1.0 General Information

1.1 Introduction

The Amersham Model 3100A Transport Container is designed to transport Type B Quantities of Cobalt-60 Sterilization Sources in the form of metallic Cobalt in IAEA, Special Form, Capsules. It can be loaded and unloaded underwater. The 3100A conforms to the criteria for Type B(U) packaging in accordance with 10 CFR 71 and IAEA Safety Series No. 6, 1973 Revised Edition (as amended 1979). It has received the approval of the United Kingdom Secretary of State for Transport, the competent Authority of Great Britain, and has been given the Competent Authority Identification Mark GB/3100A/B(U). It has been revalidated by the U.S. Department of Transportation as USA/0407/B(U).

1.2 Package Description

1.2.1 Packaging

The GB/3100A consists of a stainless steel container with depleted uranium shielding, mounted on a stainless steel pallet inside a steel and wire mesh cage. The container is 1132 mm (44.6 inches) wide x 1132 mm (44.6 inches) deep x 1360 mm (53.5 inches) high. The gross weight of the container is 2570 Kg (5,666.85 lbs.).

The inner cavity is lined with a stainless steel pipe with a 100.2 mm inside diameter (4 inches) and is 521.5 mm deep (20.5 inches). Since the container body (or flask) is designed to allow unloading underwater, there is a drain hole in the bottom of the inner cavity connected to a seamless stainless steel drain pipe with a 9.53 mm outside diameter (0.38 inches) x 1.65 mm wall (0.065 inches). The drain pipe is lined with a second seamless stainless steel pipe. The minimum ID of the drain pipe is 4 mm (0.16 inches). A Tungsten Alloy Rod is inserted in the drain pipe during transportation to provide shielding. The drain pipe is closed with a Ferralium 255-3SF plug.

The radioactive material is Cobalt-60 metal doubly encapsulated in stainless steel. The source conforms to the requirements of IAEA, Special Form, Radioactive Material. The capsules are carried in a source holder assembly, which fits into the inner cavity. This assembly consists of 25 tubes in two concentric rings around a central tube support with a circular base, and an end plate on top.

The Tubes are seamless stainless steel with a 14 mm (0.55 inches) outside diameter, and a 1 mm (0.04 inches) thick wall. They are 416 mm (16.4 inches) long. The base of the tube support is a 5/16 inch thick stainless steel plate which has 2 concentric rings of holes drilled into it to support the base of the tubes. The holes are 14.5 mm (0.57 inches) in diameter by 4.8 mm (0.19 inches) deep. There are 15 holes in the outer ring, and 10 in the inner ring. The end plate which fits on top is a 3/8 inch stainless steel plate and has the same size holes drilled into it as the base plate. The end plate supports the top of the tubes. The end plate has a key hole in the center which allows it to be placed on the tube support and rests on a shoulder of the center shaft of the tube support. It will only fit one way and cannot turn on the tube support shaft.

The end plate secures the source tubes in place and is in turn secured by a stainless steel bolt with a lifting eye on the end, which is screwed into the top of the tube support shaft.

The inner, or containment cavity is shielded by 5 blocks of depleted uranium 150 mm (5.9 inches) thick with a total mass of 1817 Kg (4006 lbs.). Four of the blocks form an open topped cylinder (the inner cavity) and the fifth, the closure plug. The two assemblies, flask body and closure, are each totally encased in stainless steel. This serves not only to hold everything together but also contains and protects the uranium which is itself a hazardous material. The outer stainless steel body cladding is 1/2 inch thick. All surfaces of the stainless steel jacket and the cavity tube exposed to the depleted uranium are either covered with a plasma sprayed, copper coating or separated from the depleted uranium by a 0.010 inch thich copper foil.

Welded around the exterior of the stainless steel jacket are 36 vertical stainless steel fins to dissipate heat generated by the contents, as well as acting as shock absorbers. In each quadrant a thicker fin is extended above and below the body providing a lifting point and a foot.

The fins are enclosed by a cylindrical jacket of thin gauge stainless steel. This serves to improve natural convection around the fins by inducing a "chimney" effect, and also to reduce heat uptake during the fire test by acting as a radiation break. Fins on the top of the closure and the underside of the body also aid heat and shock absorption.

The closure consists of a circular 2 1/2 inch thick stainless steel plate with a depleted uranium closure shield encased in stainless steel attached to the underside.

The shield is 150 mm (5.9 inches) thick, and fits into a depression in the top of the upper shield 322 mm (12.7) inches in diameter. As with the rest of the flask, stainless steel parts of the closure are separated from the depleted uranium by plasma sprayed copper coating, or by a layer of copper foil.

The closure is secured to the body by eight M20 bolts around the perimeter of the closure plate. One side of the closure plate has a slot in it which fits over one of the four thick fins. This fin retains its full width all the way to the top and has a hole drilled through the inside corner to allow a padlock to be applied. With the padlock in place it is impossible to remove the closure. There is a cavity purge point on the closure plate to facilitate the draining of water from the containment cavity. This is secured by a Ferralium 255-3SF plug.

The center of the closure plate has a threaded hole into which an M30 eyebolt may be screwed. This eyebolt may be used to lift the closure off the body, or with the eight closure bolts secured, to lift the entire flask.

The flask may also be lifted by using the lifting eyes at the top of the four thick fins.

The flask is transported on a specially built stainless steel pallet to which it is attached by eight M16 bolts. This spreads the load and allows the container to be moved by a forklift truck.

Because of high surface temperatures on the flask when fully loaded, access to the flask is prevented by means of a protective cage secured onto the pallet by four M16 bolts and two guides. The cage is also secured to the pallet by two padlocks and two security wires.

The cage is fabricated from stainless steel angle and mesh, and also serves to provide lifting and tie down points for the entire assembly. A lug with a lifting eye is provided at each of the four corners on top of the cage. Three tie down lugs are provided halfway up each of the four corners.

This container is not intended to vent continuously during transport and therefore it does not include a pressure release device from the containment system.

1.2.2 Operational Features

The source holder assembly is secured in the proper shielded storage position by means of the closure assembly. With the source holder assembly in the proper shielded storage position, the closure assembly is lowered over it. The slot in the rim engages only with the fin with the padlock point. The eight closure bolts are then secured and a padlock and seal are attached to the fin with the padlock point, locking the closure assembly into place.

The flask is secured to the steel pallet by eight bolts through the flask feet. The outer framework and cage is then lowered over the flask and bolted to the pallet with four bolts. It is also secured to the pallet by two padlocks and seals.

1.2.3 Contents of Packaging

The GB/3100A is designed to transport Cobalt 60 sterilization sources in the form of solid metallic cobalt in IAEA special form capsules. The maximum quantity would be 15 Kg (33 lbs.) and a maximum activity of 10 PBq (270 kCi). The maximum heat load in watts is 4.160 kW. The contents will run at a peak temperature no greater than 457° C.

1.3 Appendix

1.3.1 United Kingdom Certificate of Approval GB/3100A/B(U)

1.3.2 United Kingdom Application Document

1.3.3 U.S. Dept. of Transportation Revalidation of British Competent Authority Certificate

1.3.4 Design Drawings

1.3.1 United Kingdom Certificate of Approval GB/3100A/B(U)

Certificate of Approval of Package Design for the Carriage of Radioactive Materials

1. THIS IS TO CERTIFY that the Secretary of State for Transport being, for the purpose of the Regulations of the International Atomic Energy Agency, the Competent Authority of Great Britain in respect of inland surface transport and of the United Kingdom of Great Britain and Northern Ireland in respect of sea and air transport and the Department of the Environment for Northern Ireland being the Competent Authority of Northern Ireland in respect of inland surface transport, have approved the package design, as specified in paragraphs 2-4 of this certificate, submitted by Amersham International plc, Amersham

as Type B(U)

for the transport of encapsulated sources

by all modes of transport

Packages manufactured to this design meet the requirements of the regulations and codes on page 2 relevant to the mode of transport, subject to the following general condition and to the conditions in the succeeding pages of this certificate.
In the event of any alteration in the composition of the package, the package design or in any of the facts stated in the application for approval, this certificate will cease to have effect unless the Competent Authority is notified of the alteration and the Competent Authority confirms the certificate notwithstanding the alteration.

This Certificate Cancels all Previous Issues and is valid till 31 January 1991.

COMPETENT AUTHORITY
IDENTIFICATION MARK:

GB/3100A/B(U)

UNITED KINGDOM COMPETENT AUTHORITY FOR THE TRANSPORT
18 JAN 1988
OF RADIOACTIVE MATERIALS

D. J. Blackman
Transport Radiological Adviser
Department of Transport
2 Marsham Street
London SW1P 3EB

On behalf of the Secretary of State for Transport and the Department of the Environment for Northern Ireland

Regulations and Codes of Practice Governing the Transport of Radioactive Materials

INTERNATIONAL
International Atomic Energy Agency (IAEA) Safety Series No 6 Regulations for the Safe Transport of Radioactive Materials 1973 Revised Edition (As Amended).

International Maritime Organisation (IMO). International Maritime Dangerous Goods Code – Class 7 Radioactive Substances.

International Civil Aviation Organisation (ICAO). Technical Instructions for the Safe Transport of Dangerous Goods by Air.

ROAD
Great Britain only. The Radioactive Substances (Carriage by Road)(Great Britain) Regulations 1974. SI No 1735: Code of Practice for the Carriage of Radioactive Materials by Road (1982 Impression): The Radioactive Substances (Carriage by Road)(Great Britain)(Amendment) Regulations 1985 SI No 1729: The Ionising Radiations Regulations 1985 SI No 1333; and Approved Code of Practice.

Northern Ireland only. The Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1983. SR 1983 No 344. and Amendment 1986 SR 1986 No 61.

Europe only. European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), Class 7.

RAIL
Great Britain only. British Rail publication BR 22426 (1977 Edition) – Dangerous Goods by Freight Train and by Passenger Train or similar service – List of Dangerous Goods and Conditions of Acceptance – Class 7 Radioactive Substances.

Europe only. International Convention concerning the carriage of goods by rail (CIM). Annex I, International Regulations concerning the carriage of dangerous goods by rail (RID).

SEA
British ships registered in UK and other ships loading in UK ports or territorial waters only. The Merchant Shipping (Dangerous Goods) Regulations 1981 SI No 1747 and the Report of the Standing Advisory Committee on the Carriage of Dangerous Goods in Ships 1978 (The "Blue Book") Class 7.

AIR
UK Only. The Air Navigation Order 1985 SI No 1643: The Air Navigation (Dangerous Goods) Regulations 1985 SI No 1939: The Air Navigation (Dangerous Goods)(Amendment) Regulations 1986 SI No 2129 and the International Civil Aviation Organisation's (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air.

Notes

1 *Attention is drawn to the labelling and marking requirements of IAEA Section V, one provision of which is that the outside of each package shall be clearly and durably marked with the Competent Authority's Package Identification Mark.*

2 *Any questions relating to this Certificate should be addressed to the Transport Radiological Adviser, Department of Transport: 2 Marsham Street, London SW1P 3EB*
Telephone 01/212/7247
Telex 22221 Answer back DOE MAR G

3 *This Certificate does not relieve the consignor from compliance with any requirement of this or any other country through or into which the package may be transported.*

2. Specification of Packaging

Item No.	Packaging	Design Number	Quantity per Assembly
1	Outer	3100	One
2	Inner	IAEA Special Form Capsules (See paragraph 12C)	Up to a maximum of 25

The containment system comprises item no. 2

Packaging Design Details

Design No.	Title	Drawing List	Issue
3100	Stainless steel depleted uranium shielded container on its own pallet with an outer protective cage	DL 23525	E
Capsules	Any IAEA Special Form Capsule	-	-

2. Continued

The package design specification shall be in accordance with Amersham International plc document WD31 - BU 3100A - Revision 2 - Application for the Approval of Package Design No.3100A dated December 1987.

3. PERMITTED CONTENTS

Cobalt 60 sterilisation sources in the form of metallic cobalt in IAEA Special Form Capsules.

4. RESTRICTIONS ON CONTENTS

(a) The total activity shall not exceed 10 PBq (270kCi) per package.

(b) The total rate of heat generation shall not exceed 4.16 kilowatts per package.

5. INSTRUCTIONS ON USE OF PACKAGE

(a) The package shall be handled in accordance with "the Handling and Packaging Instructions, HPI 63, Issue 2, for Package Design No.3100A".

(b) When the sources, together with the sourceholder, are loaded, they shall be located in the source cavity in such a way as to prevent gross movement during both normal and accident conditions of transport.

(c) The 3100A container shall be manufactured in accordance with the drawings listed in DL 23525, Issue E, and document QCP510, Issue B.

(d) Inspection and maintenance of the package shall be carried out in accordance with "Amersham International plc PGM 176 - Turnround maintenance for Package Design 3100A, Issue 2 and PGM 177 - Annual maintenance for Package Design 3100A, Issue 2.

6. ACTIONS PRIOR TO DESPATCH

The sources shall be loaded into the flask under the direct supervision of a Responsible Officer who is fully conversant with the instructions detailed in paragraphs 5(a) and (b) of this certificate.

7. STOWAGE CONDITIONS

(a) The package shall be stowed such that air can freely circulate around the package.

(b) The package shall not be oversheeted.

(c) When transported such that the package is exposed to the elements, adequate drainage shall be provided to ensure that heat dissipation from the package is not adversely affected.

8. FULL LOAD CONDITIONS

If the contents of the package exceeds 1.2 PBq (32kCi) then it shall be shipped under FULL LOAD conditions.

1.

9. RESTRICTIONS ON SHIPMENT

Road in GB

If, for any reason, the vehicle is subject to a speed restriction of less than 20 mph the carrier shall instruct the driver of the vehicle that, before crossing any automatic half-barrier railway crossing he shall notify the railway signalman of his intention to cross and await the signalman's instructions.

10. LABELLING, MARKING AND PLACARDING

(a) Labelling and marking of packages and the placarding of vehicles shall be in accordance with the regulations listed on page 2 of this approval certificate.

(b) Road in GB. In the cab of the road vehicle there shall be prominently displayed a fire proof notice indicating that the load is radioactive and bearing the particulars and telephone number of the owner/operator of the vehicle and stating that the police should be informed in the event of an accident.

11. EMERGENCY ARRANGEMENTS

(a) Road in GB

Should emergency radiological assistance be required the driver, if able, shall inform the police immediately and request that the local NAIR* First Stage establishment be called.

(b) Rail in GB

The procedure to be followed should an emergency occur is set out in British Railways publication BR 30054 "Working Manual for Rail Staff, Part 3, Handling and Conveyance of Dangerous Goods" (Pink Pages). NAIR* First Stage Procedure shall apply.

(c) UK Ports

Should emergency radiological assistance be required in the UK port, the port authority's police shall be informed immediately and requested to call the local NAIR* First Stage establishment.

(d) Sea

In the event of an emergency the procedure set out in Section 10 of Class 7 of the IMDG Code, as supplemented by page 223 of the "Blue Book", quoted on page 2 of this approval certificate, shall apply.

(e) Airports in UK

In the event of an emergency the police shall be informed immediately and requested to call the NAIR scheme.

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*NAIR means National Arrangements for Incidents involving Radioactivity.

12. ADMINISTRATIVE ARRANGEMENTS

(A) The Consignor shall be responsible for fulfilling the conditions set out in any Competent Authorities certificates of approval associated with the shipment of this package and for compliance with the administrative requirements of the IAEA Regulations, paragraphs 826-838.

(B) Competent Authority Approval Certificates.

Copies of Competent Authority certificates of approval associated with the shipment of this package shall be available at places of loading, unloading and transhipment.

(C) Where item 2 specified in paragraph 2 of this certificate constitutes Special Form material, the Consignor shall be in possession of a valid Competent Authority Certificate of approval in accordance with the provisions of paragraph 802 of the IAEA Regulations 1973 Revised Edition (As Amended).

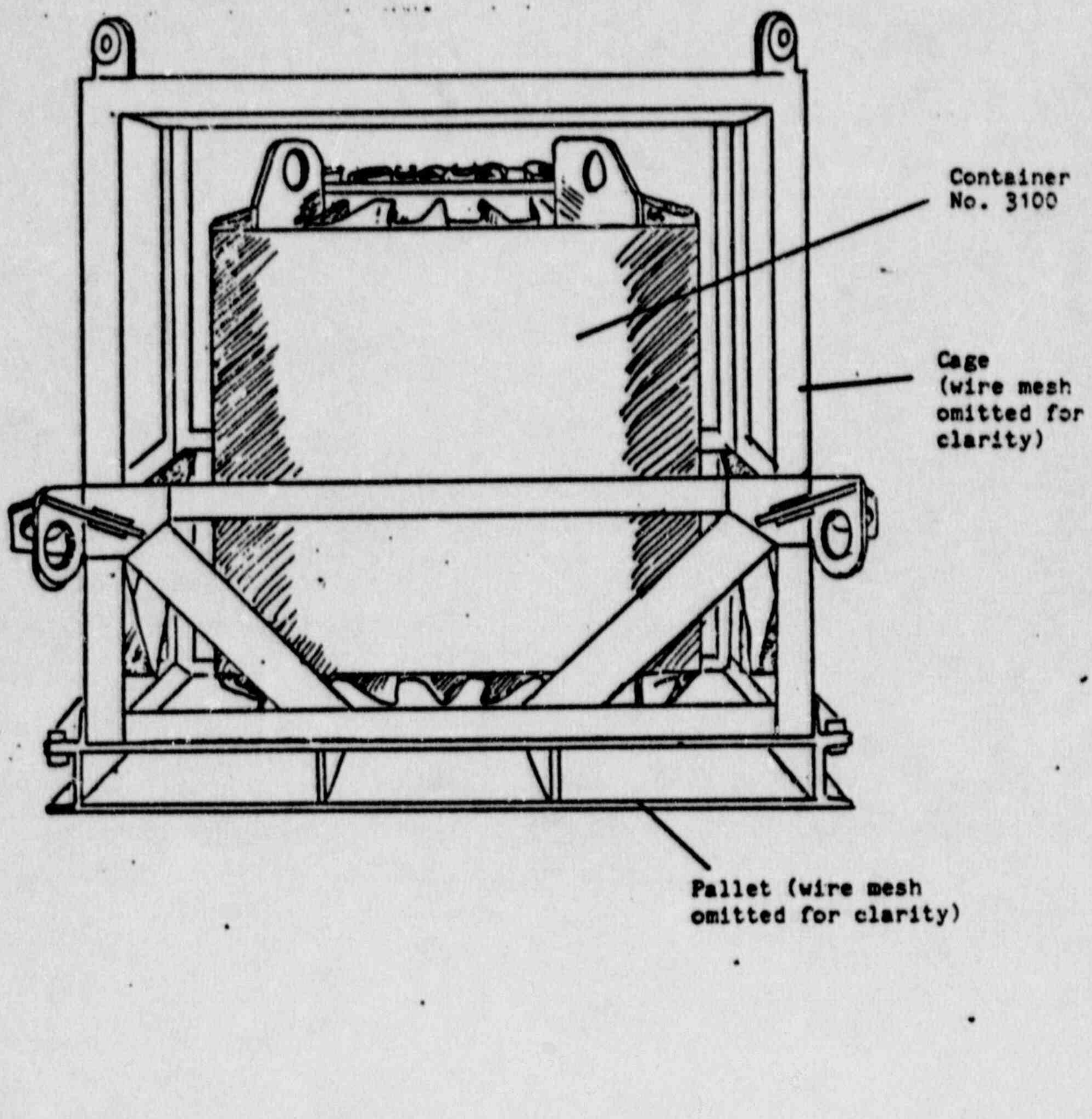
(D) Stowage Conditions

The Consignor shall notify the carrier and/or the ship's master, or the persons responsible for loading the ship, of the stowage conditions in accordance with paragraphs 7 and 8 of this certificate.

13. RENEWAL OF CERTIFICATES

If the period of validity is required to be extended, application shall be made one month in advance of expiry.

Package Illustration



Description of Package, Dimensions and Weights

Packaging: Stainless steel container with depleted uranium shielding carried on a stainless steel pallet with a steel and wire mesh cage.

Dimensions: 1132mm wide x 1132 mm deep x 1360 mm high.

Gross Weight: 2569 kg

1.3.2 United Kingdom Application Document

Transport Radiological Advisor
Radioactive Materials Transport Division
Department of Transport
2 Marsham Street
London SW1P 3EB

Date 16 December 1987

Dear Sir.

Application for Competent Authority Type B(U) Approval for Package Design Number 3100A

Approval is required for the package for radioactive materials described below
This application follows the UK "Guide to application for Competent Authority approval" (dated September 1981) and uses the paragraph numbers in this guide. This application is made under the 1973 (as ammended) edition of the IAEA Transport Regulations and the paragraphs are shown in () brackets (for reference the 1985 paragraphs are indicated in [] brackets). A full listing of the documents referenced in the application and a revision are appended.

PART 2 - ADMINISTRATIVE INFORMATION

2.1 The design number of the package is 3100A

It is defined by GA drawing number OA 23525

Relevant addresses are:

i) Applicant:	Contact D.W.Rogers Amersham International plc Amersham Place Little Chalfont Bucks HP7 9NA Tel. No. (0494) 431717 Extension 2312
ii) Designer:	Applicant (as 2.1 (i))
iii) Manufacturer:	AI as above. The package is assembled from components manufactured by sub-contractors. Inner N/A
iv) Inspection of packages:	Packages may be inspected at Amersham International.

2.2 Approval required: Type B(U)

2.3 Mode of transport: Road, air and sea

(822, 823) [724 725] 2.4 Competent Authority identification mark: GB/3100A/B(U)

2.5 Date approval required is given in the TRAMAC priorities list.

2.6 Date of initial application: September 1986

PART 3 - SPECIFICATION OF RADIOACTIVE CONTENTS

(805a) [705a] 3.1 Specification of contents

(a) General nature of contents

Sterilisation sources

(b) Radionuclides

Cobalt 60

(c) Physical state

Solid, Special Form

(d) Chemical composition

Cobalt metal

(e) Quantity

15 kg

(f) Activity

10 PBq (270 kCi)

(403, 404) [301, 302] 3.2 A1/A2 values

A1 and A2 values are listed in IAEA Safety Series 6

(805a,) [705a] 3.3 Nature of radiation emitted

Gamma.

3.4 Irradiated nuclear fuel is not to be carried

3.5 Maximum heat load in watts

4.160 kW

3.6 Effect of normal and accident transport conditions on the contents

Special Form encapsulation of contents ensures containment.

(105) [105] 3.7 Other hazards

The contents do not have any non-radioactive hazards.

PART 4 - SPECIFICATION OF PACKAGE

(805(b)) 4.1 Packaging make-up
[705(b)]

(a) Packaging components

Component	Description	Drawing Number	Design Number	Overall Dimensions mm	Weight kg	No. Per Assembly
	Cover	OA23629	-	1100x1100x1150	150	1
	Pallet	OA23628	_	1100x1100x150	170	1
	Flask body	OA23526	3100	ø650x980	1953	1
	Flask closure	OA23527	3100	ø500x255	276	1

(b) Packaging net weight 2550 kg

(c) Gross weight of package 2570 kg

(211) [526] 4.2 Security seal

AI wire seal.

4.3 Drawings

See document reference list.

4.4 Handling

(202, 203) [505] i) Method of handling

Fork-lift or four-leg sling.

ii) Special lifting equipment

None.

(201, 223) [505, 527] 4.5 Tie-down system

Lugs on outer or bolts through pallet. See also PGM 215.

4.6 Radiation shield

i) Material and thickness

Depleted uranium, 150mm

ii) Melting points of shield materials

DU, 1132°C.

(115) [121] (216) [530] 4.7 Containment system

i) Containment components

See (ii)

(135, 217) [142, 531] ii) Special Form capsule

Any Special Form capsule:
Maximum diameter : 11mm
Maximum length : 455mm

(218, 223) [532, 536] iii) Sealing and closing of containment system

Welding (see (ii))

(234) [551] iv) Compliance with the permitted activity release does not depend upon filters or a mechanical cooling system.

(235) [N/A] v) The package is not intended to vent continuously during transport.

(236) [552] vi) The package does not include a pressure release device from the containment system.

(839a) [209a] 4.8 Manufacturing inspection

(a) Containment system

Special Form approval ensures adequacy

(b) Radiation shield

The radiation shield is checked for dimensional accuracy and ultrasonically for internal defects

(c) Thermal shield

Not applicable.

(738) [401] 4.9 Performance tests before first shipment

i) Containment system

None.

ii) Radiation shield

The radiation shield is checked on receipt for general efficiency and short paths.

iii) Thermal shield

Not applicable.

iv) Heat dissipation characteristics None

v) Presence of neutron poisons

Not applicable.

(805d, 839b) [705d, 209b] 4.10 Maintenance

The container will go through turnround inspection to PGM 176. It will also be inspected annually to PGM 177.

(739) [402] 4.11 Action required by consignor before each shipment

i) Packaging instructions

See handling and packaging instructions HPI 63.

ii) Thermal equilibration

No specific action necessary.

(805g, 832) [705g, 453] 4.12 Action required during transport

See handling and packaging instructions HPI 63

(824k) [727e, 453] 4.13 Restrictions on modes of transport

None required

4.14 Emergency instructions

None required

(119) [128] 4.15 Full load conditions [Exclusive use]

Full load conditions are required when the contents exceed (90/743) x 270 = 1.2 PBq (32kCi) of Cobalt. Data from 4.27 and IAEA Safety Series No.37, 1982, para 5.42.

4.16 Stresses due to lifting

(204) [506] i) Stresses in structure

See PGM 178

(205) [507] ii) External lifting features

There are no external features which could be used for lifting or moving the package which need to be made inoperative for safety reasons on transport.

4.17 Enviromental conditions

i) Temperature

(231a, 242) (a) Ambient

-40°C to 38°C

[545] (213)[528] (b) Limits for selection of materials

-40°C and 70°C

ii) Insolation

(231b, 242) [546] (a) Data

As IAEA Safety Series No. 6 Paragraph 231b.

(b) Solar radiation barrier

Not applicable.

(c) Daily heat input to package due to insolation

The net daily heat input to the package due to insolation is zero (see Packaging Memo EPM 67).

4.18 Temperature of packaging and contents

(739a) [515, 543, 544, 555] (a) Prior to shipment

Transport cover - 38°C
Flask surface - 94°C
Contents - 450°C See PGM 188

(b) During normal transport

Transport cover - 73°C
Flask surface - 101°C
Contents - 457°C See PGM 188

(c) During and subsequent to accident conditions

Transport cover - 800°C
Contents - 705°C see PGM 188

4.19 Maximum surface temperature

(230b, 240) [555] The maximum surface temperature in the shade under normal conditions of transport is predicted to be 38°C. [544,

4.20 Low temperature effects

(241) [516, 528] i) Liquid contents

Not applicable

(213) [528] ii) Brittle fracture

The materials used are not susceptible to brittle fracture in the conditions specified in 4.17 i)

4.21 Pressure effects on packaging

i) Any pressure rise in the containment system can only arise from thermal effects. This will result in the following pressures, calculated from the temperatures in 4.18 above.

(739a) [402c] (222,237) [N/A] (a) Prior to shipment

2.65 bar

(238) [544] (b) During normal transport

2.67 bar.

(c) During and subsequent to accident conditions

3.58 bar.

ii) Precautions against effects of corrosion and radiolysis

Specific to particular Special Form Approval

iii) Containment system material specification

Specific to particular Special Form Approval.

(237, 238) [553] iv) Strength of material at MNOP

Specific to particular Special Form Approval.

(701, 702) [601, 602] 4.22 Enviromental tests

(709) [619] i) Normal conditions of transport

(711,712) [621,622] (a) Water spray plus 1.2m free drop test

Not tested as Drop I (4.22(ii)(a)) is more severe.

(713,713) [621,623] (b) Water spray plus compression test

See PGM 189

(711,714) [621,624] (c) Water spray plus 1m penetration test

Not tested as minimum skin thickness is 10mm.

(716) [625a] (d) 9m free drop test

see 4.22 (i)(a)

(717) [625b] (e) 1.7m penetration test

Not applicable.

(718) [626] i) Accident conditions of transport

(719) [627] (a) Mechanical tests

Drop I (9m free drop)
See TC Test Nos. 1027 and 1028. Note After test 1027 the flask was modified to increase shock absorption in the inverted attitude. The modifications would in no way have affected the results of Test 1028 (base drop) which was not therefore repeated.

Drop II (9m punch test)
See TC Test No. 1028

Drop III (dynamic crush test)
Not applicable]

(720) [628] (c) Thermal test

See PGM 188.

(721) [629] (d) Water immersion test

Not tested as container is designed for loading and unloading underwater.

(221) [534] 4.23 Containment system at ambient pressure of 0.25 kg/cm^2

Special Form testing is more severe.

(233) [548] 4.24 Leak tightness

Ensured by Special Form encapsulation.

4.25 Radiation shielding

i) Position and size of radiation source

See General Arrangement drawing.

(225) [537] ii) Effect of "normal conditions of transport" test on surface radiation level

The assembly is sufficiently strong to prevent significant distortion or movement of the source in normal conditions of transport (IAEA 709-714) so there can be no increase in radiation level due to these conditions.

(508a) [432, 433] iii) Surface radiation level and TI

SDR - 692 uSv
TI - 8.2
See PGM 246.

(229) [542] iv) Effects of accident conditions of transport

The assembly is sufficiently robust to prevent significant distortion in accident conditions of transport (IAEA 718-721) so there can be no significant increase in the radiation level due to these conditions

(232) [547] 4.26 Durability of thermal protection shield Not applicable

4.27 Special stowage provisions

i) Surface heat flux

Maximum heat load	- 4160	watts
Surface area (top and sides)	- 5.60	m^2
Maximum surface heat flux	- 743	W/m^2

(527) [463] ii) Special stowage provisions See HPI 63

4.28 Primary heat transfer medium Not applicable

4.29 Type B(U) and B(M) general

(206, 208) [508, 510] i) General design requirements

The package is designed to shed water and to be easily decontaminated. No features are added in transport which could affect the safety of the package

(201, 227) [541] ii) Type A requirements

The package is designed to meet all the specified Type A requirements

(517) [439] iii) Trefoil symbol

A metal label embossed with the trefoil symbol is permanently attached to the package outer surface

(242,244, 808) [557,558, 708] 4.30 Additional requirements for Type B(M) packages

i) B(U) package requirements (IAEA 233-241) not met by this package

(808b,c) [708a] Not applicable

ii) Reason for non complaince Not applicable

(808b,c) [708b,c] iii) Compensation controls Not applicable

(243) [558] 4.31 Venting packages Not applicabel

(244) [N/A] 4.32 Pressure relief system Not applicable

Application compiled by :

Signed:

Date:

Application checked by :

Signed:

Date:

Application approved by:

Signed:

Date:

Document reference list

1. Drawings as listed on DL 23525, Issue E (3100A)
   * DL 23665, Issue D (3100A Model)

2. Documents

EPM 67	Cooling of package after insolation
EPM 79, Issue 6/84	Nuclear decay power dissipation.
EPM 85, Issue 1	Package surface temperature with insolation.
HPI 63, Issue 2	3100A Handling and packaging instructions.
PGM 176, Issue 2	3100A Turnround maintenance.
PGM 177, Issue 2	3100A Annual maintenance.
PGM 178, Issue 1	3100A Lifting point assessment.
PGM 188, Issue 2	3100A Thermal test assessment.
PGM 189, Issue 1	3100A Compression assessment.
PGM 215, Issue 1	3100A Tie-down assessment.
PGM 243, Issue 2	3100A Thermal test computer analysis.
PGM 246, Issue 1	3100A Shielding test.
QCP 510, Issue B	Welding of packaging components.
RMR 500, Issue 2	Uranium for shielding
TC Test No. 1014	Copper barrier effectiveness at 800°C in helium
TC Test No. 1019	Effect of gross deformation on copper coating.
TC Test No. 1024	Effect of heating copper coating at 800°C in air.
TC Test No. 1027	9m drop test of 3100A model.
TC Test No. 1028	9m drop test and 1m punch test on 3100A model.
TC Test No. 1043	Effect of welding near copper coating.
TC Test No. 1062	Steady state thermal test on 3100A flask.

Revision record

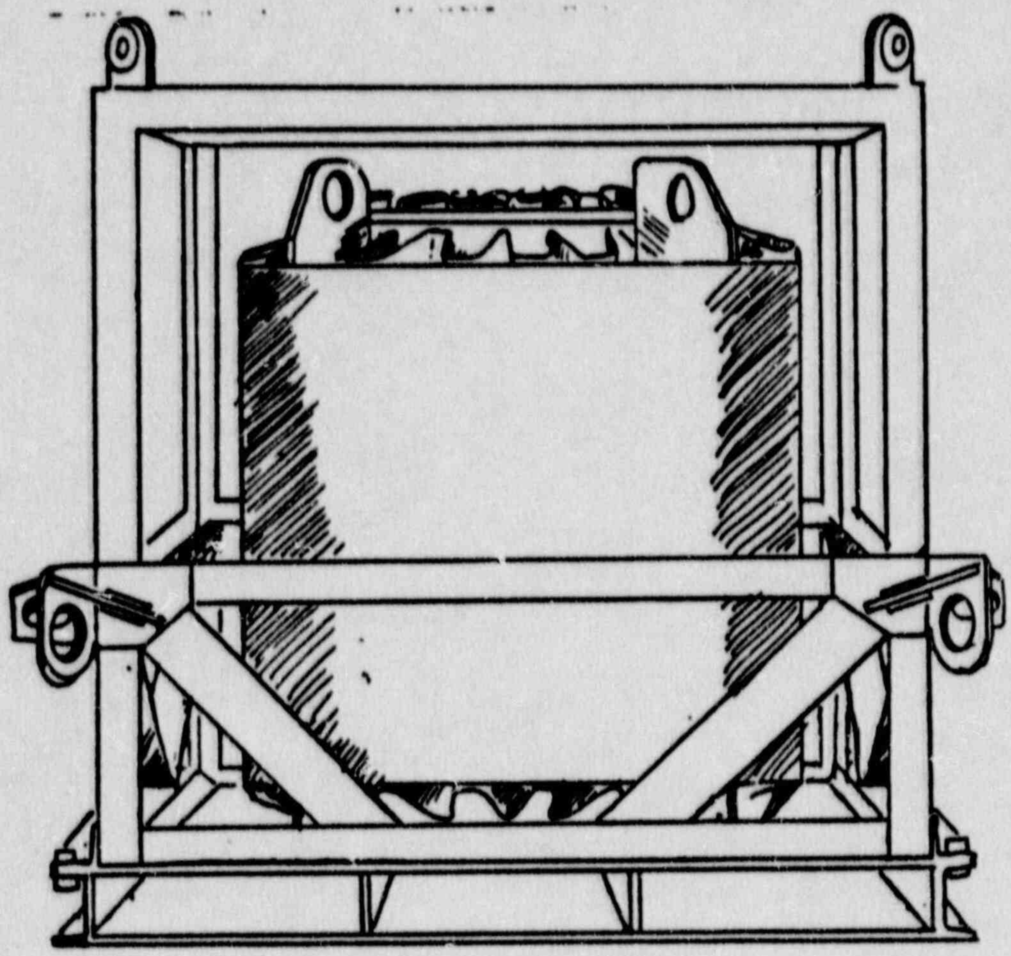
Revision	Page	Change
1		Test data included and drawings updated. Revised document list.
2		Shielding test included and drawings updated. Revised document list and format.

Reference....................

Issue........................

Page.......of..........Pages

Package Illustration



Description of Package, Dimensions and Weights

Package :

Dimensions :

Gross Weight :

1.3.3 U.S. Dept. of Transporation Revalidation of British Competent Authority Certificate

U.S. Department of Transportation
Research and Special Programs Administration

400 Seventh Street, S.W.
Washington, D.C. 20590

COMPETENT AUTHORITY CERTIFICATION FOR A TYPE B(U) RADIOACTIVE MATERIALS PACKAGE DESIGN CERTIFICATE USA/0407/B(U), REVISION 0

REVALIDATION OF BRITISH COMPETENT AUTHORITY CERTIFICATE GB/3100A/B(U)

This certifies that the radioactive materials package design described below is hereby approved for use within the United States for import and export shipments only. Shipments must be made in accordance with the applicable International Atomic Energy Agency[1] and USA regulations.[2]

1. Package Identification - U.K. Design No. 3100A
2. Packaging Description and Authorised Radioactive Contents - as described in British Certificate of Competent Authority GB/3100A/B(U), Issue 1.
3. GENERAL CONDITIONS -
   a. Each user of this certificate must have in his possession a copy of this certificate and all documents necessary to properly prepare the package for transportation in accordance with the endorsed certificate.
   b. Each user of this certificate, other than the original petitioner, shall register his identity in writing to the Office of Hazardous Materials Transportation, Research and Special Programs Administration, U.S. Department of Transportation, Washington D.C. 20590.
   c. This certificate does not relieve any consignor or carrier from compliance with any requirement of the Government of any country through or into which the package is to be transported.

----

1 "Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1973 Revised Edition" published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

2 Title 49, Code of Federal Regulations, Parts 100 - 199, USA.

CERTIFICATE USA/0407/B(U), REVISION 0

d. This certificate is issued only to authorize transport from point of entry to final destination within the United States and from point of origin in the United States to point of exit.

4. Marking and Labeling - The package shall bear the marking USA/0407/B(U) in addition to other required markings and labeling.

5. Expiration Date - This certificate expires on January 31, 1991.

This certificate is issued in accordance with paragraph 806 of the IAEA Regulations and Section 173.473 of Title 49 of the Code of Federal Regulations, and in response to the February 23, 1989 petition by Amersham Corporation, Arlington Heights, IL, and in consideration of the associated information therein.

Certified by:

Michael E. Wangler
Chief, Radioactive Materials Branch
Office of Hazardous Materials Transportation

MAR 31 1989
(DATE)

Certificate of Approval of Package Design for the Carriage of Radioactive Materials

1. **THIS IS TO CERTIFY** that the Secretary of State for Transport being, for the purpose of the Regulations of the International Atomic Energy Agency, the Competent Authority of Great Britain in respect of inland surface transport and of the United Kingdom of Great Britain and Northern Ireland in respect of sea and air transport and the Department of the Environment for Northern Ireland being the Competent Authority of Northern Ireland in respect of inland surface transport, have approved the package design, as specified in paragraphs 2-4 of this certificate, submitted by Amersham International plc, Amersham

as Type B(U)

for the transport of encapsulated sources

by all modes of transport

Packages manufactured to this design meet the requirements of the regulations and codes on page 2 relevant to the mode of transport, subject to the following general condition and to the conditions in the succeeding pages of this certificate.
In the event of any alteration in the composition of the package, the package design or in any of the facts stated in the application for approval, this certificate will cease to have effect unless the Competent Authority is notified of the alteration and the Competent Authority confirms the certificate notwithstanding the alteration.

This Certificate Cancels all Previous Issues and is valid till 31 January 1991.

COMPETENT AUTHORITY
IDENTIFICATION MARK:

GB/3100A/B(U)

UNITED KINGDOM COMPETENT AUTHORITY FOR THE TRANSPORT
18 JAN 1988
OF RADIOACTIVE MATERIALS

D. J. Blackman
Transport Radiological Adviser
Department of Transport
2 Marsham Street
London SW1P 3EB

On behalf of the Secretary of State for Transport and the Department of the Environment for Northern Ireland

Regulations and Codes of Practice Governing the Transport of Radioactive Materials

INTERNATIONAL
International Atomic Energy Agency (IAEA) Safety Series No 6 Regulations for the Safe Transport of Radioactive Materials 1973 Revised Edition (As Amended).

International Maritime Organisation (IMO). International Maritime Dangerous Goods Code – Class 7 Radioactive Substances.

International Civil Aviation Organisation (ICAO). Technical Instructions for the Safe Transport of Dangerous Goods by Air.

ROAD
Great Britain only. The Radioactive Substances (Carriage by Road)(Great Britain) Regulations 1974. SI No 1735: Code of Practice for the Carriage of Radioactive Materials by Road (1982 Impression): The Radioactive Substances (Carriage by Road)(Great Britain)(Amendment) Regulations 1985 SI No 1729: The Ionising Radiations Regulations 1985 SI No 1333; and Approved Code of Practice.

Northern Ireland only. The Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1983. SR 1983 No 344. and Amendment 1986 SR 1986 No 61.

Europe only. European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), Class 7.

RAIL
Great Britain only. British Rail publication BR 22426 (1977 Edition) – Dangerous Goods by Freight Train and by Passenger Train or similar service – List of Dangerous Goods and Conditions of Acceptance – Class 7 Radioactive Substances.

Europe only. International Convention concerning the carriage of goods by rail (CIM). Annex I, International Regulations concerning the carriage of dangerous goods by rail (RID).

SEA
British ships registered in UK and other ships loading in UK ports or territorial waters only. The Merchant Shipping (Dangerous Goods) Regulations 1981 SI No 1747 and the Report of the Standing Advisory Committee on the Carriage of Dangerous Goods in Ships 1978 (The "Blue Book") Class 7.

AIR
UK Only. The Air Navigation Order 1985 SI No 1643: The Air Navigation (Dangerous Goods) Regulations 1985 SI No 1939: The Air Navigation (Dangerous Goods)(Amendment) Regulations 1986 SI No 2129 and the International Civil Aviation Organisation's (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air.

Notes

1 *Attention is drawn to the labelling and marking requirements of IAEA Section V, one provision of which is that the outside of each package shall be clearly and durably marked with the Competent Authority's Package Identification Mark.*

2 *Any questions relating to this Certificate should be addressed to the Transport Radiological Adviser, Department of Transport: 2 Marsham Street, London SW1P 3EB*
Telephone 01/212/7247
Telex 22221 Answer back DOE MAR G

3 *This Certificate does not relieve the consignor from compliance with any requirement of this or any other country through or into which the package may be transported.*

2. Specification of Packaging

Item No.	Packaging	Design Number	Quantity per Assembly
1	Outer	3100	One
2	Inner	IAEA Special Form Capsules (See paragraph 12C)	Up to a maximum of 25

The containment system comprises item no. 2

Packaging Design Details

Design No.	Title	Drawing List	Issue
3100	Stainless steel depleted uranium shielded container on its own pallet with an outer protective cage	DL 23525	E
Capsules	Any IAEA Special Form Capsule	-	-

2. Continued

The package design specification shall be in accordance with Amersham International plc document WD31 - BU 3100A - Revision 2 - Application for the Approval of Package Design No.3100A dated December 1987.

3. PERMITTED CONTENTS

Cobalt 60 sterilisation sources in the form of metallic cobalt in IAEA Special Form Capsules.

4. RESTRICTIONS ON CONTENTS

(a) The total activity shall not exceed 10 PBq (270kCi) per package.

(b) The total rate of heat generation shall not exceed 4.16 kilowatts per package.

5. INSTRUCTIONS ON USE OF PACKAGE

(a) The package shall be handled in accordance with "the Handling and Packaging Instructions, HPI 63, Issue 2, for Package Design No.3100A".

(b) When the sources, together with the sourceholder, are loaded, they shall be located in the source cavity in such a way as to prevent gross movement during both normal and accident conditions of transport.

(c) The 3100A container shall be manufactured in accordance with the drawings listed in DL 23525, Issue E, and document QCP510, Issue B.

(d) Inspection and maintenance of the package shall be carried out in accordance with "Amersham International plc PGM 176 - Turnround maintenance for Package Design 3100A, Issue 2 and PGM 177 - Annual maintenance for Package Design 3100A, Issue 2.

6. ACTIONS PRIOR TO DESPATCH

The sources shall be loaded into the flask under the direct supervision of a Responsible Officer who is fully conversant with the instructions detailed in paragraphs 5(a) and (b) of this certificate.

7. STOWAGE CONDITIONS

(a) The package shall be stowed such that air can freely circulate around the package.

(b) The package shall not be oversheeted.

(c) When transported such that the package is exposed to the elements, adequate drainage shall be provided to ensure that heat dissipation from the package is not adversely affected.

8. FULL LOAD CONDITIONS

If the contents of the package exceeds 1.2 PBq (32kCi) then it shall be shipped under FULL LOAD conditions.

1.

9. RESTRICTIONS ON SHIPMENT

Road in GB

If, for any reason, the vehicle is subject to a speed restriction of less than 20 mph the carrier shall instruct the driver of the vehicle that, before crossing any automatic half-barrier railway crossing he shall notify the railway signalman of his intention to cross and await the signalman's instructions.

10. LABELLING, MARKING AND PLACARDING

(a) Labelling and marking of packages and the placarding of vehicles shall be in accordance with the regulations listed on page 2 of this approval certificate.

(b) Road in GB. In the cab of the roo[illegible]hicle there shall be prominently displayed a fire proof notice ind[illegible]ng that the load is radioactive and bearing the particulars and telephone number of the owner/operator of the vehicle and stating that the police should be informed in the event of an accident.

11. EMERGENCY ARRANGEMENTS

(a) Road in GB

Should emergency radiological assistance be required the driver, if able, shall inform the police immediately and request that the local NAIR* First Stage establishment be called.

(b) Rail in GB

The procedure to be followed should an emergency occur is set out in British Railways publication BR 30054 "Working Manual for Rail Staff, Part 3, Handling and Conveyance of Dangerous Goods" (Pink Pages). NAIR* First Stage Procedure shall apply.

(c) UK Ports

Should emergency radiological assistance be required in the UK port, the port authority's police shall be informed immediately and requested to call the local NAIR* First Stage establishment.

(d) Sea

In the event of an emergency the procedure set out in Section 10 of Class 7 of the IMDG Code, as supplemented by page 223 of the "Blue Book", quoted on page 2 of this approval certificate, shall apply.

(e) Airports in UK

In the event of an emergency the police shall be informed immediately and requested to call the NAIR scheme.

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*NAIR means National Arrangements for Incidents involving Radioactivity.

12. ADMINISTRATIVE ARRANGEMENTS

(A) The Consignor shall be responsible for fulfilling the conditions set out in any Competent Authorities certificates of approval associated with the shipment of this package and for compliance with the administrative requirements of the IAEA Regulations, paragraphs 826-838.

(B) Competent Authority Approval Certificates.

Copies of Competent Authority certificates of approval associated with the shipment of this package shall be available at places of loading, unloading and transhipment.

(C) Where item 2 specified in paragraph 2 of this certificate constitutes Special Form material, the Consignor shall be in possession of a valid Competent Authority Certificate of approval in accordance with the provisions of paragraph 802 of the IAEA Regulations 1973 Revised Edition (As Amended).

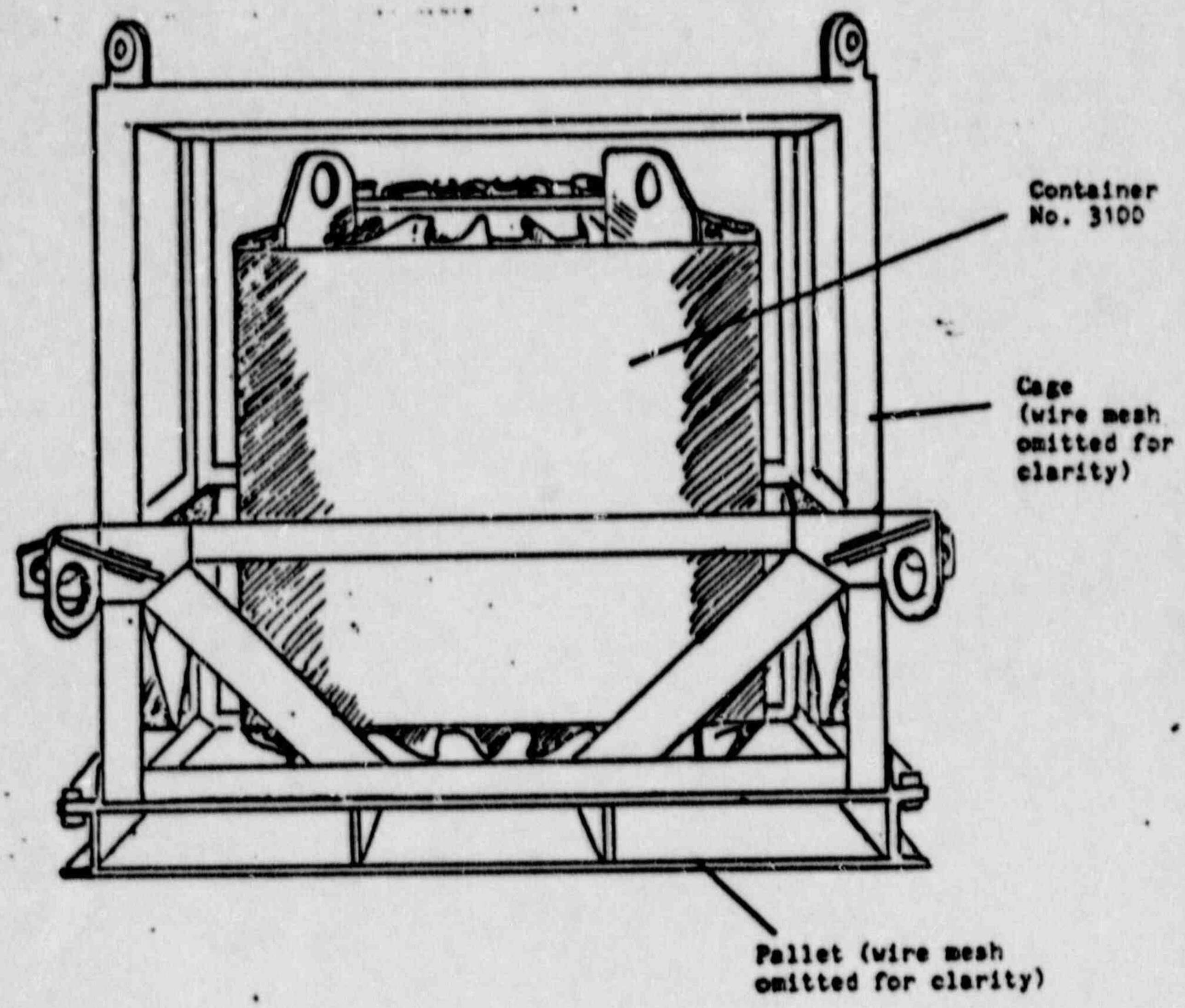
(D) Stowage Conditions

The Consignor shall notify the carrier and/or the ship's master, or the persons responsible for loading the ship, of the stowage conditions in accordance with paragraphs 7 and 8 of this certificate.

13. RENEWAL OF CERTIFICATES

If the period of validity is required to be extended, application shall be made one month in advance of expiry.

Package Illustration



Description of Package, Dimensions and Weights

Packaging: Stainless steel container with depleted uranium shielding carried on a stainless steel pallet with a steel and wire mesh cage.

Dimensions: 1132mm wide x 1132 mm deep x 1360 mm high.

Gross Weight: 2569 kg

1.3.4 Design Drawings

Drawing No.	Issue	Title
DL23525	E	ASSEMBLY FLASK DESIGN NO. 3100 A
0A 23525	E	ASSEMBLY FLASK DESIGN NO. 3100 A
0A 23525 SHT 1	D	BODY
0A 23526 SHT 2	D	BODY
0A 23526 SHT 3	D	BODY
0A 23527	E	CLOSURE
1A 23528	D	BASE SHIELD
1A 23529	D	LOWER SHIELD
1A 23530	C	JACKET
2A 23531	D	MIDDLE SHIELD
2A 23532	D	UPPER SHIELD
2A 23533	D	CLOSURE SHIELD
2A 23534	E	TUBE SUPPORT
3A 23535	B	END PLATE
3A 23536	C	TUBE
3A 23537	C	EYE BOLT
3A 23539	C	SHIELD ROD
3A 23668	C	INSERT
2A 2366[illegible]	C	PLUG
2A 23665	D	PLUG
0A 23628	D	PALLET
0A 23629	D	OUTER FRAMEWORK
2A 23838	B	DRAIN PIPE
2A 23870	B	SOURCE HOULDER ASSEMBLY
3A 23806	A	SHIELD DISC

THIS DRG FORMS PART OF AN APPROVED PACKAGE DESIGN. IT IS HELD IN A C.A.D.O. SECURITY FILE. ITS BONDED RECORD CAN ONLY BE MODIFIED WITH AUTHORITY/APROVAL.

Checked	Approved	Issue	Date	Mod.No
D.W.R.	A.M.	E	25.11.87	
D.W.R.	A.M.	D	10.9.87	
		C	31.12.86	
		2	27.11.86	
		1	22.9.86	

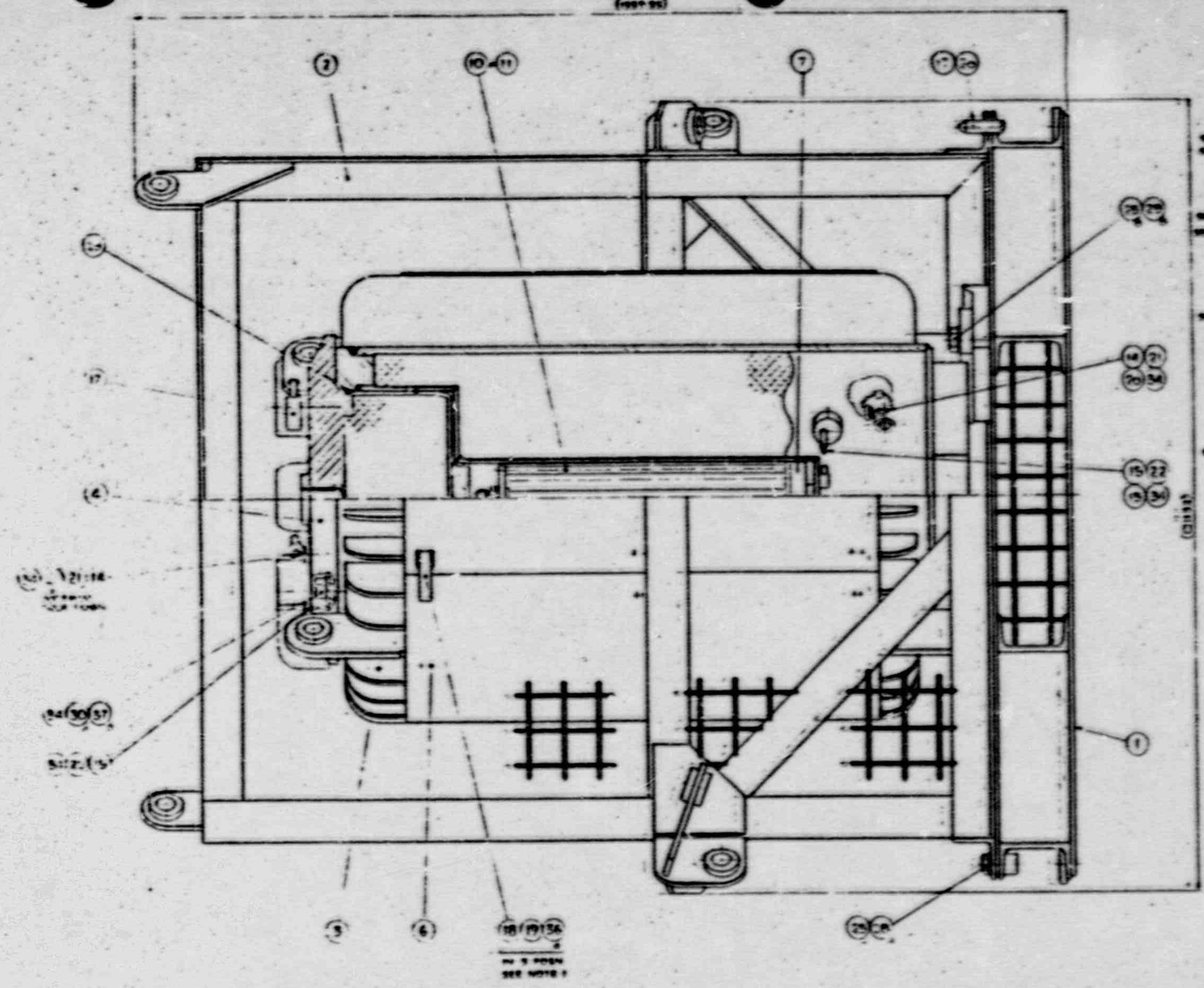
 Amersham International plc. Amersham UK

Amersham

Title
ASSEMBLY FLASK DESIGN NO. 3100 A

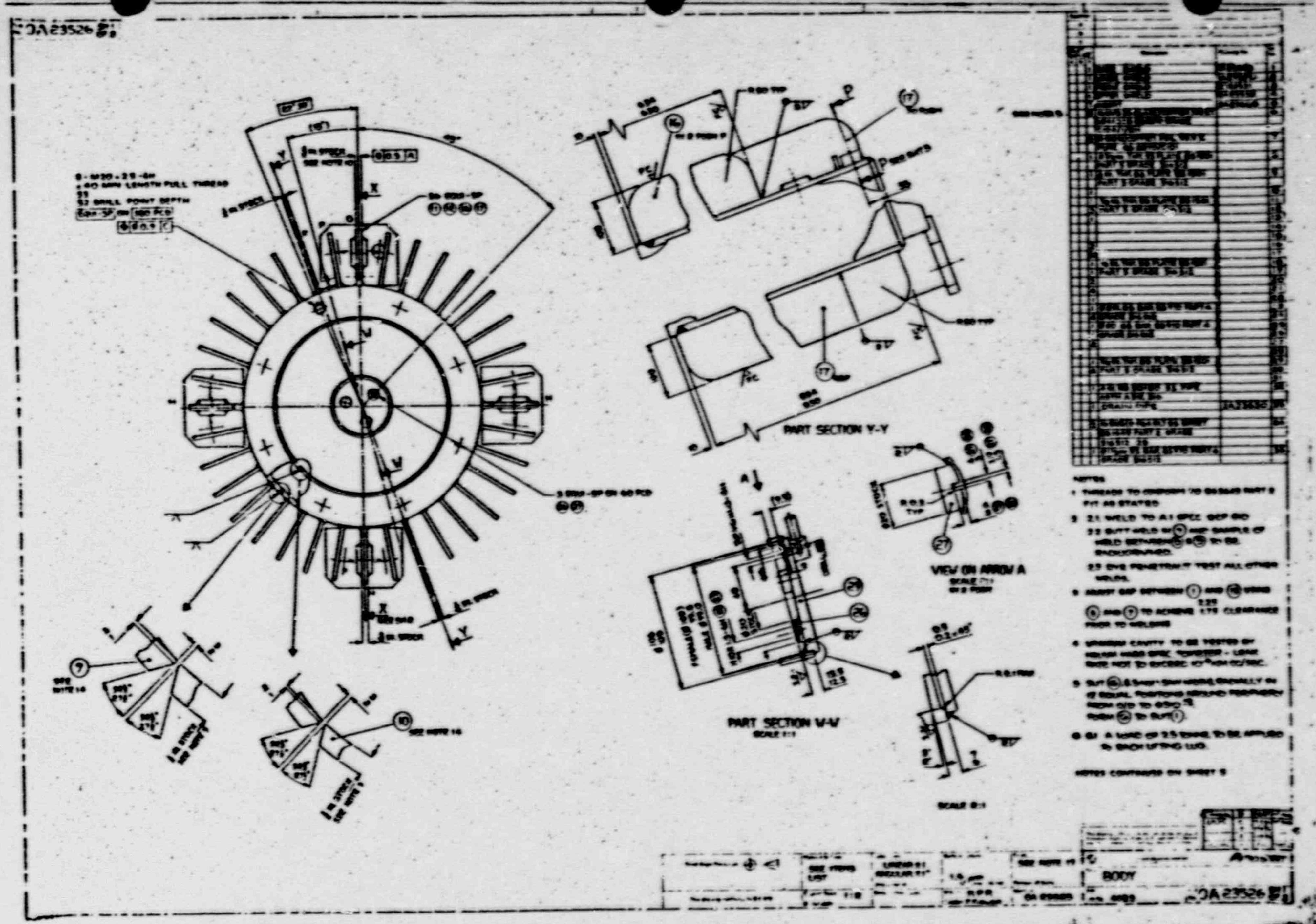
Job
Job No. S408

Drg. DL23525

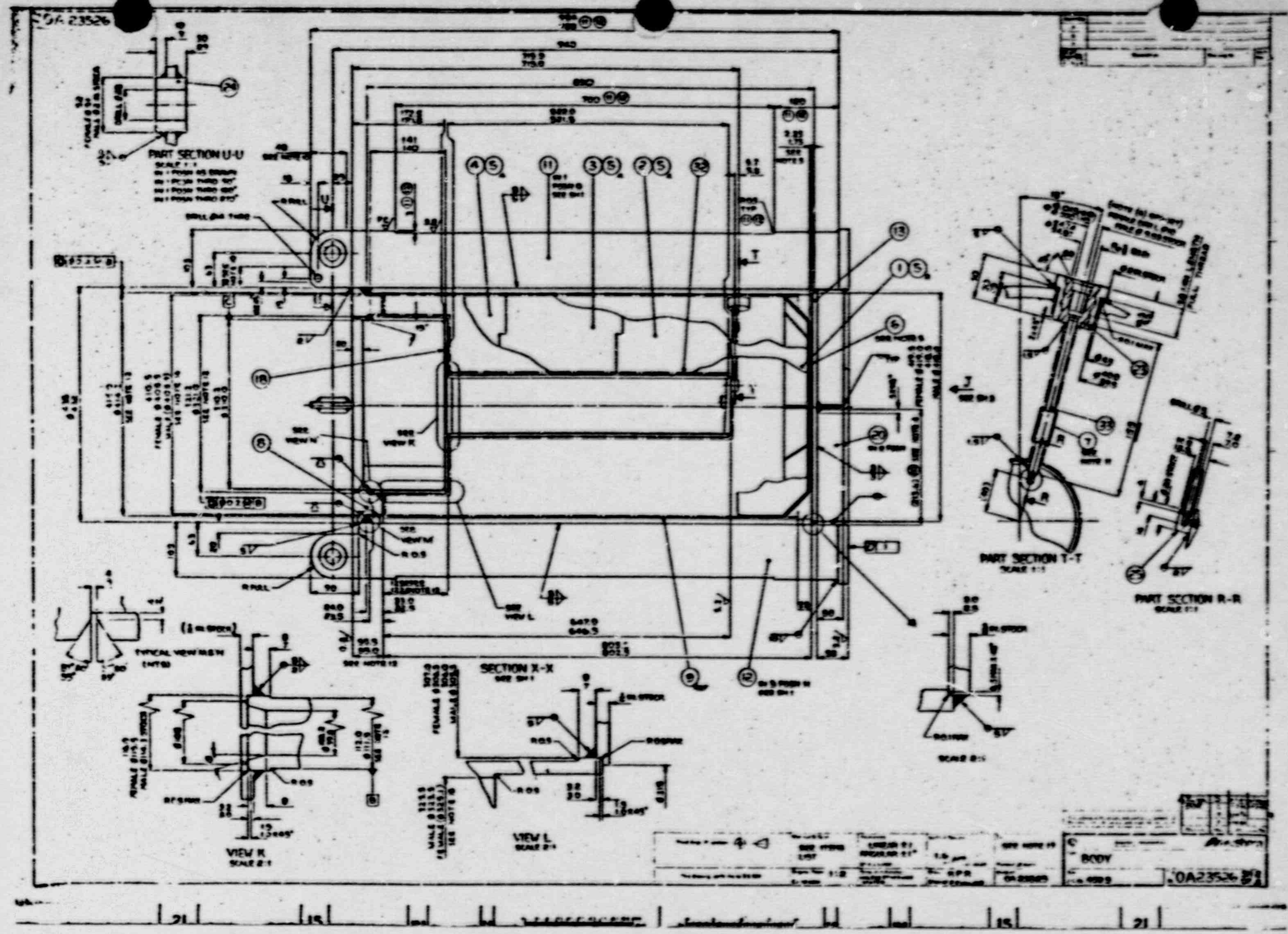


ASSEMBLY FLASK
DESIGN NO 3100 A

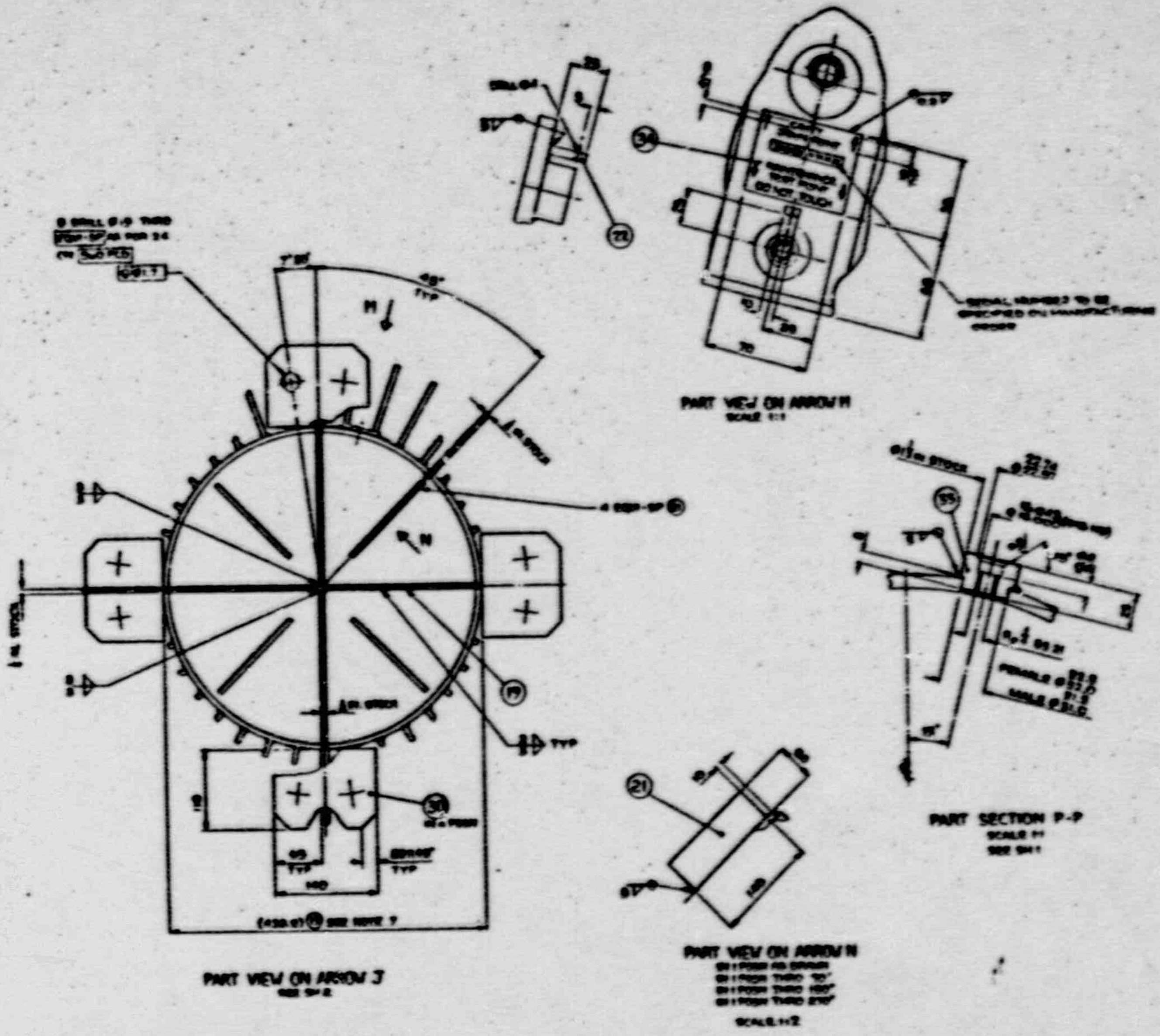
A 23525



OA 23526
PART SECTION Y-Y
PART SECTION V-V
VIEW ON ARROW A
SCALE 8:1
NOTES CONTINUED ON SHEET 2
BODY
OA 23526


0A23526
PART SECTION U-U
PART SECTION T-T
PART SECTION R-R
SECTION X-X
TYPICAL VIEW M & N
VIEW K
VIEW L
BODY
0A23526

0A 23526



6 6.2 AFTER TESTING VISUALLY INSPECT LIFTING LUG [illegible] FOR DEFECTS & DYE PENETRANT TEST TO ENSURE THE ABSENCE OF CRACKING.

7 [illegible] CLEAR 1.0/0.5 OF [illegible] AND [illegible]

8 [illegible] CLEAR 1.0/0.5 OF [illegible] AND [illegible] AND [illegible] AND [illegible]

9 [illegible] BEFORE MACHINING

10 SYMMETRY TOLERANCE AND STOCK [illegible] TO APPLY OVER SPECIFIED DIMENSIONS ONLY

11 ALL SURFACES [illegible] COPPER SPRAYED TO BE COVERED WITH (7)

12 DIMENSIONS APPLY AFTER SPRAYING

13 ORDER OF ASSEMBLY [illegible] (7) AND (6) IF REQUIRED

14 [illegible] MAY BE MANUFACTURED ALTERNATIVELY FROM [illegible] PIPE TO AN EQUIVALENT SPECIFICATION

15 [illegible] CLEAR 1.0/0.5 ON [illegible]

16 [illegible] CLEAR 1.0/0.5 ON (9)

17 TO BE SPRAYED BY [illegible] LTD [illegible] BRISTOL [illegible]

18 CALCULATED WEIGHT [illegible] kg

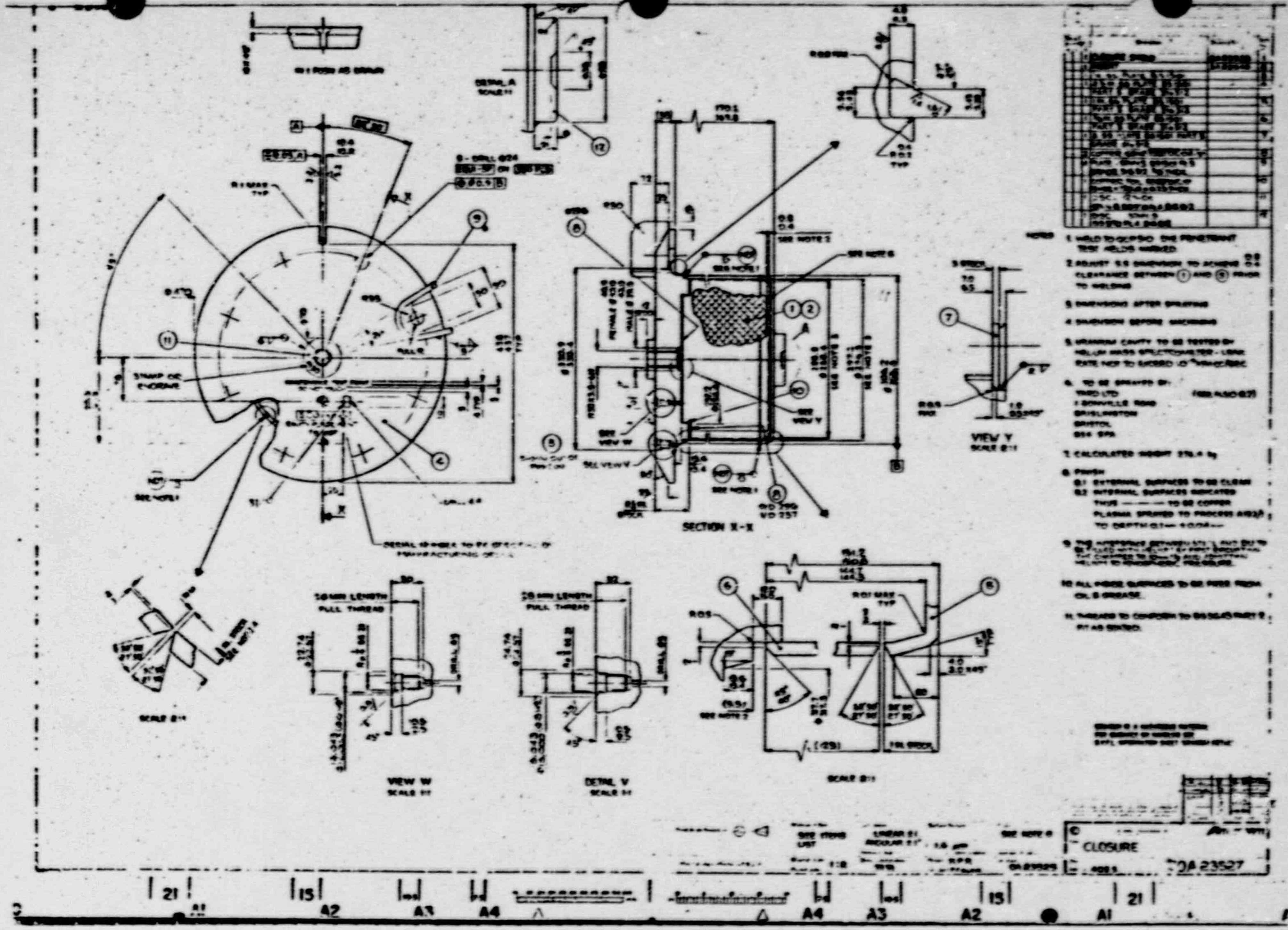
19 FINISH
19.1 EXTERNAL SURFACES TO BE CLEAN
19.2 INTERNAL SURFACES INDICATED THUS ——— TO BE COPPER PLASMA SPRAYED TO PROCESS [illegible] TO DEPTH OF [illegible]

20 [illegible]

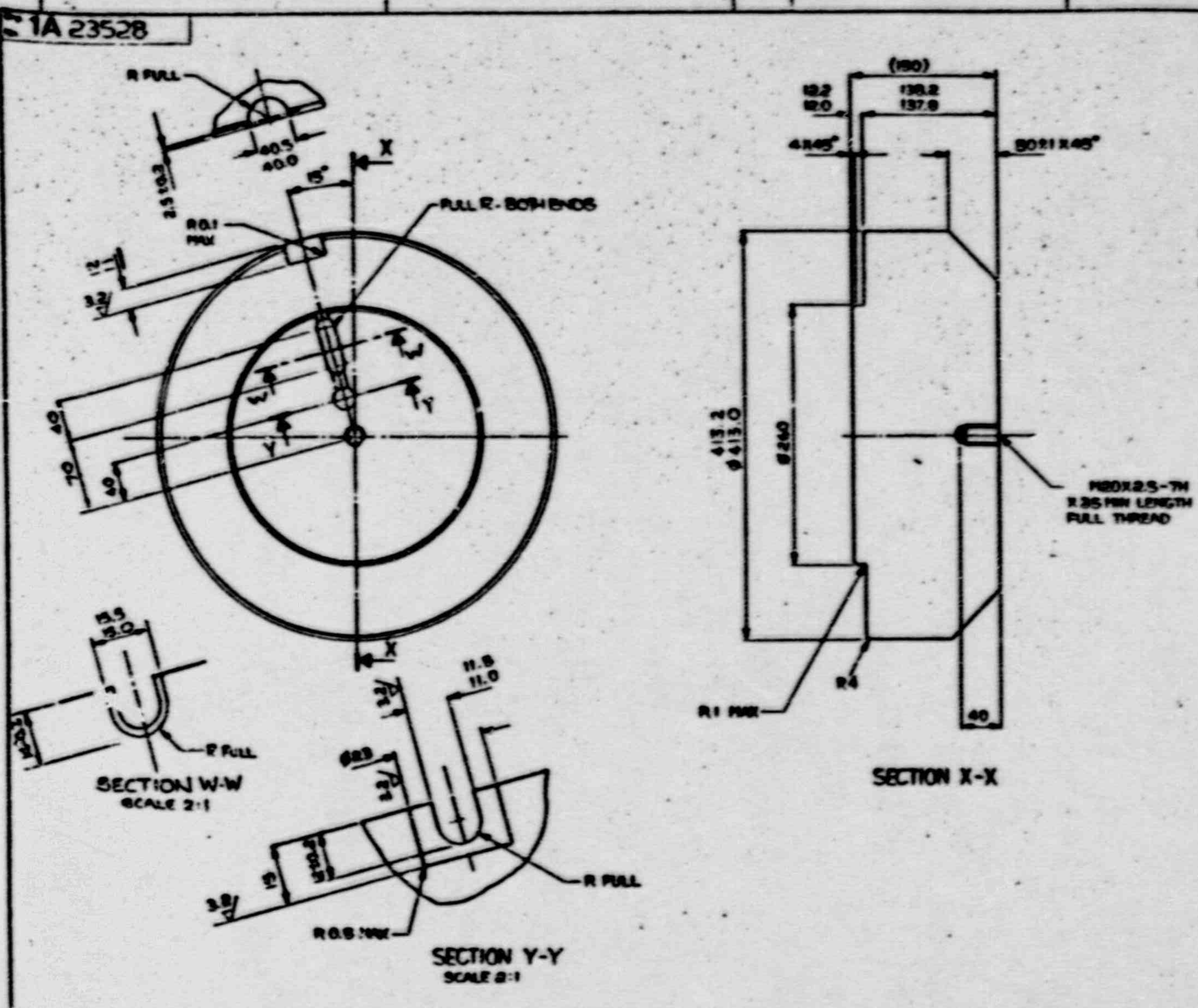
21 ALL [illegible] FROM OIL & GREASE.

