71-9296

QSA GLOBAL

QSA Global, Inc.
40 North Avenue
Burlington, MA 01803
Telephone: (781) 272-2000
Toll Free: (800) 815-1383
Facsimile: (781) 273-2216

2 March 2006

Mr. Christopher Regan
Licensing Section
Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
One White Flint
Rockville, MD 20852

Subject: Amendment to USA/9296/B(U)-96 for Addition of Se-75 as Authorized Contents

Dear Mr. Regan:

Enclosed please find a CD containing a PDF file for the corrected copy of SAR Revision 6. This corrects the activity references for the 880 Sigma device throughout the document. Should you have any additional questions or wish to discuss this submission prior to our response, please contact me as shown below.

Sincerely,

Lori Podolak

Lori Podolak
Product Licensing Specialist
Regulatory Affairs Department
Ph: (781) 272-2000 ext 241
Fax: (781) 359-9191
Email: Lori.Podolak@qsa-global.com

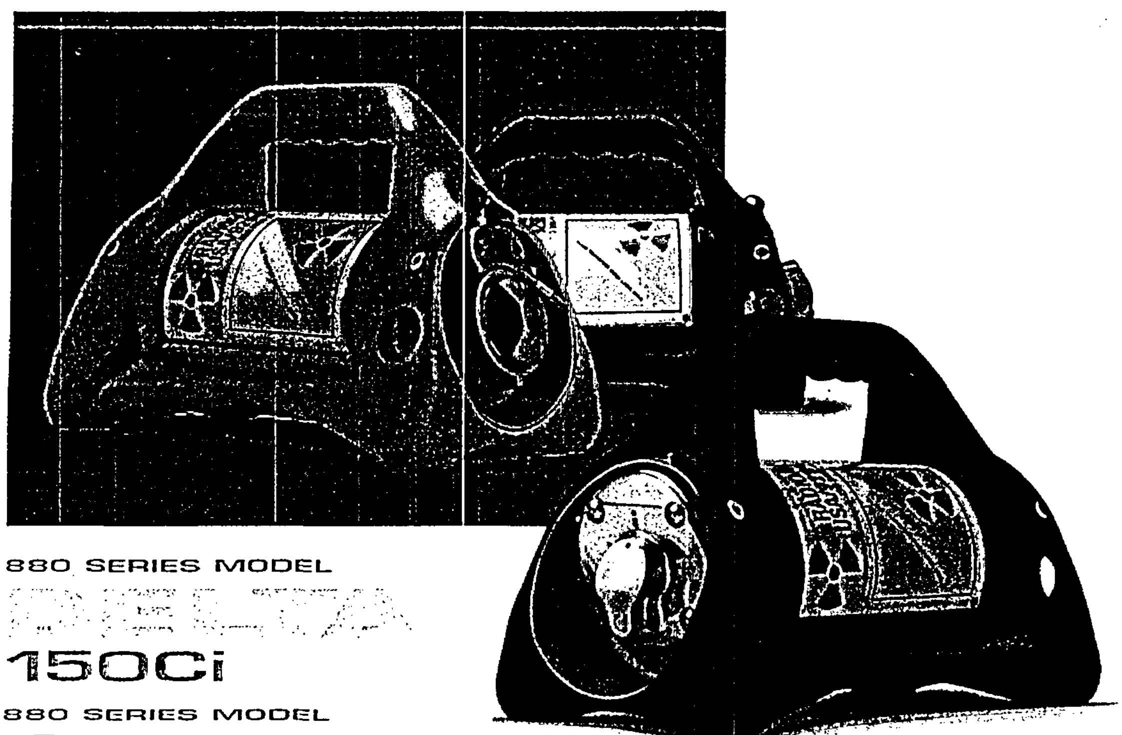
Enclosure: CD

NMSS01

SENTINEL™

880

SERIES SOURCE PROJECTOR



880 SERIES MODEL
DELTA
150Ci

880 SERIES MODEL
SIGMA
130Ci

880 SERIES MODEL
ELITE
50Ci

OPERATING AND MAINTENANCE MANUAL

AEA TECHNOLOGY
QSA

QSA GLOBAL

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Enclosure: CD

AEA Technology
QSA Inc.
40 North Avenue
Burlington, MA 01803
Telephone (781) 272-2000
Telephone (800) 815-1383
Facsimile (781) 273-2216

20 October 2005

ATTN: Document Control Desk
Director, Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
One White Flint
Rockville, MD 20852

RE: Renewal Application for USA/9296/B(U)-85

Dear Director:

Enclosed please find an application for an amendment in entirety to the Type B(U) approval of the Model 880 Series transport packages. The application was completed following updated submission guidance and includes additional compliance information in accordance with IAEA Regulations for the Safe Transport of Radioactive Material, 1996 Edition (Revised), No. TS-R-1. We request the renewal of this Type B(U) package transport certificate and that the renewed certificate be endorsed to the –96 version of IAEA (TS-R-1).

Please note that AEA Technology QSA Inc has recently changed ownership and the new name is QSA Global Inc. There is no change in the organisational structure or safety/regulatory programs of our facility.

This is an electronic submission made in accordance with 10 CFR 71.1 in CD-ROM format. Copies of this submission are authorized for publication on the USNRC document sites and for use in evaluation of this application. The contact information for questions related to this submission is:

Lori Podolak — Phone No.: (781) 272-2000 ext 241
Product Licensing Specialist
Regulatory Affairs Department — Email: Lori.Podolak@qsa-global.com
QSA Global Inc.
40 North Avenue
Burlington, MA 01463

NMSS01

The CD-ROM labeled "AEA Model 880 Series SAR Rev 6" contains the following file:

File Name	File Size	Sensitivity Level	Description
001_QSA Model 880 Series SAR Rev 6	~~29~~ MB 32	Publicly Available	Rev 6 to the SAR for the Model 880 Series package including a list of affected pages.

The electronic submission is made in Adobe Acrobat format. There are no special instructions regarding the use of the CD-ROM in order to open the files. Should you have any additional questions or wish to discuss this submission after receipt please contact me at the number shown above.

Sincerely,

Lori Podolak
Product Licensing Specialist
Regulatory Affairs Department

RA/QA Approval — 19 Oct 05
Date

Engineering Approval — 20 Oct 05
Date

Enclosures: Revision 6 to SAR
List of Affected Pages
Drawing Changes for R88000 Rev H to Rev I

QSA GLOBAL

QSA Global, Inc.
40 North Avenue
Burlington, MA 01803
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13 December 2005

Mr. Christopher Regan
Licensing Section
Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
One White Flint
Rockville, MD 20852

Docket No.: 71-9296

Subject: Amendment Request for the Model 880 Series Type B Packages

Dear Mr. Regan:

To further assist in the evaluation of this package amendment, I have enclosed a point by point evaluation of these packages and their compliance to the IAEA TS-R-1 regulations adopted into 10 CFR 71. Should you have any additional questions or wish to discuss this submission after receipt please contact me as shown below. Again your assistance is greatly appreciated in this matter.

Sincerely,

Lori Podolak

Lori Podolak
Product Licensing Specialist
Regulatory Affairs Department
Ph: (781) 272-2000 ext 241
Fax: (781) 359-9191
Email: Lori.Podolak@qsa-global.com

C. [signature] 13 Dec 05
RA/QA Approval Date

[signature] 13 Dec 05
Engineering Approval Date

Enclosures:

880 Series Evaluation for Compliance to 10 CFR 71 Regulation Change for IAEA TS-R-1

Model 880 Series Type B Transport Package Evaluation for Compliance to Criteria Adopted as Part of the Final Rule for 10 CFR 71 Effective October 1, 2004

Adopted Compliance Criteria for 10 CFR 71 Final Rule Effective October 1, 2004	Description
Issue 2: Radionuclide Exemption Values	Not applicable based on package contents.
Issue 3: Revision of A_1 and A_2	Total package activity is limited on the Certificate of Compliance, therefore changes in the A_1 and A_2 values have no impact on the package ability to comply with the final rule.
Issue 4: Uranium Hexafloride Package Requirements	Not applicable, the package is not used for transport of uranium hexafloride.
Issue 5: Criticality Safety Index	Not applicable, the package is not used for transport of fissile material.
Issue 7: Deep Immersion Test	Not applicable, the package is not used for transport of material in amounts greater than 10^5 A_2.
Issue 8: Grandfathering	The package complies with the final rule in 10 CFR 71, therefore grandfathering is not necessary for this package.
Issue 9: Changes to Various Definitions	No change is necessary to conform to the new rule.
Issue 10: Crush Test for Fissile Material Packages	Not applicable, the package is not used for transport of fissile material.
Issue 11: Fissile Material Package Design for Transport by Aircraft	Not applicable, the package is not used for transport of fissile material.
Issue 12: Special Package Authorizations	Not applicable, criteria needed to meet this requirement does not apply to this package.
Issue 13: Expansion of Part 71 Quality Assurance Requirements	QSA Global Inc. (previously AEA Technology QSA, Inc.) is the holder of an NRC-approved QA program, therefore the requirements of this rule are met.
Issue 16: Fissile Material Exemptions and General License Provisions	Not applicable, the package is not used for transport of fissile material.
Issue 17: Double Containment of Plutonium	Not applicable, the package is not used for transport of plutonium.
Issue 19: Modification of Events Reporting Requirements	No change is needed to the Certificate of Compliance or the package application to conform to the rule.

Safety Analysis Report for the Model 880 Transport Package

List of Affected Pages	
Revision 1, 06 December 2000	Changes to the thermal analysis section and addition of Appendix E.
Revision 2, 10 January 2000	Drawing Changes Appendix A.
Revision 3, 09 August 2002	Revision in entirety to incorporate reference/justification for the Model 880 Sigma device. This revision supercedes previously submitted SAR's except for previously submitted Appendices B through E.
Revision 4, 15 October 2003	Drawing Changes Appendix A. Container weight references in sections 1 and 2 updated.
Revision 5, 28 October 2003	Revision H to drawing R88000. Updates to drawing revision level in SAR.
Revision 6, 20 October 2005	Revision I to drawing R88000 and reformatting of the SAR to cover compliance to IAEA TS-R-1 and NRC guidance format.

Safety Analysis Report

QSA Global Inc.

Model 880 Series
Type B(U) - 96
Transport Package

15 February 2006

Revision 6 Corrected Copy

Contents

List of Tables

List of Figures

Section 1 - GENERAL INFORMATION

1.1 Introduction

The Model 880 Series are designed as industrial radiography exposure devices and transport packages for Type B quantities of special form radioactive material. They conform to the Type B(U)-96 criteria for packaging in accordance 10 CFR 71, 49 CFR 173, and the IAEA Regulations for the Safe Transport of Radioactive Material (TS-R-1) which were in effect at the time of sign-off of this report.

1.2 Package Description

(Reference:

- *10 CFR 71.33*
- *IAEA TS-R-1, paragraph 220 & 807)*

The Model 880 Series packages are constructed in accordance with the drawings included in Section 1.4. The 880 has three versions. Table 1.2a lists the maximum activity capacities of each version. The physical construction of the 880 Delta and the 880 Sigma (including the shield construction) is identical. These devices differ from the 880 Elite devices in the size and weight of the shield as well as the overall package weight.

The shields for the 880 Delta and 880 Sigma vary in Ir-192 unit capacity which is based on the natural variability in the shield consistency created during the depleted uranium pouring/cooling process. These variations can produce shields with slightly lower shielding capacity than the 150 Curies required for the 880 Delta (e.g. 130 Curies of Ir-192) and are therefore made into 880 Sigma packages. (Note that the capacity for both the 880 Delta and 880 Sigma are the same for Se-75. The gamma energy from Se-75 is less penetrating than Ir-192 therefore the shield variations which are clearly observable for Ir-192 do not occur with Se-75. Since the shielding on the 880 Sigma is greater than the shielding for the 880 Elite, and the 880 Elite is rated for the same Se-75 capacity as the 880 Delta, the 880 Sigma will be adequate to shield Se-75 at that same capacity.

All 880 Series packages allow for the use of an optional jacket which facilitates the package use as a radiography device and transport package. This jacket does not impair the package's ability to meet the Type B requirements as described in this Safety Analysis Report (SAR).

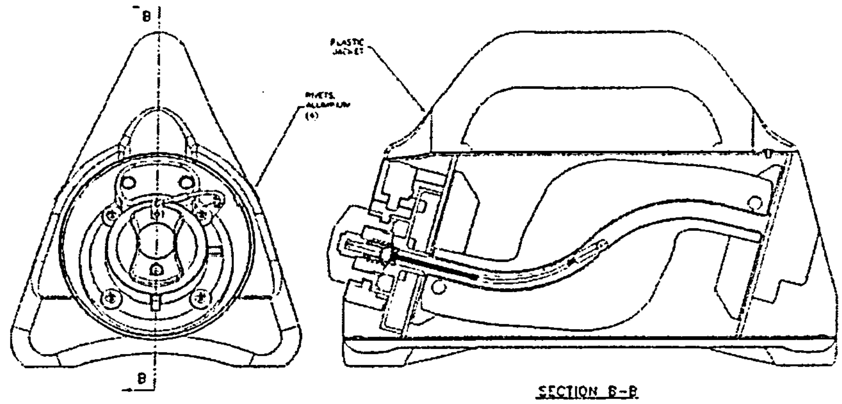


Figure 1.2a – 880 Package with Optional Jacket

The packages without the jacket measure approximately 5 inches (127 mm) in diameter by 13 5/16 inches (338 mm) long. The packages with the jacket measure approximately 13 ½ inches (343 mm) long by 7 ½ inches (191 mm) wide by 9 inches (229 mm) tall. The general package information is shown in Table 1.2a:

Table 1.2a: Model 880 Series Package Information

Identification	Nuclide	Form	Maximum Capacity[1]	Maximum DU Weight	Maximum Weight Without Jacket	Maximum Weight With Jacket
880 Delta	Ir-192	Special Form Sources	150 Ci	34 lbs (15 kg)	46 lbs (21 kg)	52 lbs (24 kg)
	Se-75	Special Form Sources	150 Ci			
880 Sigma	Ir-192	Special Form Sources	130 Ci	34 lbs (15 kg)	46 lbs (21 kg)	52 lbs (24 kg)
	Se-75	Special Form Sources	150 Ci			
880 Elite	Ir-192	Special Form Sources	50 Ci	25 lbs (11 kg)	37 lbs (17 kg)	42 lbs (19 kg)
	Se-75	Special Form Sources	150 Ci			

1.2.1 Packaging

Except for the shield assembly, fill foam, keyed lock assembly, lock cover and shield pin, all material of construction are stainless steels. The keyed lock assembly mount and the lock cover can be either stainless steel or aluminum. The major components of the package consist of the following:

[1] Maximum Capacity Activity for Ir-192 is defined as output Curies as required in ANSI N432 and 10 CFR 34.20 and in line with TS-R-1 and Rulemaking by the USNRC and the USDOT published in the Federal Register on 26 January 2004 .

- Welded cylindrical body
- Depleted Uranium shield
- Rear plate with locking assembly
- Front plate with shield port
- Optional jacket

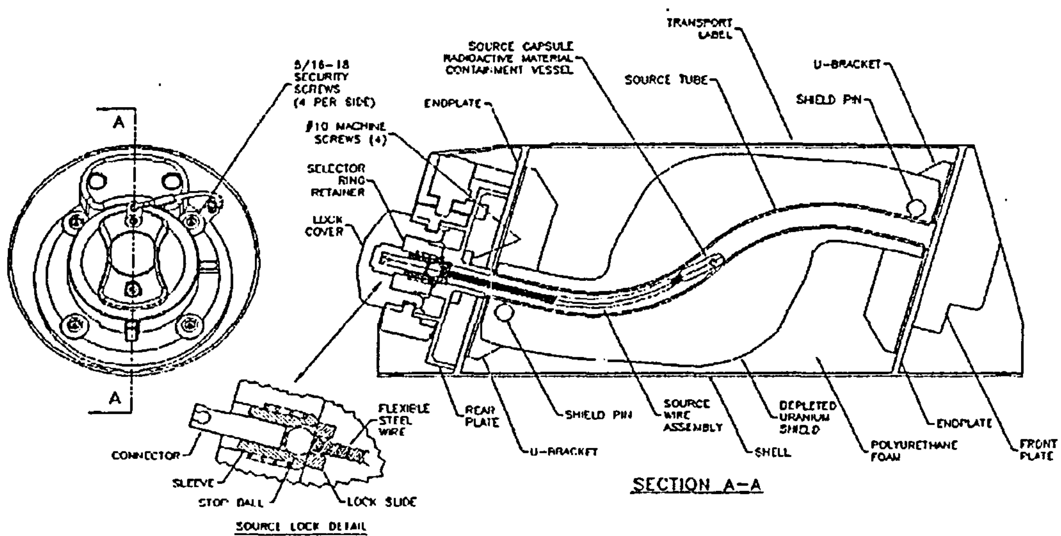


Figure 1.2b - Model 880 Transport Package

The following paragraphs describe the major components of the transport package.

1.2.1.1 Welded Cylindrical Body: The welded body consists of a 5 inch (127 mm) diameter, 0.065 inch (1.5 mm) walled stainless steel tube with 0.12 inch (3 mm) thick endplates welded to the inner tube diameter at both ends. Both endplates are parallel to each other but are angled at 75° to the horizontal tube. The endplates are machined at the 75° angle to reduce the welding gap at the tube-shell interface. A U-bracket is welded to each endplate and located on the inside cavity of the shell tube.

1.2.1.2 Depleted Uranium Shield: The depleted uranium shield is centrally located within the welded body between the endplates. It is fastened to each U-bracket by a 0.37 inch (9.5 mm) diameter, titanium shield pin. The pin passes through a hole on the end (ear) of the shield and holes of the U-bracket. A U-shaped copper spacer fills the gap between the shield and U-bracket. The shield is not supported by the source tube (S-tube).

An S-shaped titanium source tube is cast into the center of the shield. The source tube provides a cavity for the source wire assembly to travel through during use. The source capsule is positioned at the center of the shield when the source wire is in the secured position.

The depleted uranium shield weights are shown in Table 1.2a. The difference in weight is contained in the center section of the shield. The end (ear) sections of the two shield types are structurally the same.

Polyurethane foam is poured through a hole in the endplate and U-bracket to fill the cavity around the depleted uranium shield. This prevents contamination to and from the shield. A label with all the necessary transport information is riveted to the cylindrical shell body.

1.2.1.3 Rear Plate with Locking Assembly: The rear plate assembly is attached to the welded body with four (4) 5/16-18, 1 ½ inch long security (tamperproof) screws through rivnuts assembled into the endplate. The security screws are torqued to 110 ± 5 inch-pounds.

The rear plate assembly consists of a source wire locking mechanism fastened to the rear plate with four (4), #10-32, 1 ¼ inch long machine screws. These screws are torqued to 30 ± 5 inch-pounds. A lock mount with keyed plunger lock is secured to the rear plate with two (2), #10-32, ½ inch long machine screws. Torque requirements for the lock mount screws are not needed. The keyed plunger lock serves as a tertiary lock for transport. It can only be engaged when the source wire assembly is located in the fully shielded position as described in Section 1.2.4. The lock mount for the keyed plunger lock can be made from aluminum or stainless steel. Additionally the aluminum version can include a stainless steel sleeve which is inserted between the lock mount and the keyed plunger lock.

The locking mechanism of the rear plate assembly is protected during storage and transportation by a lock cover. This lock cover can be either aluminum or stainless steel.

1.2.1.4 Front Plate with Shield Port Assembly: The front plate assembly is attached to the welded body with four (4) 5/16-18, 1 ½ inch long security (tamperproof) screws through rivnuts assembled into the endplate. The security screws are torqued to 110 ± 5 inch-pounds.

The front plate assembly consists of shielded port mechanism contained within the front plate. The mechanism can only be opened with a guide tube connector fitting inserted into the opening and rotated. A knob covers the port and blocks access to the shield disc. The shield disc and knob both block access to the source assembly.

1.2.1.5 Optional Jacket: The optional polyurethane jacket covers the package cylinder, provides a handle and a stable base. It is attached to the shell cylinder by rivets located outside the shield cavity area. The jacket handle section contains a wire molded in for additional reinforcement.

A cutout in the jacket allows permanent labeling to be attached directly to the shell cylinder. Space is available on the permanent label for stick-on DOT shipping labels. The permanent label has the required information etched similar to other previously approved Type B packages (CoC 9283, 9269) which have demonstrated the ability to pass the fire test.

1.2.2 Containment System

(Reference:

- *10 CFR 71.33(a)(4)*
- *IAEA TS-R-1, paragraph 213 and 501(b))*

The locking assembly on the Model 880 Series transport packages is similar to the locking assembly on the previously approved model 660-OP package, Certificate number 9283. This allows the same source wire assemblies to be used in the Model 880 as in the 660-OP package. The radioactive material of these source assemblies is sealed in a special form source capsule. The source capsule, stop ball and connector are swaged to a flexible steel wire to form the source wire assembly.

The containment system for the Model 880 transport package is the radioactive source capsule referred to in Section 4.1 of this Safety Analysis Report. This source capsule is certified as special form radioactive material under 10 CFR Part 71, USDOT regulations in 49 CFR and the IAEA Regulations for the Safe Transport of Radioactive Material (TS-R-1).

1.2.3 Contents

(Reference:

- *10 CFR 71.33(b)*
- *IAEA TS-R-1, Section IV & paragraph 807(a))*

The Model 880 Series transport packages are designed to transport special form capsules containing the isotopes listed in Table 1.2a. Additional information for the contents is provided in Table 1.2b. The maximum decay heat for Ir-192 in table 1.2b has been adjusted to account for content activity of the source. Actual content to output activity varies based on the capsule configuration as well as variations in isotope self-absorption. A factor of 2.3 was used for Ir-192 to convert output activity to content activity as this factor reflects the worst case variation for Ir-192 sources transported in these packages. The source capsules are loaded into the Model 880 Series device and secured according to the procedure described in Section 7.

The maximum weight of the contents for the shield containers is also listed in Table 1.2b. The content weight values are calculated based on the package capacity and the lowest specific activity of Ir-192 (200 Ci/gram) used in source production for these devices.

Note: Ir-192 of higher specific activity can be used but this would produce sources with lower total mass of the contents. Se-75 has a lower density than Ir-192 and will produce source capsules of lesser maximum weight than their Ir-192 counterparts. Values listed in the Table 1.2b are the maximum content masses.

Table 1.2b: Isotope Information Permitted in the Model 880 Series Packages

Package ID	Isotope	Activity[1]	Capsule Form[2]	Chemical/Physical Form	Maximum Content Weight	Maximum Decay Heat[3]
880 Delta	Ir-192	150 Ci	Special Form	Metal	< 1 gram	3 Watts
	Se-75	150 Ci	Special Form	Metal-Selenide Compound		0.76 Watts
880 Sigma	Ir-192	130 Ci	Special Form	Metal	< 1 gram	2.4 Watts
	Se-75	150 Ci	Special Form	Metal-Selenide Compound		0.76 Watts
880 Elite	Ir-192	50 Ci	Special Form	Metal	< 1 gram	1 Watt
	Se-75	150 Ci	Special Form	Metal-Selenide Compound		0.76 Watts

[1] Maximum Activity for Ir-192 is defined as output Curies as required in ANSI N432 and 10 CFR 34.20 and in line with TS-R-1 and Rulemaking by the USNRC and the USDOT published in the Federal Register on 26 January 2004.

[2] Special Form is defined in 10 CFR 71, 49 CFR 173, and IAEA TS-R-1.

[3] Maximum decay heat for Ir-192 is calculated by correcting the output activity to content activity. A factor of 2.3 is used for Ir-192 to account for source capsule and self-absorption in this conversion. No corrections are made for Se-75.

1.2.4 Operational Features

These packages do not involve complex containment systems for source securement. The sources for these packages are all special form, welded capsules. The source wire assembly is held securely in the device by components of the rear plate assembly. One of these components, the sleeve, in conjunction with the selector ring retainer, prevents the stop ball of the source wire from being pulled through the rear of the package.

Another component of the rear plate assembly, the lock slide, prevents the stop ball from being pushed out through the front of the package when in the secured position. When the Model 880 Series device is prepared for transport, the lock slide is locked in the secured position and the selector ring is rotated to the lock position preventing source movement. A cover over the source wire connector prevents access to the source assembly until a keyed lock is actuated and the cover removed. This cover is in place during transport of the package.

1.3 General Requirements for All Packages

1.3.1 Minimum Package Size

(Reference:

- *USNRC, 10 CFR 71.43(a)*
- *USDOT, 49 CFR 173.412(b)*
- *IAEA TS-R-1, paragraph 634)*

The Model 880 transport package is cylindrically shaped, 5 inches (127 mm) in diameter and 13 5/16 inches (338 mm) in length. Therefore, it exceeds the minimum package size requirements specified in the referenced regulations.

1.3.2 Tamper-Indicating Feature

(Reference:
- *USNRC, 10 CFR 71.43(b)*
- *USDOT, 49 CFR 173.412(a)*
- *IAEA TS-R-1, paragraph 635)*

The front port of the Model 880 Series packages is designed to require a special tool (guide tube fitting) to be placed in the front port and rotated before the shield can be opened. This prevents any inadvertent or unintentional opening of the package during transport. A provision for a tamper indicator seal wire around the knob of the front plate assembly is provided. This seal wire is not readily breakable, therefore if it is broken during transport, it serves as evidence of possible unauthorized access to the contents. Use of either of these features meets the tamper indicator requirements.

1.4 Appendix: Drawings of the Model 880 Series transport packages.

Section 1.4 Appendix: Drawings of the Model 880 Series transport packages.

Drawing Changes for the 880 Series for Revision 6 of the SAR
7 October 2005

R88000, Sheet 1 of 5

1 Changed 0.328" diameter hole call-out to 0.32". Rear plate hole diameter not critical for this component to three decimal places. No safety significance.

R88000, Sheet 2 of 5

1 Moved 0.030" specification to Bill of Materials on this sheet and specified as 0.03". Actual thickness not critical for this component to three decimal places.
2 Changed 4.81" diameter for the end plate to 4.8". Actual diameter not critical for this component to two decimal places.
3 Changed 0.120" thickness for the end plate to 0.12". Thickness accuracy to two decimal places is sufficient for this component.

R88000, Sheet 3 of 5

1 Changed 3.94" diameter to 3.9". Actual diameter not critical for this component to two decimal places.
2 Changed 0.500" diameter for the selector ring retainer to 0.50". Actual diameter not critical for this component to three decimal places.
3 Changed 0.184" thickness for the lockslide to 0.18". Thickness accuracy to two decimal places is sufficient for this component.
4 Changed 0.490" width of lockslide to 0.49". Accuracy to two decimal places is sufficient for this component.
5 Added the option of "stainless steel" for the Lock Mount and the Lock Cover under the BOM and descriptions for these parts. Replacement of these components which are currently aluminum with stainless steel will not have any adverse impact on the package ability to withstand the normal or hypothetical accident conditions of transport. The stainless steel versions of these components will be stronger than the already tested aluminum components.

R88000, Sheet 4 of 5

1 Changed 3.94" diameter to 3.9". Actual diameter not critical for this component to two decimal places.

Drawing Changes for the 880 Series for Revision 6 of the SAR
7 October 2005

R88000, Sheet 5 of 5

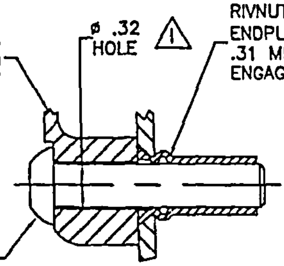
1 Following shield dimensions changed to "typical" dimensions on the drawing. As these dimensions may vary based on the shield cast process and all shields are individually evaluated for adequate shielding as part of the final device profile, these dimensions are not critical to safety:

- 4 1/16" (2X)
- 7/8" (2X)
- 2 13/16"
- 2 ¾"
- 2 3/16"
- 1 7/8"

2 Changed 0.375" diameter through hole to 0.37". Actual diameter not critical for this component to three decimal places

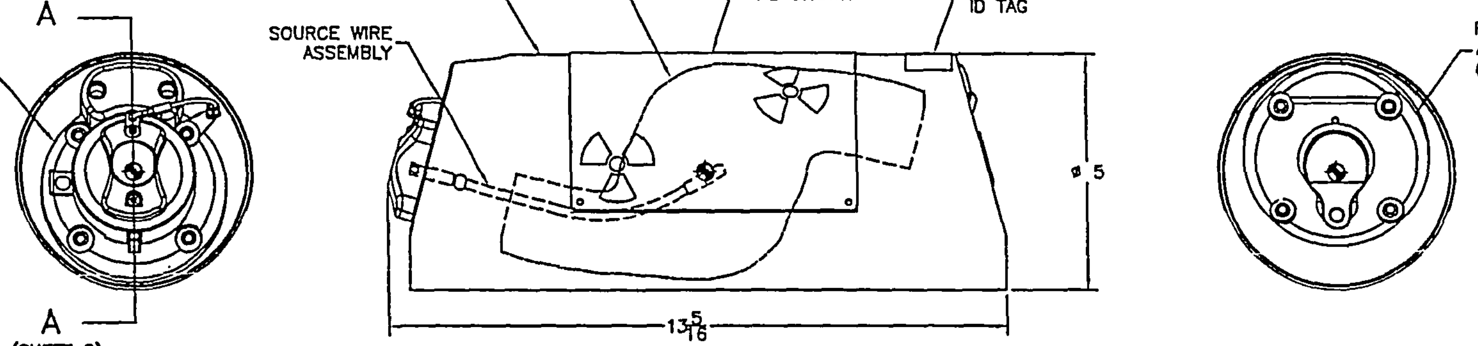
MODEL No.	MAXIMUM TOTAL PACKAGE WEIGHT WITH JACKET	MAXIMUM TOTAL PACKAGE WEIGHT WITHOUT JACKET	DEPLETED URANIUM SHIELD WEIGHT	MAXIMUM IR192 CAPACITY
880 ELITE	42 LBS.	37 LBS.	25 LBS.	50 CURIE
880 DELTA	52 LBS.	46 LBS.	34 LBS.	150 CURIE
880 SIGMA	52 LBS.	46 LBS.	34 LBS.	130 CURIE

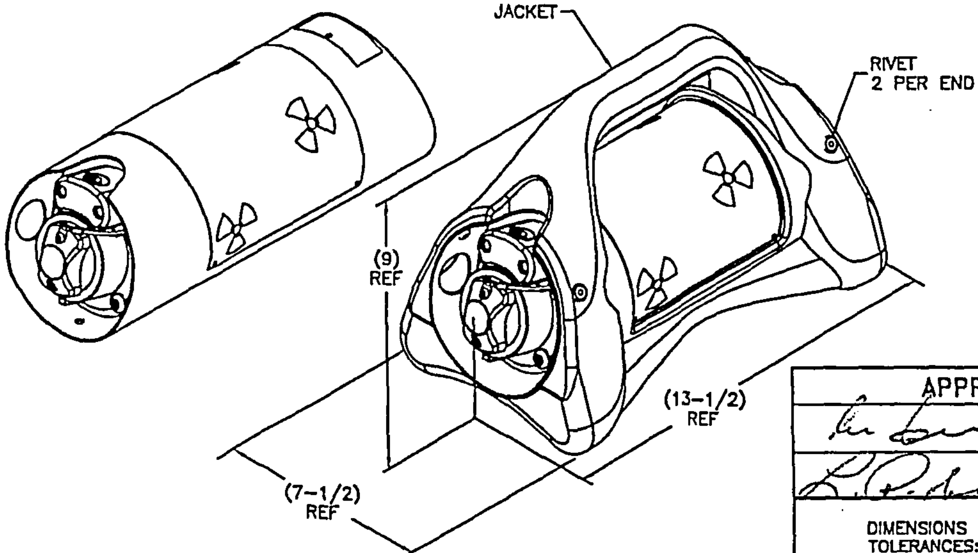
◆ INDICATES CENTER OF GRAVITY (CG).



