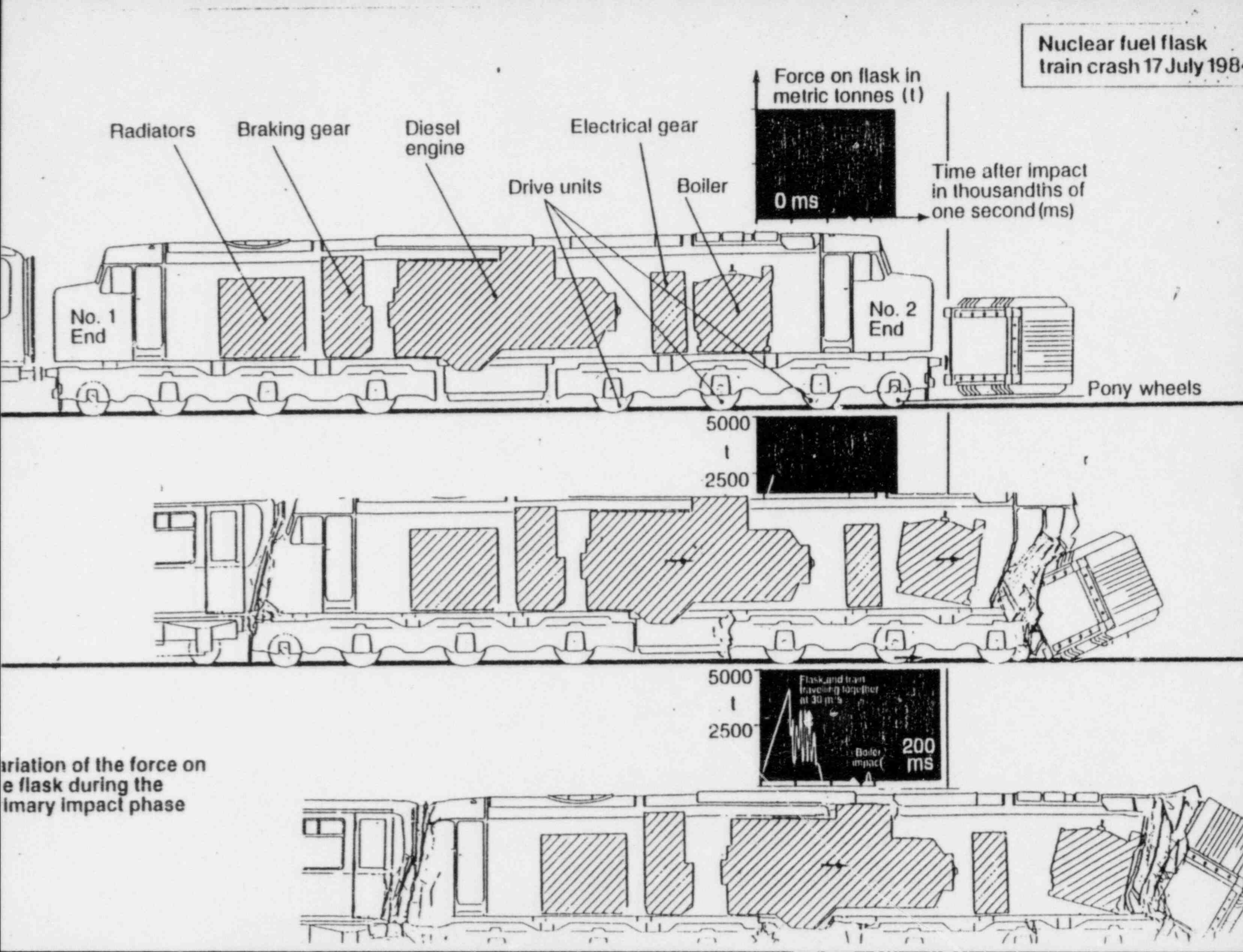


Nuclear fuel flask
train crash 17 July 1984



$80 + 2(10 + 3 \times 5.5 + 2) = 137$ = total weight of loco

Computer Model –
Lump Masses and Springs



Nuclear fuel flask
train crash 17 July 1984
Force on flask in
metric tonnes (t)
Radiators
Braking gear
Diesel
engine
Electrical gear
Drive units
Boiler
0 ms
Time after impact
in thousandths of
one second (ms)
No. 1
End
No. 2
End
Pony wheels
5000
t
2500
5000
t
2500
Boiler
impact
200
ms
ariation of the force on
e flask during the
imary impact phase

The CEGB successfully drops a spent fuel flask in public

Britain's Central Electricity Generating Board has a four-year £4 million programme aimed at validating the scale-model and other methods used to comply with the IAEA regulations and to demonstrate how full-scale flasks perform under real accident conditions. A public demonstration in which a Magnox spent fuel flask was dropped 9m on to a solid anvil showed that the flask met the regulatory drop test by a large margin.