BODY

0A 23526



SECTION X-X
VIEW Y
VIEW W
DETAIL V
DETAIL A
NOTES
3. DIMENSIONS AFTER SPRAYING
4. DIMENSION BEFORE MACHINING
7. CALCULATED WEIGHT
8. FINISH
10. ALL INSIDE SURFACES TO BE FREE FROM OIL & GREASE.
11. THREADS TO CONFORM TO
CLOSURE
0A 23527
21
15
A1
A2
A3
A4



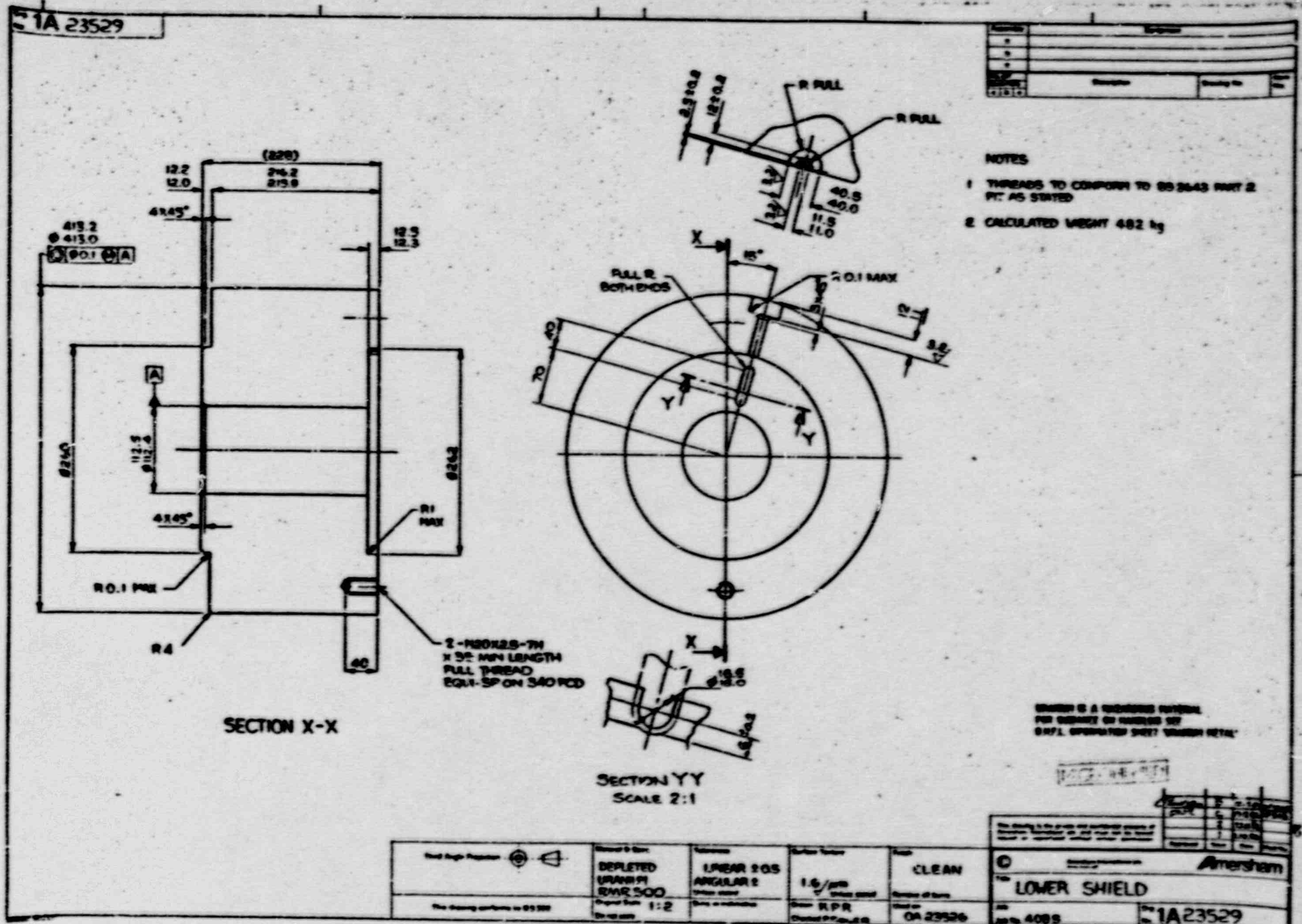
NOTES

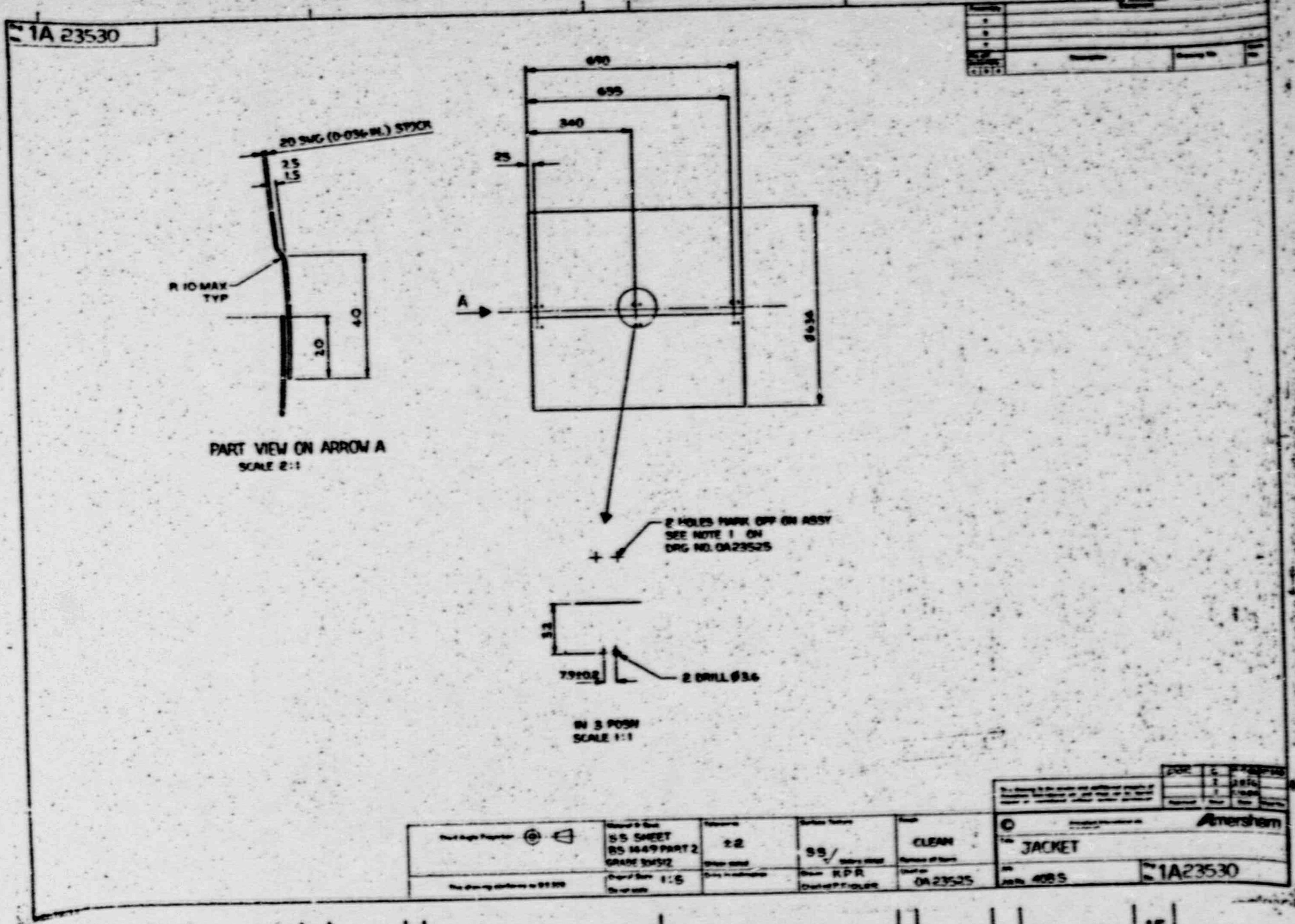
1 THREADS TO CONFORM TO BS 3643 PART 2 FIT AS STATED

2 CALCULATED WEIGHT 328 Kg

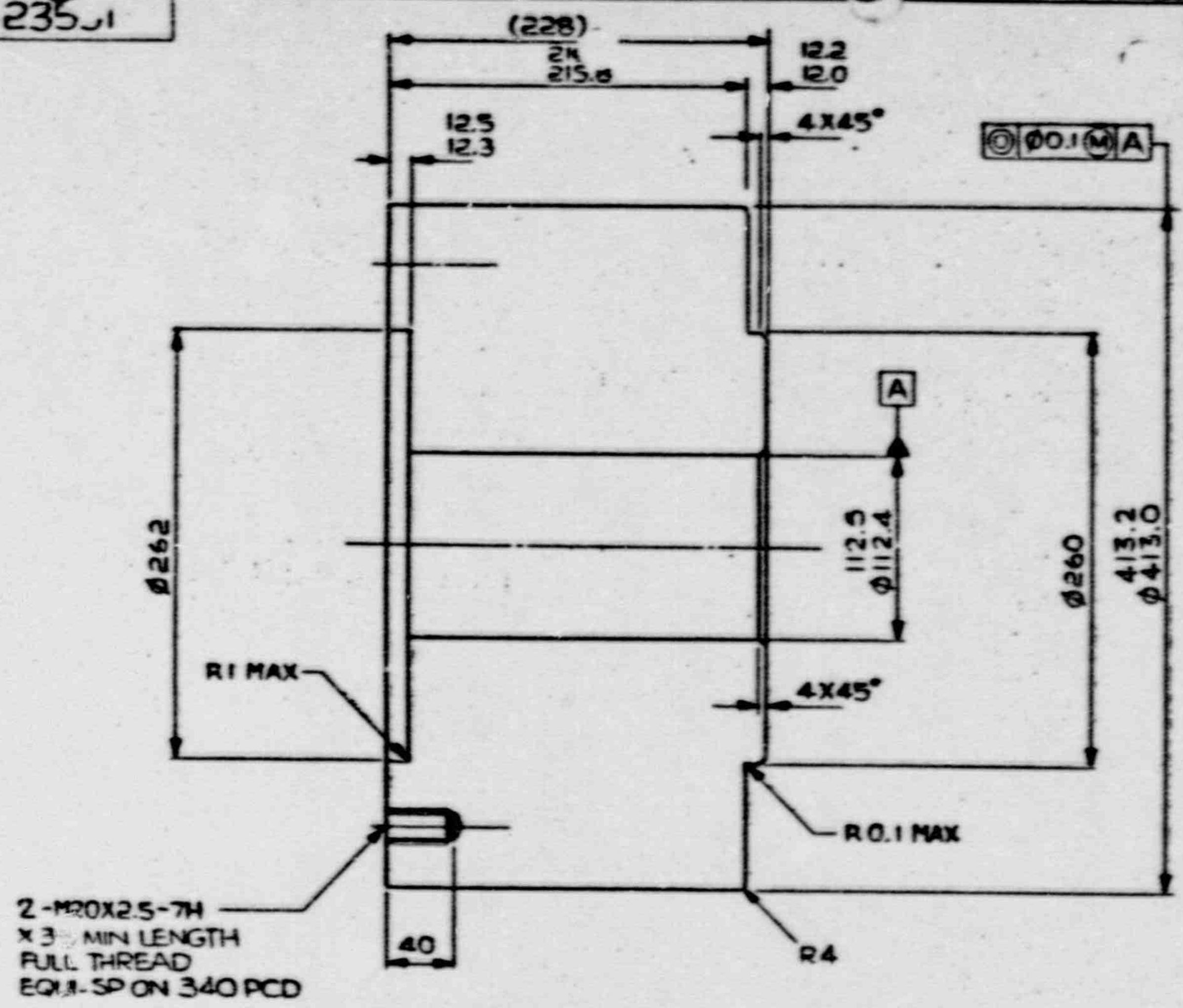
DEPLETED URANIUM RMR 500	LINEAR ±0.5 ANGULAR ±1°	1.6 μm	CLEAN	BASE SHIELD
1:2		K P R	OA 23526	1A 23528

Amersham


1A 23529
NOTES
1 THREADS TO CONFORM TO BS 3643 PART 2 FIT AS STATED
2 CALCULATED WEIGHT 482 kg
SECTION X-X
SECTION YY
SCALE 2:1
R FULL
FULL R BOTH ENDS
R 0.1 MAX
R0.1 MAX
R4
R1 MAX
4X45°
(228)
216.2
215.8
12.2
12.0
12.5
12.3
413.2
Ø 413.0
40.5
40.0
11.5
11.0
15°
70
40
2-M20X2.5-7H
X 32 MIN LENGTH
FULL THREAD
EQUI-SP ON 340 PCD
DEPLETED
URANIUM
RMR500
1:2
LINEAR ±0.5
ANGULAR ±
CLEAN
RPR
OA 23526
LOWER SHIELD
Amersham
409S
1A 23529


1A 23530
20 SWG (0·036 IN.) STOCK
2.5
1.5
R 10 MAX
TYP
40
20
PART VIEW ON ARROW A
SCALE 2:1
A
690
655
340
25
Ø636
2 HOLES MARK OFF ON ASSY
SEE NOTE 1 ON
DRG NO. 0A23525
32
7.9±0.2
2 DRILL Ø3.6
IN 3 POSN
SCALE 1:1
S.S. SHEET
BS 1449 PART 2
GRADE 304S12
±2
1:5
KPR
CLEAN
0A23525
Amersham
JACKET
408 S
1A23530
15

Drg No. 2A23531



SECTION ON ℄

NOTES

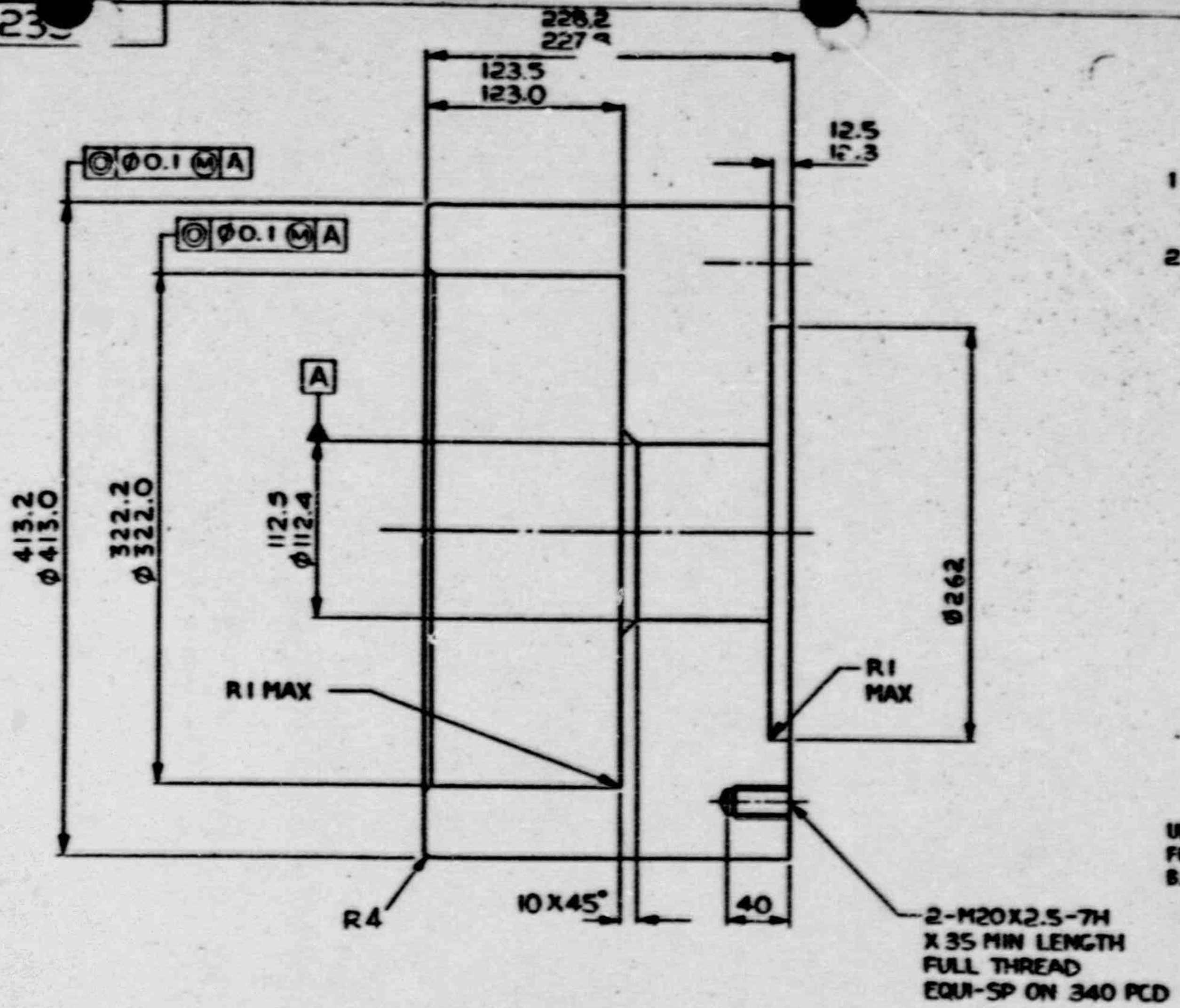
1 THREADS TO CONFORM TO BS3643 PART 2 FIT AS STATED

2 CALCULATED WIEGHT 482kg

URANIUM IS A HAZARDOUS MATERIAL FOR GUIDANCE ON HANDLING SEE B.N.F.L. INFORMATION SHEET 'URANIUM METAL'

Third Angle Projection	Material & Spec.	Tolerance	Surface Texture	Finish	© Amersham
	DEPLETED URANIUM RMR 500	LINEAR ±0.5 ANGULAR ±1° Unless stated	1.6/μm Unless stated	CLEAN Remove all burrs	Title MIDDLE SHIELD
This drawing conforms to B.S.308	Original Scale 1:2 Do not scale	Dims in millimetres	Drawn KPR Checked P.FIDLER	Used on 0A 23526	Job No. 408 S — Drg No. 2A23531

2A23?



SECTION ON ℄

NOTES

1 THREADS TO CONFORM TO BS 3643 PART 2 FIT AS STATED

2 CALCULATED WIEGHT 345Kg

URANIUM IS A HAZARDOUS MATERIAL
FOR GUIDANCE ON HANDLING SEE
B.N.F.L. INFORMATION SHEET 'URANIUM METAL'

Third Angle Projection	Material & Spec. DEPLETED URANIUM RMR 500	Tolerances LINEAR ±0.5 ANGULAR ± 1° Unless stated	Surface Texture 1.6 µm Unless stated	Finish CLEAN Remove all burrs
The drawing conforms to BS 308	Original Scale 1:2 Do not scale	Dims. in millimetres	Drawn KPR Checked PFIDLER	Used on 0A 23526

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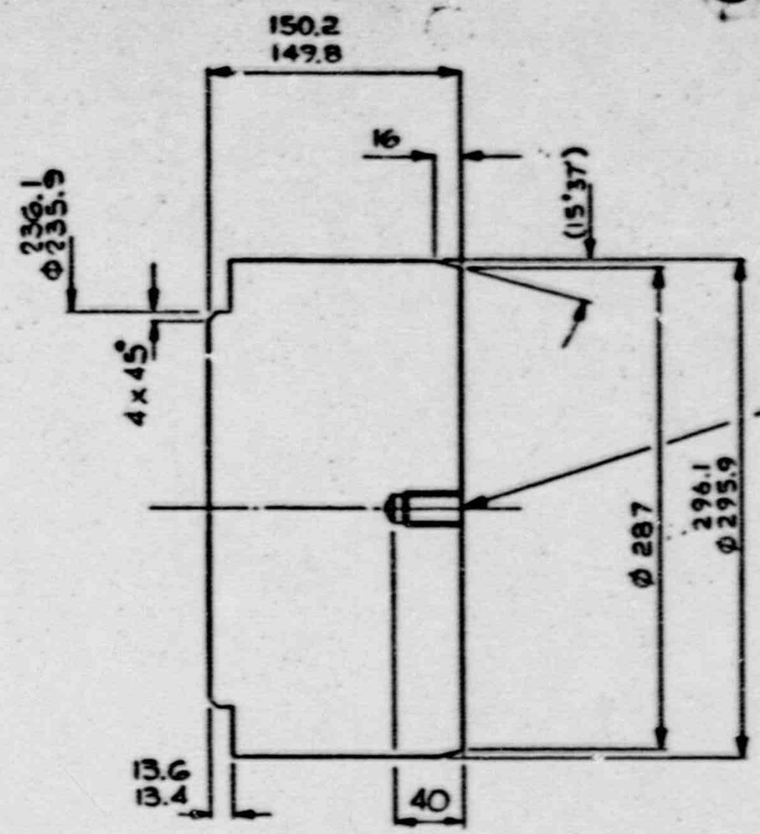
Title UPPER SHIELD

Job No. 408 S — Drg No. 2A23532

	Issue	Date	Mod No
	D		
DDR	C		
APPROVED			
	2	27.11.86	
	1	1.10.86	

2A2353



SECTION ON ℄

NOTES

1 THREADS TO CONFORM TO BS 3643 PART 2 FIT AS STATED

2 CALCULATED WIEGHT 180Kg

URANIUM IS A HAZARDOUS MATERIAL FOR GUIDANCE ON HANDLING SEE B.N.F.L. INFORMATION SHEET 'URANIUM METAL'

Third Angle Projection	Material & Spec. DEPLETED URANIUM RMR 500	Tolerances LINEAR ±0.5 Unless stated	Surface Texture 1.6/µm Unless stated	Finish CLEAN Remove all burrs
This drawing conforms to BS 308	Original Scale 1:2 Do not scale	Dims. in millimetres	Drawn K P R Checked P FOLER	Used on 0A 23527

Amersham

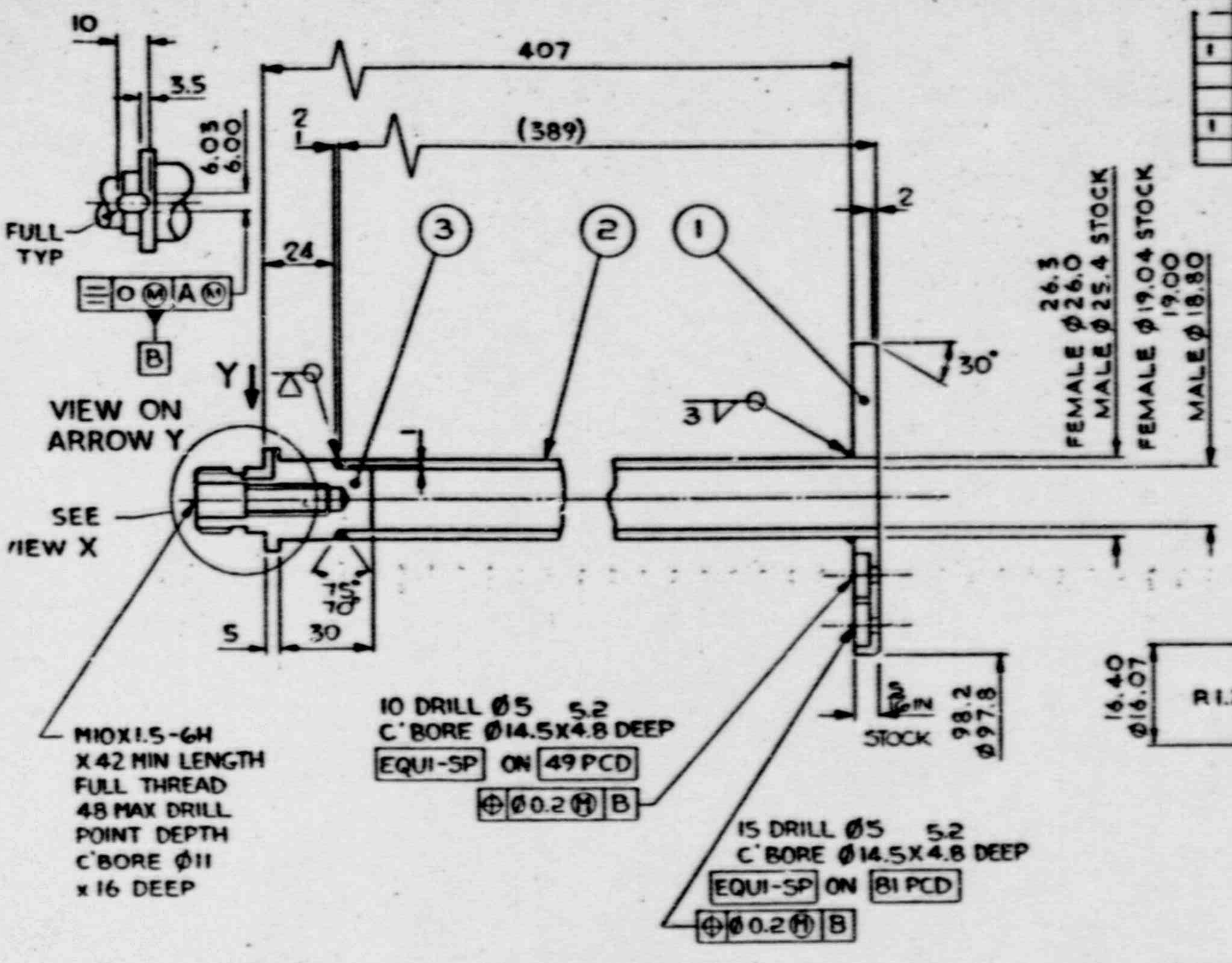
Title CLOSURE SHIELD

Job No. 408 S

Drg No. 2A23533

2A23534

NO. OFF	DESCRIPTION	DRAWING NO.	ITEM NO.
	3/8 IN. THK SS PLATE BS 1501		1
	PART 3 GRADE 316S12		
1	25.4 OD X 3.18 WALL		2
	SS PIPE SEAMLESS		
	ASTM A213 316		
1	Ø1¼ IN SS BAR BS970 PART 4		3
	GRADE 316 S12		

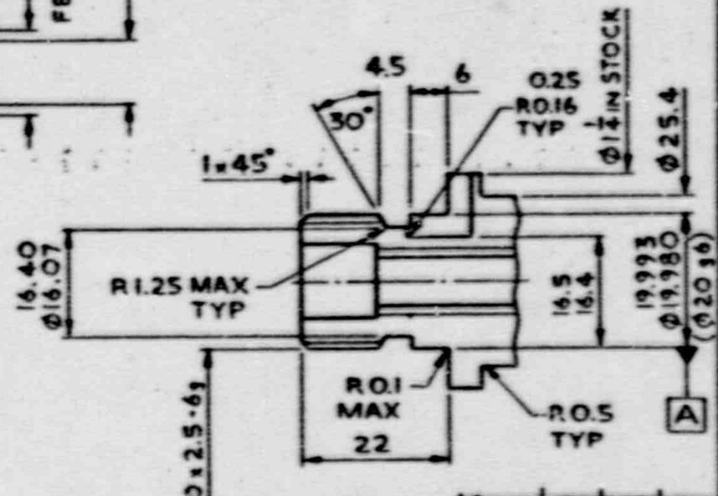


SECTION ON ℄

NOTES

1 THREADS TO CONFORM TO BS 3643 PART 2 FIT AS STATED

2 WELD TO A1 SPEC. QCP 510



VIEW X
SCALE 2:1

Issue	Date	Mod No.
E		
D		
C		
2	27.11.86	
1	7.10.86	

Third Angle Projection	Material & Spec. SEE ITEMS LIST	Tolerances LINEAR ± 0.5 ANGULAR ± 1° Unless stated	Surface Texture 1.6 µm Unless stated	Finish CLEAN Remove all burrs
This drawing conforms to BS 308	Original Scale 1:1 Do not scale	Units in millimetres	Drawn KPR Checked P FIDLER	Used on

© Amersham

Title: TUBE SUPPORT

Job No. 408 S

Drg No. 2A23534

Third Angle Projection

This drawing conforms to B.S.308

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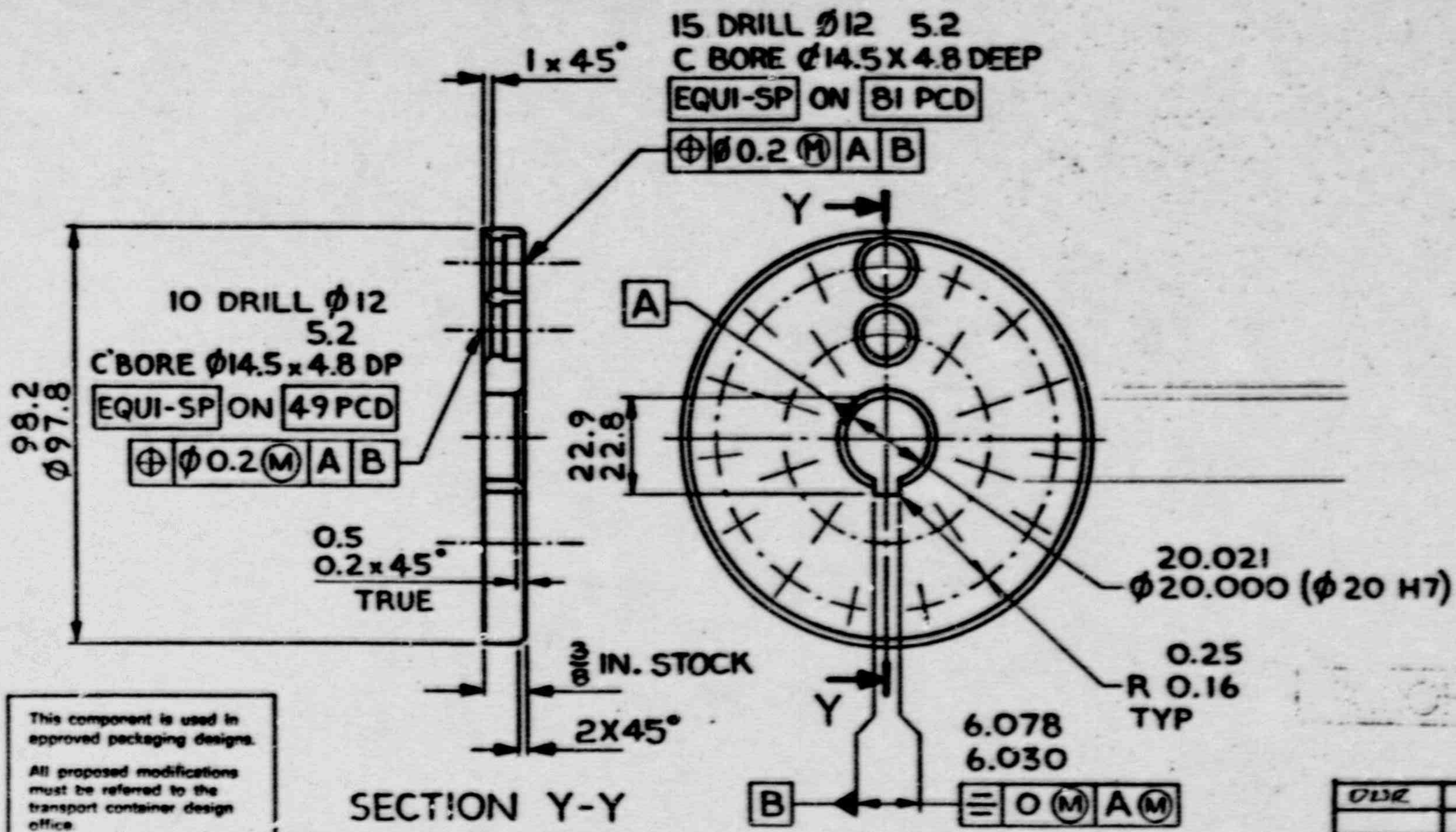

This component is used in approved packaging designs.

All proposed modifications must be referred to the transport container design office.

Approval	Issue	Date	Mod No.
DJR	B	19-12-84	MP348
	1	1.10.86	

Material & Spec.	Tolerances	Surface Texture	Finish
S S PLATE BS 1501 GRADE 316S12	LINEAR ±0.5 ANGULAR ± 1° Unless stated	1.6/µm Unless stated	CLEAN Remove all burrs
Original Scale 1:1 Do not scale	Dims. in millimetres	Drawn KPR Checked PFIOLER	Used on

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Title **END PLATE**

Job No. 408S

Drg. No. 3A23535

Third Angle Projection

This drawing conforms to B.S.308

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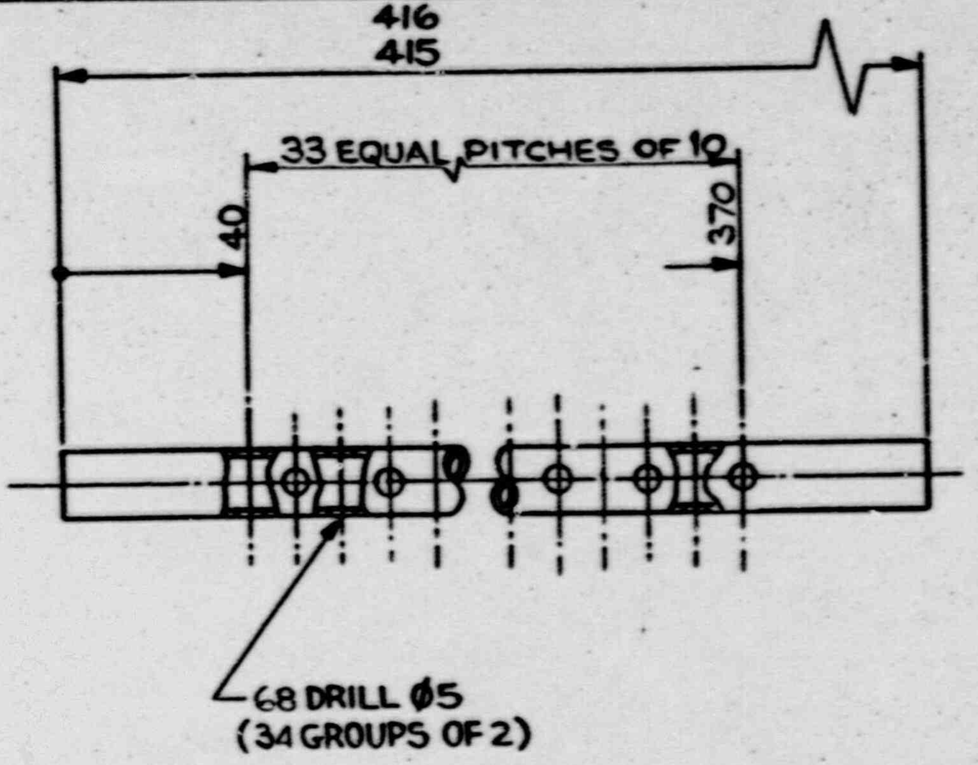

NOTE

MATERIAL SS TUBE SEAMLESS
14 OD X 1 WALL ASTM A213 316

This component is used in approved packaging designs.

All proposed modifications must be referred to the transport container design office.

Approved	Issue	Date	Mod.No.
DWR	C	19-12-86	MP345
	2	27.11.86	
	1	1.10.86	

Material & Spec.	Tolerances	Surface Texture	Finish
SEE NOTE	± 1 Unless stated	1.6/µm Unless stated	CLEAN Remove all burrs
Original Scale 1:1 Do not scale	Dims. in millimetres	Drawn KPR Checked P FIDLER	Used on

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Amersham

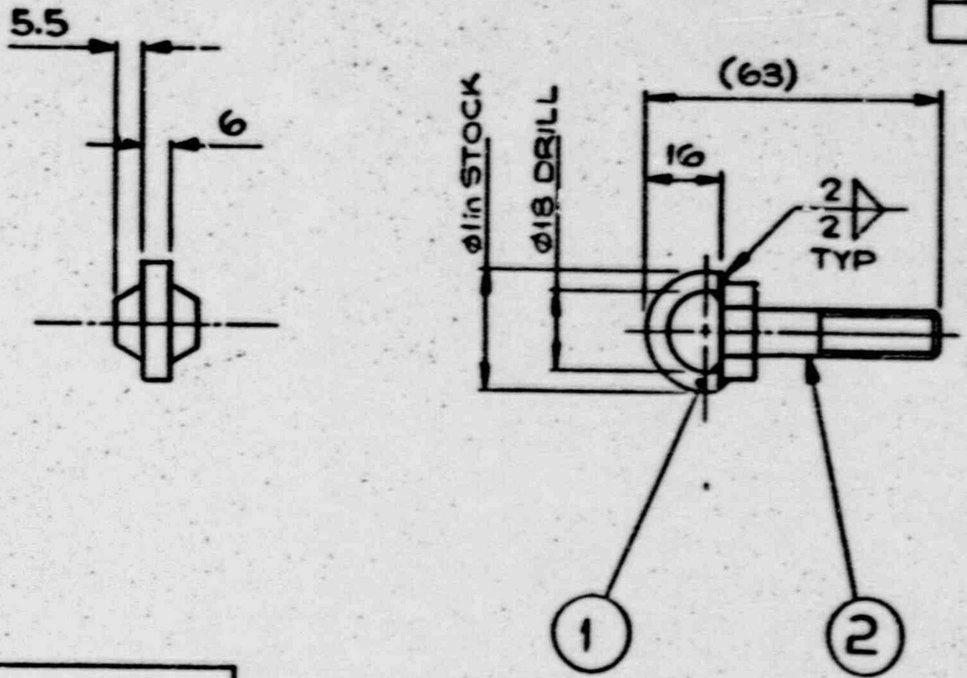
Title TUBE

Job
Job No. 408 S

Drg. No. 3A23536

Third Angle Projection ⌖	This drawing is the private and confidential property of Amersham International plc. and must not be loaned, copied or reproduced without written permission.
This drawing conforms to B.S.308	

NO. OFF	DESCRIPTION	DRAWING NO.	ITEM NO.
1	Ø1in SS BAR ROUND		1
	BS970 PART 1 GRADE 316 S11		
1	BOLT HEX HD M10 X 40 LG		2
	BS3692 SS BS6105 GRADE A2-70		



NOTES

1 WELD TO AI SPEC QCP 510 ISSUE 3

2.1 LOAD OF 60 kg TO BE APPLIED TO LIFTING EYE

2.2 AFTER TESTING VISUALLY INSPECT WELDS FOR DEFECTS AND DYE PENETRANT TEST TO ENSURE THE ABSENCE OF CRACKS

This component is used in approved packaging designs.

All proposed modifications must be referred to the transport container design office.

MICROFILMED

Approved	Issue	Date	Mod.No.
✓	C	25.11.8?	
DJR	B	19-12-86	MP348
	1	1.10.86	

Material & Spec.	Tolerances	Surface Texture	Finish
SEE ITEMS LIST	±0.5 Unless stated	3.2/µm Unless stated	AI SPEC NO. QCP 513 ISSUE 1 Remove all burrs
Original Scale 1:1 Do not scale	Dims. in millimetres UNLESS OTHERWISE STATED	Drawn KPR Checked P.FIDLER	Used on 1A 23902

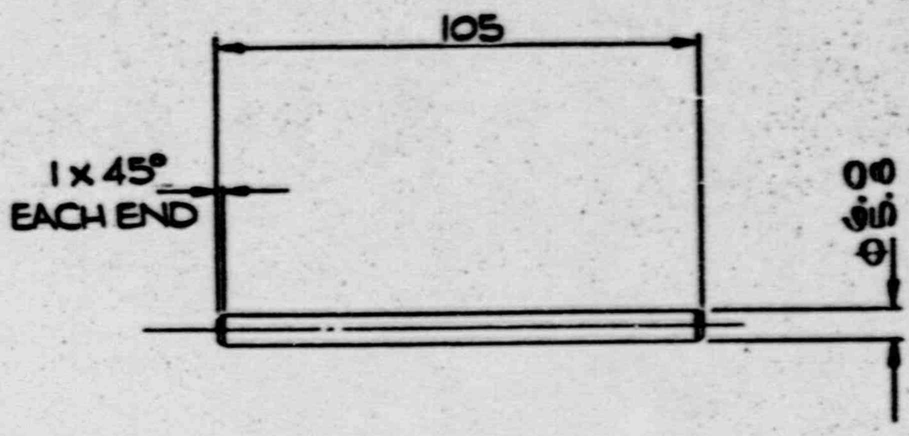
Amersham

Title LIFTING EYE

Job No. 408 S / S 587

Drg. No. 3A23537

Third Angle Projection	This drawing is the private and confidential property of Amersham International plc. and must not be loaned, copied or reproduced without written permission.
This drawing conforms to B.S.308	



This component is used in approved packaging designs.

All proposed modifications must be referred to the transport container design office.

Approved	Issue	Date	Mod.No.
[signature]	C	9.9.8[illegible]	[illegible]

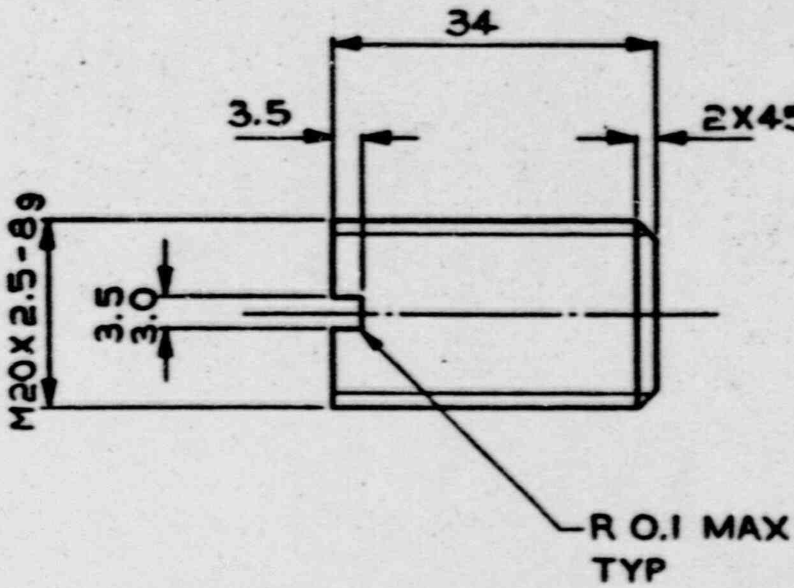
Material & Spec.	Tolerances	Surface Texture µm	Finish	© Amersham International plc. Amersham UK — Amersham
TUNGSTEN ALLOY (90%)	±2 Unless stated	1.6 Unless stated	CLEAN Remove all burrs	Title: SHIELD ROD
Original Scale 1:1 Do not scale	Dims. in millimetres	Drawn OEDC MLW Checked	Used on 0A23525	Job No. 408S — Drg. No. 3A 23539

Third Angle Projection
This drawing conforms to B.S.308

Item No.	Drawing No.	Description	No. off

NOTE

THREAD TO CONFORM TO BS 3643 PART 2 FIT AS STATED (FREE FIT)



URANIUM IS A HAZARDOUS MATERIAL
FOR GUIDANCE ON HANDLING SEE
B.N.F.L. INFORMATION SHEET 'URANIUM METAL'

MICROFILMED

Approved	Issue	Date	Mod No.
[illegible]	D	10.9.8[illegible]	[illegible]
[illegible]	C	19.12.86	MP348
	2	27.11.86	
	1	1.10.86	

Material & Spec.	Tolerances	Surface Texture	Finish
DEPLETED URANIUM RMR 500	LINEAR ±0.5 ANGULAR ±1° Unless stated	1.6/μm Unless stated	CLEAN Remove all burrs
Original Scale 2:1 Do not scale	Dims. in millimetres	Drawn KPR Checked P.FIDLER	Used on 0A23526 0A23527

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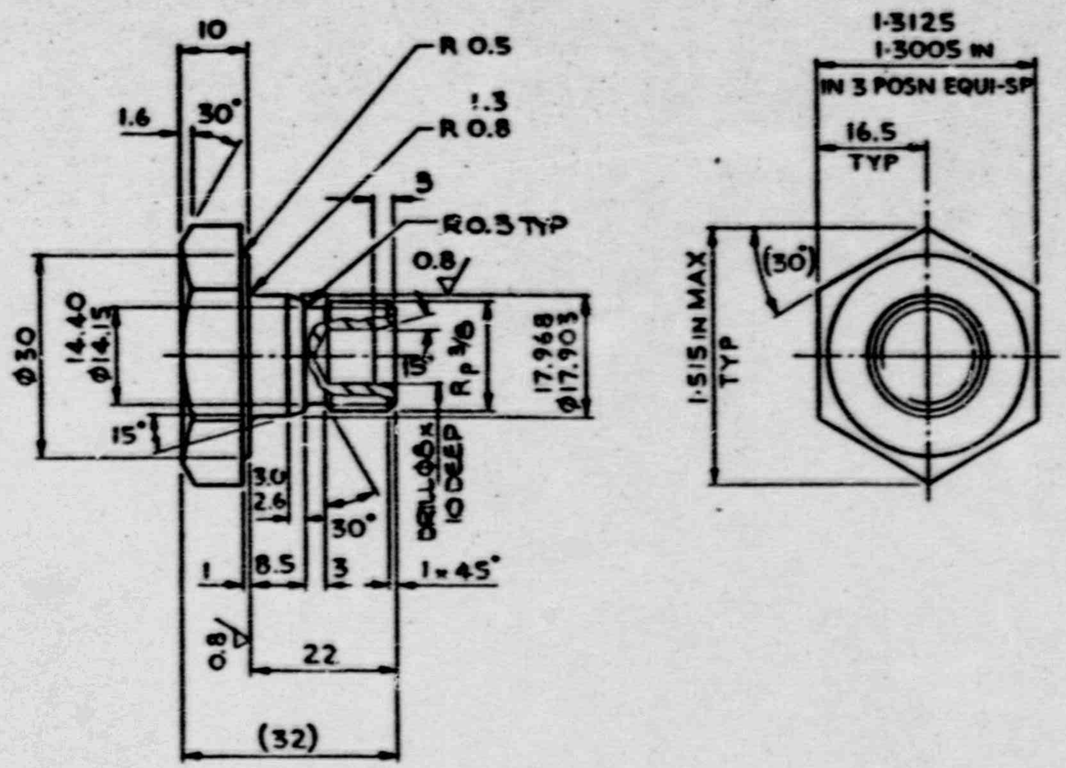
Amersham

Title INSERT

Job No. 408S

Drg. No. 3A23668



NOTE

1 THREAD TO CONFORM TO BS 21

2 MATERIAL OBTAINABLE FROM
BONAR LANGLEY ALLOYS LTD
832 YEOVIL ROAD
SLOUGH
BERKS
SL1 4JD

Third Angle Projection	Material & Spec. FERRALIUM 255 - 3SF SEE NOTE 2	Tolerances LINEAR ±0.5 ANGULAR ±1° Unless stated	Surface Texture 1.6 µm Unless stated	Finish CLEAN Remove all burrs
This drawing conforms to BS 308	Original Scale 2:1 Do not scale	Dims in millimetres UNLESS OTHERWISE STATED	Drawn M.R.P Checked P FIDLER	Used on 0A 23525 3A 23539

Approved	Issue	Date
	D	12.9.8
DJR	C	19.12.8
	2	17.11.86
	1	11.C.86

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Title PLUG (PURGE)

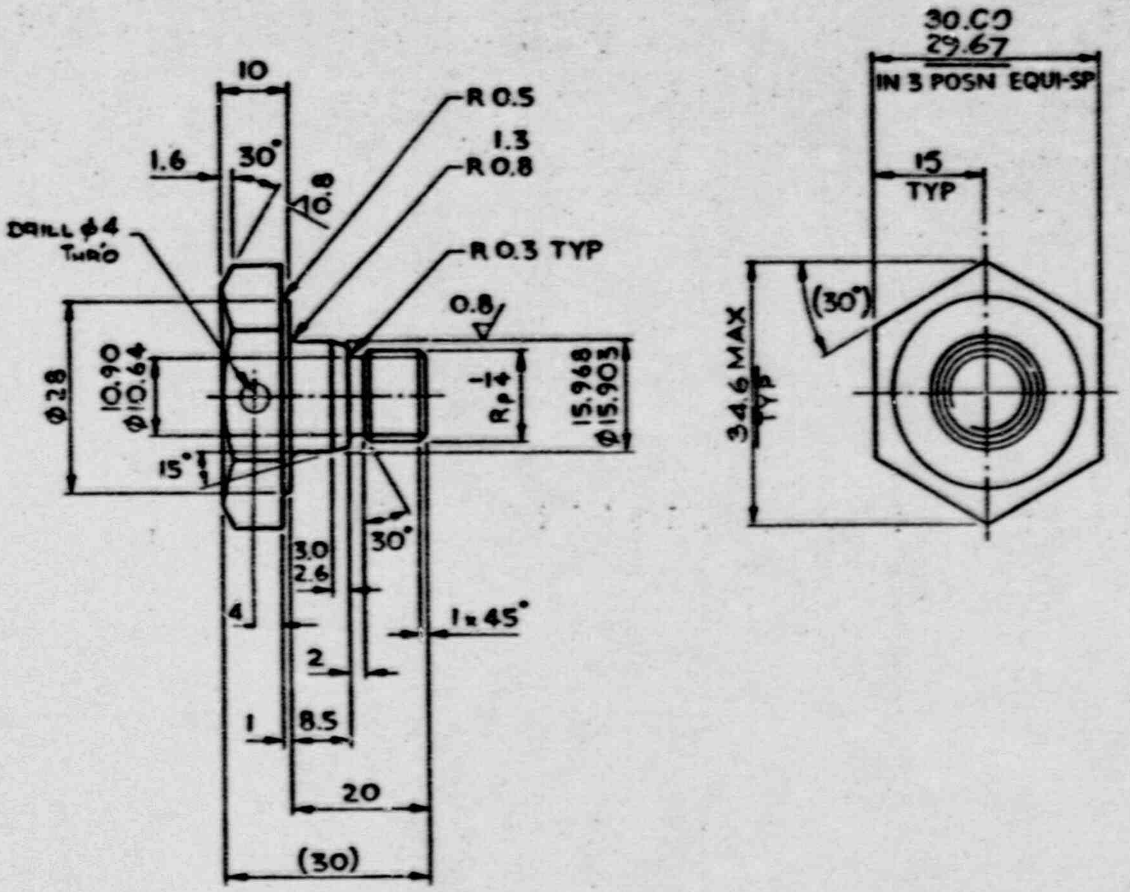
Job No. 4085

Drg No. 2A23664

10·5 7·5 mm in 7·5 10·5

2A23[illegible]5

Item No.	Description	Drawing No.	No. of assembly c b a



NOTE

1 THREAD TO CONFORM TO BS 21

2 MATERIAL OBTAINABLE FROM
BONAR LANGLEY ALLOYS LTD
832 YEOVIL ROAD
SLOUGH
BERKS
SL1 4JD

Approved	Issue	Date	Mod No.
	C	19.7.86	4P346
	2	27.11.86	
	1	1.10.86	

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Third Angle Projection	Material & Spec. FERRALIUM 255 -3SF SEE NOTE 2	Tolerances LINEAR ± 0.5 ANGULAR ± 1° Unless stated	Surface Texture 1.6 μm Unless stated	Finish CLEAN Remove all burrs
This drawing conforms to BS 308	Original Scale 2:1 Do not scale	Dims. in millimetres UNLESS OTHERWISE STATED	Drawn M.R.P. Checked P.FOUER	Used on QA 23525

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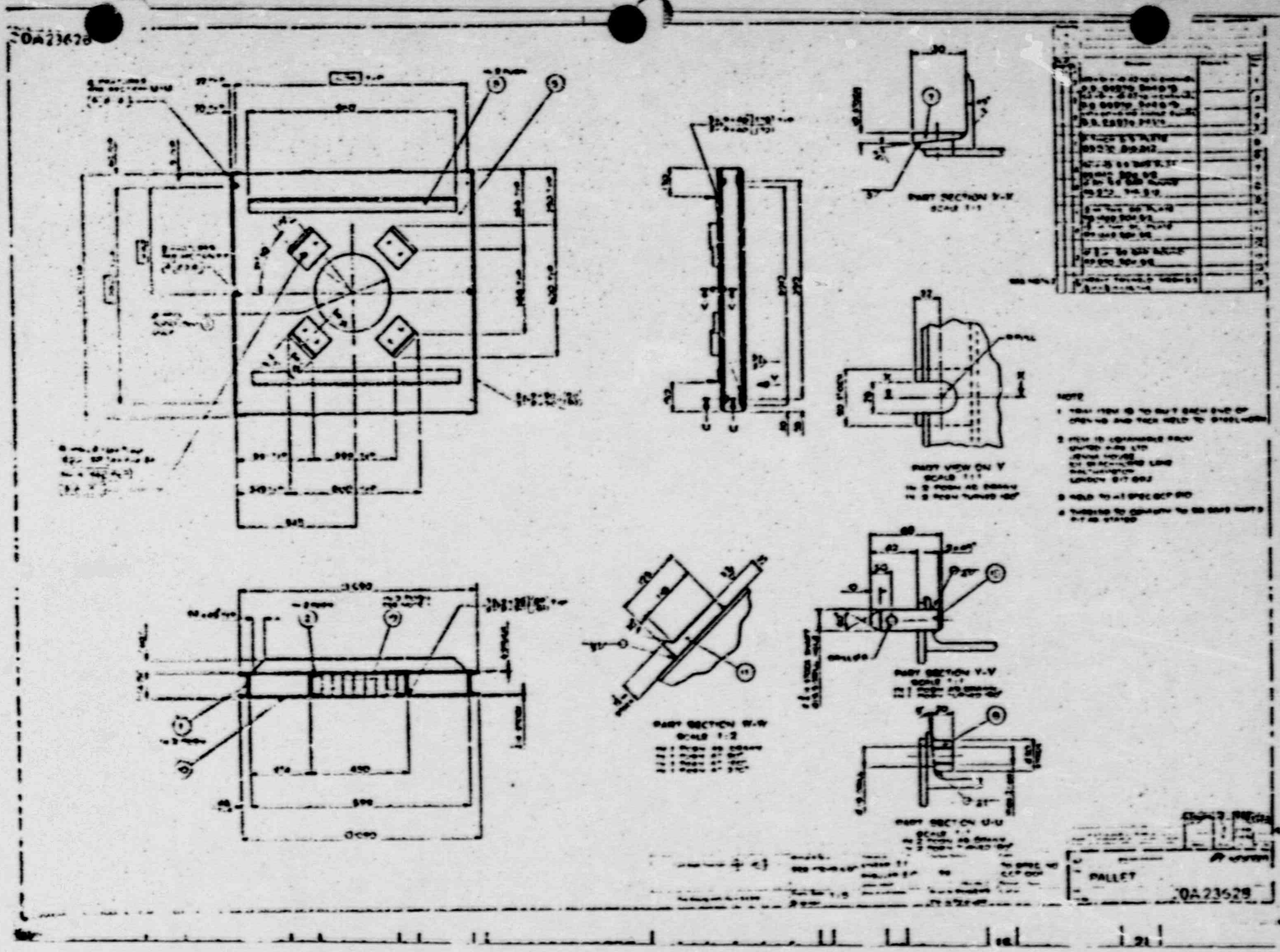
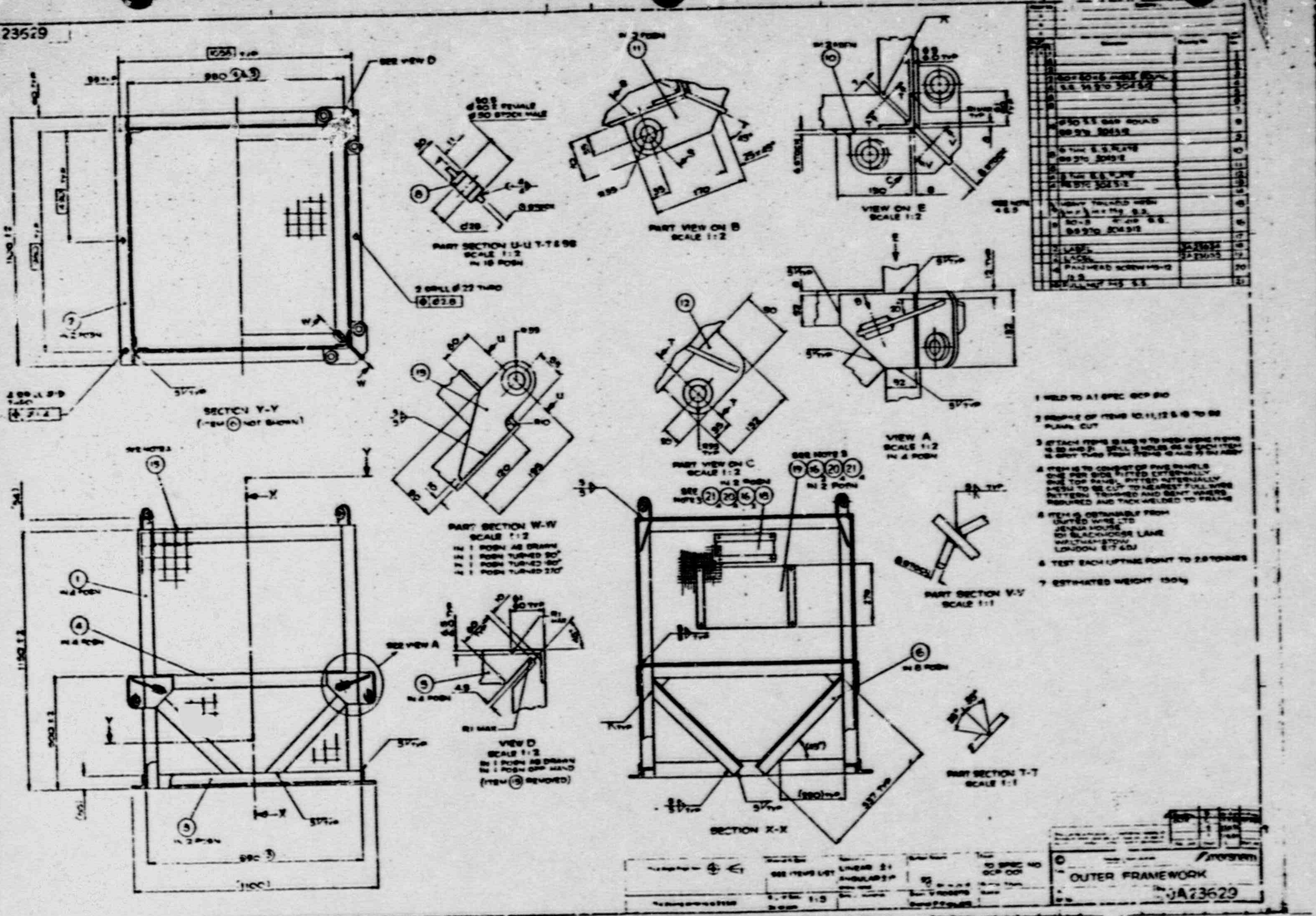
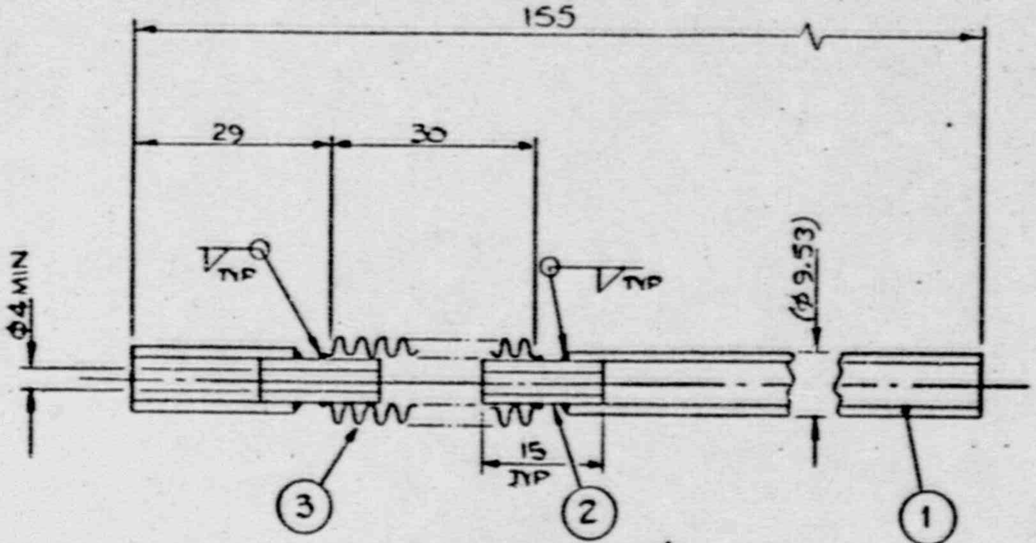
Title: PLUG (MAINTENANCE)

Job No. 408 S — Drg No. 2A23663


PART SECTION X-X
PART VIEW ON Y
PART SECTION W-W
SCALE 1:2
PART SECTION V-V
PART SECTION U-U
NOTE
PALLET


SECTION Y-Y
PART SECTION U-U T-T & 98
SCALE 1:2
PART VIEW ON B
SCALE 1:2
VIEW ON E
SCALE 1:2
PART VIEW ON C
SCALE 1:2
VIEW A
SCALE 1:2
IN 4 POSN
PART SECTION W-W
SCALE 1:2
VIEW D
SCALE 1:2
SECTION X-X
PART SECTION V-V
SCALE 1:1
PART SECTION T-T
SCALE 1:1
1 WELD TO A1 SPEC
6 TEST EACH LIFTING POINT TO 2.0 TONNES
7 ESTIMATED WEIGHT
OUTER FRAMEWORK
A23629



SECTION ON ℄

1	R	9.53 OD × 1.65 WALL ES SEAMLESS PIPE ASTM A213 316	[illegible]
2	R	INNER LINER STAIN.S SEAMLESS PIPE ASTM A213 316	—II—
3	R	¼ IN NOM I/D ANNULAR CORRUGATED HOSE STAIN.S PHOENIX REF PET/O	—II—

NOTE

1. COMPLETE ITEM MAY BE OBTAINED FROM:
   PHOENIX FLEXIBLE TUBES LTD
   ABERCANNID
   MERTHYR TYDFIL
   MID GLAMORGAN
   WALES CF 48 1UX
2. WELD TO A.I. SPEC. QCP.510.

Third Angle Projection	Material & Spec. SEE ITEM LIST	Tolerances LINEAR ±0.5mm Unless stated	Surface Texture STOCK ✓ Unless stated	Finish CLEAN Remove all burrs
This drawing conforms to B.S.308	Original Scale 2:1 Do not scale	Dims. in millimetres	Drawn F P WILLSHER Checked	Used on OA 23326

Approved	Issue	Date	Mod No
[illegible]	B	[illegible]	[illegible]
[illegible]	A	11-10-[illegible]	

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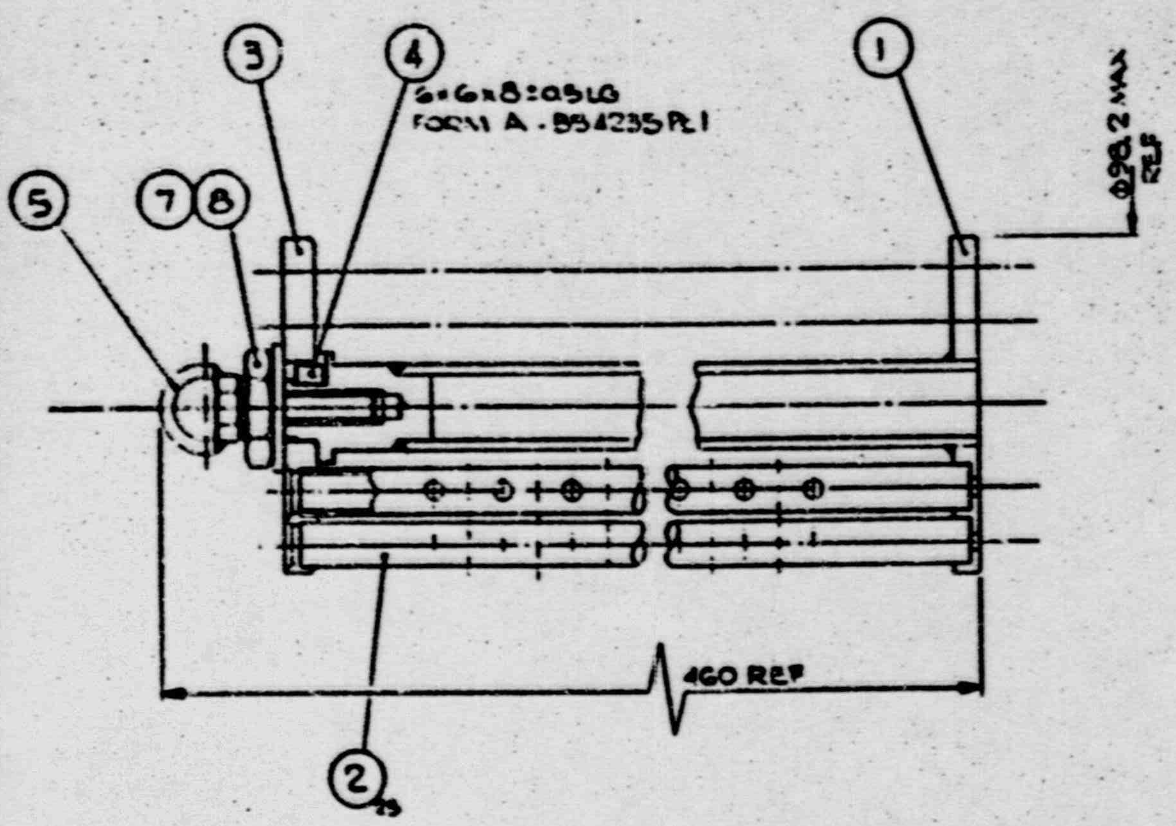
Title DRAIN PIPE

Job No. 408S

Drg. No. 2A23838

2A 23870



No. of assembly a	b	c	Description	Drawing No.	Item No.
1			TUBE SUPPORT	2A23534	1
25			TUBE	3A23536	2
1			END PLATE	3A23535	3
1			KEY STAN.S BS970P.4/316S12	THIS	4
1			EYEBOLT	3A23537	5
					6
1			NUT-THIN M20 STAN.S BS3692		7
1			WASHER-STAN.S FORM B BS4320		8
					9
					10

Third Angle Projection

Material & Spec: SEE ITEM LIST

Tolerances: - (Unless stated)

Surface Texture: √ (Unless stated)

Finish: CLEAN

Remove all burrs

Original Scale: 1:1

Do not scale

Dims in millimetres

Drawn: DEDE NEW

Checked

Used on: OA23525

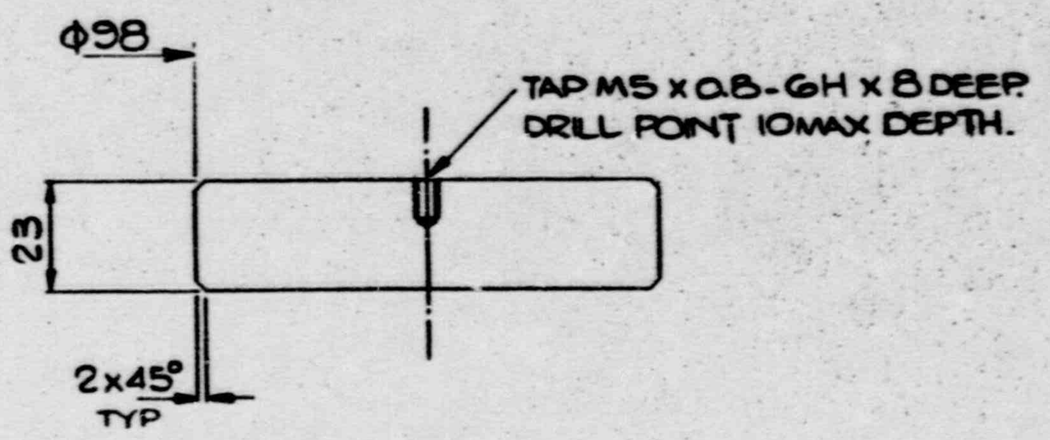
© Amersham

Title: SOURCE HOLDER ASSY

Job No: 6085

Drg No: 2A 23870

Third Angle Projection
This drawing conforms to B.S.308



This component is used in approved packaging designs.

All proposed modifications must be referred to the transport container design office.

Approved	Issue	Date	Mod.No
[signature]	A	13.11.87	

Material & Spec.	Tolerances	Surface Texture µm	Finish	© Amersham International plc. Amersham UK — Amersham
TUNGSTEN ALLOY 90%	±0.5 Unless stated	3.2 ▽ Unless stated	CLEAN Remove all burrs	Title: SHIELD DISC
Original Scale 1:1 Do not scale	Dims. in millimetres	Drawn OEDC MLW Checked OEDC [initials]	Used on 0A23525	Job / Job No. — Drg. No. 3A23896

2.0 Structural Evaluation

2.1 Structural Design

2.1.1 Discussion

The GB/3100A is comprised of seven structural components: a source capsule, source holder assembly, shield assembly, outer housing assembly, closure assembly, pallet, and outer framework or cage. The source capsule is the primary containment vessel. It satisfies the criteria for special form radioactive material.

The source holder assembly is fabricated from stainless steel and consists of 25 tubes into which the source capsules are placed. This assembly fits into a stainless steel pipe which forms the inner, or containment cavity, of the flask. The shield assembly is made of depleted uranium, and provides shielding for the radioactive material.

The outer housing is fabricated from 1/2 inch thick 316 stainless steel. The housing is finned to dissipate heat, and provides the structural integrity of the container.

The closure assembly secures the source holder assembly in the shielded position in the inner containment cavity, and assures positive closure.

The container body, or flask, is bolted to a pallet constructed of stainless steel plate and channel. The outer framework is fabricated from stainless steel and heavy twilweld mesh. It prevents access to the flask, and provides lifting and tie down points. It is bolted over the flask to the pallet.

2.1.2 Design Criteria

The GB/3100A is designed to comply with the requirements for Type B(U) packaging as prescribed by 10 CFR 71 and IAEA Safety Series No. 6, 1979 Revised Edition (as amended). All design criteria are evaluated by application of the appropriate section of IAEA Safety Series No. 6 or 10 CFR 71.

2.2 Weights and Center of Gravity

The net weight of the complete package is 2549 Kg (5621 lbs). Its gross weight is 2569 Kg (5665 lbs). The weight of the individual components are:

Outer Framework (cage)	150 Kg	(331 lbs.)
Pallet	170 Kg	(375 lbs.)
Flask Closure	276 Kg	(609 lbs.)
Flask body (including shielding)	1953 Kg	(4306 lbs.)
Depleted Uranium Shielding	1817 Kg	(4006 lbs.)

The center of gravity is located approximately in the center of the flask body, and halfway up the flask body. The tie down points on the outer framework are positioned around the center of gravity.