REAR & FRONT PLATE ASSEMBLY ATTACHMENT

8 PLACES





TRANSPORT PACKAGE WITHOUT & WITH OPTIONAL JACKET

PART NAME	QTY	MATERIAL
RIVET	4	ALUMINUM/STAINLESS STEEL
OPTIONAL JACKET	1	POLYURETHANE
SECURITY SCREW	8	18-8 STAINLESS STEEL
SOURCE ID TAG	1	304/303/302 STN STL
TRANSPORT LABEL	1	304/303/302 STN STL
SOURCE WIRE ASSEMBLY	1	MODEL 424-9 OR EQUIVALENT
SHIELD ASSEMBLY	1	SEE SHEET 5
FRONT PLATE ASSEMBLY	1	SEE SHEET 4
REAR PLATE ASSEMBLY	1	SEE SHEET 3
BODY ASSEMBLY	1	SEE SHEET 2

ERF 697

APPROVALS

[signature] 9/16/05

[signature] 16Sep05

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/16
X ± 0.1
XX ± 0.01
XXX ± 0.005

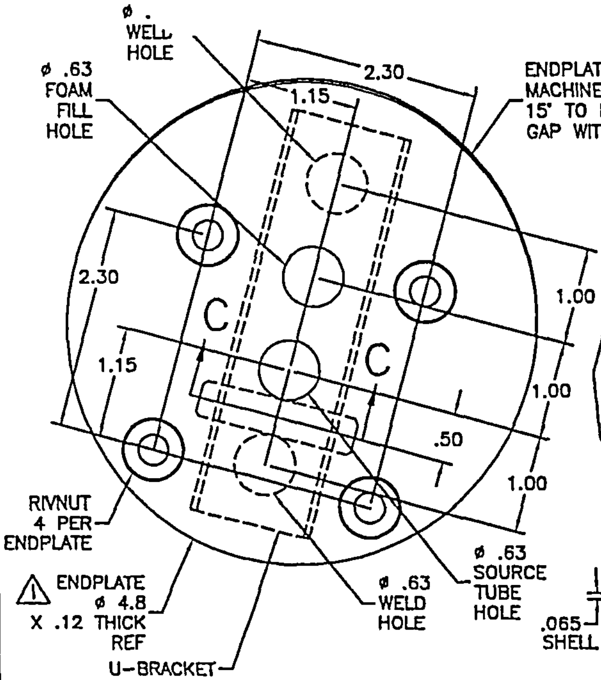
AEATECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

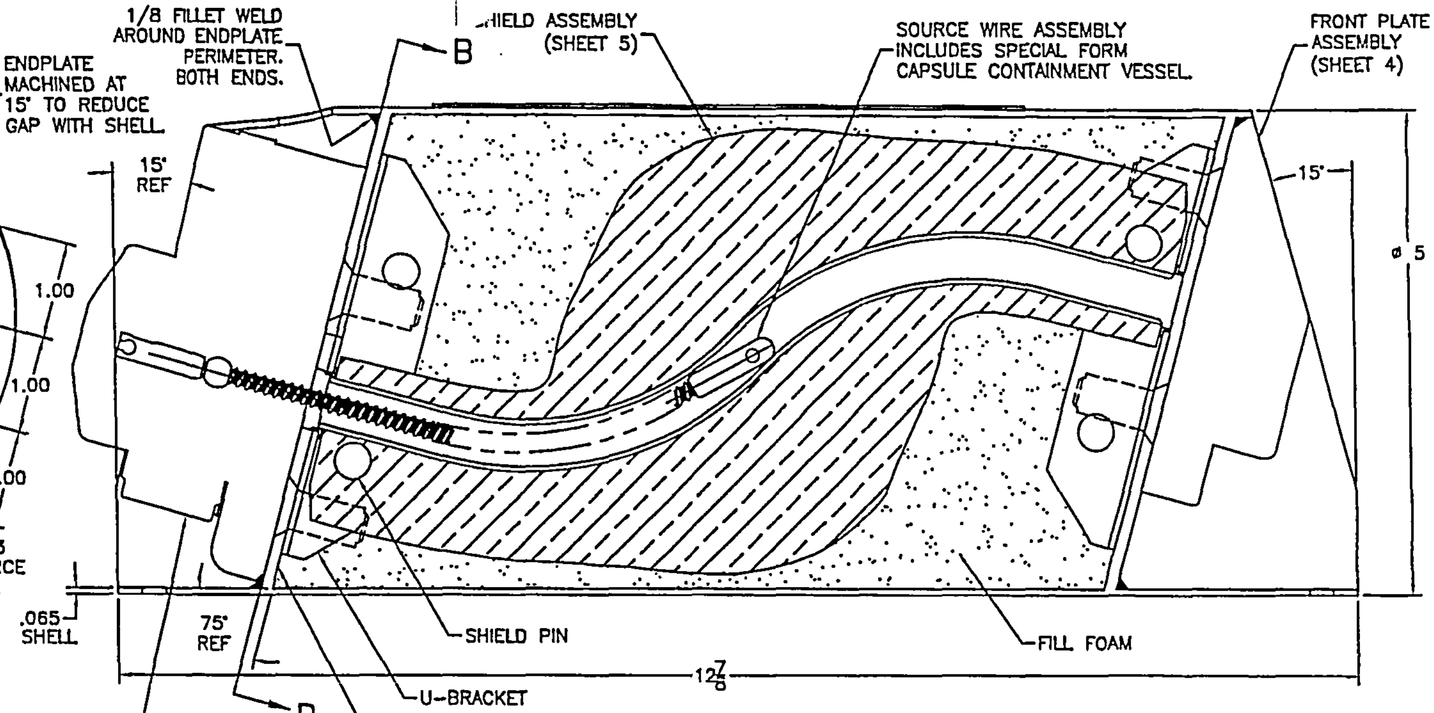
TITLE MODEL 880 PROJECTOR

SIZE A | DWG. NO. R88000 | REV 1

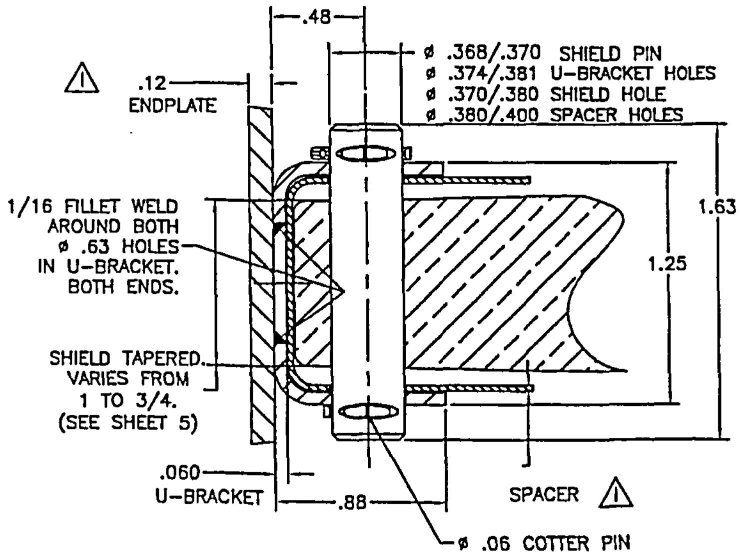
SCALE: NONE | SHEET 1 OF 5



SECTION B–B
ENDPLATE PATTERN BOTH ENDS



SECTION A–A
BODY ASSEMBLY



SECTION C–C
SHIELD ATTACHMENT BOTH ENDS
(SECTION TAKEN FROM SECTION B–B)

NOTE:
ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS STRUCTURAL WELDING CODE CURRENT AT THE TIME OF FABRICATION AND INSPECTION.

ALL WELDS HAVE VISUAL INSPECTION (VT)

PART NAME	QTY	MATERIAL
SHIELD ASSEMBLY	1	SEE SHEET 5
FILL FOAM	AR	8 PCF (MIN) POLYURETHANE
RIVNUT	8	430 STAINLESS STEEL
COTTER PIN	4	18–8 STAINLESS STEEL
SPACER	2	COPPER (MIN 0.03) △
SHIELD PIN	2	6AL–4V TITANIUM
U-BRACKET	2	304L STAINLESS STEEL
ENDPLATE	2	304L STAINLESS STEEL
SHELL	1	304L STAINLESS STEEL

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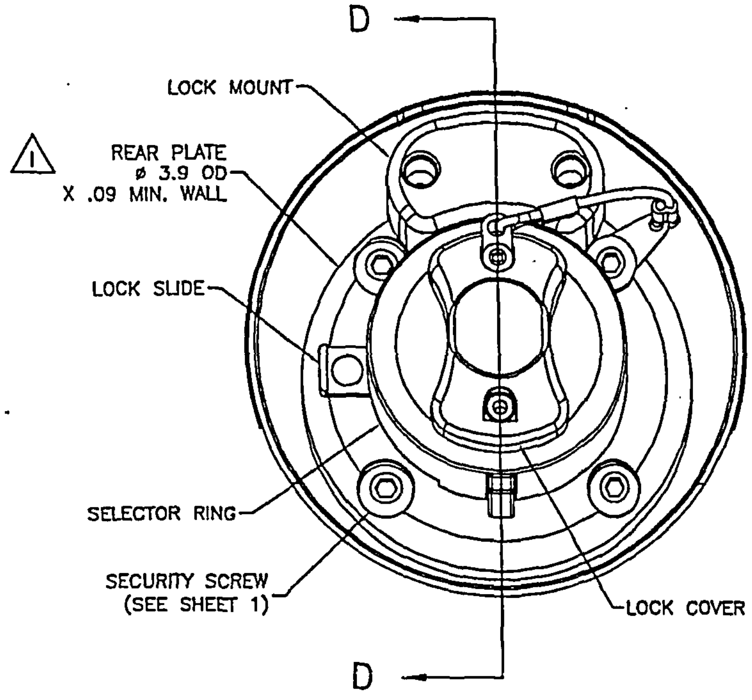
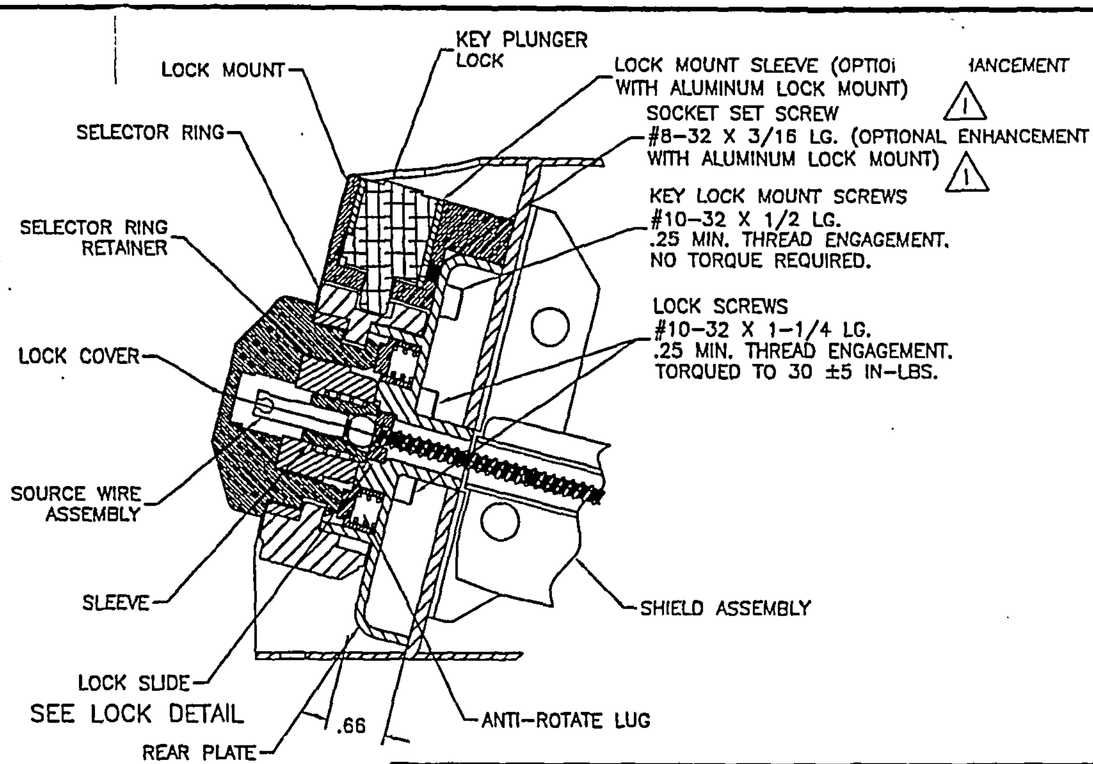
DESCRIPTIVE DRAWING

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/16
X ± 0.1
XX ± 0.01
XXX ± 0.005

TITLE	MODEL 880 PROJECTOR	
SIZE A	DWG. NO. R88000	REV 1
	SCALE: NONE	SHEET 2 OF 5

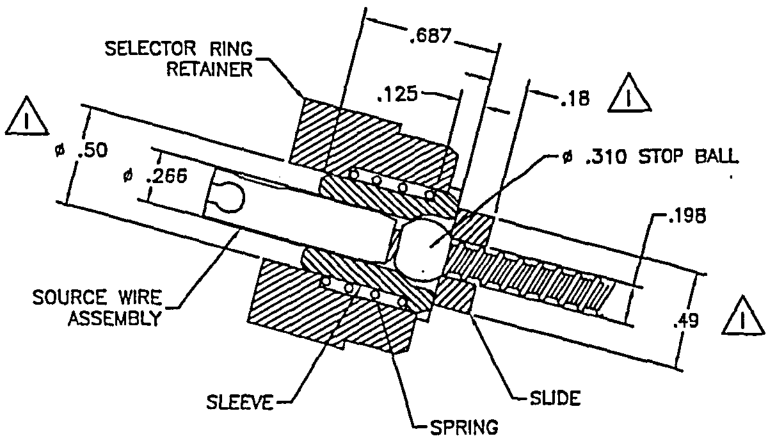


REAR PLATE ASSEMBLY



SECTION D-D

LOCK MOUNT SET SCREW	1	18-8 STAINLESS STEEL
LOCK MOUNT SLEEVE	1	303/304 STAINLESS STEEL
KEY LOCK MOUNT SCREW	2	18-8 STAINLESS STEEL
⚠1 LOCK MOUNT	1	ALUMINUM/ST.STEEL
⚠1 LOCK COVER	1	ALUMINUM/ST.STEEL
ANTI-ROTATE LUG	2	303/304 STAINLESS STEEL
LOCK SLIDE	1	17-4 PH STAINLESS STEEL
SLEEVE	1	TUNGSTEN, NICKEL PLATED
SELECTOR RING	1	303/304 STAINLESS STEEL
LOCK SCREW	4	UNS S30430 STN STL
SELECTOR RING RETAINER	1	303/304 STAINLESS STEEL
REAR PLATE	1	304/304L/303/CF8 STN STL
PART NAME	**QTY**	**MATERIAL**



LOCK DETAIL

SOURCE ASSEMBLY SECURED POSITION

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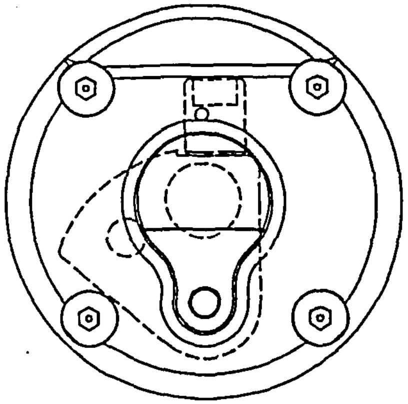
DESCRIPTIVE DRAWING

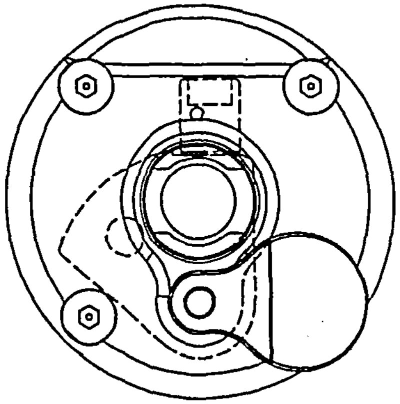
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/16
X ± 0.1
XX ± 0.01
XXX ± 0.005

TITLE	MODEL 880 PROJECTOR
SIZE A	DWG. NO. R88000
SCALE: NONE	SHEET 3 OF 5
REV	1



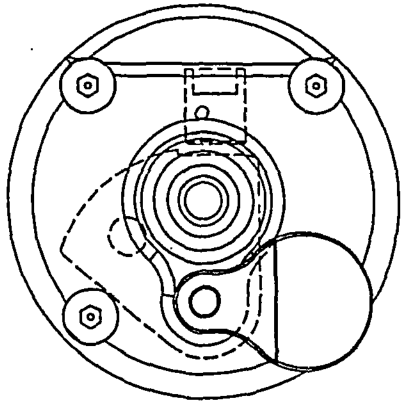
SHIPPING POSITION

PORT COVERED
& SHIELDED.



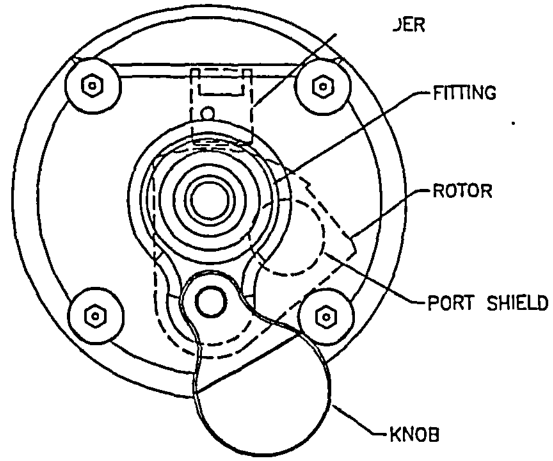
LOCKED POSITION

LIFT KNOB & ROTATE 90°.
PORT SHIELDED.



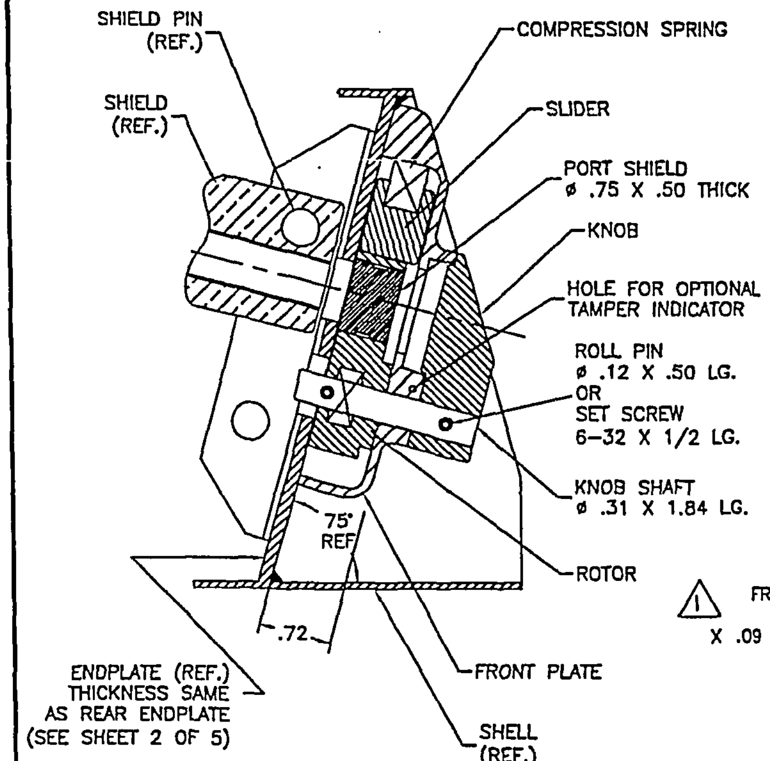
CONNECT POSITION

INSERT & ROTATE FITTING
TO RELEASE SLIDER.
PORT SHIELDED.

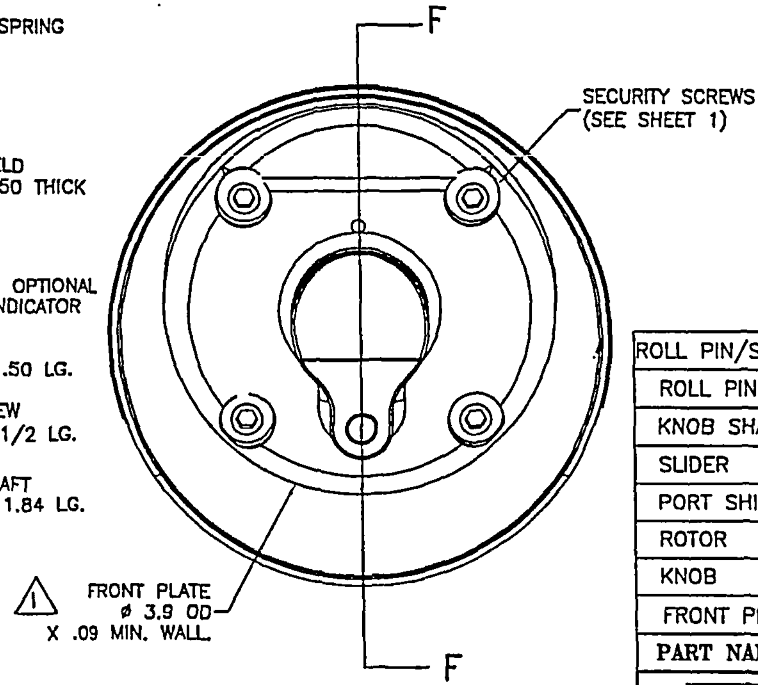


EXPOSE POSTION

ROTATE KNOB 50°
TO TURN ROTOR.
PORT OPEN.



SECTION F–F



FRONT PLATE ASSEMBLY

PART NAME	QTY	MATERIAL
ROLL PIN/SET SCREW	1/1	302/303/304 STAINLESS STEEL
ROLL PIN	2	302/303/304 STAINLESS STEEL
KNOB SHAFT	1	BRASS
SLIDER	1	BRASS
PORT SHIELD	1	TUNGSTEN, NICKEL PLATED
ROTOR	1	304/304L/303/CF8 STN STL
KNOB	1	304/304L/303/CF8 STN STL
FRONT PLATE	1	304/304L/303/CF8 STN STL

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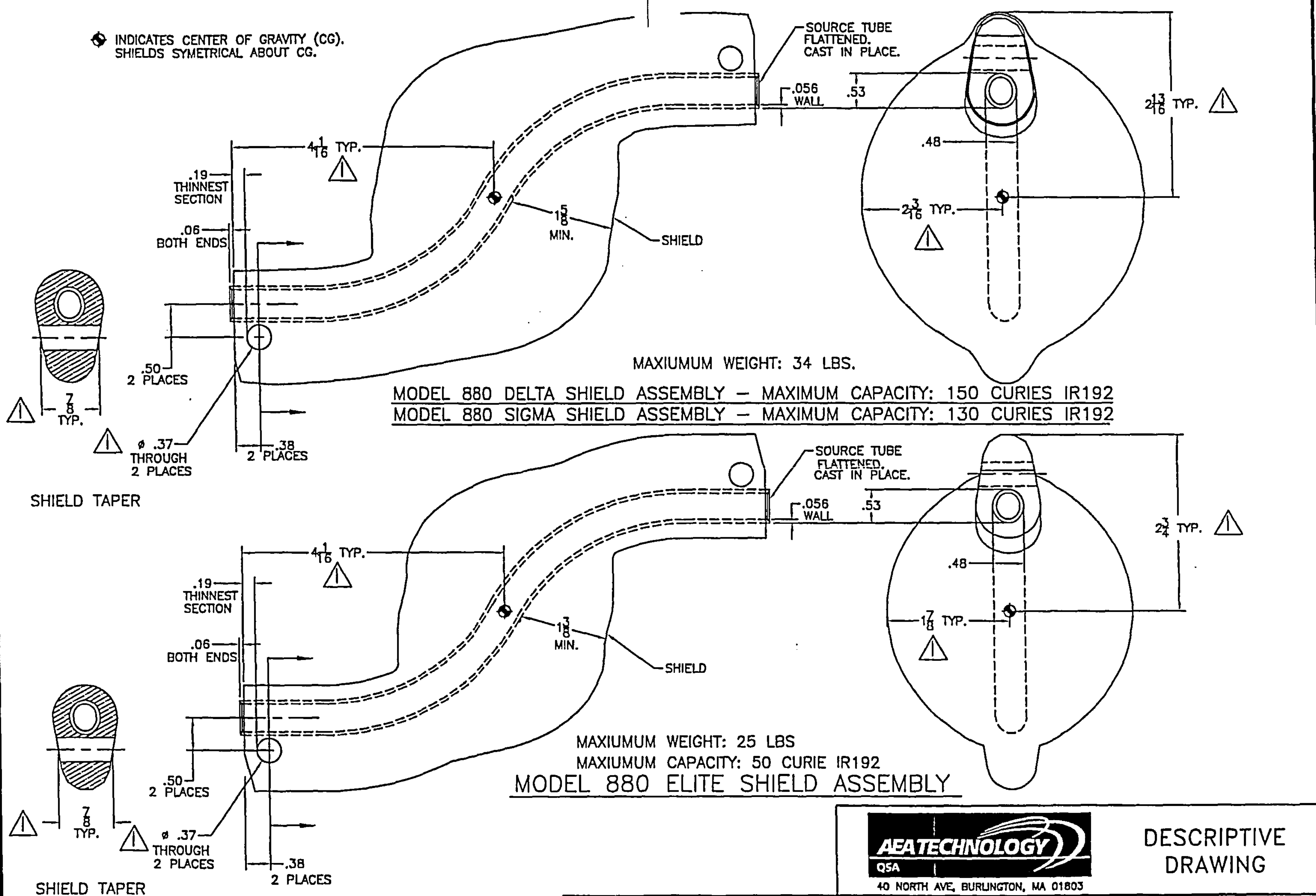
DESCRIPTIVE
DRAWING

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/16
X ± 0.1
XX ± 0.01
XXX ± 0.005

TITLE MODEL 880 PROJECTOR

SIZE A | DWG. NO. R88000 | REV 1

SCALE: NONE | SHEET 4 OF 5



PART NAME	QTY	MATERIAL
SOURCE TUBE	1	3AL-2.5V TITANIUM
SHIELD	1	DEPLETED URANIUM

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/16
X ± 0.1
XX ± 0.01
XXX ± 0.005

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DESCRIPTIVE DRAWING

TITLE: MODEL 880 PROJECTOR

SIZE: A | DWG. NO. R88000 | REV 1

SCALE: NONE | SHEET 5 OF 5

Section 2 - STRUCTURAL EVALUATION

This section identifies and describes the principal structural engineering design of the packaging, components, and systems important to safety and compliance with the performance requirements of 10 CFR Part 71.

2.1 Description of Structural Design

(Reference:
- *10 CFR 71.33(a)*
- *IAEA TS-R-1, paragraph 220 & 807(b))*

2.1.1 Discussion

The Model 880 Series transport packages are described in Section 1.2.

2.1.2 Design Criteria

The Model 880 Series transport packages are designed to comply with the requirements for Type B(U) packaging as prescribed by 10 CFR 71 and IAEA TS-R-1. All design criteria are evaluated by a straightforward application of the appropriate section of 10 CFR 71 or IAEA TS-R-1.

2.1.3 Weight and Centers of Gravity

The transport package weight varies from 37 lbs (17 kg) up to 52 lb (24 kg). The center of gravity of the 880 Series transport packages is approximately 2.5 inches (64 mm) above the bottom of the package.

2.1.4 Identification of Codes and Standards for Package Design

2.1.4.1 Package Design

See Section 2.1.2 relating to design criteria of the package. No specific codes or standards were directly incorporated in the design effort of the finished assembly for the 880 Series transport packages. However the design was based on the Type A and Type B(U) container requirements of 49 CFR, 10 CFR 71 and IAEA regulations in effect at the time of the package component design.

2.1.4.2 Fabrication & Assembly

All container fabrication (including assembly) is controlled under the QSA Global Inc. Quality Assurance Plan approved by the USNRC and ISO. All welding under this plan adheres to AWS or ASME standards appropriate to the materials and designs fabricated. All safety critical hardware meets ASME-B18 standards. All external fabrication deemed critical to safety is either verified to equivalent in-house standards or dedicated as appropriate for use prior to release as part of this transport package.

2.1.4.3 Maintenance & Use

Maintenance and use of these transport container assemblies is described in Sections 7 and 8.

2.2 Materials

(Reference:

- *10 CFR 71.33(a)(5)*
- *IAEA TS-R-1, paragraph 220 & 807(b))*

2.2.1 Material Properties and Specifications

Table 2.2a lists the relevant mechanical properties (at ambient temperature) of the principal materials used in the Model 880 Series transport package. The location and use of these materials is shown on the drawings contained in Section 1.4. The reference for the table information is listed in the last column of the table.

Table 2.2a: Mechanical Properties of Principal Safety Related Transport Package Materials

Material	Tensile Strength	Yield Strength	Source
Depleted Uranium	65 ksi	30 ksi	Reference #2
Copper	25 ksi	9 ksi	Reference #3, p. 224
Titanium	145 ksi	134 ksi	Reference 4 page 98
Tungsten	114 ksi	88 ksi	Reference 4 page 1626
Stainless Steel (304)	75 ksi	30 ksi	Reference #1, p. 854

Resource references:

1. American Society for Metals. Metals Handbook, Volume 1, Tenth Edition. Ohio: Materials Park, 1990.

2. Lowenstein, Paul. *Industrial Uses of Depleted Uranium.* American Society for Metals. Metals Handbook, Volume 3, Ninth Edition.

3. American Society for Metals. Metals Handbook, Volume 2, Tenth Edition. Ohio: Materials Park, 1990.

4. American Society for Materials, Metals Handbook desk Edition , Metals Park Ohio 1985

2.2.2 Chemical, Galvanic or Other Reactions

(Reference:
- *USNRC, 10 CFR 71.43(d)*
- *IAEA TS-R-1, paragraph 613 and 642)*

The non-safety related materials are aluminum, brass and polyurethane. These materials are more susceptible to corrosion and chemical reaction than the safety materials, but pose no threat to safety or containment. The safety related materials used in the construction of the Model 880 transport packages are depleted uranium metal, stainless steel, titanium, tungsten and copper. There will be no significant chemical or galvanic action between any of these components.

To prevent the possible formation of a eutectic alloy of steel and depleted uranium during the Hypothetical Accident Conditions thermal scenario, defined by 10 CFR 71.73(c)(4), copper separators are used at all steel-uranium interfaces. The steel-uranium eutectic alloy temperature is approximately 1,337°F (725°C). However, vacuum conditions and extreme cleanliness of the surfaces are necessary to produce the eutectic alloy at this low temperature. Due to the conditions in which the depleted uranium shield components are assembled and used in the shield containers, conditions sufficient to allow formation of this eutectic do not exist. With these container constructions, there will be no significant chemical or galvanic reaction between package components during normal or hypothetical accident conditions of transport.

2.2.3 Effects of Radiation on Materials

(Reference:
- *USNRC, 10 CFR 71.43(d)*
- *IAEA TS-R-1, paragraph 613)*

Lead, depleted uranium, tungsten, steel and polyurethane foam have been used in this package as well as other transport packaging for decades without degradation of the package performance over time due to irradiation from the package contents.

2.3 Fabrication and Examination

(Reference:
- *10 CFR 71.33(a)(5)*
- *IAEA TS-R-1, paragraph 232, 310, 638 and 807(b))*

2.3.1 Fabrication

Package components are procured, manufactured and inspected for use under QSA Global Inc. NRC approved QA Program Number 0040.

2.3.2 Examination

Section 8 describes the acceptance testing and routine maintenance requirements for package components used on the Model 880 Series packages.

2.4 Lifting and Tie-Down Standards for All Packages

2.4.1 Lifting Devices

(Reference:

- *USNRC, 10 CFR 71.45(a)*
- *IAEA TS-R-1, paragraphs 502(b), 606, 607 and 608)*

The Model 880 transport package has no lifting device but can be lifted by grasping the steel welded cylinder with two hands. The optional plastic jacket incorporates a handle with wire reinforcement to be use for lifting and carrying. The plastic jacket handle was tested and proven in Test Plan Report 115 Rev 1 (See Section 2.12.5) to withstand a static load of 125 times the package weight without failure.

The 1-1/4-inch diameter hole through the side of the shell cylinder at the lock end could possibly be used as a hoisting point. When lifted from this hole, the minimum factor of safety is 40 against yielding.

If the jacket or hoisting point feature were to fail, it would not affect the shield container and source wire security. As a result, the package safety would not be compromised. Therefore, the lifting devices comply with the requirements of 10 CFR 71.45(a).

2.4.2 Tie-Down Devices

(Reference:

- *USNRC, 10 CFR 71.45(b) (1) (2) (3)*
- *IAEA TS-R-1, paragraph 606 and 636)*

The Model 880 has no system of tie down devices that are a structural part of the transport package. The package could possibly be tied down using the 1-1/4 inch hole, but is not recommended. This hole can withstand a g-force equal to a static force 11 times the weight of the package when applied in tension. At this force, a factor of safety of 4 exists before yielding. As demonstrated in Test Plan Report 115 (Section 2.12.5) the package handle if used as a tie down can withstand 125 times the weight of the package without failure. There are no other tie-down features that are part of the structure of the package. The package can be blocked and braced according to standard transportation practices.

2.5 General Considerations

(Reference:

- *10 CFR 71.41(a)*
- *IAEA TS-R-1, paragraph 807(c))*

2.5.1 Evaluation by Test

Evaluations by direct testing are documented in the Test Plan Reports which are contained in Section 2.12.

2.5.2 Evaluation by Analysis

Evaluations by analysis are described in the section they apply to in this Safety Analysis Report or when applicable in the Test Plan Reports contained in Section 2.12.

2.6 Normal Conditions of Transport

2.6.1 Heat

(Reference:

- *USNRC, 10 CFR 71.71(c)(1)*
- *IAEA TS-R-1, paragraph 615, 617, 618, 637, 651, 662 and 664)*

The heat source for the Model 880 Series transport packages are listed in Table 1.2d. Iridium-192, approximately 8.6 milliwatts per Curie based on assuming a decay energy of 1.46 MeV/decay. The thermal evaluation for the heat test is described in Section 3 and is based on the decay energy of Ir-192 as this is greater than Se-75.

2.6.1.1 Summary of Pressures and Temperatures

(Reference:

- *IAEA TS-R-1, paragraph 615 and 661)*

Table 2.6.1.a: Summary Temperatures Normal Transport

Temperature Condition	Model 976	Comments
Insolation (38°C in full sun)	88°C (190°F)	Section 3.4.1.1.
Decay Heating (38°C in shade)	47°C (117°F)	Section 3.4.1.2

As all components are vented to ambient, no pressure will build up in the package under Normal Transport conditions that would adversely effect package performance or integrity. Evaluation of pressures for this package are contained in Section 3.4.2 and summarized in Table 3.1.4.a.