On 6 March 1984, the British Central Electricity Generating Board conducted a drop test of a full-size Magnox nuclear fuel flask in public. This was the Board's response to some expressions of public concern about the safety of irradiated fuel transport and it provided a practical demonstration that the scale model tests used by the Board, in compliance with the IAEA regulations, are a valid means of flask testing.

For the demonstration an unused 48t flask of the latest forged steel body design was dropped from 9m on to an unyielding target which had been specially constructed at the Board's Structural Test Centre at Cheddar.

A lid edge impact was selected for the demonstration since the scale model testing had indicated this to be one of the most severe tests. Comprehensive instrumentation records of the flask's responses have demonstrated a close comparison with quarter-and-half scale model predictions and mathematical predictions.

International regulations. For over 20 years irradiated fuel from the CEGB's nuclear power stations has been safely transported in extremely robust steel "flasks" by road and rail to British Nuclear Fuels' Sellafield plant for reprocessing. From the beginning it was recognised that a very high standard of containment should be provided and maintained in the event of a severe accident. Rather than try to identify a set of postulated real accident scenarios against which to measure the flasks' performance a set of accident tests was evolved having international applicability*.

This article was written by W. N. Burns, R. A. Blythe, J. D. Hart and I. Milne of the Central Electricity Generating Board, and M. Shears of Ove Arup & Partners, England.

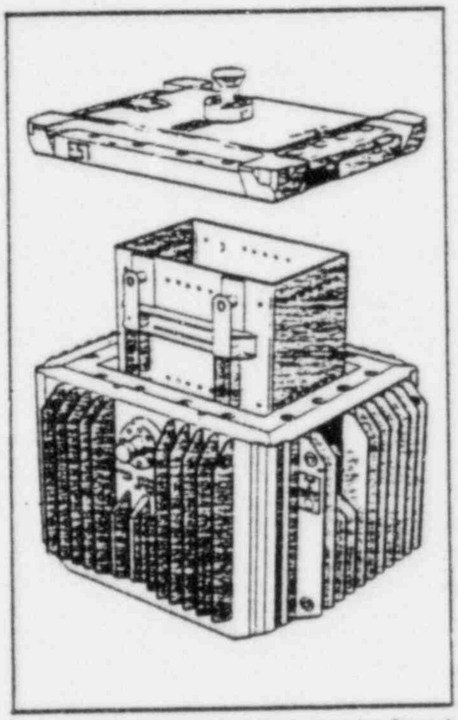


Fig. 1. Magnox spent fuel flask showing forged body and lid. The skip normally contains about 200 fuel elements.

The impact accident tests comprise a drop from 1m on to the flat end of a 150mm diameter mild steel bar and a drop from 9m on to a flat unyielding target; the thermal accident test comprises exposure to a specified heat flux for 30 minutes; both tests are to be conducted so that the cumulative effects lead to maximum damage.

In common with international practice, the CEGB has demonstrated compliance with the IAEA regulatory impact accident tests by scaling the results from the drop testing of small detailed models (mostly ¼ scale). The validity of scale modelling applied to flasks has been confirmed by a number of experimentalists (albeit mostly using cylindrical flasks). Nevertheless, some expressions of public concern in Great Britain have drawn upon the observation made in the sixth Report of the Royal Commission on the Environmental Pollution (the "Flowers" Report) that it was surprised to learn that the tests are conducted only on models.

*IAEA Safety Series No. 6 "Regulations for the safe transport of radioactive materials".

In response to the foregoing the CEGB embarked upon a four-year £4 million programme aimed at validating the methods it uses to comply with the IAEA regulations and also to demonstrate how flasks which comply with the regulations perform under real accident conditions. A major contract for the specification and organization of the programme was placed with Ove Arup & Partners with the specialist divisions of the CEGB providing management and technical support.

The programme involves analysis and testing (at scales from ½ to 1) of different flasks and associated transport equipment in impacts with different targets. The drop test described in this article is the first of the demonstrations using a full-size cuboid flask to be performed in public. In the next public demonstration it is planned to stage a full-scale train crash into a stationary flask.

Test flask design. CEGB (and South of Scotland Electricity Board) nuclear power stations are all based on gas-cooled reactors either of the natural uranium Magnox type or the slightly enriched uranium-dioxide AGR type. Both use a cuboid transport flask of approximately 2m side length for movement of spent fuel. To meet the objectives of the programme as fully as possible it was necessary to base the work on a single design of flask and the

Magnox design was selected.

The chosen flask embrances the CEGB current design thinking and is, in fact, being introduced as a replacement for the original Magnox flasks. A flask from the new supply was taken for the demonstration in preference to one which had been in service. This was because the test flask preparation was best carried out in workshops which are not licensed for work on radioactive materials and it would have been both expensive and inconvenient to make the necessary arrangements.