2.3 Mechanical Properties of Materials

All materials used in the construction of the container comply with "British Standard 970: Part 1: 1983: Wrought Steels for Mechanical and Allied Engineering Purposes: Austenitic Stainless and Heat Resisting Steels." (Appendix 2.10.1) Specifications for the depleted uranium are detailed in Appendix 2.10.2).

2.4 General Standards for All Packages

2.4.1 Minimum Package Size

The GB/3100A is 1132 mm (44.6 inches) wide x 1132 mm (44.6 inches) deep x 1360 mm (53.5 inches) high.

2.4.2 Tamperproof Feature

Two wire seals are applied to two of the four points at which the cage is bolted to the pallet. Another seal may be placed through the padlock point on the thick fin over which the slot in the closure fits. The closure could not be removed without breaking this seal.

2.4.3 Positive Closure

The cage which prevents access to the flask is secured over the flask to the pallet by a bolt in each of the four corners. Two of the corners may also be secured to the pallet by padlocks.

The closure assembly fits into the top of the flask and is secured by eight bolts. A slot in the closure assembly fits over one of the thick fins which is provided with a padlock point. With the padlock applied, the closure cannot be lifted off the flask.

2.4.4 Chemical and Galvanic Reactions

Depleted uranium when heated to temperatures of above 760°c may form an eutectic alloy with stainless steel. To comply with 10 CFR 71 and IAEA Regulations for the Safe Transport of Radioactive Materials, the container has to undergo the fire test in which temperatures of 800°c may be reached.

To prevent possible alloying of the depleted uranium with the stainless steel, thereby causing a loss of shielding, the inner side of the stainless steel is sprayed with a copper spray, or lined with a copper foil. There is no known alloying of depleted uranium with copper.

Transport Container Test No. 1014 (appendix 2.10.2) was performed to determine if a plasma sprayed copper coating is effective in preventing alloying between stainless steel and depleted uranium at 800°c. The conclusion of the test was that the copper coating successfully prevented the formation of any depleted uranium/stainless steel eutectic alloy.

The container is subjected to the fire test after the other mechanical tests are completed in which the container may buckle, therefore, the copper surface has to stay intact after distortion of the steel. Transport Container Test No. 1019 (appendix 2.10.3) was performed to test the adherence of a plasma sprayed copper coating to stainless steel subjected to gross stretching. The conclusion of the test was that the adhesion of the copper spray process is not affected by gross distortion.

Since the container is a welded fabrication, and the components are copper sprayed on the inside before welding, Transport Container Test No. 1043 (appendix page 2.10.4) was performed to see if welding would adversely affect the copper spray. The conclusion of the test was that welding of stainless steel using the tungsten inert gas process at 250 amps has no effect on a copper sprayed surface more than 8 mm away from the bottom of the weld. At a distance of 4 mm the copper is discolored but there is no loss of adhesion.

2.5 Lifting and Tiedown Standards for All Packages

2.5.1 Lifting Devices

Four lifting lugs are provided at the top of the outer framework, one in each corner. The lifting strength of the outer assembly is the minimum of either that of the lifting lugs on top of the outer framework, or that of the bolts securing the framework to the pallet.

With the outer framework removed the flask may be lifted either by the lifting eye at the top of the four thick fins, or by an eyebolt screwed into the center of the closure.

Packaging Group Memorandum PGM 178 (appendix 2.10.5) provides a detailed assessment of all the lifting points. The conclusions reached in PGM 178 are that the maximum safe loads that the lifting points can withstand are:

Outer framework lifting lugs = 4090 Kg (9018 lbs.)
Pallet/framework bolts = 50240 Kg (110,779 lbs.)
Flask lifting lugs = 4560 Kg (10,055 lbs.)
Closure eyebolt = 4500 Kg (9,923 lbs.)

The gross weight of the container is 2570 Kg (5667 lbs.), therefore all the lifting points possess adequate strength.

2.5.2 Tiedown Devices

Both the outer framework and the flask inside are provided with tiedown elements sufficiently strong to withstand normal conditions of transport. Three tiedown lugs are provided halfway up each of the four corners on the framework. In this way the forces act about the center of gravity and any toppling movements are minimized. All loading forces are transmitted through the framework, the lower half of which is heavily braced, into the pallet on which the flask is mounted. The framework is attached to the pallet by means of four bolts and two guides. All tiedown loads are transmitted through these points as horizontal shearing forces. Internal tiedown is provided by bolting the flask onto the pallet through its feet.

Packaging Group Memorandum - PGM 215 (appendix page 2.10.6), provides a detailed assessment of the performance of the tie down features under normal conditions of transport. The conclusions reached in PGM 215 are that the strength of the various elements of the containers structure under tiedown loads are as follows:

	Longitudinal	Lateral	Vertical
Frame Corner brackets	15,300Kg (33,737 lbs)	300Kg (33,737 lbs)	32,700Kg (72,104 lbs)
Frame to Pallet fastening	30,790Kg (67,892 lbs)	30,790Kg (67,892 lbs)	Not Applicable
Flask to Pallet fastening	20,400Kg (44,982 lbs)	20,400Kg (44,982 lbs	70,000Kg (154,350 lbs)
Minimum Strength	15,300Kg 33,737 lbs)	15,300Kg (33,737 lbs)	32,700Kg (72,104 lbs)
Minimum Requirements	7,710Kg (17,000 lbs)	5,140Kg (11,334 lbs)	7,710Kg (17,000 lbs)

The minimum factor of safety is therefore $\frac{15300}{7710} = 1.98$

In the event of the loads exceeding normal limit the first elements to fail would be the eyes on the frame corner brackets' thus the container structure would remain intact.

The strength of both external and internal tiedown elements of the container exceed the requirements for road, sea, and air transport, as specified in Safety Series 37, 2nd Edition IAEA, Vienna, 1982.

2.6 Normal Conditions of Transport

2.6.1 Heat

The thermal evaluation for the heat test is presented in Section 3.

2.6.1.1 Summary of Pressures and Temperatures

The container is designed to operate in ambient temperatures from -40°c to 38°c. The temperature limits for selection of the materials were -40°c and 70°c.

Temperatures of the packaging and contents are as follows:

(a) Prior to Shipment

Transport cover = 38°c
Flask surface = 94°c
Contents = 450°c (see PGM 188, Appendix 3.6.1)

(b) During Normal Transport

Transport cover = 73°c
Flask surface = 101°c
Contents = 457°c (see PGM 188, Appendix 3.6.1)

(c) During and Subsequent to Accident Conditions

Transport Cover = 800°c
Contents = 705°c (see PGM 188, Appendix 3.6.1)

The maximum surface temperature in the shade under normal conditions of transport is predicted to be 38°c. The daily heat input to the package due to insolation is zero (see EPM 67, Appendix 3.6.4)

Any pressure rise in the containment system can only arise from thermal effects. This will result in the following pressures, calculated from the temperatures listed above.

(a) Prior to Shipment
2.65 bar

(b) During Normal Transport
2.67 bar

(c) During and subsequent to accident conditions
3.58 bar

The construction materials are capable of satisfactorily meeting the 1973 IAEA SS6 Type "B" thermal testing requirements, following mechanical testing. The container will maintain its structural integrity and shielding effectiveness under both normal and adverse transport heat conditions.

2.6.2 Cold

The materials used in the container are not susceptible to brittle fractures to at least -40°c. The contents to be transported are solid, special form capsules. From this data it is concluded that the container will maintain its structural integrity and shielding effectiveness under normal transport cold condition.

2.6.3 Reduced External Pressure

The container is sufficiently strong to withstand an external pressure equal to 3.5 psi and will maintain its structural integrity and shielding effectiveness under the normal transport pressure conditions.

Primary containment is ensured by the special form encapsulation of the contents.

2.6.4 Increased External Pressure

The container is sufficiently strong to withstand an external pressure equal to 20 psi and will maintain its structural integrity and shielding effectiveness under the normal transport pressure conditions.

Primary containment is ensured by the special form encapsulation of the contents.

2.6.5 Vibration

The assembly is sufficiently strong to withstand the normal transport vibration condition and maintain its structural integrity and shielding effectiveness.

2.6.6 Water Spray

Not tested as the package is designed to be loaded and unloaded underwater, and to shed water easily.

2.6.7 Free Drop

The complete assembly of the 3100A container including the body, outer framework and pallet was subjected to a free fall test from a height of 9 m. This is described in Section 2.7.1. On the basis of this test, it is concluded that the container will maintain its structural integrity and shielding effectiveness under the normal transport free drop condition.

2.6.8 Corner Drop

Not Applicable

2.6.9 Compression

A compression test was performed on the container assembly consisting of the body, outer framework and pallet. The compression load was assumed to be spread evenly over the four vertical members of the cage. A load five times the package gross weight was used for the compression test. A detailed report of this test may be found in Packaging Group Memorandum, PGM 189 (appendix 2.10.9)

It was concluded from the test that the container has ample strength to meet the requirements of the IAEA compression test for Type B(U) and will withstand the normal conditions of transport compression condition.

2.6.10 Penetration

The container was subjected to a penetration test, positioned to impact upside down on the edge of the closure lid, so as to knock the lid/closure off. A detailed report of the test may be found in transport container test no. 1028 (appendix 2.10.10)

Damaged sustained by the body was limited to very minor denting of the closure rim and two adjacent fins. Therefore on the basis of this test it is concluded that the container will maintain its structural integrity and shielding effectiveness.

2.7 Hypothetical Accident Conditions

Hypothetical accident conditions testing of the 3100A design was performed on a third (1/3) scale model. Drawings of the model are included in Appendix 2.10.12. The model consists of a stainless steel container with depleted uranium shielding mounted on a stainless steel pallet inside a stainless steel outer framework with wire mesh. The model is 366 mm (14.4 inches) wide x 366 mm (14.4 inches) x 422 mm (16.6 inches) high. The model contained a dummy source consisting of a stainless steel bar 30 mm (1.2 inches) x 150 mm (5.9 inches). It has a gross weight of 93Kg (205 lbs). As with the actual container, the model flask consists of five depleted uranium blocks. Four form an open topped cylinder and the fifth, the closure plug. The two assemblies, flask body and closure, are each totally encased in stainless steel.

The model is not provided with the stainless steel drain tube linking the inner and outer body cladding at the base of the cavity, or the purge point in the closure assembly.

Like the actual container, the model's outer body cladding is lined with vertical fins which on the actual container disperse the heat generated by the contents, as well as acting as shock absorbers. In each quadrant a thicker fin is extended above and below the body providing a lifting point and a foot. The fins are enclosed by a cylindrical jacket of thin gauge stainless steel. Fins on the top of the closure and the underside of the body also aid shock absorption.

2.7.1 Free Drop

The complete model assembly of the 3100A design including the body, outer framework, and pallet was subjected to the conditions of the 9 m drop test for type B(U) packages paragraph (a) and (b) IAEA "Regulations for the Safe Transport of Radioactive Materials, 1973". A detailed report of the test may be found in "Transport Container Test" No. 1027 and 1028 (appendix 2.10.9 and 2.10.8)

In the first test, detailed in TCT No. 1027, the assembly was positioned to impact on the base edge of the open side of the pallet with the center of gravity of the assembly directly above the line of impact.

A second free drop, as detailed in "Transport Container Test No. 1028" (appendix 2.10.8), was performed. The flask body (without the outer framework and pallet) was allowed a single fall through 9 m. It was positioned to impact on the top rim of the body midway between two of the thicker fins with the center of gravity directly above the point of impact.

Following a 1 m punch test, the assembly was put through a third free drop test (see TCT No. 1028, Appendix 2.10.8). In this test the Flask Body was also allowed a single fall through 9 m. It was positioned with the closure angled down from the horizontal by approximately 10°.

2.7.1.1 Summary of Results

After the first free drop test (TCT No. 1027 Appendix 2.10.9). The pallet was flattened on the edge where impact occurred and the framework was slightly bent and buckled. The container body broke free from the pallet, rotating through 90° onto its side. It was however retained within the frame structure. Two of the container feet were bent, but this did not affect the weld around the base of the container. Any other damage to the body was purely superficial, i.e. slight bending of fins etc.

After the second free drop test (TCT No. 1028, Appendix 2.10.8), the shock absorbers on the closure were bent and flattened. The body was otherwise relatively undamaged i.e. slight bending of fins and scuffing of the jacket. Damage to the target area was slight.

Following the third free drop test (TCT No. 1028, appendix 2.10.8) severe deformation of the jacket and fins occurred, bending and flattening on impact. The core of the body and the integrity of the skin, however, were unaffected and the closure remained securely attached.

The conclusion as a result of these tests is that the assembly meets the requirements of the 9 m drop test for Type B (U) packages (paragraphs 719 (a) and (b) IAEA "Regulations for the Safety Transport of Radioactive Materials, 1973").

2.7.2 Puncture

Following the second free drop test, the flask body (without the outer framework and pallet) was subjected to a puncture test. This test is detailed in Transport "Container Test No. 1028" (Appendix 2.10.).

The assembly was allowed a single fall through 1 m on to the target (5 cm diameter, flat ended, mild steel bar mounted perpendicularly on a flat steel plate and of sufficient length to cause maximum damage to the specimen). The inverted container was dropped so that the steel bar impacted the edge of the lid/closure.

Damage sustained by the body was limited to very minor denting of the closure rim and two adjacent fins. Damage to the target was slight.

As a result of this test it was concluded that the assembly meets the requirements of the punch test for Type B(U) packages (paragraphs (a) and (b) IAEA "Regulations for the Safe Transport of Radioactive Materials, 1973").

2.7.3 Thermal

The thermal test which followed the free drop test is reported in section 3.5. A summary of pressures and temperatures may be found in section 2.6.1.

2.7.4 Immersion - Fissile Material

Not Applicable.

2.7.5 Immersion - All Packages

The container is designed to be loaded and unloaded underwater therefore it was not tested.

2.7.6 Summary of Damage

The tests designed to induce mechanical stress (Free Drop, puncture) cause minor deformation to the model package but no reduction in structural integrity nor impairment of any safety features.

The thermal test also had no adverse affect on the package.

As a result of these tests there was no loss of structural integrity nor release of any contents. The assembly is sufficiently strong to prevent significant distortion or movement of the sources in normal conditions of transport so there can be no increase in radiation level due to these conditions.

2.8 Special Form

The container is designed to carry Cobalt-60 in special form capsules that meet the requirements of IAEA Special form and 10 CFR 71.75 when subjected to the applicable test conditions of 10 CFR part 71.77. The source is cobalt metal doubly encapsulated in stainless steel.

2.9 Fuel Rods

Not Applicable.

2.10 Appendix

2.10.1 British Standard 970: Part 1
2.10.2 Packaging Material Specification Uranium for Shielding
2.10.3 QCP 510 Issue B Welding for Packaging
2.10.4 Transport Container Test (TCT) No. 1014
2.10.5 Transport Container Test (TCT) No. 1019
2.10.6 Transport Container Test (TCT) No. 1043
2.10.7 Packaging Group Memorandum (PGM) 178
2.10.8 Packaging Group Memorandum (PGM) 215
2.10.9 Packaging Group Memorandum (PGM) 189
2.10.10 Transport Container Test (TCT) No. 1028
2.10.11 Transport Container Test (TCT) No. 1027
2.10.12 Third Scale Model Drawings

2.10.1 British Standard 970: Part 1

BRITISH STANDARD 970: Part 1: 1983: Wrought Steels for Mechanical and Allied Engineering Purposes: Austenitic Stainless and Heat Resisting Steels

Properties minima unless stated

Grade	En[2] No.	Composition (maxima unless stated)								Tensile Strength R_m N/mm²	$R_{p0.2}$* N/mm²	$R_{p1.0}$* N/mm²	A min on 5.65 √S_o	Hardness HB[1] max	Limiting Ruling Section mm
		C	Si	Mn	P and S	Cr	Mo	Ni	Others						
302S31	-	0.12	1.0	2.0	P 0.045 S 0.030	17.0/19.0	-	8.0/10.0	-	510	190	225	40	183	160
304S11	-	0.030	1.0	2.0	*	17.0/19.0	-	9.0/12.0	-	480	180	215	40	183	160
304S15	58E	0.06	1.0	2.0	*	17.5/19.0	-	8.0/11.0	-	480	195	230	40	183	160
321S31	-	0.08	1.0	2.0	*	17.0/19.0	-	9.0/12.0	Ti 5C/0.80	510	200	235	35	183	160
347S31	-	0.08	1.0	2.0	*	17.0/19.0	-	9.0/12.0	Nb 10C/1.00	510	205	240	30	183	160
316S11	-	0.030	1.0	2.0	*	16.5/18.5	2.00/2.50	11.0/14.0	-	490	190	225	40	183	160
316S13	-	0.030	1.0	2.0	*	16.5/18.5	2.50/3.00	11.5/14.5	-	490	190	225	40	183	160
316S31	-	0.07	1.0	2.0	*	16.5/18.5	2.00/2.50	10.5/13.5	-	510	205	240	40	183	160
316S33	-	0.07	1.0	2.0	*	16.5/18.5	2.50/3.00	11.0/14.0	-	510	205	240	40	183	160
320S31	-	0.08	1.0	2.0	*	16.5/18.5	2.00/2.50	11.0/14.0	Ti 5C/0.80	510	210	245	35	183	160
310S31	-	0.15	1.5	2.0	*	24.0/26.0	-	19.0/22.0	-	510	205	240	40	207	160
303S31	-	0.12	1.0	2.0	P 0.06 S 0.15/0.35	17.0/19.0	1.0[3]	8.0/10.0	-	510	190	225	40	183	160
303S42	-	0.12	1.0	2.0	S&P 0.060	17.0/19.0	1.0[3]	8.0/10.0	Se 0.15/0.35	510	190	225	40	183	160
325S31	-	0.12	1.0	2.0	P 0.045 S 0.15/0.35	17.0/19.0	-	8.0/11.0	Ti 5C/0.90	510	200	235	35	183	160

Cold Drawn Mechanical Property Requirements

Section mm	Tensile Strength R_m N/mm²	$R_{p0.2}$ N/mm²	$R_{p1.0}$ N/mm²	A min on 5.65 √S_o
≤19	865	695	725	12
>19 ≤25	790	555	585	15
>25 ≤32	725	450	480	20
>32 ≤38	695	340	370	28
>38 ≤45	650	310	340	28

1. Straightening by reeling or cold rectification can increase surface hardness above the specified maximum.

2. Now replaced: For guidance only.

3. Optional addition.

* When specifically ordered

BRITISH STANDARD 970: 1970: Wrought Steels Part 4: Valve Steels

Properties minima unless stated

Grade	En[1] No.	Composition								Heat Treatment	Tensile Strength R_m N/mm²	Yield Stress R_e N/mm²	A min on 5.65 √S_o	Impact		Hardness HB	Limiting Ruling Section mm
		C	Si	Mn	P and S max	Cr	Mo	Ni	Others					Izod ft.lb	KCV J		
331S40	54	0.35/0.50	1.00/2.00	0.50/1.00	P 0.040 S 0.030	12.0/15.0	-	12.0/15.0	W 2.00/3.00	-	-	-	-	-	-	-	-
331S42	54A	0.37/0.47	1.00/2.00	0.50/1.00	P 0.040 S 0.030	13.0/15.0	0.40/0.70	13.0/15.0	W 2.20/3.00	-	-	-	-	-	-	-	-
349S52	-	0.48/0.58	0.25 max	8.0/10.0	P 0.040 S 0.035	20.0/22.0	-	3.25/4.50	N 0.38/0.50 [illegible]	O & PH	-	-	-	-	-	321 (352 for 0.92 min [illegible]	-

2.10.2 Packaging Material Specification Uranium for Shielding

R/IR 500
Issue 2

AMERSHAM INTERNATIONAL plc.

International Operations

Packaging Group

Packaging Material Specification

Uranium for Shielding

DV

Prepared by: D.W. Ryes .... Date: 01/12/87

Authorised by: D Warden .... Date: 7th December 1987

1: **Specification**

a) Material : Uranium U235 content not greater than 0.7%

b) Density : Not less than 18g/cc

c) Purity : Alloying content not greater than 5%

d) Porosity : i)No single void to exceed 15% of item wall thickness in the general direction of radiation.

ii)No void with dimensions exceeding 10% of item wall thickness to be grouped closer than three diameters apart.

iii)No void with dimensions exceeding 10% of item wall thickness to be aligned along the general direction of radiation.

2. **Inspection**

a) Density : Calculate by dividing measured weight by calculated volume.

b) Porosity : Either by surveying shielding efficiency by radiography or by direct imaging of defects using ultrasound techniques.

c) Inspection Frequency : 100% unless agreed otherwise in writing. Note: This is most likely to be relaxed with the submission of well proven and documented production procedures.

3. **Transport and Storage**

a) Cleanliness : Surfaces must be clean of swarf, dirt and all grease.

b) Storage and Transport :Packaging must protect items from dirt and moisture and comply with all relevant transport regulations.

DN

2.10.3 QCP 510 Issue B Welding for Packaging

AMERSHAM INTERNATIONAL plc

INTERNATIONAL DIVISION

PACKAGING GROUP

WELDING FOR PACKAGING

1. SCOPE

This procedure specifies the requirements for the welding of carbon, carbon manganese and stainless steel fabrications used in transport containers for hazardous goods.

2. DRAWINGS

(a) The manufacturing drawings will normally state:

(i) Parent materials
(ii) Weld preparation
(iii) Weld size and form
(iv) Inspection and testing

(b) In addition the drawings may also specify:

(i) Welder qualification
(ii) Welder procedure
(iii) Heat treatment

(c) When any of this information is not stated on the drawings reference should be made to the following sections where certain minimum standards are specified.

3. WELDING PROCESS

Unless otherwise specified the welding process shall be in accordance with:

(a) BS 5135 : 1984 : including Appendices A to H (for carbon and carbon manganese steels)

(b) BS 3019 : Part 2 : 1960 (for austenitic stainless steels)

4. WELD PROCEDURE

(a) Welding procedures shall comply with current codes and good practice.

(b) When specified procedure tests will be carried out in accordance with BS 4870 : Part 1 : 1981.

DW

5. WELDER QUALIFICATIONS

Unless otherwise specified all welders must meet the requirements of:

(a) BS 4871 : Part 1 : 1982 (if working to approved welding procedures)

(b) BS 4872 : Part 1 : 1982 (when welding procedure approval is not required).

6. WELDING CONSUMABLES

(a) All consumables shall be suitable for welding the parent materials in accordance with the manufacturer's instructions.

(b) All consumables must be suitable for low temperature service (see 8.d for required properties). Satisfactory evidence of this shall either be in the form of manufacturers recommendations covering parent materials and procedures or acceptable test results (see 8.d).

(c) Generally consumables shall comply with the following standards:

BS 639 : 1976 : Covered electrodes for the manual metal arc welding of carbon and carbon manganese steels

BS 1453 : 1972 : Filler materials for gas welding

BS 2901 : Part 1 : 1983 : Filler rods and wires for gas-shielded arc welding of ferritic steels

BS 2901 : Part 2 : 1983 : Filler rods and wires for gas-shielded arc welding of austenitic stainless steels

BS 2926 : 1984 : Chromium and chromium nickel steel electrodes for manual metal arc welding

BS 4165 : 1971 : Electrodes, wires and fluxes for the submerged arc welding of carbon steel and medium tensile steel

BS 5465 : 1977 : Specification for electrode wires and fluxes for the submerged arc welding of austenitic stainless steel

(d) All consumables shall be stored and prepared in accordance with the manufacturer's instructions.

7. HEAT TREATMENT

When specified, heat treatment shall generally comply with the recommendations of BS 5500 : 1985.

8. INSPECTION AND TESTING

(a) Unless otherwise specified inspection shall be visual only and shall comply with BS 5289 : 1976 (1983) and acceptance levels shall comply with BS 5135 : 1984 : Appendix F Quality Category D.

(b) Non-destructive testing, when specified, shall comply with:

BS 4416 : 1969 : Method for penetrant testing of welded or brazed joints in metals

DW

BS 6072 : 1981 : Method for magnetic particle flaw detection

BS 3923 : Part 1 : 1978 : Method for ultrasonic examination of welds. (Manual examination of fusion welds in ferritic steels)

BS 2600 : Part 1 : 1983 : Radiographic examination of fusion welded butt joints in steel. (Methods for steel 2mm to 50mm thick)

(c) Destructive testing, where specified, shall comply with BS 709 : 1983.

(d) Testing of welds for suitability in low temperature service shall be carried out in accordance with BS 131 : Part 2 : 1972. The measured impact test value must not be less than 20 Joules at -40°C.

9. STANDARDS

Unless otherwise specified it will be assumed that the latest version of a standard will apply.

Prepared by : D.W.Rogers	Date : 6.3.86
Authorised by : N.Pollitt	Date : 6.3.86

DW

2.10.4 Transport Container Test (TCT) No. 1014

AMERSHAM INTERNATIONAL PLC

PACKAGING GROUP

Transport Container Test No 1014

1. Object

To determine if a 0.10 mm thick, plasma sprayed, copper coating (Process A132/1, Yard Ltd, Bristol) is effective in preventing alloying between stainless steel and depleted uranium at 800°C.

2. Theory

Depleted uranium when heated to temperatures of above 750°C will form a eutectic alloy with stainless steel.

It is intended to use depleted uranium as the shielding material for a container which will carry large quantities of radioactive material. To contain the depleted uranium, it will be encased in stainless steel.

To comply with the IAEA regulations for the Safe Transport of Radioactive Materials the container has to undergo the fire test in which temperatures of 800°C will be reached. To prevent the alloying of the depleted uranium with the stainless steel, thereby causing a loss of shielding, the inner side of the stainless steel is to be sprayed with a copper spray. There is no known alloying of copper with depleted uranium.

3. Apparatus

The apparatus was set up as shown in the attached drawing Appendix 1.

4. Method

The depleted uranium disc was placed between the copper plate and the copper sprayed surface on the stainless steel sample. The assembly was clamped together using the stainless steel plate and the two M4 cap head screws which were maximum hand tightened wih an allen key. This sub-assembly was then placed into the stainless steel pot. Before the lid was screwed in place the cavity of the pot was back filled with helium.

Once filled with helium and the lid screwed down tightly, the assembly was placed in a furnace at 800°C. After two hours the assembly was removed and allowed to cool to room temperature in air.

The assembly was dismantled and any reaction noted.

5. Results

a) Upon opening of the pot a black powder was observed in the bottom. The powder was monitored with alpha, beta and x-ray probes and found to be active.

b) The depleted uranium disc was unclamped and the surface was found to have powdered. This powder had deposited itself on the copper and copper sprayed surfaces.

c) The majority of the powder was removed from the surface by washing. The powder was more easily removed from the copper sprayed surface than the copper plate.

d) The remainder of the powder was removed by scraping.

e) The copper sprayed surface remained intact even after vigorous scraping (see photo 1014 b).

6. Observations

1. The powdering of the depleted uranium surface was caused by air being drawn into the container after it was withdrawn from the furnace. The amount of powdering is explained by the fact that both nitrogen and oxygen readily combine with uranium at elevated temperatures. In this way air being drawn into the vessel would immediately combine with the uranium thus causing more air to be drawn in. This process would only cease when all the uranium had formed oxides and nitrides or when the temperature had dropped sufficiently.

2. The powdering has not affected the result of the test. This plainly occurred whilst the container was cooling.

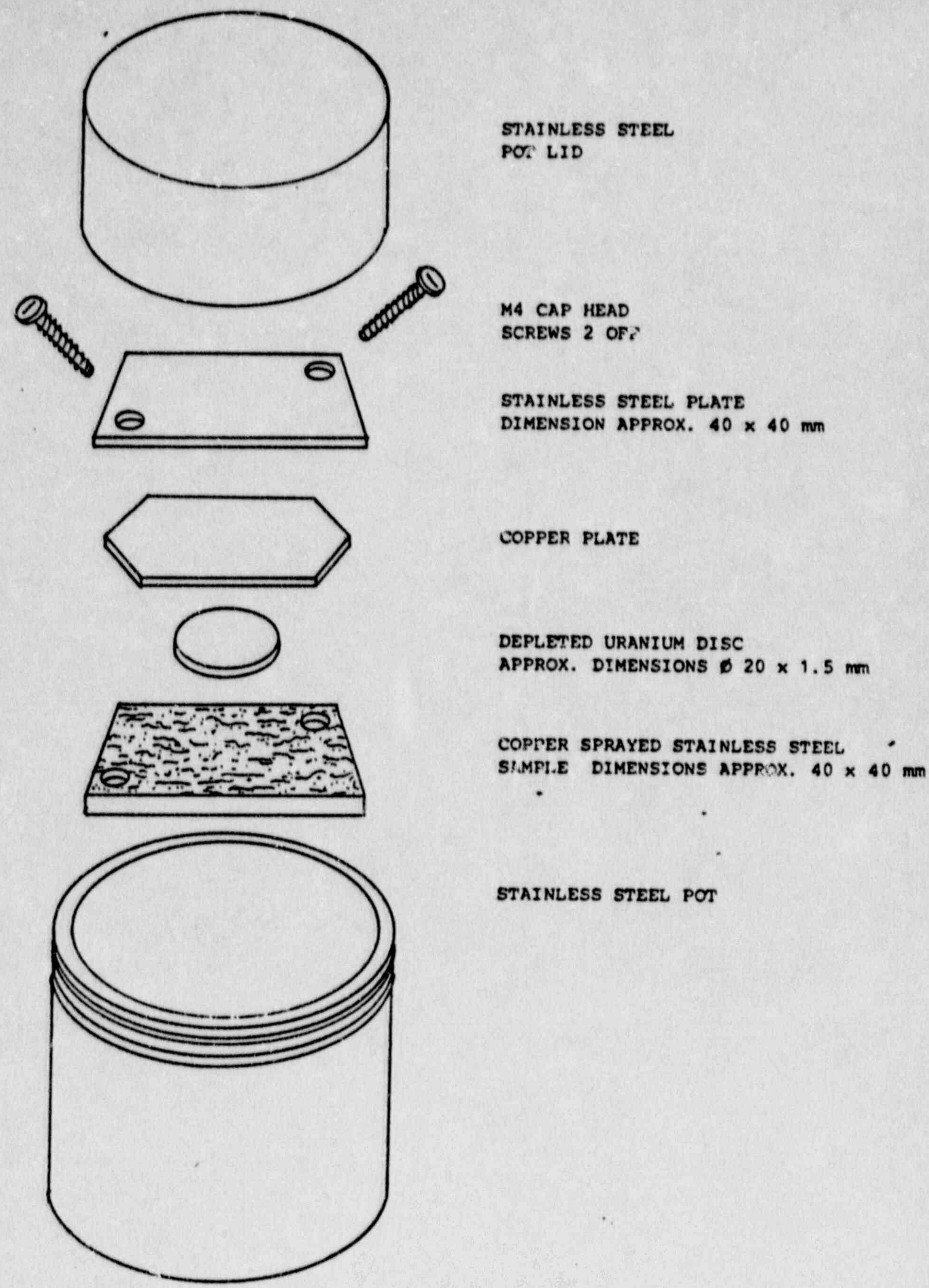
7. Conclusions

1. The copper coating successfully prevented the formation of any depleted uranium/stainless steel eutectic alloy.

R A Stubbs R.A. Stubbs.

D W Rogers DW Rogers.

7 April 1987



SEE PHOTO 1014 a)

TRANSPORT CONTAINER TEST NO 1014

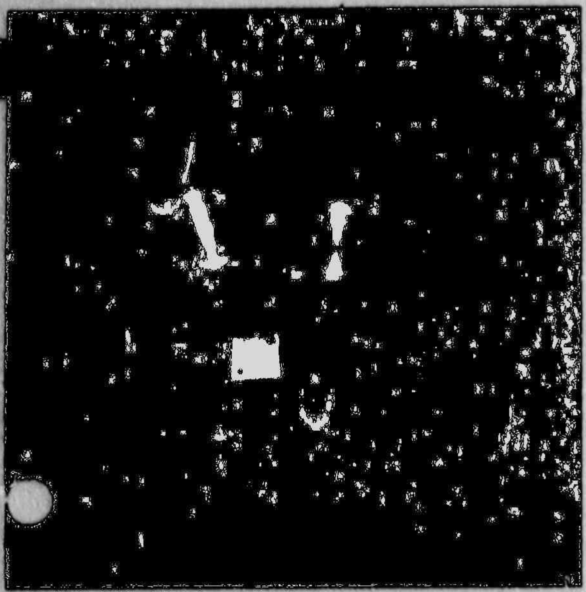
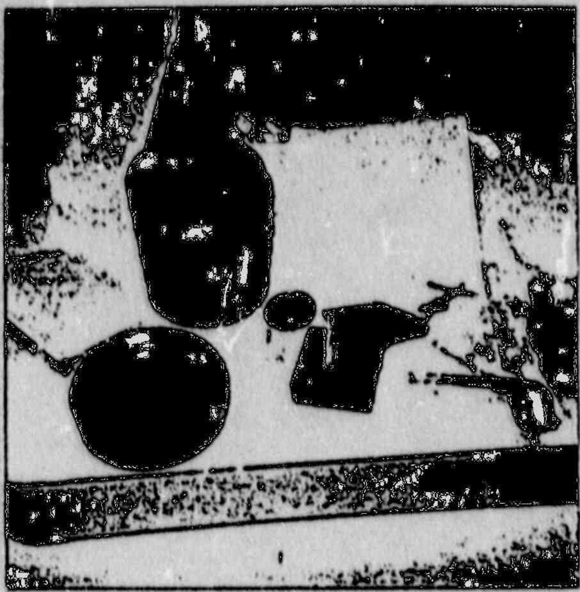


Photo 1014 a)



1014 b)

2.10.5 Transport Container Test (TCT) No. 1019

AMERSHAM INTERNATIONAL PLC

PACKAGING GROUP

Transport Container Test No 1019

1. Object

To test the adherence of a plasma sprayed, copper coating (process A132/1, Yard Ltd, Bristol) to stainless steel.

2. Theory

Depleted uranium when heated to temperatures of above 760°C may form an eutectic alloy with stainless steel.

It is intended to use depleted uranium as the shielding material for a container which will carry large quantities of radioactive material. To contain the depleted uranium, it will be encased in stainless steel.

To comply with the IAEA Regulations for the Safe Transport of Radioactive Materials, the container has to undergo the fire test in which temperatures of 800°C may be reached. To prevent possible alloying of the depleted uranium with the stainless steel the inner side of the stainless steel is to be sprayed with a copper spray. There is no known alloying of depleted uranium with copper. The container undergoes the fire test after the other mechanical tests are completed in which the container may buckle, therefore, the copper surface has to stay intact after distortion of the steel.

3. Method

A 13 x 35mm bar of type 316 S12 stainless steel was coated on one side with copper to a depth of 0.1mm by process A132/1. The bar was then bent through 135° to a radius of 50mm so that the coating was subjected to gross stretching.

4. Results

a) The copper spray remained firmly attached to the surface of the stainless steel.

b) No cracking, flaking or peeling of the copper spray was noted.

(see photo 1019 a).

5. Conclusion

The adhesion of the copper spray process as described in 1. is not affected by gross distortion.

R A STUBBS

D W ROGERS

AUGUST 1987

Photo 1019 a)

2.10.6 Transport Container Test (TCT) No. 1043

AMERSHAM INTERNATIONAL PLC

PACKAGING GROUP

Transport Container Test No 1043

1. Object

To investigate the effect of welding near a copper coating 0.1mm thick, Plasma sprayed (Process A132/1, Yard Ltd, Bristol), on a stainless steel 316/S12 bar.

2. Theory

Depleted Uranium when heated to temperatures of above 750'C may form a eutectic alloy with stainless steel.

It is intended to use depleted uranium as the shielding material for a container which will carry large quantities of radioactive material. To contain the depleted uranium, it will be encased in stainless steel.

To comply with the IAEA regulations for the safe transport of radioactive material the container has to undergo the fire test in which temperatures of 800'C may be reached. To prevent the alloying of the depleted uranium with the stainless steel,the inner side of the stainless steel is to be sprayed with a copper spray. There is no known alloying of copper with depleted uranium.

The container is a welded fabrication and the components are copper sprayed on the inside before welding. Welding should therefore not adversly affect the copper spray.

3. Method

A 13 x 35 mm bar of type 316/S12 stainless steel was coated on one side with copper to a depth of 0.1mm by process A132/1. Two welds tried on the bar , they were:-

i) a "V" weld preparation to a depth of approx. 5mm was made in the non copper sprayed side . A run of weld was put in the "V" using the tungsten inert gas process at 250 amps.

ii) a run of weld was put on the end of the bar approx. 4mm from the copper sprayed side . The tungsten inert gas process was was used at 250 amps.

4. <u>Results</u>

For Weld i)

a) The copper showed no signs of discolouration. (see photo 1043a)

b) The copper was still firmly adhered to the stainless steel surface. (see photo 1043a)

For Weld ii)

a) The copper showed signs of discolouration upto a distance of 5mm from the end of the weld (see 1043 b)

b) The copper was still firmly adhered to the stainless steel surface. (see 1043 b)

5. <u>Conclusion</u>

Welding of stainless steel using the tungsten inert gas process at 250 amps has no effect on a copper sprayed surface (process A132/1)more than 8mm away from the bottom of the weld. At a distance of 4 mm the copper is discoloured but there is no loss of adhesion.

R A STUBBS R.A. Stubbs.

D W ROGERS D W Rogers.

3 August 1987

2.10.7 Packaging Group Memorandum (PGM) 178

AMERSHAM INTERNATIONAL plc

INTERNATIONAL DIVISION

Packaging Group Memorandum PGM 178

Assessment of Lifting Points on Package Design No 3100A

3100A General Arrangement - Drg No. 0A23525
Outer Framework - Drg. No. 0A23629
Pallet - Drg. No. 0A23628
Body - Drg. No. 0A23526
Closure - Drg. No. 0A23527

A. Description

The package takes the form of a vertical, finned, stainless steel cylinder enclosing depleted uranium shielding elements weighing approximately two tonnes and mounted on a pallet. Access to the flask is prevented by means of a protective cage bolted onto the pallet. The cage is fabricated from stainless angle and mesh, and also serves to provide lifting and tie-down points for the assembly.

B. Assumptions

1. All lifting gear will be four-legged with a maximum included angle of 90°.

2. Loads may be distributed over two of the four lifting points.

3. A handling factor of 2.0 will be assumed togother with a safety factor of 2.0.

C. Calculations (Outer Framework)

The lifting strength of the outer assembly is the minimum of either that of the lifting lugs on top of the outer framework or that of the bolts securing the framework to the pallet.

1. The strength of each of the four lifting lugs is the minimum of either the strength of the weld securing the lug to the frame or the pull-out strength of the shackle boss:

(a) Strength of lug attachment weld (W1)

W1 = A x Sw

where A = area of weld = a x b

where a = width of weld = 5mm
b = length of weld = 2 (120 + 70) = 380mm

thus A = 5 x 380 = 1.90×10^3 mm^2
Sw = weld strength = 8.5kg/mm^2 (0.5 x 0.2% proof strength, BS970 Grade 316 S12)

thus W1 = $1.90 \times 10^3 \times 8.5$ = 16150kg

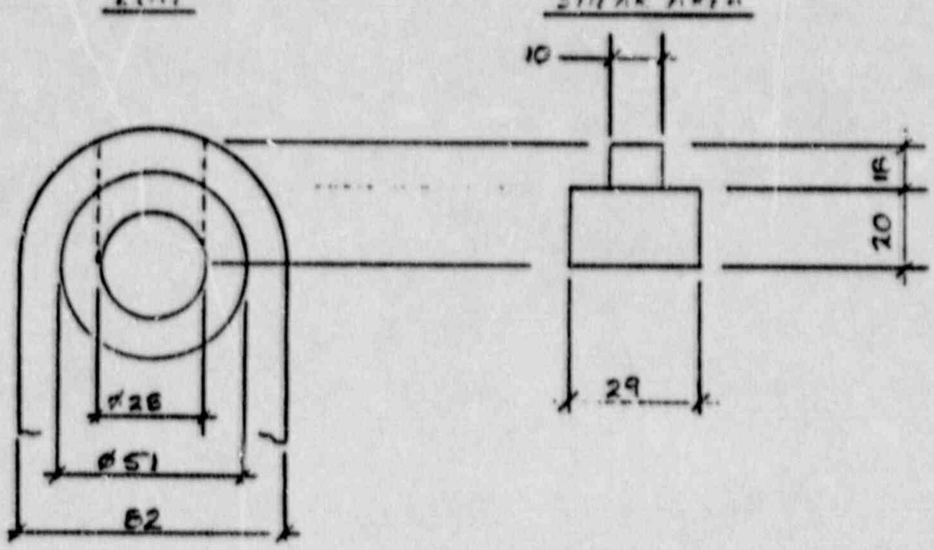
PGM 178/1 (DWR870702)
WPX: PGM2-L4423
July 1987

(b) Pull out strength at shackle boss (W2)

W2 = A x Sw

A = area of material in shear

$= 2((30 \times 20) + (8 \times 10)) = 1.36 \times 10^3\ mm^2$



$Sw = 8.5 kg/mm^2$

thus $W2 = 1.36 \times 10^3 \times 8.5 =$ 11560kg

(c) Minimum strength, W3, of lifting lugs is therefore

$$W3 = \frac{W2 \times N \times \sin y}{Fh \times Fs}$$

where W2 = minimum strength of lifting point = 11560kg
N = number of points load is distributed over = 2
y = minimum angle of sling legs to horizontal = 45°
Fh = handling factor = 2.0
Fs = safety factor = 2.0

$$\text{thus } W3 = \frac{11560 \times 2 \times \sin 45°}{2.0 \times 2.0} = 4090kg$$

2. Strength of frame bolts (W4)

W4 = N x Ab x Sb

where N = number of bolts = 4
Ab = effective cross-sectional area of bolt = $157mm^2$ (M16)
Sb = minimum tensile strength = $80kg/mm^2$ (BS3692)

thus W4 = 4 x 157 x 80 = 50240kg

D. Calculation (Flask)

1. The strength of each of the lifting lugs is the minimum of the strength of the weld securing the lug to the body and the pull out strength of the shackle boss:

(a) Strength of lug attachment weld (W5)

W5 = A x Sw

where A = area of weld = a x b

where a = width of weld = 5mm
b = length of weld = 2 x 825 = 1650mm

thus A = 5 x 1650 = 8250mm^2
Sw = weld strength = 8.5kg/mm^2

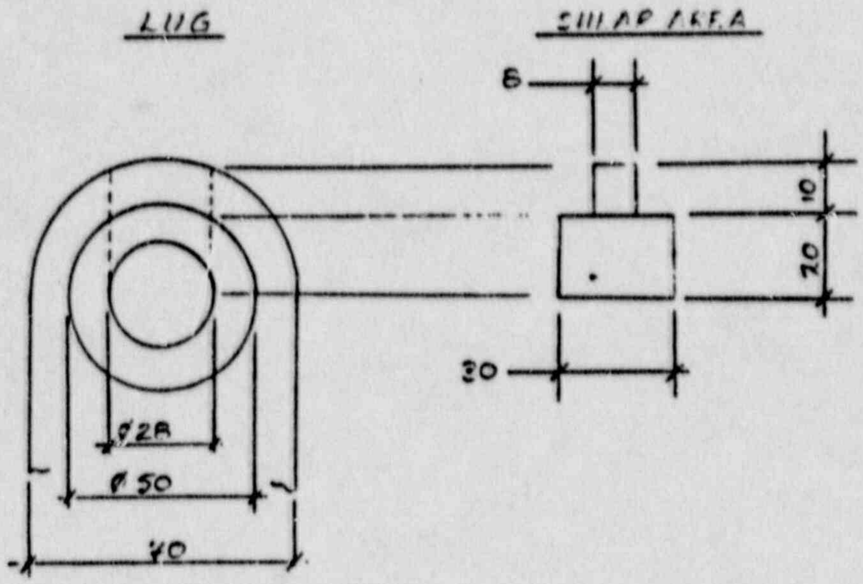
thus W5 = 8250 x 8.5 = <u>70100kg</u>

(b) Pull out strength of shackle boss (W6)

W6 = A x Sw

where A = area of material in shear

= 2 ((29 x 20) + (10 x 18)) = 1520mm^2



Sw = material shear strength = 8.5kg/mm^2

thus W6 = 1520 x 8.5 = <u>12920kg</u>

The flask may be lifted either by a lifting eye at the top of the four thick fins or by an eyebolt screwed into the centre of the closure.

(c) Minimum strength, W7, of the lifting lugs is therefore

$$W7 = \frac{W6 \times N \times \sin y}{Fh \times Fs}$$

where W6 = minimum strength of each lifting lug = 12920kg
N = number of points load is distributed over = 2
y = minimum angle of sling legs to horizontal = 45°
Fh = handling factor = 2.0
Fs = safety factor = 2.0

thus $$W7 = \frac{12920 \times 2 \times \sin 45°}{2.0 \times 2.0} = \underline{4560kg}$$

(d) Strength M30 eyebolt = 4500kg

E. Conclusions

The maximum safe loads that the lifting points on Package Design No. 3100A can withstand are:

Outer framework lifting lugs	= 4090kg
Pallet/framework bolts	= 50240kg
Flask lifting lugs	= 4560kg
Closure eyebolt	= 4500kg

The gross weight of the package is 2570kg, therefore all the lifting points possess adequate strength.

Author: D W Rogers

Signed: D W Rogers

Date: 2/7/87

2.10.8 Packaging Group Memorandum (PGM) 215

PACKAGING GROUP MEMORANDUM - PGM 215

Performance of Package Design No. 3100 Tie-down Features under Normal Conditions of Transport

3100 General Arrangement	Drg. No. 0A23525
Outer Framework	Drg. No. 0A23629
Pallet	Drg. No. 0A23428
Body	Drg. No. 0A23526

A. INTRODUCTION

Both the outer framework and the flask inside must be provided with tie-down elements sufficiently strong to withstand normal conditions of transport. The conditions are taken from the 'Advisory Material for the Application of the IAEA Transport Regulations', 2nd Edition, Safety Series No. 37, IAEA, Vienna 1982', and are as follows:

Mode/Acceleration

	Longitudinal	Lateral	Vertical	
Road	2g	2g	3g	
Sea	2g	2g	2g	
Air	3g	1.5g	3g	
Maximum	3g	2g	3g	
Load (kg)	7710	5140	7710	(Package weight 2570kg)

B. ASSESSMENT

1. External tie-down

Three tie-down lugs are provided half-way up each of the four corners on the framework. In this way forces act about the centre of gravity and any toppling moments are minimised. All loads are transmitted through the framework, the lower half of which is heavily braced, into the pallet on which the flask is mounted.

(a) Corner brackets

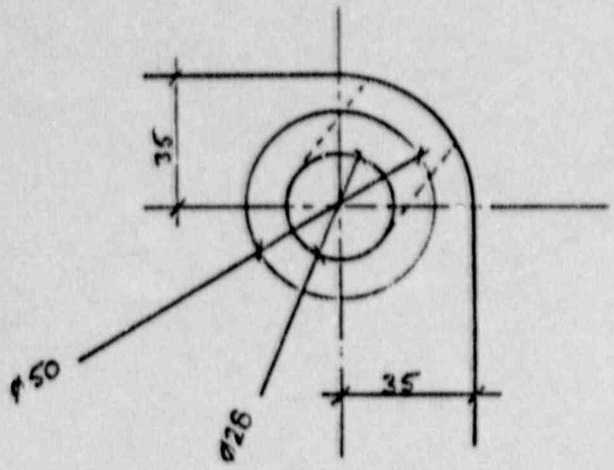
Each of the three lugs on each bracket may be considered to be taking one of the principle tie-down loads. In the horizontal directions the loads always split between two brackets, whilst in the vertical direction the load is split between four lugs.

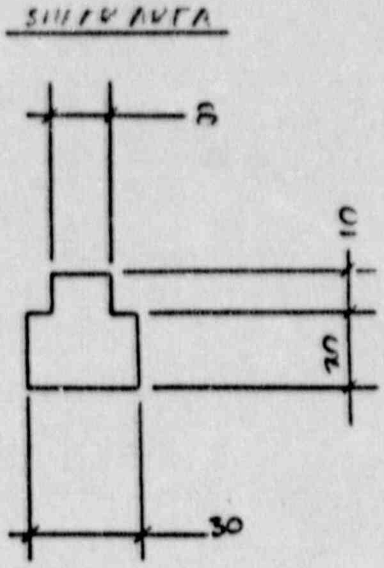
(i) Longitudinal restraint (G1)

This is a function of the lug strength which is the smaller of either the pull-out strength of the eye or the strength of the lug attachment weld.

where A = cross-sectional area of material in shear

$= 2\ (\ 20 \times 30) + (10 \times 8)) = 1360mm^2$





S = material sheer strength = $8.5kg/mm^2$ (0.5 x 0.2% proof stress) (BS970 Grade 316512)

thus W1 = 1360 x 8.5 = <u>11560kg</u>

Weld strength (W2) = A x S

where A = l x t

where l = weld length = 2 (100 + 80) = 360mm

t = weld thickness = 5mm

thus A = 5 x 360 = $1800mm^2$

thus W2 = 1800 x 8.5 = <u>15300kg</u>

Lug strength therefore = W1 = <u>11560kg</u>

Total longitudinal restraint, G1 = N x W x cos a

where N = number of lugs load is spread over = 2

W = lug strength = 11560kg

a = angle of lug from horizontal = 20°

b = angle of tie-down from side of frame = 45°

thus G1 = 2 x 11560 x cos 20 x cos 45 = <u>15300kg</u>

(ii) Lateral restraint (G2)

The lateral restraint is the same as the longitudinal restraint, thus G2 = G1 = 15300kg.

(iii) Vertical restraint (G3)

This is a function of the lug strength which is the smaller of either the eye pull-out strength or the strength of the lug attachment weld.

Pull-out strength (W3) = W1 (as before) = 11560kg.

Weld strength (W4) = A x S

where A = weld area = l x t

where l = weld length = 2(132 + 80) = 424mm

t = weld thickness = 5mm

thus A = 424 x 5 = 2120mm^2

S = weld strength = 8.5kg/mm^2

thus W4 = 2120 x 8.5 = 18020kg.

Lug strength therefore = W? = 11560kg.

Total vertical restraint, G3 = N x W x cos a

where N = number of lugs loaded = 4

W = lug strength = 11560kg

a = angle of tie-down from vertical = 45°

thus G3 = 4 x 11560 x cos 45 = 32700kg.

(b) Outer framework to pallet fastening.

The framework is attached to the pallet by means of four bolts and two guides. All tie-down loads are transmitted through these points as horizontal shearing forces.

Shear strength of bolts W5 = N x A x S

where N = number of bolts = 4

A = effective cross-sectional area of bolt = 157mm^2. (M16)

S = shear strength of material = 0.5 x St

St = tensile strength = 80kg/mm^2 (BS3692, Grade 8.8)

thus S = 0.5 x 80 = 40kg/mm^2

thus W5 = 4 x 157 x 40 = 25120kg.

Shear strength of guides, $W6 = N \times A \times S$

where N = number of guides = 2

A = effective area of guide = $\frac{3.142 \times D^2}{4}$

D = guide diameters = 19mm

thus $A = \frac{3.142 \times 19^2}{4} = 283mm^2$

S = guide sheer strength = 0.5 x St

St = tensile strength = $20kg/mm^2$ (BS970, 321S12)

thus $S = 0.5 \times 20 = 10kg/mm^2$

thus W6 = 2 x 283 x 10 = 5670kg.

Thus total shear strength of framework to pallet fastenings (G4)

= W5 + W6 = 25120 + 5670 = 30790kg.

2. Internal tie-down

The flask is bolted onto the pallet through its feet. The strength of these fastenings is the smaller of the bolt strength or the weld attaching the foot to the body.

(a) Flask foot strength

(i) Bolt strength, W7 = N x A x S

where N = number of bolts = 2

A = effective area of bolt = $157mm^2$ (M16)

S = bolt strength = $80kg/mm^2$ (BS3692, Grade 8.8)

thus W7 = 2 x 157 x 80 = 25100kg.

(ii) Foot weld strength, W8 = A x S

where A = weld area = l x t

where l = weld length = 2 x 103 = 206mm

t = weld thickness = 10mm

thus $A = 2060mm^2$

S = weld shear strength = $8.5kg/mm^2$

thus W8 = 2060 x 8.5 = 17500kg.

(iii) Flask foot strength is thus 17500kg in vertical tension. The horizontal shear strength is also 17500kg as the weld strength has already been taken as its strength in shear.

$G5 = N \times W8$

where N = number of feet = 4

$W8$ = foot strength = 17500kg

thus $G5 = 4 \times 17500 = $ <u>70000kg</u>.

(c) Longitudinal load capacity (G6)

Here the acceleration produces a moment which puts opposite feet in tension and compression. To simplify the analysis the load is assumed to be orientated through diagonally opposite feet and the contribution made by the remaining pair of feet is ignored.

$$G6 = W8 \times \frac{D}{H}$$

where D = distance between diagonally opposite feet = 560mm

H = height of flask centre of gravity = 480mm

thus $G6 = 17500 \times \frac{560}{480} = $ <u>20400kg</u>.

(d) Lateral load capacity (G7)

This is the same as the longitudinal load capacity, thus G7 = G6 = <u>20400kg</u>.

3. <u>CONCLUSIONS</u>

(a) The strength of the various elements of the 3100 structure under tie-down loads is as follows:

	Longitudinal	Lateral	Vertical
Frame corner brackets (kg)	15300	15300	32700
Frame to pallet fastening (kg)	30790	30790	N/A
Flask to pallet fastening (kg)	20400	20400	70000
Minimum strength (kg)	15300	15300	32700
Minimum requirements (kg)	7710	5140	7710

(b) The minimum factor of safety is therefore $\frac{15300}{7710} = 1.98$

(c) In the event of the loads exceeding normal limits the first elements to fail would be the eyes on the frame corner brackets; thus the package structure would remain intact.

(d) The strength of both external and internal tie-down elements of Package Design No. 3100A comfortably exceed the requirements for road, sea and air transport, as specified in Safety Series 37, 2nd Edition, IAEA, Vienna, 1982.

Author: D W Rogers

Signed: D W Rogers

Date: 5/9/87

PGM 215/1 (DWR870702)
WPX: PGM2-L473
July 1987

2.10.9 Packaging Group Memorandum (PGM) 189

Packaging Group Memorandum, PGM 189

Assessment of Package Design No. 3100A in IAEA Compression Test

GA 3100A	- Drawing No.	0A23525
Outer Framework	- Drawing No.	0A23629
Pallet	- Drawing No.	0A23428

A. Description

The package takes the form of a vertical, finned, stainless steel cylinder weighing approximately two tonnes, mounted on a pallet. Access to the flask is prevented by means of a protective cage bolted on to the pallet. The cage is fabricated from stainless angle and mesh, and also serves to provide lifting and tie-down points for the assembly.

B. Assessment Criteria

1. The maximum safe loads in structural sections are taken from BS 449, 1969, Part 2, Appendix B.

2. The compression load is assumed to be spread evenly over the four vertical members of the cage.

3. The mesh between the members is disregarded as contributing to their strength.

C. Calculations

1. Test load (Wt)

   Wt is the greater of

   (a) Five times package gross weight

   $$5 \times 2570 = 12850\text{kg}$$

   (b) 1300kg/m^2 over vertically projected area

   $$1300 \times 1.1 \times 1.1 = 1573\text{kg}$$

   $\therefore$ Wt = 12850kg.

2. Package strength (Wp)

   Wp is the compressive strength of four pieces of 60 x 60 x 6mm stainless steel angle of maximum free length 650mm

   $$Wp = 4 \times 40000 = 160000\text{kg.}$$

3. Safety factor (Fs)

   $$Fs = \frac{Wp}{Wt} = \frac{160000}{12850} = 12.5$$

D. Conclusions

Package Design No. 3100A has ample strength to meet the requirements of the IAEA compression test for Type B(U) packages.

Author: D W ROGERS

Signed: D W Rogers

Date: 7/7/87

2.10.10 Transport Containter Test (TCT) No. 1028

AMERSHAM INTERNATIONAL PLC

PACKAGING GROUP

Transport Container Test No 1028

1. Test

9 m drop followed by 1 m punch followed by 9 m drop.

2. Assembly

Package design number 3100A (as specified in drawing OA 23665 issue D, modifications from issue C as detailed in sketch no PGS 001) containing a dummy source (stainless steel bar Ø 30 x 150 long). Briefly, modifications consisted of:

1. Addition of fins around securing bolts on the closure.
2. Machining of 30° chamfer on top of lid flange.
3. Spigotting of DU into lid flange.
4. Increase spigotting of lid flange into body.

Weight of assembly = 82 kg.

3. 9 m Drop Test

The assembly was allowed a single fall through 9 m. It was positioned to impact on the top rim of the body midway between two of the thicker fins with the C of G directly above the point of impact (photos A, B and C).

4. 1 m Punch Test

The assembly was allowed a single fall through 1 m on to the target (5 cm diameter, flat ended, mild steel bar mounted perpendicularly on a flat steel plate and of sufficient length to cause maximum damage to the specimen). It was positioned to impact upside down on the edge of the lid, so as to knock the lid/closure off (photos D, E, F, G, H and J).

5. 9 m Drop Test

The assembly was allowed a single fall through 9 m. It was positioned with the closure angled down from horizontal by approximately 10° (photos K and L).

6. Results

1st 9m Drop

The shock absorbers on the closure were bent and flattened (photos M, N, P, R, S, T, U and V). The body was otherwise relatively undamaged ie. slight bending of fins and scuffing of the jacket. Damage to the target area was slight (photo W).

Punch Test

Damage sustained by the body was limited to very minor denting of the closure rim and two adjacent fins (photos X, Y and Z). Damage to the target was slight (photos AA).

2nd 9m Drop

Severe deformation of the jacket and fins occurred, bending and flattening on impact (photos AB, AC, AD). The core of the body and the integrity of the skin, however, were unaffected and the closure remained securely attached.

7. Conclusion

The assembly meets the requirements of the 9 m drop test for Type B (U) packages (paras 719 (a) and (b) IAEA "Regulations for the Safe Transport of Radioactive Materials, 1973 ").