2.6.1.2 Differential Thermal Expansion

Expansion of the outer steel shell circumference during Normal Transport is approximated by:

$$E = \pi D \alpha \Delta T$$

Where: D = Diameter of the outer shell (5 in)
α = Coefficient of Thermal expansion
ΔT = Cold temperature differential (from -40°F to 68°F)
ΔT = Hot temperature differential (from 68°F to 155°F)

Substituting we get: $E = \pi$ (5 in)(9.9μin/in°F)(108°F) = 0.016 in (cold)
$E = \pi$ (5 in)(9.9μin/in°F)(87°F) = 0.013 in (hot)

Manufacturing tolerance on this component is ± 1/16 inch, therefore the thermal expansion encountered during Normal Transport will be insignificant with respect to the manufacturing tolerances of the package.

2.6.1.3 Stress Calculations

As shown in Section 2.6.1.2, thermal differentials will have no adverse effect on the package. Mechanical loads at the maximum weight of the series (54 lbs) are distributed across the central 1/3 of the package body and are small compared to the yield strength of the steel (30,000 psi – See Table 2.2a).

Inner diameter of body = (5 in – 2(0.065 in)) = 4.87 in
Area of Central 1/3 of body cylinder = (4.87 in)(4 in) = 19.48 in^2
Stress on drum bottom = 54 lbs/19.48 in^2 = 2.8 psi

This material stress is insignificant to the yield strength of the outer stainless steel cylinder.

2.6.1.4 Comparison with Allowable Stresses

All stresses calculated in Section 2.6.1 are well below strengths for the materials of construction. Further, the Model 880 Series package was fully tested and passed under Normal Conditions of transport. It is therefore concluded that the Model 880 Series package will satisfy the performance requirements specified by the regulations.

2.6.2 Cold

(Reference:
- *USNRC, 10 CFR 71.71 (c)(2)*
- *IAEA TS-R-1, paragraph 615, 637 and 664)*

An ambient air temperature of –40 F in still air and shade has no effect on the safety of the package. The safety materials: stainless steel, titanium, tungsten and depleted uranium retain their mechanical properties at this temperature. Thus, it is concluded that the Model 880 transport package will withstand the normal transport cold condition.

2.6.3 Reduced External Pressure

(Reference:
- *USNRC, 10 CFR 71.71 (c)(3)*
- *IAEA TS-R-1, paragraph 643 & 619*

The Model 880 Series transport packages are open to the atmosphere and contains no components which could create a differential pressure relative to atmospheric conditions or components within the package. The authorized contents are special form source capsules that meet a minimum ANSI N542-1977 and ISO 2919-1999 classification of Class 3 for pressure. This classification is more limiting than the reduced external pressure requirement as it covers 25

kN/m^2 to 7MN kN/m^2. Therefore, the reduced external pressure requirements of 3.5 psi in 10 CFR, 8.7 psi (60 kPa) in 49 CFR and IAEA will not adversely affect the package containment.

2.6.4 Increased External Pressure

(Reference:

- *USNRC, 10 CFR 71.71(c)(4))*

The Model 880 Series transport packages are open to the atmosphere and contain no components which could create a differential pressure relative to atmospheric conditions. The authorized contents are special form source capsules that meet a minimum ANSI N542-1977 and ISO 2919-1999 classification of Class 3 for pressure. This classification is more limiting than the reduced external pressure requirement as it covers 25 kN/m^2 to 7MN kN/m^2. Therefore, the increased external pressure requirements of 20 psi in 10 CFR 71 will not adversely affect the package containment.

2.6.5 Vibration

(Reference:

- *USNRC, 10 CFR 71.71(c)(5)*
- *IAEA TS-R-1, paragraph 612)*

The lock assembly on the Model 880 Series package is secured using the same fasteners as are used on the Model 660 devices (Reference Certificate of Compliance USA/9283/B(U)). The Model 660 devices have been use in transport for over 20 years without incident caused by vibration.

The shield in the Model 880 Series packages is attached to the brackets by titanium pins. These pins are secured by stainless steel cotter pins. Cotter pins are routinely used in high vibration situations (i.e. wheel bearing nut retention) and will easily withstand vibration incident to transport.

The compact profile of the package ensures a limited affect from transport vibration and acceleration to critical components of the device. The lock attachment screws and end plate screws are tightened to a prescribed torque to prevent unintentional release even after repeated use. It is therefore concluded that the Model 880 Series packages will withstand vibration normally incident to transport.

2.6.6 Water Spray

(Reference:

- *USNRC, 10 CFR 71.71(c)(6)*
- *IAEA TS-R-1, paragraph 719, 720 and 721)*

The Model 880 Series transport packages are constructed of water-resistant materials throughout. Therefore, the water spray test would not reduce the shielding effectiveness or structural integrity of the package.

2.6.7 Free Drop

(Reference:

- *USNRC, 10 CFR 71.71(c)(7)*
- *IAEA TS-R-1, paragraph 722(a))*

The drop test pad used in the 1.2 m free drop, 9 m drop, and puncture tests consists of a monolithic concrete base 7.4 ft x 7.3 ft x 1.25 ft thick. The approximate weight of the concrete is 14,850 lbs. A 3.9 ft x 4 ft x 1 in thick steel plate was embedded in this concrete slab at the time of its construction. Before and after testing the drop pad was visually inspected for damage which could have a significant impact on package testing.

Four test specimens as described in Test Plan 108 (Section 2.12.2) and Test Report 108 (Section 2.12.3) were subjected to the 1.2 meter (4 foot) free drop followed by the hypothetical accident 9 m drop and puncture bar drop tests. Drop orientation impact locations for the 1.2 m free drop included the lock cover and cylinder lip, the cylinder bottom surface, the cylinder left side surface and the lock cover. As seen in Test Report 108 photographs after the 1.2 m drops (Section 2.12.3), impact of the 880 packages caused only minor deformation to the steel cylinder of the packages. Radiation profiles performed at the conclusion of all the testing showed that there was no significant increase in radiation levels. The Model 880 Series package maintained its structural integrity and shielding effectiveness under the normal transport drop test conditions and the packages comply with the requirements of this section.

2.6.8 Corner Drop

(Reference:

- *USNRC, 10 CFR 71.71(c)(8)*
- *IAEA TS-R-1, paragraph 722(b))*

This test is not applicable, as the transport package does not transport fissile material, nor is the exterior of the transport package made from either fiberboard or wood.

2.6.9 Compression

(Reference:

- *USNRC, 10 CFR 71.71(c)(9)*
- *IAEA TS-R-1, paragraph 723)*

Test Plan and Report 100 (Section 2.12.1) documents that Test Specimens P01 and P02 were subjected simultaneously to a compressive load of 459 lbs (209 kg) for a period of 24 hours. This exceeds five times the maximum transport package weight of 45 lbs for the heaviest version of the Model 880 (without the optional jacket). The actual compressive weight of 459 lbs (209 kg) is greater than 13 kPa (2 lb/in^2) multiplied by the vertically projected area of the transport package.

Following the test, no damage to the specimens was observed. Radiation profiles performed at the conclusion of the test showed no significant increase in radiation levels. The Model 880 series package maintained its structural integrity and shielding effectiveness and demonstrated that the packages comply with the requirements of this section.

2.6.10 Penetration

(Reference:
- *USNRC, 10 CFR 71.71(c)(10)*
- *IAEA TS-R-1, paragraph 724)*

Test Plan and Report 100 (Section 2.12.1) documents that Test Specimen P01 was subjected to the penetration test. The penetration bar impacted on the top, exterior of the steel cylinder at the point where the shield is closest to the steel cylinder. The penetration bar impacted as intended and caused minor damage to the steel cylinder. Radiation profiles performed at the conclusion of the test showed no significant increase in radiation levels. The Model 880 series package maintained its structural integrity and shielding effectiveness and demonstrated that the packages comply with the requirements of this section.

2.7 Hypothetical Accident Conditions of Transport

(Reference:
- *USNRC, 10 CFR 71.73*
- *IAEA TS-R-1, paragraph 726)*

Sections 2.7.1 through 2.7.5 summarize evaluations and testing for the hypothetical accident conditions of transport tests. Section 2.7.6 summarizes the results of this testing.

Four (4) test specimens were used to conduct the hypothetical accident tests. Testing was performed after performance of the test specimens has undergone a 1.2 m drop test for Normal Conditions of transport (See Section 2.6.7). Detailed description of this testing is contained in Test Report 108 (Section 2.12.3).

2.7.1 Free Drop

(Reference:
- *USNRC, 10 CFR 71.73(c)(1)*
- *IAEA TS-R-1, paragraph 727(a))*

Justification for all test unit drop orientations are included in Test Plan 108 (Section 2.12.2)

2.7.1.1 End Drop

This orientation was used for Test Specimen TP108(B) and the orientation is shown in Figure 2.7a. Results of this testing produced one broken rear plate security screw, deformation of the steel cylinder and the rear plate puckered. Radiation profiles performed at the conclusion of this and subsequent testing showed no significant increase in radiation levels and that the package had maintained its structural integrity.

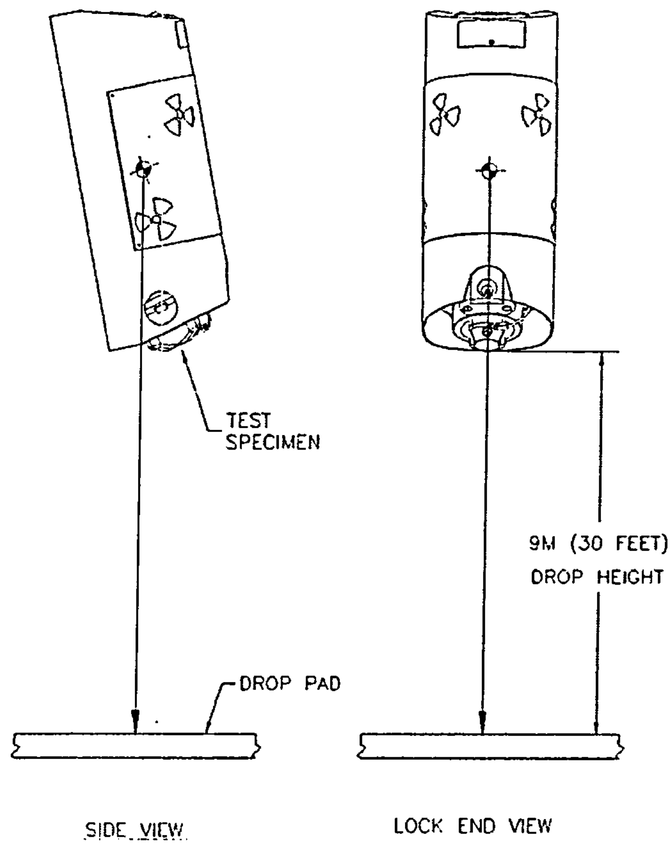

Figure 2.7a - Model 880 (TP108(B)) 9 m Drop Test Orientation – End Drop

2.7.1.2 Side Drop

The side drop was performed on Test Specimens TP108(C) and TP108(D). These drop orientations are shown in Figures 2.7b and 2.7c. Results of the testing on specimen TP108(C) produced flattening of the steel cylinder bottom and bending of the front endplate near the bottom. This caused associated binding in movement of the outlet port but did not adversely affect source securement or unit shielding.

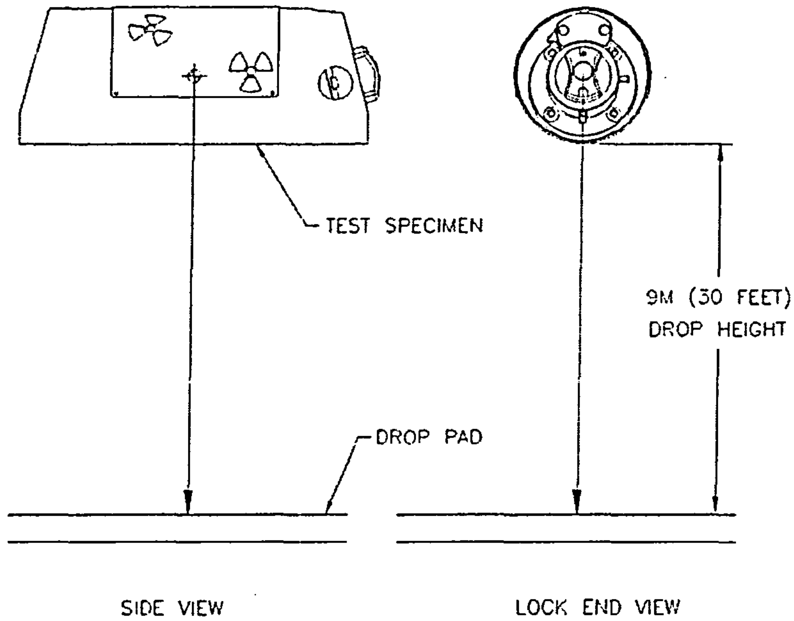

Figure 2.7b - Model 880 (TP108(C)) 9 m Drop Test Orientation – Bottom Drop

Results of the testing on specimen TP108(D) produced flattening of the left side of the steel cylinder. Radiation profiles performed at the conclusion of the 9 m (and subsequent testing) showed no significant increase in radiation levels for either test unit and demonstrated that the package maintains its structural integrity under these drop orientations.

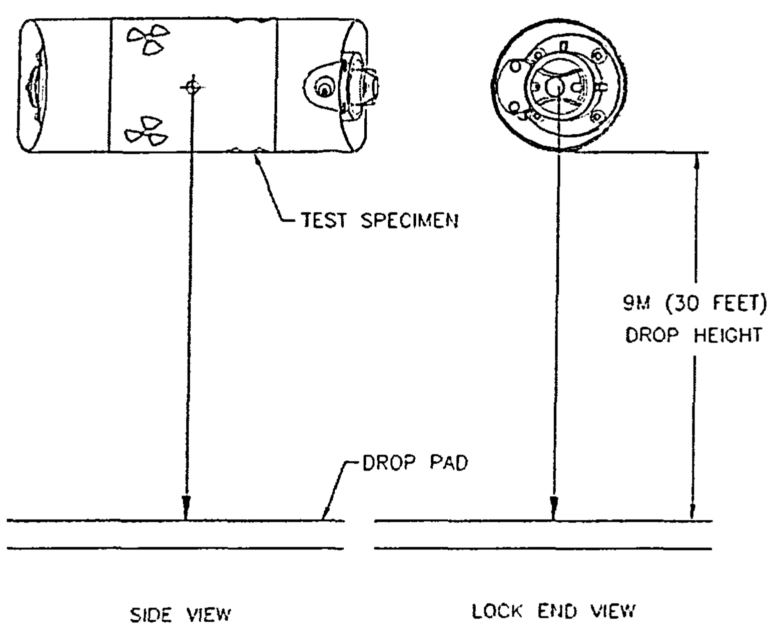

Figure 2.7c - Model 880 (TP108(D)) 9 m Drop Test Orientation – Left Side Drop

2.7.1.3 Corner Drop

Not Applicable. The 880 Series package does not have corners.

2.7.1.4 Oblique Drops

The oblique drop was not performed. In an oblique drop, the energy generated at impact distributed across the initial and secondary impact surfaces. This will produce less force on impact at the initial impact location and the force from the secondary impact will cause deformation of the ends of the steel cylinder without contributing to damage which could result in container failure.

Unlike the End and Side drops described in Sections 2.7.1.1 and 2.7.1.2, an oblique drop is less likely to cause a container failure by the mechanisms identified in Test Plan 108 (Section 2.12.2). These included fracture or penetration of the projector weldment, displacement of the shield within the projector weldment, distortion or fracture of the source, and failure of the source lock assembly and/or lock mounting screws.

2.7.1.5 Summary of Results

(Reference:
- *USNRC, 10 CFR 71.73(a) and (b)*
- *IAEA TS-R-1, paragraph 726)*

See Table 2.7.8.1 for additional test unit results summary. In all cases, radiation profiles performed at the conclusion of all testing showed no significant increase in radiation levels for the test units and demonstrated that the 880 Series packages comply with the requirements of this section.

2.7.2 Crush

(Reference:
- *USNRC, 10 CFR 71.73(c)(2)*
- *IAEA TS-R-1, paragraph 727(c))*

Not applicable. This package is not used for the Type B transport of normal form radioactive material.

2.7.3 Puncture

(Reference:
- *USNRC, 10 CFR 71.73(c)(3)*
- *IAEA TS-R-1, paragraph 727(b))*

The puncture bar is a 6 inch diameter x 12 inch long, mild steel solid bar attached to a 12 inch x 12 inch x ½ inch thick mild steel base. The bar is attached to the base with a ¼ inch circumferential fillet weld. The puncture bar is attached to the drop test pad steel plate by four stainless steel bolts. Justification for all test unit puncture orientations are included in Test Report 108 (Section 2.12.3) and results are summarized in the Sections 2.7.3.1 through 2.7.3.4.

2.7.3.1 Test Specimen TP108(B)

Test Specimen TP108(B) impacted the puncture bar on the lock cover (see Figure 2.7d). To achieve the designed impact orientation, this test specimen was dropped on the puncture bar twice. Results of this testing produced denting of the lock cover. Radiation profiles performed at the conclusion of this and subsequent testing showed no significant increase in radiation levels and that the package had maintained its structural integrity.

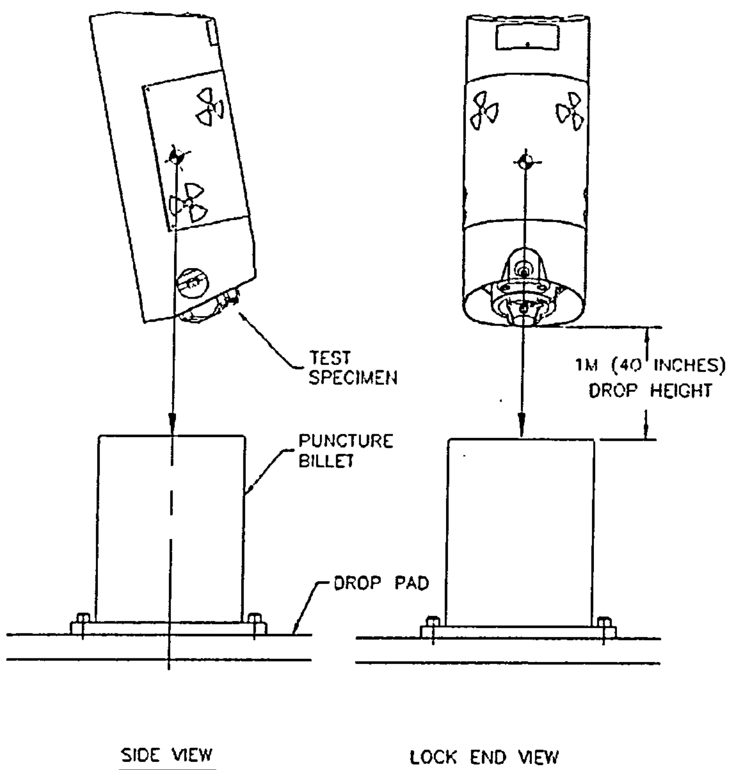

Figure 2.7d - Model 880 (TP108(B)) Puncture Drop Orientation – Lock Cover

2.7.3.2 Test Specimen TP108(C)

Test Specimen TP108(C) impacted the puncture bar on the steel cylinder bottom surface (see Figure 2.7e). Results of this testing produced no new observable damage to the test specimen. Radiation profiles performed at the conclusion of this and subsequent testing showed no significant increase in radiation levels and that the package had maintained its structural integrity.

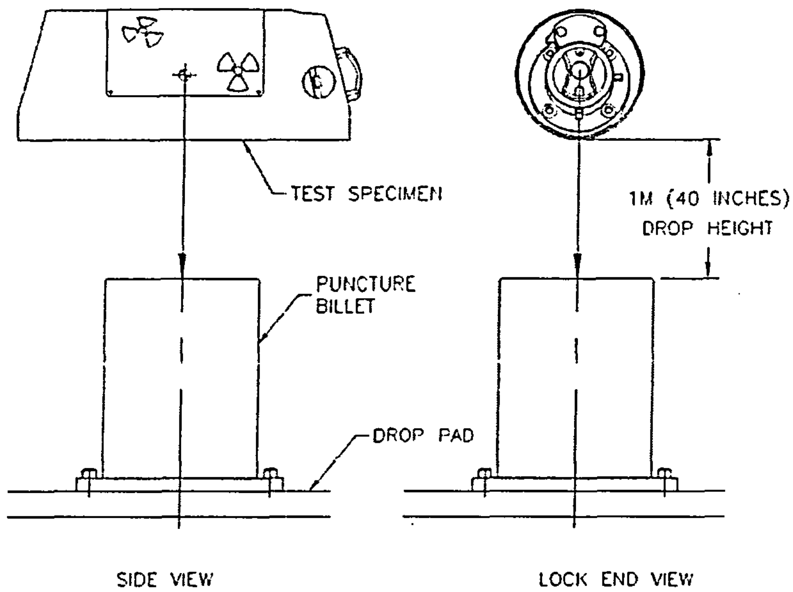

Figure 2.7e - Model 880 (TP108(C)) Puncture Drop Orientation – Bottom Surface

2.7.3.3 Test Specimen TP108(D)

Test Specimen TP108(D) impacted the puncture bar on the steel cylinder left side surface (see Figure 2.7f). Results of this testing produced no new observable damage to the test specimen. Radiation profiles performed at the conclusion of this and subsequent testing showed no significant increase in radiation levels and that the package had maintained its structural integrity.

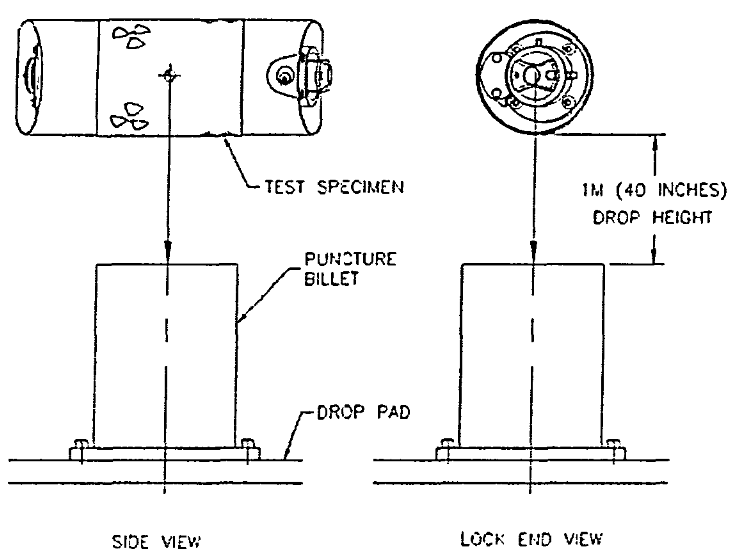

Figure 2.7f - Model 880 (TP108(D)) Puncture Drop Orientation – Left Side Surface

2.7.3.4 Test Specimen TP108(G)

Test Specimen TP108(G), which included the optional jacket, impacted the puncture bar on the lock cover (see Figure 2.7d). Results of this testing produced no new observable damage to the test specimen. Radiation profiles performed at the conclusion of this and subsequent testing showed no significant increase in radiation levels and that the package had maintained its structural integrity.

2.7.3.5 Summary of Results

(Reference:

- *USNRC, 10 CFR 71.73(a) and (b)*
- *IAEA TS-R-1, paragraph 726)*

See Table 2.7.8.1 for additional test unit results summary. Additional inspections were performed using radiography to check for potential internal damage. A more detailed summary is given in Test Report 108 (Section 2.12.3). In all cases, radiation profiles performed at the conclusion of the puncture testing showed no significant increase in radiation levels for the test units and demonstrated that the 880 Series packages comply with the requirements of this section.

2.7.4 Thermal

(Reference:

- *USNRC, 10 CFR 71.73(c)(4)*
- *IAEA TS-R-1, paragraph 651 through 655, and 728)*

The thermal test was not performed. Compliance for this requirement was assessed. The assessment demonstrates that the thermal test would not be sufficient to weaken the package and cause its failure under the final profile criteria.

Review of the condition of the test specimens after the drop tests suggests the fire test would have no affect on the resulting radiation measurements if the thermal test was performed. This is justified based on the condition of the test specimens after the drop tests and the properties of the materials used to secure and shield the source within the specimens.

2.7.4.1 Thermal Analysis

2.7.4.1.1 Condition of the Test Specimens

Damage to the outer containment was not sufficient to increase oxygen ingress to the shield, build up pressure within the assembly through the pyrolization of the foam, or expand a trapped volume of air within the cylinder. The container is vented to the atmosphere through both the front and rear end plates. These vents will relieve any internal generation or expansion of gases created by the elevated temperatures.

Damage incurred during the drop testing (4 foot, 30 foot and puncture) was minimal, consisting of insignificant deformation of the weldments, lock mounting block and dust cover, slight bowing of the end plates and loss of one rear plate bolt. There were no holes or tears in the cylinder weldment to allow air to circulate through the package. None of the damage significantly increased, or created new, pathways for the ingress of oxygen. Oxygen ingress has been shown empirically to be the primary contributing factor in the oxidation of depleted uranium shields during thermal testing (see Sections 2.12.7 and 2.12.9). Further analysis against shield degradation due to oxidation is contained in Section 2.7.4.2.

Without the possibility of gross shield oxidation, and subsequent shield degradation, failure under the thermal test conditions would require mechanical degradation of the packages' support structure. The Model 880 support structure is predominately of welded stainless steel construction.

The internal support structure for the test specimen shields was intact and fully functional. The internal support structure consists of the shield, cylinder weldment, shield pins, U-shaped brackets, and endplates with rivnuts. The source assemblies were intact, undamaged and secure in the shielded position. The source assembly consists of the source capsule, flexible wire, stop ball and source connector.

The rear plate assemblies remained intact and continued to secure the source assemblies in the shielded position within the package. The securing components of the rear plate assembly consists of the rear plate, lock slide, sleeve, selector ring, selector ring retainer, four #10 machine screws, and four 5/16-18 security screws.

The effect of structural yielding under self-weight at temperature caused by the degradation of mechanical properties of the materials of construction is insignificant. The likely failure modes are further assessed in Sections 2.7.4.1.3.

2.7.4.1.2 Oxidation of Depleted Uranium (DU) Shielding

Significant oxidation of the depleted uranium does not occur if there is insufficient flow of oxygen available to the shield. Two major contributing factors to limiting this oxidation are the oxygen inhibitive nature of charred polyurethane foam and the packages' ability to contain the foam once charred. This has been demonstrated by thermal testing conducted by QSA Global Inc. in support of previous Type B package submissions described in the following paragraphs.

Under Test Plan 74, in support of Certificate of Compliance number USA/9283/B(U) for the Model 660 Series, Specimen D was tested successfully through normal and accidental conditions. Before thermal testing, the unit showed gaps in the outer containment (shell to endplate interface) up to ½ inch wide and 1 inch long. Pyrolized foam was contained within the unit. Although the shield oxidized slightly on the end nearest the largest gap, the unit passed final profile at 0.0047 R/hr at one meter.

Under Test Plan 72-S2 (Section 2.12.10), in support of Certificate of Compliance number USA/9035/B(U) for the Model 680-OP Series, camera s/n B198 was subjected to thermal testing. Before testing, the unit was intact and essentially undamaged with no gaps between mating surfaces. After the 30 foot and puncture drop tests, ¾ inch long by 1/16 inch wide gaps were present on both sides of the unit at the side plate/shell interface. Thermocouple readings showed temperatures of up to 1000°C on the unit and over 900°C within the depleted uranium shield. The foam was completely pyrolized but was contained within the unit. No oxidation of the shield occurred and the unit passed final profile at 0.330 R/hr at one meter.

Under Test Plan 80 Report (Section 2.12.9), in support of Certificate of Compliance number USA/9269/B(U) for the Model 650L, test specimen TP80(B) was subjected to thermal testing. The drop tests (30 foot and puncture) caused the outer shell to split completely open and the inner shell to crack, creating a 3 inch long by ½ inch wide gap. Subsequent thermal testing caused pyrolization of all the foam and vaporization in the area of the gap. Some minor oxidation of the shield was also noted. Thermocouples recorded temperatures in the shield of over 900°C and close to 1000°C at the shell. Although the shield oxidized slightly in the area of the gap, the unit passed final profile at 0.028 R/hr at one meter.

As demonstrated in previous thermal testing, minor air gaps in the containment surrounding the shield are insufficient to allow significant oxidation of the depleted uranium shield during the thermal test. The Model 880 Series test specimens had no breach of the shield containment and would therefore prevent oxygen ingress to the shield and any resulting deterioration of the depleted uranium shield during the thermal test.

2.7.4.1.3 Material Properties at Elevated Temperatures

The melting temperature for all materials of the internal support structure, rear plate assembly and source assembly are above the thermal test temperature of 800°C. The thermal expansion for the internal support structure materials is less than the design clearance allowed for assembly. Further, the stainless steel and titanium components of the internal support structure, rear plate assembly and source assembly retain about 30% and 60% of their room temperature strength at 800°C.

The load condition for the thermal test is for the internal structure to support the static weight of the shield in suspension. The dynamic impact nature of the drop tests can subject the structure to a force over 100 times the static weight of the shield. This means the strength of the materials used in the structure would need to decrease by two orders of magnitude or to about 1% of their strength at room temperature. The 30-minute thermal test is not long enough for significant creep deformation to occur in the structure.

2.7.4.1.3.a Tear Out of the Shield Support Pin

If the device were suspended with its diametrical axis in the vertical, the weight of the shield would be supported by the front and rear brackets. Tear out of the materials under the pin can be assessed by assuming one (1) pin supports the entire shield.

Tear out Area = 0.4 in X 0.065 in (material thickness) X 4
= 0.104 in^2

Weight of Shield = 34 lbs. (max)

Therefore: 34 lbs. / 0.104 in^2 = 327 psi

The strength of 304 stainless steel at 800 C° = ~15,000 psi

(Reference: ASM Stainless Steels, J.R. Davis ed.,1994, p. 508)

This gives a factor of safety of approximately 46 against failure.

2.7.4.1.3.b Depleted Uranium Cracking around the Titanium Pin

The pin is in poor contact with the supporting brackets (0.065 inches thickness each side) and is in intimate contact with the shield (possible line to line). The heat transmitted through conduction from the outer shell through the bracket to the pin will be dissipated by the mass of the shield at the point of contact. Whereas upon heat up of the shield, the heat flow from the shield to the pin will be substantial. Therefore, the shield and pin should be at approximately the same temperature throughout the thermal test. Based on this assumption the relative expansion coefficients for the materials are compared to determine if the pin will exert damaging force on the DU shield.

The volume expansion coefficient of materials is taken to be approximately three times the linear expansion coefficient (Reference: ASM Material Properties Handbook Titanium Alloys, ed. Rodney Boyer, Gerhard Welsch, E.W. Collings, 1994, p. 516). As such:

Linear expansion coefficient – Titanium 11.0E-6 in/inC°
(Reference: ASM Metals Handbook Desk Edition, ed. Howard E. Boyer, Timothy L. Gall, 1985, p. 1.4)

Linear expansion coefficient – Depleted Uranium 12.0E-6 in/inC°
(Reference: Universal reference calculator, TAD Technical Services Corp)

Based on the linear expansion coefficients, the two materials will expand volumetrically at approximately the same rate. This will prevent the pin from exerting force onto the inside diameter of the hole in the shield. Therefore, the material around the pin will remain intact and the shield will remain secured to the brackets.

2.7.4.1.3.c De-Attachment of the Rear Lock Assembly

On the test unit where a security screw failed, three (3) of the four (4) security screws remained intact after the drop and puncture testing. These screws retained the rear lock assembly to prevent the source from movement relative to the shield. If the device were suspended as in 2.7.4.1.3.a with the lock assembly downward, the self-weight of the assembly would put all three screws in tension. At temperature, the stresses would be:

Stress area of 5/16-18 screw: $0.0524\ in^2$
(Reference Manual of Steel Construction, 7th Edition, page 4-125)

Total stress area (3 screws): $3(0.0524\ in^2) = 0.157\ in^2$

At 15,000 psi*, the screws will support a weight of:

$$15{,}000\ psi\ (0.157\ in^2) = 2{,}358\ lbs.$$

The lock assembly weighs approximately two (2) lbs. Therefore, the lock assembly will remain attached and undisturbed as the remaining screws can easily support the weight.

* The use of 15,000 psi is based on the yield strength of the stainless steel security screws at temperature.

2.7.4.1.4 Conclusions

The test specimens were subjected to the 9 m drop and 1 m puncture tests in accordance with Test Plan 108 (Section 2.12.2). This test plan conforms to the requirements in 10 CFR Part 71 and IAEA TS-R-1 for Type B(U) transport packages.

The test specimens demonstrated that the Model 880 Series transport packages satisfy the test requirements of Test Plan 108 (Section 2.12.2) as demonstrated in Test Report 108 (Section 2.12.3). The Model 880 Series package with the jacket does not adversely affect the results of these tests. This conclusion is drawn from the drop test results and thermal analysis as supported by the test data, test inspection data and damage assessments.

Based on the previous empirical data and analyses, we conclude that oxidation of the shield will not occur, the structural integrity of the package will remain intact and the containment of the source will not be affected. As such, the Model 880 complies with the requirements of this section.