The Magnox flask (Fig. 1), essentially consists of a body made from a single piece steel forging, a single piece forged steel lid, 16 high tensile steel bolts and double elastomer "O" ring lid seals. Normally about 200 Magnox fuel elements are laid on top of each other inside a fabricated steel skip by which they are handled into and out of the flask. For the purposes of the demonstration the fuel elements were represented by steel rods. The level of water in the flask is determined by the overflow valve which is sealed by double elastomer rings. All of the seals are provided with test points to allow interseal testing prior to despatch.

The ullage space above the water inside the flask was pressurized with nitrogen to 0.69N/mm^2 (100lb/in^2) to represent the maximum conceivable operating pressure during normal operation calculated in accordance with the assumptions contained in the IAEA regulations. As an indication of the conservatisms vested in the regulations the flask pressure recorded at the end of a typical journey is less than 0.02N/mm^2 (3lb/in^2).

Test site preparation. Since 1976, facilities at the Board's Structural Test Centre at Cheddar have been gradually increased to accommodate flask impact testing. The site, being an old limestone quarry, was originally chosen for conducting transmission tower testing since it had the natural attributes of a rock floor base and a 60m cliff face. These were ideally suited for the construction of drop testing rigs and the massive unyielding targets necessary to conduct regulatory testing.

Prior to conducting the full-size demonstration drop test, extensive model flask testing at scales between ¼ and ½ had been conducted using varying target constructions. The capability had been produced for dropping masses of up to 6t in carefully controlled attitudes from up to 40m. For such an energy dissipation a truly massive anvil was required to achieve an unyielding target (Fig. 2). Whilst this target was satisfactory for the 48t demonstration drop from 9m a number of other problems needed to be overcome.

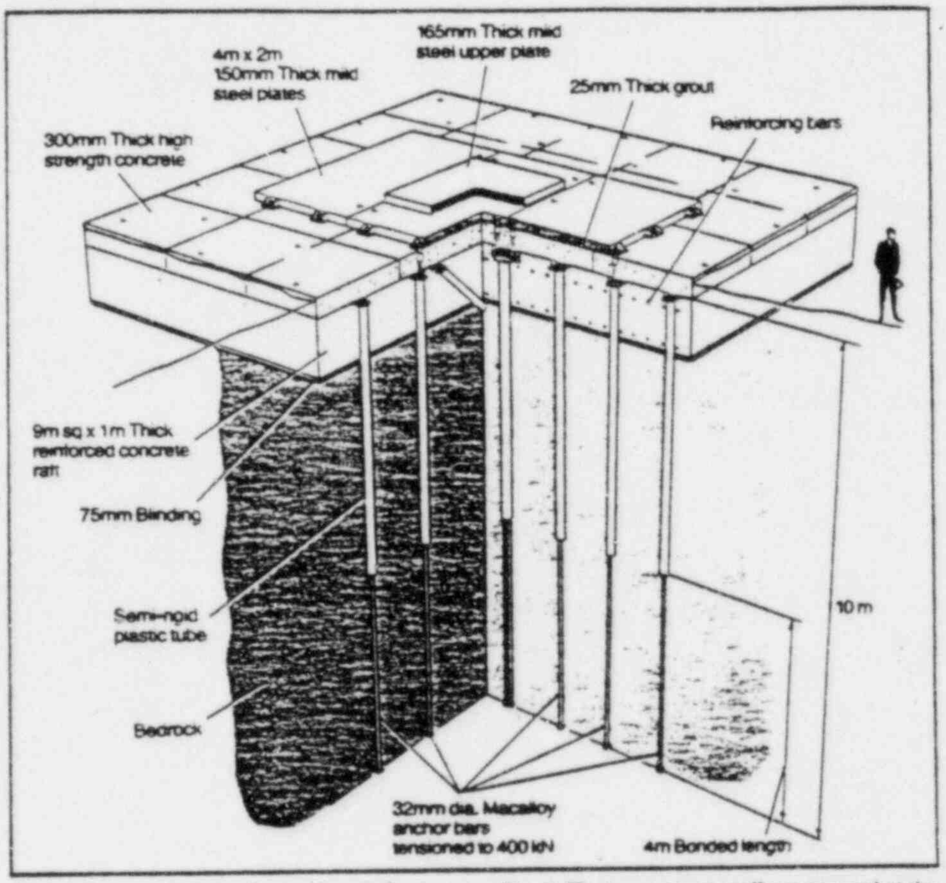


Fig. 2. The impact test anvil constructed at the CEGB's Cheddar testing station to comply with IAEA regulations for the safe transport of radioactive materials.

- A new approach road had to be constructed before the flask could be brought on to the site.
- A new drop test rig structure to support the 48t flask was designed and constructed around the lower portion of a transmission tower suitably modified at the top to accommodate a specialist lifting mechanism.
- The existing release mechanisms could not handle the increased mass and so a new system was developed which operated by fracturing a 50mm diameter suspension bolt by means of a hydraulically actuated jack.
- A weatherproof enclosure was built adjacent to the drop test rig for preparatory and post-drop inspection work and means had to be devised to move the flask from the enclosure into the drop position.