M Baynes MH Baynes

D W Rogers DW Rogers

28 May 1987

Transport Container Test No 1028

Photo A

Transport Container Test No 1028

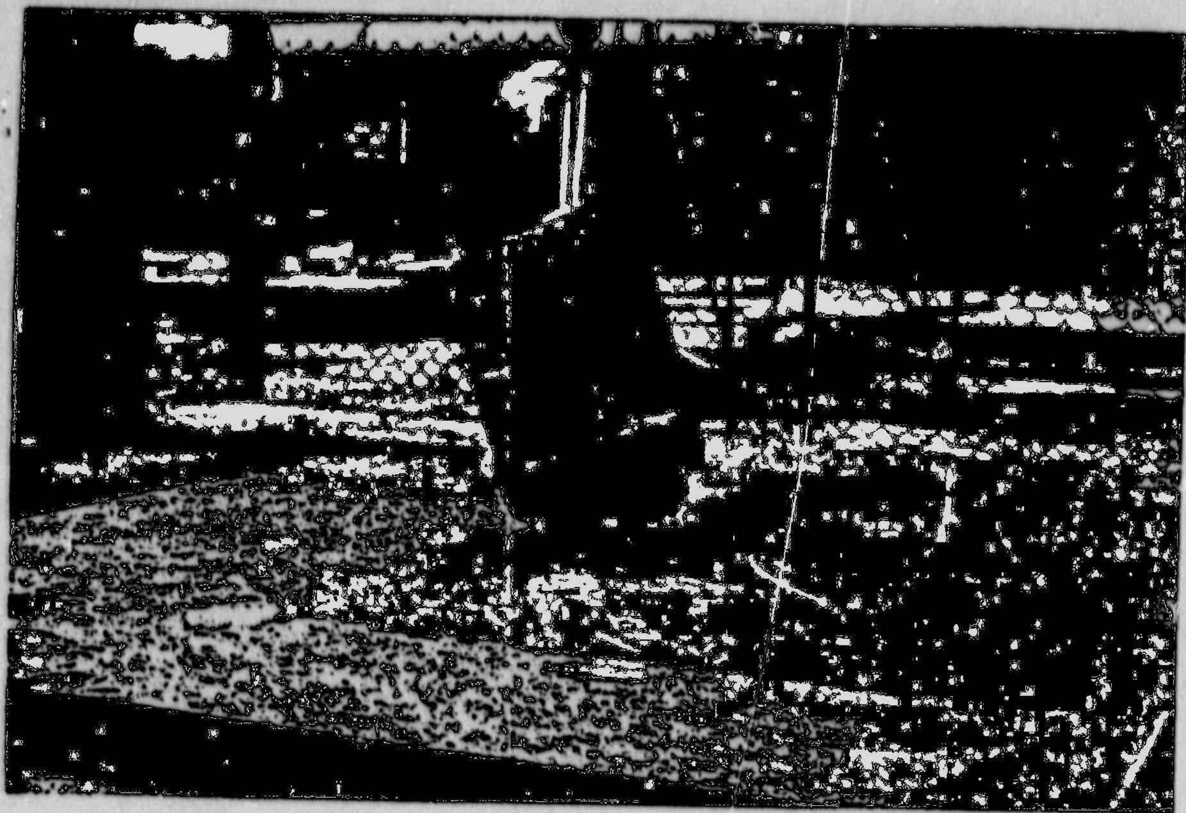


Photo B

Amersham International plc

<u>Transport Container Test No 1028</u>

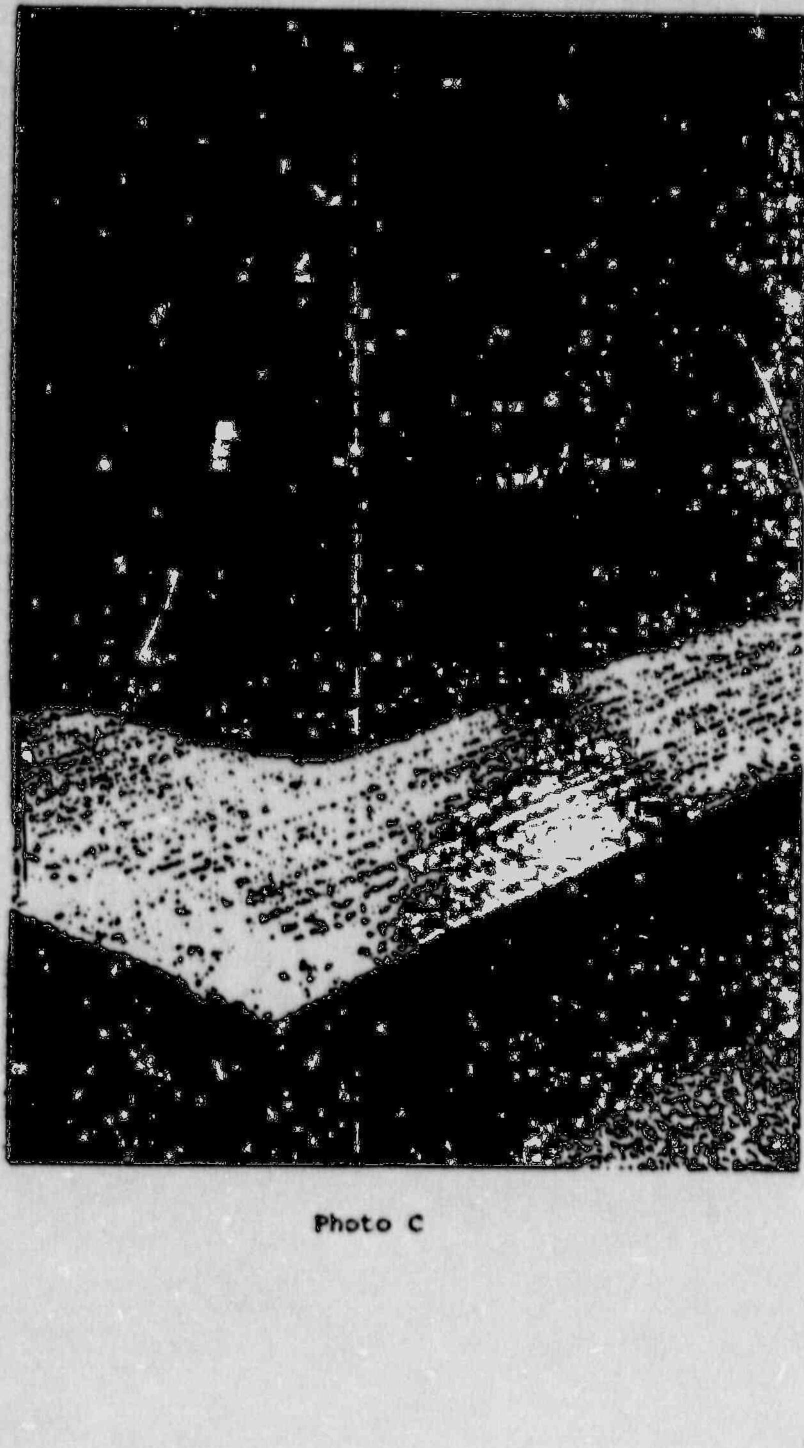


Photo C

Transport Container Test No 1020

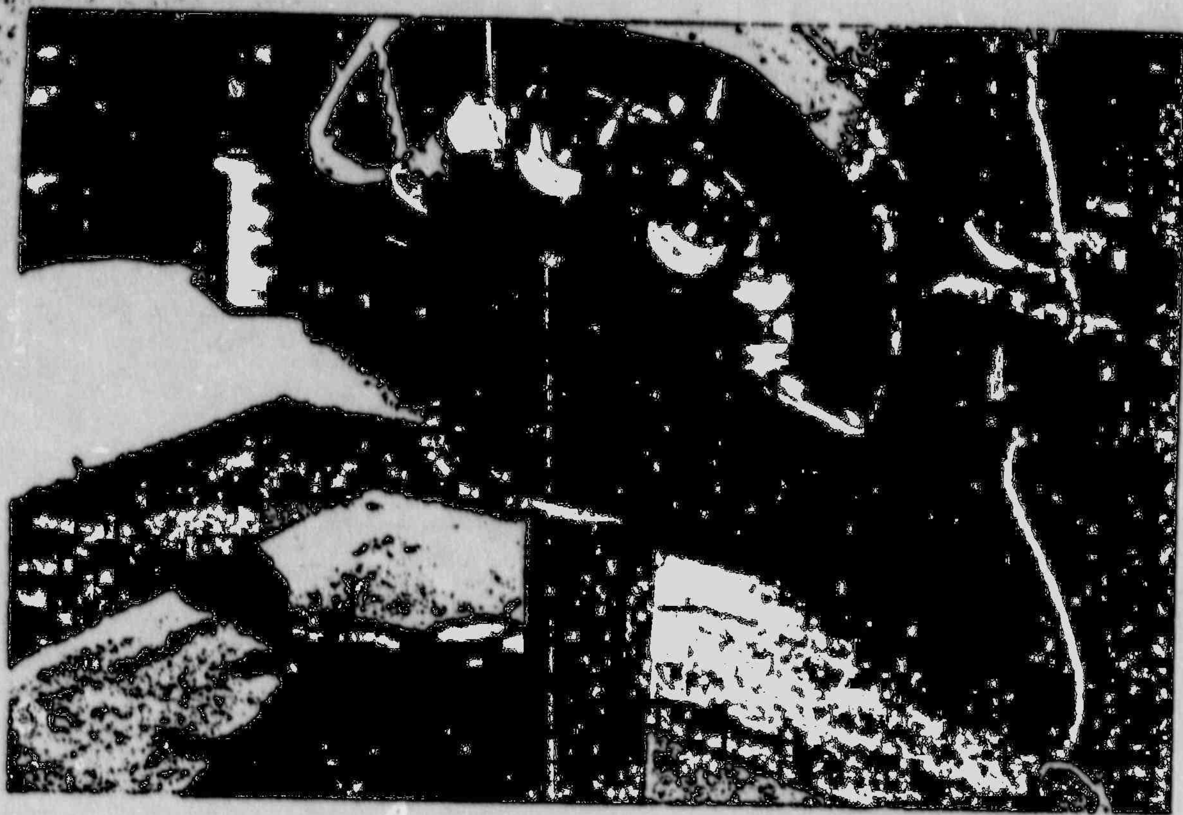


Photo D

Amersham International plc

Transport Container Test No 1028

Photo E

Transport Container Test No 1028

Photo F

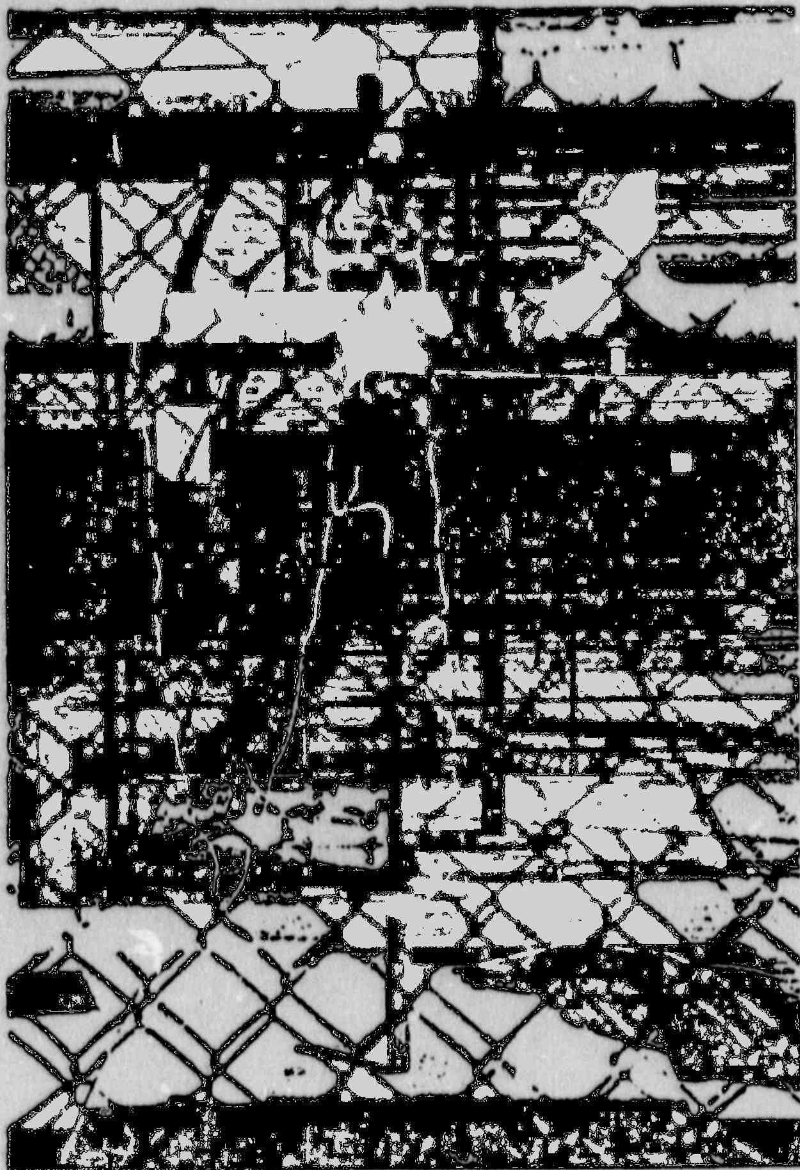


Photo G

Transport Container Test No 1028

Photo H

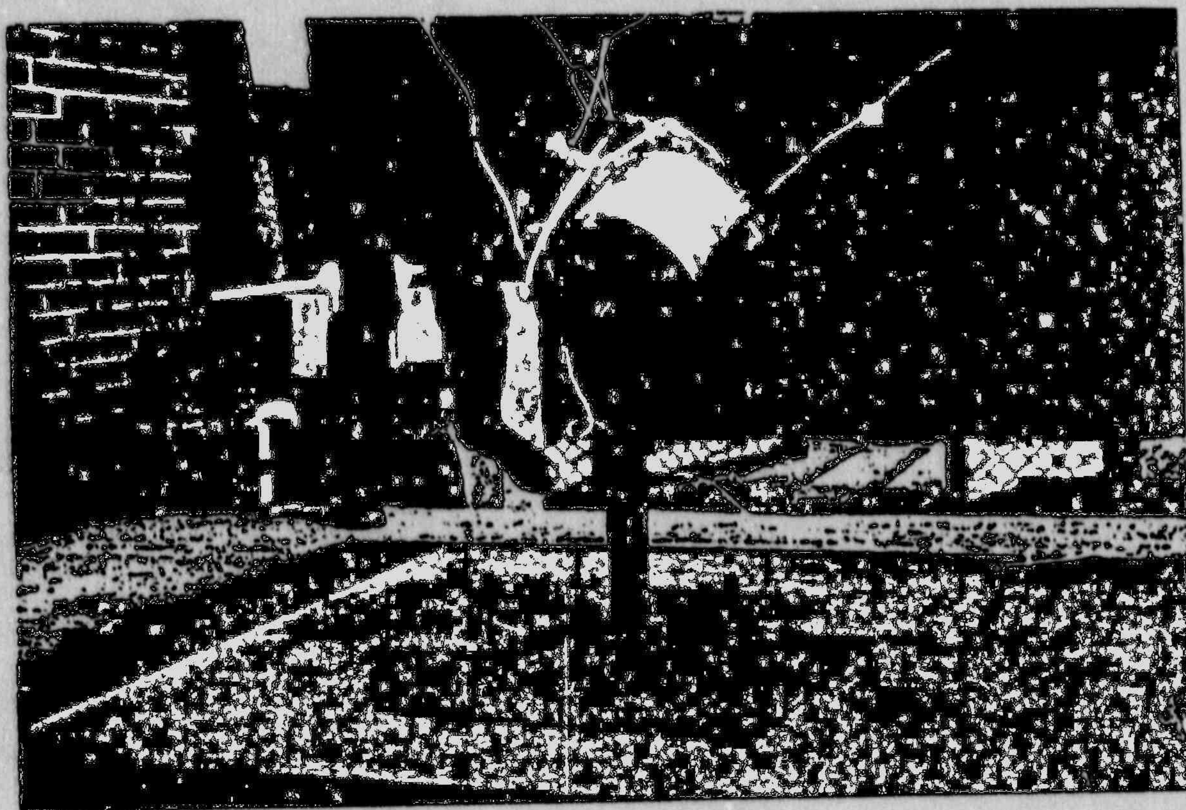


Photo J

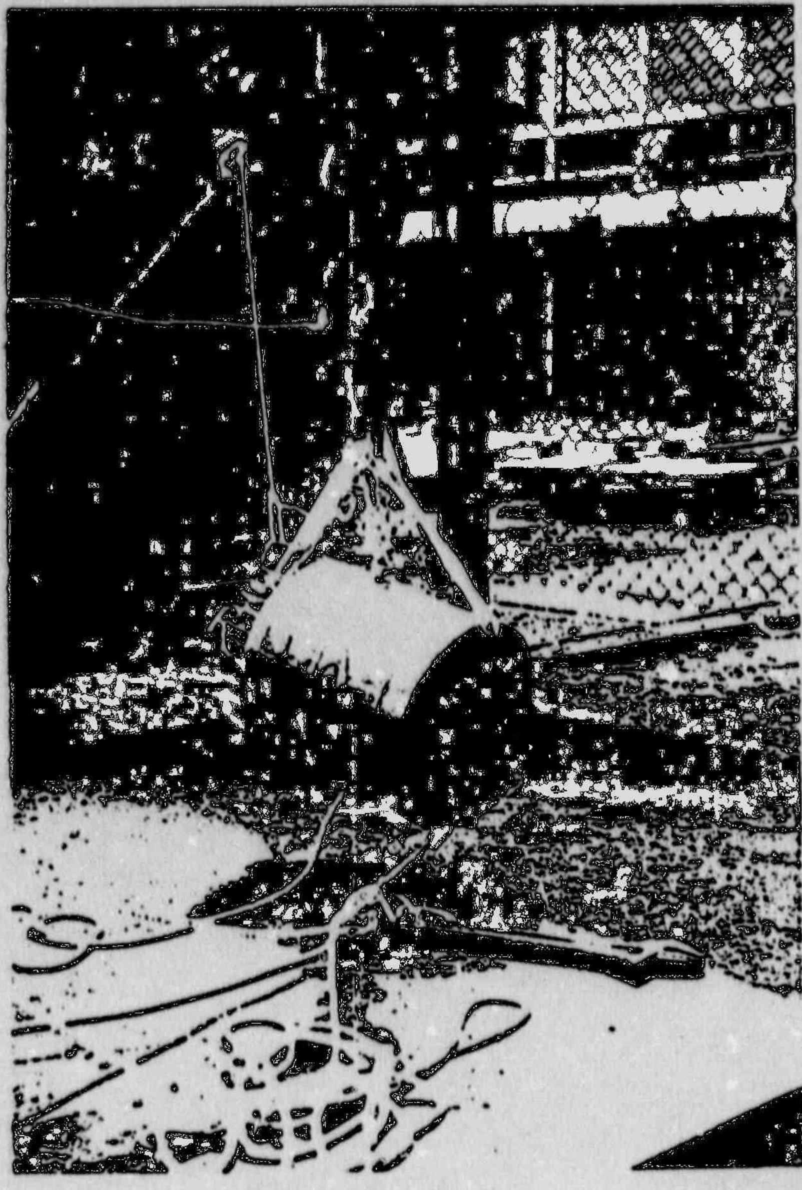


Photo K

Transport Container Test No 1028

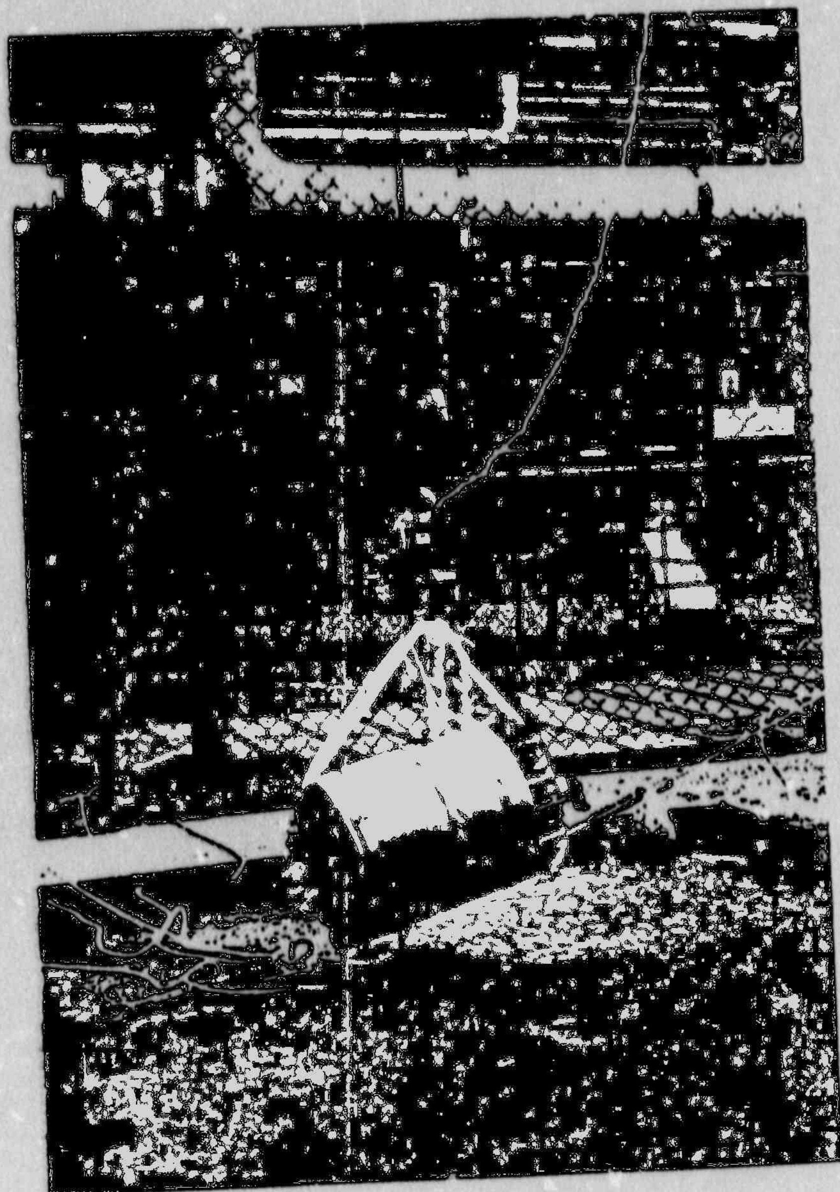


Photo L

Transport Container Test No 1028

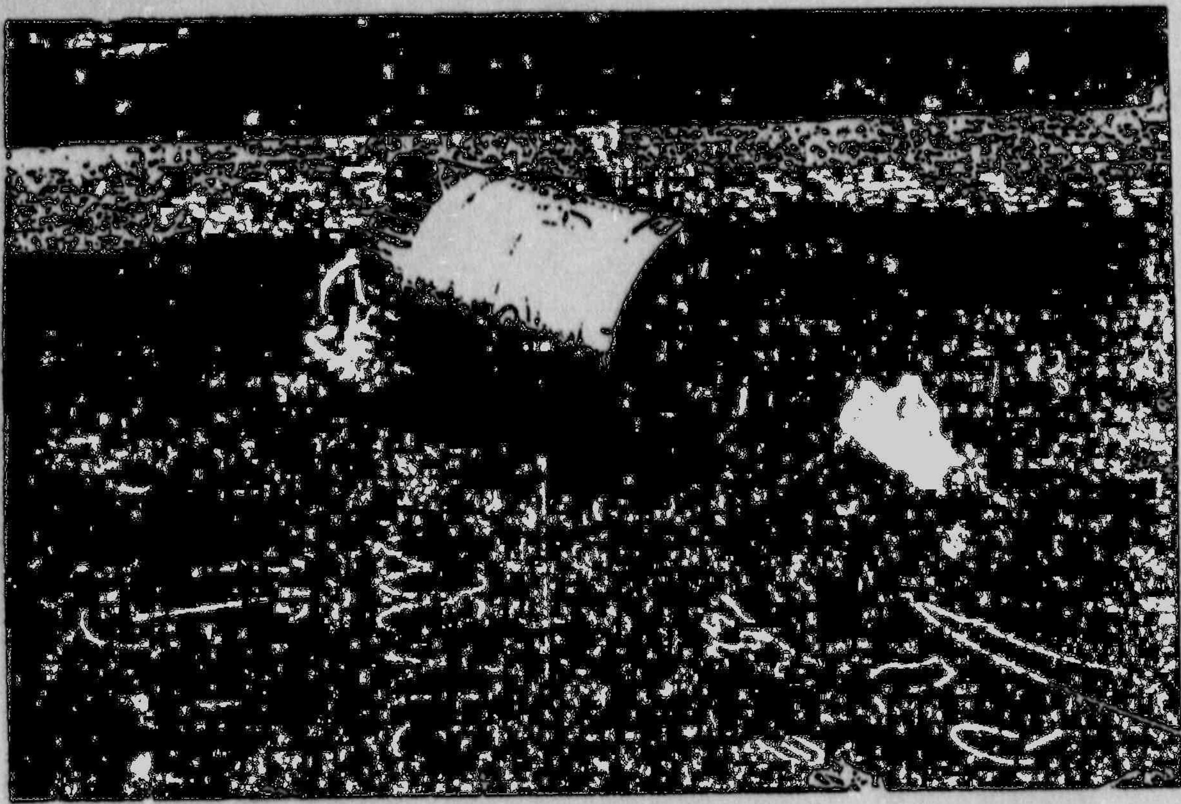


Photo M

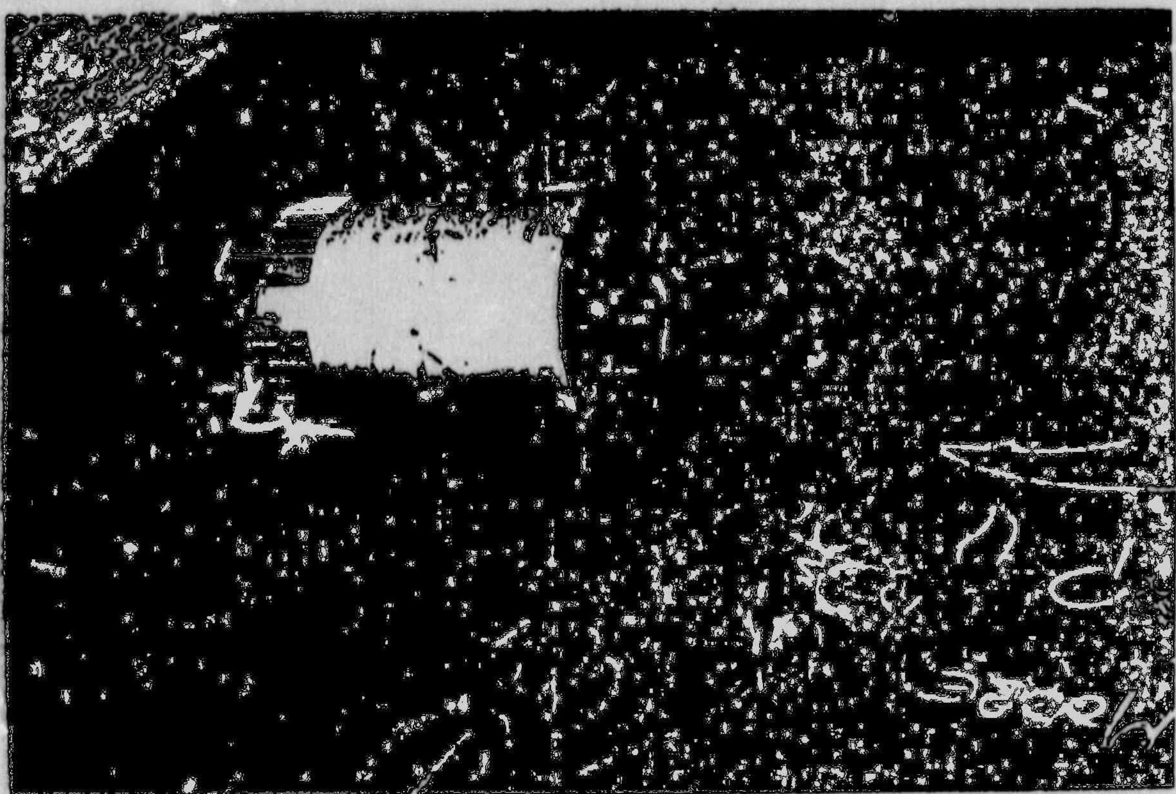


Photo N

Transport Container Test No 1028

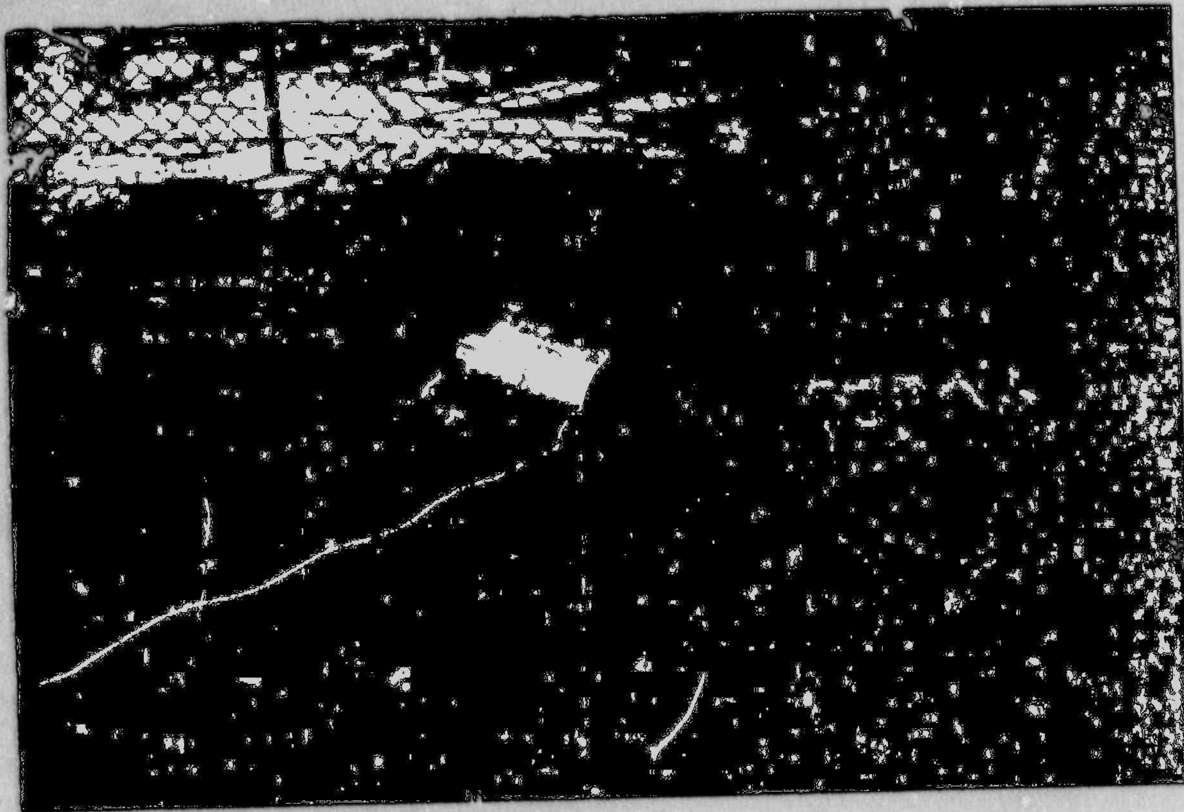


Photo P

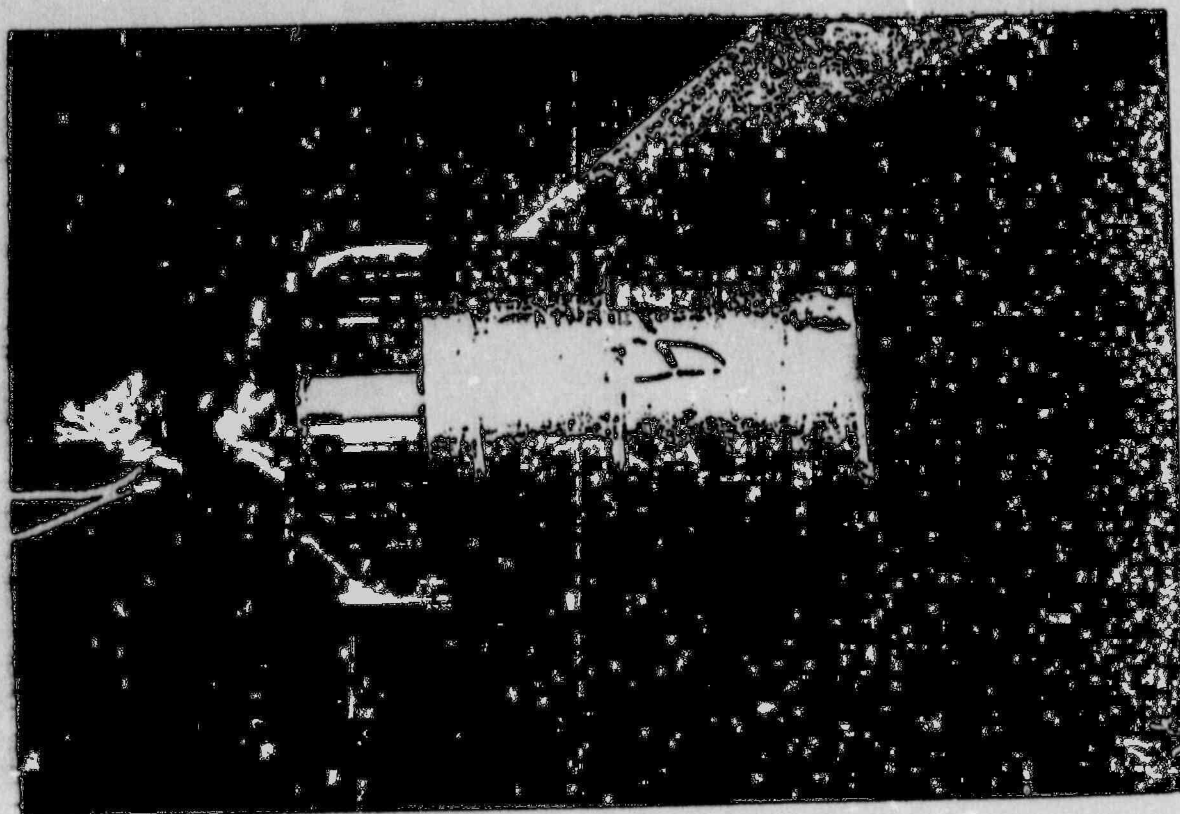


Photo R

Transport Container Test No 1028

Photo S

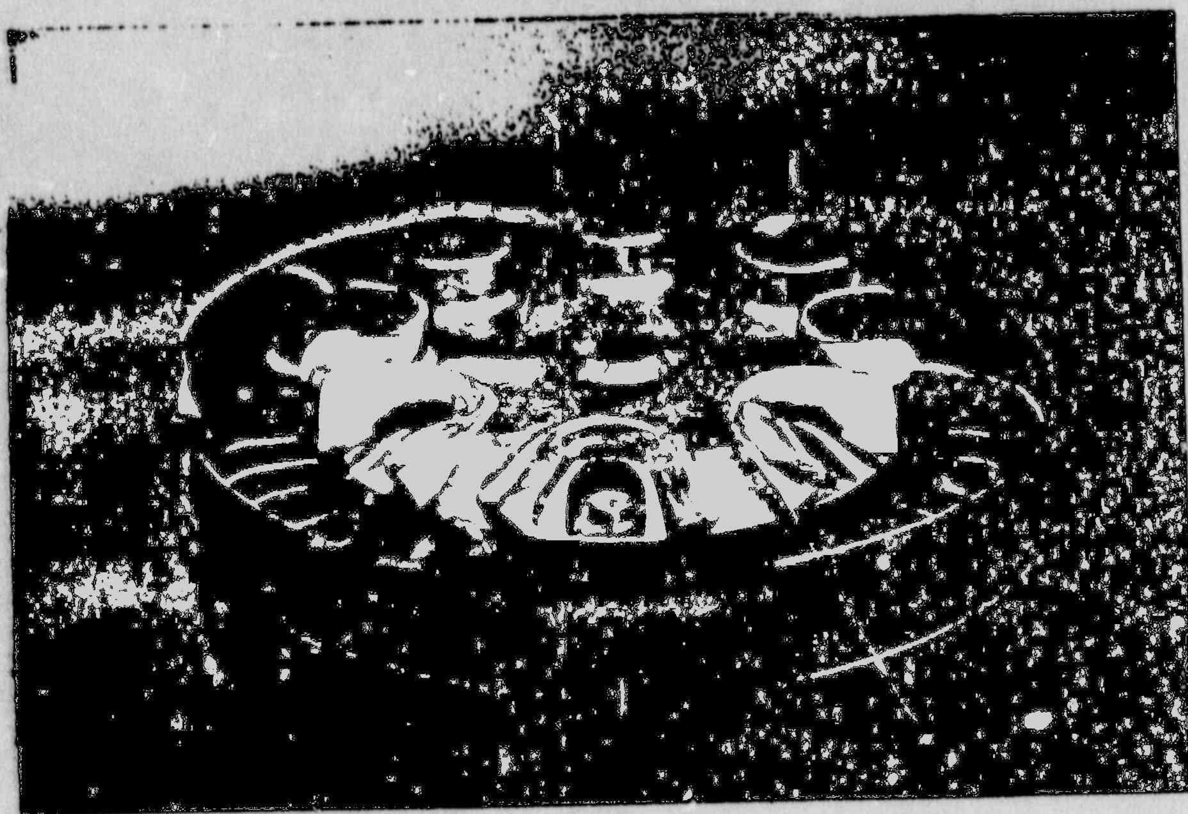


Photo T

Transport Container Test No 1028

Photo W

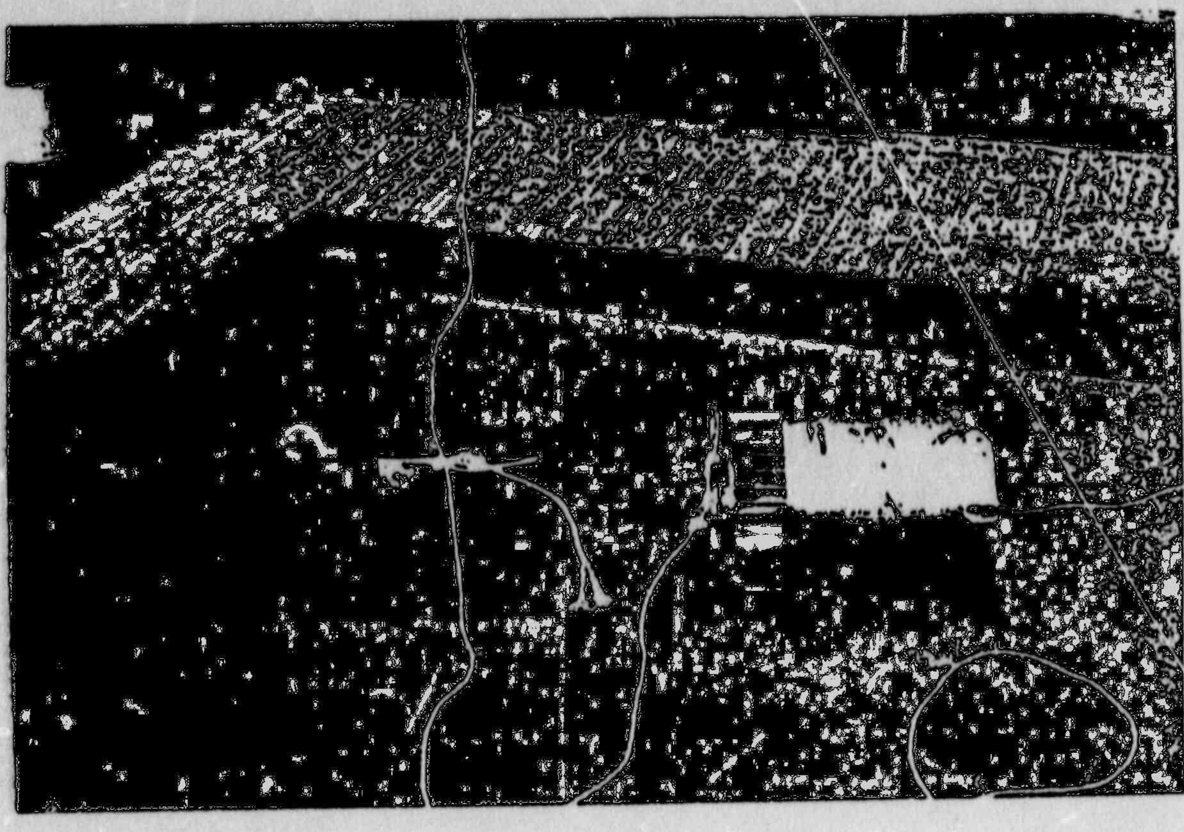


Photo X

Transport Container Test No 1028

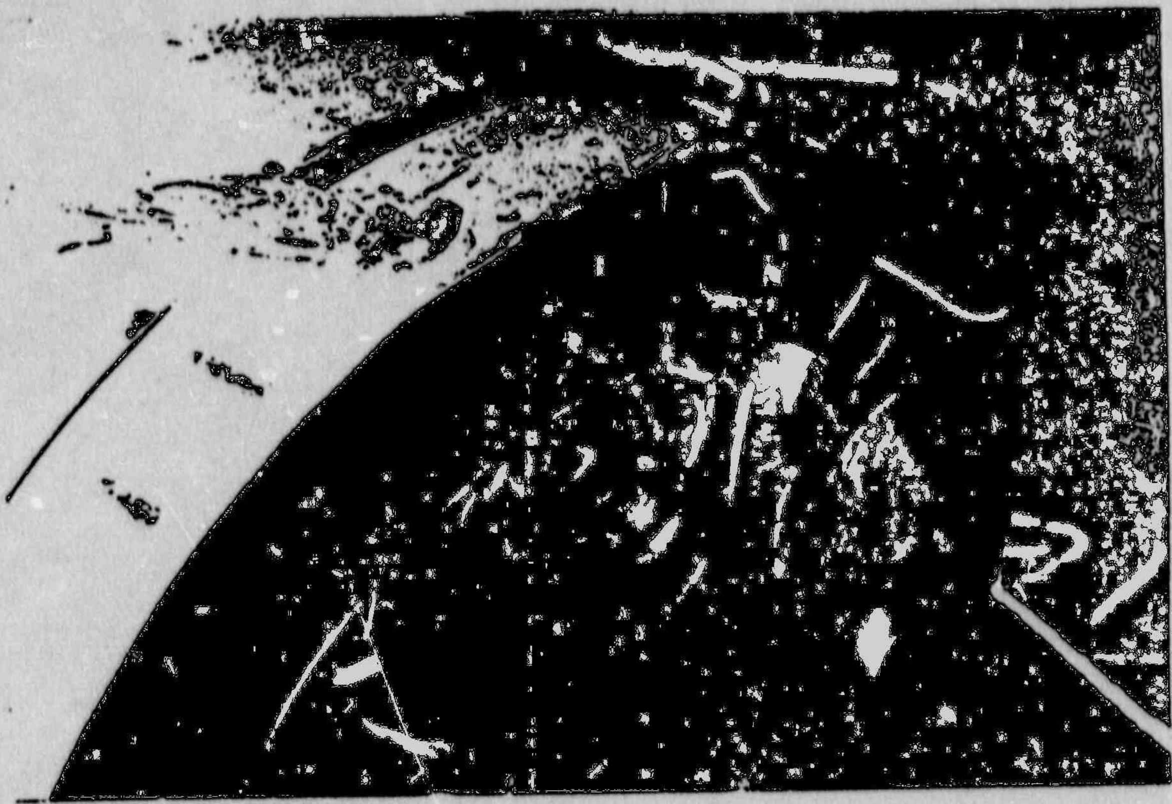


Photo Y

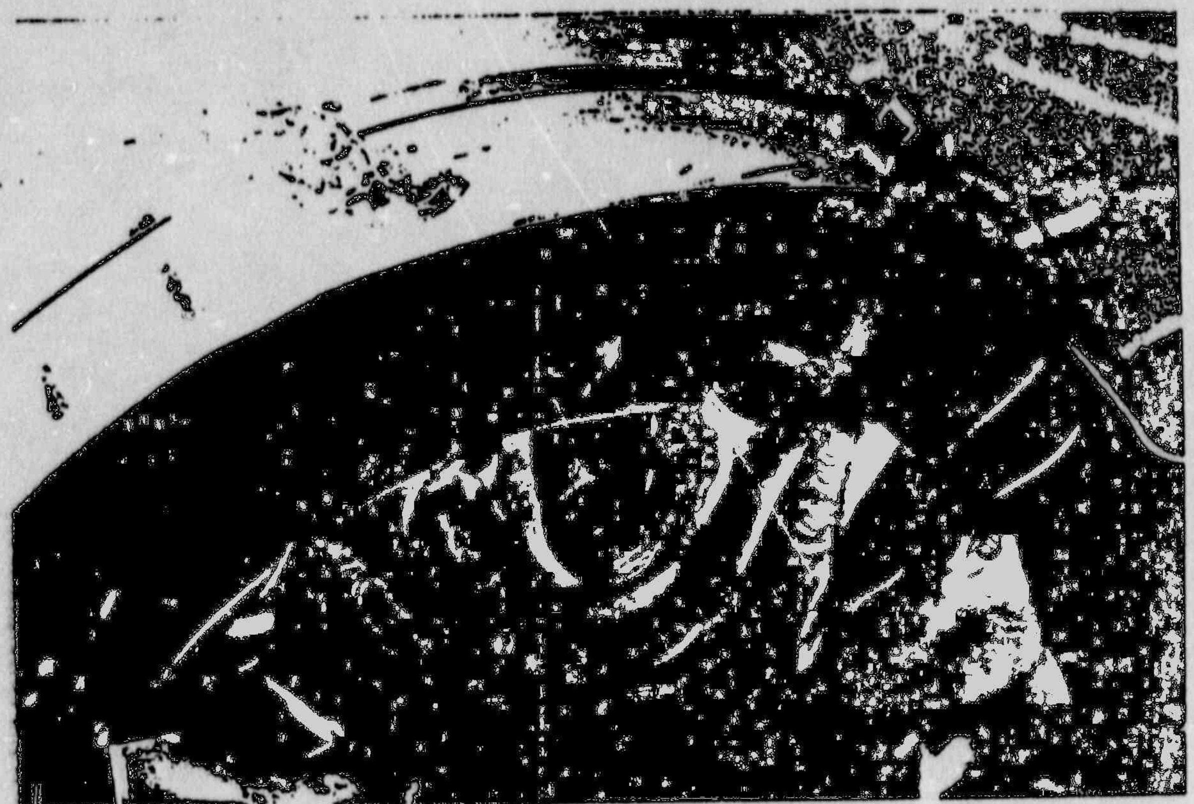


Photo Z

Transport Container Test No 1028

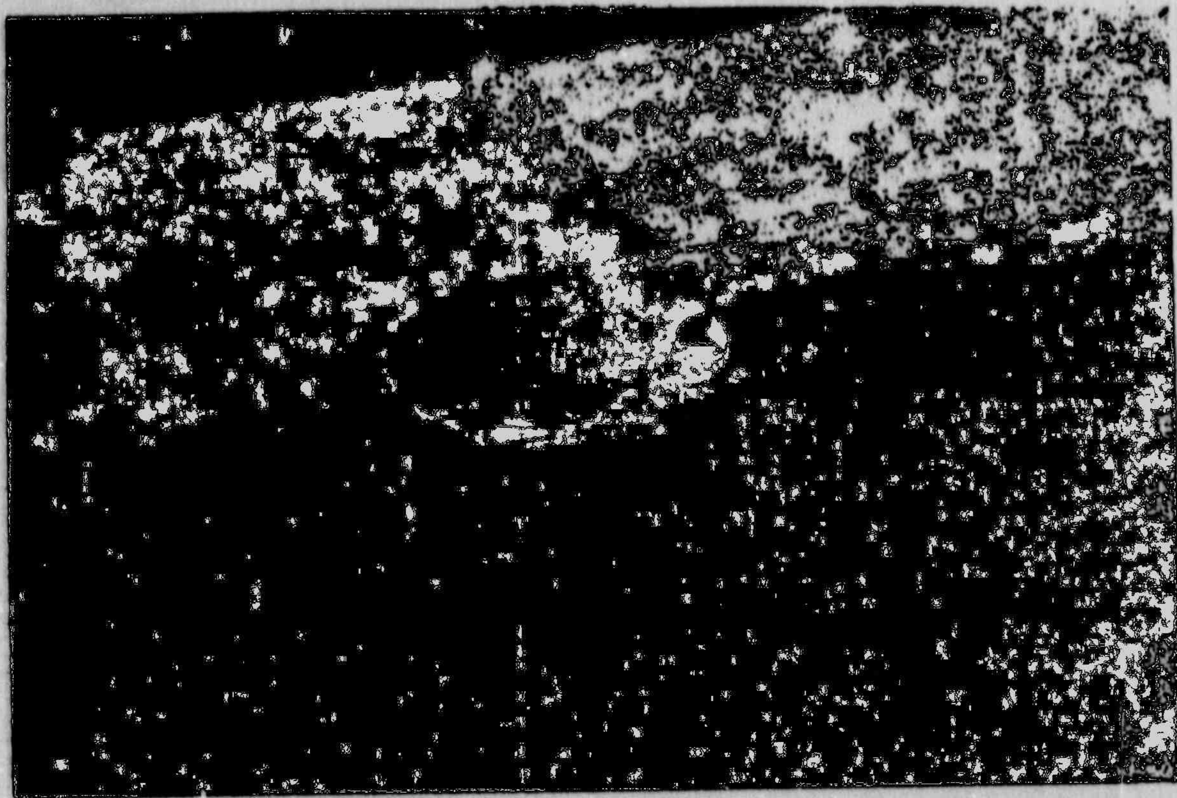


Photo AA

Photo AB

2.10.11 Transport Container Test (TCT) No. 1027

AMERSHAM INTERNATIONAL PLC

PACKAGING GROUP

Transport Container Test No 1027

1. Test

9 m drop.

2. Assembly

Package design number 3100A. Assembly consisting of the body, outer framework and pallet as specified in drawing OA 23665 issue C (photos a and b) containing a dummy source (stainless steel bar ø 30 x 150 long).

Weight of assembly = 93 kg.

3. 9 m Drop Test

The assembly was allowed to fall through 9 m. It was positioned to impact on the base edge of the open side of the pallet with the C of G of the assembly directly above the line of impact (see photos c and d).

4. Results

Inspection of the assembly for damage, as a result of testing, was carried out by eye.

The pallet was flattened on the edge where impact occurred and the framework was slightly bent and buckled. The container body broke free from the pallet, rotating through 90° onto its side. It was however retained within the frame structure (photos e, f, g, h and j). Two of the container feet were bent, but this did not affect the weld around the base of the container (photos k and l). Any other damage to the body was purely superficial, ie. slight bending of fins , etc.

5. Conclusion

The assembly meets the requirements of the 9 m drop test for Type B (U) packages (para 719 (a) IAEA "Regulations for the Safe Transport of Radioactive Materials, 1973 ").

M Baynes MHBaynes

D W Rogers D W Rogers

May 1987

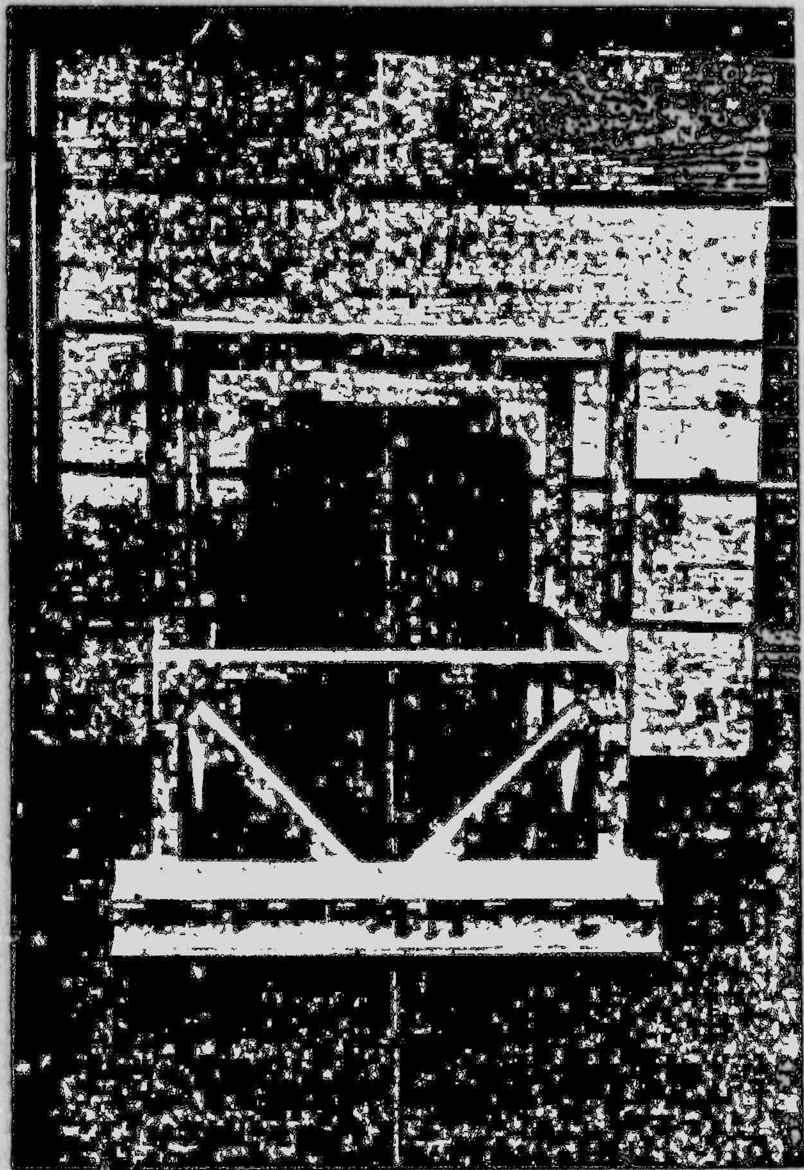


Photo A

Transport Container Test No 1027

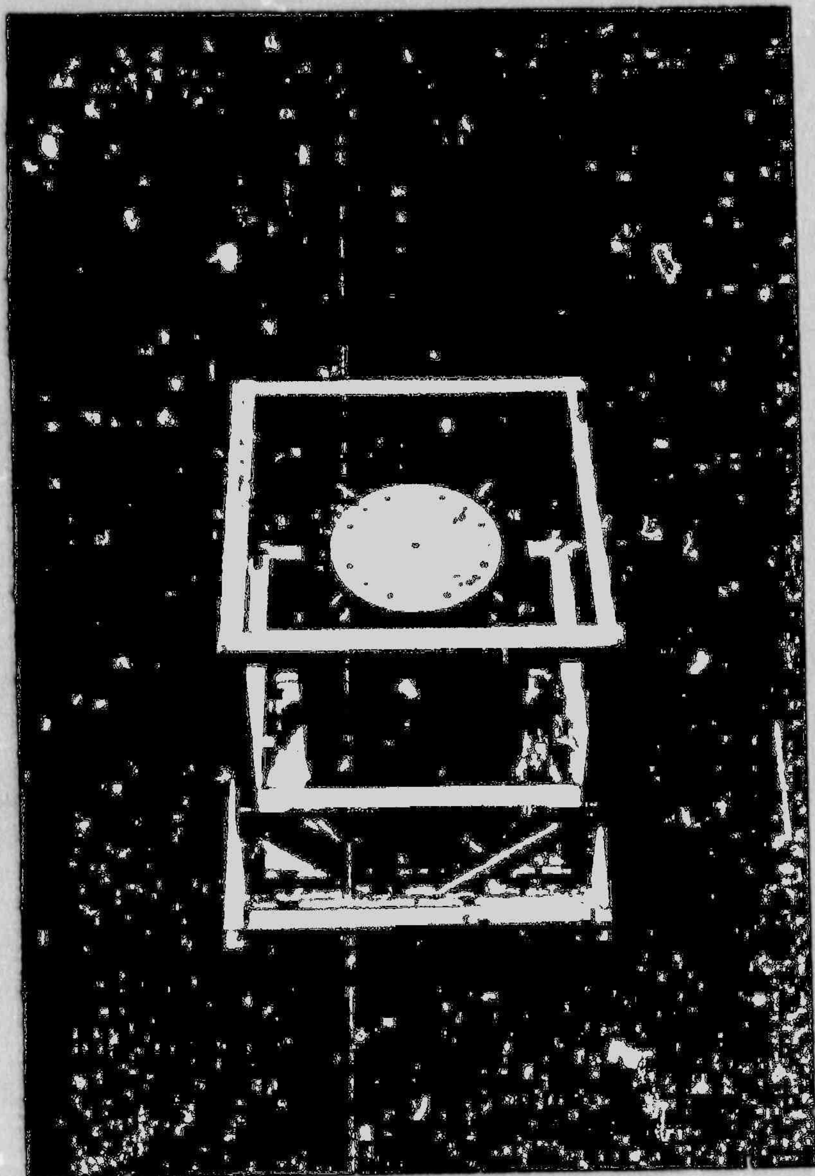


Photo B

Transport Container Test No 1027

Photo D

Transport Container Test No 1027

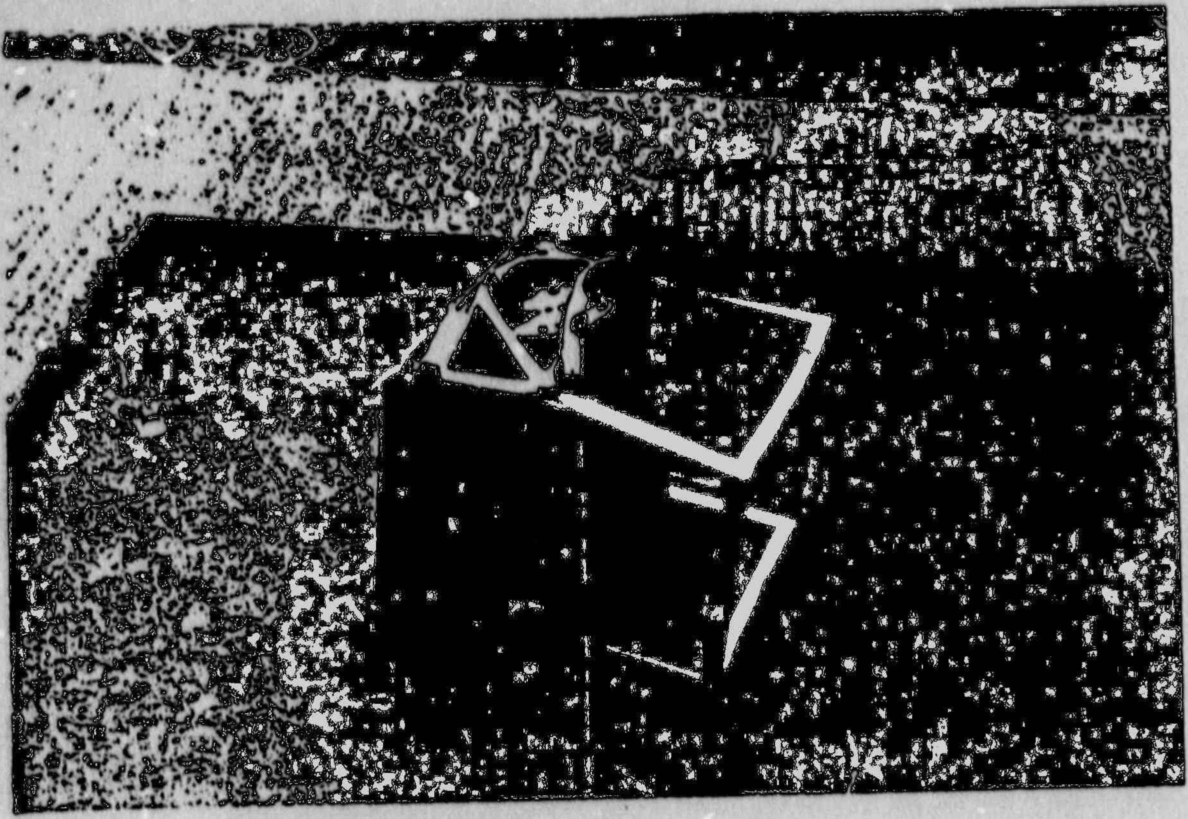


Photo E

Photo F

Photo H

Transport Container Test No 1027

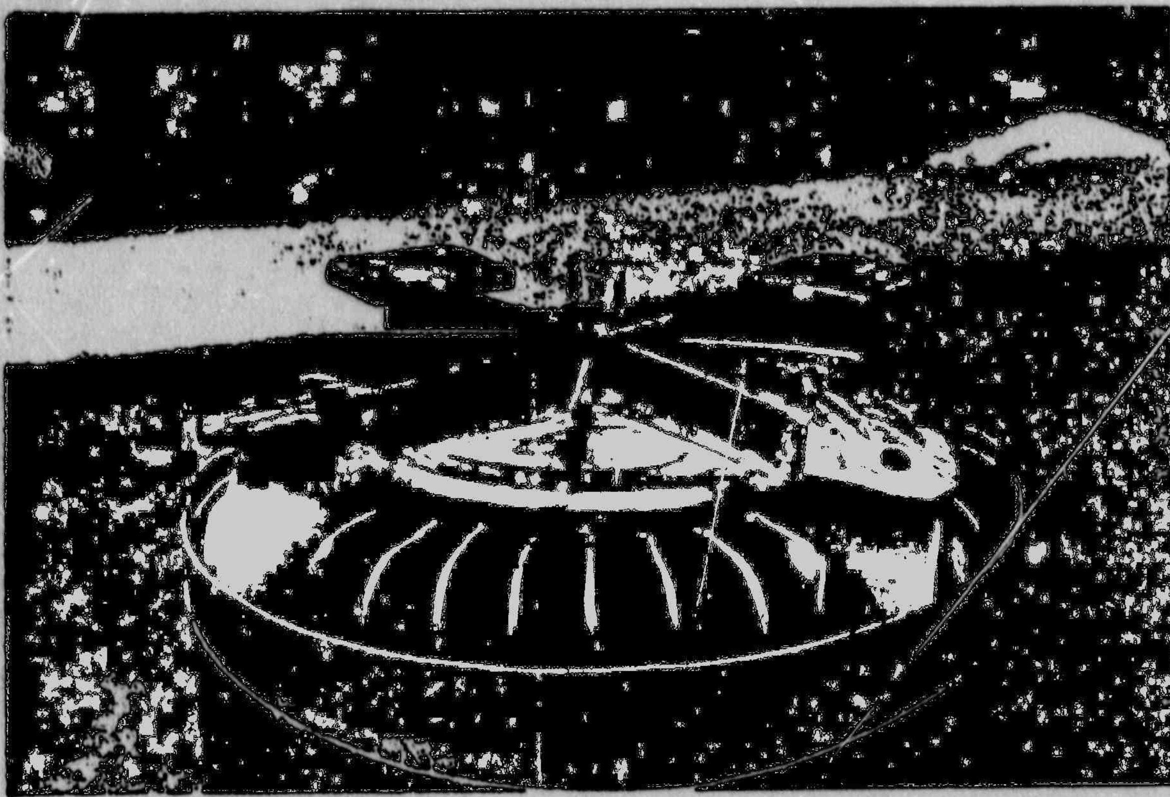


Photo K

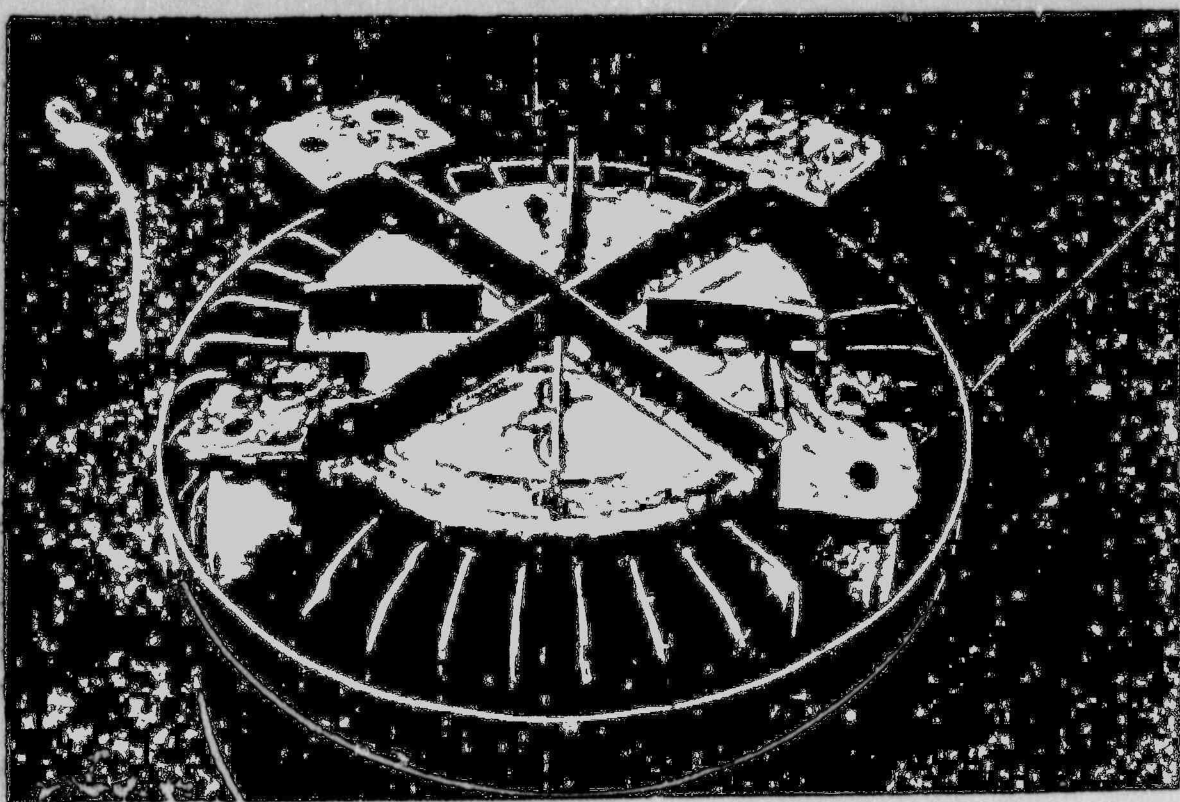


Photo L

2.10.12 Third Scale Model Drawings

Drawing No.	Issue	Title
DL 23665	D	ASSEMBLY MODEL FLASK THIRD SCALE MODEL OF DESIGN NO. 3100 A
CA 23665	D	ASSEMBLY MODEL FLASK THIRD SCALE MODEL OF DESIGN NO. 3100 A
CA 23666 SHT 1	D	BODY
0A 23666 SHT 2	D	BODY
0A 23666 SHT 3	D	BODY
0A 23619	D	CLOSURE
2A 23620	B	UPPER CLOSURE
2A 23621	B	MIDDLE SHIELD
2A 23622	B	BASE SHIELD
3A 23623	C	CLOSURE SHIELD
3A 23625	B	INSERT
CA 23626	D	PALLET
0A 23627	D	OUTER FRAMEWORK

THIS DRG FORMS PART OF AN APPROVED PACKAGE DESIGN. IT IS HELD IN A C.A.D.D. SECURITY FILE. ITS BONDED RECORD CAN ONLY BE MODIFIED WITH AUTHORITY/APROVAL.

Checked	Approved	Issue	Date	Mod.No
D.W.R.	A.M.	D	10.3.87	
		C	31.12.86	
		2	27.11.86	
		1	22.9.86	

Amersham

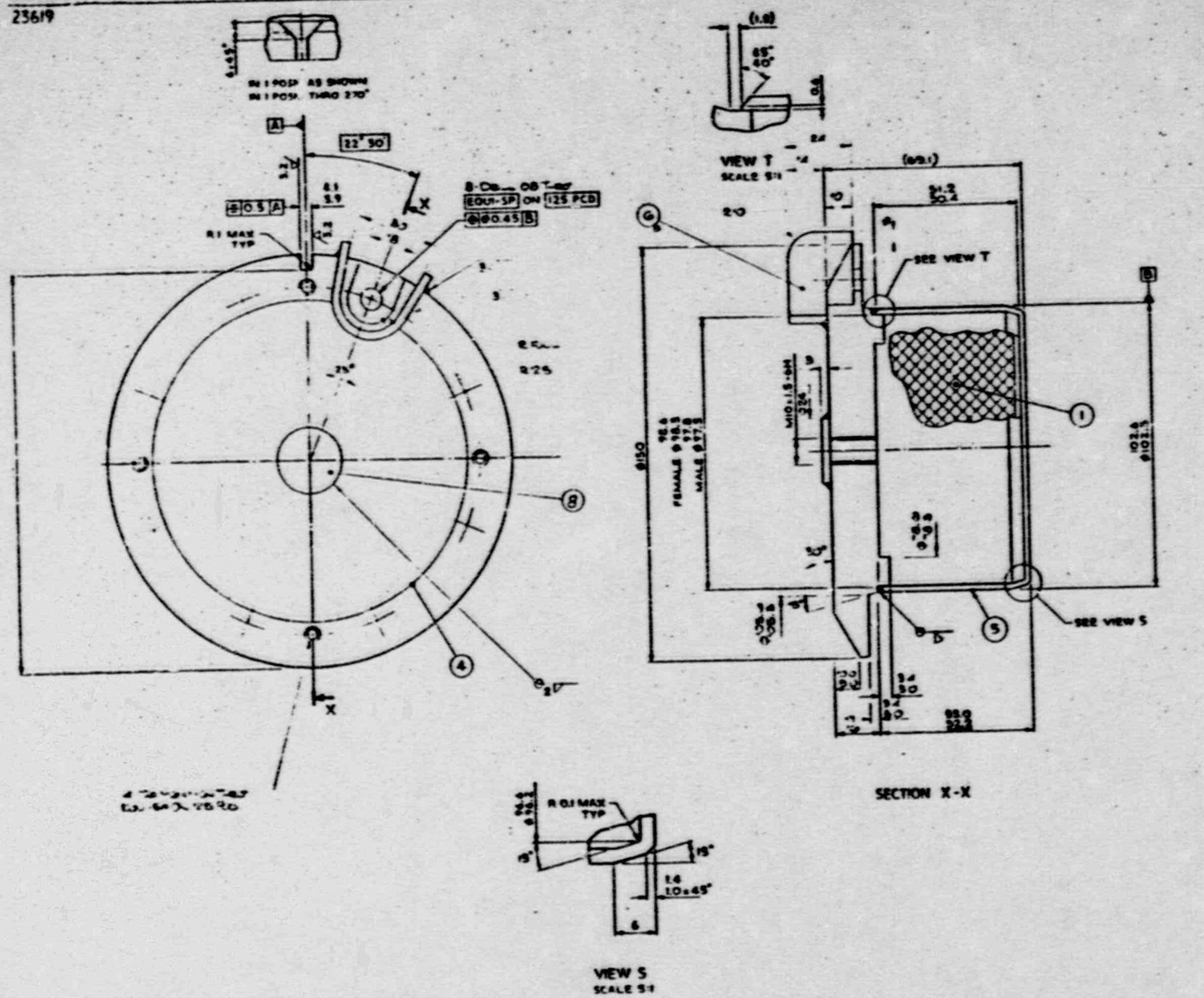
Title ASSEMBLY MODEL FLASK THIRD SCALE MODEL OF DESIGN NO. 3100 A

Job

Job No. 408 S

Drg. DL23665

23619



1	CLOSURE SHIELD	

NOTES

1 THREADS TO CONFORM TO BS 3643 PART 2 FIT AS STATED

2 WELD TO A1 SPEC QCP 510

6 CALCULATED WEIGHT 9.8 kg

SEE ITEMS LIST

LINEAR ±0.5
ANGULAR ±1°

1.6 µm

CLEAN

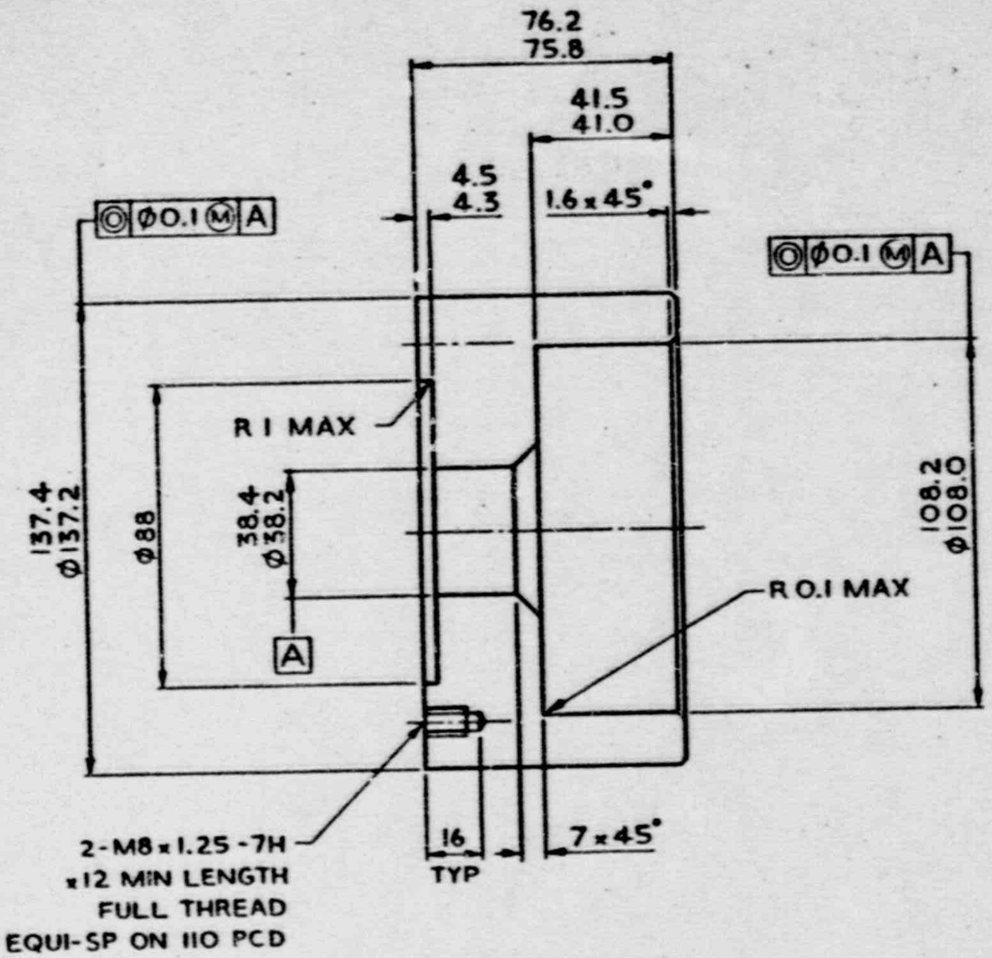
2:1

Amersham

CLOSURE

0A 23619

2A 23620



SECTION ON ℄

NOTE

1 THREADS TO CONFORM TO BS 3643 PART 2 FIT AS STATED

2 CALCULATED WEIGHT 12.9 kg

URANIUM IS A HAZARDOUS MATERIAL
FOR GUIDANCE ON HANDLING SEE
B.N.F.L. INFORMATION SHEET 'URANIUM METAL'

Assy.		Description	Drawing No.	Item No.
Equipment				

DOR	B	19-12-86	MF348
	1	1.10.86	
Approved	Issue	Date	Mod No

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Third Angle Projection	Material & Spec. DEPLETED URANIUM RMR 500	Tolerances LINEAR ±0.5 ANGULAR ±1° Unless stated	Surface Texture 1.6 µm Unless stated	Finish CLEAN Remove all burrs
This drawing conforms to B.S.308	Original Scale 1:1 Do not scale	Dims. in millimetres	Drawn MRP Checked P. FIDLER	Used on OA 23666

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Title: UPPER SHIELD

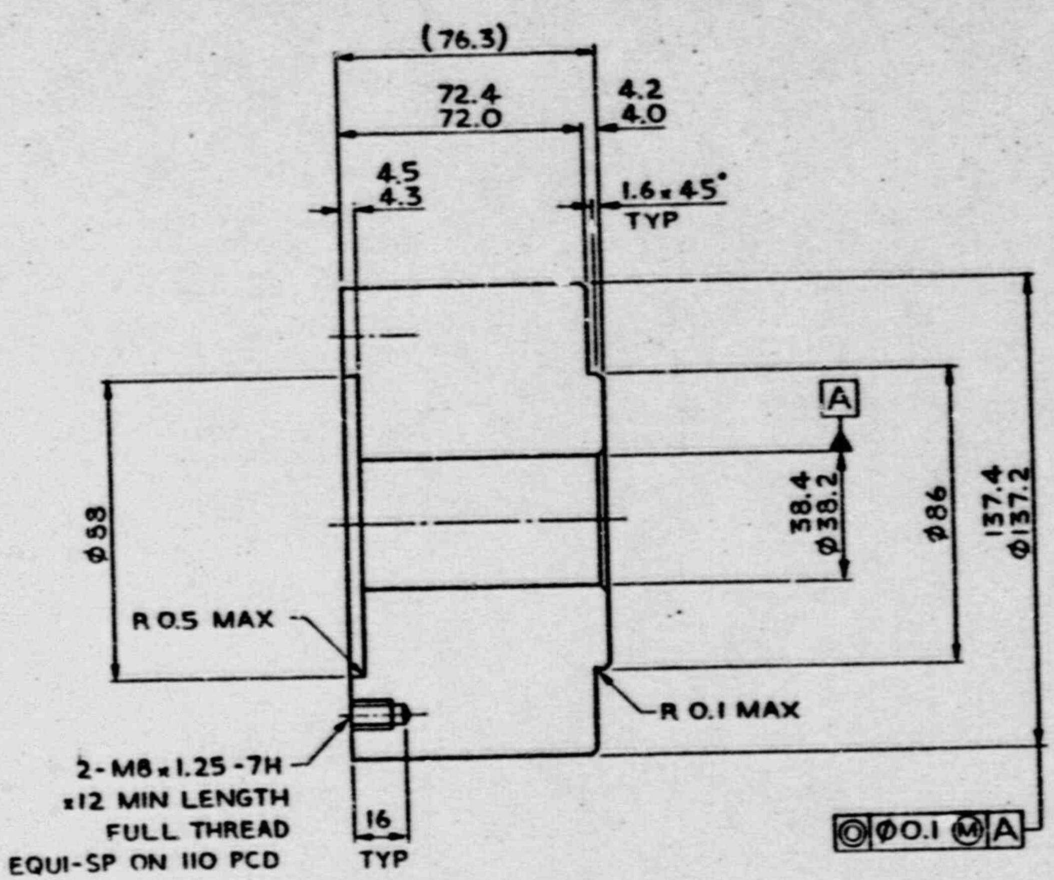
Job No. 408 S

Drg No. 2A 23620

2A 23621.

Assembly	Equipment
a	
b	
c	

No. off assembly c b a	Description	Drawing No.	Item No.



SECTION ON ℄

NOTE

1 THREADS TO CONFORM TO BS 3643 PART 2 FIT AS STATED

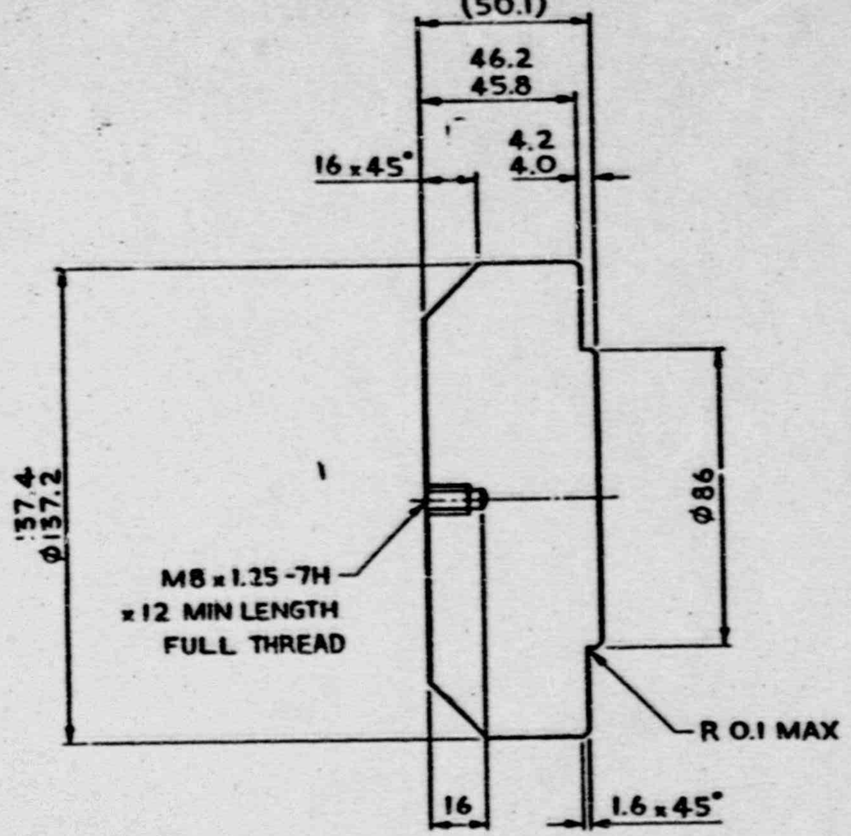
2 CALCULATED WEIGHT 18.5 kg

URANIUM IS A HAZARDOUS MATERIAL
FOR GUIDANCE ON HANDLING SEE
B.N.F.L. INFORMATION SHEET 'URANIUM METAL'

Approved	Issue	Date	Mod No
PDR	B	19.12.86	YP34B
	1	2.10.86	

Third Angle Projection	Material & Spec. DEPLETED URANIUM RMR 500	Tolerances LINEAR ±0.5 ANGULAR ±1° Unless stated	Surface Texture 1.6 μm Unless stated	Finish CLEAN Remove all burrs	© Amersham International plc. Amersham UK — Amersham
This drawing conforms to B.S.308	Original Scale 1:1 Do not scale	Dims. in millimetres	Drawn MRP Checked P FIGLER	Used on OA 23666	Title MIDDLE SHIELD; Job No. 408 S; Drg. No. 2A 23621

2A 23622



SECTION ON ℄

Assembly			
a			
b			
c			
No off assembly c b a	Description	Drawing No.	Item No.

NOTE

1 THREAD TO CONFORM TO BS 3643 PART 2 FIT AS STATED

2 CALCULATED WEIGHT 1[illegible].3 kg

URANIUM IS A HAZARDOUS MATERIAL
FOR GUIDANCE ON HANDLING SEE
B.N.F.L. INFORMATION SHEET 'URANIUM METAL'

Approved	Issue	Date	Mod No
DOE	B	19-12-86	MP348
	1	1.10.86	

Third Angle Projection	Material & Spec. DEPLETED URANIUM	Tolerances LINEAR ±0.5 ANGULAR ±1° Unless stated	Surface Texture 1.6 µm Unless stated	Finish CLEAN Remove all burrs
This drawing conforms to B.S.308	Original Scale 1:1 Do not scale	Dims. in millimetres	Drawn MRP Checked PFIDLER	Used on OA 23666

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Title: BASE SHIELD

Job No 408 S

Drg No. 2A 23622

Third Angle Projection

This drawing conforms to B.S.308

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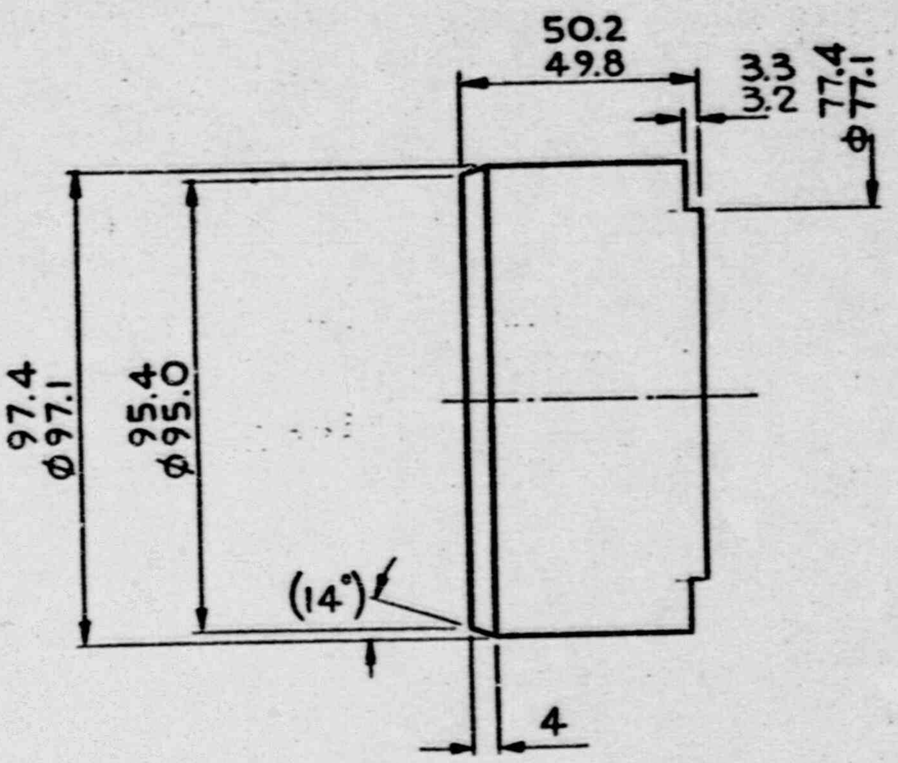
Item No.	Drawing No.	Description	No. off



URANIUM IS A HAZARDOUS MATERIAL
FOR GUIDANCE ON HANDLING SEE
B.N.F.L. INFORMATION SHEET 'URANIUM METAL'

MICROFILMED

Approved	Issue	Date	Mod.No.
[signature]	C	18.8.87	MP1003
DDR	B	19.?.86	MP348
	1	1.10.8?	