2.7.4.1.5 Summary of Pressures and Temperatures

(Reference:
- *IAEA TS-R-1, paragraph 502(d))*

Table 2.7a: Summary Table of Temperatures

Surface Temperature Condition	Model 880 Series Packages
Fire Test During	800°C (1,472°F)
Post-Fire (Maximum Temperature)	800°C (1,472°F)

The Model 880 Series containers are vented to atmosphere. As such, no pressure will build up in the units under Hypothetical Accident conditions.

Table 2.7b: Summary Table of Maximum Pressures

Package Configuration	Void Volume (in^3)	Fire Conditions 800°C (1,472°F) Pressure Developed
880 Delta	0	0 psig
880 Sigma	0	0 psig
880 Elite	0	0 psig

2.7.4.2 Differential Thermal Expansion

Expansion of the 880 steel cylinder circumference is approximated by:

$$E = \pi D \alpha \Delta T$$

Where:

D = inner Diameter of the steel cylinder = 4.87 in = 0.12 m or
Outer diameter of the depleted uranium shield = 4.38 in = 0.11 m
α = Material Coefficient of Thermal Expansion
ΔT = Fire temperature differential
(from 38°C (311°K) to 800°C (1073°K)

Substituting gives:

$$E = \pi(4.87\ \text{in})(9.9\ \mu\text{in/in°F})(1372°\text{F}) = 0.2 \text{ in steel}$$
$$E = \pi(4.38\ \text{m})(28\mu\text{m/m°F})(762°\text{K}) = 0.29 \text{ in depleted uranium}$$

This translates to a diameter increase of 0.026 inches for the steel shell and 0.04 inches for the depleted uranium. Since the depleted uranium modulus of elasticity is less than stainless steel (190 GPa versus 210 GPa, from Mechanics of Materials, Fall 1999) and the expansion rate is approximately the same, the shield cask shell will keep the depleted uranium compressed within its volume. The rear plate and front plate attachment screws will expand at approximately the same rate as the steel encasement thus maintaining the security of the source within the package.

2.7.4.3 Stress Calculations

As was shown in Section 2.7.4.2, thermal differentials will have no detrimental effect on the interfaces between the outer steel cylinder, shield or endplates. The Model 880 Series transport packages are open to the atmosphere and contain no components which could create a differential pressure relative to atmospheric conditions.

2.7.4.4 Comparison of Allowable Stresses

All stresses calculated in Section 2.7.4 are well below strengths for the materials of construction. Further, the Model 880 Series package was fully tested and passed under Normal and Hypothetical Accident Conditions of transport. It is therefore concluded that the Model 880 Series package will satisfy the performance requirements specified by the regulations.

2.7.5 Immersion - Fissile Material

(Reference:
- *USNRC, 10 CFR 71.73 (c)(5)*
- *IAEA TS-R-1, paragraphs 731-733)*

Not applicable. This package is not used for transport of Type B quantities of fissile material.

2.7.6 Immersion - All Packages

(Reference:

- *USNRC, 10 CFR 71.73 (c)(6)*
- *IAEA TS-R-1, paragraph 701 and 729)*

The Model 880 Series transport packages are open to the atmosphere and contain no other components that would create a differential pressure under immersion. All materials are impervious to water and would not be affected.

The primary containment system in the model 880 package is a special form source, which meets the ANSI 542 and ISO 2919 requirements for Class 3 pressure testing. Therefore the 880 could withstand the immersion test as Class 3 is in excess of the required 150 kPa (21.7 lb ft/in2).

2.7.7 Deep Water Immersion Test (for Type B Packages Containing More than 10^5 A_2)

(Reference:

- *USNRC, 10 CFR 71.61*
- *IAEA TS-R-1, paragraph 657, 658 and 730)*

Not applicable. This package does not transport normal form radioactive material in quantities exceeding 10^5A_2.

2.7.8 Summary of Damage

(Reference:

- *USNRC, 10 CFR 71.73(a) and (b)*
- *IAEA TS-R-1, paragraph 701, 702, 716 and 726)*

Table 2.7c summarizes the results of the Normal Conditions of Transport and Hypothetical Accident testing performed on the Model 880 Series transport packages.

Table 2.7c: Summary of Damages During Test Plan 108

Test Specimen	Test	Weight	Actual Impact Point	Damage Observed at Test Site
TP108(B)	4-foot free drop	44.2 lbs.	Lock cover & shell lip	• Shell bottom rear lip bent.
	30-foot free drop	44.4 lbs.	Lock cover & shell lip	• One rear plate security screw broken. • Rear plate puckered. • Shell lip bent further.
	Puncture drop #1	44.4 lbs.	Lock cover	• Lock cover dented.
	Puncture drop #2	NA	Lock cover	• Lock cover dented.

Test Specimen	Test	Weight	Actual Impact Point	Damage Observed at Test Site
TP108(C)	4-foot free drop	44.3 lbs.	Shell bottom surface	• Shell bottom flattened. • Shell rear lip bent in.
	30-foot free drop	44.4 lbs.	Shell bottom surface	• Shell bottom flattened further. • Shell rear top bent. • Front endplate bent near bottom. • Outlet port binds.
	Puncture drop	44.4 lbs.	Shell bottom surface	• None observed.
TP108(D)	4-foot free drop	44.4 lbs.	Shell left side	• Shell left side flattened.
	30-foot free drop	44.3 lbs.	Shell left side	• Shell left side flattened further.
	Puncture drop	44.3 lbs.	Shell left side	• None observed.
TP108(G) (with jacket)	4-foot free drop	48.8 lbs.	Lock cover	• Lock cover dented.
	30-foot free drop	48.8 lbs.	Lock cover & shell side lip	• Shell rear side lip bent. • Two jacket rivets broken. • Label rivets missing.
	Puncture drop	48.8 lbs.	Lock cover	• None observed.

Table 2.7d: Damage Measurements after Testing Under Test Plan 108

Test Specimen	Damage
TP108(B)	• Shell at rear end is bent in toward lock by about 1 inch at bottom. • Shell at front end has two spot dimples about 3/16 inch deep. • Rear plate is puckered in at selector ring about 1/16 inch. • Rear plate security screw at top right is broken. • Rear plate security screw at top left & bottom right is bent. • Rear plate security screw at bottom left slightly is bent. • Lock cover is dented 3/16 inch at three spots.
TP108(C)	• Shell bottom is depressed about 3/16 inch. • Shell top has two spot dimples about 3/16 deep. • Front plate knob pin is bent about 3/16 inch.
TP108(D)	• Shell left side is depressed about 1/8 to 1 inch. • Shell right side at rear end is bent about 3/16 inch.
TP108(G)	• Shell left side at rear end is bent about 5/8 inch. • Shell left side at front end is bent about 3/16 inch. • Rear plate security screw at top right is slightly bent. • Jacket rivets on left side are broken. • Lock cover is dented about 3/16 inch. • Lock cover pin at bottom is loose and can be removed. • Label rivets missing.

Table 2.7e: Radiographic Results after Testing Under Test Plan 108

Test Specimen	Damage
TP108(B)	• Rear plate tube feature is slightly bent but intact. • Three rear plate security screws are slightly bent but intact. • One rear plate security screw broken end remained in the rivnut.
TP108(C)	• Shield contacts the shell at the impact surface.
TP108(D)	• U-shaped bracket is bent on the left side about 1/8 inch.
TP108(G)	• No apparent internal damage.

Based on the results and assessments for the test specimens addressed in Test Report 108 (see Section 2.12.3), it is concluded that the Model 880 Series transport packages maintain structural integrity and shielding effectiveness during Hypothetical Accident Conditions and Normal Conditions of Transport.

2.8 Accident Conditions for Air Transport of Plutonium

Not applicable. This package is not used for transport of plutonium.

2.9 Accident Conditions for Fissile Material Packages for Air Transport

Not Applicable. This package is not used for transport of Type B quantities of fissile material.

2.10 Special Form

(Reference:

- *USNRC, 10 CFR 71.75*
- *IAEA TS-R-1, paragraphs 602-604)*

The Model 880 Series transport packages are designed for use with a special form source capsules with a maximum inside radius 0.12 inches (3.05 mm) and a minimum wall thickness based on the weld penetration of 0.009 inches (0.23 mm). The source capsule must be qualified as Special Form radioactive material.

2.11 Fuel Rods

Not applicable. This package is not used for transport of fuel rods.

2.12 Appendix

2.12.1 Test Plan and Report 100 (Feb 2000).

2.12.2 Test Plan 108 Issue 5 (Jul 2000).

2.12.3 Test Report 108 Minus Appendices A-C (Aug 2000).

2.12.4 Test Plan 115 (Feb 2001).

2.12.5 Test Plan Report 115 Minus Appendices (March 2001).

2.12.6 Test Plan Report 125 Rev B (Mar 2003).

2.12.7 Test Plan Report 74 (Feb 1998).

2.12.8 Test Plan 80 Rev 1 (Mar 1999).

2.12.9 Test Plan 80 Report Minus Manufacturing Records (Jun 1999).

Section 2.12.1 Appendix: Test Plan and Report 100 (Feb 2000)

SENTINEL

TEST PLAN NO. 100	
TEST PLAN COVER SHEET	
TEST TITLE: NORMAL TRANSPORT TESTS	
PRODUCT MODEL: MODEL 880	
ORIGINATED BY: S. Gl[illegible]	DATE: 8 FEB 00
TEST PLAN REVIEW	
ENGINEERING APPROVAL: [signature]	DATE: 15 FEB 00
QUALITY ASSURANCE APPROVAL: D.W. Kurtz	DATE: 17 Feb 00
REGULATORY APPROVAL: C. Rou[illegible]	DATE: 15 FEB 00
COMMENTS:	
TEST RESULTS REVIEW	
ENGINEERING APPROVAL: [signature]	DATE: 25 FEB 00
QUALITY ASSURANCE APPROVAL: Daniel W. Kurtz	DATE: 25 Feb 00
REGULATORY APPROVAL: [signature]	DATE: 25 FEB 00

Amersham QSA

TABLE OF CONTENTS

Model 880 Type A Transport Tests

1.0 Purpose

The purpose of this test is to demonstrate the Model 880-transport package meets the normal transport requirements of 49CFR173, 10CFR71, and IAEA Safety Series 6 (As amended 1990).

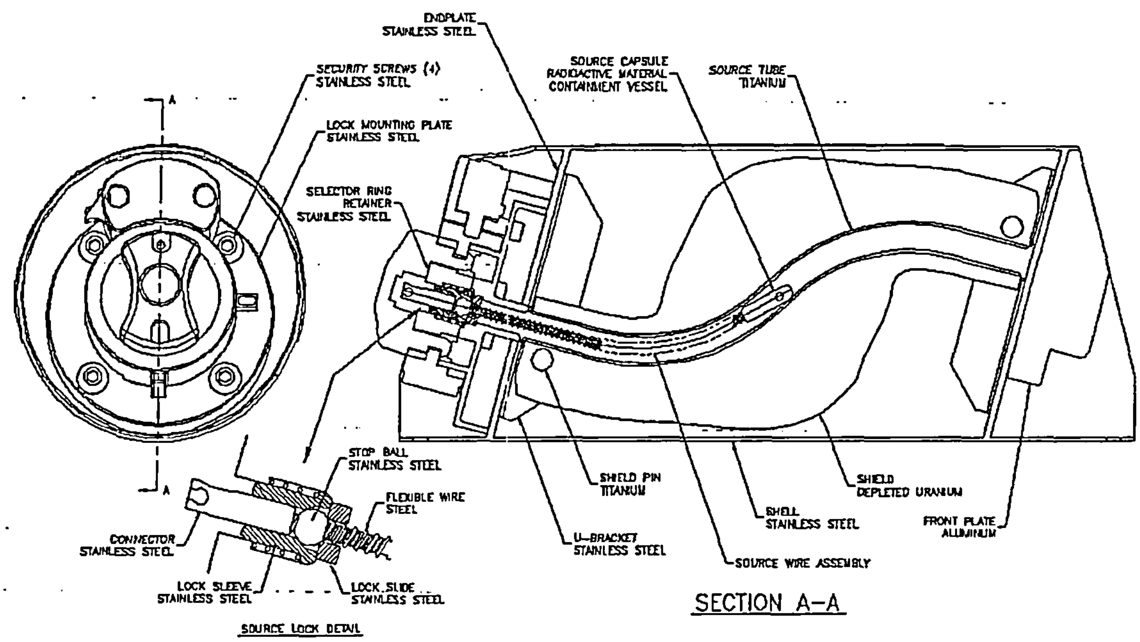

Figure 1. Model 880-Transport Package.

2.0 Package Design Description

The transport package safety features for the Model 880 are described in figure 1. The radioactive material, sealed in a special form source capsule, is located, secured and protected in the package by the following component relationships.

The capsule, stop ball and connector are swaged to a flexible steel wire. These four components form the source wire assembly. The stop ball is held securely by the lock slide and sleeve of the lock assembly. The sleeve prevents the stop ball from being pulled through the rear of the package, while the lock slide prevents the stop ball from being pushed out of the front. Both the sleeve and lock slide are captured by the selector ring retainer and lock mounting plate.

The selector ring retainer is fastened to the lock mounting plate with four, #10, stainless steel machine screws. The lock mounting plate is bolted to the welded endplate of the cylinder shaped shell housing using four, 5/16-18 by 1-1/2 inch long stainless steel security screws.

A U-shaped bracket welded to the endplate holds a 3/8-inch diameter titanium pin that connects the shield within the U of the bracket. This structure secures the shield to the welded package. Copper spacers prevent contact of the depleted uranium shield with the stainless steel components. This method of shield attachment is repeated at both ends of the shell.

The shield is centered in the shell and has the source tube cast into its center. The source tube provides a cavity for the source wire assembly to travel through during use. The capsule with radioactive material is positioned at the center of the ball of the shield within the source tube cavity.

Polyurethane foam fills the air void between the shield and shell inner walls. The foam acts only to prevent the ingress of material into the air void.

The outlet port, located at the front end, serves to block access into or out of the source tube cavity. Four security screws fix the front plate to the shell endplate.

A plastic jacket, not shown in figure 1, may be used to carry the package. This jacket will not be on the specimen for the tests below. Testing without the jacket will not significantly affect the results of the 4-foot drop test; in fact the plastic material and geometry of the jacket will prevent enough damage to the shell to cause failure of the lock mounting plate. The extra drop energy supplied by the 4-pound jacket would be offset by its impact absorption characteristics. The jacket would provide better protection against the penetration bar at its most vulnerable area and would provide additional support to the shell under compression. Therefore testing without the jacket would give more conservative test conditions.

3.0 Failures of Interest

The failures of interest will depend upon the test being performed on the package. Each test will be conducted on the same specimen so as to incur a cumulative damage affect to the package.

The compression test will try to flatten the package to deform the shell enough to shorten the distance from the source to an outer surface measurement point. This may raise radiation measurements above the requirement limits of 200 mR/hr at the surface.

The penetration test will attempt to puncture through the shell housing at its thinnest and most unsupported area. This may reduce the effectiveness of the package and raise radiation levels due to possible access to the inner void of the shell housing. Material thickness and support of other features on the package would prevent sufficient damage from the bar's impact and therefore not considered.

The 4-foot free drop test will try to shear the four lock mounting plate screws upon impact on the bottom edge of the shell at the lock end. This may produce enough deformation to the shell to bend the lock mounting plate and shear the screws. This could remove the source wire assembly from the package or increase radiation levels as a result of relocation of the capsule within the shield.

Two other orientations reviewed for the four-foot free drop are:
1. Shear the shield pins by orientating the shell and shield pins parallel with the impact surface. The pins are designed to take at least a 500-G load upon impact. The estimated load at impact for this drop is about 50G's. Therefore this orientation will not be considered.
2. Bend the U-bracket by orientating the shell and bracket parallel with the impact surface. The shield is less than ¼ -inch from the shell. This prevents sufficient shield travel when you consider the shell deflects to meet the shield upon impact. Therefore this orientation will not be considered.

4.0 Test Conditions and Orientations

The materials used in the construction of the package, see figure 1, retain their mechanical properties within the temperature range of -40 F to +158 F and pressure range of 3.6 psi to 20 psia as specified in the test requirements. Except for the source capsule (tested special form), the package is open to the atmosphere allowing inner and outer pressures to equalize naturally. Therefore testing at ambient conditions, both temperature and pressure would not change the results of these tests and are therefore acceptable initial conditions.

Since the materials of construction are metallic and do not loose strength when exposed to a water spray, the water spray test per 49CFR173.465(b) is not required and will not be conducted.

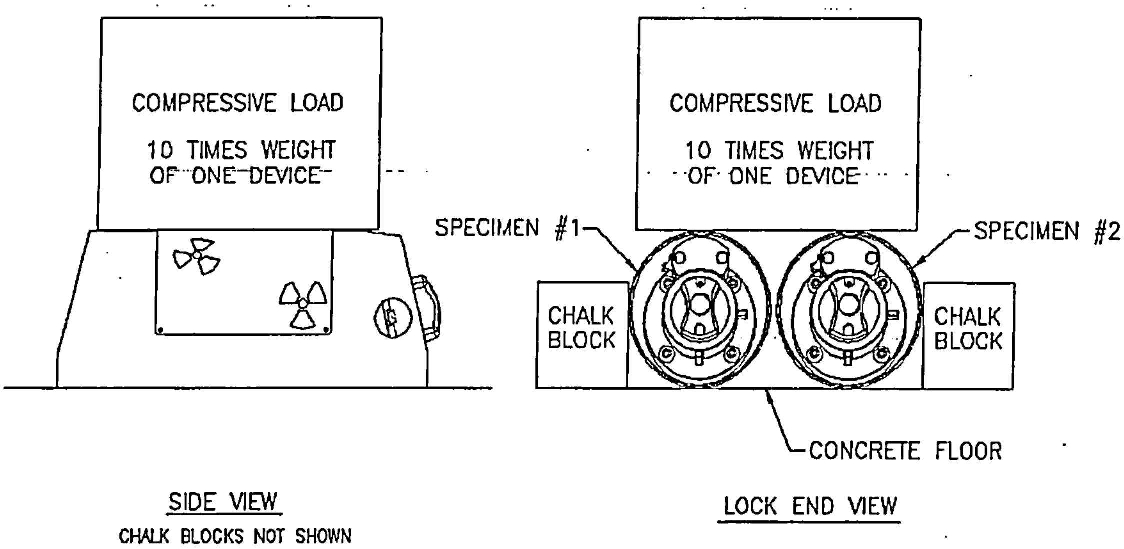

Figure 2. Stacking Test Setup.

Orientation for the stacking test, as shown in figure 2, is with the cylindrical shell housing lying horizontally with its longitudinal surface touching the ground. This would be its natural orientation during transport. The load is distributed opposite the floor contact surface. Two packages will be tested together to provide a stable setup. If this is the case, then the compressive load will be 5 times the weight of each specimen. For example, if the specimen weighs 40 lbs., then the total compressive load for 2 specimen tested together is 5 x 40 x 2 = 400 lbs. The actual compressive weight will be determined at the time of the test.

Blocking or specimen restraint may be used to prevent the specimen from rolling, provided the blocking or restraint does not support the specimen vertically. Use figure 2 as a guide to place the blocks next to the specimen.

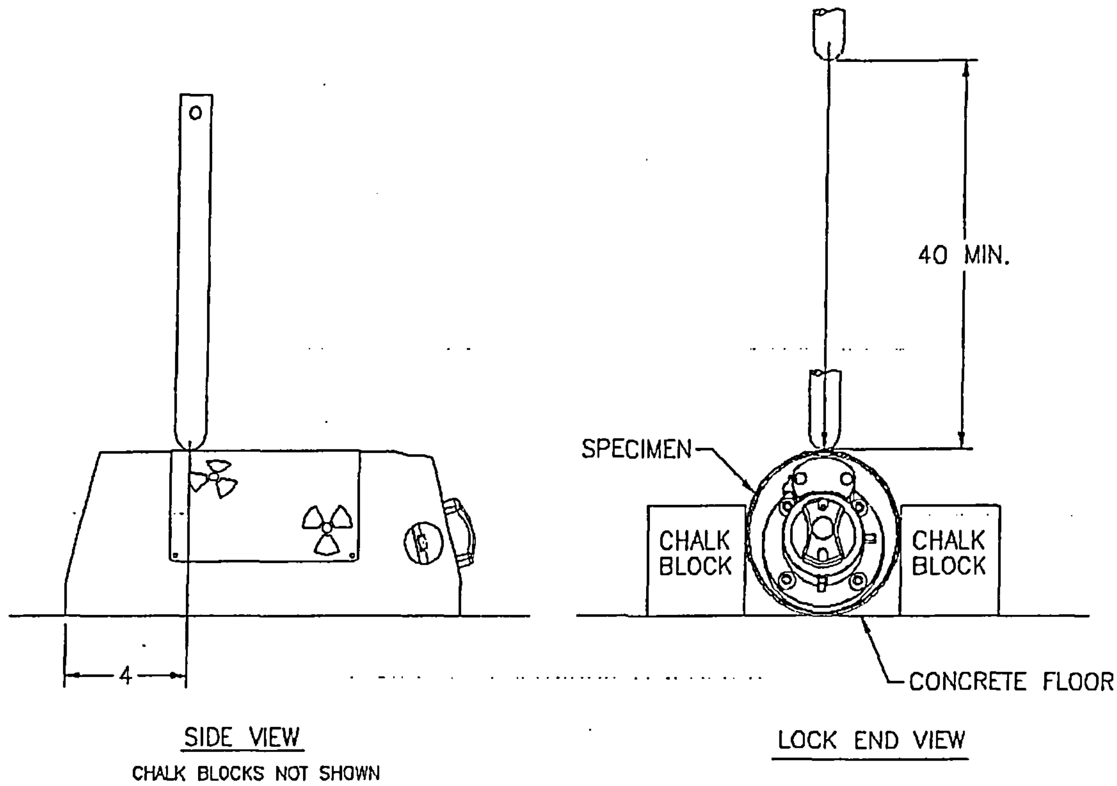

Figure 3. Penetration Test Setup.

Orientation for the penetration test, as shown in figure 3, is with the cylindrical shell lying horizontally with its longitudinal surface touching the ground. The ends of the shell are reinforced by welded endplates and the shield is in close proximity to the housing at the midpoint. The most vulnerable spot for sufficient penetration is at a point about 4 inches from either end of the shell. This point provides the least support for the shell.

Blocking or specimen restraint may be used to prevent the specimen from rolling, provided the blocking or restraint does not support the specimen vertically. Use figure 3 as a guide to place the blocks next to the specimen.

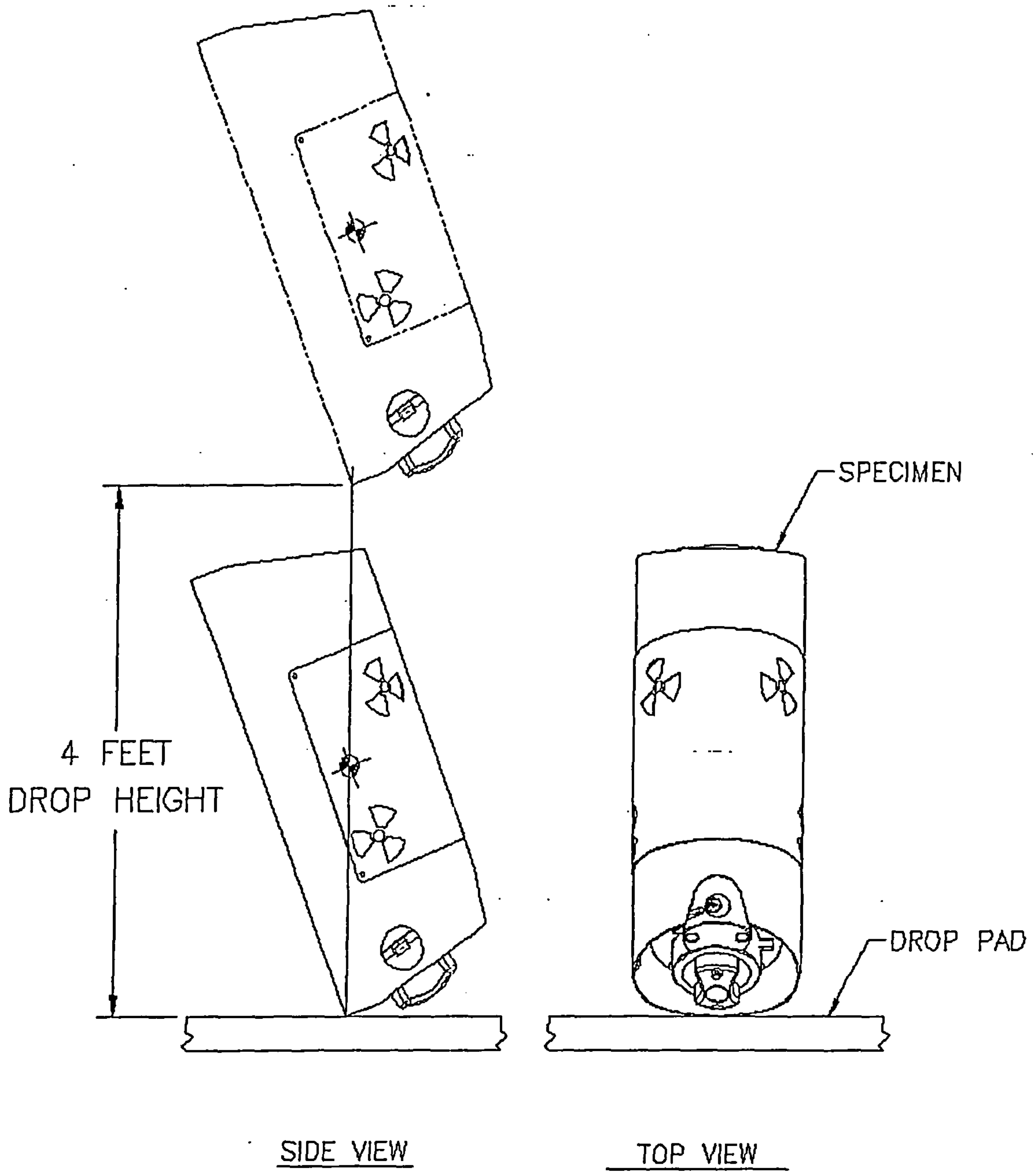

Figure 4. Four-Foot Free Drop Test.

Orientation for the 4-foot free drop, as shown in figure 4, is with the longitudinal axis of the package nearly vertical, but at a slight angle to the impact surface. The impact point is on the bottom edge of the shell at the lock end with the center of gravity directly over that point. This is the most vulnerable spot to produce enough deformation of the housing to bend the lock mounting plate and shear the attachment screws.

5.0 Changes to Test Conditions or Orientations

Changes to the planned test conditions or orientations shall only be done after careful consideration and documented justification. Prior to performing the test, Engineering, Regulatory and Quality Assurance shall approve the justification.

6.0 Pass and Fail Criteria

Post Test Initial Assessments.

- An initial assessment shall be made upon the completion of each test to evaluate the specimen's performance against the requirements of the test.

Post Test Final Assessment.

- A final assessment shall be made upon the completion of the entire test sequence to evaluate the specimen's performance against the test requirements and determine a pass or fail judgement. The specimen(s) shall be considered passing the test requirement, if the following conditions apply to the specimen after being subjected to all three tests:
  1. The source capsule must remain within the source tube, attached to the source wire and undamaged.
  2. The radiation profile results must be less than 200 mR/hr at the package's surface and must not be a significant increase between initial profile measurements and post-test profile measurements. Profile measurements evaluated against type A quantities of radioactive material, in this case 27.0 curies of IR192.

7.0 Test Equipment

Table of key test equipment:

Equipment	Drawing No.	Serial No.	Tolerance	Used on
Weight Scale				All tests
Temperature gage				All tests
Penetration bar	BT10129, Rev. B			Penetration test
Drop pad	AT10122, Rev B			Free drop test

8.0 Test Specimen

The test specimen is clearly described on drawing number TP100 revision A. A minimum of two test specimen shall be manufactured in accordance with drawing TP100 and the AEA Technology QSA Inc. quality assurance system.

9.0 Test Procedure

1. Manufacture and inspect the specimens per the test specimen drawing.
2. Perform and record radiation profile inspections per WI-Q09.
3. Conduct stacking test per 49 CFR 173.465 (d).
   - Record test data, damage descriptions (if any), initial test assessment.
4. Conduct penetration test per 49 CFR 173.465 (e).

- Record test data, damage descriptions (if any), initial test assessment.

5. Conduct 4-foot free drop test 49 CFR 173.465 (c).
   - Record test data, damage descriptions (if any), initial test assessment.
6. Perform and record radiation profile inspections per WI-Q09.
7. Record final test assessment.

Appendix A: Drawings and Figures.

- Test Specimen TP100, Revision A.

Appendix B: Worksheets.

- Compression Test.
- Penetration Test.
- 4-foot Free Drop Test.
- Final Test Assessment.

Compression Test 49 CFR 173.465(d)	
Test Specimen: Drawing No. ______ Rev. ______ Serial Number: ______ Weight: ______ Scale used: ______	
Test Setup: Photograph setup Use Figure 2 to position the specimen and apply the compressive load. Setup verified by: ______ Date: ______	
Compressive Load: Weight: ______ Scale used: ______	
Test Period: Start date & time: ______ Ambient Temp. ______ Gage used: ______ Stop date & time: ______ Ambient Temp. ______ Gage used: ______	
Damage description: Photograph damage (if present) ______ ______	
Post test initial assessment: ______ ______ ______	
Recorded by:	Date:
Witnessed by:	Date:
Quality Assurance Review by:	Date:

Notes:

Penetration Test
49 CFR 173.465 (e)

Test Specimen:

Drawing No. ____________________ Rev. ______ Serial Number: ____________

Test Setup:

Photograph Setup

Use Figure 3 to position specimen, locate impact point and set drop height (40 inches).

Setup verified by: ____________________ Date: ____________________

Penetration Bar:

Drawing No. ____________________ Rev. ______ Weight: ____________________

Test Period:

Date & time: ____________________ Ambient Temp. ________ Gage used: ____________

Specimen Damage:

Photograph Damage (if present)

____

____

____

Post test initial assessment:

____

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____

Recorded by:	Date:
Witnessed by:	Date:
Quality Assurance Review by:	Date:

Notes:

Free Drop Test
49 CFR 173.465 (c)

Test Specimen:

Drawing No. ______________________ Rev. ______ Serial Number: ____________

Pretest weight __________________________ Scale Used ____________________

Test Setup:

Photograph Setup

Use Figure 4 to position specimen, locate impact point and set drop height (4 feet).

Setup verified by: __________________________ Date: _____________________

Drop surface:

Drawing No. ______________________ Rev.. ______ Location: _________________

Test Period:

Date & time: _____________________ Ambient Temp. _______ Gage used: _________

Specimen Damage:

Photograph Damage (if present)

Post test weight _________________________ Scale Used ____________________

____

____

Post test initial assessment:

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____

Recorded by:	Date:
Witnessed by:	Date:
Quality Assurance Review by:	Date:

Notes:

Final Test Assessment

49 CFR 173.412 (j)

Test Specimen:

Model 880 Serial Number(s): ____________________

Loss or Dispersal of Radioactive Contents:

Did the source capsule remain within the source tube, attached to the source wire and undamaged? ____________________

Verified by: ____________________ Date: ____________________

Increase in radiation levels:

Are the final radiation profile results less than 200 mR/hr at the package's surface? __________

Is there a significant increase between pre-test profile measurements and post-test profile measurements? ____________________

Verified by: ____________________ Date: ____________________

Comments:

____

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Engineering Review by:	Date:
Regulatory Review by:	Date:
Quality Assurance Review by:	Date:

TEST PLAN # 100 RESULTS

TABLE OF CONTENTS

Model 880 Type A Transport Test Results

1.0 Introduction

This document describes the type A transport test results for the Model 880-transport package. The tests were conducted in accordance with AEA Technology QSA test plan #100.

One test specimen was tested and assessed to the type A test requirements. The test specimen experienced minor deformation to the shell, had radiation measurements less than 200 mR/hr at the surface with type A quantity material, and showed no significant increase in radiation measurement compared with the pre-test radiation measurements.

The final assessment concludes the model 880 transport package meets the requirements for Type A per DOT 49CFR173, NRC 10CFR71, and IAEA Safety Series 6 (As amended 1990).

2.0 Test Specimen

Two test specimen were manufactured at the AEA Technology QSA facility to the test specimen drawing TP100, revision A. One specimen was tested through all tests with the other as a spare.

Both specimens are identical except for the front plate assembly differences. These differences are documented on the route card or attached list.

3.0 Changes to Test Conditions or Orientations

There were no changes to the planned test conditions or orientations.

4.0 Compression Test Data

Both test specimen, serial number P01 & P02, tested.

Damage description.

- There was no apparent damage to either test specimen.

Post Test Initial Assessment.

- The damage caused by the test indicates the test specimens meet the requirements of the test.

5.0 Penetration Test Data

Test performed on test specimen serial number P01 only.

Damage description.

- A spherical bent approximately 1/8 inch deep at the point of impact. Point of impact as per the setup, 4 inches from front end and on top.

Post Test Initial Assessment.

- The damage caused by the test indicates the test specimens meet the requirements of the test.

6.0 Four Foot Free Drop Test Data

Test performed on test specimen serial number P01 only.

Damage Description.

- The rear end of the shell lip bent up towards the lock assembly. Bend of the shell lip approximately ½ inch out of original location.
- The front end of shell has a slight, ¼ inch dent.