A general view of the rig with the flask in position for the drop is shown in Fig. 3.

Preparing for the drop. Prior to the delivery of the flask to the Cheddar test site, a number of small modifications were made to the flask to accommodate instrumentation. Small areas on the outside of the body and lid were milled flat and drilled and tapped to receive accelerometers. Holes were drilled at an angle through the body wall to emerge in the tapered throat by the lid spigot for displacement transducers and others were drilled through the lid in the vicinity of the lifting pintle for pressure transducer leads. Further holes in the rim of the lid and the body feet did not penetrate into the flask cavity. The former allowed depth gauges to be used for measuring the separation of the lid flange from the body flange whilst the latter were used to make attachments for handling the flask into the drop attitude.

Detailed metrology of the flask body lid, and lid bolts was conducted before and after impact so that changes in flatness of seal faces, bolt extensions and any other distortions could be determined.

The instrumentation system consisted of 23 electronic transducers mounted on the flask which were connected via an umbilical cable to signal conditioning and tape recording equipment housed in a cabin adjacent to the test anvil. Three 14-track high-speed magnetic tape recorders were employed giving maximum frequency response and a degree of redundancy to guard against spurious recording faults. The recorded information was transferred to a computer where the signals were processed digitally in order to produce filtered, integrated and/or frequency transformed data. The transducers mounted on the flask comprised three accelerometers to measure global decelerations, 16 strain gauges to measure the transient strains in each bolt, two displacement transducers to monitor the lateral movement of the lid relative to the body and two pressure transducers to measure the transient water pressure.

Four high-speed 16mm cine cameras running at speeds of 2000 and 5000 frames per second were installed to record the drop from three different angles. These required additional lighting and special units were brought on to the site making the installed lighting capacity around 350kW. A summary of the basic drop test data is given in Table 1.

Acceptance standards. Before considering the behaviour of the flask in the regulatory drop test it will be helpful to put into perspective the derivation of an acceptance level.

The acceptance standard set by the IAEA regulations is expressed in terms of activity release following the impact and thermal tests. The starting point for assessing the possible activity release is the leak tightness standard which all flasks must meet before they are despatched. Whilst changes in leak tightness are looked for after impact tests, this is just a coarse indication of the success of the test. To satisfy the regulations, a knowledge of any permanent distortions at the sealed joints existing after the impact test is required so that these distortions may be combined with any additional distortions arising from the thermal test in order to allow the overall change in seal performance to be determined. The effect of such joint distortions has been assessed in leakage tests on seals in a Magnox flask configuration as a function of joint separation both before and after the seals have been subjected to a thermal transient similar to that predicted for the regulation thermal accident condition. The tests showed that for a uniform joint flange separation of about 2mm, additional distortions due to the thermal transient did not cause leakage beyond the pre-despatch acceptance standard, even though at least an order of magnitude increase in leakage would still have been acceptable for the accident condition.

Results of the tests. Throughout the programme, scale models of the flasks were dropped in a variety of attitudes. The results from these tests, together with analysis, showed that one of the most severe attitudes, in terms of joint separation, is where the flask impacts on a lid edge with its centre of gravity centred over the line of impact. This attitude was, therefore, chosen for the public demonstration test on 6 March 1984.

Fig. 4 shows the flask on rebound from the anvil with deformed shock absorbers; it finally came to rest in much the same attitude. The pressure in the flask cavity was measured immediately before and after the test and the pressure loss was shown to be $0.1N/mm^2$ ($1.5lb/in^2$). The high-speed cine photography showed that, as expected, there was a small transient leakage of water during the impact which has negligible radiological significance.

Fig. 3. The drop-test rig showing the Magnox flask suspended 9m above the test anvil.