Material & Spec.	Tolerances	Surface Texture	Finish
DEPLETED URANIUM CMS 500	LINEAR ±0.5 Unless stated	1.6 µm Unless stated	CLEAN Remove all burrs
Original Scale 1:1 Do not scale	Dims. in millimetres	Drawn MRP Checked P. FIDLER	Used on 0A23619

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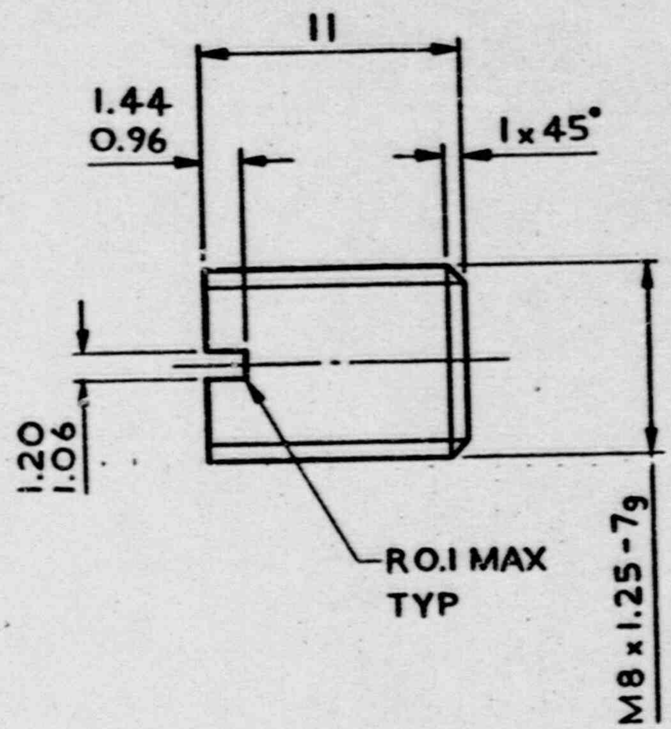
Title: CLOSURE SHIELD

Job

Job No. 408 S

Drg. No. 3A 23623

Third Angle Projection This drawing conforms to B.S.308	This drawing is the private and confi... al property of Amersham International plc. and must not be loaned, copied or reproduced without written permission.	Item No.	Drawing No.	Description	No. off



NOTE

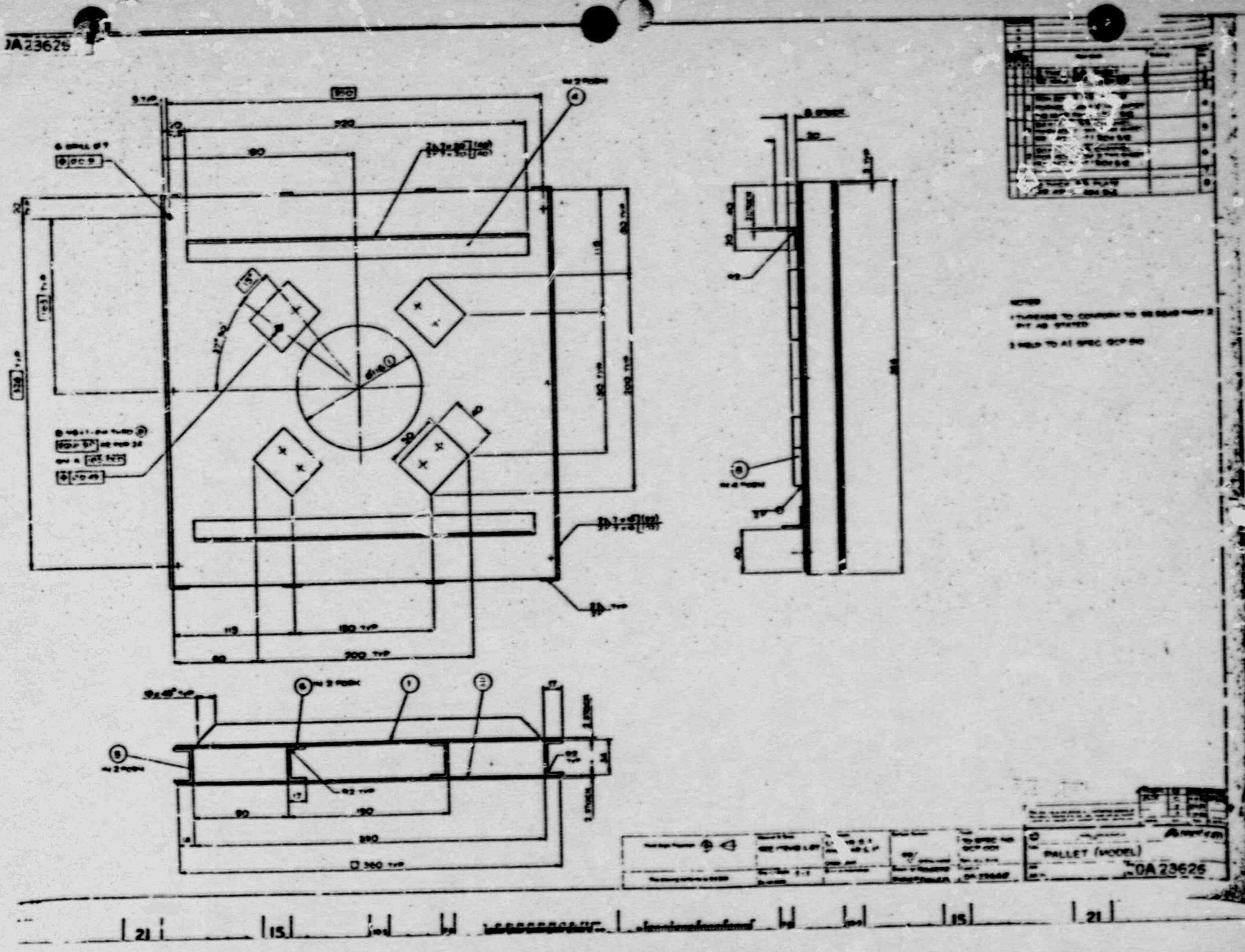
1 THREAD TO CONFORM TO BS 3643 PART 2 FIT AS STATED

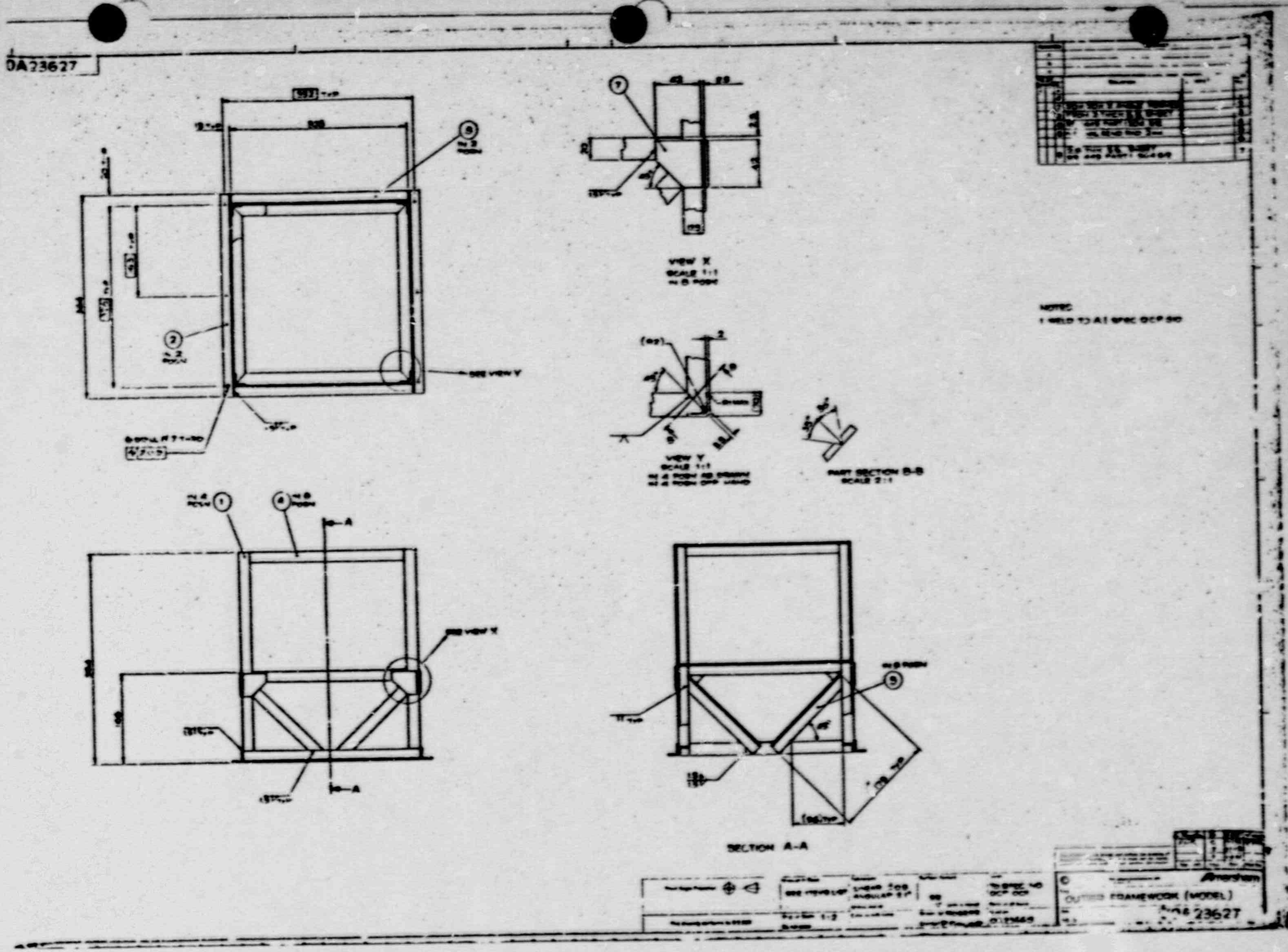
URANIUM IS A HAZARDOUS MATERIAL
FOR GUIDANCE ON HANDLING SEE
B.N.F.L. INFORMATION SHEET 'URANIUM METAL'

MICROFILMED

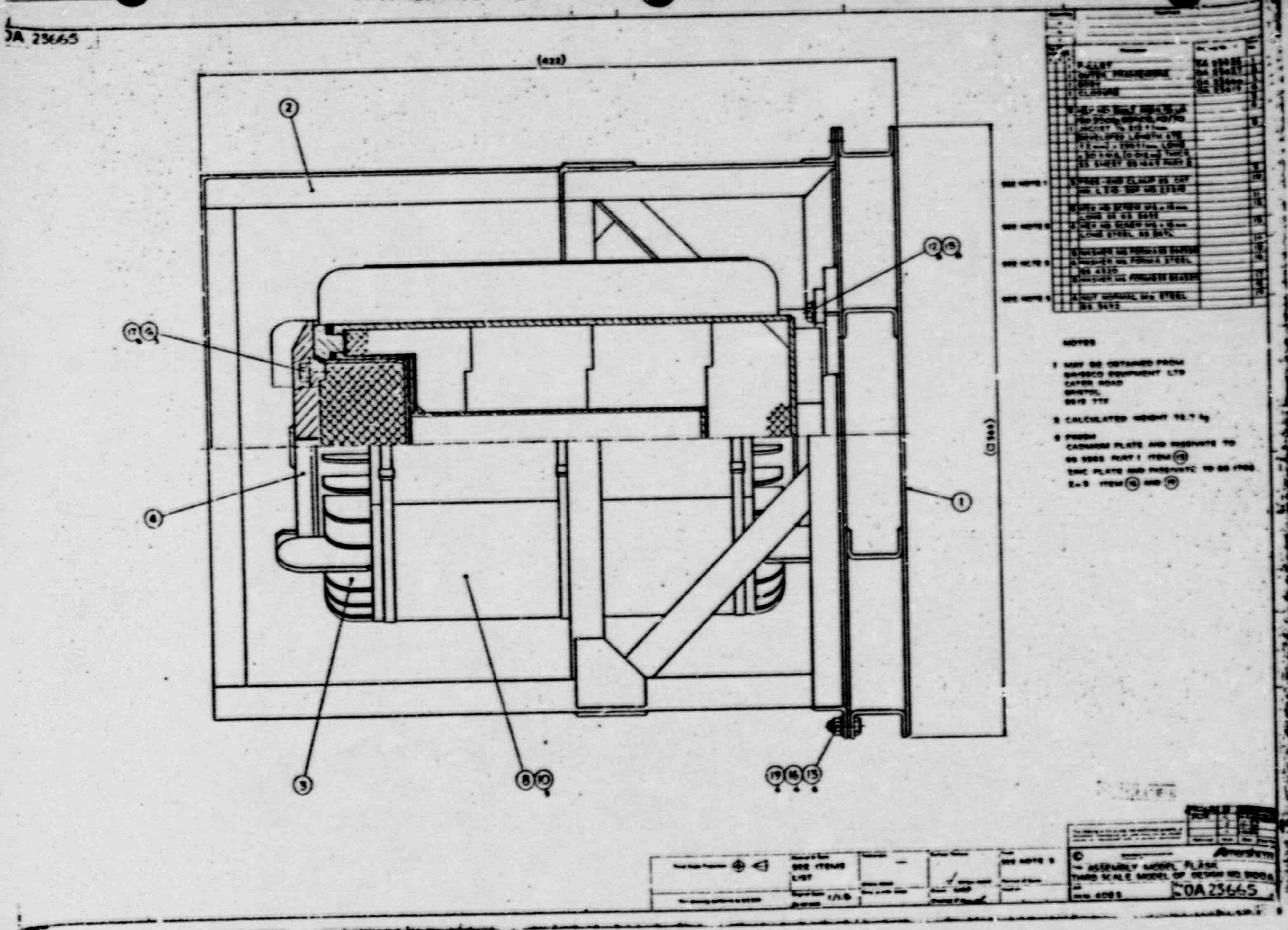
Approved	Issue	Date	Mod.No.
DDR	8	19-12-86	MP348
	1	1.10.86	

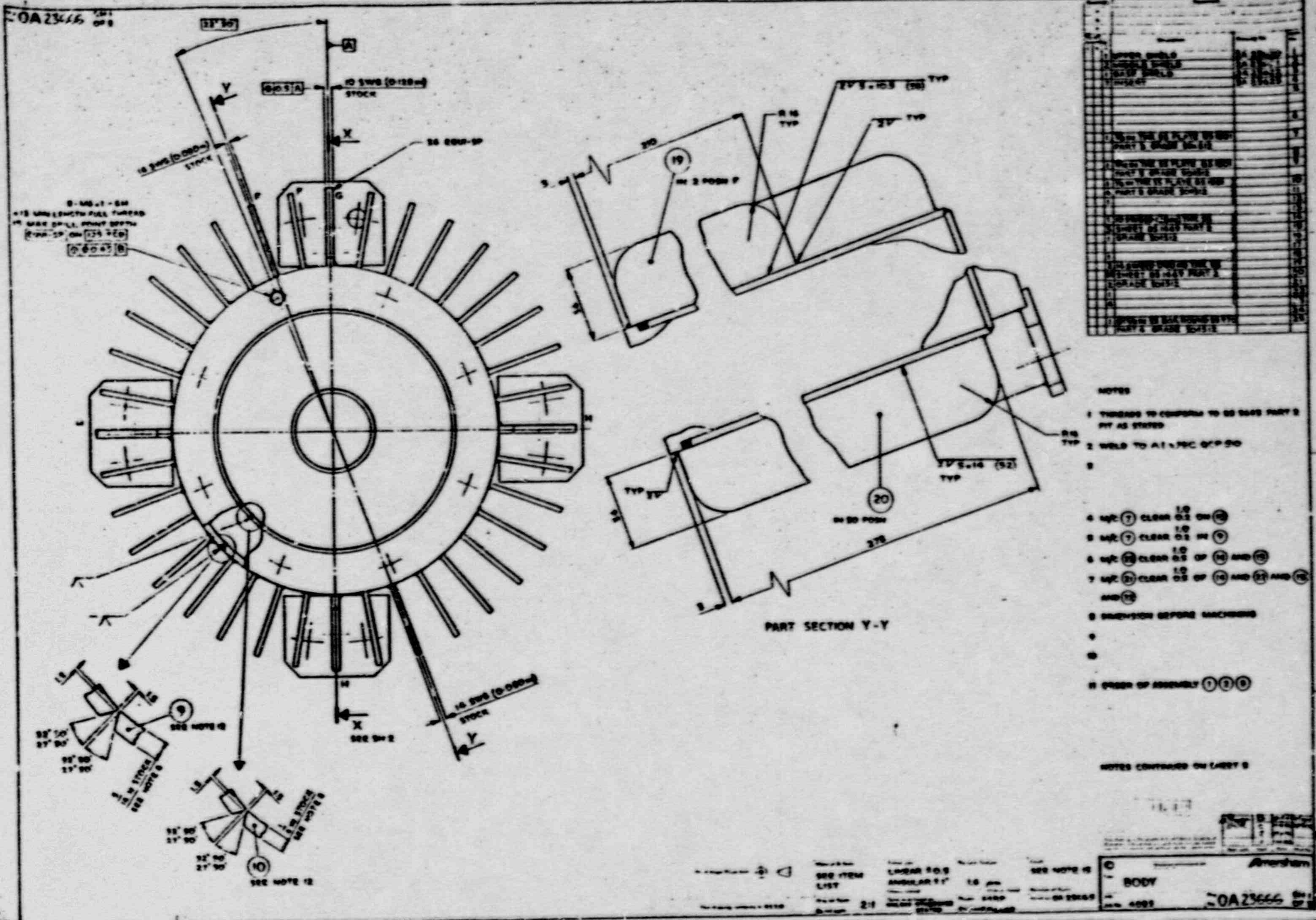
Material & Spec.	Tolerances	Surface Texture	Finish	© Amersham International plc. Amersham UK — Amersham
DEPLETED URANIUM BMR 500	LINEAR ±0.5 ANGULAR ±1° Unless stated	1.6 µm Unless stated	CLEAN Remove all burrs	Title INSERT
Original Scale 5:1 Do not scale	Dims. in millimetres	Drawn MRP Checked P.FIDLER	Used on OA 23666	Job Job No. 408S Drg. No. 3A 23625

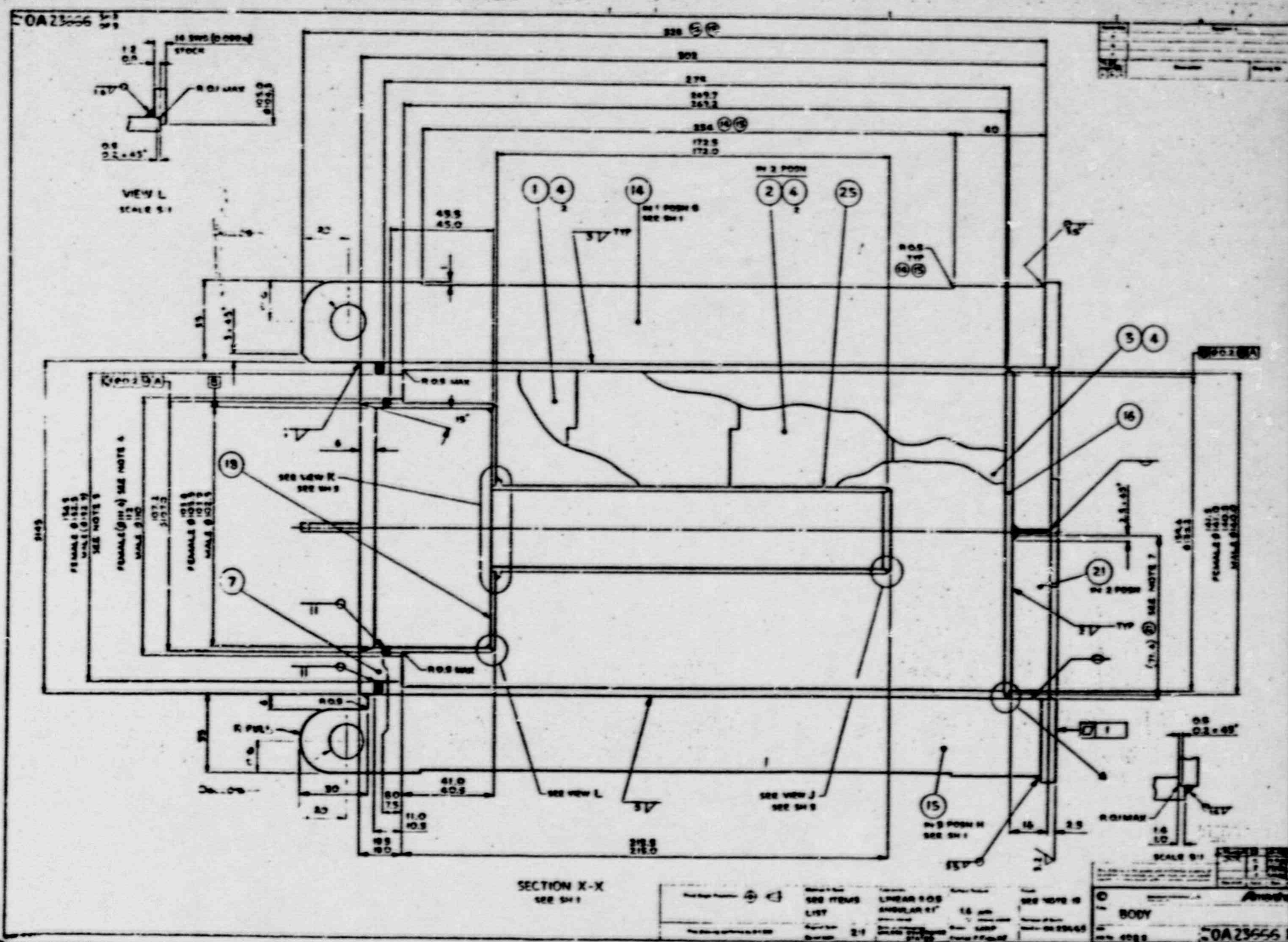

0A23626
PALLET (MODEL)
0A 23626

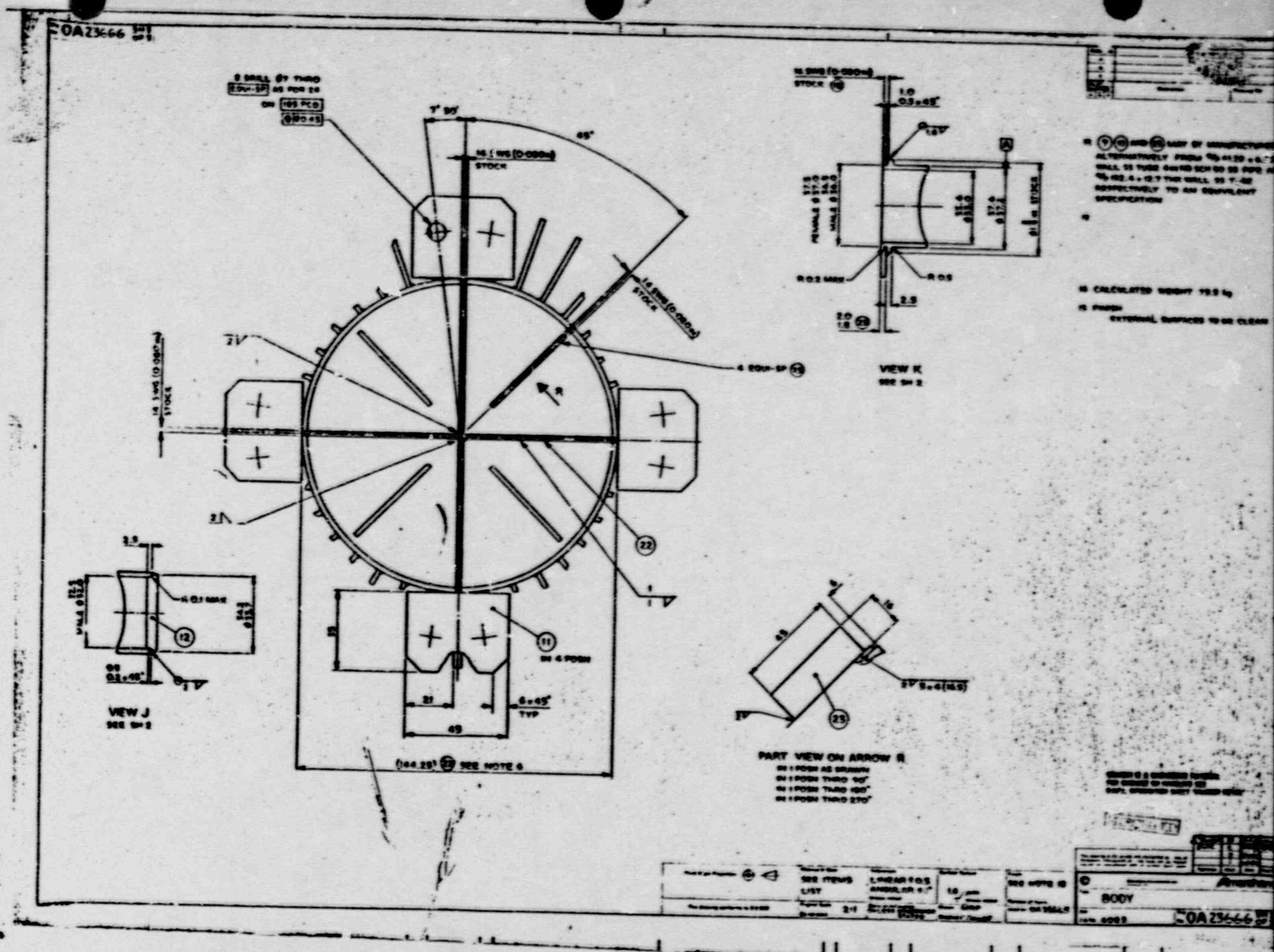


0A23627
VIEW X
SCALE 1:1
VIEW Y
SCALE 1:1
PART SECTION B-B
SCALE 2:1
SECTION A-A
NOTES
OUTER FRAMEWORK (MODEL)
0A 23627


0A 23665
(422)
NOTES
CALCULATED WEIGHT
Amersham
ASSEMBLY MODEL FLASK
THIRD SCALE MODEL OF DESIGN
0A 23665


0A23666
10 SWG (0.128in) STOCK
16 SWG (0.080in) STOCK
PART SECTION Y-Y
NOTES
2 WELD TO
8 DIMENSION BEFORE MACHINING
11 ORDER OF ASSEMBLY
BODY
0A23666


0A23666
VIEW L
SCALE 5:1
SECTION X-X
SEE SH 1
SEE VIEW K
SEE VIEW L
SEE VIEW J
SEE ITEMS
LIST
LINEAR ±0.5
BODY
0A23666



0A23666
VIEW K
SEE SH 2
VIEW J
SEE SH 2
PART VIEW ON ARROW R
CALCULATED WEIGHT
EXTERNAL SURFACES TO BE CLEAN
SEE NOTE 6
BODY
0A23666

3.0 Thermal Evaluation

3.1 Discussion

The 3100A design is a completely passive thermal device and has no mechanical cooling system nor relief valves. All cooling of the container is through free convection and radiation.

The container is a vertical, finned cylinder approximately 1.0 m (3.28 ft) high and 0.6 m (1.96 ft) in diameter. It is designed to carry high activity gamma sources and is constructed of depleted uranium shielding in a stainless steel skin. The fins aid dissipation of heat generated by the contents. The fins are enclosed by a cylindrical jacket of thin gauge stainless steel. This serves to improve natural convection around the fins by inducing a "chimney" effect and also to reduce heat uptake during a fire by acting as a thermal radiation break. Fins on the top of the closure and the underside of the body also aid heat dispersion.

To keep accessible surfaces cool, the flask is transported on a pallet enclosed in a framework of angle and wire mesh.

The maximum heat source would be 10 PBq (270 kCi) of Cobalt 60. The maximum heat load in watts is 4.160kW.

3.2 Summary of Thermal Properties of Materials

The melting temperatures of the metals used in the construction of the container are:

Depleted uranium	1132°c
300 series steel	>1345°c
Copper	1083°c
Tungsten	3410°c

Additional data on the thermal properties of the materials may be found in Packaging Group Memorandum (PGM 243 Appendix 3.6.2).

3.3 Technical Specifications of Components

Not Applicable.

3.4 Thermal Evaluation for Normal Conditions of Transport

3.4.1 Thermal Model

The thermal evaluation for normal conditions of transport is presented in "Packaging Group Memorandum" (PGM) 188 and 243 along with "Transport Container Test" (TCT) 1062, which may be found in Appendix 3.6. The steady state thermal test was conducted with a 3100A design flask (G.A. Draw. No. OA 23525) without pallet, transport frame, jacket or drain plug. A complete description of the 3100A flask may be found in section 1.2.1, and the drawing in Appendix, section 1.3.4.

Thermocouples were attached around and inside the flask and to three of the Co-60 capsules used. The flask was then placed in a shielded cell where it remained for the duration of the test. The thermocouples were connected to a 30 point chart recorder. All thermocouples were calibrated at ambient temperature before the start of the test, and with the exception of No. 2 after the completion of the test.

The drain hole was plugged from the inside of the cavity to prevent air circulation through the drain tube. In addition, a thin aluminum ring was placed around the top of the cavity where it would be sandwiched under the closure. This provided two thermocouple points with which to measure the cavity wall temperature at the top (adjacent to the capsules being monitored).

The source holder was then loaded in three stages:

a) 28 capsules (x170 type capsules, each 2,360 kCi Co 60) were loaded, 27 into three evenly spaced groups. One group was on the inner tube ring and the other two on the outer ring. The center top capsule in each group carried a thermocouple clamped to its top face under the head of a small screw. The closure was replaced and the flask left to stabilize.

b) A further 23 capsules were loaded. The closure was replaced and the flask left to stabilize again.

c) A further 23 capsules were loaded bringing the total to 74, one short of a full load. The closure was replaced and the flask left to stabilize again.

The results of this test are in Appendix 3.6.

3.4.2 Maximum Temperatures

As presented in PGM 188, 243 and TCT 1062 in Appendix 3.6, the maximum temperatures which may be expected are 73°C on the transport cover, 101°C on the flask surface with the contents at 457°C. The maximum surface temperature in the shade under normal conditions of transport is predicted to be 38°C. The maximum temperatures encountered under normal conditions of transport will have no adverse effect on the structural integrity or shielding efficiency of the package.

3.4.3 Minimum Temperatures

The minimum normal operating temperatures of the 3100A would be those shown in PGM 188, in Appendix 3.6.1 as expected prior to transport. That indicates the external surfaces to be at 38°C, the flask surface at 94°C and the contents at 450°C.

3.4.4 Maximum Internal Pressures

Any pressure increase in the containment system can only arise from thermal effects. This will result in the following pressures, calculated from the temperatures in PGM 188.

Prior to shipment - 2.65 bar
During Normal Transport - 2.67 bar
During and Subsequent to Accident Conditions - 3.58 bar

3.4.5 Maximum Thermal Stresses

The maximum temperatures which will occur during normal transport are sufficiently low to assure that thermal gradients will cause no significant thermal stress.

3.4.6 Evaluation of Package Performance for Normal Conditions of Transport

The normal transport thermal conditions will have no adverse effect on the structural integrity or shielding efficiency of the package. The applicable conditions of IAEA Safety Series 6 for type B packages are shown to be satisfied by PGM's 188,243, and TCT 1062 which can be found in the Appendix, section 3.6.

3.5 Hypothetical Accident Thermal Evaluation

3.5.1 Thermal Model

The performance of the 3100A in the thermal test has been modeled using the TAU finite element programs developed by The United Kingdom AEA, and the 1985 IAEA SS 37 Guidelines. The conceptual model, simplified from the original drawings, is shown as figure 1 in PGM 243 Issue 2 Part 1 (Appendix 3.6.2). It concentrates on a 2D horizontal (XY) (RZ) section.

The XY cross section model took full advantage of the symmetry of the flask so, in fact, only a 5 degree sector was considered from the center of a fin to the point equidistant between that fin and its neighbor.

Various parameters were investigated including:

- The spacing between the shield and the body
- The type of gas within the voids
- The external heat transfer coefficient
- The amount of penetration of the ambient conditions between the fins.

The model is further described in PGM 243 in the Appendix, Section 3.6.2.

3.5.2 Package Conditions and Environment

TCT No. 1027, Appendix 2.10.9, shows that the flask will remain within the pallet and framework enclosure. The tests designed to induce mechanical stress (fee drop and puncture) cause minor deformation but no reduction in structural integrity, nor impairment of any safety features, including shielding efficiency.

3.5.3 Package Temperatures

Subjected to the 800°C thermal test condition, the surfaces of the container will follow the fire temperature and therefore rise to 800°C as calculated in PGM 188 (Appendix 3.6.1). The peak temperature of the contents would be 705°C.

3.5.4 Maximum Internal Pressures

The pressure in the containment system can only increase due to thermal effects. These will result in an internal pressure of 3.58 bar during, and subsequent to accident conditions, calculated from the temperatures in section 3.5.3.

The contents of the container and primary containment are special form capsules. As the requirements for special form testing are more severe it can be concluded the internal pressure generated by 800°C temperatures would not affect the source capsule, nor will it affect the container.

3.5.5 Maximum Thermal Stress

There are no significant thermal stresses generated during the thermal test.

3.5.6 Evaluation of Package Performance

Examination of the melting temperatures of the materials used in the construction of the container indicates there will be no damage to the container as a result of this thermal test. However, as discussed in section 2.4.4, stainless steel and uranium do have the theoretical ability to form a eutectic alloy at temperatures down to 750°C. To

prevent this from happening all adjacent stainless steel and uranium surfaces have been separated by a copper barrier. Tests included in Appendix 2.10 showed that the copper barrier was sufficiently durable to withstand the requirements of the manufacturing process and test conditions.

The computed behavior of the flask in the thermal test shows that the greatest component temperatures at any stainless steel to uranium interface were in the range of 460 to 522°C. That indicates that the copper barrier could be omitted from the design without compromising its ability to meet the test requirements.

In conclusion, the 3100A container will undergo no loss of structural integrity or shielding when subjected to the thermal accident conditions. The pressures and temperatures have been demonstrated to be within the required limits. The construction materials are capable of satisfactorily meeting the 1973 IAEA SS 6 type B thermal testing requirements following mechanical testing.

3.6 Appendix

3.6.1 Packing Group Memorandum (PGM) 188
3.6.2 Packing Group Memorandum (PGM) 243
3.6.3 Transport Container Test (TCT) 1062
3.6.4 Engineering Packaging Memo (EPM) 67
3.6.5 Engineering Packaging Memo (EPM) 79
3.6.6 Engineering Packaging Memo (EPM) 85 Revision 1

3.6.1 Packing Group Memorandum (PGM) 188

International Operations

Packaging Group Memorandum

Performance of 3100A Flask under IAEA Type "B" Thermal Requirements

G A Drawing No. OA 23525

A. DESCRIPTION

The 3100 flask is a vertical, finned cylinder approximately 1.0m high and 0.6m diameter. It is designed to carry high activity gamma sources and is constructed of depleted uranium shielding in a stainless steel skin. The fins aid dissipation of heat generated by the contents. To keep accessible surfaces cool, the flask is transported on a pallet enclosed in a framework of angle and wire mesh. The compactness of the flask and the absence of a conventional thermal barrier means that particular attention must be given to assessing its performance under the IAEA thermal requirements. In this case these are:-

1. Prior to transport: Equilibrium in the shade in an ambient of 38°C.

2. During transport: Peak temperature under the sun in an ambient of 38°C, followed by:-

3. During and subsequent to accident conditions: Peak temperature caused by a fire test at 800°C for 30 minutes.

4. Performance of materials.

B. ASSESSMENT

1. Equilibrium prior to despatch.

   a) External surfaces (pallet and outer framework): Due to the great ease of air flow, not only through the wire mesh sides of the framework but also through the pallet, no accessible surface is expected to be hotter than the ambient air temperature of 38°C.

   b) Flask surface: Temperatures at different points on the surface vary widely, so the fin tip temperature at the mid-height is assumed to be the most representative figure, i.e 94°C (see TC Test No. 1062).

   c) Contents: Capsule temperatures were measured with three different total activities in the flask and the results displayed on a graph (see TC Test No. 1062). The source temperature with 10PBq Co 60 load is predicted to be 450°C.

2. During transport.

   a) External surfaces: Likely to reach up to 73°C (see EPM 85).

b) Flask surface: Heat input due to insolation is as follows:- (ref. IAEA SS6, Table III)

Horizontal area (i.e lid)

$$Q_n = A_n \times I_n$$
$$= 3.142 \times 0.235^2 \times 800$$
$$= 139 \text{ watts}$$

Vertical area (i.e fin envelope)

$$Q_v = A_v \times I_v$$
$$= 3.142 \times 0.64 \times 0.98 \times 200$$
$$= 394 \text{ watts}$$

Total heat input therefore = $Q_n + Q_v$ = 533 watts

In normal, fully loade[illegible] equilibrium with an internal heat load of 4.160kW, the flask will run at an average of 94°C above ambient. By simple proportion, therefore, when it has an additional 533 watts to dissipate, the average surface temperature will be:-

$$94 + \frac{(94 - 38)\ 533}{4160}$$

$$= 94 + 7$$
$$= \underline{101°C}$$

c) Contents: The temperature of the conte[illegible] will increase by no more that the increase in the average surface temperature due to insolation. Thus the contents will run at a peak temperature no greater than 450 + 7 = 457°C

3. During and subsequent to accident conditions.

a) External surfaces: TC Test No. 1027 shows that the flask will remain within the pallet and framework enclosed after the mechanical tests. These surfaces will follow the fire temperature and therefore rise to 800°C.

b) Flask surface: The performance of the flask in the thermal test has been modelled using the TAU finite element programme and the 1985 IAEA SS 37 guidelines.

c) Contents: The computer assessment only models the behaviour of the flask as far in as the cavity wall. In order to predict the temperature of the contents at the elevated temperatures of the fire test it is necessary to establish how heat is being transfered from the source capsule to the cavity wall. There are three modes of heat transfer - conduction, convection, and radiation. The first two vary in simple proportion to the temperature difference more or less regardless of actual temperature. Radiant heat transfer however varies in proportion to the difference of the fourth power of the temperatures in absolute units .This means that at higher temperatures radiant heat transfer becomes increasingly efficient.

It is possible to estimate the relative proportion of each mode by simple calculation. It must be stressed however that because the true situation is complicated by the source capsules being enclosed in tubes in two concentric rings. The values calculated are only be used for comparison. The actual amounts of heat being transfered may be very different from the values calculated.

i) Conduction: $H_{cd} = (T_1 - T_2) \times A \times t \times k$

T_1 = source capsule temperature = 450°C
T_2 = cavity wall temperature = 200°C
A = minimum of either cavity wall area or capsule area

cavity wall area = $[(3.142 \times 50^2 \times 2) + (3.142 \times 100 \times 510)] \times 10^{-6} = 0.176 m^2$

source capsule area = $25 \times 3.142 \times 10 \times 452 \times 10^{-6} = 0.355 m^2$

Thus $A = 0.176\ m^2$
t = average distance between cavity wall and capsule = 0.018
k = Conductivity of nitrogen at 300°C = 0.030 W/m°C

Thus $H_{cd} = (450 - 200) \times 0.176 \times 0.018 \times 0.030 =$ <u>0.02 watts</u>

ii) Convection: $H_{cv} = (T_1 - T_2) \times A \times L_{cv}$

T_1 = 450°C
T_2 = 200°C
$A = 0.176 m^2$
L_{cv} = 6 watts/m^2°C (typical value)

Thus $H_{cv} = (450 - 200) \times 0.176 \times 6 =$ <u>264 watts</u>

iii) Radiation: $H_r = (K_1^4 - K_2^4) \times A \times E \times S$

K_1 = 450 + 273 = 723°K
K_2 = 200 + 273 = 473°K
$A = 0.176 m^2$
E = emmissivity = 0.8 (typical value)
S = Stefan Boltzman constant = 5.67×10^{-8} watts/m^2K^4

Thus $H_r = (723^4 - 473^4) \times 0.176 \times 0.8 \times 5.67 \times 10^{-8}$
= 1782 watts

These calculations indicate that radiant heat transfer is accounting for almost all (87%) of the total heat transfer between the source capsule and the cavity wall. It is possible to check this conclusion using the value shown in TC Test 1062, App 3, Graph 1. If the capsule to cavity temperature difference is determined by radiant heat transfer lone it should be possible to take one experimentally obtained pair of temperatures and from that calculate other temperature pairs. These can then be compared with the temperatures measured. In the following table the lowest pair of temperatures has been taken as the datum. From these a factor is derived ($K_1^4 - k_2^4/PBq$) which is proportioned to the efficiency of the heat transfer process and takes account of the actual heat load. The next step is to calculate the capsule temperature with different cavity temperatures and heat loads using the equation $K_3 = (K_2^4 + (PBq \times F))^{0.25}$. Note that it has been possible to drop out many of the factors in the standard equation because they are constant throughout the excercise. The final lines show the discrepancy between measured ans calculated capsule temperatures both as a temperature and as a proportion of the absolute cavity temperature.

	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5 (fire test)
Capsule temperature (K_1)	507	601	653	718	971
Cavity temperature (K_2)	367	399	428	473	856*
Heat loading (PBq)	2.45	4.44	6.48	10	10
$(K_1^4 - K_2^4)$ /PBq (F)	1.96×10^{10}	-	-	-	-
$(K_2^4 + (F \times PBq))^{0.25}$ (K_3)	-	579	633	704	925
°C Discrepancy ($K_1 - K_3$)	-	22	20	14	46
% Discrepancy ($K_1 - K_3$)100/K_3	-	3.8	3.2	2.0	5.0

* Peak cavity temperature occured on top face of tungsten disc (see PGM 243)

The results show that capsule temperatures can be predicted with a fair degree of accuracy when heat transfer is assumed to be radiation only. The final column calculates the source temperature for a cavity temperature of °K (fire test peak - see PGM 243,Pt2). However an allowance must be made for discrepances before this can be used. As temperatures rise heat transfer by radiation will only become more dominant and therefore the calculations more accurate. As the maximum discrepancy calculated was 3.8% and the tendancy is for this to diminish at higher temperatures a 5% margin is considered more than adequate. The only step remaining is to add the allowance for insolation:-

Peak capsule temperature = K_3 + 7
= 971 + 7
= <u>978 °K (705°C)</u>

4. Performance of materials.

The constructional materials have individual melting points well in excess of the temperatures experienced. However, stainless steel and uranium do have the theoretical ability to form a eutectic alloy at temperatures down to 750°C. To prevent the possibility of this happening, all adjacent stainless steel and uranium surfaces have been separated by a copper barrier, either in the form of a thin sheet or a plasma sprayed coating on the stainless steel. Copper has a melting point of 1083°C and has no tendency to alloy with the other materials at the temperatures in question. In order to prove that the coating is sufficiently durable to survive the constructional and IAEA test requirements the following tests were conducted:

a) TC Test No. 1043: The effect of welding on the adherence of a copper sprayed coating to stainless steel

b) TC Test No. 1019: The effect of gross deformation on the adherence of a copper sprayed coating to stainless steel.

c) TC Test No. 1024: The effect of 800°C on the adherence of a copper sprayed coating to stainless steel.

d) TC Test No. 1014: The effectiveness of a copper sprayed coating as a barrier between uranium and stainless steel at 800°C in a helium atmosphere.

These tests showed that the copper sprayed coating was sufficiently durable to withstand the requirements of the manufacturing process and test conditions.

Note: The computed behaviour of the flask in the thermal test showed that the greatest component temperatures at any stainless steel/uranium interface would be 522/460°C

C. CONCLUSION

1. With contents of 10PBq of Co 60, the following temperatures may be expected:

	External Surfaces	Flask Surface	Contents
Prior to transport	38°C	94°C	450°C
During transport	73°C	101°C	457°C
During thermal test	800°C	-	705°C

2. The construction materials are capable of satisfactorily meeting the 1973 IAEA SS6 Type "B" thermal testing requirements, following mechanical testing

3. The copper barrier may be omitted from the design without compromising its ability to meet the test requirements above.

D. ADDENDUM

In response to a requirement to transport lower specific activity material a second source holder has been designed with a capacity increased from 25 to 32 source positions (Source Holder 2, Dr.No.2A 23978). In order that the thermal assessment is not invalidated (i.e. the capsules do not run hotter) the following precautions have been taken:

a) The physical distribution of the capsules within the flask cavity has not been changed. The capsules are arranged around the same two diameters as in the previous holder.

b) The tubes which formed each source position have been replaced with four alignment plates for the whole array. In this way heat transfer between each capsule and its environment is greatly enhanced.

The capsules in Source Holder 2 will run cooler than in Source Holder 1 due to the far greater ease of heat transfer. The assessment for Source Holder 1 may therefore stand as the worst case.

Author:

Signed:.................................Date: 17/2/88

Checked:

Signed:.................................Date: 17 February 1988

3.6.2 Packing Group Memorandum (PGM) 243

AMERSHAM INTERNATIONAL FLASK - APRIL 1987

1. Preamble

The investigation turned out not merely to be a calculation on a well defined model but a survey of the possible outcomes of the variation of a number of parameters. The parameters considered were:

- the spacing between the shield and the body
- the type of gas within the voids
- the external heat transfer coefficient
- the amount of penetration of the ambient conditions between the fins.

The conceptual model, simplified from the original drawings, is shown as figure 1. This exercise intended to concentrate on a 2D horizontal (XY) cross-section supported by an axisymmetric (RZ) section.

The XY cross-section model took full advantage of the symmetry of the flask so in fact only a 5 degree sector was considered from the centre line of a fin to the point equidistant between that fin and its neighbour. Figures 2 and 3 illustrate the model used for the "penetration" and "non-penetration" assumptions.

Various cases run are summarised in the following table.

	gap	filling	htc	penetration	jacket is in position
1	.5mm	He	10	no	no
2	.5	He	10	yes	no
3	.5	He	??	no fins	no
4	1.0	He	10	no	no
5	1.0	N	10	no	no
6	1.0	N	30	no	no

2 The XY "no penetration" model

The flask wall and the sides of the fins radiate to an atmosphere at the prescribed temperature immediately beyond the end of the fins. This is equivalent in the fire test to saying that the radiating part of the flame is not able to penetrate between the fins, or in the furnace test to saying that the radiative heat comes essentially from the distant furnace walls.

The ambient atmosphere is represented in the model by an additional array of elements which remain at the prescribed temperature and which reside immediately beyond the fin tips.

This assumption implies that the fins might cause a reduction in the amount of heat absorbed by the flask, because the view factor from the flask wall to the ambience is considerably reduced, most of the radiative heat which reaches the flask wall being by reflection or re-radiation from the fins. This effect is of course offset by the increased surface area provided by the fins which receive heat and pass it into the flask by conduction. A priori, it is not clear which effect dominates.

3. The "penetration" model

Radiation is exchanged between the flask surface and the sides of the fins and an atmosphere at the prescribed temperature in immediate contact with them. Here of course the atmosphere is not modelled since every part of the surface exchanges heat with its immediate surroundings with an unreduced view factor.

This assumption implies that the fins will certainly cause additional heat to be absorbed by the flask compared with a flask which has no fins, and there is no compensating phenomenon to offset this effect.

4. The "no fin" model

The intention of this model was to obtain by experiment a set of enhanced heat transfer coefficients and radiation coefficients which would mimic the temperatures of the other models when the fins were removed. This was to provide suitable external boundary conditions for the axisymmetric model where of course the fins cannot be modelled. As a by-product it provided information about the efficiency of the fins in the normal steady state use of the flask, and about the shielding effect of the fins during the fire test when the "no penetration" model is used.

5. The RZ case

The RZ model is shown as figures 4 and 5. Because the gaps are so very thin, a scale drawing does not show them so an out of scale picture has also been produced. This together with the data replay listings gives confidence that the intended model has in fact been set up.

The heat input on the finned surface was represented by a flux, varying with time, which gives the same temperatures as the XY cross-section model. This is expected to be pessimistic because the top and bottom corners will in practice heat up rather more rapidly than the central region and the flux at these points will reduce.

6. Results for the finned XY cases

time	inner surface temperatures, case 1	2	4	5	6	outer surface temperatures, case 1	2	4	5	6
0	228	208	240	379	345	137	116	137	137	80
200	229	210	241	380	346	215	340	228	249	277
400	235	227	245	380	347	274	443	298	350	420
600	248	263	256	384	353	324	495	355	430	511
800	258	307	273	390	363	366	531	398	489	564
1000		352	295	400			559	433	532	
1200	319		320	413	396	428		460	560	612
1500	360	452	358	435	426	464	613	493	587	628
1800	399	502	395	460	457	495	638	520	605	640
1900	411			469	467	466			563	562
2000	423	528	417	477	477	446	530	464	528	498
2200	440	545	435	491	492	418	477	426	471	407
2400	452	552	447	502	502	398	444	399	426	340
2700	459	550	455	513	509	377	414	372	379	276
3000	460	541	458	518	510	361	391	353	344	234
3300	457			520.47	508	349			318	206
3600	451	512	453	520.56	504	338	358	326	299	188

.5 gap 1.

He N

10 30 htc

7. Results for the no fin case

Using data to correspond to case 1, removing the fins, and allowing the outside of the flask to "see" the ambient conditions with no reduction of view factor, at steady state initial conditions the inside and outside temperatures were 347 and 261 respectively, an increase of about 120 degrees. The efficiency of the fins is even greater if we compare case 3 with case 2 when the no fin case produces temperatures 140 degrees higher.

In order to produce steady state temperatures in case 3 corresponding to those of case 1, the heat transfer coefficient coefficient was increased from 10 to 27 and the radiation coefficient from 3.7795E-8 to 10.2E-8. (Note that no physical justification is intended for these numbers, we could have increased one of them more and the other correspondingly less to obtain the same result. They have merely been found experimentally to reproduce the temperatures of case 1.)

It was found to be necessary to reduce rather than enhance the radiation coefficient in order to obtain case 3 temperatures in the transient to correspond to those of case 1. This presumably demonstrates the shielding effect of the fins when the "non-penetration" model is used.

A reduced radiation coefficient of 1.E-8 and an enhanced heat transfer coefficient of about 20 give reasonably close results at the start of the transient but it did not in fact appear to be possible to find a pair of coefficients which would remain constant through the transient. Instead, the heat fluxes on the surface of the XY model, and those crossing the outermost gap, were obtained and then modified experimentally until reasonable agreement was obtained.

8. Results for the RZ case

Only one RZ case has been run so far, to correspond with XY case 1. The fluxes crossing the outer gap of the XY run were modified slightly and applied to the outer surface of a no fin case. The temperature history obtained followed that of the original case very closely during the fire phase but then showed slightly too much cooling so that the peak internal surface temperature was underestimated by about 40 degrees. (A further experiment could remove this discrepancy.) This flux was then applied to the outer surface of the axisymmetric model. At a particular height the RZ temperature history again followed very closely the results of case 1 providing useful confirmation of the consistency of the models and indicating that the peak temperature on the vertical cylindrical wall is adequately predicted by the XY model.

The peak internal surface temperature in the RZ model however turned out to be at the centre of the horizontal circular base where the temperature exceeds that on the vertical wall by about 50 degrees.

Careful checking of the model indicated a misunderstanding of the original drawings which resulted in the steel base being rather too thin and insufficient clearance between the base shield and the lining above it. Correction of these two items will cause a reduction in the peak temperature mentioned above. The stiffening plates below the flask base have not been considered and since these increase the surface area it was thought that perhaps the heat transfer coefficient of the base should be increased. This will have the effect of raising the temperature again. These runs have not been performed at 1 April 1987.

9. The effect of the jacket

The jacket is very simple to model in the XY and RZ sections but raises many questions as to the correct data to represent the boundary conditions. A model with a jacket has not been run.

The issues are as follows:

at steady state

The jacket might reduce heat loss because the fins are not exposed to the atmosphere.

The jacket might improve heat loss because natural convection is enhanced by the "chimney effect". Subsidiary calculations are needed to establish a heat transfer coefficient correlation.

in the fire/furnace

The jacket might help because it acts as a radiation shield.

The jacket might cause higher internal temperatures if the "chimney effect" acts in reverse. The jacket will certainly cause higher internal temperatures if the flames are present between the jacket and the main flask body as has been seen in some fire tests on larger flasks.

Conclusions

The program attempts to give accurate solutions as demonstrated by the verification cases and by a variety of other checks on its use over the years. It is not inherently pessimistic, indeed in a general purpose program what gives pessimistic results in one situation might be regrded as optimistic in another. The pessimism of the results presented therefore depends on the data which is provided.

The peak temperature on the inside of the flask reaches an acceptable 450 degrees C under the preferred assumptions but reaches 520 with the combination of nitrogen gap filling (either by design or by the loss of the helium and its replacement by air) a heat transfer coefficient of 10 and a gap size of 1 mm. A case which could possibly produce worse results, that is, nitrogen, htc=10, gap=1mm together with a penetrating atmosphere has not been run. The effect of the RZ calculation on the estimate of 450 degrees is not yet clear but as already discussed it is not expected to be large.

The effect of changing the internal gap is seen by comparing cases 1 and 4. This has a deleterious effect on the normal running but improves the performance in the transient by only a very small amount.

The penetrating atmosphere assumption raises the peak temperature by almost 100 degrees.

The effect of changing from helium to nitrogen is seen by comparing cases 4 and 5. Again the temperature in normal use is considerably elevated, and this time the transient performance also suffers, though this is probably due to the higher initial temperature at the start of the transient. The peak temperature is also reached later.

The effect of increasing the heat transfer coefficient from 10 to 30 is surprising, compare case 5 and case 6. The internal peak temperature turns out to be lower with 30, probably due in part to the lower initial temperature, but it is quite clear that the higher heat transfer coefficient does not cause a much higher internal temperature because of its efficiency in cooling down the flask after the end of the fire. The high temperature front passing through the flask wall is damped down before it reaches the middle. If the fire continued for longer then it is very likely that the higher heat transfer coefficient would result in a higher centre temperature.

Appendix

AMERSHAM INTERNATIONAL FLASK

Material Data

Uranium

density 18.78g/cc = 1.878E4 kg/cu.m

conductivity 0.067 + 2.1E-5*T cal/cm/sec/deg C

= 4.1868*(0.067 + 2.1E-5*T) joules/cm/sec/deg c
or watts/cm/deg C

= 418.68*(0.067 + 2.1E-5*T) w/m/deg C

temp deg C	cond
0	28.05151
1000	36.84294

specific heat 2.61 + 8.95E-3*T + 1.17E5*T^-2 cals/mole/deg C

=(2.61 + 8.95E-3*T + 1.17E5*T^-2)*4.1868/0.238
joules/kg/deg C

temp deg C	sp ht
0	116.5
200	129.6
400	156.4
600	186.1
800	216.6
1000	232.1

Steel

density 7.97 g/cc 7.97E3 kg/cu.m

conductivity .038 cgs units ?= cal/cm/sec/deg C

= 4.1868*.038*100 = 15.90982 watts/m/deg C

specific heat .12 no units !

use

temp deg C	spht
50	469
450	565
750	615 joules/kg

as given over telephone by D W Rogers

Helium

density = p / 2077.3 * T (Pascal/deg K) kg/cu.m

not used

specific heat Cv = 5195 joules/kg deg C
Cp = 3117 joules/kg deg C

not used

conductivity = 2.682E-3 * (1 + 1.123E-8.p) * T^.71*(1 - 2E-9.p)
watts/m deg C

where T is deg K
p is Pascal

assume p = 1.E5 Pa (1 bar)
though in fact the effect of variation
with p is marginal

T (deg C)	cond	cond (p:T)
0	.143971	.143971
200	.212675	.212714
400	.273171	.273249
600	.328585	.328699
800	.380400	.380514
1000	.429409	.429633

Nitrogen

density p / (296.77 T) kg/cu.m (not used)

conductivity = 2.4001E-2 + 7.2991E5*T - 4.8409E-8*T^2
+ 5.6391E-11*T^3 - 4.5175E-14*T^4
+ 1.8473E-17*T^5 - 1.3010E-21*T^6

where T is deg C

temp	cond
0	.0240
200	.0370
400	.0479
600	.0575
800	.0661
1000	.0743

Stefan's constant = 5.66925E-8 watts/sq.m deg K sec

Gas filled gaps, emissivity = .8 both sides

effective emissivity = $\frac{\epsilon_1 \epsilon_2}{\epsilon_1 + \epsilon_2 - \epsilon_1 \epsilon_2} = \frac{64}{96} = \frac{2}{3}$

radiation constant used is 2/3 * Stef = 3.7795E-8

Radiation to ambient; emissivity .8 on flask and fin surface and in atmosphere

Convection to atmosphere		10 watts/sq.m deg C sec
	or	30 " " " "

Internal heat generation = 4.160 kwatts

internal surface area is 2 * π * .05*.05 + 2 * π * .05 * .535

= .015798 + .168075

= .183783 sq.m

surface heat flux is 22635 watts/sq.m

(for the XY cross-section the pessimistic assumption could be made that no heat was lost axially, then the flux would equal 24751.)

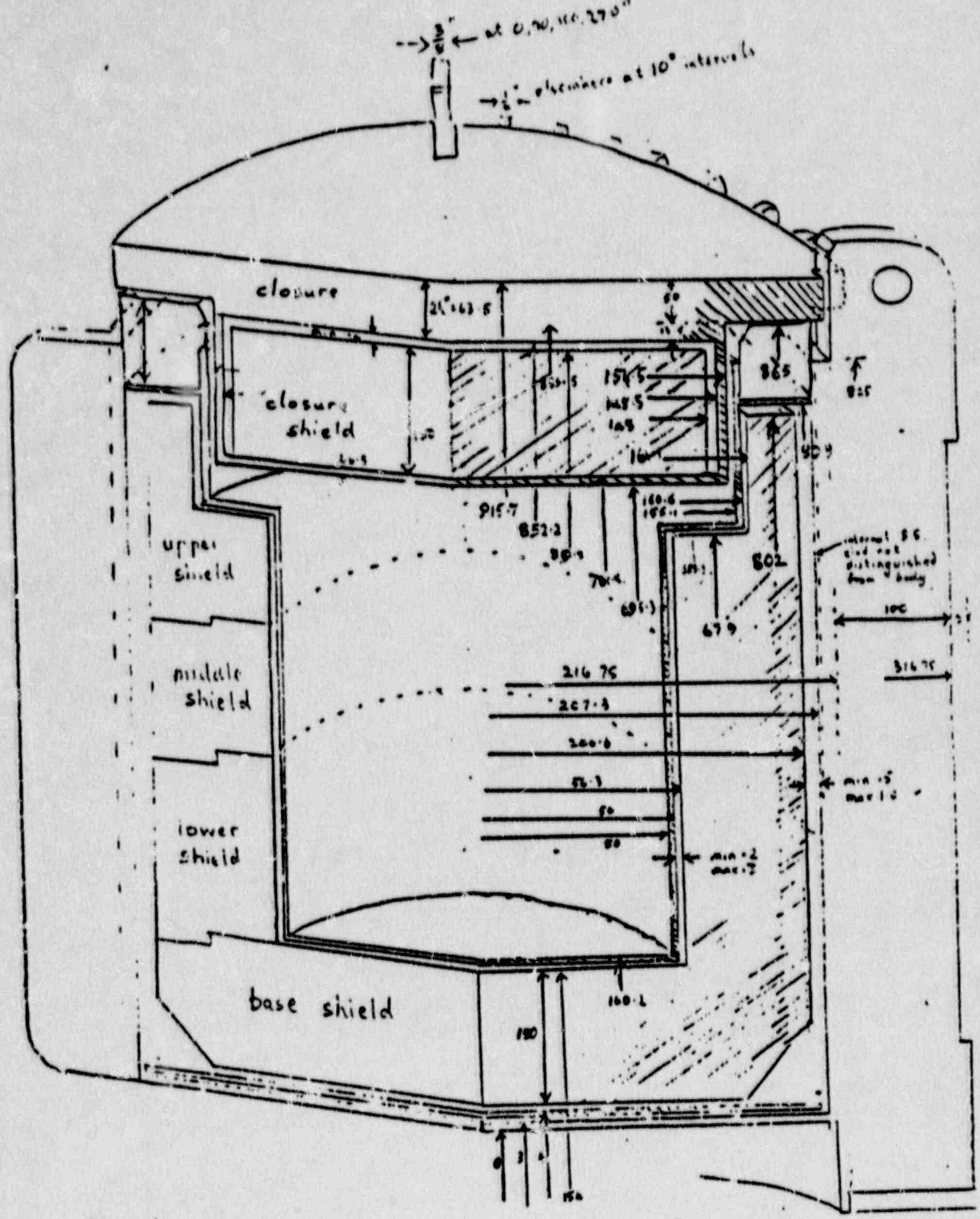
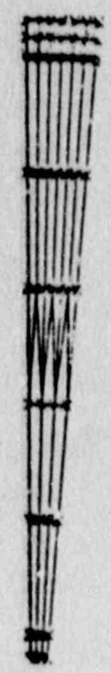
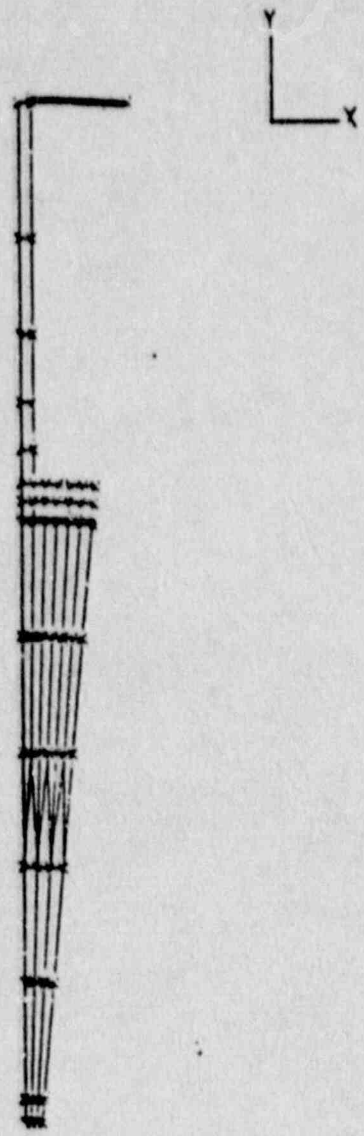

closure
closure shield
upper shield
middle shield
lower shield
base shield
865
802
679
915.7
852.2
216.75
207.3
200.6
160.1
180

Figure 1



AMER[illegible]NTL TRANSPORT FLASK______ 3

Figure



AMERSHAM INTL TRANSPORT FLASK______ 1

Figure 3

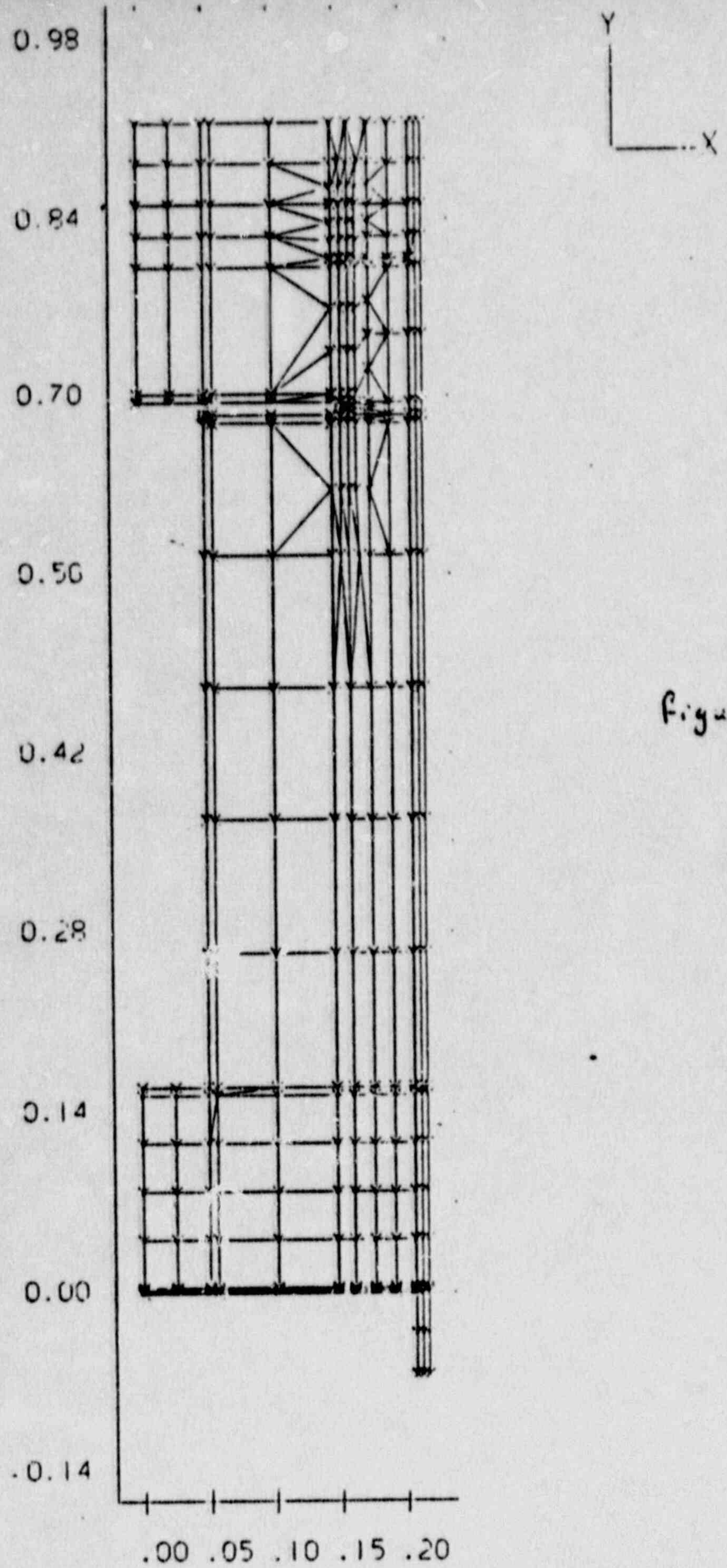
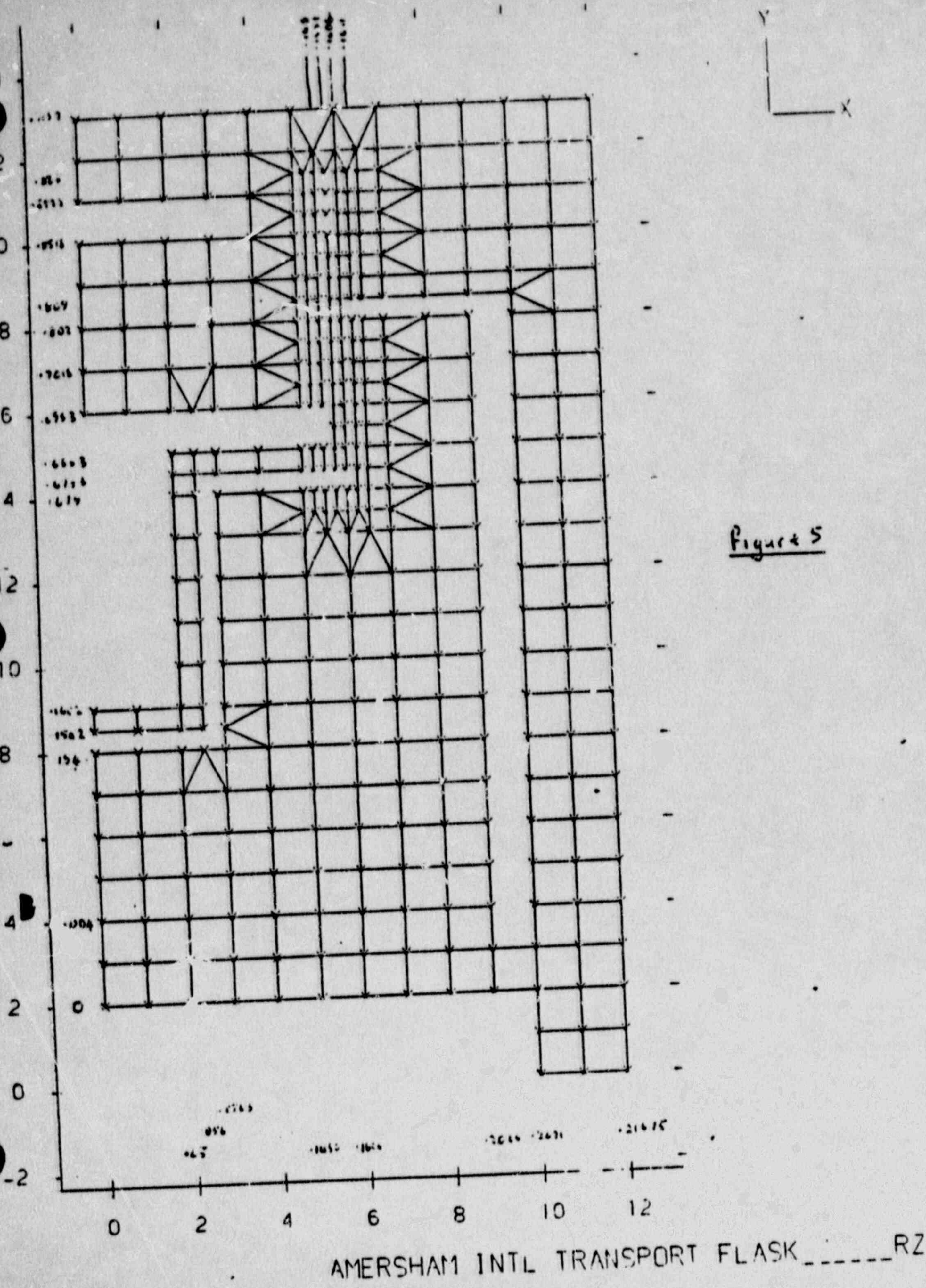


Figure 4.

AMERSHAM INTL TRANSPORT FLASK



Y
X
24
22
20
18
16
14
12
10
8
4
2
0
-2
0
2
4
6
8
10
12
Figure 5
AMERSHAM INTL TRANSPORT FLASK ______ RZ

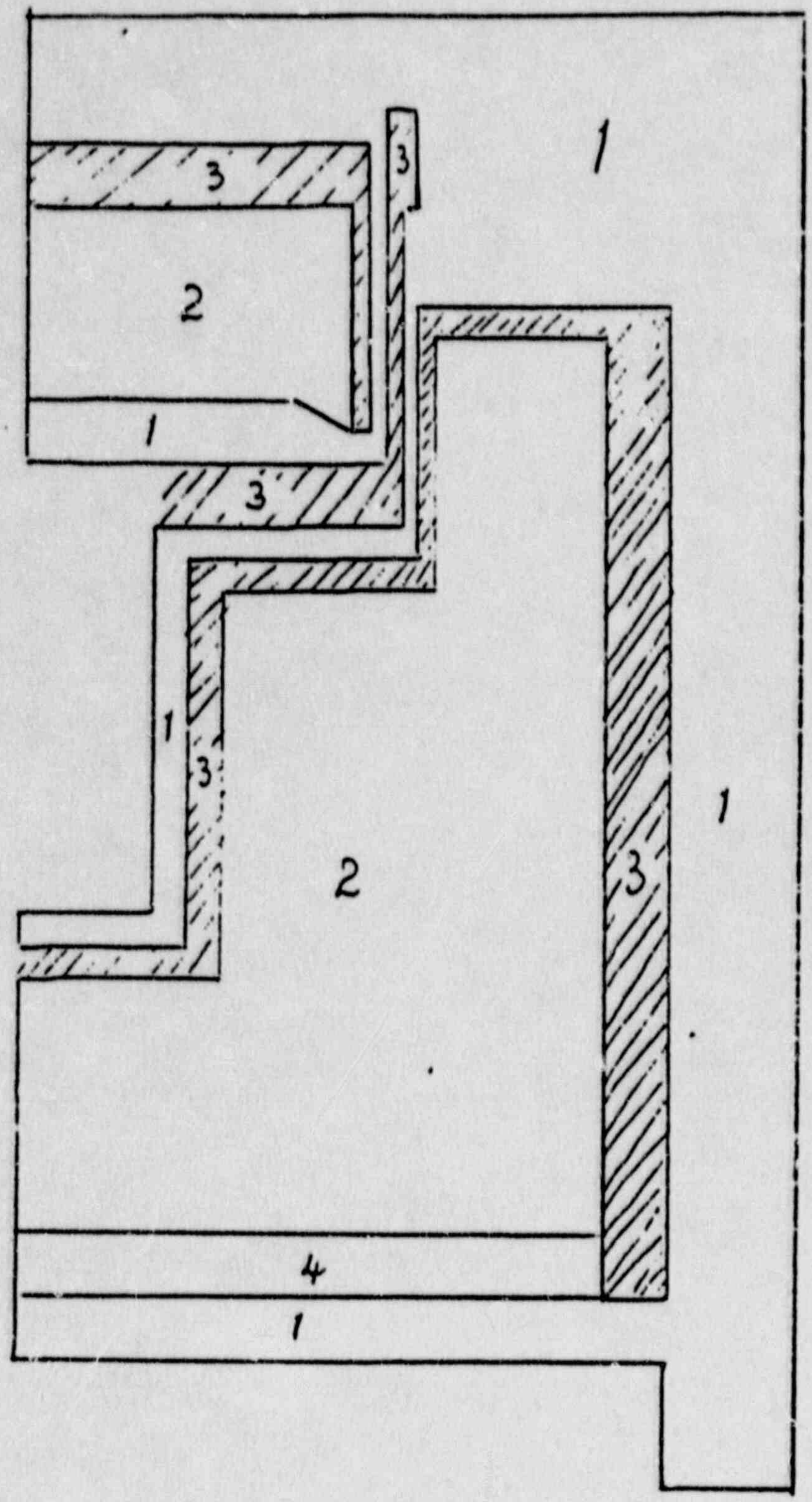


figure 6

1 : steel
2 : uranium
3 : gas (He or N)
4 : copper

note:
conduction and radiation in 3.

AMERSHAM INTERNATIONAL FLASK - DECEMBER 1987

1. Preamble

1.1 The investigation earlier in the year turned out not merely to be a calculation on a well defined model but a survey of the possible outcomes of the variation of a number of parameters. The current exercise settles on a single flask design but calculations are performed with and without the jacket and also with and without a tungsten disk at the bottom of the cavity.

1.2 The conceptual model, simplified from the original drawings, is shown as figure 1. This exercise concentrates on a 2D horizontal (XY) cross-section supported by an axisymmetric (RZ) section.

1.3 The XY cross-section model takes full advantage of the symmetry of the flask so in fact only a 5 degree sector is considered from the centre line of a fin to the point equidistant between that fin and its neighbour. Figures 2 and 3 illustrate the models used with and without the jacket.

2. The XY model without jacket (figure 2)

2.1 During the fire the flames penetrate between the fins to provide heat by convection to the flask and fin surfaces, but because the flames are said to be relatively transparent, it has been assumed that no radiant heat is provided by the thin layer of flame in that region. This is the "non-penetration" assumption of the report of 2/4/87. Radiant heat is input from the much thicker flame layer beyond the ends of the fins.

2.2 The ambient atmosphere is represented in the model by an additional array of elements which remain at the prescribed temperature and which reside immediately beyond the fin tips.

2.3 This assumption implies that the fins might cause a reduction in the amount of heat absorbed by the flask, because the view factor from the flask wall to the ambience is considerably reduced, most of the radiative heat which reaches the flask wall being by reflection or re-radiation from the fins. This effect is of course offset by the increased surface area provided by the fins which receive heat and pass it into the flask by conduction. A priori, it is not clear which effect dominates.

3. The model with a jacket (figure 3)

3.1 The outer surface of the flask, the surfaces of two adjacent fins and the inner surface of the jacket form an enclosure within which radiation is exchanged. Because flames and products of combustion will pass up this enclosure, its walls receive heat by convection just as if they were exposed directly to the fire, however the path length through the reasonably transparent flame is so short that the flames contribute no radiant heat at this point.

3.2 The outer surface of the jacket exchanges heat with the ambient conditions by both convection and radiation (of course without enhancement by fins).

3.3 The jacket is in poor thermal contact with the slender fin tips so it is assumed that no heat transfer by conduction takes place. All heat transfer between the jacket and the vessel and fins is by radiation.

4. The "no fin" model

4.1 Since the fins cannot be modelled in the axisymmetric representation one cannot merely attach the recommended heat transfer coefficients to the outer surface without enhancing them in some way to make allowance for the additional heat collected by the fins and passed into the vessel. An XY model without fins was therefore set up to determine experimentally the conditions required on the outer surface to give the same effects during the transient as the correctly modelled fins. A set of surface fluxes was determined which were then applied to the outer surface of the RZ model.

5. The RZ cases

5.1 The RZ model is shown as figures 4 and 5. Because the gaps are so very thin, a scale drawing does not show them so an out of scale picture has also been produced. This together with the data replay listings gives confidence that the intended model has in fact been set up.

5.2 The heat input on the finned surface was represented by a flux, varying with time, which gives the same temperatures as the XY cross-section model. This is expected to be pessimistic because the top and bottom corners will in practice heat up rather more rapidly than the central region and the flux at these points will reduce.

5.3 A further case was developed, see figure 10, which included a 30mm thick tungsten disc at the bottom of the cavity supported on steel bosses which provided an air gap between the tungsten and the steel liner.

6. Heat transfer coefficients

6.1 The heat transfer coefficients were applied along the outer surface of the flask between the fins and along the fin surfaces.

The run which included the jacket had the htc on the inner and outer surfaces of the jacket as well.