Post Test Initial Assessment.

- The damage caused by the test indicates the test specimens meet the requirements of the test.

Function Check.

- The dummy source easily cycles in and out of the package without hindrance.

7.0 Radiation Measurement Data (Serial number P01 only)

Radiation measurements taken on the test specimen consisted of slowly scanning over the surface and at a meter of the package. The highest measured readings are recorded for each quadrant and each end.

A 147-curie source was used for the pre-test radiation measurements. This produced surface readings on the shell below 200 mR/hr and port readings on the ends under 300 mR/hr. One-meter readings around the shell were below 1 mR/hr and at or under 2 mR/hr at the ends.

A 128-curie source was used for the post-test radiation measurements. This produced the same results as the pre-test measurements with very little difference between each measured point.

Factored for a 27-curie source, the maximum intensity is calculated to be under 50 mR/hr at the surface and under 0.4 mR/hr at a meter.

8.0 Post Test Final Assessment.

The test specimen was tested in accordance with test plan #100 and therefore tested to the normal transport test requirements of DOT 49CFR173, NRC 10CFR71, and IAEA Safety Series 6 (As amended 1990). The model 880-transport package sustained very little damage and remained intact.

The dummy source remained secured in its fully shielded position within the source tube, attached to the source wire and undamaged.

The radiation profile results for a 27.0 curie, IR192 source is less than 200 mR/hr at the package's surface and there is no significant increase between initial profile measurements and post-test profile measurements.

Based on the above results, the model-880 prototype build passes the normal transport test requirements of 49CFR173, 10CFR71, and IAEA Safety Series 6 (As amended 1990).

TP#100
RESULTS
SG 25FEB00

RADIATION MEASUREMENT SUMMARY

10-Feb-00 150 Curie Max Activity Capacity
147.3 Curie Activity Used

S/N P01	Direct At Surface	Surface Factor	Direct At Meter	Capacity Factor	Corrected At Surface	Corrected At Meter
Top	95	1.27	0.5	1.02	123	0.5
Right	110	1.27	0.5	1.02	142	0.5
Front	250	1.10	2.0	1.02	280	2.0
Left	150	1.27	0.6	1.02	194	0.6
Rear	230	1.10	1.3	1.02	258	1.3
Bottom	145	1.27	0.8	1.02	188	0.8

25-Feb-00 150 Curie Max Activity Capacity
128 Curie Activity Used

S/N P01	Direct At Surface	Surface Factor	Direct At Meter	Capacity Factor	Corrected At Surface	Corrected At Meter
Top	130	1.27	0.6	1.17	193	0.7
Right	110	1.27	0.6	1.17	164	0.7
Front	210	1.10	1.6	1.17	271	1.9
Left	110	1.27	0.5	1.17	164	0.6
Rear	170	1.10	1.4	1.17	219	1.6
Bottom	120	1.27	0.7	1.17	179	0.8

25-Feb-00 27 Curie Max Activity Capacity
128 Curie Activity Used

S/N P01	Direct At Surface	Surface Factor	Direct At Meter	Capacity Factor	Corrected At Surface	Corrected At Meter
Top	130	1.27	0.6	0.21	35	0.1
Right	110	1.27	0.6	0.21	29	0.1
Front	210	1.10	1.6	0.21	49	0.3
Left	110	1.27	0.5	0.21	29	0.1
Rear	170	1.10	1.4	0.21	39	0.3
Bottom	120	1.27	0.7	0.21	32	0.1

SENTINEL

"880 Prototype"

SHIELDING PROFILE AND INSPECTION FORM

WI-Q09 Work Sheet

COPY

Model: 880 Serial Number: PO1 Radionuclide: IR 192 Max.Capacity: 150 Ci

Shield Data

Shield Heat#: 38909-1	Mass of Shield: 33.50 Lbs.	Lot #: 00024-1

Initial Profile

Source Model: ________ Source SN: ________ Activity: ________ Ci

Survey Inst.: ________ SN: ________ Date Cal.: ________ Date Due: ________

Surface	Observed Intensity mR/hr	Surface Correction Factor		Adjusted Intensity mR/hr
Top			N/A	
Right			Capacity Correction Factor: ____	
Front				
Left				
Rear				
Bottom				

Inspector: ________ Date: ________ NCR #: ________

Final Profile

Source Model: 424-9 Source SN: D2879 Activity: 147.3 Ci Mass of Device: ________ Lbs.

Survey Inst.: AN/PDR27T SN: SM392401 Date Cal.: 10 May 99 Date Due: 10 May 00

Surface	Observed Intensity mR/hr: At Surface	Surface Corr. Factor	At One Meter	6"		Adjusted Intensity mR/hr: At Surface	At One Meter	6"
Top	95	1.27	12	.5	Capacity Correction Factor: 1.01	122	12.1	.5
Right	110	1.27	15	.5		141	15.1	.5
Front	250	1.10	40	2.0		278	40.4	2.0
Left	150	1.27	17	.6		192	17.1	.6
Rear	230	1.10	45	1.3		256	45.4	1.3
Bottom	145	1.27	20	.8		186	20.2	.8

Inspector: MBoyd Date: 10 Feb 00 NCR #: N/A

QI6-1/1

Comments: MBoyd

~~wees~~ Start/Locked Position: .392

Amersham QSA

SENTINEL

SHIELDING PROFILE AND INSPECTION FORM

Model: 880 Serial Number: P01 Radionuclide: IR 192 Max.Capacity: 150 Ci

Shield Data		
Shield Heat#:	Mass of Shield: Lbs.	Lot #:

Initial Profile

Source Model: Source SN: Activity: Ci

Survey Inst.: SN: Date Cal.: Date Due:

Surface	Observed Intensity mR/hr	Surface Correction Factor		Adjusted Intensity mR/hr
Top			N/A	
Right			Capacity Correction Factor:	
Front				
Left				
Rear				
Bottom				

Inspector: Date: NCR #:

Final Profile

Source Model: 424-9 Source SN: D2879 Activity: 128.0 Ci | Mass of Device: Lbs.

Survey Inst.: AN/PDR27T SN: SM392401 Date Cal.: 10 MAY 99 Date Due: 10 MAY 00

Surface	Observed Intensity mR/hr: At Surface	Surface Corr. Factor	At One Meter		Adjusted Intensity mR/hr: At Surface	At One Meter
Top	130	1.27	.6		193	.7
Right	110	1.27	.6		163	.7
Front	210	1.10	1.6	Capacity Correction Factor: 1.17	270	1.9
Left	110	1.27	.5		163	.6
Rear	170	1.10	1.4		219	1.6
Bottom	120	1.27	.7		178	.8

Inspector: Dave [signature] Date: 25 feb 00 NCR #:

016-1/1

Comments:

Amersham QSA

Appendix A. Test Data.

Compression Test
49 CFR 173.465(d)

Test Specimen:

Drawing No. TP100 Rev. A Serial Number: P01

Weight: 42.95 lbs. Scale used: OHAUS # 35014

Test Setup:

Photograph setup

Use Figure 2 to position the specimen and apply the compressive load.

Setup verified by: Dave Ammis Date: 23 feb 00

Compressive Load:

Weight: 459 lbs Scale used: Port Beam Scale # L482397

Test Period:

Start date & time: 23 feb 00 12:05 PM Ambient Temp. 73.4 °F Gage used: OMEGA HH21 #ENG-12

Stop date & time: 24 feb 00 12:30 PM Ambient Temp. 73.1 °F Gage used: OMEGA HH21 #ENG-12

Damage description:

Photograph damage (if present)

NO DAMAGE

Post test initial assessment:

NO DAMAGE THEREFORE INITIAL INDICATIONS ARE THE TEST SPECIMEN MEETS THE REQUIREMENTS OF THIS TEST.

Recorded by: Dave Ammis	Date: 24 feb 00
Witnessed by: [signature]	Date: 24 Feb 00
Quality Assurance Review by: Daniel W. Kurtz	Date: 24 Feb 00

Notes:

Compression Test
49 CFR 173.465(d)

Test Specimen:

Drawing No. TP100 Rev. A Serial Number: P02

Weight: 43.00 lbs Scale used: OHAUS # 35014

Test Setup:

Photograph setup

Use Figure 2 to position the specimen and apply the compressive load.

Setup verified by: Dave [signature] Date: 23 feb 00

Compressive Load:

Weight: 459 lbs. Scale used: Port Beam Scale #L482397

Test Period:

Start date & time: 23 feb 00 12:05 PM Ambient Temp. 73.4°F Gage used: OMEGA HH21 #ENG-12

Stop date & time: 24 feb 00 12:30 PM Ambient Temp. 73.1°F Gage used: OMEGA HH21 #ENG-12

Damage description:

Photograph damage (if present)

NO DAMAGE

Post test initial assessment:

NO DAMAGE THEREFORE INITIAL INDICATIONS ARE THE TEST SPECIMEN MEETS THE REQUIREMENTS OF THIS TEST

Recorded by: Dave [signature]	Date: 24 feb 00
Witnessed by: [signature]	Date: 24 FEB 00
Quality Assurance Review by: Daniel W. [signature]	Date: 24 Feb 00

Notes:

Penetration Test **49 CFR 173.465 (e)**
Test Specimen: Drawing No. TP100 Rev. A Serial Number: P01
Test Setup: Photograph Setup Use Figure 3 to position specimen, locate impact point and set drop height (40 inches). Setup verified by: [signature] Date: 24 feb 00
Penetration Bar: Drawing No. BT10129 Rev. B Weight: 13.4 lbs SN 1
Test Period: Date & time: 24 feb 00 2:53 PM Ambient Temp. 58° F Gage used: OMEGA HH-21 ENG-12
Specimen Damage: Photograph Damage (if present) DENT .134 DEEP
Post test initial assessment: MINOR DAMAGE INDICATES THE TEST SPECIMEN MEETS THE REQUIREMENTS OF THIS TEST.

Recorded by: [signature]	Date: 24 feb 00
Witnessed by: [signature] / [signature]	Date: 24 FEB 00 / 24 FEB 00
Quality Assurance Review by: [signature]	Date: 24 FEB 00

Notes:

Free Drop Test
49 CFR 173.465 (c)

Test Specimen:

Drawing No. TP100 Rev. A Serial Number: P01

Pretest weight 42.95 lb. Scale Used 35014

Test Setup:

Photograph Setup

Use Figure 4 to position specimen, locate impact point and set drop height (4 feet).

Setup verified by: Dave Aunt Date: 24 feb 00

Drop surface:

Drawing No. A T10122 Rev. B Location: VALLY TREE GROVELAND, MA

Test Period:

Date & time: 24 Feb 00 3:00 PM Ambient Temp. 59° F Gage used: OMEGA HH81 #ENG-12

Specimen Damage:

Photograph Damage (if present)

Post test weight 42.90 lbs Scale Used 35014

*** Post test initial assessment:**

DAMAGE:
REAR OF DEVICE SHELL MATERIAL ROLLED APPROX 1/2" (DENTED)
FRONT OF DEVICE SHELL MATERIAL SLIGHTLY BENT APPROX 1/4"

Recorded by: Dave Aunt	Date: 24 feb 00
Witnessed by: Steve Bruni / [illegible]	Date: 24 Feb 00 / 24 Feb 00
Quality Assurance Review by: Dennis W. Kunt	Date: 24 Feb 00

Notes:

* MINOR DAMAGE INDICATES THE TEST SPECIMEN MEETS THE REQUIREMENTS OF THIS TEST.

FUNCTIONAL TEST: DUMMY SOURCE PROJECTS AND SECURES WITHOUT HINDERANCE.

DW 24 feb 00
SB 24 Feb 00
[illegible] 24 Feb 00 [illegible]

Final Test Assessment
49 CFR 173.412 (j)

Test Specimen:

Model 880 Serial Number(s): P01

Loss or Dispersal of Radioactive Contents:

Did the source capsule remain within the source tube, attached to the source wire and undamaged? Yes

Verified by: [signature] Date: 25 feb 00

Increase in radiation levels: * FOR 27 CURIES OF IR192

Are the final radiation profile results less than 200 mR/hr at the package's surface? Yes *

Is there a significant increase between pre-test profile measurements and post-test profile measurements? NO

Verified by: [signature] Date: ~~24~~ (DW) 25 feb 00 25 feb 00

Comments:

Engineering Review by: S. G[signature]	Date: 25 Feb 00
Regulatory Review by: [signature]	Date: 25 Feb 00
Quality Assurance Review by: D.W. K[signature]	Date: 25 Feb 00

W/O M107730 + Q89650

Description of nonconformance	Disposition	Prod.	Eng.	Insp.
DWG A88012 REV 1 TRIGGER ASSEMBLY (1) PARTS NOT AVAILABLE FOR ASSEMBLY S/N P01 + P02	USE WITHOUT	RWE 23 Feb 00	SD 23 Feb 00	DW 23 feb 00
DWG. B88013 REV 1 LOCK MOUNT ASSEMBLY (1) TRIGGER ASSEMBLY NOT INCLUDED. (2) TRIGGER ASSY SCREW NOT INCLUDED. S/N P01 + P02	USE WITHOUT TRIGGER ASSY	RWE 23 Feb 00	SD 23 Feb 00	DW 23 feb 00
DWG B88011 REV. 2 BODY WELDMENT (1) TUBE SLEEVE (A88006) GLUED TO FRONT + REAR ENDPLATES. (2) SHIELD SPACER (A88005) TAPED TO SHIELD. (3) BOTH ENDS OF STUBE RADIUS + DEBURRED ON INSIDE TO REMOVE SHARP EDGES. (4) STAMPED SERIAL NUMBER TO ENDPLATE S/N P01 + P02	UPDATE DWGS	RWE 23 Feb 00	SD 23 Feb 00	DW 23 feb 00
DWG B88020 REV. 1 REAR PLATE ASSEMBLY (1) STAMPED SERIAL NO. ON BACK. (2) TORQUED ITEM 12 TO 30 IN-LBS [illegible] (3) ADDED VIBRATITE TO ITEMS 12 + 13. (4) LUBRICATED ITEMS 5 + 8 (5) SLIDE CHANGED TO REV. 3, DWG A88024. S/N P01 + P02	UPDATE DWGS. — TORQUE WRENCH:	RWE 23 Feb 00	SD 23 Feb 00	DW 23 feb 00
DWG B88030 REV 1. FRONT PLATE ASSEMBLY (1) REPLACED PIN TO DWG A88037 REV 3. (2) MODIFIED ROTOR TO DWG B88032 REV 5. (3) MODIFIED KNOB TO DWG A88033 REV. 2 (4) ADDED GRIP KNOB PER DWG A88038 REV 1 (5) ADDED PIVOT DISK PER DWG A88039 REV 1 (6) ADDED FLAT HD SCREWS	UPDATE DWGS. S/N P01 ONLY.	RWE 23 Feb 00	SD 23 Feb 00	DW 23 feb 00

w/o M107730 + Q89650

~~	Description of nonconformance	Disposition	Prod.	Eng.	Insp.
	DWG. TP100 + TP104 TEST SPECIMEN DWG. (1) ADDED ANTI-SIEZE TO 5/16 BOLTS. (2) ADDED RELIEF TO LOCK PLATES TO CLEAR WELD (1/16 High AT Bottom Lip between BOLT Holes) S/N P01 + P02	UPDATE DWG	R209 23Feb00	(SL) 23Feb00	(DW) 23 feb 00

SENTINEL

ROUTE CARD

QC NA | Complete Lot: / | Total WO Qty.: 2 | Serial No: P01

CM. | Split Lot: ✓ | Rte. Cd. Qty.: 1 | Lot No: NA

Part # TP100		Description MODEL 880 TEST UNIT TYPE A		Dwg TP100			Rev A	WO Q89650
Oper. Seq.	Department	Operation Description	By	Date	Qty Acc	Qty Rej	Reference	Comments
0010	ASSY / MS	ASSEMBLE PER NOTES 1-4	RWE	23 Feb 00			TP100	
020	QC	INSPECTION	DW	23 feb 00	1	0	SOP-Q015	
030	QA	QA REVIEW	[signature]	23 Feb 00			SOP-Q025 & TP100	
040	IC	STOCKROOM PROCESSING	AC	23Feb00			SOP-M002	
		DELIVER TO QC FOR						
		TESTING						

Drawing	Checklist	Initials	WI-Step	Checklist	Initials	WI-Step	Checklist	Initials
TP100	NOTE 1. TORQUE 110 +/-5" LBS.	RWE DW						
TP100	NOTE 3 TOTAL WEIGHT	42.95						
		DW 23 feb 00						

ENGINEERING: S. G[signature] 23 Feb 00 | REGULATORY: [signature] 23 Feb 00 | MATERIALS: Alan Cain 23 Feb 00

PRODUCTION: RW Evans 23 Feb 00 | QUALITY ASSURANCE: D.W. Kurtz 23 Feb 00 | ISSUE NUMBER: 1

QP25-1/2

NTINEL

NO	DESCRIPTION OF NONCONFORMANCE	DISPOSITION	INDIV/ DATE	INSP/DATE	PART NUMBER	DESCRIPTION	CM	SERIAL/ LOT NO.	INITIALS	DATE
					88011	BODY WELDMENT	A	P01	RWE	23 Feb 00
					88020	REAR PLATE ASSY.	A	P01	RWE	23 Feb 00

MTE SN	MTE DESCRIPTION	CAL DUE DATE	INITIALS	DATE
ASSY/15	TORQUE WRENCH	4-2-00	RWC	23 Feb 00
35014	SCALE	11-24-00	(TD)	23 Feb 00

CHANGE VERIFICATION

PART NUMBER	DESCRIPTION	REV	ECO	INDIVIDUAL	VERIFIED

SIMCO electronics
127 RIVERNECK ROAD
CHELMSFORD, MA 01824

DA 21 OCT 99 Certificate No. 1054915

KEMA CERTIFIED
ISO 9002 REGISTERED
CERT.NO. 10458.01

CERTIFICATE OF CALIBRATION FOR AEA TECHNOLOGIES

Description: **OMEGA ENGINEERING, HH21, MICROPROCESSOR THERMOMETER**

Serial No: **T179139** Asset No: **ENG-12** Simco ID: **24948-10**

Dept: **NONE** PO No: **P4732-00**

Calibration Date: 10/18/99	Calibration Interval: 12 Months	Recall Date: 10/18/00

Arrival Condition:	Service:
MEETS MANUFACTURER'S SPEC'S.	CLEAN/CALIBRATE TO MFR'S SPEC

Procedure: **PER MFRS. SPEC** Cal Ratio: **2.00:1**
Temperature: **67°F** Relative Humidity: **38%**

Standards Used:

Type	Simco ID	Due Date	Intvl Mos	Accuracy	NIST No
POTENTIOMETER	23565*210	01/08/00	6	+/-12uV	413348
POTENTIOMETER	23565*210	01/08/00	6	+/-0.6'C	255343

Work performed by: DA
Duane A. Archambault
Technician (11468)

Reviewed by:
Phillip A. Maltais P. Maltais
Lab Supervisor

All calibrations are performed using internationally recognized standards traceable to the National Institute of Standards and Technology (NIST) or the National Physical Laboratory (NPL), or using natural physical constants or ratio calibration techniques. Our calibration system complies with MIL-STD-45662A and ANSI/NCSL Z540-1. The information shown on this certificate applies only to the instrument identified above and may not be reproduced, except in full, without prior written consent from SIMCO Electronics.
Dated: 10/18/99

```
Customer: AEA TECHNOLOGY                                              P.O. No.: P4634-00
                                                                      Date Cal: 11/24/99
    ID.No.: 268                Manufacturer: TOLEDO                   Date Due: 11/24/00
  2 ID.No.:                      Serial No.: 2642125-2VT            Technician: DD
Department:                       Model No.: 8582                Cal. Proc. No: 01
Deviation u.:                  Standard No.: 018          Cal.: 03/24/99   Due: 03/24/00
  Accuracy: +/-4%              Standard No.:              Cal.:            Due:
  Accuracy:                    Standard No.:              Cal.:            Due:
                               Standard No.:              Cal.:            Due:
 Gage Type: 0-10.0lb SCALE
           :
 Required: :  0     1.0     2.0     5.0     7.0     10.0 lb
Deviation: :
 Measured: : REF   1.000   2.000   5.000   7.000   10.000 lb
           :---------------------------------------------------------------

Customer: AEA TECHNOLOGY                                              P.O. No.: P4634-00
                                                                      Date Cal: 11/24/99
    ID.No.: 269                Manufacturer: NCI                      Date Due: 11/24/00
  2 ID.No.:                      Serial No.: SR878400111            Technician: DD
Department:                       Model No.: 8300                Cal. Proc. No: 01
Deviation u.:                  Standard No.: 018          Cal.: 03/24/99   Due: 03/24/00
  Accuracy: +/-4%              Standard No.:              Cal.:            Due:
  Accuracy:                    Standard No.:              Cal.:            Due:
                               Standard No.:              Cal.:            Due:
 Gage Type: 0-10.0lb DIGITAL SCALE
           :
 Required: :  0     1.0     2.0     5.0     7.0     10.0lb
Deviation: :
 Measured: : REF   1.000   2.000   5.002   7.002   10.002lb
           :---------------------------------------------------------------

Customer: AEA TECHNOLOGY                                              P.O. No.: P4634-00
                                                                      Date Cal: 11/24/99
    ID.No.: 3500               Manufacturer: DILLON                   Date Due: 11/24/00
  2 ID.No.:                      Serial No.: D-3500                 Technician: DD
Department:                       Model No.:                     Cal. Proc. No: 22
Deviation u.:                  Standard No.: 018          Cal.: 03/24/99   Due: 03/24/00
  Accuracy: +/-4%              Standard No.: 031          Cal.: 02/23/95   Due: 02/23/00
  Accuracy:                    Standard No.:              Cal.:            Due:
                               Standard No.:              Cal.:            Due:
 Gage Type: 0-500lb FORCE GAGE
           :
 Required: :  0     50.0    100.0    150.0    200.0 lb
Deviation: :
 Measured: : REF   51.0    103.0    153.0    202.0 lb
           :---------------------------------------------------------------

Customer: AEA TECHNOLOGY                                              P.O. No.: P4634-00
                                                                      Date Cal: 11/24/99
    ID.No.: 35014              Manufacturer: O'HAUS                   Date Due: 11/24/00
  2 ID.No.:                      Serial No.: 35014                  Technician: DD
Department:                       Model No.: DS10                Cal. Proc. No: 01
Deviation u.:                  Standard No.: 018          Cal.: 03/24/99   Due: 03/24/00
  Accuracy: +/-4%              Standard No.: 031          Cal.: 02/23/95   Due: 02/23/00
  Accuracy:                    Standard No.:              Cal.:            Due:
                               Standard No.:              Cal.:            Due:
 Gage Type: 0-110lb DIGITAL SCALE
           :
 Required: :  0     5.0     10.0     20.0     50.0     70.0     100.0lb
Deviation: :
 Measured: : REF   5.00    10.00    20.00    50.00    69.95    100.00lb
           :---------------------------------------------------------------
```

CERTIFICATE OF CALIBRATION

Test and Inspection Report prepared by ~~Commercial Scale Control~~ METTLER TOLEDO

This is to certify that the undersigned has inspected the following for

AEA TECHNOLOGIES

Make NES

Capacity 2000 LB.

Grad Size .5

Type PORT BEAM SCALE

Model No. PORT BEAM

Serial No. L 482397

Location ASSEMBLY-11

I. D. No.

SCALE READINGS

STANDARD'S USED	BEFORE ADJUSTMENTS	AFTER ADJUSTMENTS		
0	0	N/A		
500 LB.	500.0			
1000 "	1000.0			
1500 "	1498.0			

☑ **SCALE PASSES** ☐ **DOES NOT PASS**

This is to certify that the weighing device identified above has been calibrated using certified test weight traceable to the National Institute of Standards and Technology (formerly NBS) and is guaranteed accurate to the tolerance indicated. Traceability # 12691 CT.

Inspection in accordance with National Bureau of Standard Handbook 44 and Mil Standard C-45662A.

Additional Data:

Scale Inspector Carmine J Belleville Date: 11-22-99

Company METTLER TOLEDO Due Date: 5-22-2000

Service Report / Order No.

Customer: AEA TECHNOLOGY   P.O. No.: 3753
Date Cal: 04/01/99
ID.No.: 273 A&B   Manufacturer: THREADS, INC.   Date Due: 04/01/00
2 ID.No.:   Serial No.:   Technician: PR
Department: Model No.:   Cal. Proc. No: 15
Deviation u.:   Standard No.: 006   Cal.: 02/10/99   Due: 08/31/99
Accuracy: GO +0.000 20"   Standard No.: 021   Cal.: 02/10/99   Due: 08/31/99
Accuracy: NG -0.000 20"   Standard No.:   Cal.:   Due:
Standard No.:   Cal.:   Due:
Gage Type: GO/NO GO PLAIN PLUG SET

:	GO		NO GO	
Required: :	0.6250"		0.6256"	
Deviation: :	+0.00001"	+0.00001"	-0.00001"	-0.00001"
Measured: :	+0.62501"	+0.62501"	-0.62559"	-0.62559"

:--

Customer: AEA TECHNOLOGY   P.O. No.: 3753
Date Cal: 04/01/99
ID.No.: 285 A&B   Manufacturer: REGAL BELOIT   Date Due: 04/01/00
2 ID.No.:   Serial No.:   Technician: PR
Department: Model No.:   Cal. Proc. No: 15
Deviation u.:   Standard No.: 011   Cal.: 03/23/99   Due: 06/30/99
Accuracy: GO -0.000 30"   Standard No.:   Cal.:   Due:
Accuracy: NG +0.000 30"   Standard No.:   Cal.:   Due:
Standard No.:   Cal.:   Due:
Gage Type: 1.0"-8 UN-2A THREAD RING SET   (SET PLUG PASSES)

:	GO	NO GO
Required: :	0.9168"	0.9100"
Deviation: :	0.0000"	0.0000"
Measured: :	0.9168"	0.9100"

:--

Customer: AEA TECHNOLOGY   P.O. No.: 3753
Date Cal: 04/01/99
ID.No.: ASSY-1   Manufacturer: MITUTOYO   Date Due: 04/01/00
2 ID.No.:   Serial No.:   Technician: PR
Department: MACHINE SHOP   Model No.: 101-105   Cal. Proc. No: 03
Deviation u.:   Standard No.: 026   Cal.: 02/10/99   Due: 08/31/99
Accuracy: +/-0.000 10"   Standard No.:   Cal.:   Due:
Accuracy: Standard No.:   Cal.:   Due:
Standard No.:   Cal.:   Due:
Gage Type: 0-1.0" OD MICROMETER

:							
Required: :	0	0.100"	0.115"	0.250"	0.500"	0.750"	1.000"
Deviation: :	REF	0	0	0	0	0	0
Measured: :	REF	0.1000"	0.1150"	0.2500"	0.5000"	0.7500"	1.0000"

:--

Customer: AEA TECHNOLOGY   P.O. No.: 3753
Date Cal: 04/02/99
ID.No.: ASSY-15 (A)   Manufacturer: CRAFTSMAN   Date Due: 04/02/00
2 ID.No.:   Serial No.:   Technician: PR
Department: Model No.: 44593   Cal. Proc. No: 23
Deviation u.:   Standard No.: 158   Cal.: 07/06/98   Due: 07/06/99
Accuracy: +/-4%   Standard No.: 159   Cal.: 07/06/98   Due: 07/06/99
Accuracy: Standard No.: 160   Cal.: 07/06/98   Due: 07/06/99
Standard No.:   Cal.:   Due:
Gage Type: 25.250 in/lb TORQUE WRENCH   C.W.   (PART 1 OF 2)

:							
Required: :	25.0	50.0	75.0	100.0	150.0	200.0	250.0 lb
Deviation: :	+0.32	+0.63	-0.74	+0.3	+2.4	+5.0	+4.1 lb
Measured: :	25.32	50.63	74.26	100.3	152.4	205.0	254.1 lb

:--

Customer: AEA TECHNOLOGY
P.O. No.: 3753
Date Cal: 04/02/99
ID.No.: ASSY-15 (B) Manufacturer: CRAFTSMAN Date Due: 04/02/00
2 ID.No.: Serial No.: Technician: PR
Department: Model No.: 44593 Cal. Proc. No: 23
viation u.: Standard No.: 158 Cal.: 07/06/98 Due: 07/06/99
Accuracy: +/-4% Standard No.: 159 Cal.: 07/06/98 Due: 07/06/99
Accuracy: Standard No.: 160 Cal.: 07/06/98 Due: 07/06/99
Standard No.: Cal.: Due:
Gage Type: 25.250 in/lb TORQUE WRENCH C.C.W. (PART 2 OF 2)

Required:	25.0	50.0	75.0	100.0	150.0	200.0	250.0 lb
Deviation:	-0.51	+1.02	+1.26	+2.1	+3.6	+4.8	+6.1 lb
Measured:	24.49	51.02	76.26	102.1	153.6	204.8	256.1 lb

Customer: AEA TECHNOLOGY
P.O. No.: 3753
Date Cal: 04/01/99
ID.No.: ASSY-2 Manufacturer: MITUTOYO Date Due: 04/01/00
2 ID.No.: Serial No.: Technician: PR
Department: MACHINE SHOP Model No.: 505-644-50 Cal. Proc. No: 16
Deviation u.: Standard No.: 026 Cal.: 02/10/99 Due: 08/31/99
Accuracy: +/-0.0010" Standard No.: 088 Cal.: 02/10/99 Due: 08/31/99
Accuracy: Standard No.: 137 Cal.: 02/10/99 Due: 02/28/00
Standard No.: Cal.: Due:
Gage Type: 0-8.0" DIAL CALIPER

Required:	0	PARA	ID	OD	1.0"	2.0"	4.0"	6.0"	8.0"
Deviation:	REF	.0005	+.0005		+.0005	+.0005	+.0005	-.0010	-.0010
Measured:	REF	.0005	1.0005"		1.0005"	2.0005"	4.0005"	5.9990"	7.9990"

Customer: AEA TECHNOLOGY
P.O. No.: 3753
Date Cal: 04/01/99
ID.No.: ASSY-4 (A) Manufacturer: MITUTOYO Date Due: 04/01/00
2 ID.No.: Serial No.: Technician: PR
Department: MACHINE SHOP Model No.: 505-628-50 Cal. Proc. No: 16
Deviation u.: Standard No.: 027 Cal.: 02/10/99 Due: 08/31/99
Accuracy: +/-0.0010" Standard No.: 088 Cal.: 02/10/99 Due: 08/31/99
Accuracy: Standard No.: 134 Cal.: 02/10/99 Due: 02/28/00
Standard No.: Cal.: Due:
Gage Type: 0-12.0" DIAL CALIPER (PART 1 OF 2)

Required:	0	PARA	ID	OD	1.0"	2.0"	4.0"
Deviation:	REF	.0010	-.0010		-.0010	-.0010	-.0010
Measured:	REF	.0010	0.9990		0.9990"	1.9990"	3.9990"

Customer: AEA TECHNOLOGY
P.O. No.: 3753
Date Cal: 04/01/99
ID.No.: ASSY-4 (B) Manufacturer: MITUTOYO Date Due: 04/01/00
2 ID.No.: Serial No.: Technician: PR
Department: MACHINE SHOP Model No.: 505-628-50 Cal. Proc. No: 16
Deviation u.: Standard No.: 027 Cal.: 02/10/99 Due: 08/31/99
Accuracy: +/-0.0010" Standard No.: 088 Cal.: 02/10/99 Due: 08/31/99
Accuracy: Standard No.: 134 Cal.: 02/10/99 Due: 02/28/00
Standard No.: Cal.: Due:
Gage Type: 0-12.0" DIAL CALIPER (PART 2 OF 2)

Required:	6.0"	8.0"	10.0"	12.0"
eviation:	-.0010	-.0010	-.0010	-.0010
leasured:	5.9990"	7.9990"	9.9990"	11.9990"

SENTINEL

ROUTE CARD

QC ... # 11930 | Complete Lot:______ | Total WO Qty.: 10 | Serial No: P01

Split Lot:______ | Rte. Cd. Qty.: 1 | Lot No: NA

FOR PROTOTYPE FABRICATION ONLY

Part # ~~88000~~ TP100 + TP104 23 Feb 00 | Description (TEST SPECIMEN) MODEL 880 ASSEMBLY | Dwg TP100 + TP104 ~~B88000~~ | Rev YA | WO M107730