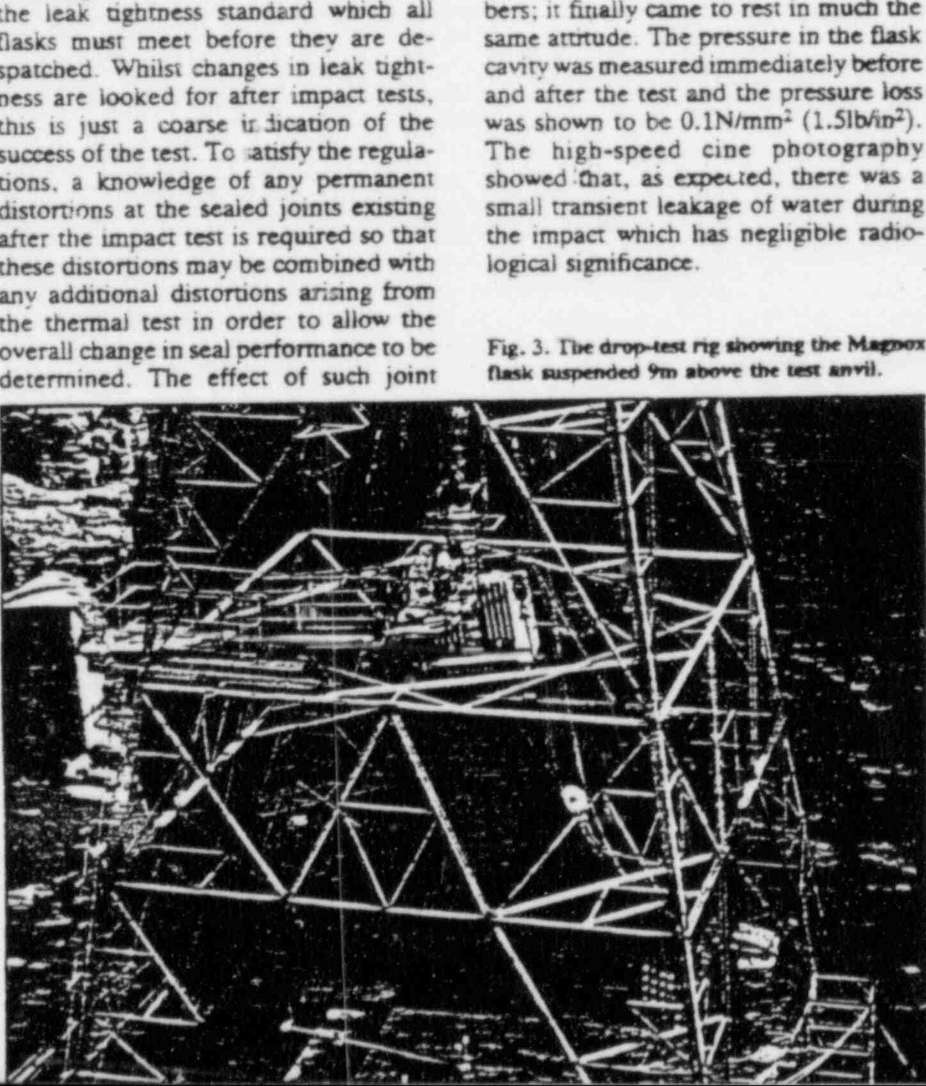


Table 1: Basic Drop Test Data	
Drop Test Rig	
Overall height	19m
Base area	13m x 13m
Lifting and release capacity	100t
Anvil	Mild steel plate 6m x 4m x 150mm thick. Additional mild steel plate: 2m x 2m x 165mm. Effective anvil mass 2000t. Number of rock anchors – 70
Magnox Flask	
Overall dimensions	2.18m x 2.56m x 2.21m
Weight of flask body, bolts, valves, etc.	37t
Weight of flask lid	7t
Weight of skip + simulated contents (steel bars)	3t
Weight of water	1t
Test Details	
Drop height	9m
Impact velocity	30mph (13.4m per second)
Drop attitude	Long lid edge with centre of centre of gravity of flask over line of impact
Flask cavity gas pressure	$0.69N/mm^2$ ($100lb/in^2$)
Inter lid seal leak test standard	$0.062N/mm^2$ ($9lb/in^2$) = max. drop in 1hr from $2.1N/mm^2$ ($304.6lb/in^2$)
Instrumentation	3 Accelerometers 2 Pressure transducers 2 Lid displacement transducers 16 strain gauged lid bolts
Recording equipment	½in magnetic tape recorders
High-speed cine cameras	16mm: 2 @ 5000 frames/sec 2 @ 2000 frames/sec
Photographic Lighting	Approximately 350kW

The separation of the joint between the lid and body were measured after the drop at positions around the flask between the bolt hole locations. These movements are shown in Fig. 5 where they are compared with predictions obtained by the linear scaling of model test results.

The full-scale lid/body movements can be seen from Fig. 5 to lie generally below both ¼ and ½ scale predictions and all well below the 2mm level discussed earlier. The comparison of the predicted acceleration/time traces with the full-scale event showed an even closer fit with a maximum recorded acceleration of 164g, 151g and 156g for full-scale, half-scale and quarter-scale respectively.

An understanding of the sensitivity of impact damage to variations in parameters such as impact attitude, friction and lid spigot to body gap was evolved from the development of a three dimensional mathematical model of the whole flask based upon the Ansys computer code, together with detailed physical and analytical modelling of the shock absorbing features using Dyna 3D. The

Main events during impact

0-1.5ms: The west lid edge touches the anvil and the lid commences to slide across the body seal face. At 1.5ms the gap between the lid spigot and body is closed on the east face.

1.5-3.4ms: On the east face the lid climbs the 17° sloping throat in the body until it is stopped by friction and bolt loads at 3.4ms.

3.4-6.5ms: During this period there is no relative movement of lid and body at the spigot.