6.2 The values of htc were calculated from the equations detailed in the appendix for the fire and cooling phases. The same formula should apply for the initial steady state as in the cooling phase and would give a value of around 6, and this was done in case 21. For later runs of case 22 however a decision was made to use a fixed htc of value 10 since this gave steady state temperatures which agreed with those measured experimentally.

6.3 The heat transfer coefficient and radiative coefficients on the outer surface of the RZ model were replaced as explained by a time-dependent heat flux. There seems so little justification for applying the same flux to the top and bottom of the flask, but both surfaces are finned and so the same problem exists, that radial and axial fins cannot be modelled in an axisymmetric representation. An approximation often used is to double the heat transfer coefficient to allow for the effect of the fins, though often experimentation will produce a factor somewhat different from 2.0. Converaely, becauue the top and bottom will not experience the high flame velocities applying to the sides Amersham suggested halving the htc in these regions. Taking these two statements together implies an unmodified htc at the top and bottom and again, since the accuracy of any precise formulation is likely to be spurious, a value of 10 was taken during the fire, and a time dependent value running down from 10 to 5 was used during the cooling phase.

6.4 It would perhaps be better to run a number of cases with various interpretations of the top and bottom htc. We note particularly that SS No 37 para A628.20 states that the correlations used to obtain the mean value of Nu imply that the averaging process includes the top and bottom. Perhaps this implies that we could in fact apply our surface flux to these surfaces.

6.5 A full 3D model would side-step these problems because the fins would be modelled explicitly and the recommended values of htc would be attached to each flask and fin surface. The additional cost of running the 3D model is probably not justified.

7. Results

TEMPERATURES for cases without jacket

	case 21 XY with fins				case 23 XY no fins to emulate 21		case 24 RZ based on 21,23		
time	CIS	FS	FR	FT	CIS	FS	CIS	CB	FS
0	268	180	175	113	268	178	254	303	166
200	269	259	266	438	270	279	255	304	261
400	275	318	334	594	276	341	262	310	325
600	288	367	388	666	287	395	277	327	378
800	308	406	428	700	305	435	299	353	419
1000	332	438	459	717	326	465	325	385	451
1200	358	464	485	726	351	491	353	419	481
1500	397	498	517	735	388	523	395	471	519
1800	435	527	544	741	425	549	435	519	552
1810	436	519	539	722	427	540	437	520	544
1850	441	505	523	660	431	522	442	527	527
1900	447	492	505	600	437	502	448	534	508
2000	459	470	477	514	449	470	460	549	480
2200	478	440	439	407	470	429	479	573	444
2500	492	411	404	316	487	394	491	589	417
2750	495	396	386	274	492	378	493	590	405
3000	493	384	373	246	492	367	491	584	396
3300	488	373	361	226	488	357	485	572	386
3600	481	363	351	212	482	348	478	558	376
	D	B	A				E	F	C

where

CIS > cavity inner surface (side wall)
CB > cavity inner surface (centre of bottom)
FS > flask surface (side wall)
FR > fin root
FT > fin tip

A,B,C,D,E,F refer to curves on figure 6

Note: for case 24, at steady state, the peak temperature is about half way up the cavity as might be expected. As the transient proceeds this peak disappears and the cavity inner surface temperature increases monotonically as one moves down the side wall and along the bottom. Column E gives the temperatures at the node where the steady state peak was.

TEMPERATURES for cases with jacket

	case 22 XY with fins					case 23 XY no fins to emulate 22		case 24J RZ based on 21,23			case 25 RZ based on 21,23 with tungsten disc			
time	CIS	FS	FR	FT	JO	CIS	FS	CIS	CB	FS	CIS	CB	FS	TD
0	245	155	149	89	54	245	149	233	283	152	233	248	152	339
200	245	210	215	298	654	245	218	234	284	219	234	249	219	339
400	249	256	258	438	669	250	272	239	290	271	239	253	270	341
600	260	296	312	523	683	259	316	250	304	313	250	264	313	346
800	275	331	349	575	695	272	353	266	327	349	266	281	349	356
1000	293	361	380	507	704	289	383	286	354	379	286	304	379	372
1200	314	388	407	628	710	308	408	309	385	404	309	330	404	393
1500	347	422	441	648	717	339	442	345	431	438	345	373	438	430
1800	381	453	470	662	724	371	472	380	475	470	380	416	470	469
1810	382	449	468	655	619	372	470	381	477	468	381	418	468	471
1850	386	441	457	618	454	377	460	386	483	460	386	424	458	476
1900	392	432	445	575	386	382	448	392	490	448	392	431	445	483
2000	402	416	424	505	322	392	426	403	504	426	403	445	426	496
2200	420	393	394	411	251	411	396	422	527	396	422	470	395	522
2500	435	370	366	325	195	429	368	438	546	371	438	495	371	553
2750	441	357	351	281	170	437	354	444	550	360	444	505	360	569
3000	442	348	339	252	154	441	346	447	548	354	446	510	354	579
3300	440	338	329	229	142	442	337	447	541	348	446	508	348	583
3600	436	331	321	214	134	440	330	444	532	343	444	502	343	581
	5							1	2	3	1	2	3	4

where

- CIS > cavity inner surface (side wall)
- CB > cavity inner surface (centre of bottom)
- FS > flask surface (side wall)
- FR > fin root
- FT > fin tip
- JO > jacket outer surface
- TD > tungsten disc centre

1 2 3 4 5
refer to curves
on figures 9, 12

Note again that the CIS columns for cases 24J and 25 give temperatures at the node where the steady state peak was. From 1200 seconds onwards temperatures are higher at nodes nearer the . . . .

8. Conclusions

8.1 The program TAU

8.1.1 The program TAU has been used to predict temperatures in a small transport flask designed at Amersham for carrying radioactive products. TAU is a member of a group of programs which make use of the UNCLE finite element system. The program has had extensive use and validation and has been found to be suitable for a wide variety of heat transfer calculations within the UKAEA, the Authority cannot however take responsibility for the correctness of the results produced or for any event subsequent upon the use of those results when the program is operated by or on behalf of any other organisation or person.

8.1.2 The program attempts to give accurate solutions as demonstrated by the verification cases and by a variety of other checks on its use over the years. It is not inherently pessimistic, indeed in a general purpose program what gives pessimistic results in one situation might be regrded as optimistic in another. The pessimism of the results presented therefore depends on the data which is provided.

8.2 Without jacket

8.2.1 The XY case indicates that the peak temperature on the inside of the flask reaches an acceptable 495 degrees C under the assumptions made.

8.2.2 The RZ temperatures for the outer surface of the flask, half way up, closely follow the XY temperatures (compare curves A, B and C in figure 6). So too does the temperature on the inside (cylindrical surface) of the flask (compare D and E) though after about 1500 seconds this point no longer represents the peak temperature. This provides some confidence in the method adopted.

8.2.3 The peak temperature is found to be at the bottom of the cavity and reaches 590 (curve F). What effect would other assumptions about the boundary condition have on this?

8.3 With the jacket

8.3.1 The XY case indicates that the peak temperature half way up the side wall of the cavity reaches only 447. This is not strictly comparable with the non-jacket case beacause of the different assumption made at steady state (see paragraph 6.2). Under the same steady state assumptions we would assume the temperatures to be about 30 degrees higher, say 475-480, still distinctly cooler than without the jacket.

8.3.2 Again the hottest point is to be found at the bottom of the cavity with a temperature of 550 but we should note the fall off in temperature with radius so that at the crucial radius of 25 mm the temperature is 538.

8.3.3 The highest steel uranium interface temperature is 544/471 occurring at the centre of the base of the cavity.

8.4 With jacket and tungsten disk

8.4.1 The inclusion of the disk of course makes no difference to the side wall temperature at the half way position and above but has a marked effect on the temperature distribution at the base. At steady state the disc has a maximum temperature of 339 and the steel liner below it is at 248 compared with a cavity bottom temperature of 283 when the disk is not in place. This is explained by the air gap below the disk. The peak temperature in the tungsten during the transient is 583, the steel below it attains a temperature of 523. The temperature of the disk is uniform with no reduction in temperature at a radius of 25 mm.

8.4.2 Note that the highest cavity wall temperature seen by the flask contents is about 475, immediately above the level of the tungsten disk.

8.4.3 The highest steel uranium interface temperature is 522/460 occurring at the centre of the base of the cavity.

8.5 Caveat

8.5.1 TAU is known to predict temperatures accurately in a wide variety of situations but cannot produce results of better quality than the data. The initial steady state temperatures have an important bearing on the temperature distribution throughout the transient in the sense that starting off say 20 degrees cooler will cause the peak temperature during the transient to be almost 20 degrees less. The choice of heat transfer coefficient is important as it largely determines the total amount of heat absorbed and lost during the transient, though we might remark on the discovery in April that a high htc throughout the transient causes the outer regions of the flask to heat up quickly, but then this heat is removed equally quickly resulting in internal temperatures marginally lower.

8.5.2 The htc at the base is the data item most in doubt which is unfortunate since this must have some effect on the peak temperature in the cavity base which is within acceptable limits ~~by the smallest margin~~.

9. References

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2. IAEA Safety Guide no 37 (third edition) 1987

3. TAU a computer program for the analysis of temperature in two- and three-dimensional structures - D Johnson - UKAEA - ND-R-218(R)

4. Radiation of heat in the heat transfer program TAU - W D Collier - UKAEA - ND-R-555(R)

5. Validation cases for TAU - W D Collier - UKAEA - ND-R-556(R) revision 1

6. UNCLE finite element scheme - Enderby, Collier et al. - UKAEA - ND-R-1331(R)

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WA3 6AT

14 December 1987

AMERSHAM INTERNATIONAL FLASK

Material Data

Uranium

density 18.78g/cc = 1.878E4 kg/cu.m

conductivity 0.067 + 2.1E-5*T cal/cm/sec/deg C

= 4.1868*(0.067 + 2.1E-5*T) joules/cm/sec/deg C
or watts/cm/deg C

= 418.68*(0.067 + 2.1E-5*T) w/m/deg C

temp deg C	cond
0	28.05151
1000	36.84294

specific heat 2.61 + 8.95E-3*T + 1.17E5*T^-2 cals/mole/deg C

=(2.61 + 8.95E-3*T + 1.17E5*T^-2)*4.1868/0.238
joules/kg/deg C

temp deg C	sp ht
0	116.5
200	129.6
400	156.4
600	186.1
800	216.6
1000	232.1

Steel

density 7.97 g/cc 7.97E3 kg/cu.m

conductivity .038 cgs units ?= cal/cm/sec/deg C

= 4.1868*.038*100 = 15.90982 watts/m/deg C

specific heat

temp deg C	spht
50	469
450	565
750	615 joules/kg

Handbook of Chemistry and Physics 58th ed. CRC press

Copper
------

density	8960 kg/cu.m							
conductivity	temps	0	100	300	70C	1000		
		403	395	381	354	344		
specific heat	temps	0	100	200	300	500	800	
		.379	.397	.408	.419	.43	.44	

Tungsten
----

density 18000 kg/cu.m

conductivity 178 watts/m/degC

specific heat 134 joules/kg/degC

handbook of physics and chemistry 58th ed CRC press

Air
---

conductivity:	temps	0	200	400	600	800
	cond	.02412	.038641	.050841	.061442	.070853

Helium

density = p / 2077.3 * T (Pascal/deg K) kg/cu.m

not used

specific heat Cv = 5195 joules/kg deg C
Cp = 3117 joules/kg deg C

not used

conductivity = 2.682E-3 * (1 + 1.123E-8.p) * T^.71*(1 - 2E-9.p)

watts/m deg C

where T is deg K
p is Pascal

assume p = 1.E5 Pa (1 bar)
though in fact the effect of variation
with p is marginal

T (deg C)	cond	cond (p:T)
0	.143971	.143971
200	.212675	.212714
400	.273171	.273249
600	.328585	.328699
800	.380400	.380514
1000	.429409	.429633

Stefan's constant = 5.66925E-8 watts/sq.m deg K sec

Gas filled gaps, emissivity = .8 both sides

effective emissivity = $\frac{\epsilon_1 \epsilon_2}{\epsilon_1 + \epsilon_2 - \epsilon_1 \epsilon_2} = \frac{64}{96} = \frac{2}{3}$

radiation constant used is 2/3 * Stef = 3.7795E-8

Radiation to ambient; emissivity .8 on flask and fin surface
.9 in flames

Internal heat generation = 4.160 kwatts

internal surface area is 2 * π * .05*.05
+ 2 * π * .05 * .535

= .015798 + .168075

= .183783 sq.m

surface heat flux is 22635 watts/sq.m

(for the XY cross-section the pessimistic assumption could be made that no heat was lost axially, then the flux would equal 24751.)

HEAT TRANSFER COEFFICIENTS FOR THE AMERSHAM FLASK

For the calculations during April and May 1987, the heat transfer coefficient was chosen to be 10 or 30. For the current calculations, September 1987, more detailed recommendations have been made.

During the fire

The Dept of Transport issue guide-lines and their "safety series" no. 37 is relevant.

Paragraph A-628.20 suggests

$$Nu = .036 * Pr^{1/3} * Re^{.8}$$

"as quoted by McAdams".

In fact "Heat Transmission" by W H McAdams on page 249 quotes

$$\left(\frac{h}{cp\,V\,\rho}\right)_1 \left(\frac{cp\,\mu}{k}\right)_f^{2/3} = \frac{.036}{(L\,V\,\rho\,/\,\mu)_1^{.2}}$$

where h is the mean heat transfer coefficient for use up the whole vertical surface

cp is specific heat

ρ is density

k is conductivity

μ is dynamic viscosity

L is the height of the plate

V is the velocity of the flowing fluid

and where subscript 1 implies bulk properties of the fluid (see McAdams page 224) ie 800 C in this case.

f implies fluid properties at the "film temperature" .5*(Tbulk + Twall) (see page 205).

Using the usual non-dimensional nomenclature

$$Nu = h\,L\,/\,k$$

$$Pr = cp\,\mu\,/\,k$$

$$Re = L\,V\,\rho\,/\,u$$

$$St = h / (c_p V \rho)$$

we may rewrite the above formula as

$$St_1 \, Pr_f^{2/3} = .036 \, Re_1^{-.2}$$

We may also verify that

$$Nu = St.Pr.Re$$

so we may write

$$St_1 \, Pr_f \, Re_1 = .036 \, Re_1^{.8} \, Pr_f^{1/3}$$

or

$$Nu_1 = St_1 \, Pr_1 \, Re_1 = .036 \, Re_1^{.8} \, Pr_1^{1/3} \left[\frac{Pr_1}{Pr_f} \right]^{2/3}$$

For T = 800, Pr = .736 and for T = 350, Pr = .698.

Pr_1 / Pr_f thus varies from 1.054 to 1 and $[Pr_1 / Pr_f]^{2/3}$ varies from 1.036 to 1 and so may safely be ignored.

Thus we have an expression for heat transfer coefficient:

$$h = .036 \, \frac{k}{L} \, Re^{.8} \, Pr^{1/3}$$

The flame velocity is said to be in the range 5 to 10 m/sec. Evaluating all the air properties at the flame bulk temperature of 800 C we have the following results.

L = .916 m

T = 800 C

cp = 1.1562 kJ /Kg C

ρ = .32473 kg / cu.m

μ = 4.5108E-5 Pa sec

k = 7.0853E-2 W / m C

Pr = .73613

note that we have kJ in cp and W in k. This necessitates a factor of 1000 in the definition of Pr.

V = 5 .... 10 m / sec

Re = 32971 65942

h = 10.3495 .... 18.0157

note that h is constant throughout the fire phase since constant flame temperature T and velocity V are assumed.

We should note that the formula is recommended by McAdams in situations where the Reynolds number is in excess of about 500000. This is a factor of 10 up on the actual values calculated but it is assumed that the fire conditions are inherently turbulent and that heat transfer coefficients will be of this order of magnitude. The uncertainties are such that there is no point in using a spuriously precise formula and the recommended value of 10 was adopted (see A-628.20).

Cooling down

Paragraph A-628.21 offers a formula

$$Nu = .13\ (Pr.Gr)^{1/3}$$

This too may be derived from McAdams. On page 172 he considers the product of Grashof and Prandtl numbers, and evaluating the fluid properties at the film temperature throughout suggests

$$Nu = .59\ (\ Gr.Pr\ )^{1/4} \quad \text{for Gr.Pr in } 10^{4} .. 10^{9}$$

$$Nu = .13\ (\ Gr.Pr\ )^{1/3} \quad \text{for Gr.Pr in } 10^{9} .. 10^{12}$$

where $Gr = \dfrac{L^3\ \rho^2\ g\ B\ DT}{\mu}$

g = acceleration due to gravity

B = volumetric expansion coefficient
= 1/Tbk

Tbk = absolute bulk temperature of coolant
= 38 + 273 in this case

DT = temperature potential
= Twall - Tbulk

Taking a couple of possible values during the transient

Twall	= 562	262
Tfilm	= 300	150
ρ	= .60808	.823716
cp	= 1.0452	1.0172
μ	= 2.9822E-5	2.4113E-5
k	= .044982	.035257
Pr	= .69291	.69568
DT	= 524	224
Gr	= 5.2768E9	6.3312E9
Pr.Gr	= 3.6565E9	4.40449E9
Nu	= 200.26	213.08
h	= 9.83417	8.2015

L	= .916
g	= 9.801
B	= .0032154

We note that Pr.Gr is in the range recommended by McAdams though one might ask whether this flask corresponds to the "short" surfaces for which the experimental data was correlated. We note too that the heat transfer coefficients are of the expected size.

The RZ model

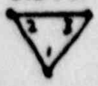
The following elements and cells were used in the construction of the RZ model.

Elements

\1 = RZ4N four noded axisymmetric isoparametric element

solid steel, depl.uranium, copper, tungsten, or exceptionally a conducting fluid

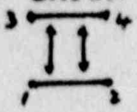
\2 = RZ3N three noded axisymmetric element



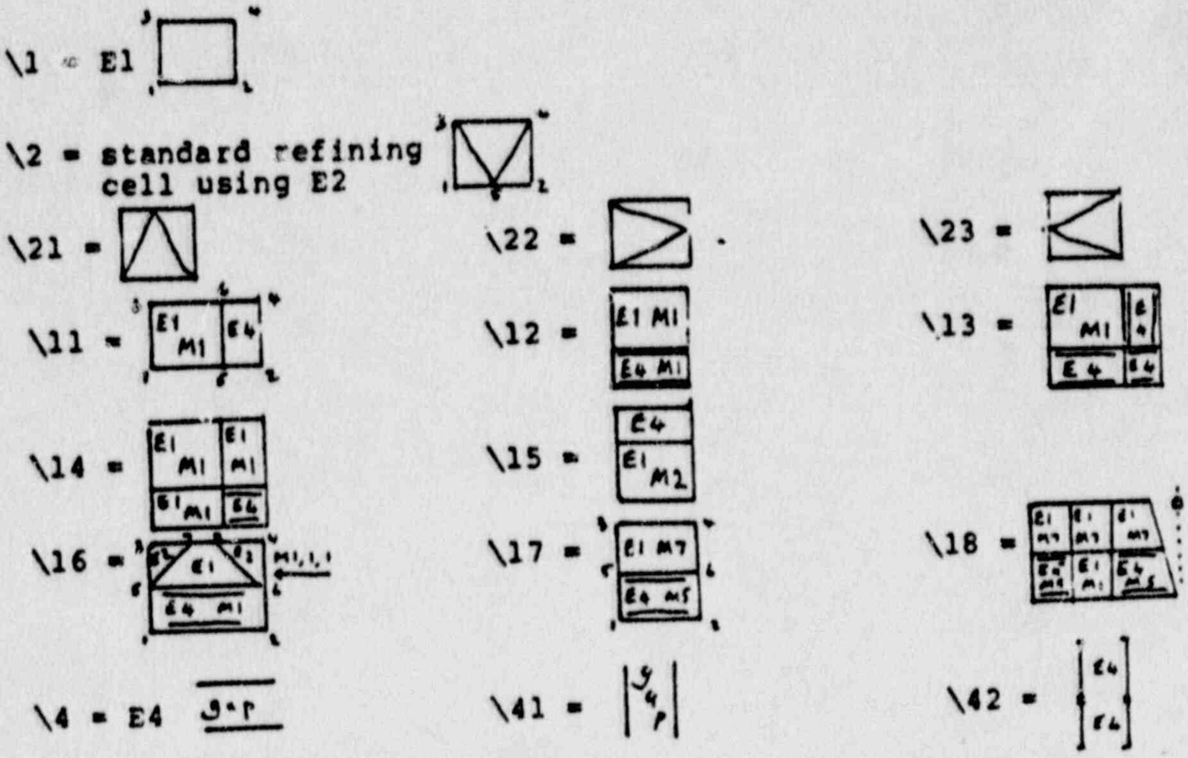
solid as \1

\3 = RZ2S two noded axisymmetric surface element

\4 = GAP2R four noded axisymmetric gap element



Cells



The cells were arranged in the arrays 1 and 2 as shown on the out-of-scale figures 4 and 10a.

The material properties associated with the elements either through a specification in the cell definition or one in the array definition are as follows.

materials		
	solid	gap/surface
M1	steel	helium gap
M2	depleted uranium	flask surface
M3	-	internal cavity surface
M4	copper	top and bottom surface
M6	helium at chamfer of base shield	-
M7	tungsten	-

The geometry produced the model shown in figure 5. The gaps are far too small to be seen, but subregion plots and numbers from the tabular listings of the data provide confirmation that the model is as defined.

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0

150mm

6"

1

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

Amersham International Transport Flask

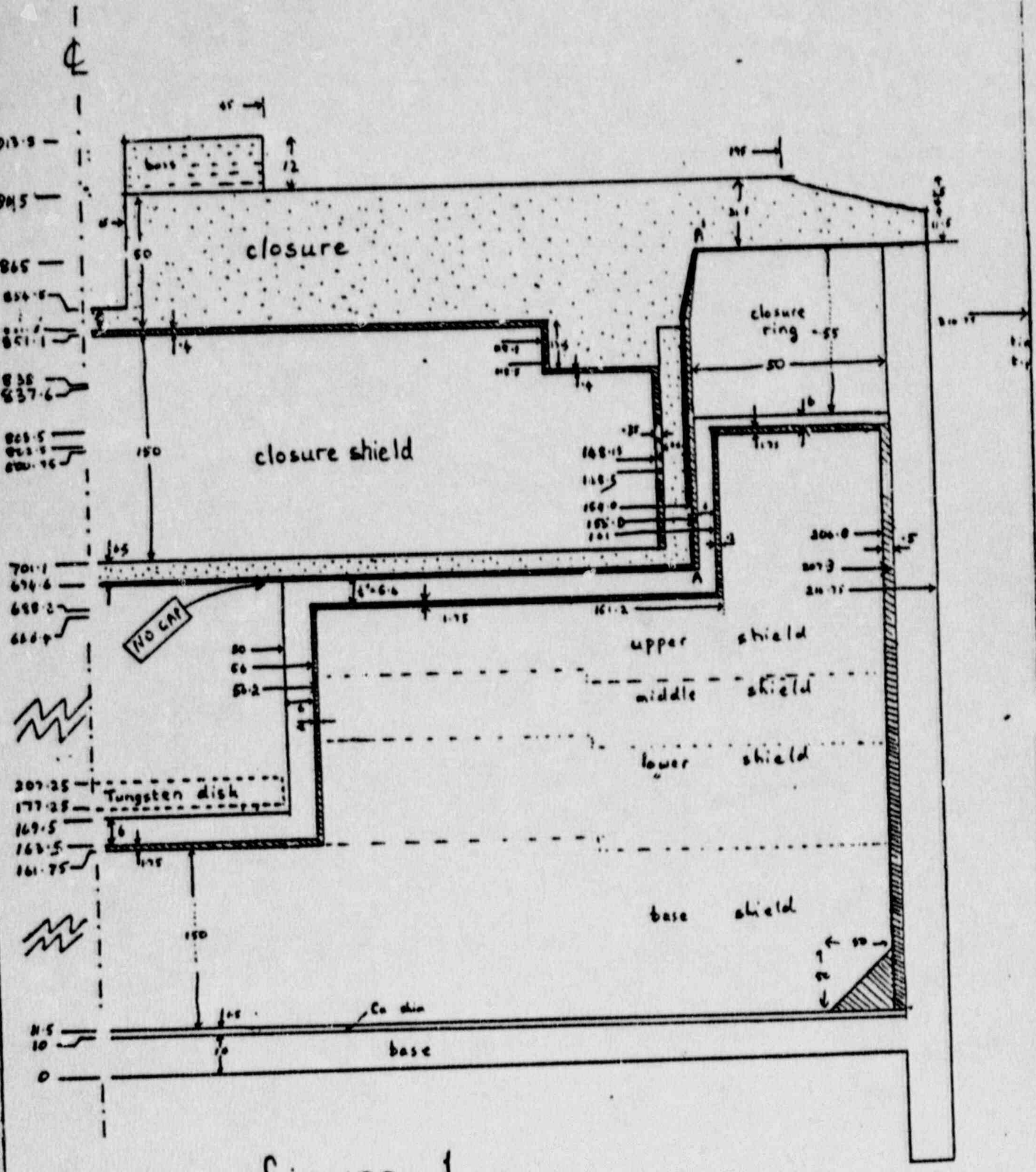
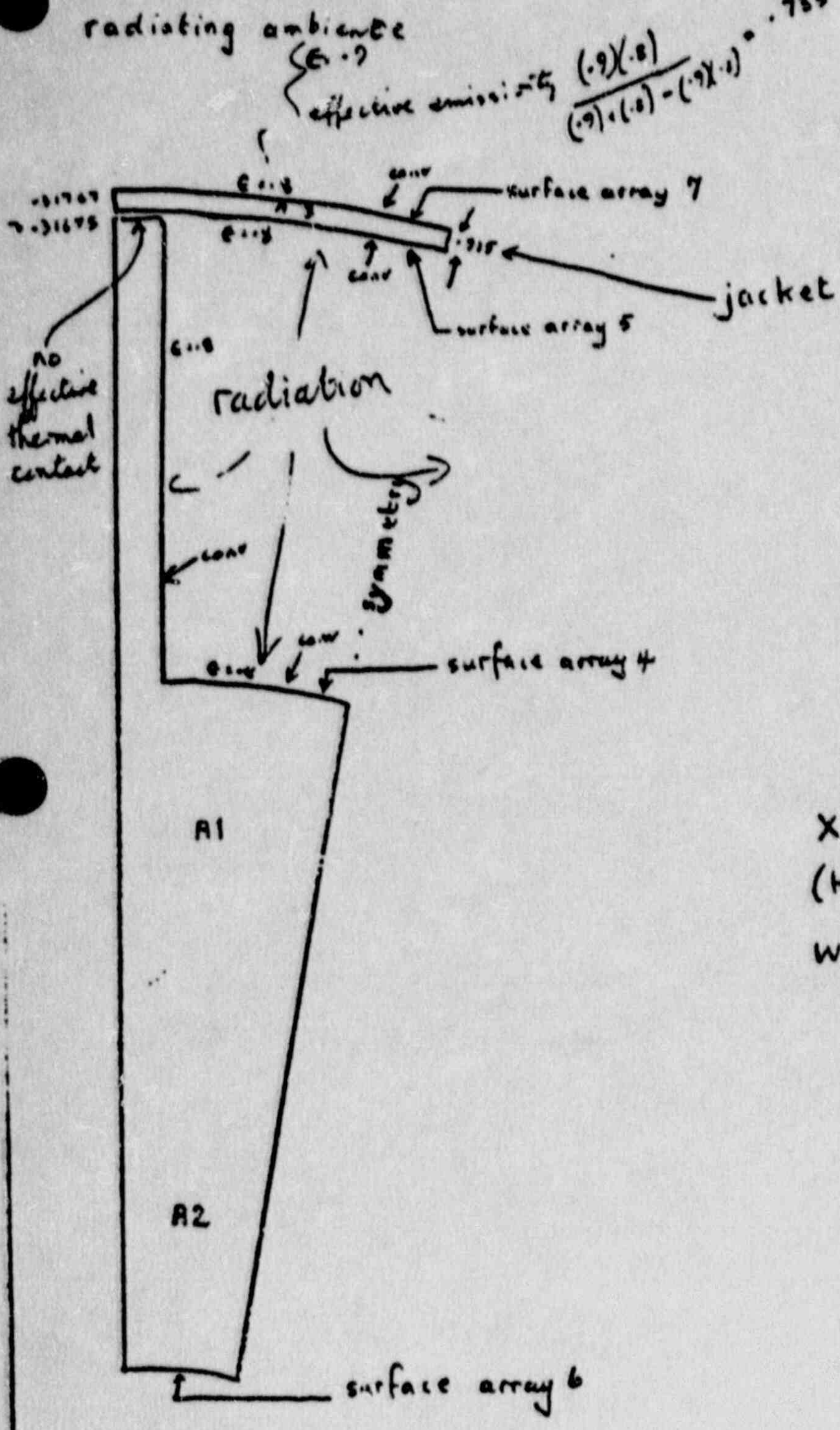


figure 1

CASE 22



XY model
(horizontal cross-section)
with jacket

Figure 3

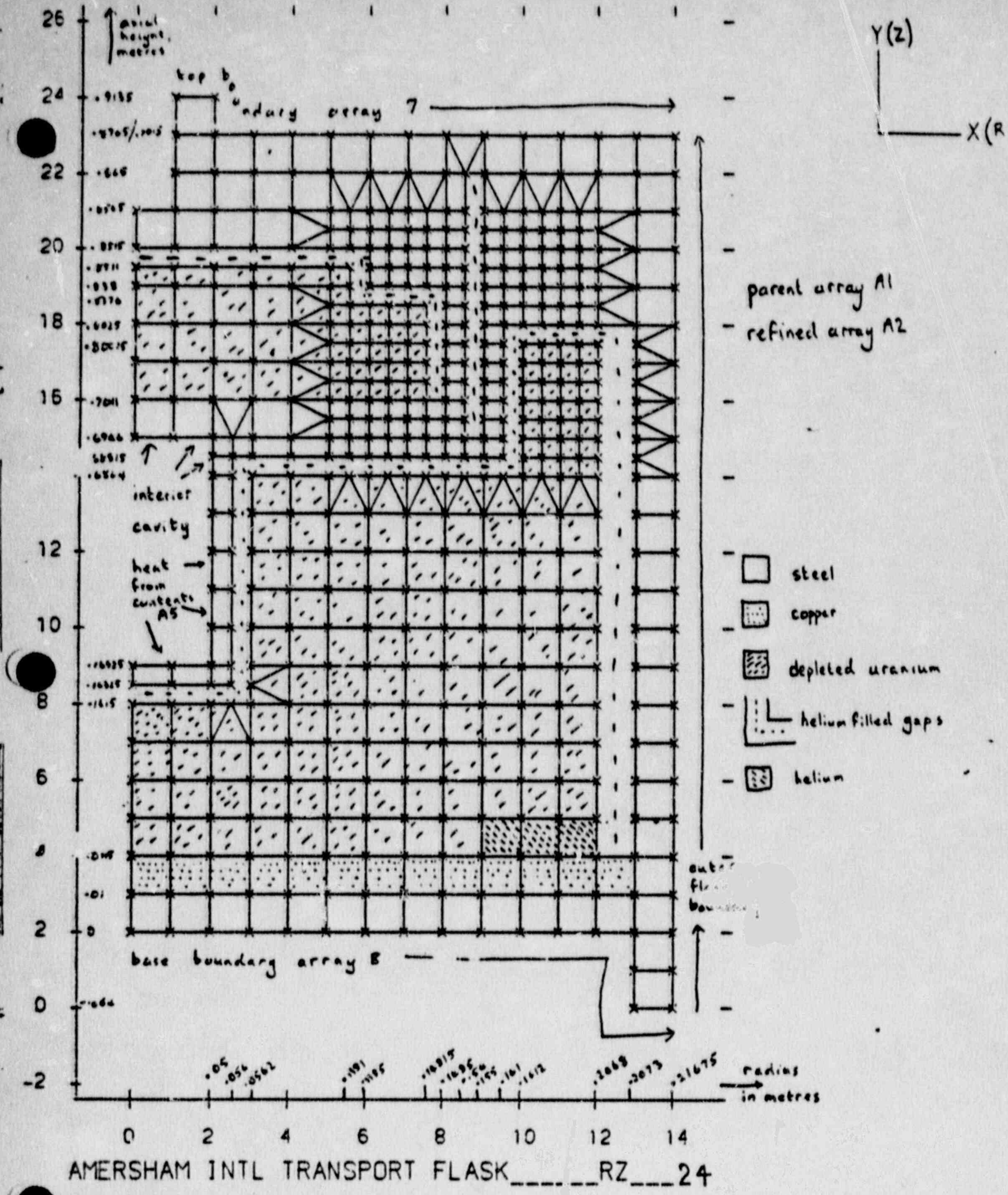

axial height, metres
top boundary array 7
Y(Z)
X(R
parent array A1
refined array A2
interior cavity
heat from contents A5
steel
copper
depleted uranium
helium filled gaps
helium
outer flask boundary
base boundary array 8
radius in metres
AMERSHAM INTL TRANSPORT FLASK_____RZ___24

Figure 4

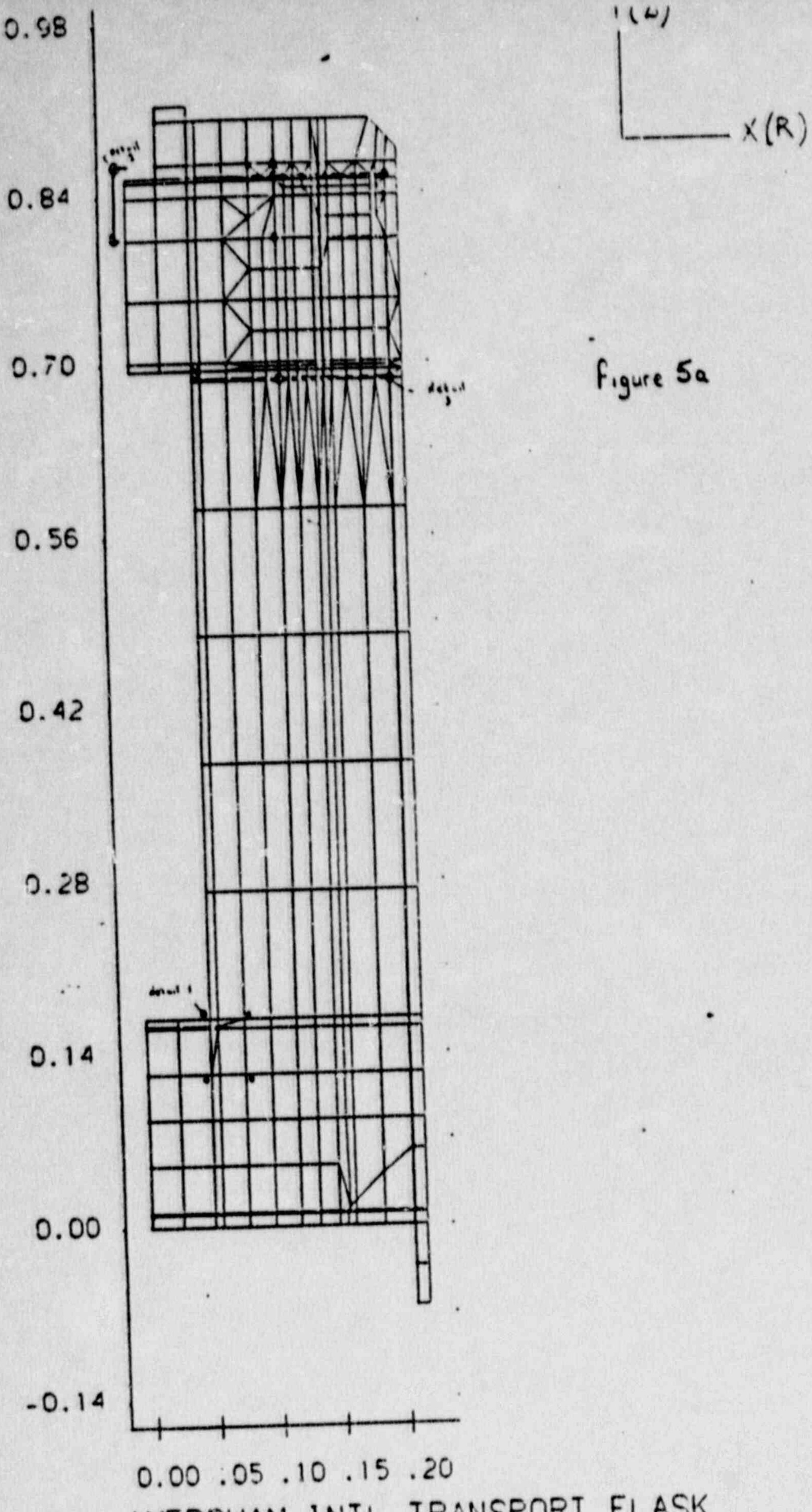


Figure 5a

AMERSHAM INTL TRANSPORT FLASK______RZ___24

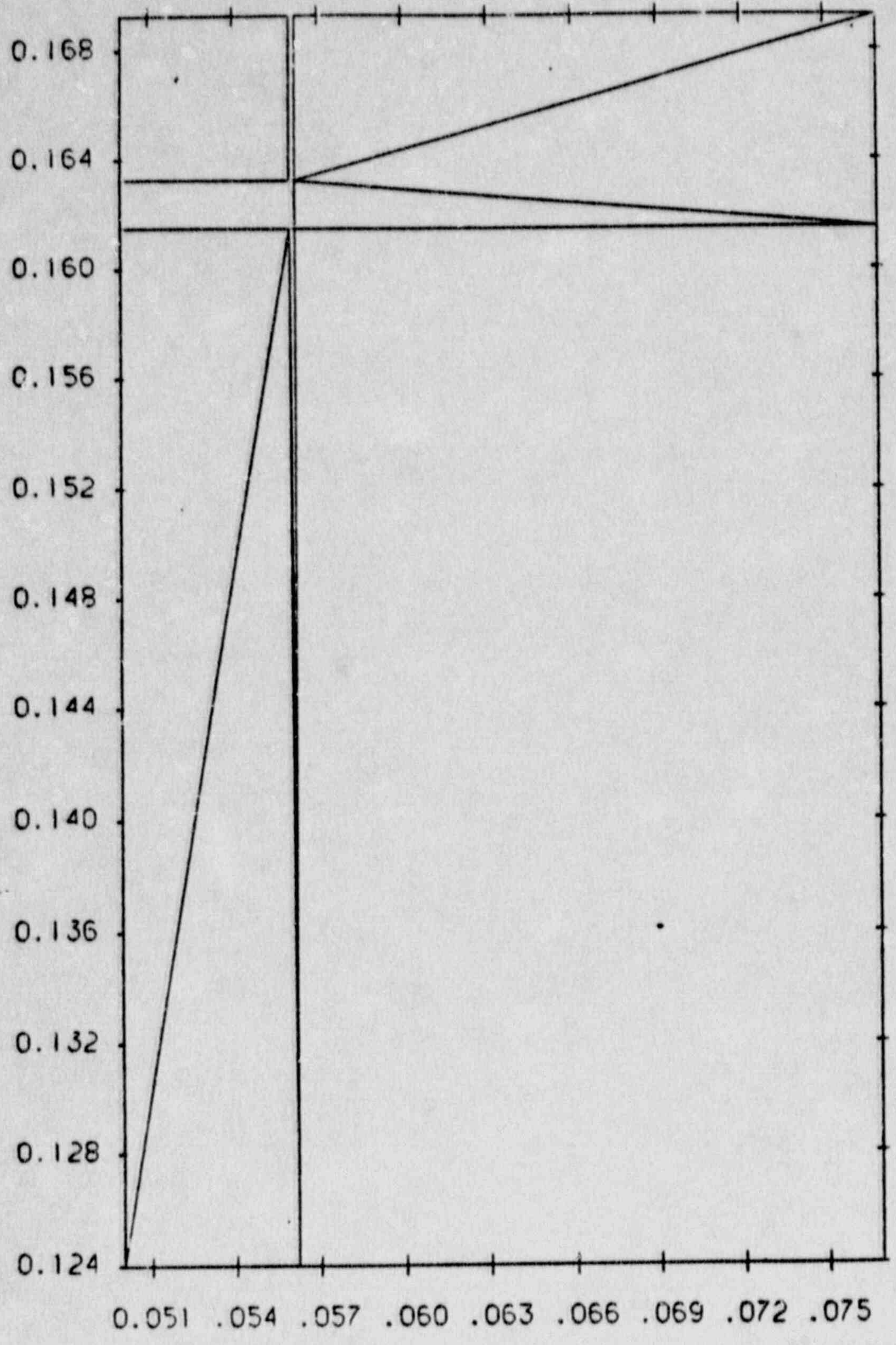
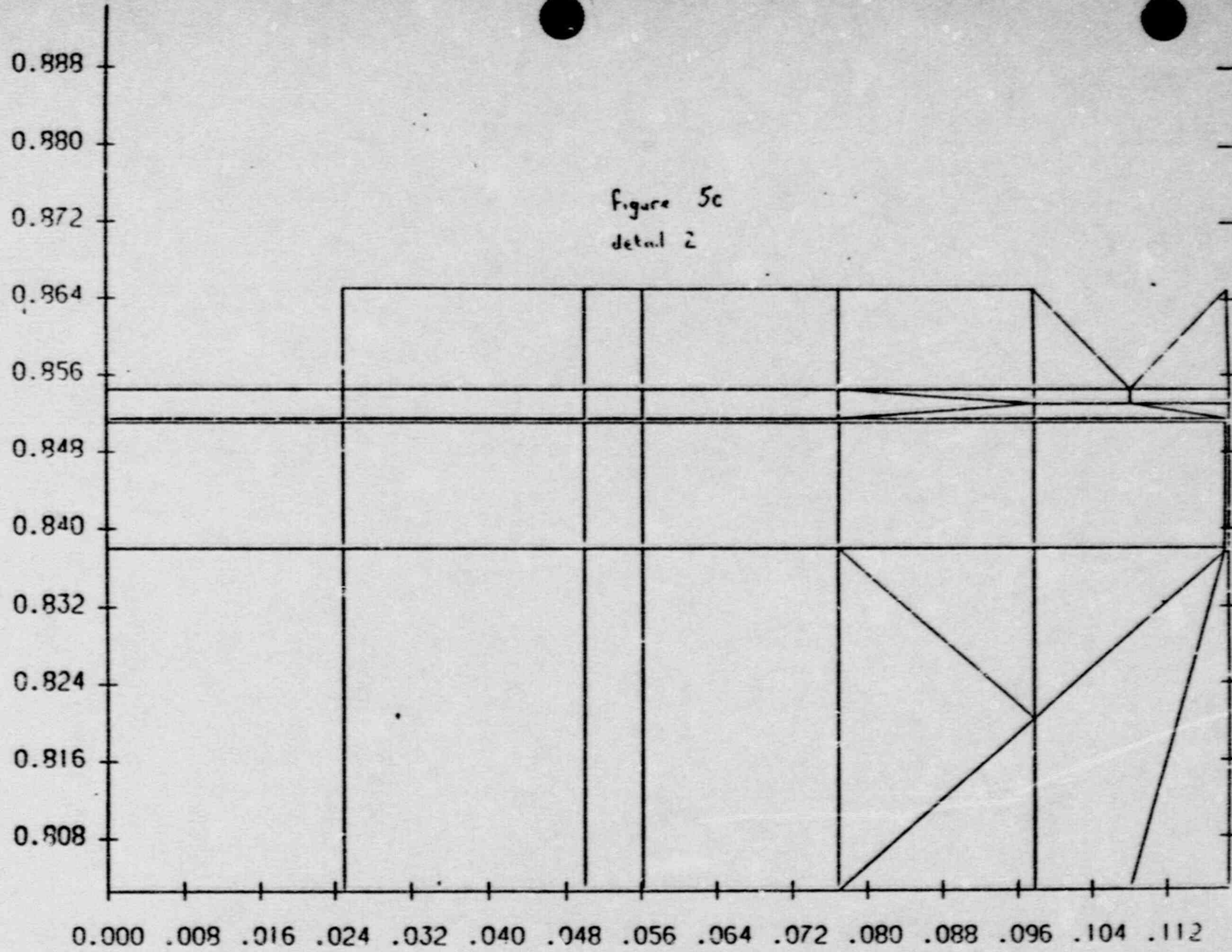


figure 5b

detail 1

AMERSHAM INTL TRANSPORT FLASK______RZ___



AMERSHAM INTL TRANSPORT FLASK______RZ___

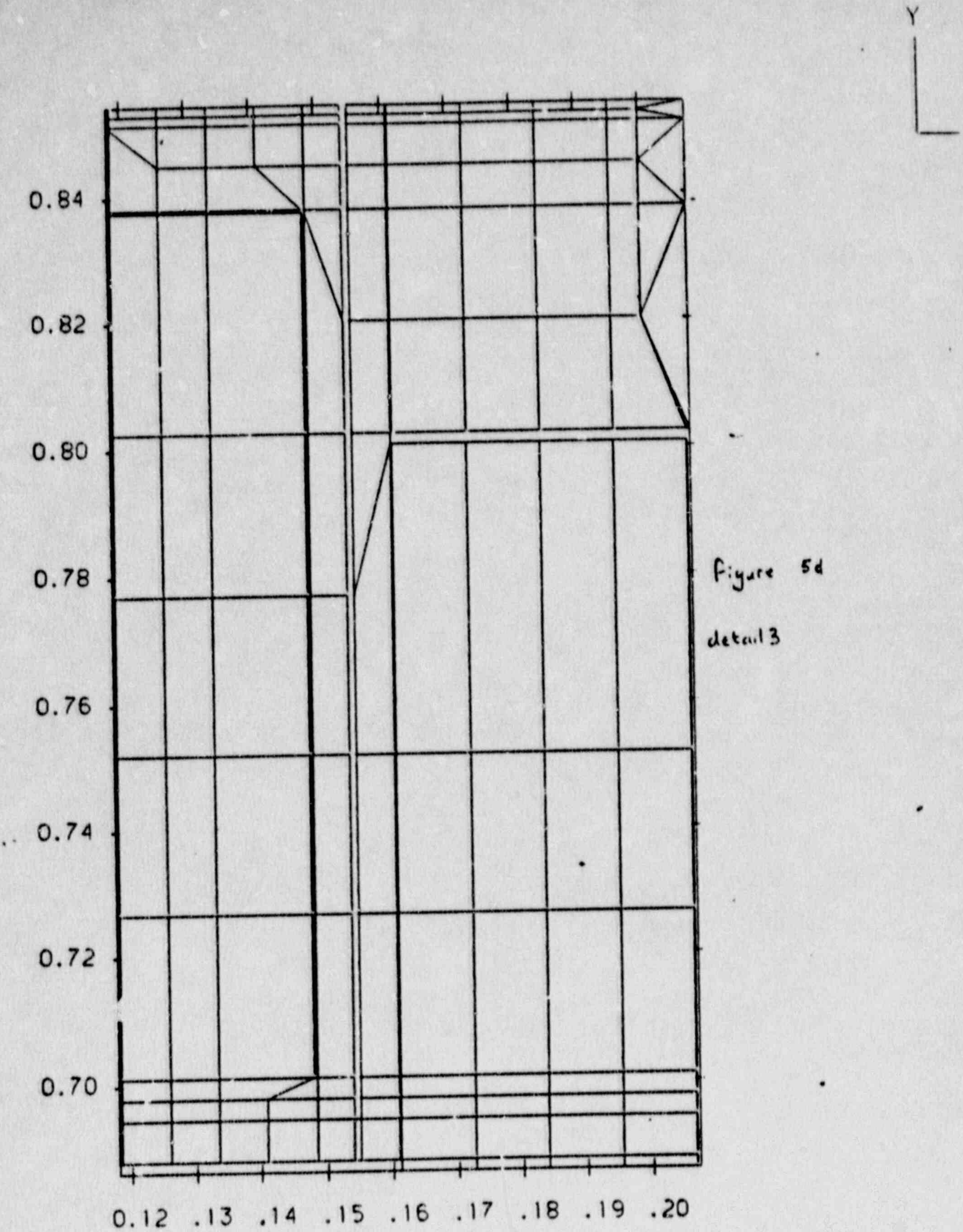


Figure 5d

detail 3

AMERSHAM INTL TRANSPORT FLASK______RZ___

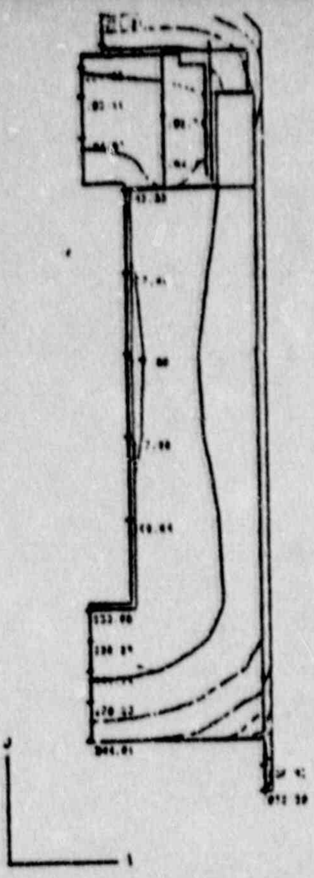


figure 7a

case 24 without jacket
without disc

TEMPERATURES TIME = 600.0000 INTERVAL BETWEEN CONTOURS = 20.000

PLOT 1 [illegible] AMERSHAM [illegible] TRANSPORT FLASK ____ [illegible] VALUES IN BRACKETS ARE NEGATIVE

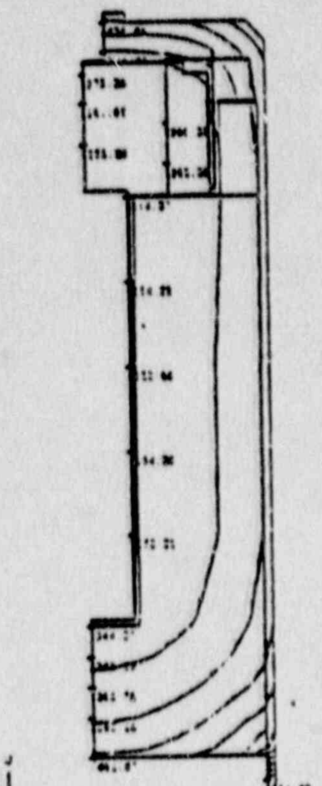


figure 7b

TEMPERATURES TIME = 1200.0000 INTERVAL BETWEEN CONTOURS = [illegible]

PLOT 1 [illegible] AMERSHAM [illegible] TRANSPORT FLASK ____ [illegible] VALUES IN BRACKETS ARE NEGATIVE

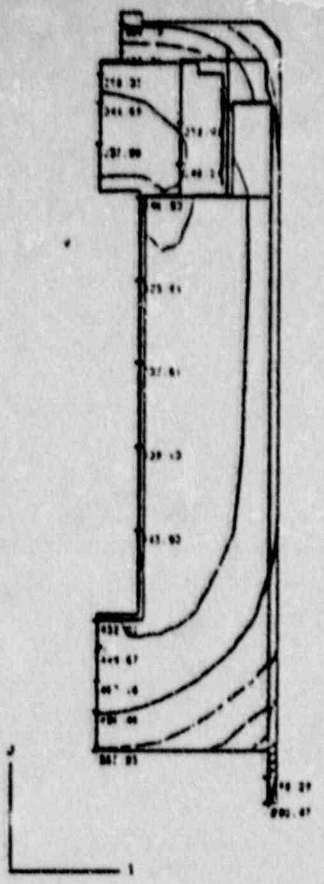


figure 7c

TEMPERATURES TIME = 1800.0000 INTERVAL BETWEEN CONTOURS = 20.000

PLOT 1 ... TRANSPORT FLASK ... (VALUES IN BRACKETS ARE NEGATIVE)

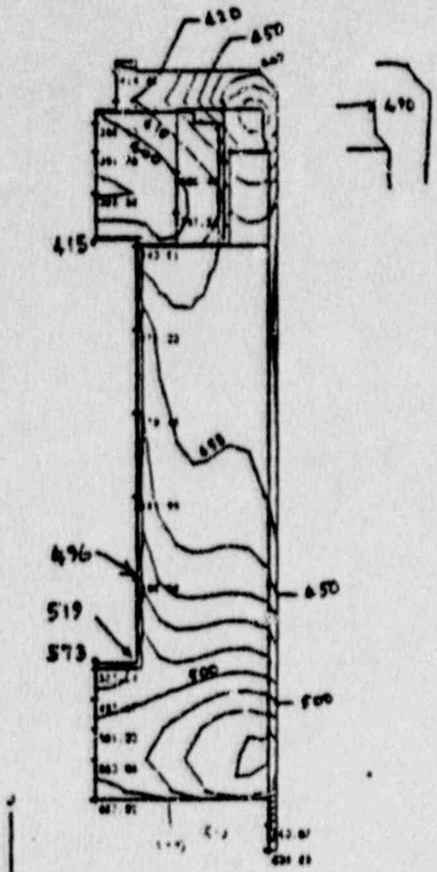


figure 7d

TEMPERATURES TIME = 2200.0000 INTERVAL BETWEEN CONTOURS = 10.000

PLOT 1 ... TRANSPORT FLASK ... (VALUES IN BRACKETS ARE NEGATIVE)

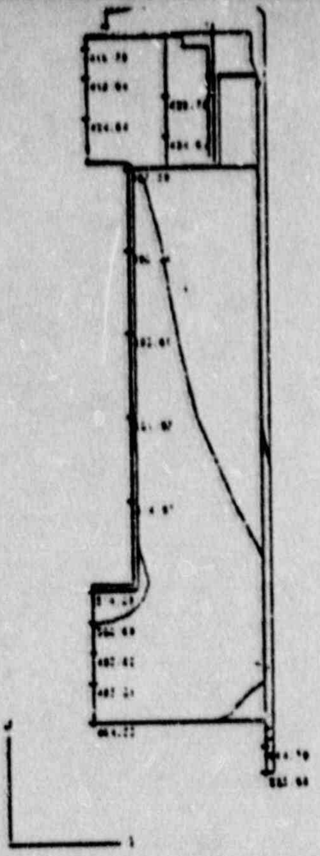


figure 7e

TEMPERATURES TIME = 2750.0000 INTERVAL BETWEEN CONTOURS = 50.000

PLOT 1 [illegible] AMERSHAM INT. TRANSPORT FLASK_____R2___ VALUES IN BRACKETS ARE NEGATIVE

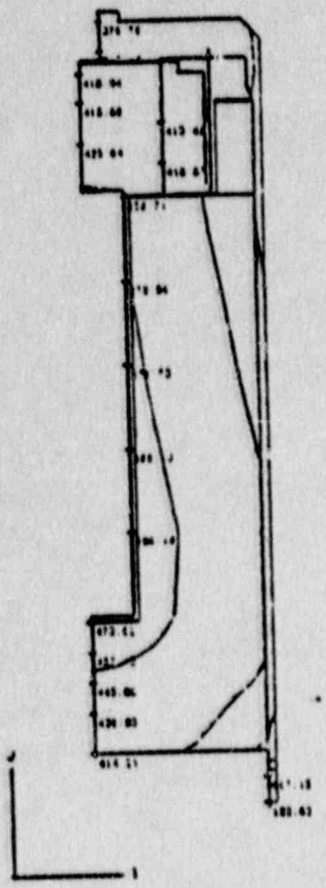
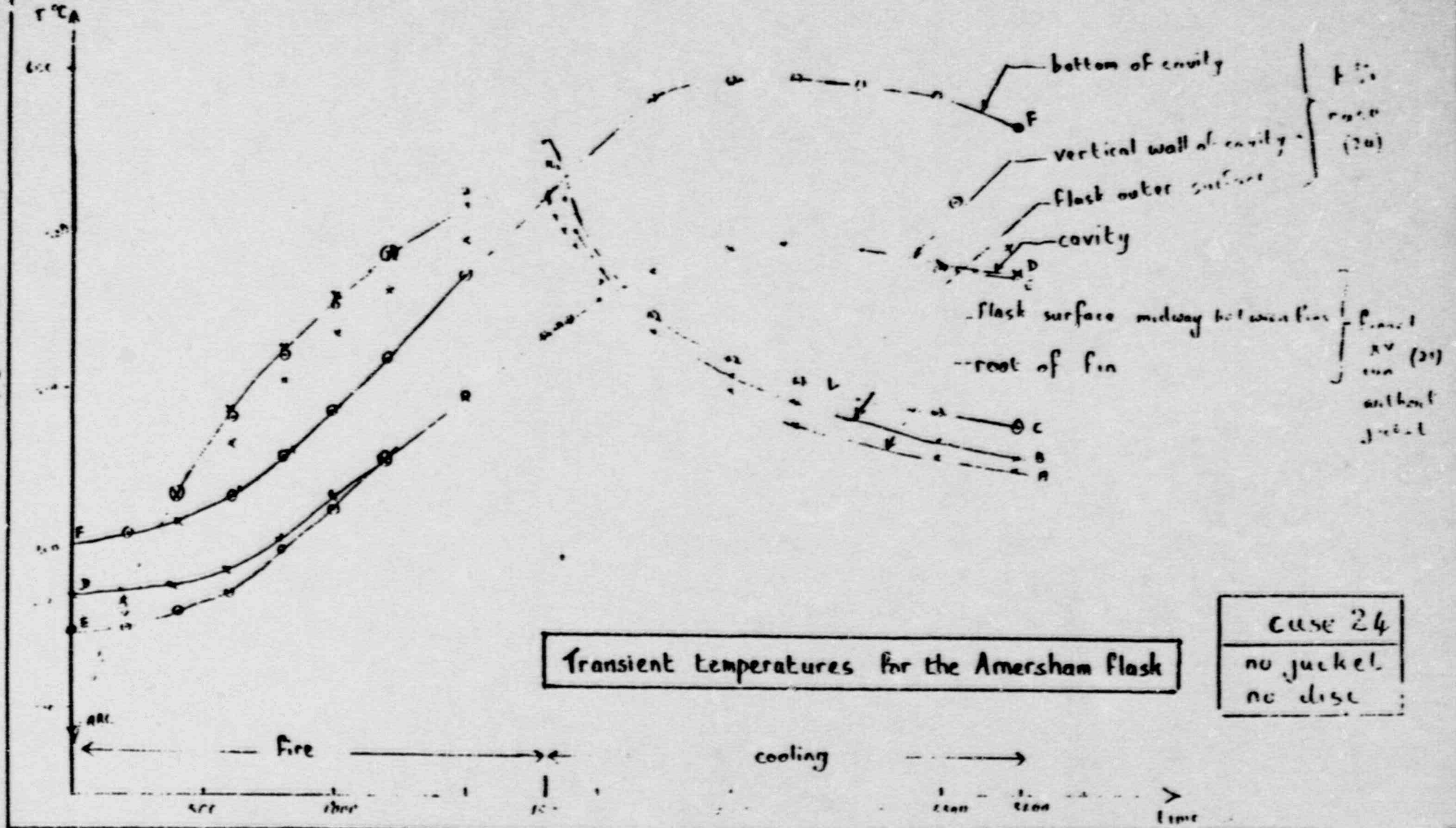


figure 7f

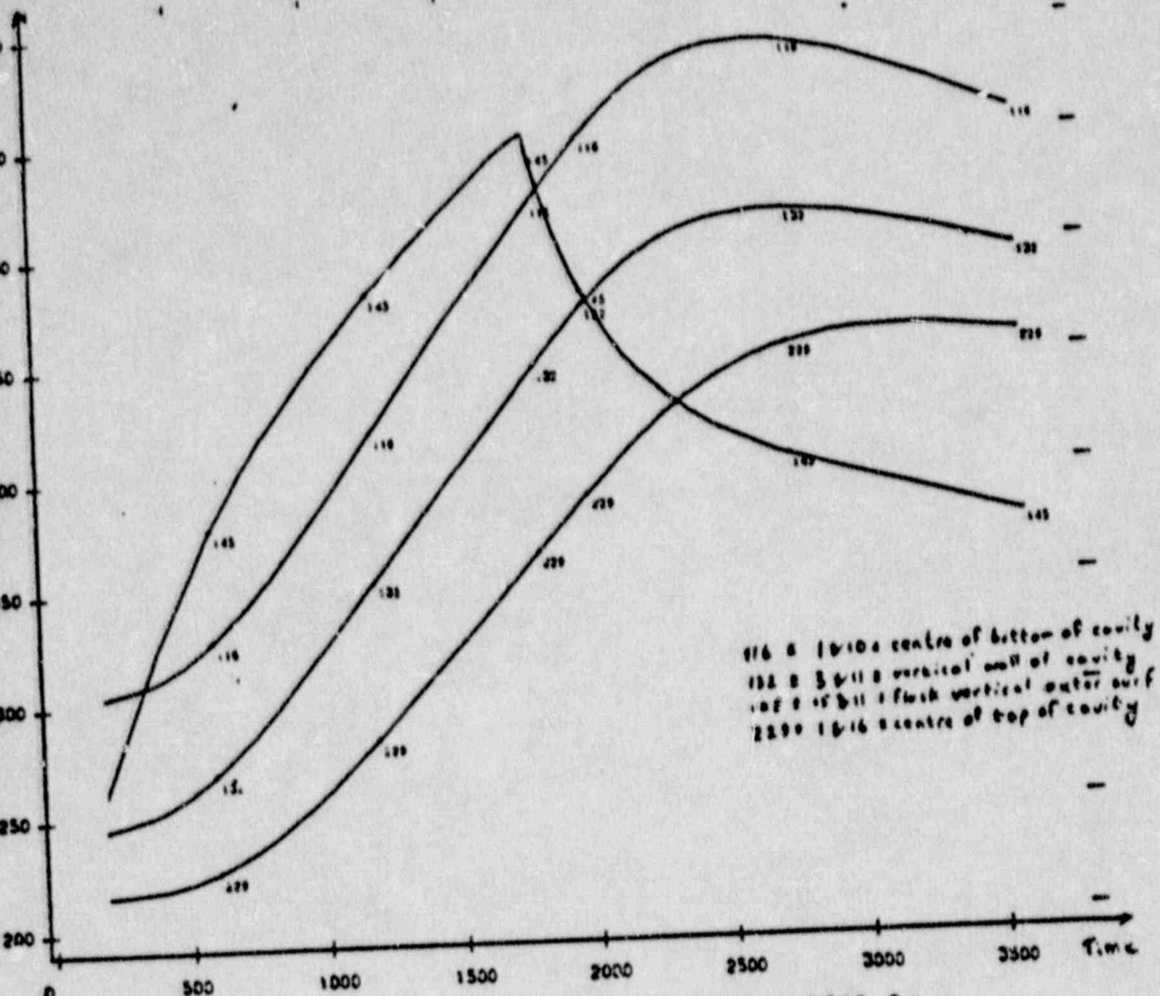
TEMPERATURES TIME = 3600.0000 INTERVAL BETWEEN CONTOURS = 50.000

PLOT 1 [illegible] AMERSHAM INT. TRANSPORT FLASK_____R2___ VALUES IN BRACKETS ARE NEGATIVE



T °C
bottom of cavity
vertical wall of cavity
flask outer surface
cavity
flask surface midway between fins
root of fin
fire
cooling
time
Transient temperatures for the Amersham flask
case 24
no jacket
no disc

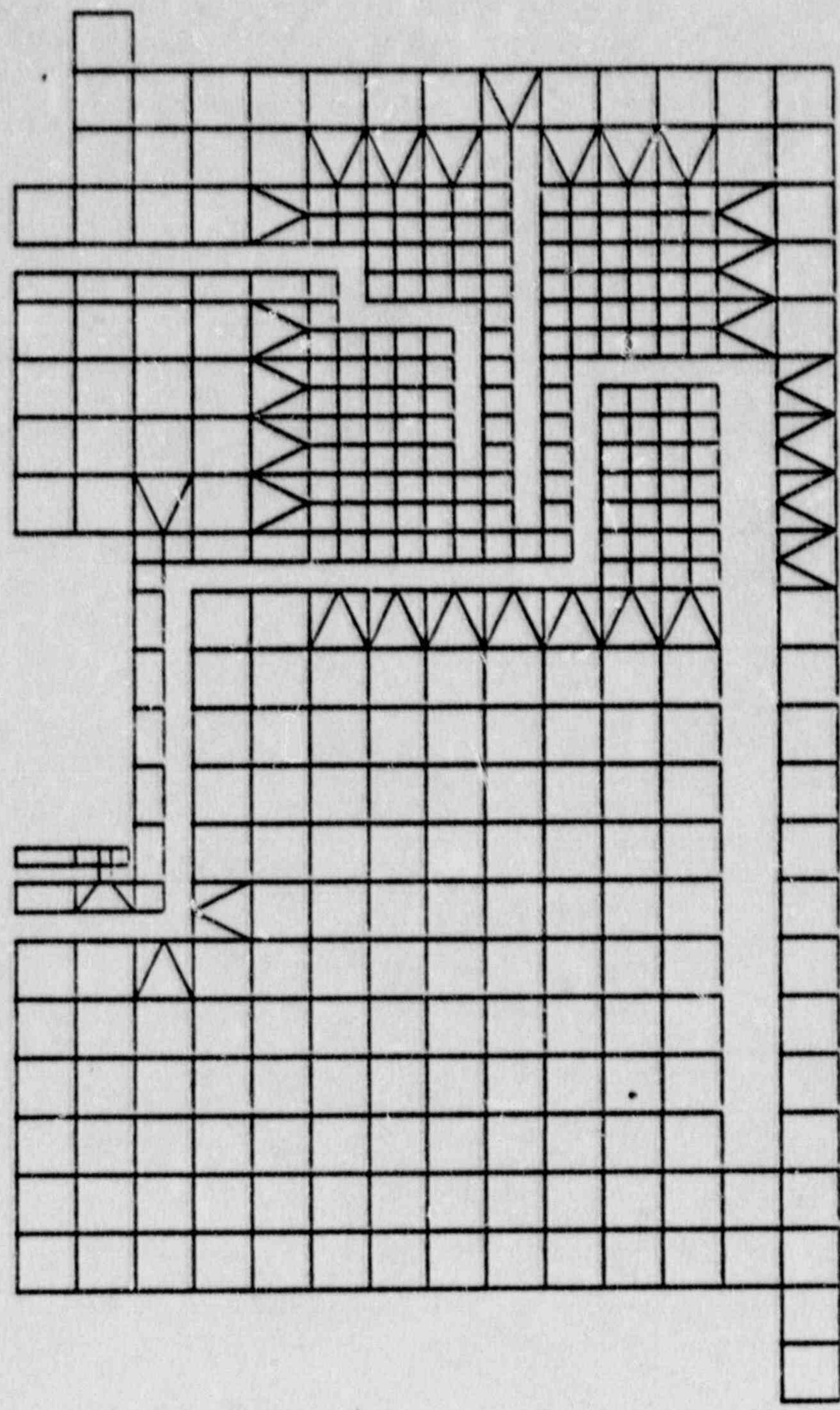
Figure C



TEMPERATURES CASE 24

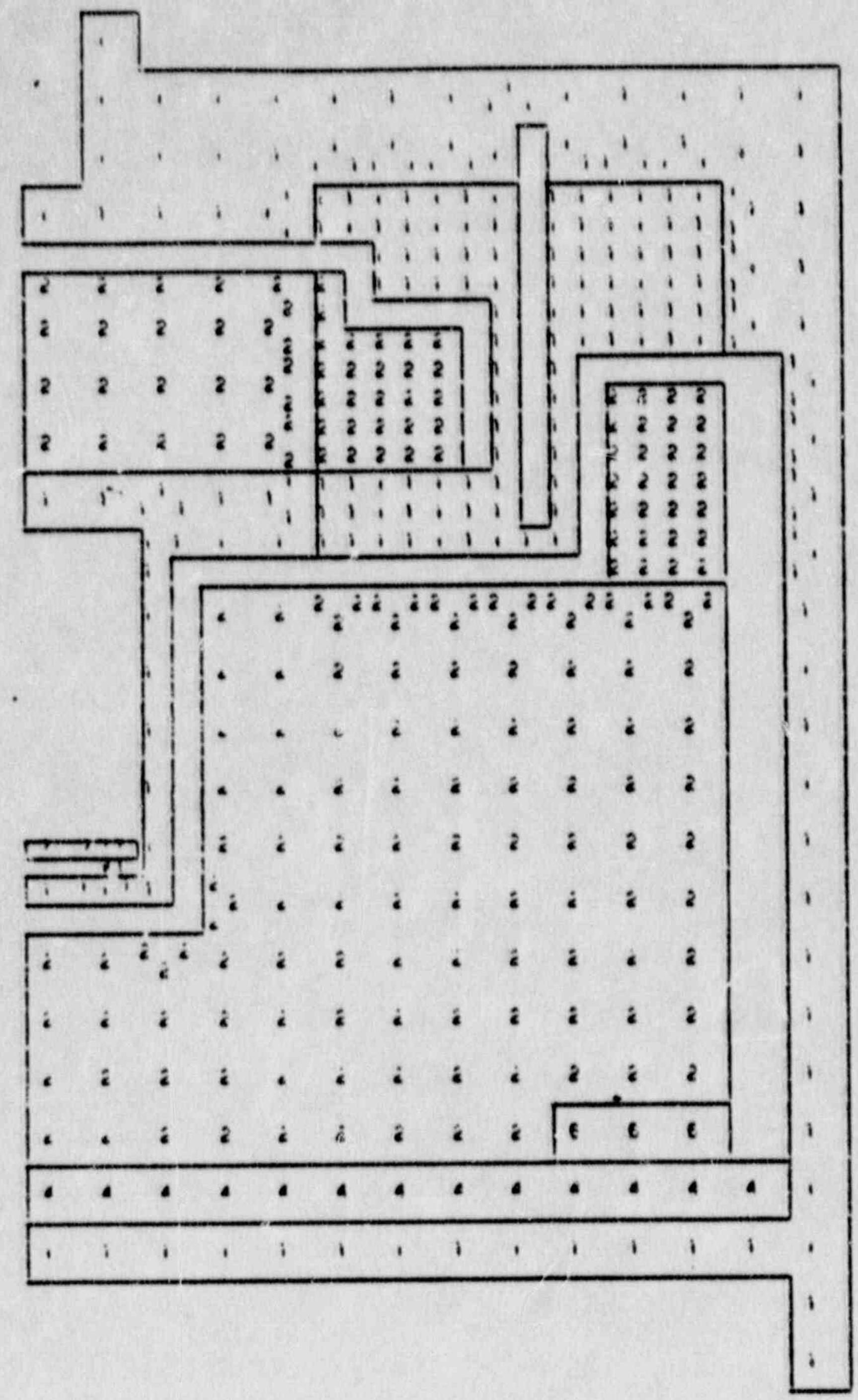
CASE 24 WITHOUT JACKET WITHOUT DISC

figure 8.