Oper. Seq.	Department	Operation Description	By	Date	Qty Acc	Qty Rej	Reference	Comments
010	MS	WELD	DRD	3 FEB 00			A88010	REV.2
020	QC	INSPECT	MRB	3 Feb 00	2 ~~0~~	~~0~~ 2	A88010	REV.2 LOT# QCL#11852
030	MS/ ASSY.	ASSEMBLE	—	NA	—		A88012	REV.1 (SEE ATTACHED)
			23 Feb 00	RWE			B88013	REV.1
			RWE	23 Feb 00			B88020	REV.1
			RWE	23 Feb 00			B88030	REV.1
040	QC	INSPECT	—	NA	—	—	A88012	REV.1
			DW	23 Feb 00	1	0	B88013	REV.1
			DW	23 Feb 00	1	0	B88020	REV.1 LOT# SN 135 00054-1
			DW	23 Feb 00	1	0	B88030	REV.1
050	MS	ASSEMBLE	DFW	4 FEB 00			B88011	REV. 2 WI-AS48
060	QC	ENDPLATES PROPERLY ATTACHED TO SHIELD	[illegible]	4 Feb 00	1	0	B88011	REV.2 LOT# P01
070	MS/ASSY	TACK WELD & ASSEMBLE	DRD	4 FEB 00			B88011	REV.2 WI-AS48
080	QC	*INSPECT & INITIAL PROFILE	MRB	10 Feb 00	0	1	B88011	REV.2 *Tack Welds
090	MS	WELD, FOAM & ASSEMBLE	DRD RWE	11 FEB 00 17 Feb 00	1		~~B88000~~ TP100	REV ~~1~~ A B88011 REV.2 WI-AS48, AS40
100	QC	~~FINAL INSPECTION~~ Weld Only	MRB	17 Feb 00	~~1~~ 1	~~0~~ 0	UAE 17 Feb 00 ~~B88000~~ TP100	Undercut/Oversize QCL 11956 REV. A
110	QC	~~FINAL PROFILE~~	Process Shifted				TP100 ~~B88000~~	REV. YA
120	QA	~~QA REVIEW~~	to TP100 + TP104				SOP-Q025	
130	IC	STOCKROOM PROCESSING	Route Card				SOP-M02	

DW 23 Feb 00

WI-STEP	Checklist	Initials	WI-Step	Checklist	Initials	Drawing #	Checklist	Initials
9.3	PERFORM & VERIFY FINAL CUT OF SHIELD	RWE	9.20	VERIFY S.N. OF SHELL vs. NAMEPLATE AND LABELS	RWE	B88000	TOTAL PACKAGE WEIGHT	DW 42.95 lb
			9.21	TORQUE	RWE			
9.5	VERIFY S.N. OF DEVICE STAMPED ON SHELL	RWE	9.23	FUNCTONAL TEST W/ DUMMY SOURCE	RWE			

ENGINEERING: S-Green 3 Feb 00 | REGULATORY: C. Ronghan 3 Feb 00 | MATERIALS: Alan Cain 3 Feb 00

PRODUCTION: RW Evans 3 Feb 00 | QUALITY ASSURANCE: [signature] 3 Feb 00 | ISSUE NUMBER: 1

38.50 (B88011)

SENTINEL

NO	DESCRIPTION OF NONCONFORMANCE	DISPOSITION	INDIV/DATE	INSP/DATE
1	OP.SEQ 0020 88010 ~~NCR-4939 W-2~~	* NCR 4939 VOIDED MSB 3Feb00 * ~~See NCR~~		
1	NCR# QCL 11852	SUBMIT DCR TO CHG DWG.		
		(1/16 min) (SD) 3Feb00	CMR 3Feb00	
		RWE 3Feb00		
		F 3Feb00		
2	P/N 88037 Rev 2	RWK in MS	[illegible]	F 4 Feb 00
	Rework from 1	DFW 4FEB00		
		(SD) 4Feb00 F 4 Feb 00		
	washer	CMR 4Feb00		
3	add flat washer one on each	F 4Feb00		
	End Plate between	(SD) 4Feb00		
	Cotter Pin + Bracket	CMR 4Feb00		
	(at installation of Pin Asm	RWE 4Feb00		
	P/N 65006-6) 2 per	step 0020		
5	operation .0030 to	Proceed to 0050		
	0050 not performed due	(SD) 7Feb00 F 7Feb00		
	to part availability	RWE 7Feb00		
		CMR 7Feb00		
	IT IS ACCEPTABLE TO GO OUT OF SEQUENCE			
	ON THIS ROUTE CARD FOR PROFILE PURPOSES.			
	A FUNCTIONAL TEST HAS BEEN PERFORMED.			
	DWK 10FEB00	CMR 10Feb00		
		RAM 10Feb00		
		(SD) 10Feb00		
(6)	Fail Initial Profile (See Attached SPI F/G-11/ NCR QCL 11930)	PROCEED to WELD + FINISH ASSY B88011	(SD) 17Feb00	[illegible] 14Feb00
(7)	1/2" [illegible] + 1/[illegible] OVERSIZE	UAI [illegible]		

PART NUMBER	DESCRIPTION	CM	SERIAL/ LOT NO.	INITIALS	DATE
88001	D.U. SHIELD	Heat Lot	38904-1 00024-1	RWE	4Feb00
88004	ENDPLATE	A	LOT 00034-2	DRB	13 FEB 00
88010	ENDPLATE WELD'T.	A	LOT 00034-5	MSB	3 Feb 00
88011	BODY WELDMENT	A	00054-2	DW	23 feb 00
88020	REAR PLATE ASSY.	A	00054-1	DW	23 feb 00
88021	LOCK MTG. PLATE	A	00034-1	DW	23 feb 00
CBL004	7 X 19 CABLE	A	000	RWE	8 Feb 00
SCR003	10-32 X 1 ½ SCREW	A	99139-1	RWE	8 Feb 00
*	WELD ROD	A	LOT 94048-4	DRB	16 FEB 00
*	ac 16 Feb 00 DW 16 Feb 00				

MTE SN	MTE DESCRIPTION	CAL DUE DATE	INITIALS	DATE
ASSY-2	CALIPERS	4-1-00	RWE	4 Feb 00
ASSY-15	TORQUE WRENCH	4-2-00	RWE	23 Feb 00
269	FOAM SCALE	11-24-00	RWE	17 Feb 00
35014	SCALE	11-24-00	DW	23 Feb 00

CHANGE VERIFICATION

PART NUMBER	DESCRIPTION	REV	ECO	INDIVIDUAL	VERIFIED

SEI INEL

TP 100

INSPECTION INSTRUCTION AND RECORD	ORIGINATOR / DATE	REV	PART NO.	SUPPLIER
	[signature] 23 Feb 00	A	TP100	ASSEMBLY
	QA APPROVAL / DATE: [signature] 23 Feb 00	CM A	P/L NA	DESCRIPTION: MODEL 880 TYPE A TEST SPECIMEN

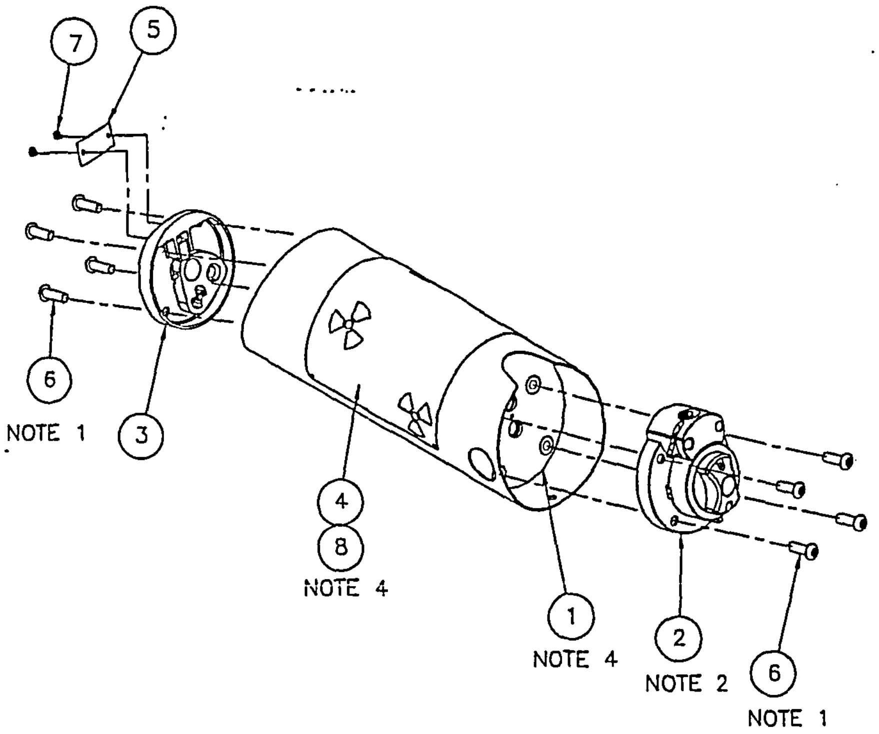
CHARACTERISTICS	TOLERANCE	MTE / SN.	AQL	1	2	3	4	5	6	7	8	9	10
GENERAL VISUAL	NA	NA	C/100%	0/2									
VERIFY ALL ITEMS PRESENT PER DWG.	NA	NA	↓	0/2									
NOTE 1 TORQUE 110 IN LB ± 5	± 5 IN LB	SEE ROUTE CARD	↓	0/2									
NOTE 2 INSTALL DUMMY SOURCE ASSY	NA	NA	↓	0/2									
NOTE 3 RECORD TOTAL WEIGHT	NA	SEE ROUTE CARD	↓	0/2									
NOTE 4 MARK SN ON END PLATE & LABEL	NA	NA	↓	0/2									

COMMENTS:		1	2	3	4	5	6	7	8	9	10
	PO/WO #										
	TRAVELER / QCL #	N/A									
	LOT / SERIAL #	P01 / P02									
	LOT QTY.	2									
	QTY. REJ / NCR #	0 / NA									
	QTY. ACC.	2									
	INSP / DATE	DW 23 Feb 00									

REVISIONS

	EO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2655	INITIAL RELEASE	SEE TITLE BLOCK	

PRODUCTION PRINT
THIS DRAWING FOR USE WITH
ORDER NUMBER Q89650 ONLY.
FEB. 2000
RETURN TO ENGINEERING WITH DCR
IF NOTES ARE ADDED DURING MANUFACTURING.
THIS DRAWING IS NOT TO BE USED FOR PRODUCTION
FOLLOWING THE COMPLETION OF THE WORK ORDER.



ITEM	DRAWING NO.	QTY.	DESCRIPTION
9	42409XL	1	DUMMY SOURCE ASSEMBLY
8	RIV003	4	POP RIVET
7	SCR137	2	BINDER HEAD SCREW, #6-32 X 3/16 LG.
6	SCR154	8	SECURITY SCREW, 5/16-18 X 1-1/2 LG.
5	A88043	1	SOURCE ID TAG
4	B88042	1	LABEL
3	B88030	1	FRONT PLATE ASSEMBLY
2	B88020	1	REAR PLATE ASSEMBLY
1	B88011	1	BODY WELDMENT

NOTES:

1. TORQUE ITEM 6 TO 110 ± 5 IN LB.
2. INSTALL AND SECURE DUMMY SOURCE ASSEMBLY.
3. RECORD TOTAL WEIGHT.
4. MARK SERIAL NUMBER ON ENDPLATE AND LABEL.

MATERIALS: SEE PARTS LIST

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 125
3. TOLERANCES APPLY AFTER PLATING.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: .X ± 0.1; .XX ± 0.01; .XXX ± 0.005; FRACTIONS ± 1/64; MACHINED ANGLES ± 1°

USED ON:

DRAWN S.G.
CHECKED
APPR.

THIRD ANGLE PROJECTION

SAFETY CLASS A

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: MODEL 880 TYPE A TEST SPECIMEN

SIZE B | DWG. NO. TP100 | REV A

SCALE: 1/2 | SHEET 1 OF 1

24 FEB00

TEST PLAN #100 AND #104 DEVIATIONS

(1) ADDED A .094 DIAMETER HOLE IN SHELL AT THE TOP FRONT END OF BOTH TEST SPECIMEN (P01 + P02).
THIS WILL PROVIDE SINGLE POINT HANG FOR THE DROP TESTS.

(SD) 24FEB00
(DW) 24 feb 00
[illegible] 25FEB00
DWK 25 Feb 00

Section 2.12.2 Appendix: Test Plan 108 Issue 5 (Jul 2000).

Issue 5

TEST PLAN 108

MODEL 880

RADIOGRAPHY PROJECTOR TYPE (B) TRANSPORT PACKAGE TESTS

As of

July 13, 2000

Contents

List of Figures and Tables

Test Plan No. 108

Section 1 Introduction

This document describes the mechanical test plan for the Model 880 Projector to meet NRC requirements for Type B(U)-85 packages as described in the Code of Federal Regulations, 10 CFR Part 71, revised as of March 31, 1999. The test plan also covers the criteria stated in the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Series No.6 1985 Edition (As Amended 1990).

This document describes the test package specifications, testing equipment, testing scenario, justifies the package orientations for the different test specimens and provides test worksheets to record key steps in the testing sequence.

Section 2 Transport Package Description

Figure 2.1 describes the Model 880 projector transport package. Figure 2.2 shows the transport package with the plastic jacket.

The radioactive material is sealed in a special form source capsule. The source capsule, stop ball and connector are swaged to a flexible steel wire to form the source wire assembly. The source wire assembly is held securely to the device by components of the rear plate assembly. One of these components, the sleeve, in conjunction with the selector ring retainer, prevents the stop ball of the source wire from being pulled through the rear of the package. Another component, the lock slide, prevents the stop ball from being pushed out of the front when in the secured position. A cover over the source wire connector prevents access to the source assembly until a keyed lock is actuated and the cover removed. This cover is in place during transport of the package. This source assembly securing mechanism is functionally identical to the existing model 660 and 680 projector transport packages.

The selector ring retainer is fastened to the rear plate with four, #10 stainless steel machine screws. The rear plate is attached to rivnuts assembled on the endplate weldment with four 5/16-18 stainless steel security screws. The endplate weldment consists of the endplate disc, a U-shaped bracket and the four rivnuts. The U-brackets are welded to the endplate disc and the endplate disc is welded to the cylindrical shell.

The shield is fastened within the device at each end by a titanium shield pin. The pin passes through the shield and the U-bracket. The shield is centered in the shell and has the source tube cast into its center. The source tube provides a cavity for the source wire assembly to travel through during use. The source capsule is positioned at the center of the ball of the shield within the source tube cavity when the source wire is in its secured position.

The model 880 uses polyurethane foam to fill the cavity around the depleted uranium shield. The foam prevents contamination to and from the depleted uranium shield.

Previous thermal tests have shown charred polyurethane foam will inhibit the flow of oxygen to the shield and prevent oxidation from occurring during a fire as long as the foam remains confined. This is shown on AEA Technology QSA Test plan number 70.

It has also been shown the charred foam will not support the shield at temperatures of 800°C. The model 880 relies on the shield pins to hold the shield in place at all times. These pins are designed to retain the shield throughout testing without the added support of the foam.

The outlet port, located at the front end, serves to block access into or out of the source tube cavity. Four stainless steel security screws fix the front plate to the endplate rivnuts.

The plastic jacket is not part of the Type B transport package and therefore not considered for the type B transport testing. The absence of the jacket will present a worst case 30-foot drop and puncture test condition. In a drop, the plastic jacket protects the transport package from further damage by absorbing energy upon impact.

However, since the jacket will usually be on the package during transport and its weight will add approximately 4lbs, one specimen will be tested with the jacket. The "with jacket" 30-foot drop and puncture orientations will be based on damage observed from previously selected orientations and speculative damaging effects the jacket may have on the safety aspects of the package.

The weight of the Model 880 transport package without the jacket is not greater than 46 pounds. The total weight of the package with the jacket is not greater than 50 pounds.

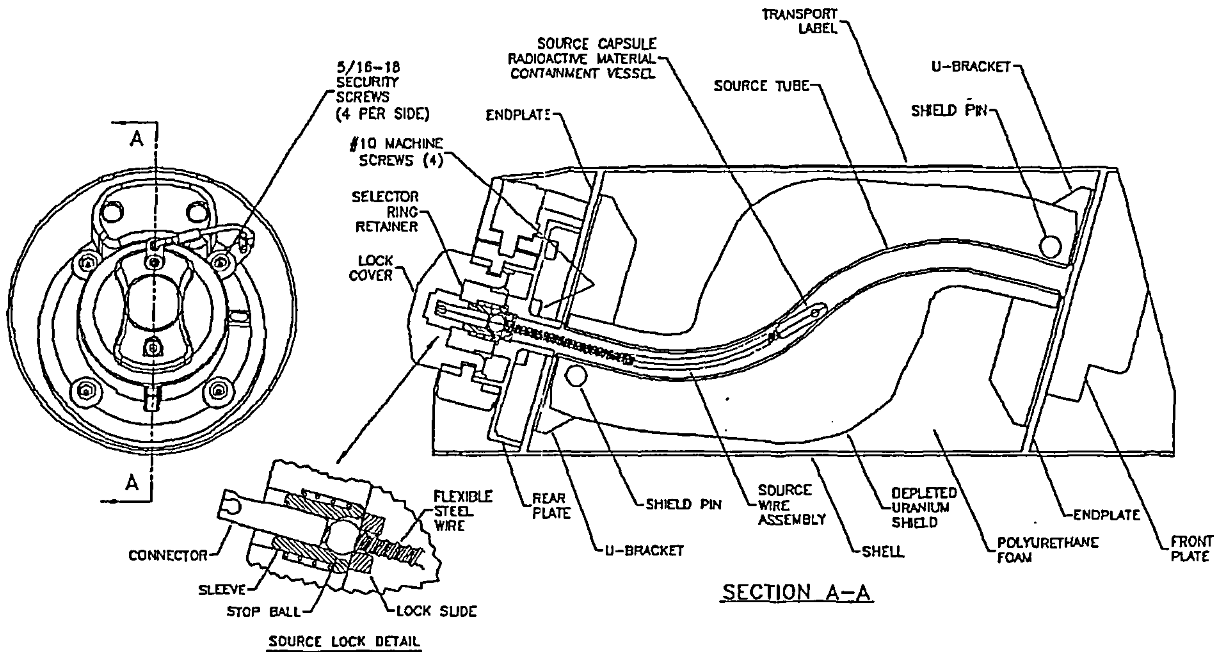


FIGURE 2.1: MODEL 880 PROJECTOR TRANSPORT PACKAGE.

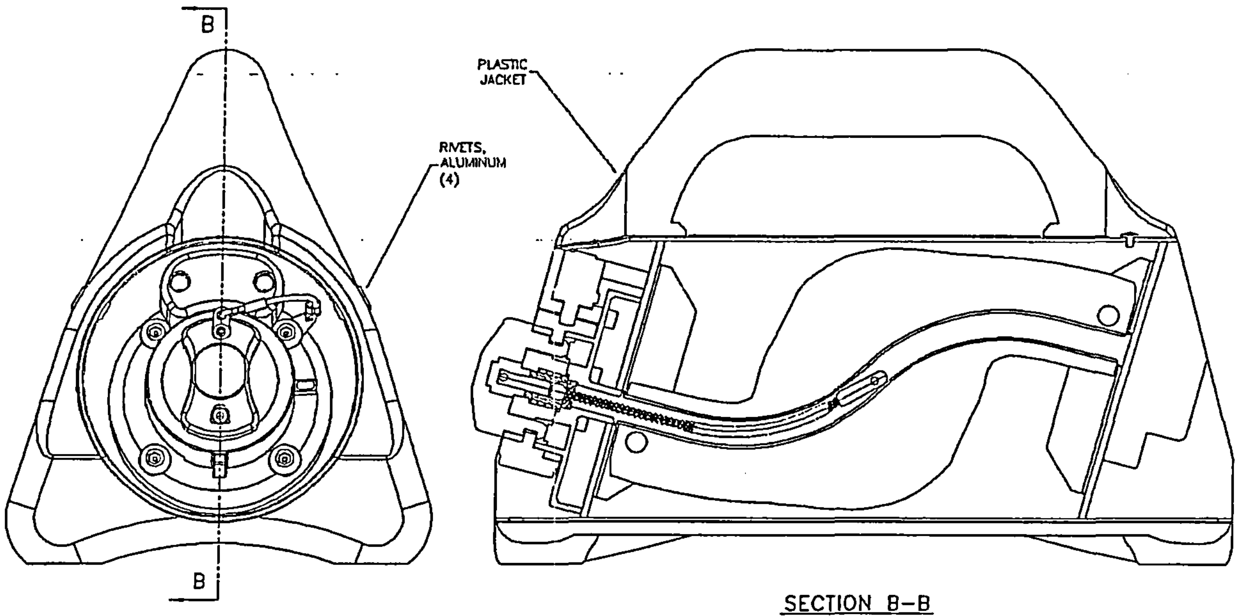


FIGURE 2.2: MODEL 880 PROJECTOR WITH JACKET.

Section 3 Regulatory Compliance

The purpose of this plan, which was developed in accordance with AEA Technology QSA SOP-E005, is to demonstrate that the Model 880 projector complies with the Type B(U)-85 transport package test requirements of 10 CFR 71 and the IAEA Safety Series No.6.

The tests for Normal Conditions of Transport (10 CFR 71.71) were performed under AEA Technology QSA test plan number 100. However, the 4-foot drop will be performed as the first test to produce typical damage that might occur during normal transport conditions. The 4-foot drop of test plan number 100 was the only test to produce any significant damage to the package.

The water spray preconditioning of the package will not be performed as the Model 880 projector is constructed of waterproof materials throughout. The water spray would not contribute to any degradation in structural integrity.

The Hypothetical Accident Tests (10 CFR 71.73) to be performed are the 9m (30 foot) free drop test and the puncture test.

The crush test (10 CFR 71.73(c)(2)) will not be performed because the radioactive contents are qualified as Special-Form radioactive material.

The thermal test of (10 CFR 71.73(c)(4)) will either be evaluated using a finite element analysis model or subjected to a simulated fire test in an oven at 800°C for at least 30 minutes.

The melting points for the materials of the package are listed below:

Material	Melting Point
Stainless steel	1390°C (2530°F)
Depleted uranium	1135°C (2075°F)
Titanium	1700°C (3100°F)
Tungsten	3410°C (6170°F)
Copper/Brass	1080°C (1980°F)
Aluminum	580°C (1080°F)
Rubber/Plastic	Less than 540°C (1000°F)

The immersion test will not be performed. Only the source capsule (containment vessel) is sealed and able to pressurize as a result of 50 feet of water depth. The source capsule is designed and tested to withstand external pressures well in excess of 22 lbf/in^2.

Section 4 Discussion on System Failure Modes of Interest

4.1 General

The tests in this plan focus on damaging those components of the package which could cause displacement of the source from its stored position within the depleted uranium shield and which affect the integrity of the shield itself.

4.2 Normal and Accident Conditions of Transport

The modes of failure under normal and accident conditions that could lead to elevated dose rates include the following:

4.2.1 Fracture or penetration of the projector weldment.

4.2.2 Displacement of the shield within the projector weldment and distortion or fracture of the source.

4.2.3 Failure of the source lock assembly and/or lock mounting screws.

The test conditions specified in this Test Plan are intended to challenge the ability of the Model 880 package with respect to these failure modes.

Section 5 Assessment of Package Conformance

5.1 Regulatory Requirements

5.1.1 Normal Conditions of Transport (71.43(f))

There should be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels and no substantial reduction in the effectiveness of the packaging.

IAEA Safety Series No. 6 para. 537 stipulates the same criteria except that it states in paragraph 537(b) that the loss of shielding integrity should not result in more than a 20% increase in the radiation level at any external surface of the package.

5.1.2 Hypothetical Accident Conditions (71.51(a))

There should be no escape of radioactive materials greater than A_2 in one week and no external dose rate greater than 1 R/hr at 1m from the external surface with the maximum radioactive contents which the package is designed to carry.

5.2 Test Package Contents

The Model 880 projector is designed to carry a special form source. Containment of the radioactive source is tested at manufacture. The source capsule design has been certified in accordance with the performance requirements for special form as specified in 10 CFR Part 71 and IAEA Safety Series #6.

This test plan therefore does not discuss/specify tests of the containment of the radioactive source. The purpose of the tests is to demonstrate that the source remains shielded within the limits specified by the regulations.

Since source integrity has been demonstrated through special form testing, a simulated source will be used during testing of the package. The radiation levels after testing will be measured by replacing the simulated source with an active source. The post-test measurements will be compared with pre-test measurements to verify the source has not shifted within the shield.

Section 6 Construction and Condition of Test Specimens

The Model 880 transport package test specimens will be constructed in accordance with AEA Technology QSA drawing B88015 revision A and the AEA Technology QSA Quality Assurance Program. The weight of the test specimens per this drawing is not greater than 46 pounds.

The "With Jacket" test specimen will be constructed in accordance with AEA Technology QSA drawing B88000 revision A and the AEA Technology QSA Quality Assurance Program. This specimen is the same as the specimen built to drawing B88015 revision A, but with the plastic jacket and rivets added. The weight of the "With Jacket" test specimen is not greater than 50 pounds.

The structural materials of the Model 880 are made of AISI Type 300 series stainless steel and titanium. The shielding materials are depleted uranium and tungsten. The non-safety related parts are made from aluminum, brass, copper, plastic, and rubber.

Except for the thermal test, all tests of this plan will subject the test specimen to an impact from a drop. The mechanical strength and ductility of the critical components of the package must continue to perform as expected at the ambient temperature conditions of –40°F to 100°F.

The fracture toughness, strength and ductility, of the structural materials in the Model 880 does not change significantly at or between the temperatures of –40°F to 100°F. The shielding materials are relatively brittle throughout this entire temperature range. Therefore, any temperature within the –40°F to 100°F range for the 4-foot, 30-foot, and puncture tests will have the same result. So, the test specimen will be dropped at ambient temperature at time of testing.

The internal operating pressure of the containment system, namely the source capsule, is considered to be in equilibrium with the outside pressure of the package. The sealed capsule is welded at atmospheric pressure and except for the capsule, the package is open to the atmosphere. Therefore, the initial internal pressure of the containment system is considered to be insignificant.

Section 7 Material and Equipment List

The equipment list worksheets in Section 9 identify the equipment required, with additional space to list other necessary equipment and measuring instruments needed to perform the tests. Additional materials and equipment used to facilitate the tests will be listed as needed.

Section 8 Test Procedure

8.1 General

All test specimens are to be tested in the sequence presented below. Each test has been designed to check the integrity of various components of the package. An assessment of transport integrity of the package can be made based on the cumulative effect of the tests performed on the package

After completing the 4-foot, 30-foot, and puncture drop test sequence on all three specimens, a "With Jacket" test specimen will follow the same drop sequence. The "With Jacket" test specimen will have an orientation chosen from either the first three orientations or another orientation selected to produce the most damage to the package. The justification and description for this orientation shall be documented.

The tests have the following sequence:

1. Test specimen preparation and inspection
2. 1.2m (Four-foot) free drop test (10 CFR 71.71(c)(7))
3. 9m (30-foot) free drop test (10 CFR 71.73(c)(1))
4. Puncture test (10 CFR 71.73(c)(3))
5. Test inspection.
6. Thermal test or analysis (10 CFR 71.73(c)(4)).
7. Final test inspection and/or assessment.
8. Test specimen storage.

8.2 Roles and Responsibilities

The responsibilities of the groups identified in this plan are:

- **Engineering** executes the tests according to the test plan and summarizes the test results. Engineering also provides technical input to assist Regulatory Affairs and Quality Assurance as needed.

- **Regulatory Affairs** monitors the tests and reviews test reports for compliance with regulatory requirements.

- **Quality Assurance** oversees test execution and test report generation to assure compliance with the AEA Technology QSA Quality Assurance Program.

- **Engineering, Regulatory Affairs** and **Quality Assurance** are jointly responsible for assessing test and specimen conditions relative to 10 CFR 71 and IAEA Safety Series #6.

- **Quality Control** is responsible for ensuring test and specimen data is measured and recorded throughout the test cycle.

8.3 Test Specimen Preparation and Inspection

1. Manufacture five Model 880 projectors per AEA Technology QSA drawing number B88015, revision A. Clearly and indelibly mark each specimen: "TP108(X)". Where X is an alphabetically incremented letter beginning with "A". One of the five projectors will be used as a spare and used to replace a specimen dropped onto the wrong impact point, if necessary. The spare, if used, will follow the same test sequence as the initially selected specimen.

2. Measure and record the weight of each specimen.

3. Inspect the test specimens to ensure that:

   - All fabrication and inspection records are documented in accordance with the AEA Technology QSA Quality Assurance Program.

   - The test specimens comply with the requirements of the drawing.

4. Measure and record the location of the source from the front plate using the source location tool.

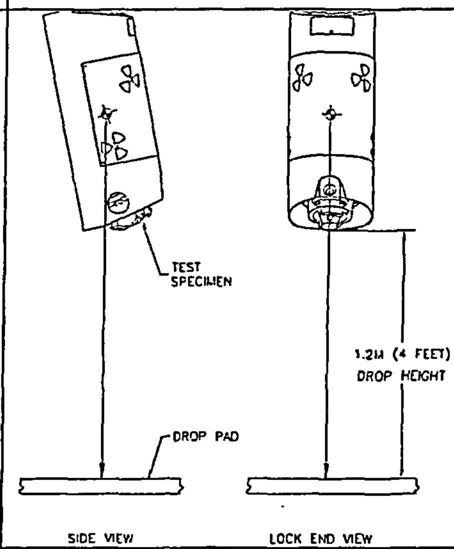
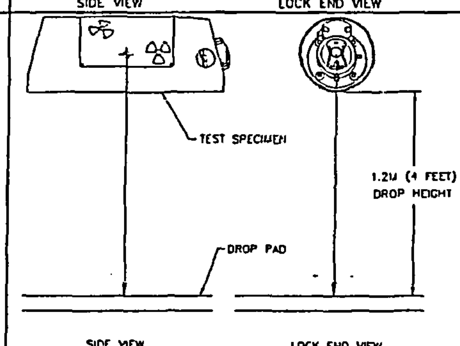
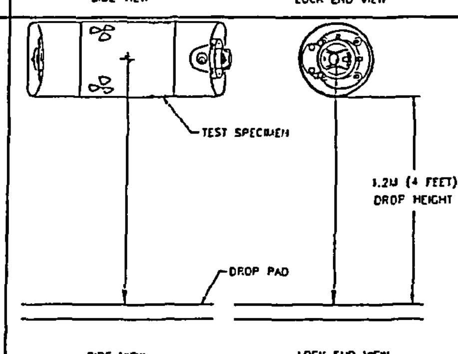
5. Perform and record the radiation profile in accordance with AEA Technology QSA Work Instruction WI-Q09.

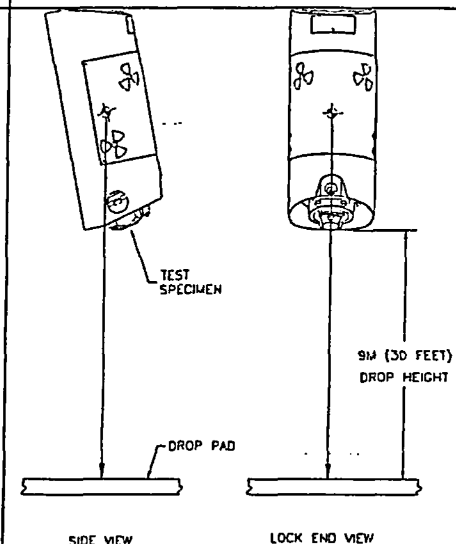
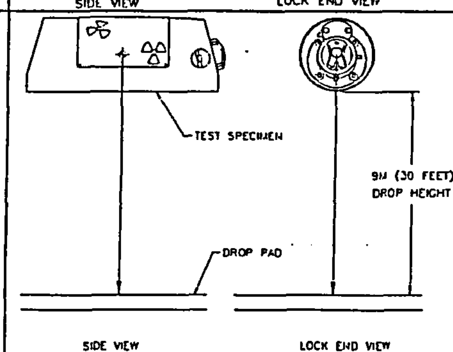
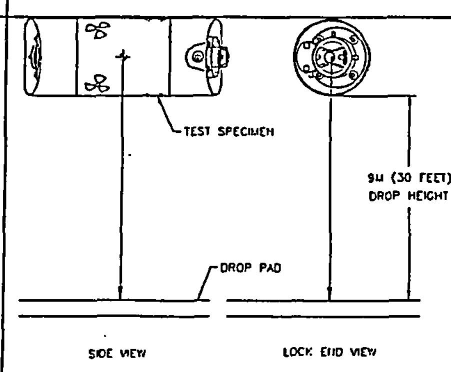
6. **Engineering, Regulatory Affairs** and **Quality Assurance** will jointly verify that the test specimens comply with the drawings and the AEA Technology QSA Quality Assurance Program.

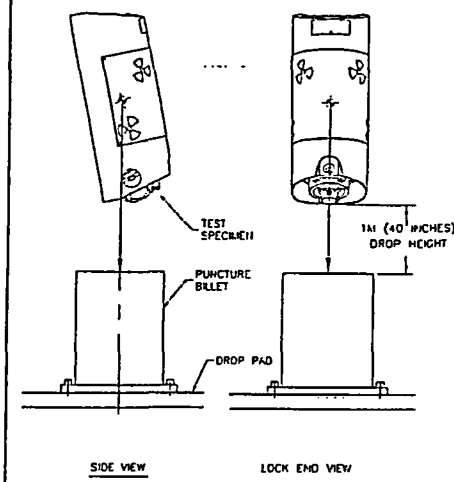
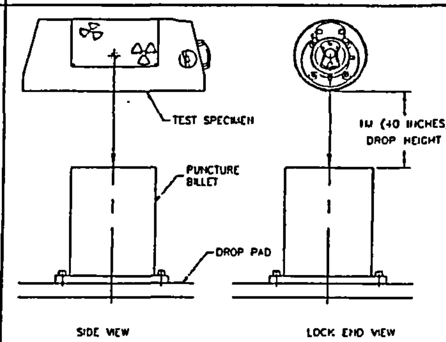
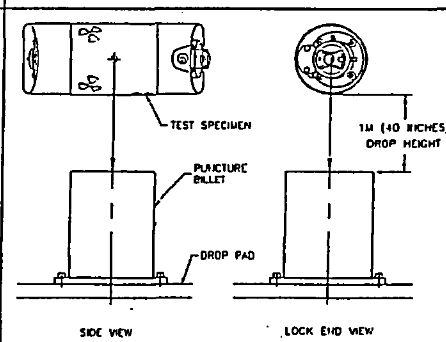
7. Prepare the test specimens for transport.