6.5-7.5ms: Flexural vibrations along with the rising impact load cause the lid to move further up the sloping throat in the body, until again it is stopped by friction at 7.5ms.

7.5-14.5ms: From 7.5ms until the end of the impact there is no further relative movement at the spigot.
Over the whole of the 14.5 milliseconds, the lid shock absorbers are undergoing metal flow and the flask decelerates in proportion to the shock absorber, knock-back force.

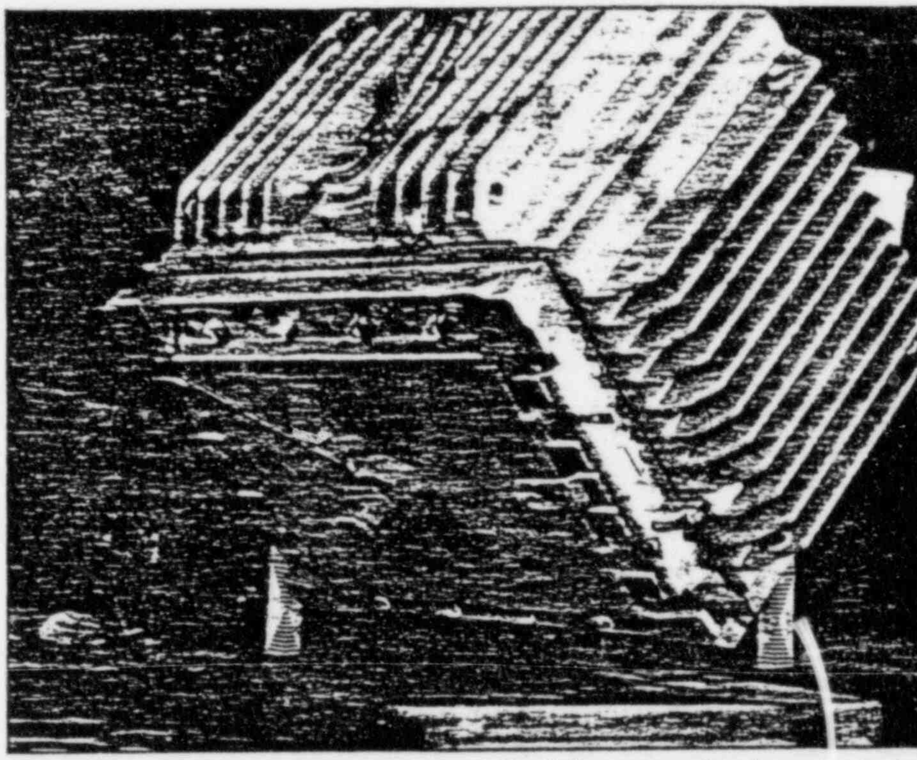
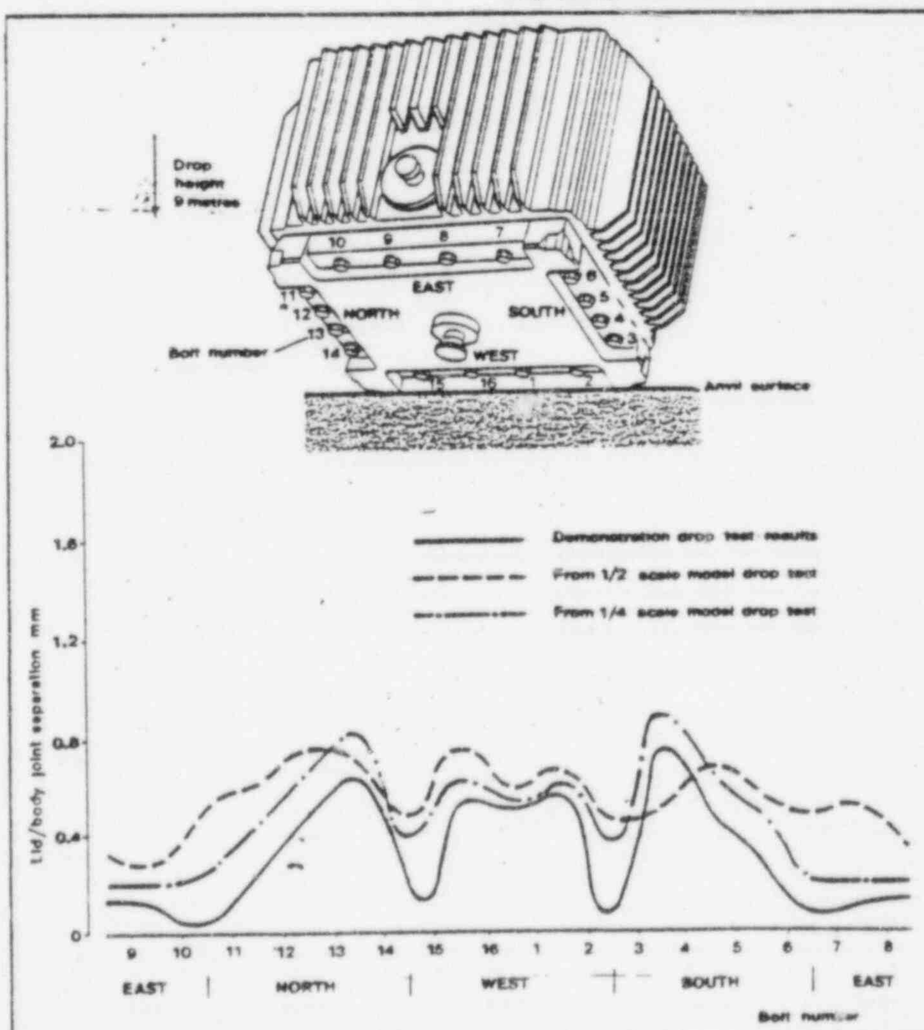