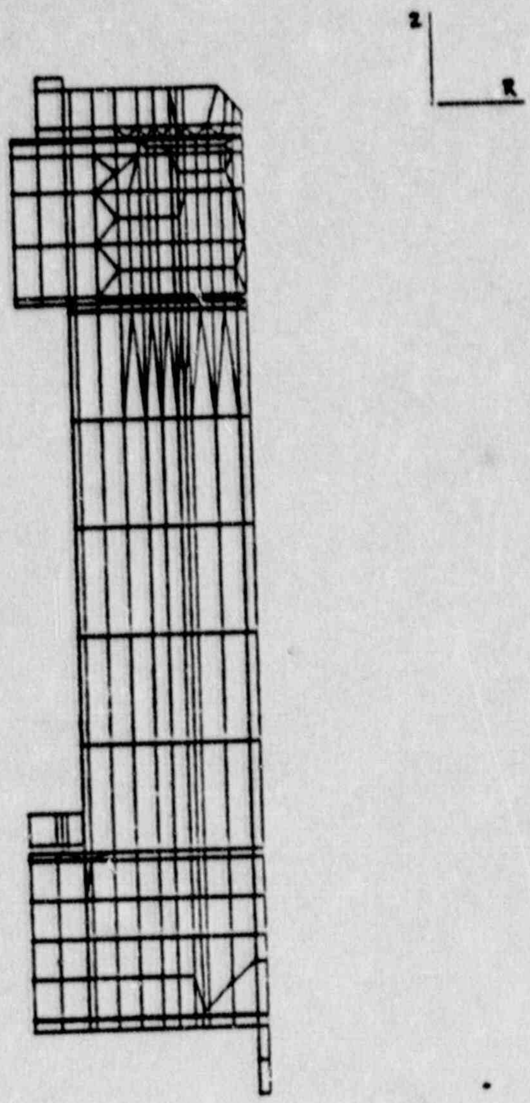
Case 25 - with tungsten disc

Figure 10a



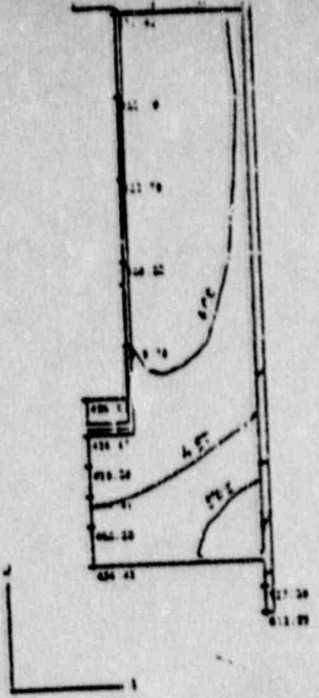
Case 25 - with tungsten disc

Figure 10b



AMERSHAM INTL TRANSPORT FLASK______RZ___25

figure 10c.



case 25
time 2000

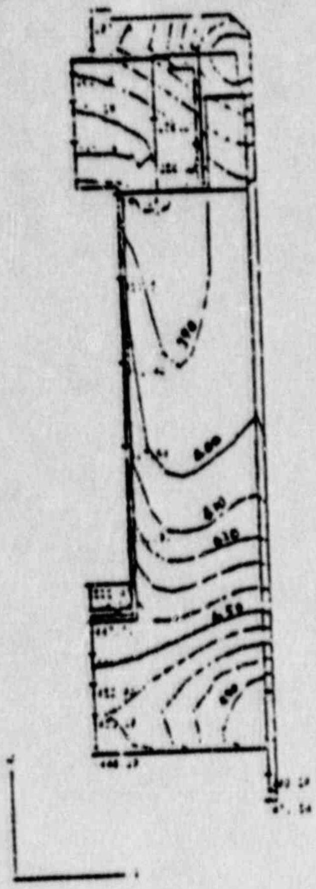


Fig 11b

Case 25

TEMPERATURES TIME = 2200.0000 [illegible]
[illegible]

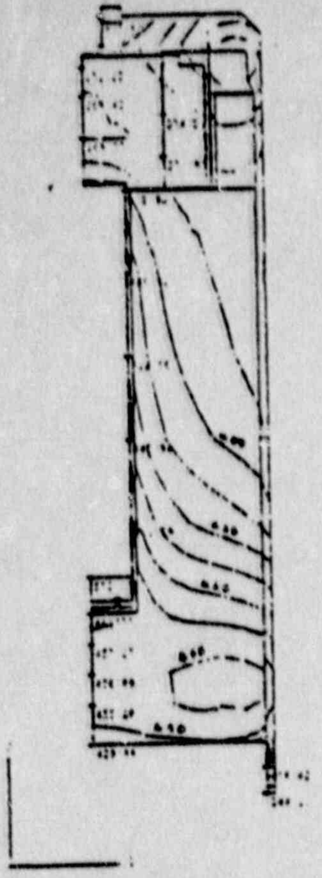


Fig 11c

case 25

TEMPERATURES TIME = 2500.0000 INTERVAL BETWEEN CONTOURS = [illegible]

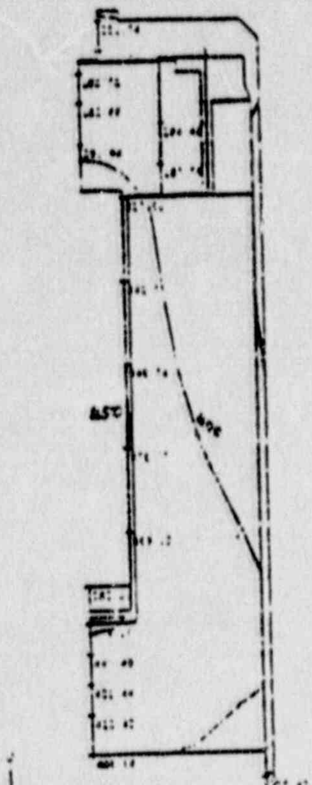


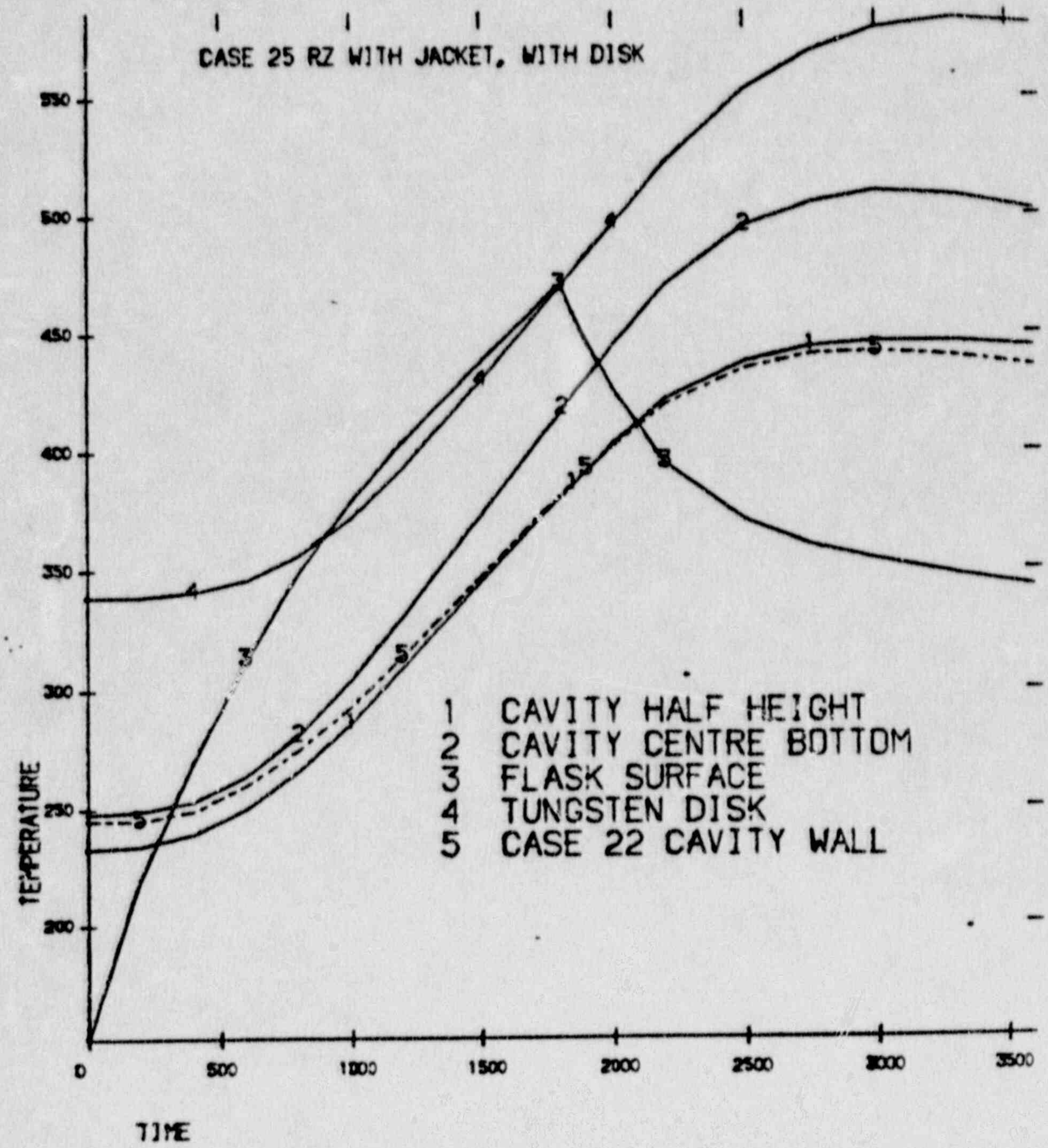
Fig 11d

case 25

TEMPERATURES TIME = 3300.0000 INTERVAL BETWEEN CONTOURS = [illegible]

[illegible] VALUES IN BRACKETS ARE NEGATIVE

Figure 12



CASE 25 RZ WITH JACKET, WITH DISK
550
500
450
400
350
300
250
200
TEMPERATURE
0
500
1000
1500
2000
2500
3000
3500
TIME
1 CAVITY HALF HEIGHT
2 CAVITY CENTRE BOTTOM
3 FLASK SURFACE
4 TUNGSTEN DISK
5 CASE 22 CAVITY WALL

3.6.3 Transport Container Test (TCT) 1062

AMERSHAM INTERNATIONAL plc

INTERNATIONAL

PACKAGING GROUP

Transport Container Test No. 1062

Test Steady State thermal test

Assembly

Flask Design No. 3100A (G.A. Drg. No. OA 23525) without pallet, transport frame, jacket or drain plug.

Test

Thermocouples were attached around and inside the flask and to three of the Co 60 capsules used (see Appendix 1). The flask was then placed in a shielded cell where it remained for the duration of the test. The thermocouples were connected to a 30 point chart recorder obtained from the AERE instrument loan pool. All the thermocouples were calibrated at ambient temperature before commencement and with the exception of No. 2, after completion of the test. The drain hole was plugged from the inside of the cavity to prevent air circulation through the drain tube. In addition a thin aluminium ring was placed around the top of the cavity where it would be sandwiched under the closure. This provided two thermocouple points with which to measure the cavity wall temperature at the top (adjacent to the capsules being monitored).

The source holder was then loaded in three stages:-

a) 28 capsules* were loaded, 27 into three evenly spaced groups. One group was on the inner tube ring and the other two on the outer ring. The centre top capsule in each group carried a thermocouple clamped to its top face under the head of a small screw. The closure was replaced and the flask left to stabilise.

b) A further 23 capsules were loaded. The closure was replaced and the flask left to stabilise again.

c) A further 23 capsules were loaded bringing the total to 74, one short of a full load. The closure was replaced and the flask left to stabilise again.

* X 170 type capsules, each 2.360kCi Co60.

Results

a) In each case the flask temperatures reached 90% of their final values within three hours. For the purposes of this test therefore equilibrium has been assumed to have been reached after six hours. The printouts from the chart recorder are shown in Appendix One.

b) Flask surface temperatures varied widely. The coolest point was at the outer edge of the fins at the bottom. The hottest point was at the mid height of the flask body. Graphs of the temperatures at various points with increasing flask contents are shown in Appendix Two. Note however that these figures should only be taken as indicative. Air flow in the handling cell was restricted by decking at flask top height which was necessary to prevent any capsules being dropped onto the floor.

c) The temperature difference between the capsules and the adjacent cavity wall with increasing flask contents is shown in Appendix Three. When the contents are extrapolated to 10Pbq of Co 60 this figure is 250°C.

Author: D. W. Rogers / M. Baynes

Signed: D W Rogers M H Baynes

Date: 10/9/97

Appendix One **TC TEST No. 1062**

1. Thermocouples: Type K, glassfibre double insulated.

2. Locations:

1	Capsule
2	Capsule
3	Capsule
4	Aluminium ring
5	Aluminium ring
6	Body at top
7	Fin tip at top
8	Body at mid-height
9	Fin tip at mid height
10	Body at bottom
11	Fin tip at bottom
12	Fin tip at base centre
13	Body base at centre
14	Body maintenance test point
15	Drain tube at inside end
16	Lid at centre
17	Lid halfway out
18	Lid at edge
19	Ambient air temperature above cell decking

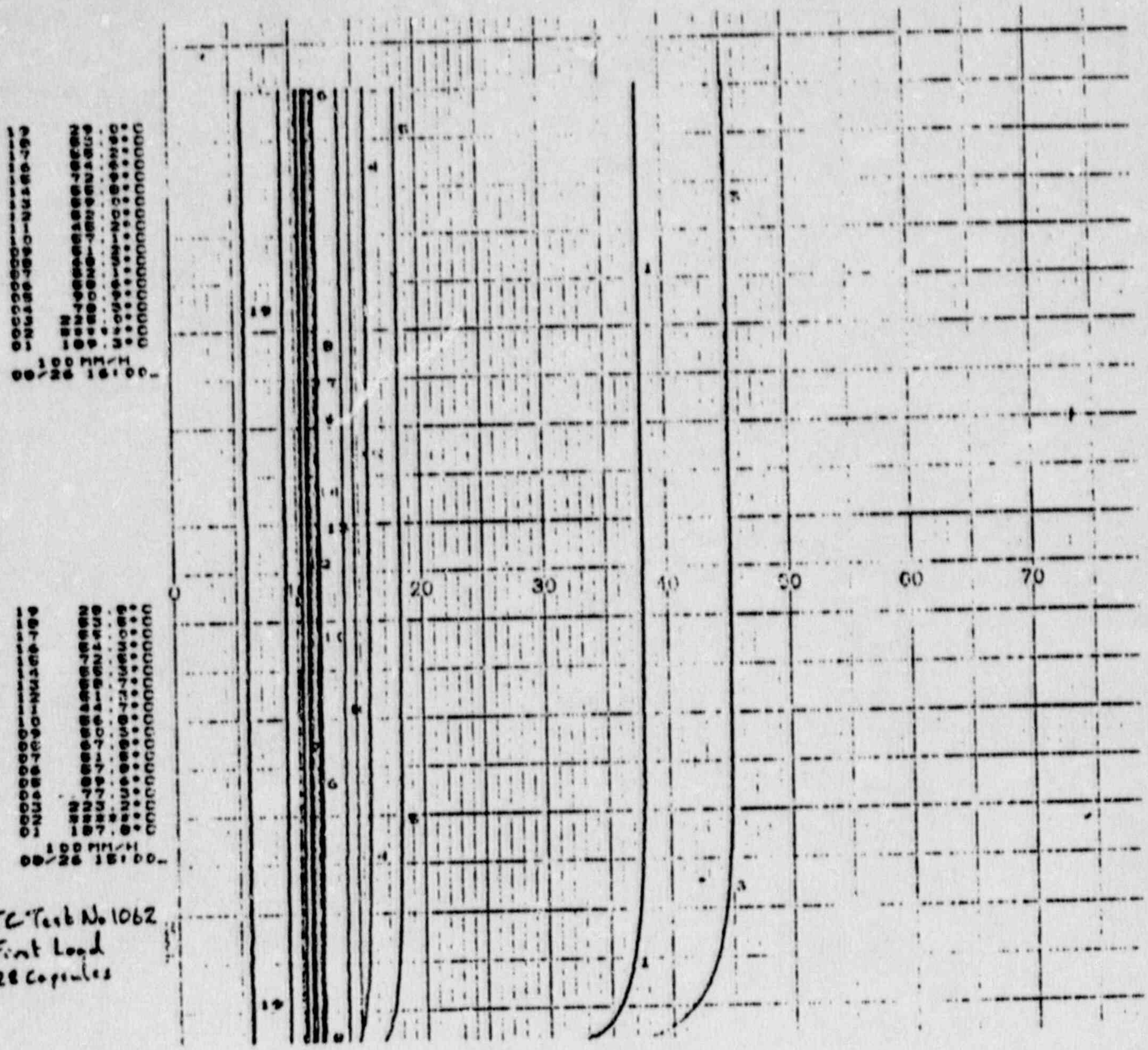
3. Results:

a) Printout 1 Flask loaded with 28 capsules* (2.45TBq Co60)

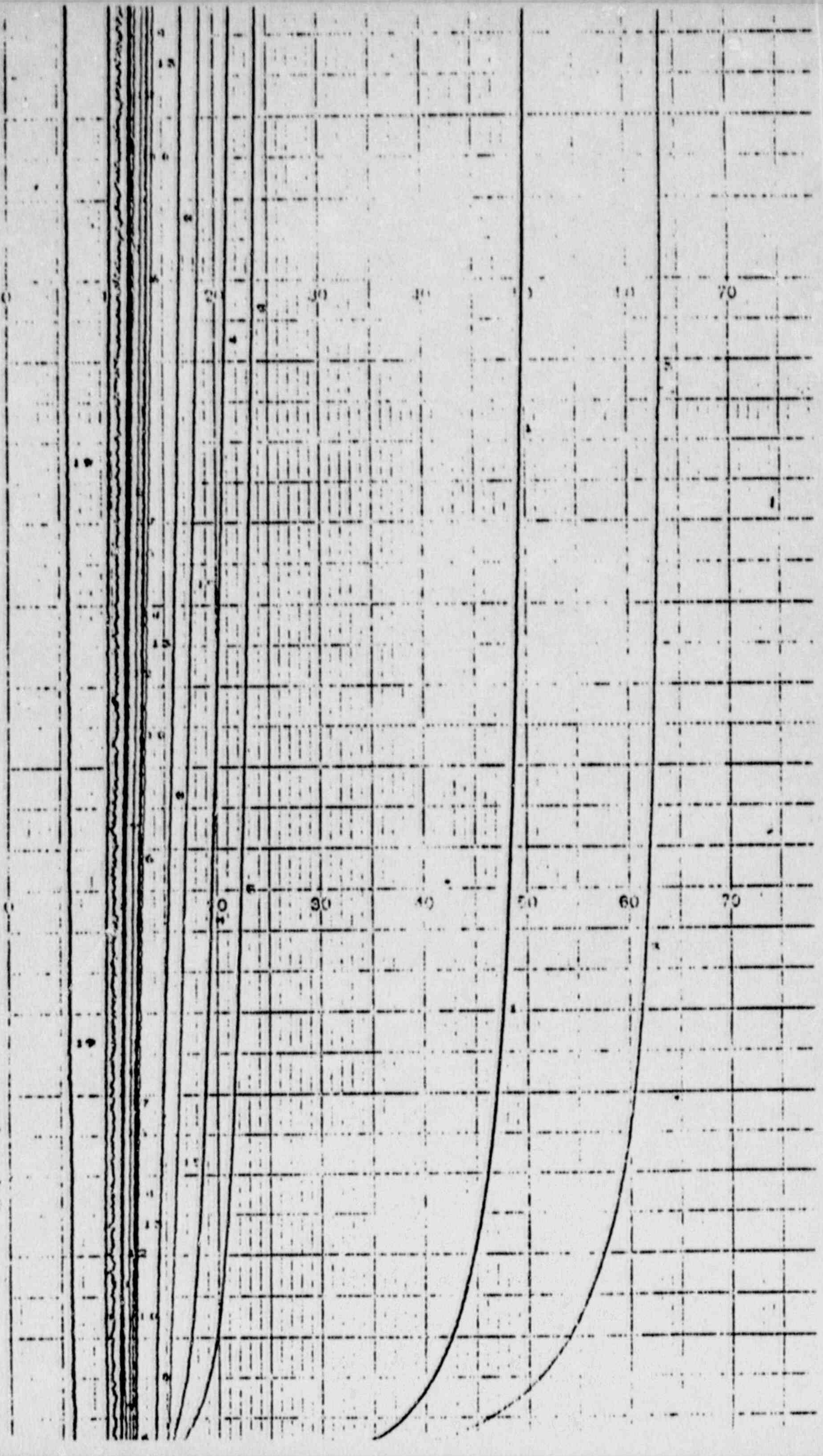
b) Printout 2 Flask loaded with 51 capsules (4.44TBq Co60)

c) Printout 3 Flask loaded with 74 capsules (6.48TBq Co60)

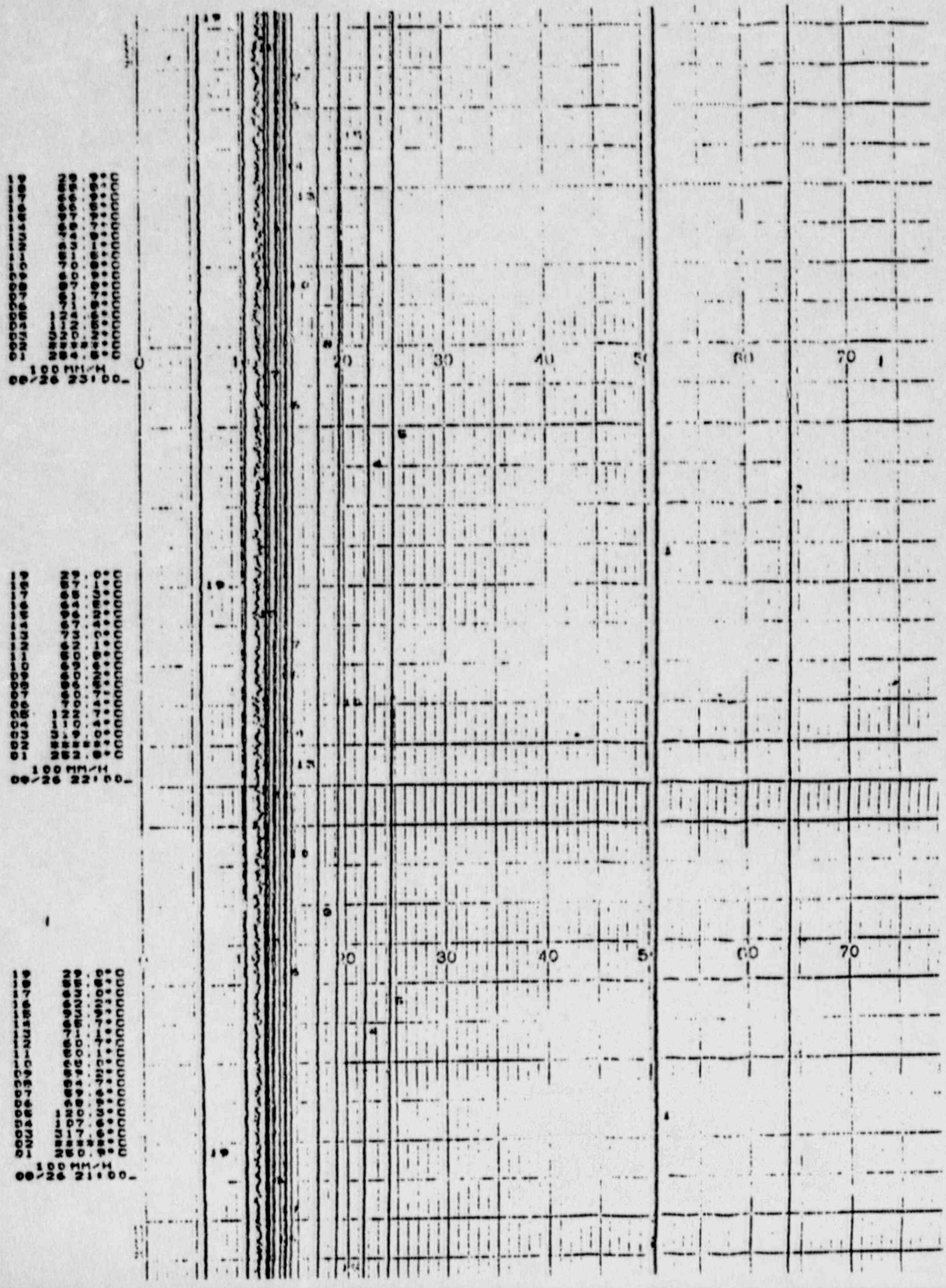
* This printout was halted after two hours. The flask had been prewarmed [illegible] 28 capsules for the previous 24 hrs and it only needed to [illegible]

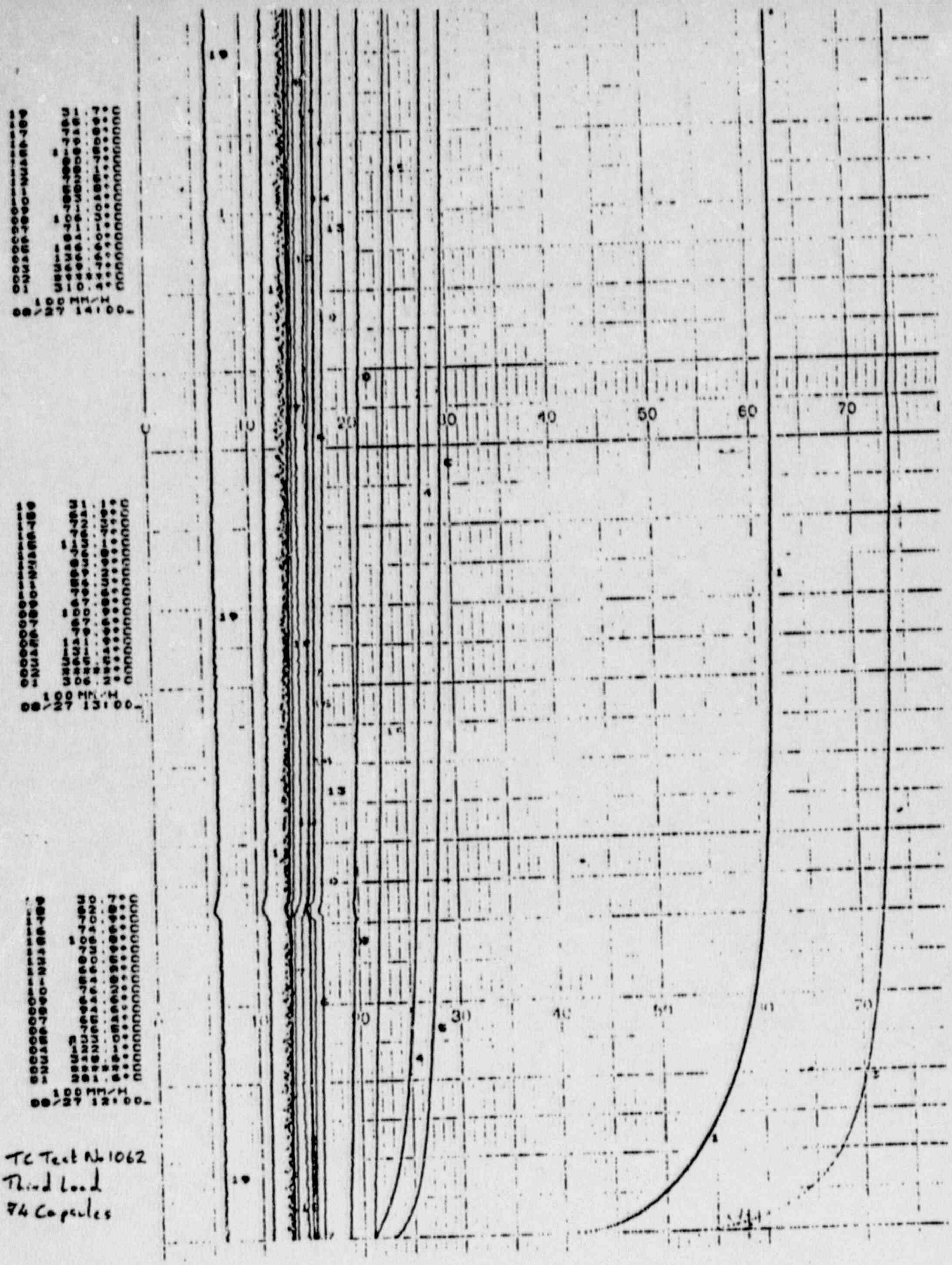


TC Test No 1062
First Load
28 Capsules

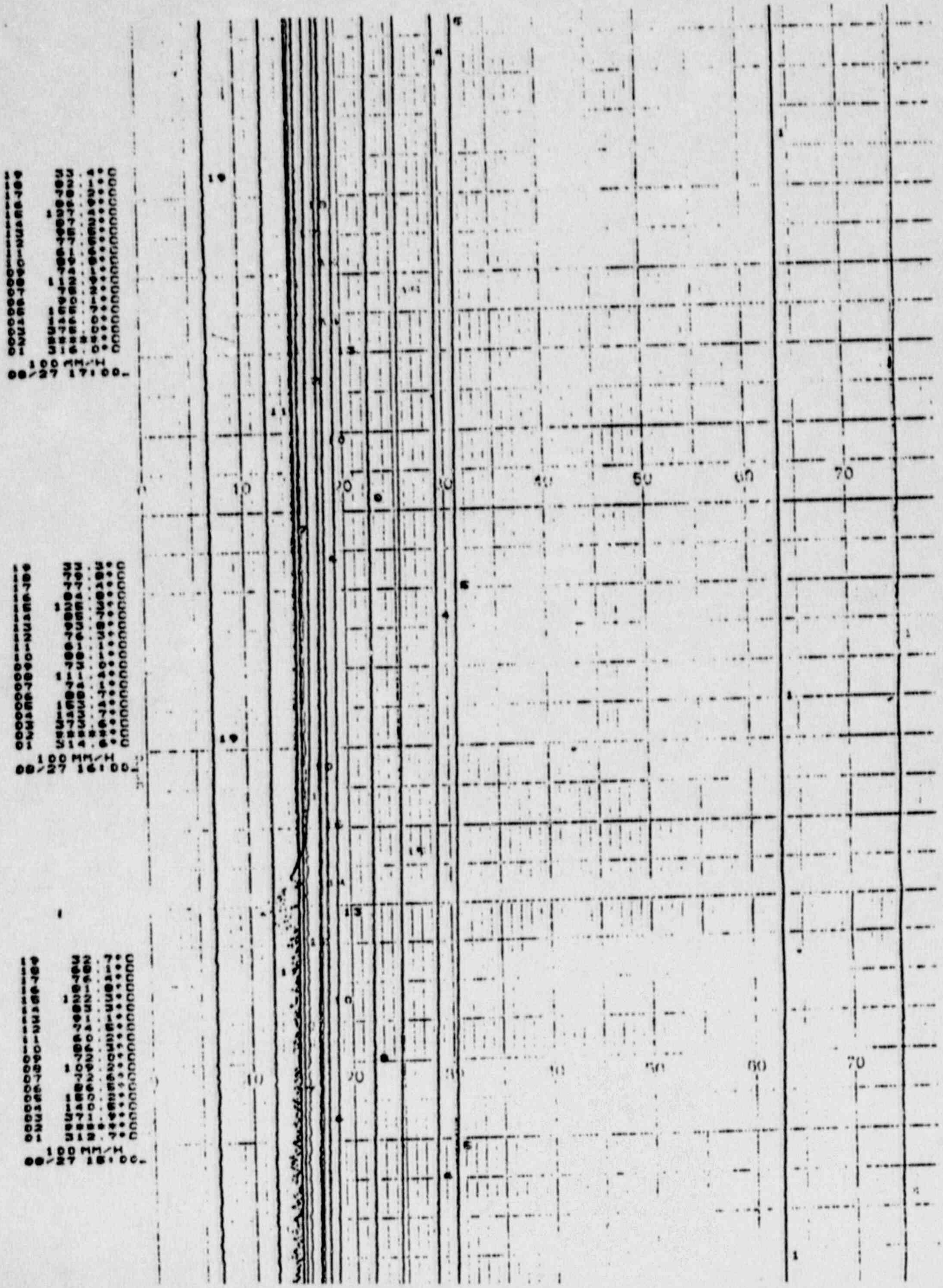


TC Test No 1062
Second Load
51 Capsules


100 MM/H
08/26 23:00
100 MM/H
08/26 22:00
100 MM/H
08/26 21:00
0
10
20
30
40
50
60
70

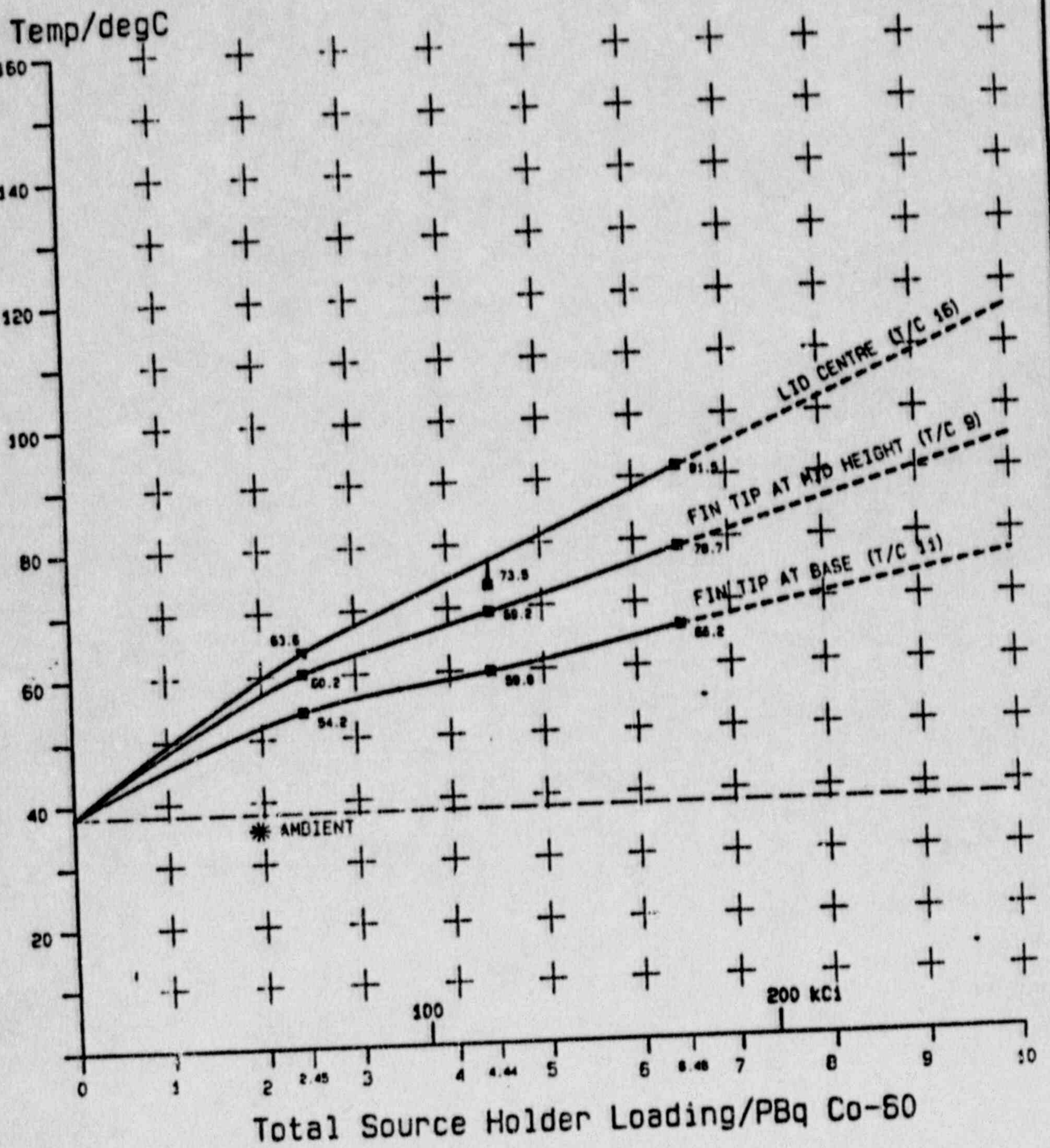


TC Test No 1062
Third Load
74 Capsules



100 MM/H
08/27 17:00
100 MM/H
08/27 16:00
100 MM/H
08/27 15:00
10
20
30
40
50
60
70

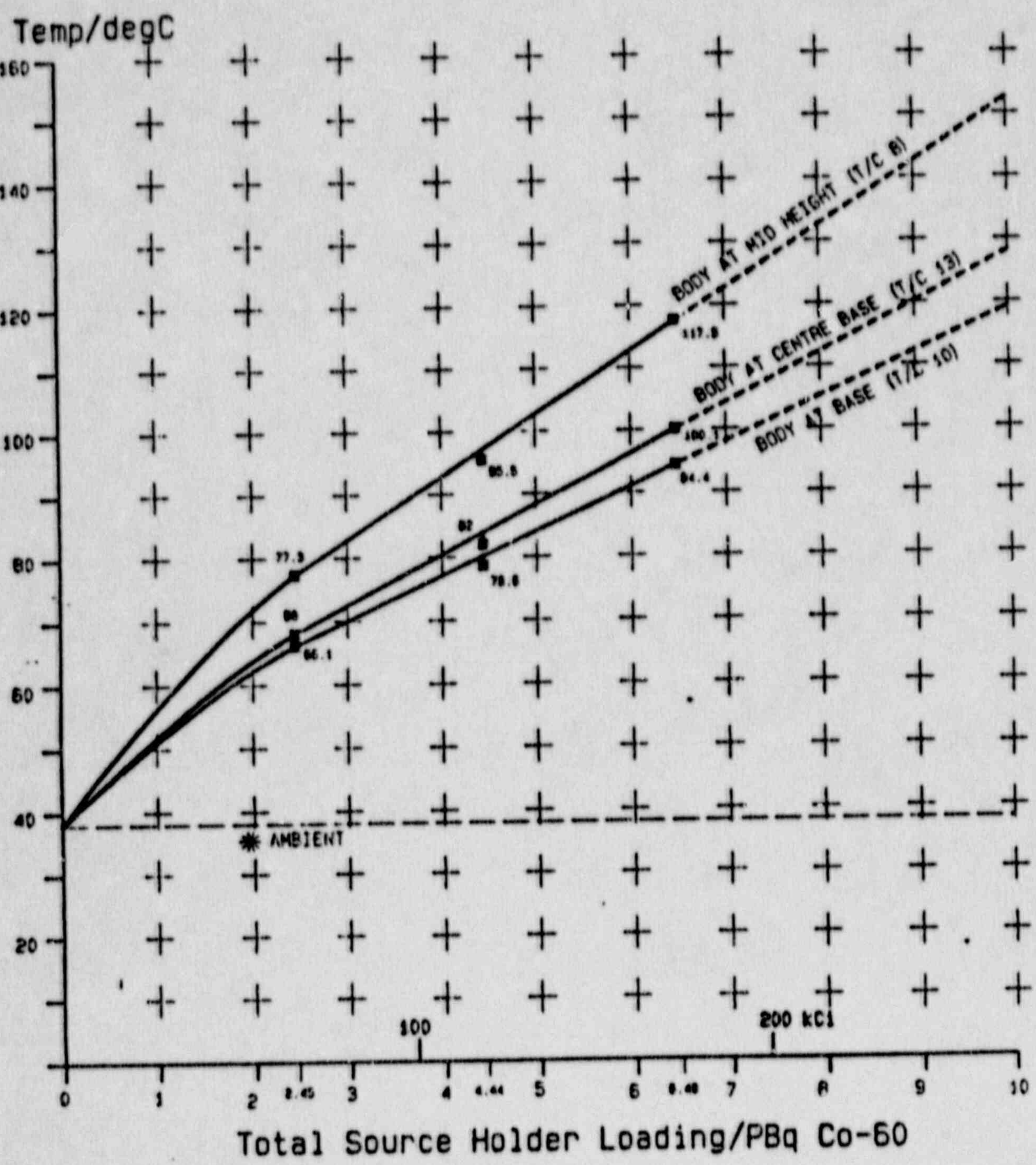
TEMPERATURE
AT VARIOUS POINTS
ON THE SURFACE OF THE 3100A FLASK



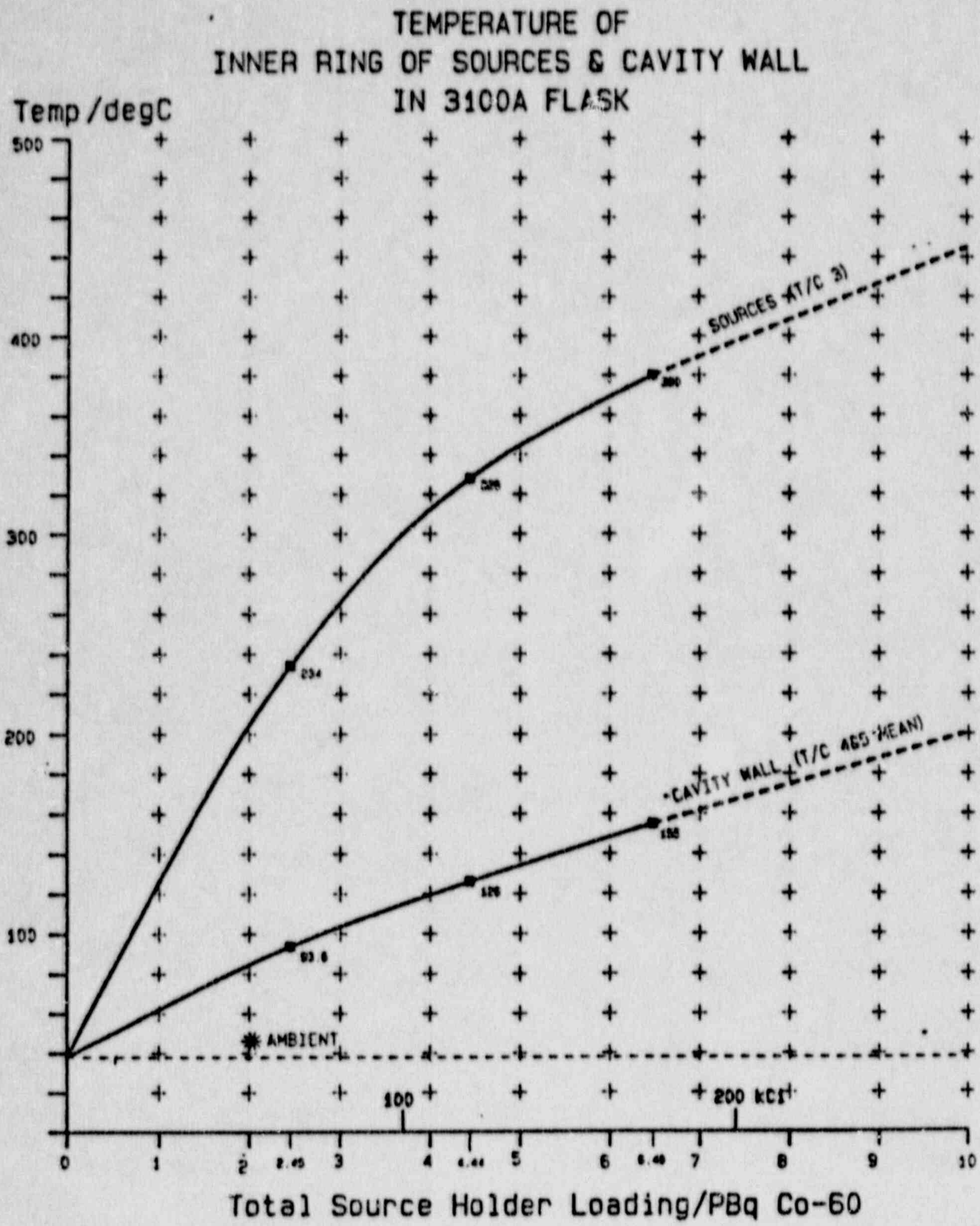
* ALL READINGS CORRECTED FOR AN AMBIENT TEMPERATURE OF 38 degC

SEPT 1987

TEMPERATURE
AT VARIOUS POINTS
ON THE SURFACE OF THE 3100A FLASK

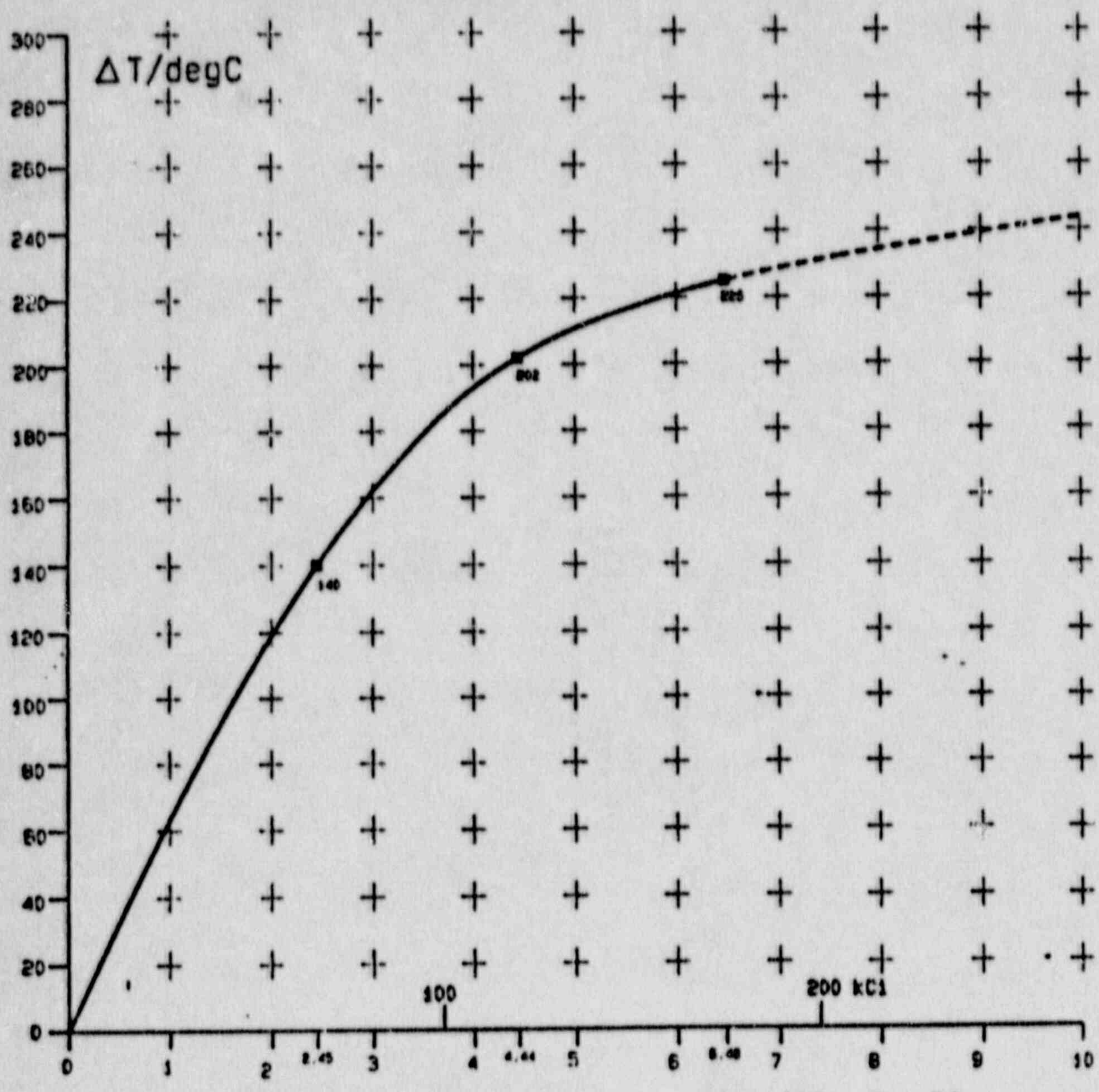


* ALL READINGS CORRECTED FOR AN AMBIENT TEMPERATURE OF 38 degC



* ALL READINGS CORRECTED FOR AN AMBIENT TEMPERATURE OF 38 degC

TEMPERATURE DIFFERENCE
BETWEEN INNER RING OF SOURCES
AND CAVITY WALL IN 310CA FLASK



3.6.4 Engineering Packaging Memo (EPM) 67

AMERSHAM INTERNATIONAL

ENGINEERING

PACKAGING MEMO EPM 67

Cooling of Packages from IAEA - Specified Insolation Equilibrium

1. Introduction

Notes by Gardner (1), (2), addressed the insolation heating problem. The former calculated an equilibrium situation, neglecting both diurnal variation and sinusoidal variation within the day. The latter considered only a single twelve hour sinusoidal heating cycle, the requirements of paragraph 230a in the IAEA Regulations (3) being answered by the statement at paragraph 6(5) that ". . . ambient temperature is probably regained in all cases before the onset of the next insolation cycle (at 24 hours)". This present memo investigates the cooling of packages in the period from 12 to 24 hours in the Gardner (2) report (effectively from 1800h to 0600h).

2. Analytical Background

The rate of heat loss, R, by a package to its surroundings is the sum of the rates of loss by convection, R_C, and by radiation, R_R.

$R_C = h_f (T - T_a)$ where T = package surface temperature
T = ambient temperature
h_f = free heat transfer coefficient

$R_R = \sigma \varepsilon (T^4 - T_a^4)$ where σ = Stefan - Boltzman constant
= 5.67×10^{-12} J/m² s K⁴
ε = surface emissivity

Thus $R = h (T - T_a) + \sigma \varepsilon (T^4 - T_a^4)$ W/m²

and the power dissipated = RA Watts where A = surface area of package

Over a time period, t, the total heat lost is then

$H - H_R = RAt$ where H = initial heat content
H_R = residual heat content

so $H_R = H - RAt$

The specific heat capacity of the package is the sum of that for the components, typically

C = mc (lead pot) + mc (insulation) + mc (outer)

where m = mass of the component
c = average specific heat capacity of component

thus the residual temperature above ambient is $\frac{H_R}{C}$ °C.

3. Calculations

3.1 Assumptions Made

1. The initial temperature is the insolation equilibrium temperature as calculated in (1); This may be regarded as an over estimate. Calculations at (2) give temperatures of no more than 70°C, and typically about 50-60°C.

2. No allowance has been made for thermal lag due to insulation within the package.

3. For curve 1 in figure 1 below, an ambient temperature of 38°C was assumed. The h vs T curve in Ref. (1) is then truly relevant, but the cooling curve can only approach the 38°C line asymptotically and it can never be shown that the package will regain the specified ambient before the next insolation cycle. For curves 2 and 3 an ambient temperature of 24°C was assumed as an arbitrary hot night temperature. The h/T curve is then assumed to maintain the same form with the temperature scale moved by 14°C.

4. Due to the rapid variation of h_t with temperature, especially as ambient temperature is approached, an incremental calculation is necessary. Increments of 1000 seconds, giving temperature drops of the order of 1°C, were used here.

3.2 Data Assumed

Specific Heat Capacity	Steel	420 J/kg°C
	Lead	126 J/kg°C
	Cork	2040 J/kg°C
	Vermiculite Concrete	1300 J/kg°C
Minimum Surface Emissivity	White Paint	0.85
	Galvanised Steel	0.20

Typical Middle Weight Package (0666S)

Lead Pot	41 kg
Steel Drum	5.1 kg
Cork	4.9 kg
Surface Area	0.46 m²
Mean Initial Temperature	87°C
Outer surface galvanised	

Typical Heavy Canister Package (1936A)

Inner Pot	2050 kg	(assumed all lead)
Steel of Canister	655 kg	(approximate
Vermiculite Concrete	75 kg	(approximate
Surface Area	3.15 m²	
Mean Initial Temperature	84°C	
Outer surface painted white		

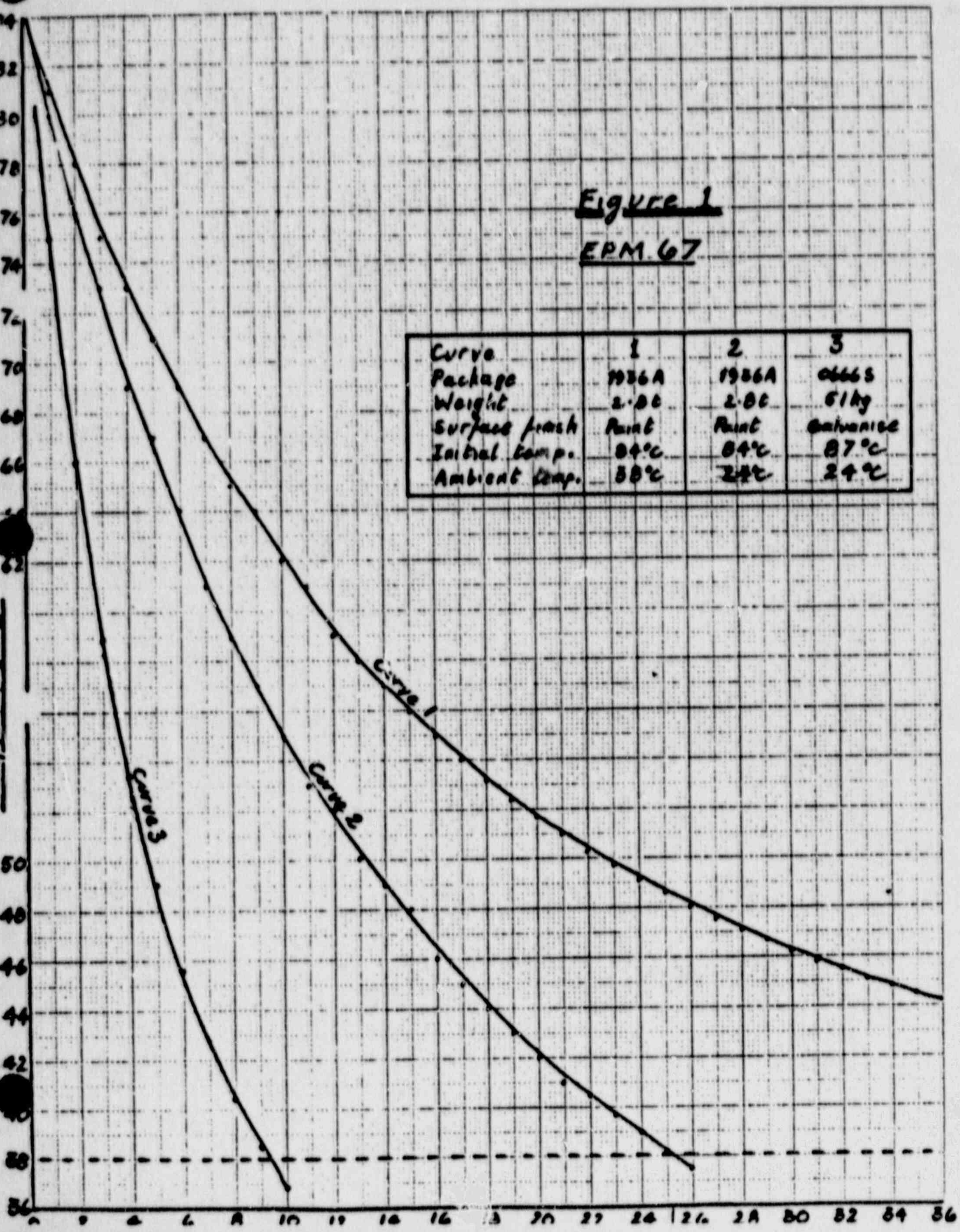


Figure 1
EPM 67
Curve 1 2 3
Package 1936A 1936A
Weight 51kg
Surface finish Paint Paint Galvanise
Initial temp. 84°C 84°C 87°C
Ambient temp. 38°C 24°C 24°C
Curve 1
Curve 2
Curve 3
30 50 48 46 44 42 40 38 36
0 2 4 6 8 10 12 14 16 20 22 24 28 30 32 34 36

3.6.5 Engineering Packaging Memo (EPM) 79

AMERSHAM INTERNATIONAL

ENGINEERING

PACKAGING MEMO EPM 79

NUCLEAR DECAY POWER DISSIPATION (SELF HEATING)

1. Introduction

When radiation is emitted by a decaying nucleus a certain amount of energy is transmitted into the surrounding material. When this energy is absorbed in the material it will appear as heat - this heating will take place within the bulk of the decaying material as well as in surrounding material (such as shielding). The maximum heating will occur when all the radiation is absorbed; in practice, in assemblies when nuclear heating is of significance, more than 99% of the radiation is absorbed in the necessary biological shielding and the effective heating rate is at the maximum.

2. Theory

The total energy emitted by a decaying radioactive isotope is given by the product of the radiation energy and the probability of emission of that radiation. In the cases of alpha, gamma and internal transition decays, the relevant energy is simply the decay energy. In beta decays the decay energy is distributed between the emitted charged particle (beta or positron) and the associated antineutrino or neutrino respectively. This takes the form of a statistical distribution, giving a continuous beta energy distribution (complementary to the antineutrino energy distribution) from zero energy up to a maximum, endpoint, energy. As a result of its extremely low interaction with matter, the neutrino carries all its energy away leaving none in the material and so having no heating effect. The only heating is from the absorption of the beta particle and the energy deposited is a complex mean value. This mean is typically about 0.3 of the endpoint energy, up to a value of about 1.5 MeV. Actual values are tabulated in Ref. 1.

For a given radiation and energy the heating rate is given by

$$H = Ep \text{ MeV/disintegration where } E = \text{decay energy in MeV}$$

$$p = \text{probability of that decay}$$

$$= Ep \times 3.7 \times 10^{10} \text{ MeV/Ci s}$$

now $1\text{eV} = 1.602 \times 10^{-19}\text{J}$

so $1 \text{ watt } (= 1\text{J/s}) = 6.242 \times 10^{12} \text{ MeV/s}$

then $$H = Ep \times \frac{3.7 \times 10^{10}}{6.242 \times 10^{12}} \text{ W/Ci}$$

$$= 5.93 \, Ep \text{ mW/Ci}$$

The total self heating rate, or power dissipation (P), for an isotope is thus

$$P = \sum_n H_n$$

$$= 5.93 \sum_n Ep_n \text{ mW/Ci}$$

3. Conclusions

The above theory and worked examples (Appendix) confirm most previously published data (e.g. Haworth IPU Tech. Memo 76/27) within narrow limits.

An error in the previously accepted figure for Iridium-192 has been found - this should now read 5.69mwatts/Ci (instead of 3.8mW/Ci).

4. Reference

Radioactive decay data tables - D C Kocher.

Technical Information Center of US.

Department of Energy (paper DOE/TIC - 11026).

S T Winfield
6 June 1984

3. Worked Examples (Data Ref. 1)

IRIDIUM-192

Radiation	Energy MeV	Probability
Beta	0.071	0.057
	0.161	0.414
	0.209	0.483
	0.276	0.004
X-Ray	0.009	0.041
	0.065	0.026
	0.067	0.045
	0.076	0.020
Gamma	0.136	0.002
	0.296	0.290
	0.308	0.297
	0.317	0.829
	0.416	0.007
	0.468	0.481
	0.589	0.046
	0.604	0.082
	0.612	0.053
	0.885	0.003
$\sum Ep$	0.959 MeV	
P	5.69 mW/Ci	

COBALT-60

Radiation	Energy MeV	Probability
Beta	0.096	1.00
Gamma	1.173	1.00
	1.332	1.00
$\sum Ep$	2.601 MeV	
P	15.4 mW/Ci	

AMERICIUM-241

Radiation	Energy MeV	Probability
Alpha	5.388	0.014
	5.443	0.128
	5.486	0.852
	5.512	0.002
	5.544	0.003
Gamma	0.026	0.024
	0.033	0.001
	0.060	0.359
$\sum Ep$	5.496 MeV	
P	32.6 mW/Ci	

CAESIUM-137

Radiation	Energy MeV	Probability
Beta	0.157	0.946
	0.415	0.054
Gamma (Ba137m)	0.662	0.900
$\sum Ep$	0.767	
P	4.55 mW/Ci	

STRONTIUM-90

Radiation	Energy MeV	Probability
Beta (Sr-90)	0.196	1.00
(Y -90)	0.935	1.00
P	6.7 mW/Ci	

3.6.6 Engineering Packaging Memo (EPM) 85 Revision 1

AMERSHAM INTERNATIONAL

ENGINEERING

PACKAGING MEMO EPM 85 Revision 1

Equilibrium surface temperature of packages subject to insolation

1. Summary

A theoretical analysis of solar heating of packages in equilibrium, derived from basic physical laws, is presented. Typical values are given and one example is shown worked in full. A tabulation of the predicted surface temperatures for a range of Amersham's packages is given. The maximum mean equilibrium surface temperature is predicted to be 72°C; the maximum equilibrium surface temperature is predicted to be 109°C.

2. Introduction

Earlier notes on this subject written at Amersham (1,2) are now seen to be unsatisfactory in three respects:

i) A specific case of internally generated heat flux is considered.

ii) The verbal approach used leads to a lack of clarity in the argument.

iii) The insolation values used are about 3% lower than are to be specified in (4).

The present note takes two of the basic laws of heat transfer (Newton's Law of Cooling and Stefan-Bolzman's and Kirchoff's Law of Radiation) and sums them to give a general solution, to which is added an internally generated surface heat flux. Typical values of the relevant parameters are tabulated and finally some typical values are calculated for a range of Amersham's Type B package outers.

3. Theory

In free standing conditions, heat loss will be by two modes, convection and radiation, only.

Newton's law of cooling for heat loss by convection in still air gives

$$q_c = A\,h\,(T_s - T_a) \quad \text{(e.g. ref (3), eq 1.14)}$$

where q = heat loss (watts)

A = hot surface area (m^2)

h = free convection heat transfer coefficient ($W/m^2\,K$)

T_s = temperature of the hot surface at equilibrium

T_a = ambient temperature in the shade.

Radiative cooling is defined by Stefan-Bolzman and Kirchoff as

$$q_r = \sigma A \varepsilon \; (T_s^4 - T_a^4) \quad \text{(e.g. ref (3), eq 13.1)}$$

where σ = Stefan's constant

ε = emissivity of the surface

In the case of a package standing on the ground, upper horizontal surfaces will radiate freely to the sky, assumed to be at an effective temperature of T_a. No heat will be gained or lost by radiation or convection at the package base; if the surface is a poor thermal conductor, it may also be assumed that heat transfer by conduction is negligable. For a vertical surface, the upper 90° of azimuth can radiate freely to the sky in the same way as the upper surfaces. Radiation emitted in the lower 90° will be intercepted by the ground which is also being heated by the incident insolation. If the thermal characteristics of the ground are similar to those of the package, then the ground temperature will be similar to that of the package and no significant transfer will occur. To allow for this asymetrical characteristic a geometrical factor, g, is introduced which halves the effective vertical cooling surface.

$$q_r = \sigma A \varepsilon g \; (T_s^4 - T_a^4)$$

The total heat loss, Q, is then

$$Q = q_c + q_r$$

$$= Ah \; (T_s - T_a) + \sigma A \varepsilon g \; (T_s^4 - T_a^4)$$

The insolation heating rate is specified in reference 4 (IAEA Safety Series 6): in equilibrium conditions the absorbed fraction of this balances the total heat dissipated.

i.e. $\alpha IA = Q$

where α = absorptivity coefficient

I = insolation heating rate (W/m^2)

thus

$$\alpha I = h \; (T_s - T_a) + \sigma \varepsilon g \; (T_s^4 - T_a^4)$$

4. The effect of internal heating

In the special case of packages carrying radioactive materials, nuclear decay heating can generate an additional heat flux, q_s, to be dissipated by the surface. This flux is additional to the net flux aI, above.

thus

$$q_s + aI = h(T_s - T_a) + \sigma \varepsilon g \, (T_s^4 - T_a^4)$$

This additional factor causes a negligible extra rise in temperature, as shown in the tabulation (6) below.

5. Typical or Standard values

$I = 800 \ W/m^2$ (upper flat horizontal surfaces) (4)

$I = 400 \ W/m^2$ (curved surfaces) (4)

$I = 200 \ W/m^2$ (flat vertical surfaces) (4)

(These values for I are those in (4). They are about 3.3% higher than those in the 1973 Edition of the IAEA Regulations).

Temperature K	h W/m^2K	Temperature K	h W/m^2K	Temperature K	h W/m^2K (5)
311	0.0	333	3.6	357	5.0
313	1.3	337	3.9	361	5.2
317	2.2	341	4.2	365	5.3
321	2.6	345	4.5	369	5.4
325	3.0	349	4.6	373	5.5
329	3.4	353	4.8	377	5.6

(These values of h are interpreted from Fig. 1 (2). They are not the data points for that curve.)

T_a = 38°C = 311K (4)

σ = $5.67 \times 10^{-8} \ W/m^2 \ K^4$ (Stefan's constant)

g = 1 (Upper flat horizontal surfaces)

g = 0.5 (Vertical surfaces)

	Emmissivity ε	Absorptivity, α (6)
Galvanised Steel	0.20 - 0.30	0.40 - 0.65
White Paint	0.85 - 0.95	0.30 - 0.50
Dark Paint	0.85 - 0.95	0.65 - 0.80
Bright Aluminium	0.40 - 0.60	0.30 - 0.50

6. Typical Calculation (in full)

Consider typical large rectangular package of overall dimensions 2.3 x 2.1 x 2.0 m (high) (Design Number 1512) painted all white with negligible nuclear heat load.

For vertical surfaces

$$\alpha I = h\,(T_v - T_a) + \varepsilon\sigma g\,(T_v^4 - T_a^4)$$

where T_v = temperature of the insolated vertical surfaces.

Inserting the standard values from 4 above, and using the more pessimistic values for α and ε (i.e. minimum ε, maximum α) gives:

$$0.5 \times 200 = h\,(T_v - 311) + 5.67 \times 10^{-8} \times 0.85 \times 0.5\,(T_v^4 - 311^4)$$

$$\text{or} \quad 100 = h\,(T_v - 311) + 2.41 \times 10^{-8}\,(T_v^4 - 9.35 \times 10^9)$$

This equation is solved by iteration as follows:

Try T_v = 329K (56°C) h = 3.4 W/m^2K RHS = 118 W/m^2 (too high)

Try T_v = 327K (54°C) h = 3.2 W/m^2K RHS = 101 W/m^2 (very near)

Try T_v = 326K (53°C) h = 3.1 W/m^2K RHS = 93 W/m^2 (too low)

So best estimate for the vertical surface temperature in an ambient of 38°C is 54°C

Similarly, the temperature of the upper surface T_h, can be found from

$$\alpha I = h\,(T_h - T_a) + \sigma\varepsilon g\,(T_h^4 - T_a^4)$$

Inserting standard values from 4 above, and using the more pessimistic values for α and ε, gives

$$0.5 \times 800 = h\,(T_h - 311) + 5.67 \times 10^{-8} \times 0.85 \times 1\,(T_h^4 - 311^4)$$

$$\text{or} \quad 400 = h\,(T_h - 311) + 4.82 \times 10^{-8}\,(T_h^4 - 9.35 \times 10^9)$$

Again solving this equation by iteration

Try T_h = 337K (64°C) h = 3.9 W/m^2K RHS = 272 W/m^2 (much too low)

Try T_h = 345K (72°C) h = 4.5 W/m^2K RHS = 385 W/m^2 (too low)

Try T_h = 346K (73°C) h = 4.5 W/m^2K RHS = 397 W/m^2 (just too low)

Try T_h = 347K (74°C) h = 4.5 W/m^2K RHS = 410 W/m^2K (too high)

So the best estimate for the horizontal upper surface temperature in an ambient of 38°C is 73°C.

The equilibrium temperatures of the five exposed surfaces in an ambient of 38°C are then:

Flat top	73°C	4.8 m^2
Sides	54°C	17.6 m^2
Mean Value	58°C	22.4 m^2 (total)

7. Other Results

Package Outer	Finish	Temperatures °C								
		Upper Surface			Sides			Mean		
		0W/m^2	15W/m^2	30W/m^2	0W/m^2	15W/m^2	30W/m^2	0W/m^2	15W/m^2	30W/m^2
1250 Can	Tinplate[1]	85	85	88	71	73	75	73	75	77
0818 Drum	White	73	74	75	65	67	68	66	68	69
0666 Drum	Galvanised	106	108	109	83	85	86	87	89	90
0924 Drum	Galvanised	106	108	109	83	85	86	88	90	91
1939 Drum	Galvanised	106	108	109	83	85	86	86	88	89
3206 Keg	Stainless[2]	79	N/A	N/A	65	N/A	N/A	75	N/A	N/A
1933 Canister[3]	White	73	74	75	65	67	68	66	68	69
1934 Canister[3]	White	73	74	75	65	67	68	66	68	69
1935 Canister[3]	White	73	74	75	65	67	68	66	68	69
1936 Canister[3]	White	73	74	75	65	67	68	66	68	69
1512 Crate	White	73	74	75	54	56	57	58	60	61

Notes:

1. Absorptivity and emissivity assumed to be the same as bright aluminium.

2. Absorptivity and emissivity assumed to be the same as galvanised.

3. All canisters neglect the effect of shackle plates as cooling/heating fins - the geometery is assumed to be a plain vertical cylinder.

8. References

1. IPU Tech Memo 77/12 - Solar heating of transport packages - P R Gardner, 1977.

2. IPU Tech Memo 77/14 - Solar heating of transport packages taking into account radiative dissipation - P R Gardner, 1977.

3. Heat Tranfer (Third edition) - A J Chapman, Macmillan, 1974.

4. Proposed Regulations for the Safe Transport of Radioactive Materials -1985 Edition - International Atomic Energy Agency Safety Series 6.

5. An introduction to heat transfer principles and calculations - A J Ede, 1967 (via ref. 2 above).

6. Heating, ventillating and Air conditioning guide - American Society of Heating and Ventillating Engineering (via Mitchells Building Construction (Materials) - A Everett).

7. IPU Tech Memo 78/20-Calculation of temperature rise in drum type containers as a result of insolation - P R Gardner, 1978.

S T Winfield
Engineering
18 October 1984

D. MacDougall
Quality Control
19 November 1984

Revision 1 - Delete shaded sides from calculation of mean temperatures on page 5

S T Winfield
19 March 1987

9. Additional Work

The majority of packages used by Amersham are not 'temperature sensitive' in making a case for them to be approved by the Department of Transport as Type B(U) or for shipment under Special Arrangement. Some special purpose packages, such as those designed to carry significant heat loads or to carry liquids, are critically dependant on proving minimal heating from external factors. These factors are ambient temperature, the thermal test and insolation.

The ambient temperature is specified in (4) as 38°C (except in special cases). Experimental data exists for many typical designs in the thermal test. No experimental work has been carried out on insolation. Three Amersham memos have been written on the subject of insolation: two ((1) and (2)) are superceded by this memo and one (7) reports a computer calculation on an idealised situation. All inevitably make assumptions in relation to the geometry of the package and in the variation of the insolation rate over a 24 hour period. (1), (2) and this note assume equilibrium conditions of average insolation over an infinite time - a totally impractical situation, but one which enables straightforward calculation. (7) assumes a stepped, but generally sinusoidal variation over a 12 hour period - this is a big advance over the equilibrium situation but many of the geometrical approximations continue.

Three organisations within the UK are believed to have facilities capable of reproducing the insolation specified in (4).

Military Vehicles Engineering Establishment, Chobham, Surrey,
British Aerospace, Stevenage
University of South Wales, Cardiff (Prof. Brinkworth).

It is proposed to approach these organisations to determine availability, capability (insolation and mechanical handling) and costs. On the basis of the responses received a possible experimental programme will be considered in relation to the costs and benefits that may result.

S T Winfield
Engineering
18 October 1984

D. McDougall
Quality Control
15 November 1984

4.0 Containment

4.1 Containment Boundary

4.1.1 Containment

The primary containment system for the 3100A container is the special form capsule. This capsule is certified as special form radioactive material in IAEA Certificate of Competent Authority number GB/343/S.

4.1.2 Containment Penetrations

There are no penetrations of this containment.

4.1.3 Seals and Welds

The containment capsule is seal welded by Tungsten inert gas process according to IAEA special form requirements.

4.1.4 Closure

Not Applicable.

4.2 Requirements for Normal Conditions of Transport

4.2.1 Containment of Radioactive Material

Any source transported in this container will have satisfied the stringent requirements for special form radioactive material as delineated in IAEA Safety Series Number 6 and 10 CFR 71.77. Therefore, there will be no release of radioactive material under normal conditions of transport.

4.2.2 Pressurization of the Containment Vessel

As the sources that will be transported are tested to ANSI Standard N542 (1977), and have achieved a rating of C64426, they will successfully withstand pressures of at least 290 psi. Even during the most extreme hypothetical thermal accident conditions, the pressure exerted would not approach 290 psi. Therefore, the containment vessel will withstand the pressure variations of normal transport.

4.2.3 Containment Criterion

The sources that will be transported in the container are subjected to the following tests after welding:

1) Dry wipe test with a 5 nCi maximum permissible contamination limit.
2) Helium leak test.

4.3 Containment Requirements for Hypothetical Accident Conditions

4.3.1 Fission Gas Products

Not Applicable

4.3.2 Containment of Radioactive Material

The hypothetical accident conditions of 10 CFR 71.73 will result in no loss of package containment (see sections 2.7 and 3.5).

4.4 Special Requirements

Not Applicable.