8.4 Summary of Test Schedule

This section provides an overall view of the test specimen orientations for each test.

Normal Conditions Test	Para.	Specimen	Diagram
1.2m Drop 1.	71.71(c)(7)	TP108(A)	
1.2m Drop 2.	71.71(c)(7)	TP108(B)	
1.2m Drop 3.	71.71(c)(7)	TP108(C)	

Accident Conditions Test	Para.	Specimen	Diagram
9m Drop 1.	71.73(c)(1)	TP108(A)	
9m Drop 2.	71.73(c)(1)	TP108(B)	
9m Drop 3.	71.73(c)(1)	TP108(C)	

Puncture 1.	71.73(c)(3)	TP108(A)	
Puncture 2.	71.73(c)(3)	TP108(B)	
Puncture 3.	71.73(c)(3)	TP108(C)	

8.5 1.2m (4-foot) Free Drop Test (10 CFR 71.71(c)(7))

The Normal Transport Conditions Test is the 1.2m (4-foot) free drop test as described in 10 CFR 71.71(c)(7).

The figures of section 8.5.2.1, 8.5.3.1, and 8.5.4.1 illustrate the orientations for the test specimens.

8.5.1 1.2m Free Drop Test Set-up

To set up a package for the 1.2m (4-foot) drop test:

1. Place each specimen on the drop surface and position it according to the specimen-specific orientation shown in Figure 8.5.2.1, Figure 8.5.3.1, or Figure 8.5.4.1
2. Raise the package so that the impact target is 1.2m (4 feet) above the drop surface. Ensure the center of gravity is over the impact point
3. Measure and record the ambient temperature.
4. Photograph the set-up.
5. Start the video recorder.
6. Drop the package.
7. Stop the video recorder.
8. Record the damage to the package and take a photographic record.

8.5.2 Specimen TP108(A) Orientation for the 1.2m Drop Test

Figure 8.5.2.1 shows the package orientation for Specimen TP108(A). The object of the drop is to use the shell lip as leverage to drive the rear plate across the endplate to shear the rear plate mounting screws. This drop is meant to stiffen the impact area to reduce energy absorption during the 30-foot drop test.

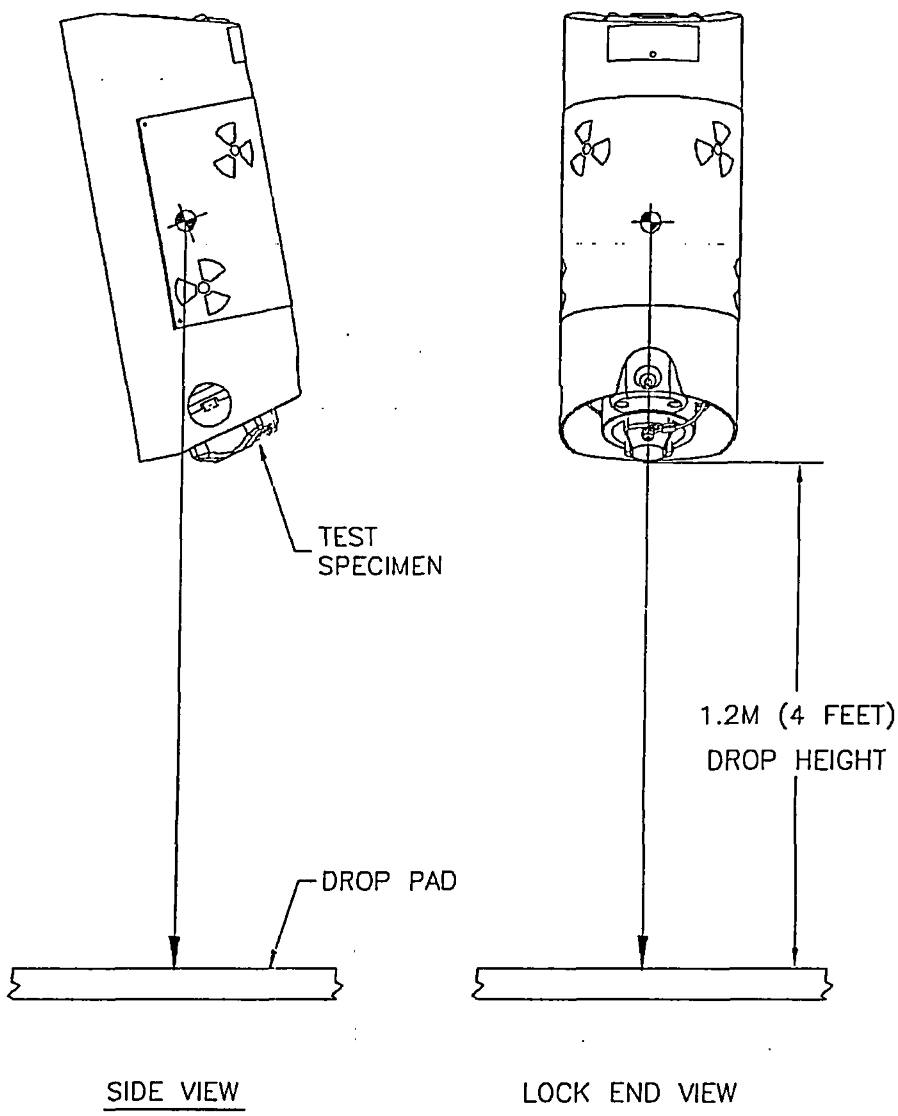


Figure 8.5.2.1: Specimen TP108(A) Orientation for the 1.2m Drop Test

8.5.3 Specimen TP108(B) Orientation for the 1.2m Drop Test

Figure 8.5.3.1 shows the package orientation for Specimen TP108(B). The object of this drop is to test the integrity of the shield pins and to determine the effect of the drop on the depleted uranium shield.

The specimen will be dropped with its axis parallel to the drop surface onto the cylindrical shell with the transport label facing up.

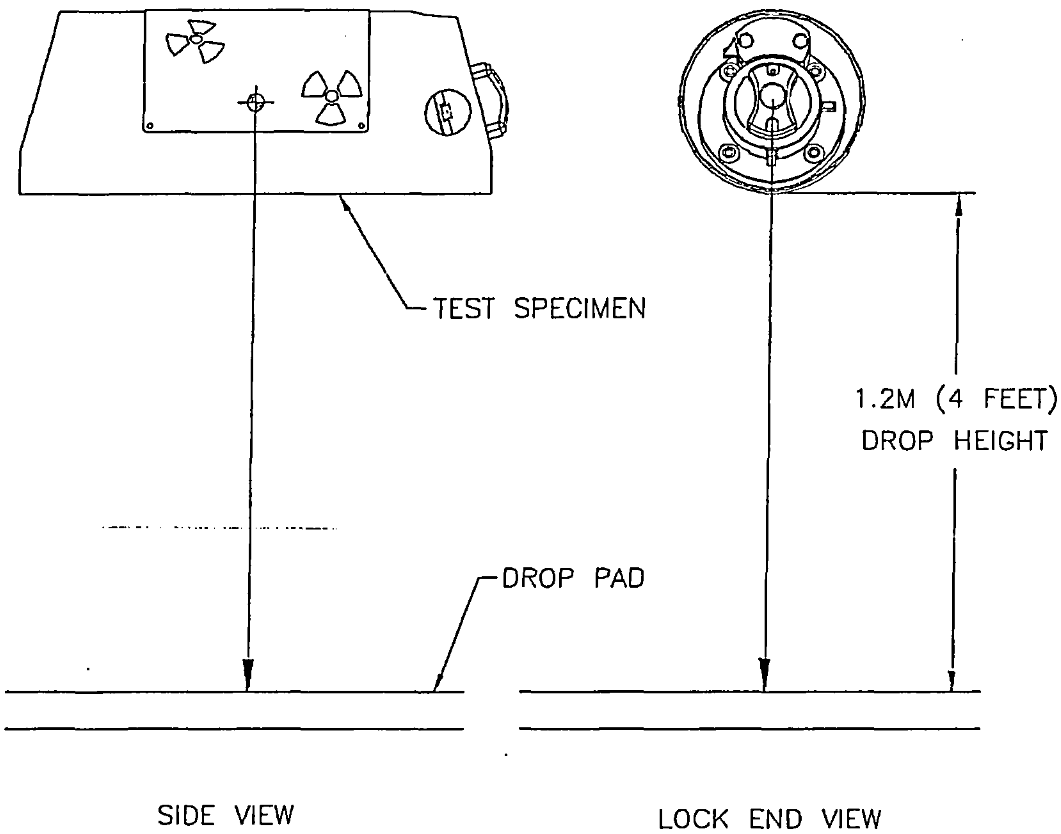


Figure 8.5.3.1: Specimen TP108(B) Orientation for the 1.2m Drop Test

8.5.4 Specimen TP108(C) Orientation for the 1.2m Drop Test

Figure 8.5.4.1 shows the package orientation for Specimen TP108(C). The object of this drop is to test the integrity of the U-brackets and to determine the effect of the drop on the depleted uranium shield.

The specimen will be dropped with its axis parallel to the drop surface onto the cylindrical shell with the transport label facing out to the side.

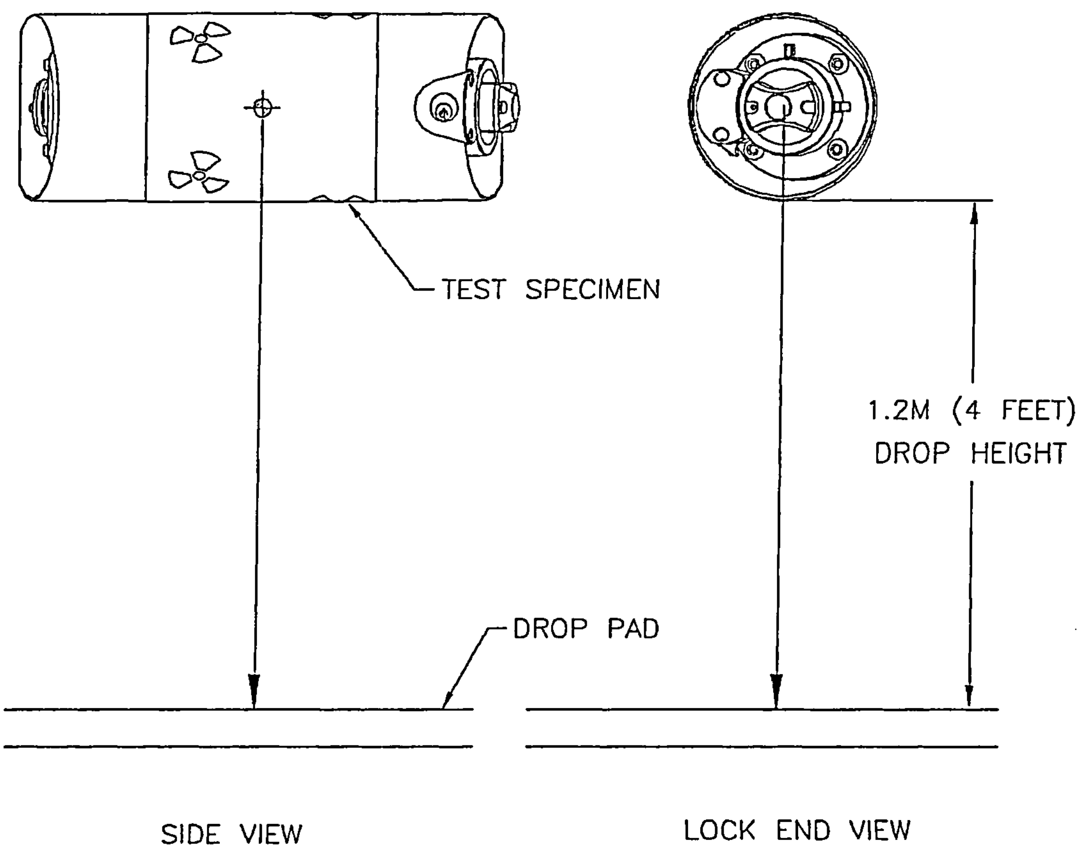


Figure 8.5.4.1: Specimen TP108(C) Orientation for the 1.2m Drop Test

8.5.5 1.2m Free Drop Test Assessment

Upon completion of each test, **Engineering**, **Regulatory Affairs** and **Quality Assurance** team members will jointly take the following actions:

- Review the test execution to ensure that each test was performed in accordance with 10 CFR 71, IAEA Safety Series #6, and this test plan.
- Make a preliminary evaluation of the specimens relative to the requirements of 10 CFR 71 and IAEA Safety Series #6.
- Assess the damage to each specimen to decide whether testing of that specimen is to continue.
- Evaluate the condition of each specimen to determine what changes, if any, are necessary in package orientation in the 30-foot drop test to achieve maximum damage.

8.6 9m Free Drop Test (10 CFR 71.73(c)(1))

The first Hypothetical Accident Test is the 9m (30-foot) free drop test as described in 10 CFR 71.73(c)(1).

The figures of section 8.6.2.1, 8.6.3.1, and 8.6.4.1 illustrate the orientations for the test specimen.

8.6.1 9m Free Drop Test Set-up

To set up a package for the 9m (30-foot) drop test:

1. Measure and record the weight of each of the test specimens.
2. Place each specimen on the drop surface and position it according to the specimen-specific orientation as shown in Figure 8.6.2.1, Figure 8.6.3.1, or Figure 8.6.4.1.
3. Raise the package so that the impact target is 9m (30 feet) above the drop surface. Ensure the center of gravity is over the impact point
4. Measure and record the ambient temperature.
5. Photograph the set-up.
6. Start the video recorder.
7. Drop the package.
8. Stop the video recorder.
9. Record the damage to the package and take a photographic record.

8.6.2 Specimen TP108(A) Orientation for the 9m Drop Test

Figure 8.6.2.1 shows the package orientation for Specimen TP108(A). The object of the drop is to use the shell lip as leverage to drive the rear plate across the endplate to shear the rear plate mounting screws.

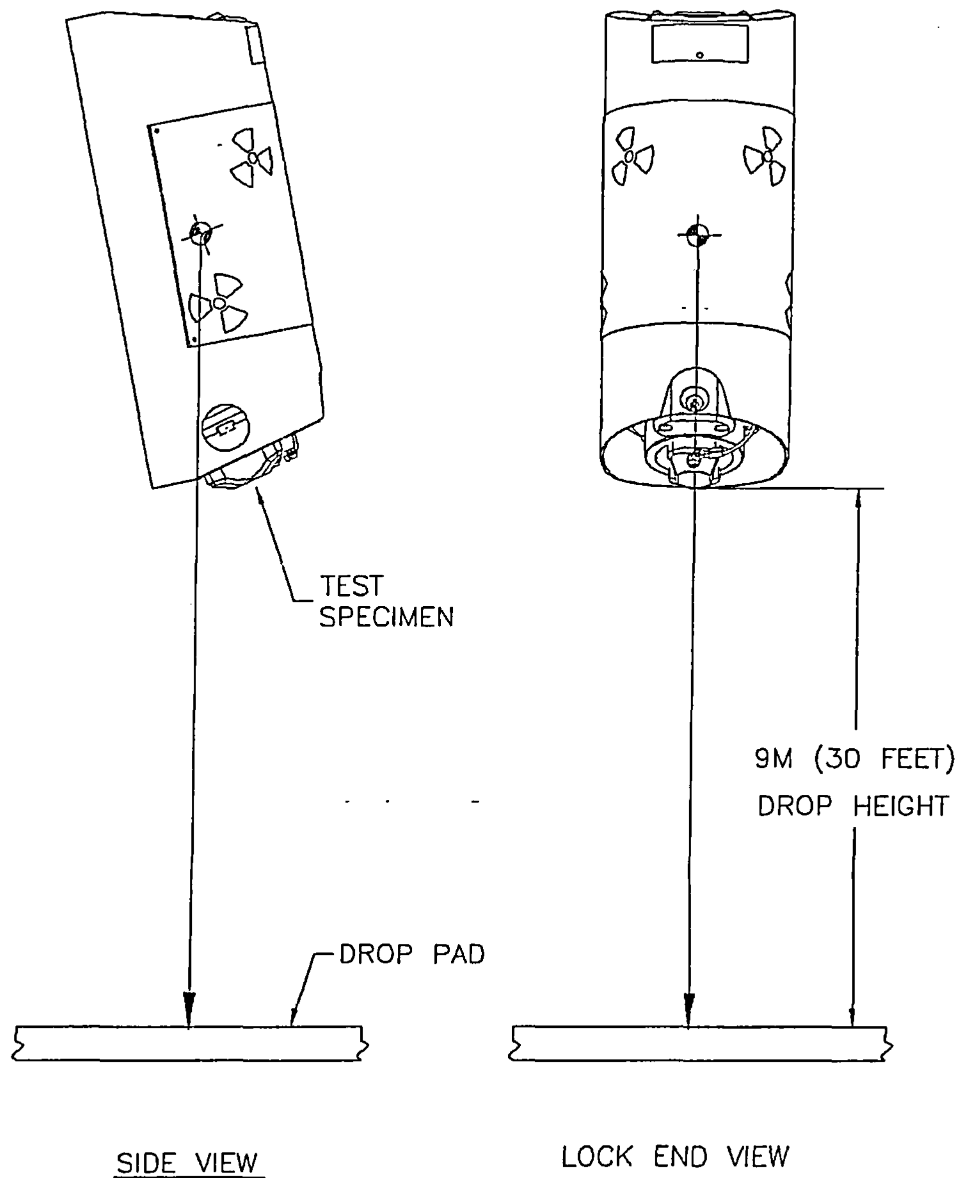


Figure 8.6.2.1: Specimen TP108(A) Orientation for the 9m Drop Test

8.6.3 Specimen TP108(B) Orientation for the 9m Drop Test

Figure 8.6.3.1 shows the package orientation for Specimen TP108(B). The object of this drop is to test the integrity of the shield pins and to determine the effect of the drop on the depleted uranium shield.

The specimen will be dropped with its axis parallel to the drop surface onto the cylindrical shell with the transport label facing up.

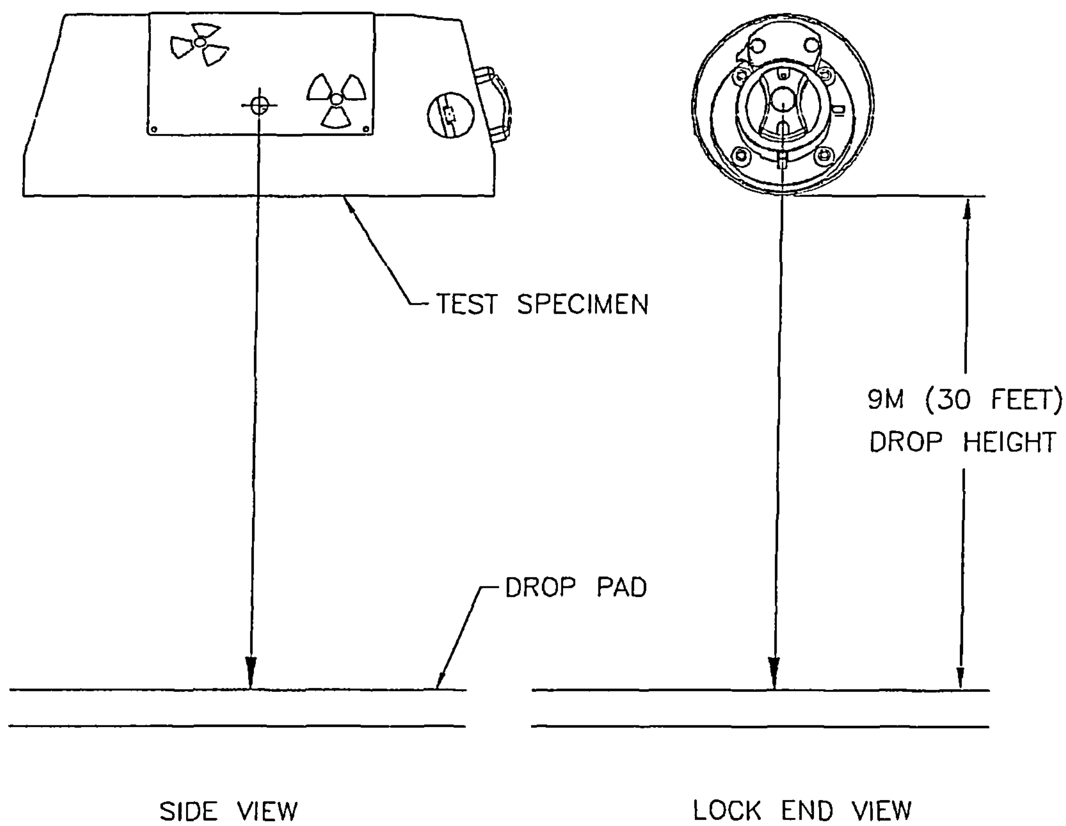


Figure 8.6.3.1: Specimen TP108(B) Orientation for the 9m Drop Test

8.6.4 Specimen TP108(C) Orientation for the 9m Drop Test

Figure 8.6.4.1 shows the package orientation for Specimen TP108(C). The object of this drop is to test the integrity of the U-brackets and to determine the effect of the drop on the depleted uranium shield.

The specimen will be dropped with its axis parallel to the drop surface onto the cylindrical shell with the transport label facing out to the side.

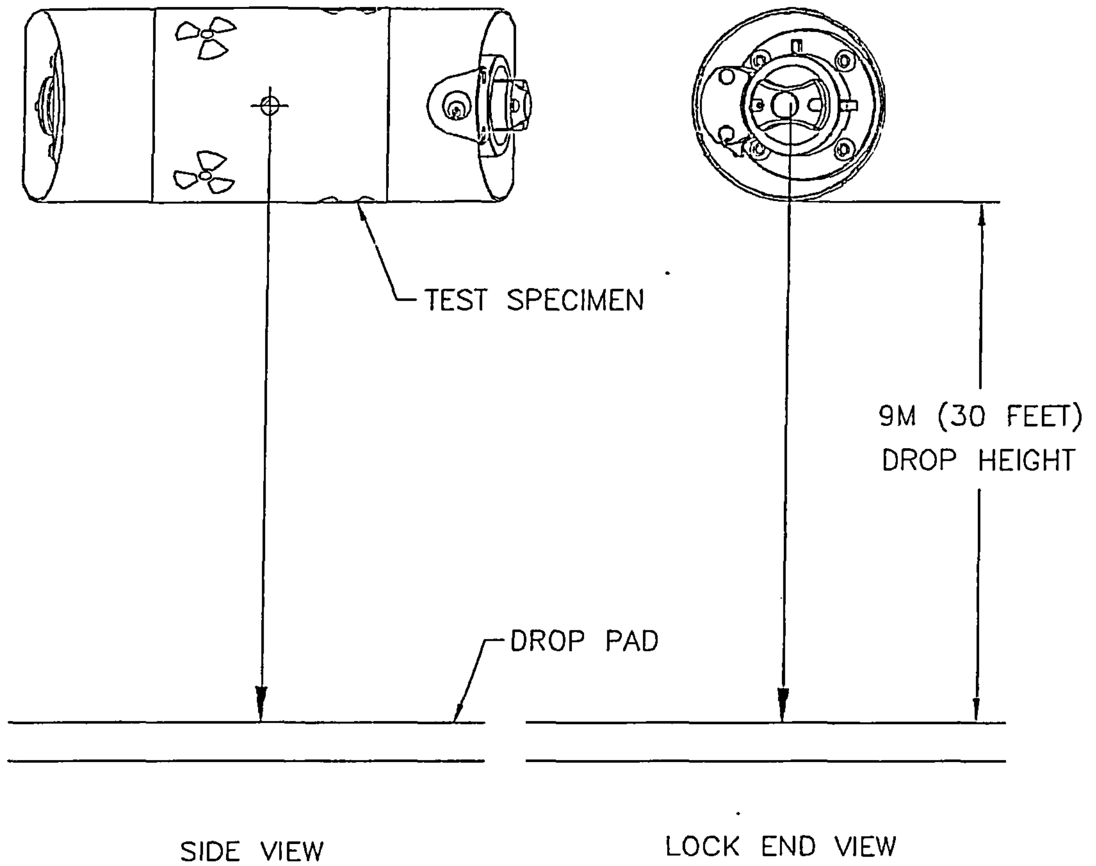


Figure 8.6.4.1: Specimen TP108(C) Orientation for the 9m Drop Test

8.6.5 9m Free Drop Test Assessment

Upon completion of each test, **Engineering, Regulatory Affairs** and **Quality Assurance** team members will jointly take the following actions:

- Review the test execution to ensure that each test was performed in accordance with 10 CFR 71, IAEA Safety Series #6, and this test plan.
- Make a preliminary evaluation of the specimens relative to the requirements of 10 CFR 71 and IAEA Safety Series #6.
- Assess the damage to each specimen to decide whether testing of that specimen is to continue.
- Evaluate the condition of each specimen to determine what changes, if any, are necessary in package orientation in the puncture test to achieve maximum damage.

8.7 Puncture Test (10 CFR 71.73(c)(3))

The package is dropped from a height of 1m (40") onto the puncture billet. This test uses the 12" high puncture billet. The billet meets the minimum height (8") required in 10 CFR 71.73(c)(3). The specimen has no projections or overhanging members longer than 12" which could act as impact absorbers, allowing the billet to cause the maximum damage to the specimen. The billet is to be bolted to the drop surface used in the drop tests.

The figures: 8.7.2.1, 8.7.3.1, and 8.7.4.1 illustrate the orientations for each puncture test.

The justification for each puncture orientation is the same as the orientation for the 30-foot drop test. If the orientation needs to be changed, the new orientation must be documented and approved with a justification describing how it would be a worst condition than the planned orientation.

8.7.1 Puncture Test Set-up

NOTE: *Because each test is designed to add to damage inflicted on a specific component or assembly in the preceding test, it is important that each specimen maintain its identity throughout the battery of tests and that the set-up instructions specific to the specimen are strictly followed.*

To set up a package for the puncture test:

1. Measure and record the weight of the test specimen.
2. Measure and record the ambient temperature.
3. Position the test package according to the specimen-specific orientation shown in figures 8.7.2.1, 8.7.3.1, or 8.7.4.1.
4. Raise the package so that the impact target is 1m (40") between the impact point on the package and the top of the puncture billet. Ensure the center of gravity is over the impact point
5. Photograph the set-up.
6. Start the video recorder.
7. Drop the package.
8. Stop the video recorder.
9. Record the damage to the package and take a photographic record.

8.7.2 Specimen TP108(A) Orientation for the Puncture Test

The objective of this drop orientation (Figure 8.7.2.1) is to continue the damage inflicted on the specimen by the 9m-drop test.

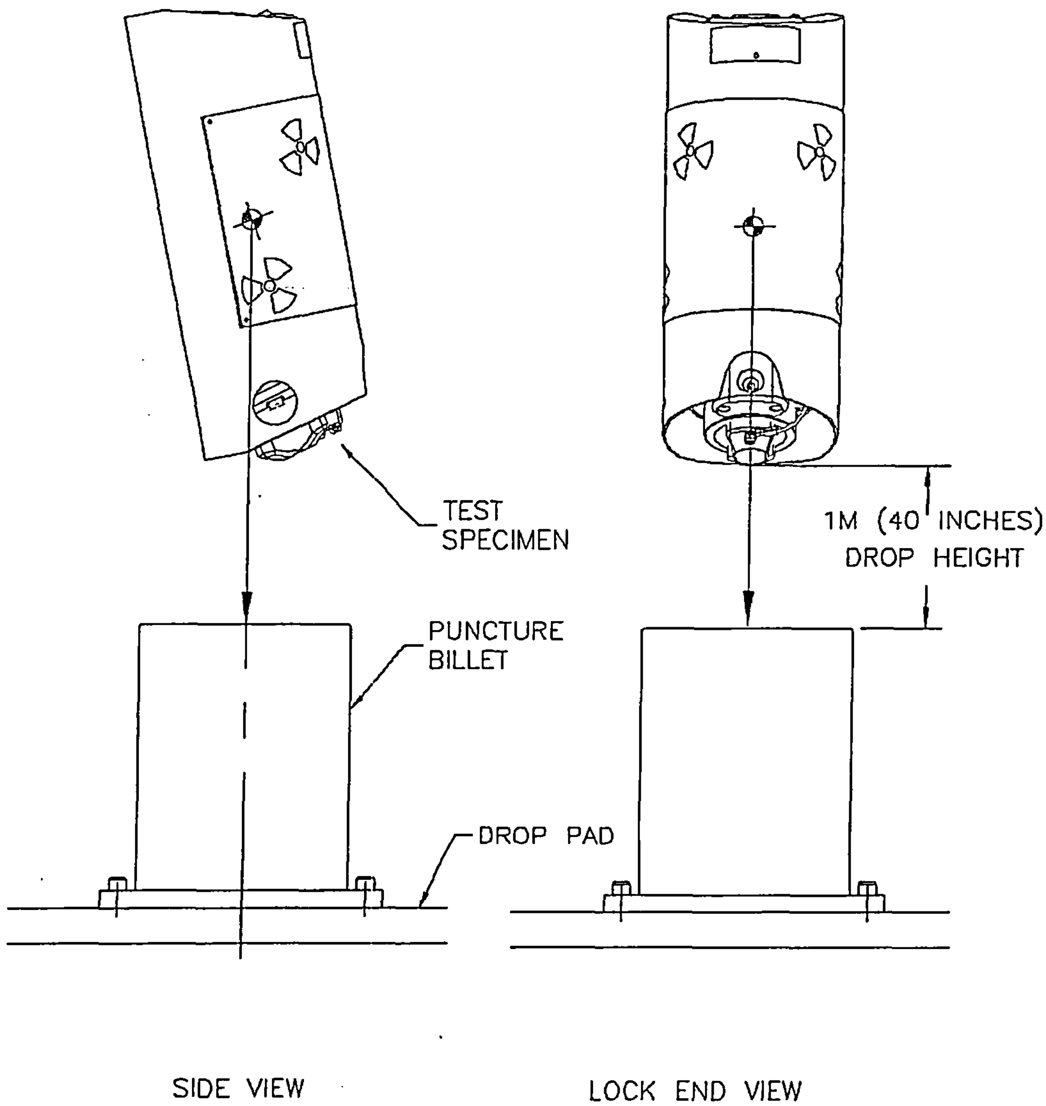


Figure 8.7.2.1: Specimen TP108(A) Orientation for the Puncture Test

8.7.3 Specimen TP108(B) Orientation for the Puncture Test

The objective of this drop orientation (Figure 8.7.3.1) is to continue the damage inflicted on the specimen by the 9m-drop test.

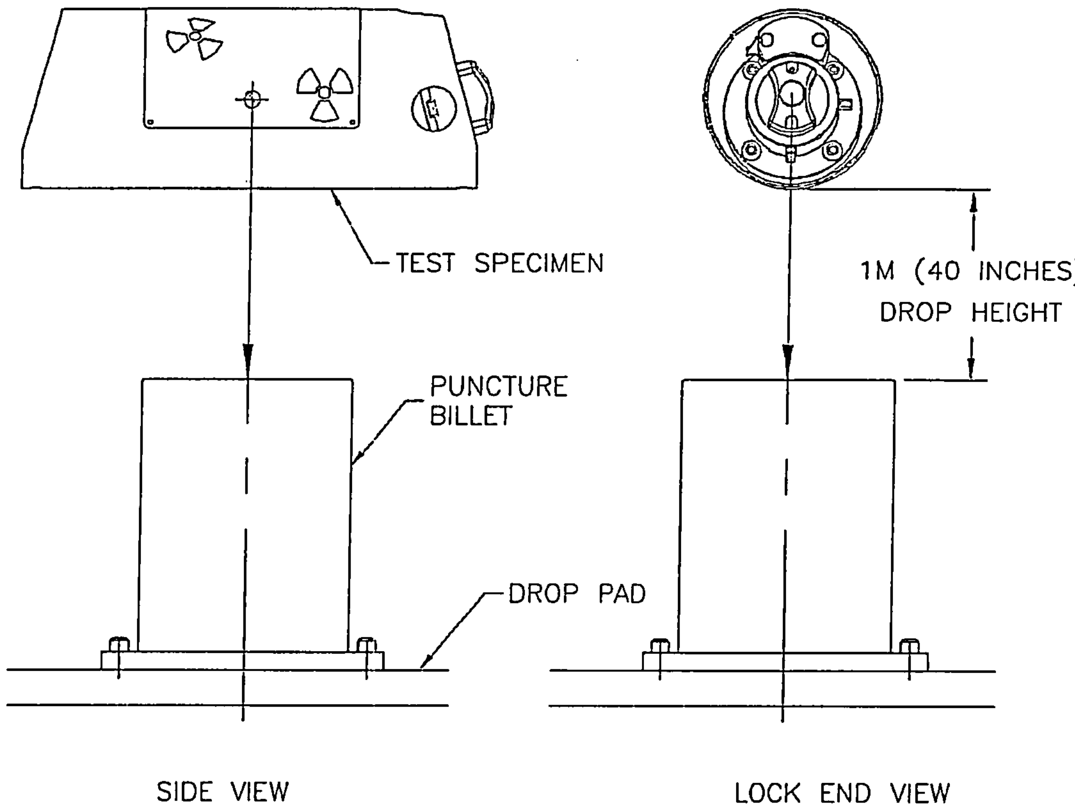


Figure 8.7.3.1: Specimen TP108(B) Orientation for the Puncture Test

8.7.4 Specimen TP108(C) Orientation for the Puncture Test

The objective of this drop orientation (Figure 8.7.4.1) is to continue the damage inflicted on the specimen by the 9m-drop test.