Fig. 4. The 48t Magnox flask on rebound from the test anvil after free fall from a height of 9m on to the impact test anvil.

Fig. 5. Comparison of the demonstration drop test result with predictions derived by scaling the lid/body joint movements obtained from drop testing model flasks.



additional instrumentation provided detailed information on the transient behaviour of flask water pressure, bolt strains and lid movements, all of which have been used to cross-correlate with theoretical predictions to build up a description of the important events as they occurred during the impact. These are listed in the panel.

Scale-model tests validated. The public demonstration drop test of the Magnox flask design showed that the flask will meet the IAEA regulatory drop test by a large margin. Together with the results of the supporting test programme on scale modelling, it was demonstrated that the predictions of behaviour obtained in regulatory drop tests can be accurately obtained from tests of scale models provided that the important features are accurately represented in the models.

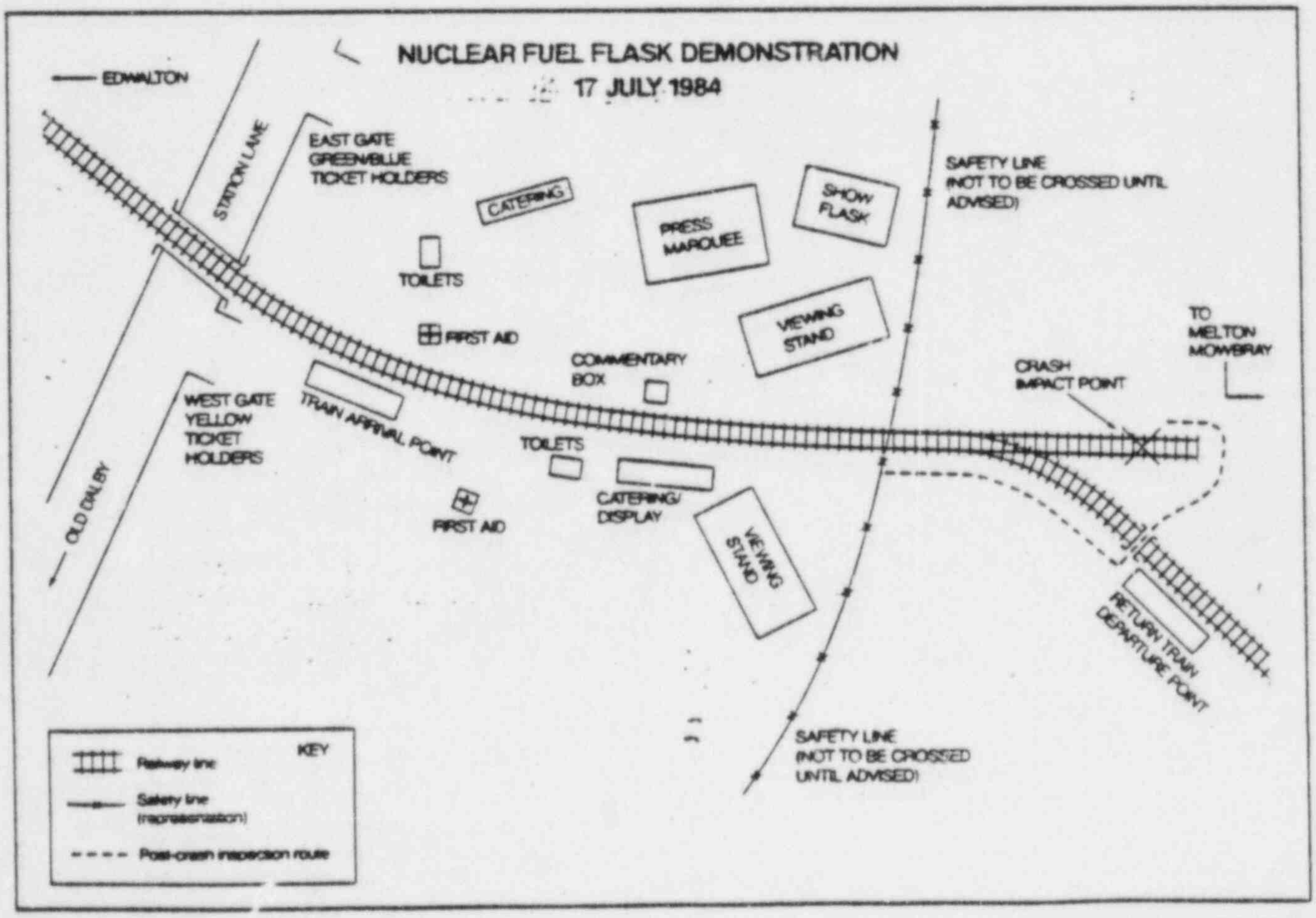
Acknowledgements

The work for this test programme was performed at Ove Arup & Partners and within Technology Planning & Research Division, Transmission & Technical Services Division and Generation Development & Construction Division of the Central Electricity Generating Board, and the authors wish to acknowledge the work of the many colleagues involved. It is intended that more detailed reporting of the individual components of the work will provide due recognition.

Acknowledgement is due also to the Central Electricity Generating Board for permission to publish this article.

TIMETABLE (LISTEN FOR ANNOUNCEMENTS)

10.30	Site open for coach arrivals from Wymeswold airfield, refreshments available.
10.45	Arrival of Train A charter from St. Pancras.
11.30	Box lunches available in refreshment marquees.
12.06	Arrival of Train B charter from St. Pancras.
12.30	All guests to take their seats in the viewing stands.
12.35	Spare locomotive passes through Old Dalby.
12.40	The crash area is cleared.
13.05	Crash locomotive starts its run from Edwalton.
13.09	Crash locomotive cleared through first abort point.
13.11	Crash locomotive cleared through second abort point.
13.12	Locomotive crashes into nuclear fuel flask and flatrol positioned on railway line.
13.15	Safety examination commences.
13.40	Viewing commences from walkways around wreckage.
14.00	Coaches begin return journeys from entrance gates to Wymeswold airfield.
14.30	Check-in for departure of Train B.
15.30	Check-in for departure of Train A.
16.30	Last coach departs for Wymeswold airfield.
17.00	Site closed.



BACKGROUND TO TODAY'S DEMONSTRATION

The CEGB has decided to stage today's demonstration following representations by MPs, trade unionists and local councillors who were concerned that the Board's case about the excellent safety record of its nuclear fuel flasks was not being understood.

It is not essentially a scientific or engineering exercise, although data will be gained from it. It is a dramatic public demonstration of the Board's total confidence in the immense strength of these containers.