4.5 Appendix

4.5.1 Safety Evaluation of Model CKC.LSA Sealed Source
(submitted to Illinois Department of Nuclear Safety 3/28/89)

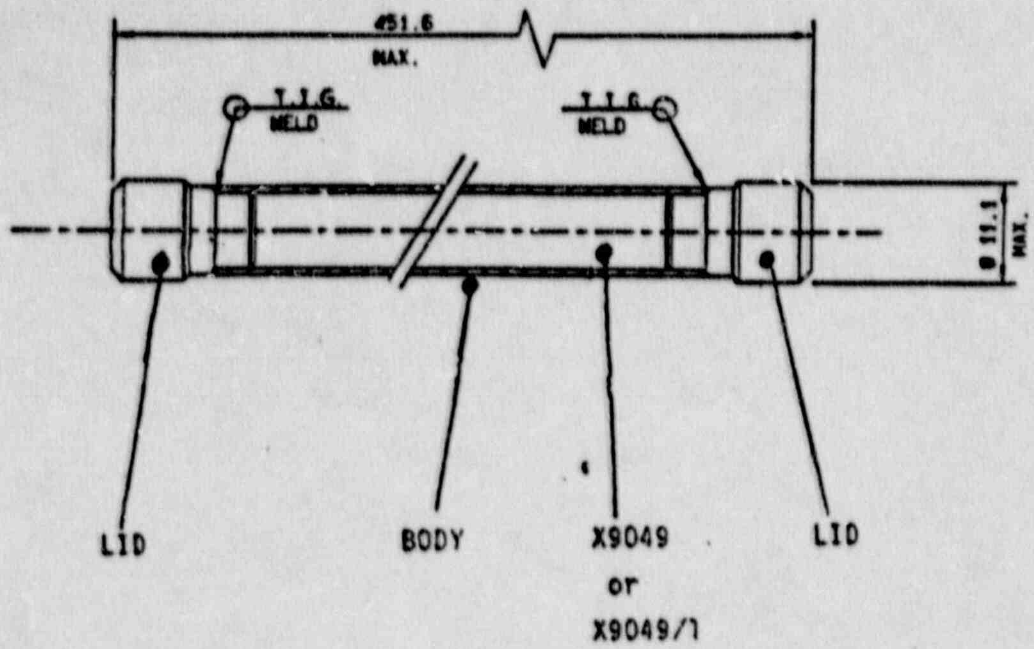
4.5.1 Safety Evaluation of Model CKC.LSA Sealed Source

Safety Evaluation of Model CKC.LSA

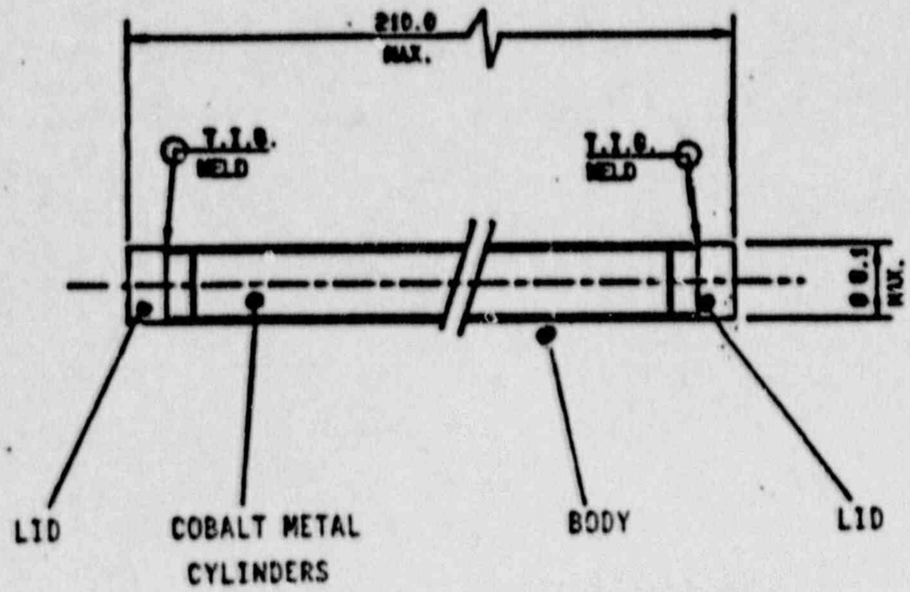
Date	March 28, 1989
Manufacturer	Amersham International Amersham Place Little Chalfont, Bucks England, HP7 9NA
Distributor	Amersham Corporation 2636 South Clearbrook Drive Arlington Heights, IL 60005
Sealed Source Type	High Energy Photon Source
Model	CKC.LSA
Isotope	Co-60
Maximum Activity	20 kCi
Leak Test Frequency	"Dry" irradiation plants: 6 months "Wet" irradiation plants: continuous (on-line monitoring of water purification system)
Principal Use	Gamma ray processing in industrial "dry" and "wet" irradiation plants. Principal use codes J, K, L and M (USNRC Regulatory Guide 10.11 June 1987).
Custom Sealed Source	No

Description

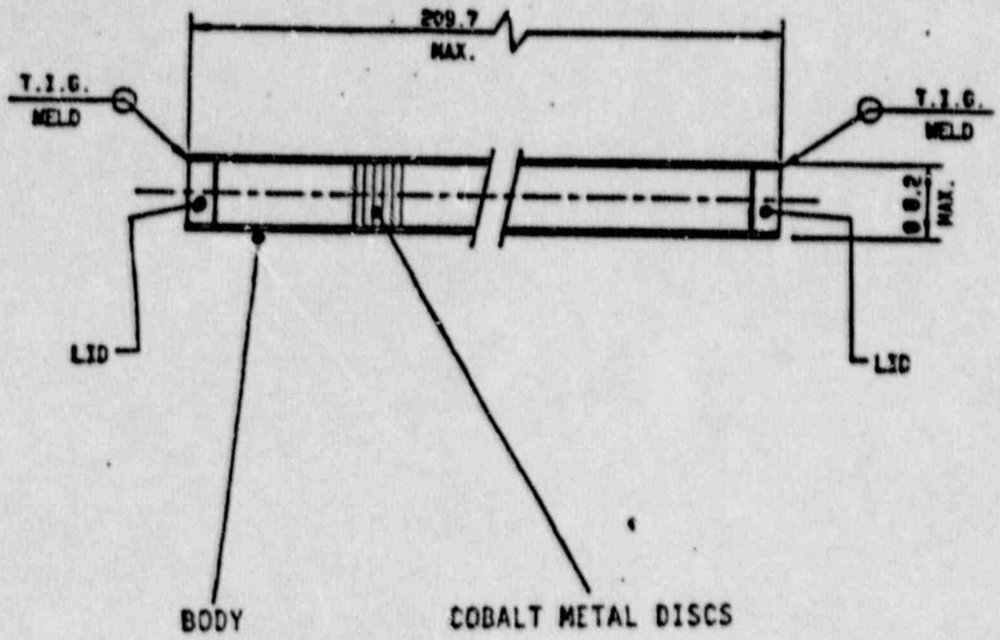
Model CKC.LSA consists of a 316L stainless steel outer X2089 capsule containing either two 316L stainless steel X9049 inner capsules or two AISI 321 stainless steel X9049/1 inner capsules. Sketches of these three capsule designs are shown immediately below:



X2089 capsule
(dimensions in mm)



X9049 capsule
(dimensions in mm)



X9049/1 capsule
(dimensions in mm)

The X9049 active capsule is produced by loading a quantity of two naturally occurring, inactive Co-59 "right" cylinders into the capsule body and T.I.G. welding lids into the ends. The X9049 is then placed in a reactor where neutron irradiation produces Co-60. The minimum wall thickness of the X9049 body is 0.475 mm.

The X9049/1 active capsule is produced by loading a quantity of Co-60 discs into the capsule body and T.I.G. welding lids into the end. The minimum wall thickness of the X9049/1 body is 0.32 mm.

Model CKC.LSA is now produced by inserting two as-irradiated X9049's or two X9049/1's into an X2089 body, which has already had one lid welded into place. The final lid is then inserted into the X2089 body and welded to achieve closure. The minimum wall thickness of the X2089 body is 0.63 mm.

The Model CKC.LSA will be shipped in an approved Type B(U) transport container.

Prototype Testing

The X2089 capsule has been tested in accordance with the requirements of ANSI N542 (1977) and has achieved a rating of C64426. This rating is exhibited in QCS 685, issue 1, which is enclosed.

The X2089 capsule has also been Special Form tested and both the Special Form Certificate of Approval, GB/343/S, issue 1, and QCS 678, issue 3, are enclosed. The diagram of capsule X2089 on page 2a of this submission is the same as drawing 3A61844 referenced on the two QCS certificates.

Conditions of Use

The Model CKC.LSA source will be used primarily in an industrial environment for gamma ray processing in wet irradiation plants. However, it may also be used in dry irradiation plants.

External Radiation Levels

Co-60 is a high energy photon emitter. Gamma energies at 1.173 MeV and 1.332 MeV result in a Specific Gamma Ray Constant of 1.3 R/hr/Ci at 1 meter.

Consequently, the following maximum external radiation exposure rates can be expected from the CKC.LSA containing 15 kCi Co-60:

Distance	Exposure Rate
5 cm	7.8×10^6 R/hr
30 cm	2.17×10^5 R/hr
100 cm	19,500 R/hr

Labelling

The X2089 is permanently engraved with the following information:

1) trefoil
2) Co-60
3) Unique Serial Number
4) AI

In addition, the X9049 is engraved with a unique serial number and the X9049/1 is engraved with a unique serial number and the year of manufacture.

Documentation

Each CKC.LSA will be accompanied by a test report documenting the leak test and contamination test results as well as the radiation emission measurement results.

Quality Assurance and Control

All materials used in the fabrication of the inner and outer capsules are checked against suppliers specification prior to use in manufacture.

Inner sources (X9049 and X9049/1) are subjected to the following tests after welding:

1) Measurement of exposure rate in a re-entrant ion chamber.
2) Dry wipe test with a 50 nCi maximum permissible removable contamination limit.

The finished X2089 is subjected to the following tests after welding:

1) Dry wipe test with a 5 nCi maximum permissible removable contamination limit.
2) Helium leak test.

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Certificate of radioactive source integrity QCS 678 Issue 3

Title : Gamma Irradiation Sources

Assembly code : X2089

Assembly drawing : 3A 61844

Nuclide : Cobalt-60 (Co-60)

Radiotoxicity group : B1

Maximum activity : 740 TBq (20 KCi)

CLASSIFICATION : Special Form Test Data

RECOMMENDED WORKING LIFE : 15 Years (see overleaf)

Test sources : Two Helium filled inactive capsules lettered E and F. Assembled as per Drawing Number 3A 61844 Issue A. Except for the active Cobalt rods which were replaced by inactive rods. Void volume of > 100 mm^3. Two simulated samples serial numbers 0032EE and 0040EE each containing approximately 25 micro Curie Cobalt-60 chloride. Assembled as per Drawing Number 3A61844 Issue A. Except of the active Cobalt rods which were omitted.

Tests carried out in accordance with Recommendation of:

IAEA Safety Series No.6: 1985

Leak test method	TEMPERATURE	Percussion	IMPACT	Bend	Final Test	Units
Vacuum Bubble (QCP 112)	Pass Pass	Pass Pass	Pass Pass	Pass Pass		Visual
Helium Pressurisation (QCP 113)					1.8×10^{-7} 1.9×10^{-7}	mbar l s^{-1}
Immersion (QCP131)			Pass < 5.0 < 5.0			Nanocuries

Refer overleaf

QA Manager.

Production Manager - Industrial Products.

Reference GB/343/S

Certificate Issue 1

Certificate of Approval
of Design for Special Form Radioactive Material

Title	
Capsule X.2089	
Drawing Nos and Specification Reference	
Assembly 3A 61844 Issue B Details 3A 61843 Issue B PG/S591/X2089 Dated 9 February 1988	
Radioactive Material	Maximum Activity
Cobalt 60	740 TBq (20 kCi)

THIS IS TO CERTIFY that the Secretary of State for Transport being, for the purposes of the Regulations of the International Atomic Energy Agency, the Competent Authority of Great Britain in respect of inland surface transport and of the United Kingdom of Great Britain and Northern Ireland in respect of sea and air transport and the Department of the Environment for Northern Ireland being the Competent Authority of Northern Ireland in respect of inland surface transport, have approved the above-mentioned Special Form Design. Radioactive material manufactured to the above-mentioned design qualifies as special form radioactive material and as such will meet the requirements of the regulations overleaf.

This Certificate of Approval applies only to the design as set out in the above named drawings and specifications submitted by Amersham International plc

In the event of any alteration to the above mentioned drawings and specifications or in any of the facts stated in the application for approval, this certificate will cease to have effect unless the Competent Authority is notified of the alteration and the Competent Authority confirms the certificate notwithstanding the alteration.

This Certificate Cancels all Previous Issues and is valid until 31 March 1991.

Competent Authority
Identification Mark:

GB/343/S

UNITED KINGDOM COMPETENT AUTHORITY FOR THE TRANSPORT
24 MAR 1988

D. J. Blackman

Transport Radiological Adviser
Department of Transport
2 Marsham Street

Amersham International plc
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Buckinghamshire England HP7 9LL

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Certificate of radioactive source integrity QCS 685 Issue 1

Title	:	Gamma Irradiation Source
Assembly code	:	X2089
Assembly drawing	:	3A 61844
Nuclide	:	Cobalt-60 (Co-60)
Radiotoxicity group	:	B1
Maximum activity	:	740 TBq (20 kCi)

CLASSIFICATION : BS/ISO/ANSI 77 C64426

RECOMMENDED WORKING LIFE : 15 Years (see overleaf)

Test sources : 2 off inactive sources, serial numbers E and F, containing inactive cobalt rods and helium filled. Assembled as in drawing number 3A 61844 issue A. Void volume >100mm³.

Tests carried out in accordance with Recommendation of:

BS.5288: 1976 ISO.2919: 1980(E) ANSI N542: 1977 IAEA Safety Series No.6: X

Leak test method	TEMPERATURE	PRESSURE	IMPACT	VIBRATION	PUNCTURE	Units
	6	4	4	2	6	
Vacuum Bubble (QCP 112)	Pass Pass	Pass Pass	Pass Pass	Pass Pass	Pass Pass	
Helium Pressure (QCP 113)	6.8 x10-7 5.2 x10-7	3.4 x10-7 2.6 x10-7	3.8 x10-7 2.6 x10-7	5.1 x10-7 6.3 x10-7	3.8 x10-7 2.6 x10-7	mbar l s-1

QA Manager.

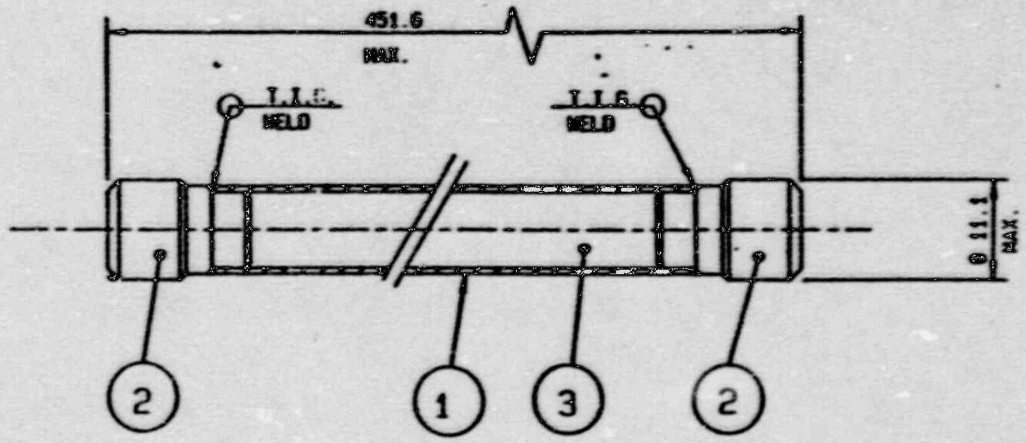
Production Manager - Industrial Products.

Third Angle Projection This drawing conforms to BS 308	This drawing is the private and confidential property of Amersham International plc. and must not be loaned copied or reproduced without written permission.

Components shown form a capsule of approved design.
Modifications must not be made without reference to the capsule design office.

Item No	Drawing No		Description	No off
1	3A61843	ITEM.1.	BODY	1
2	3A61843	ITEM.2.	LID	2
3			[illegible]	—

ENGRAVE TO QCP.114



ACTUAL DIA.SIZE

NOTE; T.I.G.WELDS TO BE FLUSH WITH TUBE.

Approved	Issue	Date	Mod.No
A.H.B.	C	[illegible]	[illegible]
A.H.B.	B	[illegible]	[illegible]
A.H.B.	A	[illegible]	

Material & Spec.	Tolerances	Surface Texture	Finish
———	——— Unless stated	——— ✓ Unless stated	——— Remove all burrs
Original Scale Do not scale 2/1	Dims.in millimetres	Drawn M.A. Checked F.J.B.	Used on ———

Amersham

Title
ASSEMBLY OF SOURCE CAPSULE X2089

Job
Job No.

Drg. 3A61844

5.0 Shielding Evaluation

5.1 Discussion and Results

The containment cavity is shielded by 5 blocks of depleted uranium 150 mm (5.9 inches) thick with a total mass of 1817 Kg (4006 lbs). Four of the blocks form an open topped cylinder (the containment cavity) and the fifth, the closure plug. A Tungsten alloy rod is inserted in the cavity drain pipe to provide shielding during transportation.

Shielding tests indicated that some additional shielding was required (See Packaging Group Memorandum (PGM) 246 in Appendix 5.5.1). As a result of these tests, a 19 mm thick stainless steel ring was positioned between the sources and the underside of the lid. In addition, a Tungsten disc 98 mm in diameter and 23 mm thick is inserted between the drain hole and the sources.

Table 5.1

Summary of Maximum Dose Rates (mrem/hr)

	Package Surface			At One Meter		
	Side	Top	Bottom	Side	Top	Bottom
Normal Conditions						
Gamma	27.2	69.2	34.2	8.2	8.2	4.0
Neutron	NA	NA	NA	NA	NA	NA
Total	27.2	69.2	34.2	8.2	8.2	4.0

	Package Surface			At One Meter		
	Side	Top	Bottom	Side	Top	Bottom
Hypothetical Accident Conditions						
Gamma	27.2	69.2	34.2	8.2	8.2	4.0
Neutron	NA	NA	NA	NA	NA	NA
Total	27.2	69.2	34.2	8.2	8.2	4.0

As discussed in sections 2.7 and 3.5 there would be no loss of shielding effectiveness in hypothetical accident conditions.

5.2 Source Specification

5.2.1 Gamma Sources

The sources used were Co-60 special form capsules containing 2.64 kCi in a model X170 capsule.

5.2.2 Neutron Sources

Not Applicable

5.3 Model Specification

The basic information on radiation dose rates was generated experimentally using the actual flask. Dose rates were measured on the flask containing 270 kC of cobalt-60. (See PGM 246 in Appendix 5.5.1).

5.4 Shielding Evaluation

A shielding efficiency test of the container was conducted. The initial test revealed two areas of concern. A disc of significantly higher level radiation was being emitted at a height equivalent to the underside of the lid and a fairly tight beam was coming from the drain hole. As there are no direct shine paths in these areas it was concluded that the cause was high energy scatter tracking along certain stainless steel boundaries in the flask structure. More tests were conducted and found that the addition of a stainless steel ring positioned between the sources and the underside of the lid, and a Tungsten alloy disc inserted between the drain hole and the sources, solved this problem. Details of the shielding tests may be found in PGM 246 in Appendix 5.5.1.

The results of the tests demonstrate that the dose rates surrounding this container are within the regulatory limits.

5.5 Appendix

5.5.1 Packaging Group Memorandum (PGM) 246
"Shielding Tests on 3100A Wet Flask."

5.5.1 Packaging Group Memorandum (PGM) 246

A I Plc

International

Packaging Group Memorandum

Shielding Tests on 3100A Wet Flask

A. Introduction

Following final assembly of the 3100A wet Flask it was loaded with source capsules and on initial radiation survey carried out. This revealed two areas of concern. A disc of significantly higher level radiation was being emitted at a height equivalent to the underside of the lid and a fairly tight beam was coming from the drain hole. As there are no direct shine paths in these areas it was concluded that the cause was high energy scatter tracking along certain stainless steel boundaries in the flask structure. Subsequently more detailed tests were conducted with a variety of shielding elements incorporated both underneath and on top of the source holder. Details of the method, the equipment used and the data obtained may be found in the Appendix. The following sections analyse the results and conclude with the modifications necessary to the flask.

B. General levels

Tests conducted without any additional shielding pieces inside the cavity show that the maximum general levels are at the flask mid-height (see tests 2,4,5,9). As any shielding pieces added above or below the sources would not effect these levels they may now be taken as the levels to aim for in the problem areas. To calculate the levels to be expected with the flask's maximum load (270k Ci Co 60) the values are increased in the same proportion as the contents after having deducted the background levels (see test 1). Because the background levels are due, in part, to the radiation from the flask's depleted uranium shielding these are then added back on:-

$$DR\ max = \left((DR - Bg) \times \frac{ACT\ max}{ACT} \right) + Bg$$

$$\text{thus SDR max} = \left((200-20) \times \frac{270}{193} \right) + 20 = \underline{272}\ uSv$$

$$\text{and TI max} = \left((60-5) \times \frac{270}{193} \right) + 5 = \underline{82\ uSv}$$

C. Drain hole levels

Results from the 33mm discs inserted between the drain hole and the sources (tests 13-19) show that satisfactory levels are obtained with either the lead or d/u discs and that a slightly thicker stainless steel disc would have been sufficient. Unfortunately there is not enough room in the cavity to use a thicker disc and lead cannot be used as it could melt. The only materials left are depleted uranium or tungsten. Tungsten falls mid way between lead and d/u in shielding efficiency, is far more stable chemically and has no radiation hazards of its own. It is therefore recommended that tungsten is used. The improved shielding efficiency also means that a thinner disc may be used. The GEC comparison tables between lead and tungsten with broad beam Co 60 radiation show that a tungsten thickness of 23mm is equivalent to a lead thickness of 33mm. The radiation levels expected are therefore:-

$$SDR\ max = \left((250-20) \times \frac{270}{193} \right) + 20 = \underline{342\ uSv}$$

$$TI\ max = \left((30-5) \times \frac{270}{193} \right) + 5 = \underline{40\ uSv}$$

D. Lid underside levels

Results from the 19mm thick rings positioned between the sources and the underside of the lid (tests 20-23) show that satisfactory levels are obtained using a stainless steel ring. The levels expected are:-

$$SDR\ max = \left((500-20) \times \frac{270}{193} \right) + 20 = \underline{692\ uSv}$$

$$TI\ max = \left((60-5) \times \frac{270}{193} \right) + 5 = \underline{82\ uSv}$$

E. Conclusions

1. The maximum radiation levels from the 3100A when it is carrying 270k Ci Co 60 are as follows:-

SDR = 692 uSv or 69 mR/hr

TI = 82 uSv or 8.2 mR/hr

2. The higher than average radiation levels occuring at lid underside height and at the drain hole can be brought down to not more than the levels above if a tungsten disc (dia. 98mm x thickness 23mm) and a stainless steel ring (dia. 98mm x thickness 19mm) are introduced respectively below and above the source holder.

Author = D W Rogers

Signed = [signature]

Date = 9 '11 '87

Appendix

1. Method

The tests were conducted in one of the cells in building 443.26 at AERE Harwell. The flask stood directly on the cell floor so radiation measurements at the base were made without the benefit of the special pallet it would be standing on during transport. X170 capsules each containing 2.64k Ci Co 60 were used. The length of these capsules meant that each tube in the source holder could carry up to three capsules. The maximum flask content was therefore 75 capsules. After establishing the general efficiency of the flask's shielding the two areas of weakness were investigated. Fortunately the flask's cavity was sufficiently long for additional shielding elements to be added both underneath and above the sources. With the flask loaded with 25 capsules, either at the bottom of the source holder or at the top on spacers, discs of different shielding materials were placed below the source holder and rings placed on top. Finally the source holder was loaded as fully as possible to ascertain whether or not this made a significant difference.

2. Equipment

a) Shielding discs	=	Diameter	=	98mm
		Thickness	=	33mm
		Materials	=	St/st, lead & d/uranium
b) Shielding rings	=	Outside Diameter	=	98mm
		Inside Diameter	=	30mm *
		Thickness	=	19mm
		Materials	=	St/st & lead
c) Monitors	=	NE 2603 (gamma) 0-20 mSv/hr		
		Teletector 6112B (gamma) 0-1000R/hr		
		High level 3247-2 (beta/gammma) 0-1000 mSv/hr		

* to clear lifting ring on source holder.

3. Results

		Contents kCiCo60	SDR uSv	TI uSv
1.	Background levels	-	20	5
2.	Flask mid-height	193	200	60
3.	Flask lid (sources at bottom of cavity)	66	15	10
4.	Flask lid (sources at bottom of cavity)	132	20	15
5.	Flask lid (sources at top of cavity)	66	80	50
6.	Flask lid (sources at top under s/s ring)	66	35	25
7.	Flask lid (sources at top under lead ring)	66	30	20
8.	Flask lid (sources under s/s ring)	193	45	25
9.	Flask base (sources on 33mm spacer)	66	180	-
10.	Flask base (sources on s/s disc)	66	70	-
11.	Flask base (sources on lead disc)	66	50	-
12.	Flask base (sources on d/u disc)	66	25	-
13.	Drain hole (sources in bottom of cavity)	66	4,000	620
14.	Drain hole (sources in bottom on 33mm spacer)	66	2,000	310
15.	Drain hole (sources in bottom on s/s disc)	66	600	77
16.	Drain hole (sources in bottom on lead disc)	66	250	30
17.	Drain hole (sources in bottom on d/u disc)	66	120	25
18.	Drain hole (sources in bottom on s/s disc)	132	400	80
19.	Drain hole (sources in top on s/s disc)	66	55	40
20.	Underlid (sources at top of cavity)	66	1,000	80
21.	Underlid (sources at top under s/s ring)	66	500	60
22.	Under lid (sources at top under lead ring)	66	400	50
23.	Under lid (s/s ring over sources)	193	500	60

6.0 Criticality Evaluation

Not Applicable

7.0 Operating Procedures

7.1 Procedures for Loading Package

The procedures for loading the 3100A container are as follows:

1. Unlock and remove the two padlocks securing the outer framework and the two security wires.

2. Unscrew and remove the four M16 bolts holding the outer framework down.

3. Attach four slings and shackles (SWL 1000 Kg each) to the four lifting eyes on top of the outer framework (mass 150 Kg) and attach a suitable hoist.

4. Lift the frame vertically to clear the flask and lower into position in a suitable storage area.

5. Undo the eight M16 bolts securing the flask feet to the pallet.

6. Lift the flask (2,230 Kg) off the pallet, using four slings and shackles (SWL 1000 Kg each) attached to the eyes in the top of the fins.

7. Gently lower the flask onto a flat, firm base capable of supporting the load as close as practical to where its to be loaded.

8. Remove the padlock and seal securing the flask closure.

9. Ensure the flask is clean enough to enter the loading facility (pond or cell).

10. Only when the flask is ready to enter the facility, loosen the eight M20 closure bolts each by one turn and check the M30 eyebolt, together with the shackle and sling, is securely screwed into the center of the closure.

11. The flask is now ready to enter the facility. For dry loading, proceed to paragraph 25.

<u>Wet Loading</u>

12. Remove the closure purge plug and the flask drain plug.

<u>CAUTION</u> - (a) The plugs are clearly labelled. On no account should any attempt be made to undo the maintenance test plugs which are wired and sealed.

(b) Behind the flask drain plug is a rod. Remove this carefully as it is fragile.

13. Lower the flask slowly into the water.

14. Undo the closure bolts.

15. Lift off the closure and place it down carefully in a clean area in the pond.

16. Carefully lift the source holder out of the flask cavity and complete the loading operation.

NOTE: - (a) There are two source holders in use. S/H 1 can carry up to 25 full length or 50 half length capsules. S/H 2 can carry up to 32 full length capsules. Both carry the capsules in the same array and use the lifting lug.

(b) If the source holder is not to be fully loaded, ensure that the capsules are evenly distributed.

(c) If there are any capsules less than 430 mm long, ensure that they are suitably packed to maintain vertical float to less than 25 mm.

17. Carefully replace the holder in the flask, ensuring it goes right down.

18. Replace the closure.

    NOTE: The slot in its rim engages only with the fin with the padlock point.

19. Replace the closure bolts and ensure they are screwed fully home, but not tight.

20. Lift the flask out of the water using the four fin lifting eyes and hold it above the surface until water has stopped draining from the drain hole.

CAUTION: Do not attempt to lift the flask using the lid eyebolt.

21. Lower the flask carefully onto the ground.

22. Check that radiation levels are nowhere greater than 1 R/hr and contamination levels are within the limits specified: 4 Bq/cm^2(1.8×10^{-4} uCi/cm^2) beta, gamma, 0.4 Bq/cm^2 (1.8×10^{-7} uCi/cm^2) alpha when averaged over any area of 300 cm^2.

23. Check one at a time that the bolts are lubricated with copper lubricant and tighten securely to 15 kgfm.

24. When the flask has dried out, replace the drain hole rod and the purge and drain plugs.

NOTE: (a) The cavity will dry out more quickly if dry compressed air is blown through it. If this is done, use the purge point on the closure 3/8" BSPP female) and remove the drain plug and rod.

(b) At normal operating temperature, an oxide film will form on the surface of the stainless steel source capsules. This is quite harmless but, if necessary, may be avoided by purging the flask cavity with an inert gas such as Argon, Nitrogen or Helium before it is sealed.

Dry Loading

25. Lift the flask and lower it down carefully inside the cell.

26. Undo the closure bolts.

27. Lift the source holder clear and place it down carefully on a heat resistant surface.

28. Load the holder with source capsules (see note in paragraph 16).

29. Carefully replace the holder in the flask, ensuring it goes right down.

30. Replace the closure ensuring it is fully home.

NOTE: The slot in the rim engages only with the fin with the padlock point.

31. Replace the closure bolts and ensure that they are fully screwed home but not tight.

32. Lift the flask out of the cell and place it down carefully on the ground.

33. Check radiation levels are nowhere greater than 1 R/hr and contamination levels are within the limits specified (see paragraph 22).

34. Check one at a time that the closure bolts are lubricated with copper lubricant and tighten securely to 15 kgfm. (see note 6 in paragraph 24).

7.2 Procedures for Unloading Package

The procedures for unloading the 3100A container are as follows:

1. Unlock and remove the two padlocks serving the outer framework and the two security wires.

2. Unscrew and remove the four M16 bolts holding the outer framework down.

3. Attach four slings and shackles (SWL 1000 Kg each) to the four lifting eyes on top of the outer framework (mass 150 Kg) and attach a suitable hoist.

4. Lift the frame vertically to clear the flask and lower into position in a suitable storage area.

CAUTION: The flask surfaces may be hot enough to burn unprotected hands. It is advisable to wear gloves if the flask is carrying more than 4.0 PBq (100 kCi) of Cobalt-60.

5. Undo the eight M16 bolts securing the flask feet to the pallet.

6. Lift the flask (2,230 Kg) off the pallet, using four slings and shackles (SWL 1000 Kg each) attached to the eyes in the top of the fins.

7. Gently lower the flask onto a flat, firm base capable of supporting the load as close as practical to where it is to be unloaded.

8. Remove the padlock and seal securing the flask closure.

9. Ensure the flask is clean enough to enter the unloading facility (pond or cell).

10. Only when the flask is ready to enter the facility, loosen the eight M20 closure bolts each by one turn and check the M30 eyebolt, together with the shackle and sling, is securely screwed into the center of the closure.

11. The flask is now ready to enter the facility. For dry unloading, proceed to paragraph 26.

<u>Wet Unloading</u>

12. Remove the closure purge plug and the flask drain plug.

<u>CAUTION</u>: (a) The plugs are clearly labelled. On no account should any attempt be made to undo the maintenance test plugs which are wired and sealed.

(b) Behind the flask drain plug is a rod. Remove this carefully as it is fragile and may be very hot.

13. Precool the flask if it is carrying more than 4.0 PBq (100 kCi) of Cobalt 60 by:

(a) playing a water spray over it for ten minutes: - start with a fine spray and only progress to a stronger jet when boiling on contact has ceased.

(b) air cooling the contents for thirty minutes - connect a source of clean, dry, oil free air at not more than 6.0 bar to the closure purge point (3/8" BSPP).

<u>CAUTION</u>: Air exiting from the drain point may be extremely hot.

14. Lower the flask slowly into the water.

NOTE: If the flask should have been precooled but the facilities were not available, lower the flask into the water in steps of not more than 10 cm, pausing at least a minute between each step.

15. Undo the closure bolts.

16. Lift off the closure and place it down carefully in a clean area in the pond.

17. Carefully lift the source holder out of the flask cavity and complete the unloading operation.

NOTE: There are two source holders in use. S/H 1 can carry up to 25 full length or 50 half length capsules. S/H 2 can carry up to 32 full length capsules. Both carry the capsules in the same array and use the lifting lug.

18. Carefully replace the holder in the flask, ensuring it goes right down.

19. Replace the closure.

NOTE: The slot in its rim engages only with the fin with the padlock point.

20. Replace the closure bolts and ensure they are screwed fully home, but not tight.

21. Lift the flask out of the water using the four fin lifting eyes and hold it above the surface until water has stopped draining from the drain hole.

CAUTION: Do not attempt to lift the flask using the lid eyebolt.

22. Lower the flask carefully onto the ground.

23. Check that radiation levels are nowhere greater than 1 R/hr and contamination levels are within the limits specified: 4 Bq/cm^2(1.8 x 10^{-6} uCi/cm^2) beta, gamma, 0.4 Bq/cm^2 (1.8 x 10^{-7} uCi/cm^2) alpha when averaged over any area of 300 cm^2.

24. Check one at a time that the bolts are lubricated with copper lubricant and tighten securely to 15 kgfm.

25. When the flask has dried out, replace the drain hole rod and the purge and drain plugs.

NOTE: (a) The cavity will dry out more quickly if dry compressed air is blown through it. If this is done, use the purge point on the closure (3/8" BSPP female) and remove the drain plug and rod.

(b) At normal operating temperature, an oxide film will form on the surface of the stainless steel source capsules. This is quite harmless but, if necessary, may be avoided by purging the flask cavity with an inert gas such as Argon, Nitrogen or Helium before it is sealed.

Dry Unloading

26. Lift the flask and lower it down carefully inside the cell.

27. Undo the closure bolts.

28. Lift the source holder clear and place it down carefully on a heat resistant surface.

CAUTION: The source capsules are likely to be extremely hot (up to 400° C). Remove ALL flammable materials from the unloading area.

29. Load the holder (see note in paragraph 16).

30. Carefully replace the holder in the flask, ensuring it goes right down.

31. Replace the closure ensuring it is fully home.

NOTE: The slot in the rim engages only with the fin with the padlock point.

32. Replace the closure bolts and ensure that they are fully screwed home but not tight.

33. Lift the flask out of the cell and place it down carefully on the ground.

34. Check radiation levels are nowhere greater than 1 R/hr and contamination levels are within the limits specified (see paragraph 22).

35. Check one at a time that the closure bolts are lubricated with copper lubricant and tighten securely to 15 kgfm. (see note 6 in paragraph 24).

7.3 Preparation of Empty Package for Transport

The procedures for preparing the container for empty return are as follows:

1. The package and all equipment must be checked to ensure that the contamination levels do not exceed those for uncontrolled areas 4 Bq/cm² (1.8×10^{-6} uCi/cm²) (Beta, Gamma), 0.4 Bq/cm² (1.8×10^{-7} uCi/cm²) (Alpha) when averaged over any area of 300 cm².

2. Repack in the general reverse procedure, paying particular attention to the following:

   (a) turnaround maintenance as set forth in Packaging Group Memorandum (PGM) 176 (Appendix 8.3.1).

   (b) All nuts and bolts must be tightened securely.

   (c) All padlocks must be repositioned.

   (d) All seals must be replaced.

3. Check all tools against the list provided and return to the tool box.

4. Remove the old labels and relabel as appropriate. Ensure the necessary paperwork is complete for transport. Check that labels and documentation agree with measured radiation levels. Check in particular around the drain point.

5. When the flask is being returned empty, it may be described as "Exempt" in the transport documents provided that:

   (a) the surface dose rate is less that 5 uSv/hr.

   (b) the internal surface contamination levels do not exceed 400 Bq/cm² (1.8×10^{-4} uCi/cm²) (Beta,Gamma) or 40 Bq/cm² (1.8×10^{-5} uCi/cm²) (Alpha).

   (c) The external surface contamination levels do not exceed those specified in paragraph 1.

   (d) all category labels have been removed or covered up.

7.4 Appendix

7.4.1 Handling and Packaging Instructions for Package Design 3100A (HPI 63)

7.4.1 Handling and Packaging Instructions for Package Design 3100A

AMERSHAM INTERNATIONAL plc

International Operations

Packaging Group

Handling and Packaging Instructions
for Package Design No. 3100A

GA DRAWING NUMBER OA 23525

A. CONTENTS

Warnings
Unloading and loading instructions.
Return of container
Appendix 1: Equipment and tools for Package Design No. 3100A.
Appendix 2: Spare parts list for Package Design No. 3100A.

B. ASSOCIATED DOCUMENTS

1. Safety instructions for unloading and use of high activity gamma radiation sources.

2: Package assembly drawings.

3. PGM 176 - Turnround maintenance for Package Design No. 3100A.

C. WARNINGS

1. All supervisory personel must ensure that they are completely familiar with this document and associated documents before commencing to unload or transfer sources from this package.

2. All personnel handling the package must be competent in working with radiation hazards and fully informed about the operations necessary.

3. Check contamination levels on all exposed surfaces on the package and all equipment before authorising work to proceed. They must not exceed those for non-controlled areas ($4Bq/m^2$ (beta, gamma), $0.4Bq/m^2$ (alpha) when averaged over any area of $300cm^2$).

4. For shipment of radioactive material, check that the package will not require annual maintenance before the shipment is completed.

5. The package must only be transported using a vehicle of 4.0 tonnes minimum capacity which is provided with adequate tie-down facilities. Note that more often than not this package must travel as a FULL LOAD (see F.5).

D. <u>EQUIPMENT REQUIRED</u>

1. Hoist : SWL 4.0 tonnes minimum.

2. Equipment and tools for Package Design No. 3100A (Appendix 1)

3. Spare parts for Package Design No. 3100A (Appendix 2).

E. <u>UNLOADING AND LOADING INSTRUCTIONS</u>

1. Unlock and remove the two padlocks securing the outer framework and the two security wires.

2. Unscrew and remove the four M16 bolts holding the outer framework down.

3. Attach four slings and shackles (SWL 1000kg each) to the four lifting eyes on top of the outer framework (mass 150kg) and attach a suitable hoist.

4. Lift the frame vertically to clear the flask and lower into position in a suitable storage area.

   <u>Caution:</u> The flask surfaces may be hot enough to burn unprotected hands. It is advisable to wear gloves if the flask is carring more than 4.0PBq of Cobalt 60.

5. Undo the eight M16 bolts securing the flask feet to the pallet.

6. Lift the flask (mass 2300kg) off the pallet, using four slings and shackles (SWL 1000kg each) attached to the eyes in the top of the four thick fins.

7. Gently lower the flask onto a flat, firm base capable of supporting the load as close as practical to where it is to be (un)loaded.

8. Remove the padlock and seal securing the flask closure.

9. Ensure the flask is clean enough to enter the (un)loaded facility (pond or cell).

10. Loosen the eight M20 closure bolts by one turn each and insert the M30 eyebolt into the centre of the closure.

11. The flask is now ready to enter the facility. For dry (un)-loading proceed to para.27.

Wet (un)loading

12. Remove the closure purge plug and the flask drain plug.
Caution: (a) The plugs are clearly labelled. On no account should any attempt be made to undo the Maintenance Test plugs which are wired and sealed.

(b) Behind the flask drain plug is a tungsten rod. Carefully remove this taking care that it does not get bent or broken.

13. Pre-cool the flask if it is carrying more than 4.0PBq of Cobalt 60 by:

a) Playing a water spray over it for ten minutes:- Start with a fine spray and only progress to a stronger jet when boiling on contact has ceased.
b) Air cooling the contents for thirty minutes:- Connect a source of clean, dry, oil free air at not more than 6.0 bar to the closure purge point. NOTE: Air exiting from the drain point may be extremely hot.

14. Lower the flask slowly into the water. NOTE: If the flask should have been precooled but the facilities were not available lower the flask into the water in steps of not more than 10cm pausing at least a minute between each step.

16. Undo the closure bolts.

17. Lift off the closure and place it down carefully in a clean area in the pond.

18. Carefully lift the source holder out of the flask cavity and complete (un)loading operation. NOTE If it is not to be fully loaded, ensure that the sources are evenly distributed around the basket.

19. Carefully replace the source holder in the flask, ensuring it goes right down.

20. Replace the closure. NOTE The slot in its rim engages only with the fin with the padlock point.

21. Replace the closure bolts and ensure that they are screwed fully home but not tight.

22. Lift the flask out of the water, holding it above the surface until water has stopped issuing from the drain hole.

23. Lower the flask carefully down onto the ground.

24. Check that radiation levels are nowhere greater than 1R/hr and contamination levels are within the limits specified in C 3.

25. Check one at a time that the bolts are lubricated with copper or PTFE lubricant and tighten securely to 15kgfm.

26. When the flask has dried out, replace the tungsten rod, purge and vent plugs. NOTE. The cavity will dry out more quickly if dry compressed air is blown through it. If this is done, use the purge point on the closure ($^3/8$" BSPP female) and remove the drain plug and tungsten rod.

Dry (un)loading

27. Lift the flask and lower it down carefully inside the cell.

28. Undo the closure bolts.

29. Lift the closure clear and place it carefully down in a clean area in the cell.

30. Lift the source holder clear and place it down carefully on a heat resistant surface.

31. (Un)load the holder with source capsules. NOTE If it is not to be fully loaded ensure that sources are evenly distributed around the holder.

32. Carefully replace the holder in the flask, ensuring it goes right down.

33. Replace the closure ensuring it is fully home. NOTE The slot in the rim engages only with the fin with the padlock point.

34. Replace the closure bolts and ensure they are screwed fully home but not tight.

35. Lift the flask out of the cell and place it down carefully on the ground.

36. Check radiation levels are nowhere greater than 1R/hr and contamination levels are within the limits specified in C 3.

37. Check one at a time that the closure bolts are lubricated with copper or PTFE lubricant and tighten securely to 15kgfm.

F. RETURN OF CONTAINER

1. The package and all equipment must be checked to ensure that the contamination levels do not exceed those for non-controlled areas (4Bq/cm^2 (beta, gamma), 0.4Bq/cm^2 (alpha) when averaged over any area of 300cm^2).

2. Repack in the general reverse procedure, paying particular attention to the following points:

a) Turnround maintenance to PGM 176 must be carried out.

b) All nuts and bolts must be tightened securely.

c) All padlocks must be repositioned.

d) All seals must be replaced.

3. Check all tools against the list provided and return to the tool box.

4. Remove the old labels and re-label as appropriate. Ensure the necessary paperwork is complete for transport. Check that labels and documentation agree with measured radiation levels. Check in particular around the drain point.

C. <u>ESSENTIAL CARRIER INFORMATION</u>

1. <u>Stowage Restrictions</u>

The package may generate significant quantities of heat. The following precautions ensure that heat is dissipated safely. The consignor <u>must</u> ensure that they are complied with at all times during transport.

Contents (Co 60)	Precautions
Up to 180TBq (5KCi)	No special precautions are necessary
180TBq to 660TBq (5KCi to 18KCi)	Minimum clearance around package of 750mm
660TBq to 1.18PBq (18KCi to 32KCi)	Minimum clearance around package of 750mm. Package must not be oversheeted.
Above 1.18PBq (32KCi)	FULL LOAD conditions apply. Package must not be oversheeted.

2. <u>Steam</u>

When the flask is fully loaded loaded its surface temperature may exceed 100°C. In the event of rain or water spray falling on the flask large quantities of steam may be generated. This is perfectly normal and in no way indicates nay lack of safety. The consignor <u>must</u> ensure that all carriers are aware of this before the flask is despatched.

Author: [signature] Date: 1/12/87

Checked: [signature] Date: 4.12.87

Appendix 1

Recommended equipment and tools for Package Design No.3100A

Description

Lifting	Qty	Size.
1: Lifting straps	4	1000kg SWL
2: Shackles	4	1000kg SWL
	1	4000kg SWL
3: Eyebolt	1	M30
4: Lifting strap	1	4000kg SWL
Tools		
5: Ring spanner	2	M16 and M20 (24mmx39mmA/F)
6: Socket	2	M16 and M20
7: Adjustable spanner	1	Up to M24 (36mm A/F)
8: Ratchet handle	1	Standard
9: Socket extension	1	Standard
10: Pair of pliers	2	Long nose and heavy duty
11: Screwdriver	4	Assorted
12: Mallet	1	Hide and copper faced
13: Torque wrench	1	0-25kgfm
Miscellaneous		
Security seals	6	Standard AI issue
Security wire	600cm	Standard AI issue
Copper or PTFE Lubricant	1 tube	Standard
High temp. Locktite	1 tube	Standard
Disposable		
White tape	1 roll	
Cotton gloves	4 pairs	
Muslin	---	
Personal (per radiation worker)		
Coveralls	1	
Safety shoes	1 pair	
Radiation bleeper	1	
Film badge	1	
QFE	1	
Supplementary		
Mini monitor	1 beta/gamma	
Package monitor	1 2R/hr max.	
Package monitor	1 50R/hr max.	
Transport labels	1 set.	
Documentation	1 set	
Assembly drawings	1 set	
Approval certificate	1 set	
Padlock keys	2 sets	

Appendix 2

Recommended Spare Parts List for Package Design No. 3100A

Description	Qty	Item No. (see Drg.No.0A23525)
1: Padlock and keys	2	17
2: O-rings	2	21
3: O-rings	2	22
4: O-rings	1	23
5: Screws	2	25
6: Screws	2	37
7: Washers	2	28
8:Washers	2	29
9:Washers	2	30

8.0 Acceptance Tests and Maintenance Program

8.1 Acceptance Tests

All containers of this design will be manufactured and used in accordance with Amersham Corporation's Quality Assurance Program for Type B Radioactive Material Transport Packages, No. 0320, Revision No. 2 which was approved by The Nuclear Regulatory Commisssion on November 30, 1987 (Appendix 8.3.1).

8.1.1 Visual Inspection

All components of the container are visually examined to insure proper assembly and that padlocks and seals are in place and secure. The container is also examined to insure that the proper marking and labelling is in place. (See Packaging Group memorandum (PGM) 176 in Appendix 8.3.1).

8.1.2 Structural and Pressure Tests

Prototypes of each special form design are tested to a minimum of 290 psi external pressure.

8.1.3 Leak Tests

Each radioactive source capsule will be subjected to the leak tests prescribed for special form sources in IAEA Safety Series No. 6, and or the USA Regulations in 49 CFR Part 173. Sources failing these tests will not be used.

8.1.4 Component Tests

The closure assembly, outer framework, and padlocks are tested for fit and function, to insure that the security of the container will be maintained. Components failing these tests will not be used until the faulty part is repaired or replaced and retested.

8.1.5 Tests for Shielding Integrity

The radiation levels are checked to insure that they are nowhere greater than 1 R/hr. If the radiation level does exceed 1R/hr, the container will be repacked and the radiation level remeasured.

8.1.6 Thermal Acceptance Test

Not Applicable.

8.2 Maintenance Program

8.2.1 Structural & Pressure Tests

Not Applicable.

8.2.2 Leak Tests

As described in section 8.1.3, the radioactive source capsule is leak tested at manufacture, and thereafter at not more than 6-monthly intervals. The stainless steel skins on the flask body and closure provide both environmental and mechanical protection for the depleted uranium shielding within. During the annual maintenance performed on the container, the stainless steel skins are leak tested. The procedure is described in detail in Packaging Group Memorandum (PGM) 177 which may be found in Appendix 8.3.2.

8.2.3 Subsystem Maintenance

Not Applicable.

8.2.4 Valves, Rupture Disks and Gaskets

Not Applicable.

8.2.5 Shielding

Before shipment of the loaded container, the shielding integrity is tested as described in Section 8.1.5. A survey of the fully assembled package including the outer framework is done to ensure that radiation levels do not exceed 200 mR/hr at the surface of the container (outer framework) and 10 mR/hr at one meter from the surface.

8.2.6 Thermal

Not Applicable.

8.2.7 Miscellaneous

Before each shipment, loaded or empty, the turn around maintenance outlined in PGM 176 (Appendix 8.3.1) must be performed.

During the annual maintenance, a dye penetration test is performed on the key structural points such as the lifting eyes, feet, and flange bolts. Details of the annual maintenance may be found in PGM 177, Appendix 8.3.3.

8.3 Appendix

8.3.1 Amersham Corporation Quality Assurance Program for Type B Radioactive Material Transport Packages.

8.3.2 Packaging Group Memorandum (PGM) 176 "Turnaround Maintenance."

8.3.3 Packaging Group Memorandum (PGM) 177 "Annual Maintenance."

8.3.1 Amersham Corporation Quality Assurance Program

NRC FORM 311 (9-87)

U. S. NUCLEAR REGULATORY COMMISSION

QUALITY ASSURANCE PROGRAM APPROVAL FOR RADIOACTIVE MATERIAL PACKAGES

1. APPROVAL NUMBER	REVISION NUMBER
0370	2

Pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and Title 10, Code of Federal Regulations, Chapter 1, Part 71, and in reliance on statements and representations heretofore made in item 5 by the person named in item 2, the Quality Assurance Program identified in item 5 is hereby approved. This approval is issued to satisfy the requirements of Section 71.101 of 10 CFR Part 71. This approval is subject to all applicable rules, regulations, and orders of the Nuclear Regulatory Commission now or hereafter in effect and to any conditions specified below.

2. NAME: Amersham Corporation

STREET ADDRESS: 2636 South Clearbrook Drive

CITY: Arlington Heights — STATE: IL — ZIP CODE: 60005

3. EXPIRATION DATE: November 30, 1992

4. DOCKET NUMBER: 71-0370

5. QUALITY ASSURANCE PROGRAM APPLICATION DATE(S): November 4, 1987

6. CONDITIONS

Activities conducted under applicable criteria of Subpart H of 10 CFR Part 71 to be executed with regard to transportation packages.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

Charles E. MacDonald

CHIEF, TRANSPORTATION BRANCH
DIVISION OF SAFEGUARDS AND TRANSPORTATION
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS

DATE: NOV 30 1987

Amersham Corporation
Quality Assurance Program
For Type B Radioactive Material
Transport Packages

Revised October 15, 1987

Amersham Corporation
Quality Assurance Program
For Type B Radioactive Material
Transport Packages

Introduction

Purpose

This Amersham Corporation Quality Assurance Program is promulgated to comply with the requirements of Subpart H Section 71.51 and Appendix E of 10 CFR Part 71 "Packaging of Radioactive Material for Transport and Transportation of Radioactive Material", of the United States Nuclear Regulatory Commission.

Scope

This Amersham Corporation Quality Assurance Program, as required by 10 CFR Part 71, applies to all activities affecting the components of the packaging which are significant to safety. Those activities include designing, purchasing, fabricating, handling, shipping, storing, cleaning, assembling, inspecting, testing, operating, maintaining, repairing and modifying.

I. Organization

A. The overall responsibility for the Quality Assurance Program is retained and exercised by Amersham Corporation.

B. The responsibility for the Amersham Corporation Quality Assurance Program is shared by a number of departments within the company. The responsible departments, by function, include:

1. Facilities and Procurement

   a. The responsibility for design control; instructions, procedures and drawings in support of the design; assuring that all parts and components are manufactured to specifications; evaluation of the capability of a supplier to provide an acceptable service; all testing requirements; receiving inspections and the control of measuring and test equipment rests with the Engineering Department.

   b. The responsibility for communicating to the manufacturers, via procurement documents, all applicable 10 CFR Part 71, requirements rests with the Purchasing Department.

2. Environmental Regulatory Aff. rs
   The responsibility for overall coordination and monitoring of the handling, storage and shipping of these containers related to the containment of activity and operator safety rests with the Environmental Regulatory Affairs Department.

Environmental Regulatory Affairs also has responsibility for advising other departments on regulatory requirements and auditing the program to see that the requirements are being met.

3. Manufacturing
The responsibility for proper handling, loading and unloading of containers rests with the Manufacturing Department.

4. Operational Services
The responsibility for proper usage of containers during preparation for shipping and after receipt, routine inspection, handling and maintenance rests with the Operational Services Department.

C. A current organizational chart is included with this document as Attachment #1.

D. The key positions within Amersham Corporation that are involved in the administration of the Quality Assurance Program and included in the departments listed in I.B. are listed below with a brief description of each. The specific responsibilities of each position, or of those under the person in the position described, are spelled out in Standard Operating Procedures.

1. The President has overall responsibility for Quality Assurance at Amersham Corporation. This responsibility is delegated to:

a. Manager, Operations who has the responsibility for seeing that the following persons in the following departments carry out their listed responsibilities.

- Shipping Supervisor has responsibility for the receipt, routine inspection, storage, handling and shipping of Type B packages.

- Manager, Manufacturing has the responsibility for proper handling loading and unloading of Type B packages.

- Manager, Procurement and Facilities has responsibility for the coordination and implementation of all engineering aspects of the QA Program. This includes design control, producing instructions, procedures and drawings in support of a design evaluating the capability of supplier to provide an acceptable service, assuring that all parts and components are manufactured to specifications, ensuring that testing requirements are met performing receiving inspections and the exercising control over measur' g and test equipment.

- Senior Buyer has responsibility for purchasing some Type B packages and communicating to participating organizations the QA requirements which must be met.

c. Manager, Scientific and Regulatory Affairs has the responsibility to see that the program is being administered effectively.

- Manager, Environmental and Safety Regulatory Affairs has the responsibility for seeing that the following person carries out her listed responsibilities.

  - Environmental Safety Officer has responsibility for reviewing the activities of other departments with regard to operator safety, for ensuring that all departments are advised of regulatory requirements which must be met and for auditing the Quality Assurance Program to assess if it is in compliance with 10 CFR Part 71. This person also acts as Transport Container Officer for the company.

d. Vice President, Finance and Industrial Products who has the responsibility for seeing that persons in the Industrial Products Department carry out their listed responsibilities.

- Supervisor Customer Service has responsibility for purchasing some Type B packages and communicating to participating organizations the QA requirements which must be met.

E. The Transport Container Officer maintains overall responsibility and authority for the Type B Package Quality Assurance Program and ensures that any deficiencies found in the program are noted and corrected.

The Transport Container Officer should be a technically-degreed, exempt employee who has had sufficient professional experience to judge that the safety-related issues involved in the manufacture and use of a Type B container are addressed in the Quality Assurance Program.

F. It is the responsibility of all individuals listed in I.D. to ensure that quality products are produced. Therefore, each person listed has been delegated the necessary authority to stop unsatisfactory work and control further processing, delivery or installation of nonconforming material until proper disposition of the material is made.

II. Quality Assurance Program

A. The Manager, Environmental and Safety Regulatory Affairs regularly assesses the scope of the QA Program to assure that it is adequate and complies with 10 CFR Part 71 Appendix E.

B. The Manager, Scientific and Regulatory Affairs regularly assesses the status, implementation, and effectiveness of the QA Program for Type B Radioactive Material Packages.

C. Procedures are established to control the distribution of Type B container quality assurance manuals and revisions thereto. This will be the responsibility of the Standards and Specifications Department.

D. The Transport Container Officer communicates to all responsible organizations and individuals that quality policies and procedures are mandatory requirements which must be implemented and enforced.

E. Amersham Corporation Engineering will ensure that all safety-related systems, structures and components are identified and reviewed. These systems will be subject to the QA fabrication and inspection programs.

F. The Transport Container Officer has the responsibility and authority to resolve disputes involving quality arising from a difference of opinion between personnel having QA responsibilities and personnel from other departments.

G. Indoctrination and training programs are established, such that personnel responsible for performing quality-related activities are instructed as to the purpose, scope and implementation of the QA instructions and procedures. They are trained and qualified in the principles and techniques of the activity being performed, and their proficiency is maintained by retraining, reexamining and recertifying. The scope, the objective, and the method of implementing the above program is formally documented.

H. All quality-related activities are to be performed with proper equipment under suitable environmental conditions and all prerequisites will have been satisfied prior to inspection and testing.

III. Design Control

A. Measures are established to carry out design activities in a planned, controlled, and orderly manner.

B. Measures are established to correctly translate the applicable regulatory requirements and design bases into the specifications, drawings, written procedures and instructions.

C. Quality standards are specified in the design documents and deviations or changes from the quality standards are controlled.

D. Designs are reviewed to ensure that:

1. The design characteristics can be controlled, inspected and tested and

2. Inspection and testing criteria have been identified and requirements for handling, storage, cleaning and maintenance are addressed.

E. Proper selection and accomplishment of design verification or checking processes such as design reviews, alternate calculations, or qualification testing are performed. When a test program is used to verify the adequacy of a design, the prototype is subjected to the most adverse design conditions.

F. Design verification will be conducted by a person other than the original designer.

G. All design and specification changes are subject to the same design controls and approvals as the original design.

H. The authority and responsibility of persons performing design reviews and other design verification activities are identified and controlled by written procedures.

IV. Procurement Document Control

A. Procedures are established that clearly delineate the sequence of actions to be accomplished in the preparation, review, approval and control of procurement documents.

B. Procurement documents identify the applicable 10 CFR Part 71 requirements which must be addressed and complied with during fabrication of the container.

C. The procurement documents contain or reference the design technical requirements including the applicable regulatory requirements, and any applicable material and component identifications, drawings, specifications, codes and industrial standards, test and inspection requirements and special process instructions.

D. The procurement documents identify the documentation to be prepared, maintained, and submitted to the purchaser for review and approval.

E. The procurement documentation identifies those supporting records to be retained, controlled, and maintained by the supplier, and those delivered to the purchaser prior to use of the hardware.

F. Procurement documents contain the procuring agency's right of access to a supplier's facilities and records for source inspection and audit.

G. All changes and revisions to the procurement documents are subject to the same review as the original document.

V. Instructions, Procedures and Drawings

A. Activities affecting quality are prescribed and accomplished in accordance with documented instructions, procedures or drawings.

B. Procedures are established which delineate the sequence of actions to be accomplished in the preparation, review, approval, and control of instructions, procedures and drawings.

C. The QA organization outlined in I.B. reviews, and concurs with the inspection plans; test, calibration and special process procedures; drawings and specifications; and changes thereto or acceptable alternatives.

VI. Document Control

A. The review, approval and issuance of documents and changes thereto, prior to release, are procedurally controlled to assure that they are adequate and that quality requirements are stated.

B. Changes to documents, including instructions, procedures, and drawings are reviewed by the same organization that performed the original review and approval or by other qualified, responsible organizations as delegated by Amersham Corporation.

C. Approved changes are included in instructions, procedures, drawings and other documents simultaneously with the implementation of the change.

D. Current issues of applicable documents will be available at the location where an activity is being performed. This will preclude the use of obsolete or superseded documentation.

E. A master list, or equivalent, is established to identify the current revision number of instructions, procedures, specifications, drawings and procurement documents.

VII. Control of Purchased Materials, Parts and Components

A. Qualified personnel evaluate the supplier's capability to provide acceptable quality services and products.

B. The evaluation of a supplier will be based on one or more of the following:

1. The supplier's capability to comply with the elements of Appendix E of 10 CFR Part 71 that are applicable to the type of material, equipment or service being procured.

2. A review of previous records and performance of the supplier on similar articles of the type being procured.

3. A survey of the supplier's facilities and QA procedures to determine his capability to supply a product which meets the design, manufacturing, and quality requirements.

C. The results of the supplier evaluations are documented and filed.

D. Surveillance, if required, of suppliers during fabrication, inspection, testing, and shipment of materials, equipment and components is planned and performed in accordance with written procedures to assure conformance to the purchase order requirements.

E. The supplier will furnish the following records to Amersham Corporation when the container is delivered:

1. Documentation showing which of the purchased material or equipment meets the requirements in the procurement document.

2. Documentation that identifies any procurement requirements which have not been met together with a description of those nonconformances dispositioned "accept as is" or "repair".

F. A receiving inspection of the supplier-furnished material, equipment and services is performed to assure:

1. The material, component or equipment is properly identified and corresponds with the identification on receiving documentation.

2. Materials, components, equipment and acceptance records are inspected and judged acceptable in accordance with predetermined inspection procedures, prior to installation or use.

3. Inspection records or certificates of conformance attesting to the acceptance of material and components are available prior to installation or use.

4. Items accepted and released for use are identified as to their inspection status prior to forwarding them to a controlled storage area or releasing them for further work.

VIII. Identification & Control of Materials, Parts & Components

A. Procedures are established to identify and control materials, parts and components, including partially fabricated sub-assemblies.

B. Procedures are established to ensure that identification of an item is maintained by part number, serial number, or other appropriate means, either on the item or on records traceable to the item to preclude use of incorrect or defective items.

C. Identification of materials and parts important to the function of safety-related systems and components will be traceable to the appropriate documentation, such as drawings, specifications, purchase orders, manufacturing and inspection documentation, deviation reports, and physical and chemical mill test reports.

D. The location and method of identification will not affect the fit, function, or quality of the item being identified.

E. Correct identification of materials, parts and components is verified and documented prior to release for fabrication, assembling and installation.

IX. Control of Special Processes

A. All special processes, such as welding, are procedurally controlled.

B. All procedures, equipment, and personnel connected with special processes are qualified in accordance with applicable codes, standards and specifications.

C. The qualification records of procedures, equipment, and personnel associated with special processes are established, filed, and kept current.

X. Inspection

A. An inspection program which verifies conformance of quality affecting activities with requirements is established, documented and accomplished in accordance with written and controlled procedures.

B. The inspection personnel are independent from the individuals performing the activity being inspected.

C. The inspectors are qualified in accordance with applicable standards and company training programs. Their qualifications are kept current through continued retraining on revised procedures.

D. Modifications, repairs and replacements are inspected in accordance with the original design and inspection requirements or acceptable alternatives.

E. Provisions are established that identify mandatory inspection hold points for witness by an inspector.

XI. Test Control

A. A test program to demonstrate that the item or component will perform satisfactorily in service is established, documented and accomplished in accordance with written, controlled procedures.

B. Modifications, repairs and replacements are tested in accordance with the original design and testing requirements or acceptable alternatives.

C. Test results are documented, evaluated, and their acceptability determined by a qualified, responsible individual or group.

XII. Control of Measuring & Test Equipment

A. Measuring and test instruments are calibrated at appropriate intervals based on the required accuracy, purpose, degree of usage, stability characteristics and other conditions affecting the measurement.

B. Test equipment is identified and traceable to the calibration test data.

C. Measures are taken and documented to determine the validity of previous inspections performed when measuring and test equipment is found to be out of calibration.

D. Reference and transfer standards are traceable to recognized standards; or, where recognized standards do not exist, provisions are established to document the basis for calibration.

XIII. Handling, Storage and Shipping

A. Any special handling, preservation, storage, cleaning, packaging and shipping requirements for Type B containers are established and accomplished by qualified individuals in accordance with predetermined instructions.

B. All conditions of the NRC package approval and US Department of Transportation shipping requirements are satisfied prior to shipment.

C. All necessary shipping papers will be prepared as required.

D. The departure, arrival time and destination of any Type B containers will be established and monitored to a degree consistent with the safe transportation of the package.

XIV. Inspection, Test and Operating Status

A. The appropriate identification of packages as to the status of inspections and testing and therefore the overall operating status of the unit, is known by affected organizations.

B. The application and removal of inspection and welding stamps, and status indicators such as tags, markings, labels and stamps are procedurally controlled.

C. The bypassing of required inspections, tests and other critical operations is procedurally controlled.

D. The status of nonconforming, inoperative, or malfunctioning packages or components is clearly indicated in such a manner to prevent their unauthorized use.

XV. Nonconforming Material, Parts or Components

A. The identification, documentation, segregation, disposition, review and notification to affected organizations of nonconforming materials, parts components or services are procedurally controlled.

B. Documentation identifies a nonconforming item; describes the nonconformance, the disposition of the nonconformance and the inspection requirements; and includes the appropriate approval signature related to the disposition.

C. Nonconforming items are clearly segregated from acceptable items and are identified as discrepant until properly dispositioned.

D. All rework or repair of materials, parts, components and systems is verified by reinspecting and retesting the item as it was originally inspected and tested or as verified by a method which is at least equal to the original inspection and testing method.

XVI. Corrective Action

A. The evaluation of conditions detrimental to quality (such as nonconformances, deficiencies, failures, malfunctions, deviations and defective material and equipment) is conducted to determine the need for corrective action in accordance with established procedures.

B. Corrective action is initiated following the determination of a condition adverse to quality to preclude recurrence.

C. Follow-up reviews are conducted to verify proper implementation of corrective actions and to formally close out the corrective action documentation.

XVII. Quality Assurance Record

A. Sufficient records are maintained to provide documentary evidence of the quality and safety of items, and the activities affecting quality and safety.

B. The QA records maintained for Type B containers include qualification of personnel, procedures and equipment; list of nonconformances; corrective action reports for nonconformances; results of reviews, inspections, tests, audits and material analysis; other documentation such as drawings, specifications, procurement documents and calibration procedures.

C. Records are identifiable and retrievable.

D. A list of the required records and their storage locations will be maintained.

E. All design related records (e.g., drawings, calculations, etc.) are maintained for the life of the shipping package and all other records are maintained for a minimum of two years.

F. The inspection and test records contain the following where applicable:

1. A description of the type of observation.

2. Evidence of completing and verifying a manufacturing, inspection, or test operation.

3. The date and results of the inspection or test.

4. Information related to conditions adverse to quality.

5. Inspector or data recorder identification.

6. Evidence as to the acceptability of the results.

XVIII. Audits

A. Audits are performed in accordance with pre-established written procedures or check lists and conducted by personnel not having direct responsibilities in the area being audited.

B. The results of audits are documented and reviewed with responsible management of areas audited.

C. The responsible management takes the necessary action to correct deficiencies revealed by the audit on a timely basis.

D. Deficient areas will be reaudited on a timely basis to verify implementation of corrective actions to minimize recurrence of deficiencies.

E. Audits of the QA program are performed at least annually based on the safety significance of the activity audited.

F. The audit plan includes:

a. purpose or objective of audit;

b. scope;

c. specific organizations to be audited;

d. names of team members and team leader;

e. approximate schedule;

f. written notification to audited organization;

g. pre-audit conferences;

h. post-audit conferences (exit interview); and

i. method of reporting and evaluating findings.

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8.3.2 Packaging Group Memorandum (PGM) 176

AMERSHAM INTERNATIONAL plc.

International Operations

Packaging Group Memorandum

Turnround Maintenance for Package Design No. 3100A

GA 3100A - Package Assembly, OA 23525

A. Notes

1: Handling of this package must only be carried out by personnel competent in working with radioactive hazards and fully informed about the operations necessary. If you have a Health Physics Department it should check contamination levels on all exposed surfaces before authorising work to continue.

2: Any rectification actions necessary, other than simple replacement or securing of a component, must first be approved by Amersham International, Industrial Quality Assurance.

3: All rectification work must be supervised by competent personnel, fully conversant with requirements of the regulations governing the packaging and transport of radioactive materials and with all pertinent site regulations and procedures.

4: All maintenance documentation, i.e. inspection records, rectification procedure approvals and QA records, must be kept by or returned to Amersham International.

5: This document should be used as the basis for a checklist which will then record inspection as well as any remedial work. These records should be filed in a packaging maintenance file identifying both design and serial number.

B. Equipment needed

1: Hoist - minimum SWL 4.0 tonnes.

2: Equipment and tools (see HPI 63, Appendix 1)

C. General

1: Remove outer framework and, if the flask is loaded, complete unloading operation (see HPI 63).

2: Check all surfaces for contamination. Clean any non-fixed contamination to non-controlled area levels, 4Bq/cm^2 (beta/gamma) and 0.4Bq/cm^2 (alpha), when averaged over any area of 300cm^2.

3: Remove all temporary labelling and marking.

4: Clean all surfaces of accumulated grime and dirt.

D. Specific

The following items require specific attention.

Description	Qty.	Defect	Inspection Method	Remedial action
Flask body				
1. Lifting eyes	4	Distortion Cracking	Visual Visual	Note 1 Note 2
2. Feet	4	Distortion Cracking	Visual Visual	Note 1 Note 2
3. Flange bolt points	8	Dirty	Visual	Clean
4. Fins	36	Distortion Cracking	Visual Visual	Note 1 Note 2
5. Maintenance test plug	1	Loose Missing	Visual Visual	Note 3 Note 2
6: Plug wire seal	1	Broken or missing	Visual	Replace
7. Drain plug	1	Rod missing Thread dirty	Visual Visual	Replace Clean
8. Plug O-ring	1	Missing or broken	Visual	Replace
9. Drain tube	1	Dirty or blocked	Visual	Clean carefully
10. Padlock	1	Missing or not working	Visual	Replace
Closure				
11. Lifting point	1	Dirty	Visual	Clean
12. Flange O-ring	1	Missing or broken	Visual	Replace
13. Flange bolts	8	Dirty Distorted Thread damaged	Visual Visual Visual	Clean Replace Replace
14. Maintenance test plug	1	Loose Missing	Visual Visual	Note 3 Note 2
15. Plug wire seal	1	Broken or missing	Visual	Replace
16. Cavity purge plug	1	Thread dirty	Visual	Clean
17. Plug O-ring		Missing or Broken	Visual	Replace
18. Cavity purge point	1	Thread dirty Hole blocked	Visual Visual	Clean Clean

Description	Qty	Defect	Inspection Method	Remedial action
Source holder				
19. Eyebolt	1	Cracking Loose	Visual Visual	Replace Retighten
20. Thin nut	1	Loose	Visual	Retighten
21. Tubes	25	Distorted Cracked	Visual Visual	Straighten Replace
22. Assembly	1	Dirty	Visual	Clean
23. Shield disc	1	Cracking or missing	Visual	Replace
Pallet				
24. General	1	Distortion Cracking	Visual Visual	Note 1 Note 2
25. Flask bolts	8	Worn or damaged	Visual	Replace
26. Flask bolt points	8	Dirty Thread damage	Visual Visual	Clean Note2
27. Frame bolts	4	Worn or damaged	Visual	Replace
28. Frame bolt points	4	Dirty Thread damage	Visual Visual	Clean Note 2
Outer Framework				
29. Frame lifting eyes	4	Distortion Cracking	Visual Visual	Note 1 Note 2
30. Frame tie-down eyes	12	Distortion Cracking	Visual Visual	Note 1 Note 2
31. Permanent labels	4	Dirty Missing or illegible Insecure	Visual Visual Visual	Clean Replace Secure
32. Padlock	2	Missing or Not working	Visual	Replace

E. Notes

1: Continue usage only if handling, loading, assembly and tie-down are unaffected. Pay special attention to looking for cracks around distorted areas. If operation is adversely affected, return the flask, unloaded, to Amersham International plc, IPU, AERE, Harwell, Oxon OX11ORG, for futher inspection.

2: Return the flask, unloaded, to the above address for further inspection.

3: Retighten securely and arrange to have the cavity evacuated and backfilled with heliun to atmospheric pressure at the earliest opportunity. The flask may safely continue to be operated in the interim but will run a few degrees hotter when it is loaded.

Author: D W Rogers Date: 1/12/87

Checked: [illegible] Date: 4.12.87

8.3.3 Packaging Group Memorandum (PGM) 177

AMERSHAM INTERNATIONAL plc.

International Operations

Packaging Group Memorandum

Annual Maintenance for Package Design No. 3100A

GA 3100A - Package Assembly, OA 23525

A. Notes

1: Handling of this package must only be carried out by personnel competent in working with radioactive hazards and fully informed about the operations necessary. If you have a Health Physics Department it should check contamination levels on all exposed surfaces before authorising work to continue.

2: Any rectification actions necessary, other than simple replacement or securing of a component, must first be approved by Amersham International, Industrial Quality Assurance.

3: All rectification work must be supervised by competent personnel, fully conversant with requirements of the regulations governing the packaging and transport of radioactive materials and with all pertinent site regulations and procedures.

4: All maintenance documentation, i.e inspection records, rectification procedure approvals and QA records, must be kept by or returned to Amersham International.

5: This document should be used as the basis for a checklist which will then record inspection as well as any remedial work. These records should be filed in a packaging maintenance file identifying both design and serial number.

B. Equipment needed

1: Hoist - minimum SWL 4.0 tonnes.

2: Equipment and tools (see HPI 63, Appendix 1)

3: Helium mass spectrometer with suitable connectors.

C. General

1: Remove outer framework and, if the flask is loaded, complete unloading operation (see HPI 63).

2: Check all surfaces for contamination. Clean any non-fixed contamination to non-controlled area levels, 4Bq/cm^2 (beta/gamma) and 0.4Bq/cm^2 (alpha), when averaged over any area of 300cm^2.

3: Remove all temporary labelling and marking.

4: Clean all surfaces of accumulated grime and dirt.

D. Specific

The following items require specific attention.

Description	Qty.	Defect	Inspection Method	Remedial action
Flask body				
1. Lifting eyes	4	Distortion Cracking	Visual Note 3	Note 1 Note 2
2. Feet	4	Distortion Cracking	Visual Note 3	Note 1 Note 2
3. Flange bolt points	8	Dirty Damaged	Visual Visual	Clean Note 2
4. Fins	36	Distortion	Visual	Note 1
5. Maintenance test plug	1	Excessive leak rate	Note 4	Note 2
6. Drain plug	1	Rod missing Thread dirty	Visual Visual	Replace Clean
7. Plug O-ring	1	Missing or broken	Visual	Replace
8. Drain tube	1	Dirty or blocked	Visual	Clean carefully
9. Padlock	1	Missing or not working	Visual	Replace
Closure				
10. Lifting point	1	Dirty Damaged	Visual Visual	Clean Note 2
11. Flange O-ring	1	Missing or broken	Visual	Replace
12. Flange bolts	8	Dirty Distorted Thread damaged Cracked	Visual Visual Visual Note 3	Clean Replace Replace Replace
13. Maintenance test plug	1	Excessive leak rate	Note 4	Note 2
14. Cavity purge plug	1	Thread dirty Thread damaged	Visual Visual	Clean Note 2
15. Plug O-ring		Missing or Broken	Visual	Replace
16. Cavity purge point	1	Thread dirty Thread damaged Hole blocked	Visual Visual Visual	Clean Note 2 Clean

Description	Qty	Defect	Inspection Method	Remedial action
Source holder				
17. Eyebolt	1	Cracking	Visual	Replace Retighten
18. Thin nut	1	Loose	Visual	Retighten
19. Tubes	25	Distorted Cracked	Visual Visual	Straighten Replace
20. Assembly	1	Dirty	Visual	Clean
21. Shield disc	1	Cracked or missing	Visual	Replace
Pallet				
22. General	1	Distortion Cracking	Visual Visual	Note 1 Note 2
23. Flask bolts	8	Worn or damaged	Visual	Replace
24. Flask bolt points	8	Dirty	Visual	Clean
25. Frame bolts	4	Worn or damaged	Visual	Replace
26. Frame bolt points	4	Dirty Thread damage	Visual Visual	Clean Note 2
Outer Framework				
27. Frame lifting eyes	4	Distortion Cracking	Visual Note 3	Note 1 Note 2
28. Frame tie-down eyes	12	Distortion Cracking	Visual Visual	Note 1 Note 2
29. Permanent labels	4	Dirty Missing or illegible	Visual Visual	Clean Replace
30. Padlock	2	Insecure Missing or Not working	Visual Visual	Secure Replace

E. **Notes**

1: Continue usage only if handling, loading, assembly and tie-down are unaffected. Pay special attention to looking for cracks around distorted areas. If operation is adversely affected, return the flask, unloaded, to Amersham International plc, IPU, AERE, Harwell, Oxon OX110RG, for futher inspection.

2: Return the flask, unloaded, to the above address for further inspection.

3: Dye penetrant test accordance with BS 4416, 1969 ensuring personnel are qualified to use this technique.

4: Leak testing: The stainless steel skins on the flask body and closure provide both environmental and mechanical protection for the depleted uranium shielding within. Leake testing assures their integrity.

a) Ensure the helium mass spectrometer has been calibrated and the operator is fully conversant with manufacturer's operating instructions.

b) Remove the wire and seal from the plug on the flask body marked "Maintenance test point".

c) Undo the plug and connect the helium mass spectrometer to the test point (1/4" BSPP female).

d) Test the pipework and connections by blowing helium around them and measuring in-leakage.

e) Provide a simple enclosure (a plastic bag or similar is adequate) around the flask and fill with helium.

f) Measure helium in-leakage after allowing readings to settle down. The leak-rate must not exceed 10^{-6} atm.cc/sec. If it does, follow Note 2, otherwise record leak-rate in the Package Maintenance Record and proceed to (g).

g) Evacuate flask body and back-fill with helium to atmospheric pressure.

h) Replace plug, using new O-ring and high temperature locktite on the thread.

i) Secure the plug, with a new wire and seal.

j) Repeat instructions (b) through to (i) for the flask closure.

F. **"Maintenance Due" label**

When the maintenance has been satisfactorily completed, renew this label dating it year and month twelve months ahead.

Author: D W Ryes .... Date: 1/12/87

Checked: [signature] .... Date: 4.12.87