Spent nuclear fuel has been transported in complete safety from CEGB nuclear power stations for reprocessing since 1962. In more than 7,000 journeys there have been no accidents involving the release of radioactivity. Currently there are around 500 flask movements a year. Reprocessing produces valuable re-usable materials which in turn are used to make new fuel to produce some of Britain's cheapest electricity.

The CEGB gives absolute priority to safety and today's demonstration illustrates the Board's determination to be vigilant and responsive to concern about the transport of spent fuel.

In today's crash, a class 46 diesel locomotive hauling three passenger carriages will accelerate to 100 mph over about 8 miles of track. The train is a type used throughout the British Railways network and is the heaviest of the locomotives used by BR.

The train will strike the nuclear fuel flask on the lid as it lies on the track in the cradle of a derailed flatrol — the worst imaginable position. Steel bars simulating a two-tonne load of nuclear fuel will be carried in the flask.

The flask is 48 tonnes in weight and forged from a single block of steel, to eliminate the need for welds. Engineering tests on scale models give the Board total confidence that the flask will emerge unscathed. The locomotive will be destroyed.

It will take about 5 seconds for all components involved in the crash to come to rest. Initially the locomotive is likely to be crushed and decelerate while the flask experiences maximum forces and accelerates, so that the train and flask are moving together at about 70 mph. In the post impact period the flask, flatrol and train will come to rest over the 200 metre length of disused railway siding.

The demonstration will illustrate how safe these flasks are. To meet international regulations, the flasks are subject to stringent tests which simulate damage to flasks under severe accident conditions during transport. Assessments are made of the cumulative effects of punch tests, drop tests and engulfment for 30 minutes in an 800°C fire.

Earlier this year the Board organised a full-scale drop test at the Board's Structural Test Centre at Cheddar, Somerset. It was highly successful in showing that the predictions from earlier scale model tests were correct. The full scale flask performed perfectly.

Elaborate precautions are necessary because, by law, if there is any risk from radiation (no matter how small), the public must be protected to the maximum practicable extent. In practice this means that there is better protection from radiation accidents than from any other type of accident. This ultra cautious approach reflects the fact that although experts know more about radiation risks than many other risks, and although radiation risks are small, public perception may be different. Radiation cannot be seen, smelt or felt and extra assurance is necessary.

The probability of a serious accident to a flask is estimated to be as remote as one in ten million years.

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