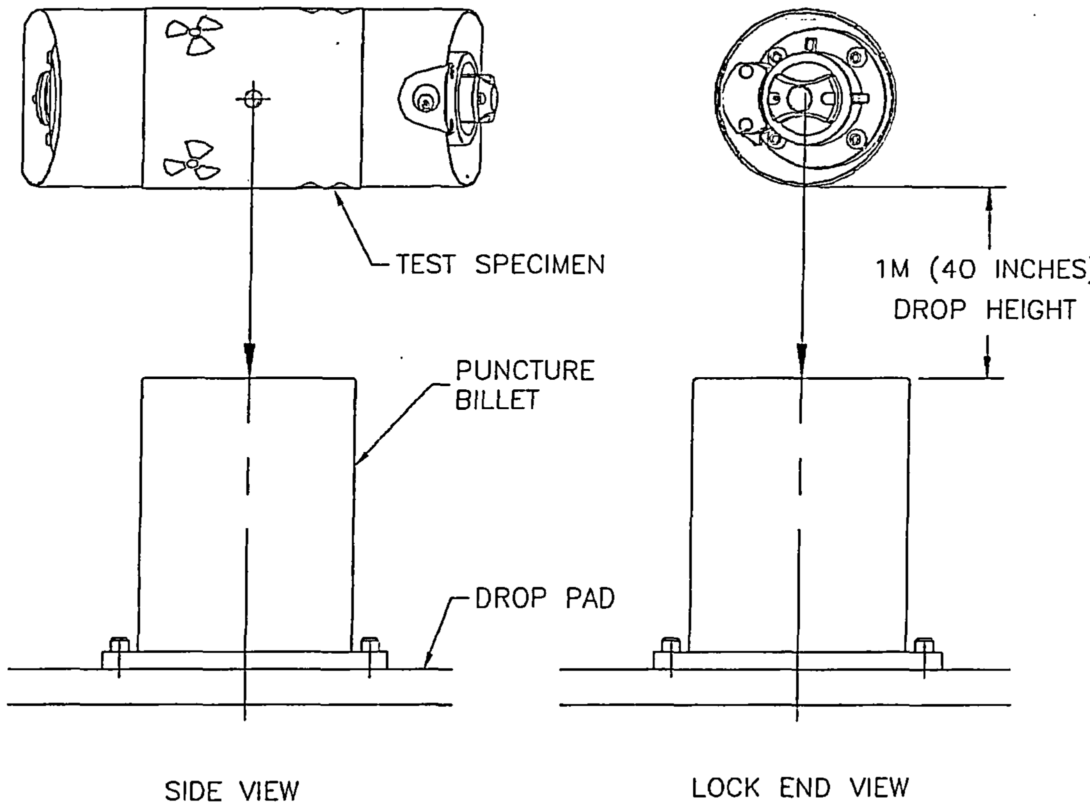


Figure 8.7.4.1: Specimen TP108(C) Orientation for the Puncture Test

8.7.5 Puncture Test Assessment

Upon completion of the test, **Engineering, Regulatory Affairs** and **Quality Assurance** team members will jointly take the following actions:

- Review the test execution to ensure that the tests were performed in accordance with 10 CFR 71, IAEA Safety Series #6, and this test plan.
- Make a preliminary evaluation of each specimen relative to the requirements of 10 CFR 71 and IAEA Safety Series #6.
- Justify and describe the orientation for the "With Jacket" test specimen test sequence.

8.8 "With Jacket" Test Sequence

Repeat the 4-foot, 30-foot, and puncture drop test sequence on the "with jacket" test specimen per the orientation determined in section 8.7.5. Document and justify the selected orientation.

8.9 Test Inspection

Perform the test inspection after the puncture tests.

1. Measure and record the damage to each of the test specimens. Measure and record the package for signs of any permanent strain.

2. Measure and record the location of the source from the front plate using the source location tool.

3. Remove and assess the condition of the simulated source.

4. Reassemble the packages using a representative active source, making sure that the source position and the package configuration are the same as they were immediately after the puncture test.

5. Measure and record a radiation profile of each test specimen in accordance with AEA Technology QSA Work Instruction WI-Q09.

6. Assess the significance of any change in radiation at the surface and at one meter from the packages.

7. Determine whether it is necessary to radiograph the test specimens for inspection of hidden component damage or failure.

8. Record any damage or failure found in radiograph of the test specimens, if performed.

8.10 Thermal Test (10 CFR 71.73(c)(4))

The thermal test shall be evaluated using either a finite element thermal analysis or a physical test. Either shall be performed to the requirements of 10 CFR 71.73 (c)(4).

The thermal test specimen orientation will be determined on an assessment performed after the puncture test. The documented justification must consider the worst case position for the specimen due to the damage inflicted from the previous tests.

If a finite element analysis is to be performed, no further actions are required under this section and proceed to section 8.11.

If a physical test is to be performed, complete section 8 of this test plan. The test environment will be a vented oven operating above 800°C. There will sufficient airflow to allow combustion. Air will be allowed to enter the oven through the door opening. The temperature of the package's exterior surface closest to the air entry point will be monitored throughout the test to ensure that the package remains above 800°C.

If the specimen is burning when it is removed, the unit is allowed to extinguish by itself and then cool naturally. The final evaluation of the package shall be performed when the specimen reaches ambient temperature.

8.10.1 Physical Thermal Test Set-up

To set up a package for the thermal test:

1 Heat the oven above 800°C.

2 Attach thermocouples to the package's external surface.

3 Place the package in the oven and close the door.

4 When all thermocouples indicate 800°C, start the 30-minute timer.

5 Measure and record the oven and test specimen temperatures.

6 Monitor the specimen and oven temperature throughout the 30-minute test period to ensure that all temperatures remain above 800°C.

7 At the end of 30-minutes, remove the specimen from the oven.

8 Allow the specimen to self-extinguish and cool.

9 Photograph and weigh the test specimen.

8.10.2 Thermal Test Assessment

Upon completion of the test, **Engineering, Regulatory Affairs** and **Quality Assurance** team members will jointly take the following actions:

- Review the test execution to ensure that the tests were performed in accordance with 10 CFR 71, IAEA Safety Series #6, and this test plan.

- Make a preliminary evaluation of each specimen relative to the requirements of 10 CFR 71 and IAEA Safety Series #6.

8.11 Final Test Inspection

Perform the following inspection after the thermal test.

1. Measure and record the damage to each of the test specimens.

2. Measure and record the location of the source from the front plate using the source location tool.

3. Remove and assess the condition of the simulated source.

4. Reassemble the packages using a representative active source, making sure that the source position and the package configuration are the same as they were immediately after the thermal test.

5. Measure and record a radiation profile of each test specimen in accordance with AEA Technology QSA Work Instruction WI-Q09.

6. Assess the significance of any change in radiation at the surface and at one meter from the packages.

7. Determine whether it is necessary to dismantle either of the test specimens for inspection of hidden component damage or failure.

8. If the decision is taken to proceed with the inspection, record and photograph the process of removing any component.

9. Measure and record any damage or failure found in the process of dismantling the test specimens.

Engineering, **Regulatory Affairs**, and **Quality Assurance** team members will make a final assessment of each test specimen and jointly determine whether the specimens meet the requirements of 10 CFR 71 and IAEA Safety Series #6.

8.12 Test Specimen Storage

Place the test specimens in an appropriate container and store the container in the "low level" waste room. Dispose the test specimens only when the governing regulatory body provides written authorization to do so.

Section 9 Worksheets

Use the following worksheets for executing the tests of section 8. Each test shall have three worksheets; an equipment list, a procedure checklist, and a data sheet. Record the information onto copies of these worksheets for each test performed.

Attach a copy of the relevant inspection report or calibration certificate after the range and accuracy of the equipment has been verified.

Drop & Puncture Test Equipment List

Test:		
Description *** Mark NA when not used.**	**Enter the Model and Serial Number**	**Attach Inspection Report or Calibration Certificate**
Test Specimen, Drawing No.		
Drop Surface, Drawing No.		
* Puncture Billet, Drawing No.		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificates.		
Signature	**Print Name**	**Date**
Completed by:		
Verified by:		

Drop & Puncture Test Checklist

Test:		
Test Location:		
Step	**Data**	**Measuring Instrument**
1. Record test specimen serial number:		
2. Record the test specimen weight:		
3. Record the ambient temperature (°C):		
4. Record set-up orientation figure:		
5. Verify set-up orientation and drop height.		
6. Photograph set-up in at least two perpendicular planes.		
7. Begin video recording of the test so that impact is recorded.		
8. Release the test specimen.		
9. Stop the video recorder. Ensure the point of impact and orientation specified in the plan has been achieved.		
10. Record the damage to the test specimen on a separate sheet and attach.		
11. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach.		

Test witnessed by (Signature)	**Print Name**	**Date**
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Drop & Puncture Test Data Sheet

Test Unit Model/Serial No.:	Test:
Test Date:	Test Time:
Describe drop orientation and drop height:	
Describe impact (location, rotation, etc.):	
Describe on-site inspection (damage, broken parts, etc.):	
On-site test assessment: Engineering: Regulatory: QA:	
Describe any post-test disassembly and inspection:	
Describe any change in source position:	
Describe results of radiography:	
Completed by:	Date:

Thermal Test Equipment List

Test:		
Description *** Mark NA when not used.**	**Enter the Model and Serial Number**	**Attach Inspection Report or Calibration Certificate**
Test Specimen, Drawing No.		
Thermometer		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificates.		
Signature	**Print Name**	**Date**
Completed by:		
Verified by:		

Thermal Test Checklist

Test:		
Test Location:		
Step	**Data**	**Measuring instrument**
1. Record test specimen serial number:		
2. Record the start time:		
3. Record the oven temperature(°C):		
4. Record the test specimen temperature (°C):		
5. Monitor oven and test specimen temperature.		
6. Record stop time:		
7. Record the oven temperature(°C):		
8. Record the test specimen temperature (°C):		
9. Remove test specimen, let it self extinguish and cool.		
10. Record the damage to the test specimen on a separate sheet and attach.		
11. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach.		

Test witnessed by (Signature)	**Print Name**	**Date**
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Thermal Test Data Sheet

Test Unit Model/Serial No.:	Test:
Test Date:	Test Time:
Describe orientation:	
Describe on-site inspection (damage, broken parts, etc.):	
On-site test assessment: Engineering: Regulatory: QA:	
Describe any post-test disassembly and inspection:	
Describe any change in source position:	
Describe results of radiography:	
Completed by:	Date:

Section 2.12.3 Appendix: Test Report 108 Minus Appendices A-C (Aug 2000).

Test Report #108

Model 880 Type (B) Transport Package Test Results

TABLE of CONTENTS

Section 1 Introduction

This document describes the results of the package design tests conducted in accordance with Test Plan #108.

The tests described under test plan #108 subjects the Model 880 Projector to the hypothetical accident test requirements for Type B(U)-85 packages as described in the Code of Federal Regulations, 10 CFR Part 71, revised as of March 31, 1999 and the IAEA Regulations for the Safe Transport of Radioactive Material; Safety Series No.6 1985 Edition (As Amended 1990).

This report will show the Model-880 transport package satisfies the test requirements as described in test plan #108 and therefore meets the hypothetical accident test requirements for type B(U)-85 transport packages. Additionally, the plastic jacket does not adversely affect the results of these tests.

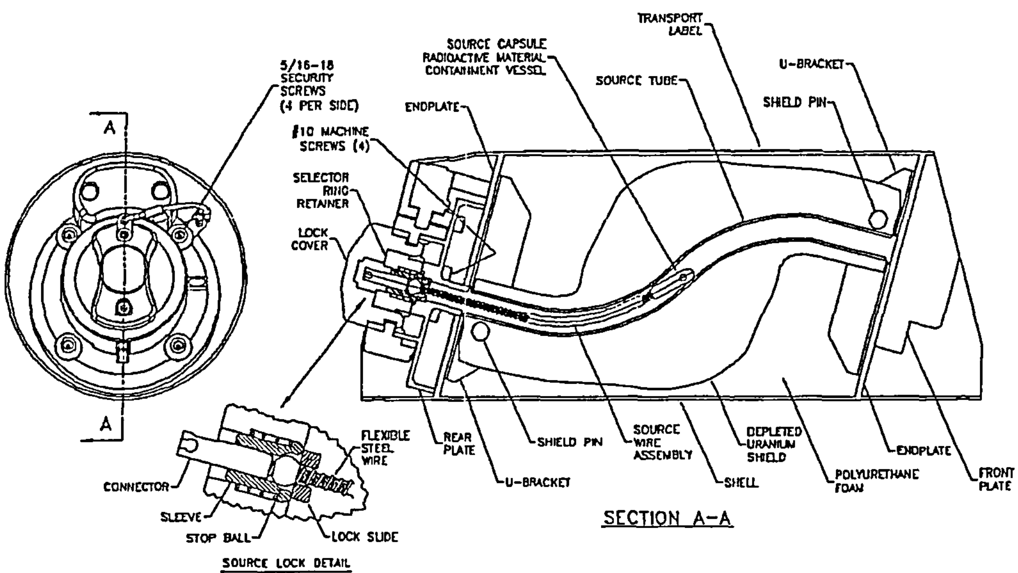


FIGURE 1. MODEL 880 PROJECTOR TRANSPORT PACKAGE.

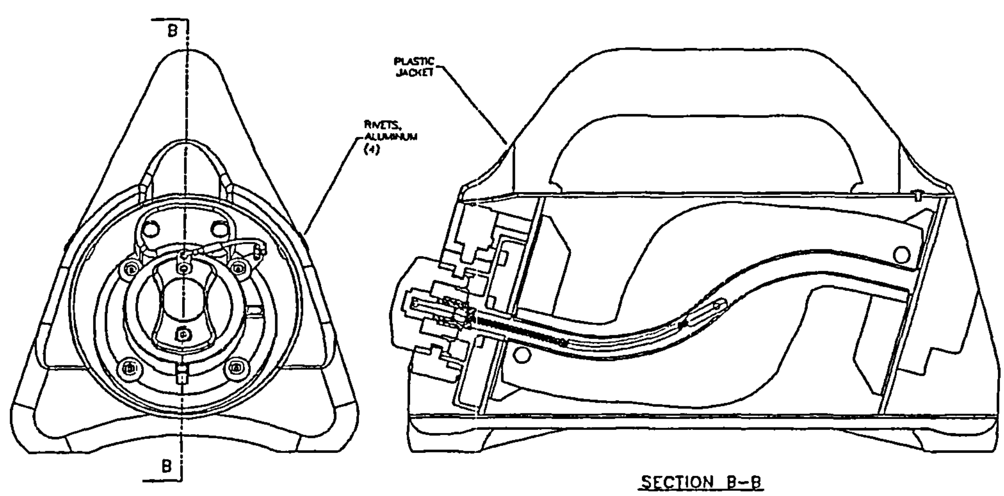


FIGURE 2. MODEL 880 PROJECTOR WITH JACKET.

Section 2 Construction and Acceptance of Test Specimens

A total of seven Model-880 transport package test specimens were manufactured in accordance with the AEA Technology QSA Quality Assurance Program. One of the seven, TP108(A), was not accepted due to borderline initial surface measurements taken during radiation profile inspection. The remainder of the six were constructed per drawing B88015 revision A. One of the six, TP108(G), was identified as the "With Jacket" test specimen and further assembled to meet the requirements of drawing B88000 revision A.

Since the test plan describes orientations for specifically identified test specimens and test specimen TP108(A) was not used, the drop test orientation for each specimen was shifted. TP108(B) took the place of TP108(A), TP108(C) for TP108(B), and so on.

Table 2.1. Test specimen data.

Test Specimen	Package Weight	Initial Source Location	Maximum Initial Surface Measurements	Maximum Initial 1 Meter Measurements	Test Orientation impact point
TP108(A)	Not used – Borderline initial surface measurements.				
TP108(B)	44.2 lbs.	6-47/64 in.	178 mR/hr	1.2 mR/hr	Lock cover
TP108(C)	44.3 lbs.	6-47/64 in.	178 mR/hr	0.9 mR/hr	Shell bottom
TP108(D)	44.4 lbs.	6-48/64 in.	160 mR/hr	1.1 mR/hr	Shell left side
TP108(E)	44.4 lbs.	6-46/64 in.	193 mR/hr	0.7 mR/hr	Not used
TP108(F)	44.1 lbs.	6-47/64 in.	192 mR/hr	1.0 mR/hr	Not used
TP108(G)	48.8 lbs.	6-48/64 in.	176 mR/hr	1.4 mR/hr	Lock cover

Section 3 Test Objectives and Orientations

3.1 Test objectives

The objective in each of the tests was to target specific areas of the package that could cause displacement of the source from its stored position within the depleted uranium shield and/or affect the integrity of the shield itself.

The modes of failure under the test conditions that could achieve the test objectives and lead to elevated dose rates include the following:

- Fracture or penetration of the shield and shell weldment.
- Displacement of the shield within the shell weldment and distortion or fracture of the source.
- Failure of the source lock assembly and/or rear plate security screws.

3.2 Package Drop Orientations

Test plan #108 identified three basic drop orientations to target three specific areas on the package. One test specimen was used for each orientation in the entire drop test sequence: 4-foot, 30-foot, and puncture, unless otherwise assessed.

The first orientation was an attack on the lock mechanism and its attachment screws by impacting on the lock cover in conjunction with the shell weldment. The object was to use the shell lip as leverage to drive the rear plate across the endplate and shear the rear plate security screws. Test specimen TP108(B) was used for this orientation.

The next orientation attacks the shield and its attachment to the shell weldment by impacting on the bottom surface of the shell weldment. This orientation has two objectives; (1) Fracture the shield by hitting the shield at a point where it is closest to the outer surface. (2) Break the shield attachment pin by forcing the shield through it as the shield is driven back up into the shell or pivots around the center of gravity upon impact. Test specimen TP108(C) was used for this orientation.

The last orientation is similar to the one above. It also attempts to fracture the shield by hitting it at a point in close proximity to the exterior surface. It also could cause failure at the shield and shell connection point by forcing the shield through the attachment pin as the shield or shell translates or rotates in relation to one another. Test specimen TP108(D) was used for this orientation.

The "with jacket" orientation is similar to the first orientation. The first orientation was considered the worst orientation for the package based on the damage recorded on test specimen TP108(B). The justification and description for the orientation is recorded on each of the drop test checklists for the "with jacket" test specimen. The "with jacket" test specimen was TP108(G).

Section 4 Drop Test Data

The drop tests were conducted at Valley Tree in Groveland, Mass., on July 21, 2000. All test specimens were tested as planned per Test plan #108 and hit their intended target impact points.

Table 4.1 Test data summary.

Test Specimen	Test	Weight	Actual Impact Point	Damage Observed at Test Site
TP108(B)	4-foot free drop	44.2 lbs.	Lock cover & shell lip	• Shell bottom rear lip bent.
	30-foot free drop	44.4 lbs.	Lock cover & shell lip	• One rear plate security screw broken. • Rear plate puckered. • Shell lip bent further.
	Puncture drop #1	44.4 lbs.	Lock cover	• Lock cover dented.
	Puncture drop #2	NA	Lock cover	• Lock cover dented.
TP108(C)	4-foot free drop	44.3 lbs.	Shell bottom surface	• Shell bottom flattened. • Shell rear lip bent in.
	30-foot free drop	44.4 lbs.	Shell bottom surface	• Shell bottom flattened further. • Shell rear top bent. • Front endplate bent near bottom. • Outlet port binds.
	Puncture drop	44.4 lbs.	Shell bottom surface	• None observed.
TP108(D)	4-foot free drop	44.4 lbs.	Shell left side	• Shell left side flattened.
	30-foot free drop	44.3 lbs.	Shell left side	• Shell left side flattened further.
	Puncture drop	44.3 lbs.	Shell left side	• None observed.
TP108(G) (with jacket)	4-foot free drop	48.8 lbs.	Lock cover	• Lock cover dented.
	30-foot free drop	48.8 lbs.	Lock cover & shell side lip	• Shell rear side lip bent. • Lock mount dented. • Two jacket rivets broken. • Label rivets missing.
	Puncture drop	48.8 lbs.	Lock cover	• None observed.

Section 5 Test Inspection Results

The tables below summarize the inspection results after the drop test sequence. A physical thermal test was not conducted, but instead evaluated by analysis. Since the condition of the test specimens does not change, a final test inspection is not needed.

Table 5.1. Damage Measurements.

Test Specimen	Damage
TP108(B)	• Shell at rear end is bent in toward lock by about 1 inch at bottom. • Shell at front end has two spot dimples about 3/16 inch deep. • Rear plate is puckered in at selector ring about 1/16 inch. • Rear plate security screw at top right is broken. • Rear plate security screw at top left & bottom right is bent. • Rear plate security screw at bottom left slightly is bent. • Lock cover is dented 3/16 inch at three spots.
TP108(C)	• Shell bottom is depressed about 3/16 inch. • Shell top has two spot dimples about 3/16 deep. • Front plate knob pin is bent about 3/16 inch.
TP108(D)	• Shell left side is depressed about 1/8 to 1 inch. • Shell right side at rear end is bent about 3/16 inch.
TP108(G)	• Shell left side at rear end is bent about 5/8 inch. • Shell left side at front end is bent about 3/16 inch. • Rear plate security screw at top right is slightly bent. • Jacket rivets on left side are broken. • Lock cover is dented about 3/16 inch. • Lock cover pin at bottom is loose and can be removed. • Label rivets missing.

Table 5.2. Radiograph Inspection.

Test Specimen	Damage
TP108(B)	• Rear plate tube feature is slightly bent but intact. • Three rear plate security screws are slightly bent but intact. • One rear plate security screw broken end remained in the rivnut.
TP108(C)	• Shield contacts the shell at the impact surface.
TP108(D)	• U-shaped bracket is bent on the left side about 1/8 inch.
TP108(G)	• No apparent internal damage.

Table 5.3. Source Location Measurements.

Test Specimen	Before Test Measurement	After Test Measurement	Difference
TP108(B)	6-47/64 in.	6-45/64 in.	1/32 in.
TP108(C)	6-47/64 in.	6-47/64 in.	0 in.
TP108(D)	6-48/64 in.	6-48/64 in.	0 in.
TP108(G)	6-48/64 in.	6-46/64 in.	1/32 in.

Table 5.4. Simulated Source Condition Assessment.

Test Specimen	Condition
TP108(B)	No indication of damage
TP108(C)	No indication of damage
TP108(D)	No indication of damage
TP108(G)	No indication of damage

Table 5.5. Maximum Radiation Measurements at Surface.

Test Specimen	Before Test Measurement	After Test Measurement	% Change
TP108(B)	178 mR/hr	180 mR/hr	1.1
TP108(C)	178 mR/hr	180 mR/hr	1.1
TP108(D)	160 mR/hr	150 mR/hr	-6.3
TP108(G)	176 mR/hr	150 mR/hr	-14.8

Table 5.6. Maximum Radiation Measurements at One Meter from Surface.

Test Specimen	Before Test Measurement	After Test Measurement	% Change
TP108(B)	1.2 mR/hr	1.1 mR/hr	-8.3
TP108(C)	0.9 mR/hr	0.8 mR/hr	-11.1
TP108(D)	1.1 mR/hr	0.8 mR/hr	-27.3
TP108(G)	1.4 mR/hr	0.9 mR/hr	-35.7

Section 6 Drop Test Results

The damage measurements and radiograph inspections, tables 5.1 and 5.2, respectively show no fracture or penetration of the shield or shell weldment, displacement of the shield within the projector or distortion or fracture of the source.

Table 5.1 does reveal one broken and three bent rear plate security screws on test specimen TP108(B). However, the rear plate and lock assembly with source remained firmly attached to the shell weldment and in the shielded position. The bent screws held even after a repeated puncture drop on the same impact point and in the same direction as the 4-foot & 30-foot drops. The "with jacket" specimen, TP108(G), was dropped in a similar orientation as specimen TP108(B), except an adjustment was made to miss hitting the jacket at the bottom rear edge. The damage indicates similar results, although less in magnitude. The rear plate security screws are bent but none are broken on TP108(G).

Radiograph examination of the specimens, from table 5.2, indicates no damage to the shield or its attachment structure. Test specimen TP108(D) showed some minor bending of the U-shaped bracket in the direction in which it was dropped. The shield remains securely fastened to the welded shell for all test specimens.

The source location, see table 5.3, for each of the two specimens, TP108(B) & TP108(G), indicates similar displacement of the source about 1/32 inch towards the front end. This appears to be the result of the lock cover being forced into the rear plate upon impact. The maximum radiation measurements given in tables 5.5 and 5.6 show this displacement does not affect radiation levels at the surface or at one meter from the surface of the package.

Test specimen TP108(G) was measured for radiation levels without the jacket before the tests and with the jacket after the test. This would explain the lower readings and high percent change for this specimen.

The radiation levels at the surface and at one meter did not change significantly; in fact, they changed very little, if at all. The average 1 mR/hr maximum "after test" reading is well below the one R/hr limit for all specimens.

Table 5.4 shows that there was no affect on the simulated source condition for any of the specimen after the test.

Section 7 Thermal Analysis

Review of the damage to all test specimens after the drop tests suggest the fire test would have no affect on the radiation measurements taken after the drop tests. The reasons for this can be justified based on the condition of the test specimen after the drop tests and the properties of the materials used to secure and shield the source within the specimen.

Condition of Test Specimens

- The internal support structure for the shield is intact and fully functional. The internal support structure consists of the shield, shell weldment, shield pins, U-shaped brackets, and endplates with rivnuts.
- There are no holes or tears in the shell weldment to allow air to circulate through the package.
- The source assembly is intact, undamaged and secure in the shielded position. The source assembly consists of the source capsule, flexible wire, stop ball and source connector.
- The rear plate assembly continues to securely attach the source assembly to the package in the shielded position. The securing components of the rear plate assembly consists of the rear plate, lock slide, sleeve, selector ring, selector ring retainer, four #10 machine screws, and four 5/16-18 security screws.

Material Properties at Elevated Temperatures

- The melting temperature for all materials of the internal support structure, rear plate assembly and source assembly is above the thermal test temperature of 800°C.
- The thermal expansion for all materials of the internal support structure is less than the design clearance allowed for assembly.
- The stainless steel and titanium components of the internal support structure, rear plate assembly and source assembly have about 30% and 60% of their room temperature strength at 800°C, respectively.

  The load condition for the thermal test is for the internal structure to support the static weight of the shield in suspension. The dynamic impact nature of the drop tests can subject the structure to a force over 100 times the static weight of the shield. This means the strength of the materials used in the structure would need to decrease by two orders of magnitude or to about 1% of their strength at room temperature. The 30-minute thermal test is not long enough for significant creep deformation to occur in the structure.

Section 8 Conclusion

The test specimens were tested in accordance with test plan #108 and therefore as required in 10 CFR Part 71 and IAEA Safety Series No. 6 for type B(U)-85 transport packages.

The Model-880 transport package satisfies the test requirements of test plan #108. The Model-880 with jacket does not adversely affect the results of these tests. This conclusion is drawn from the drop test results and thermal analysis as supported by the test data, test inspection data and damage assessments.

APPENDIX D

TEST PHOTOGRAPHS

Test Specimen (B)

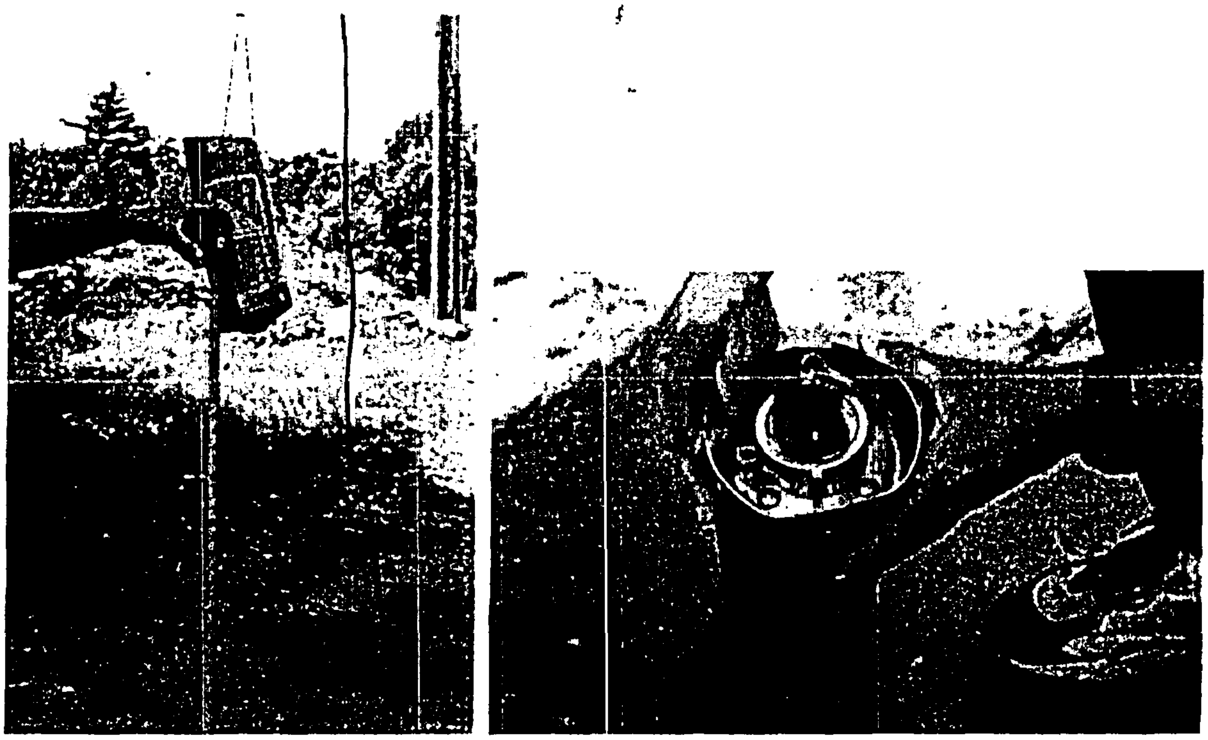


Figure 1: Four Foot Drop of Specimen (B)

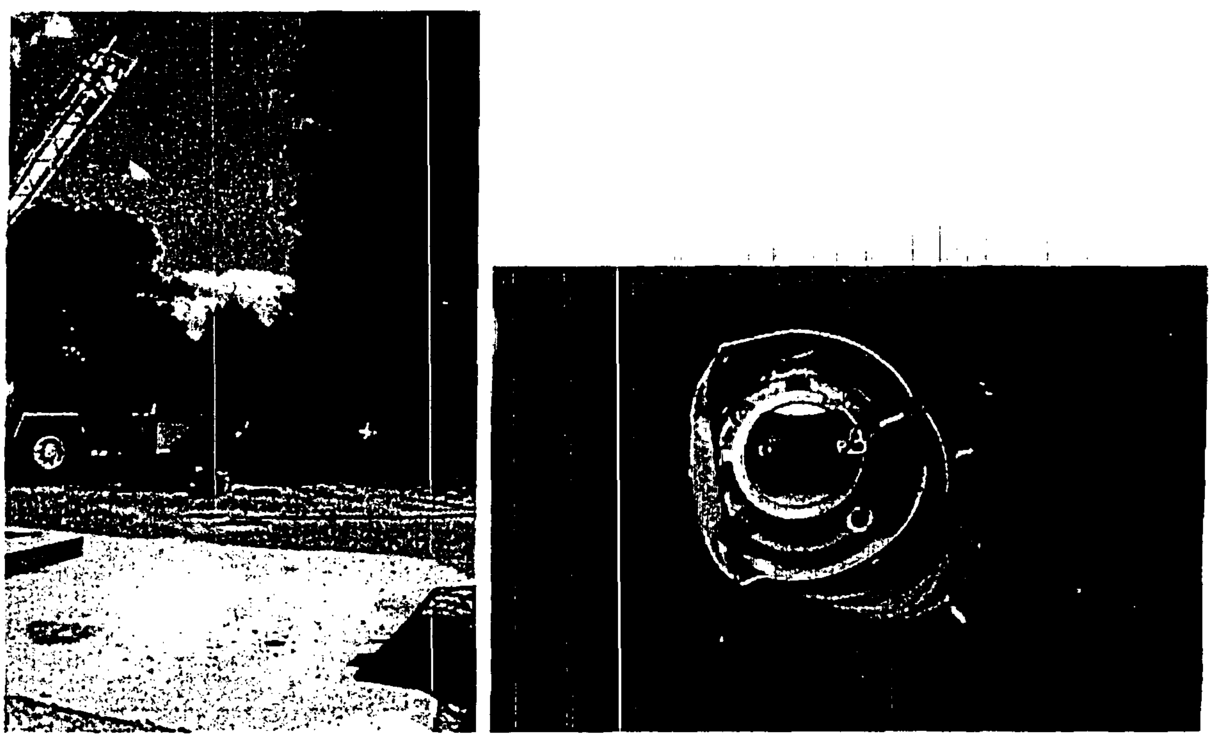


Figure 2: Thirty Foot Drop of Specimen (B)

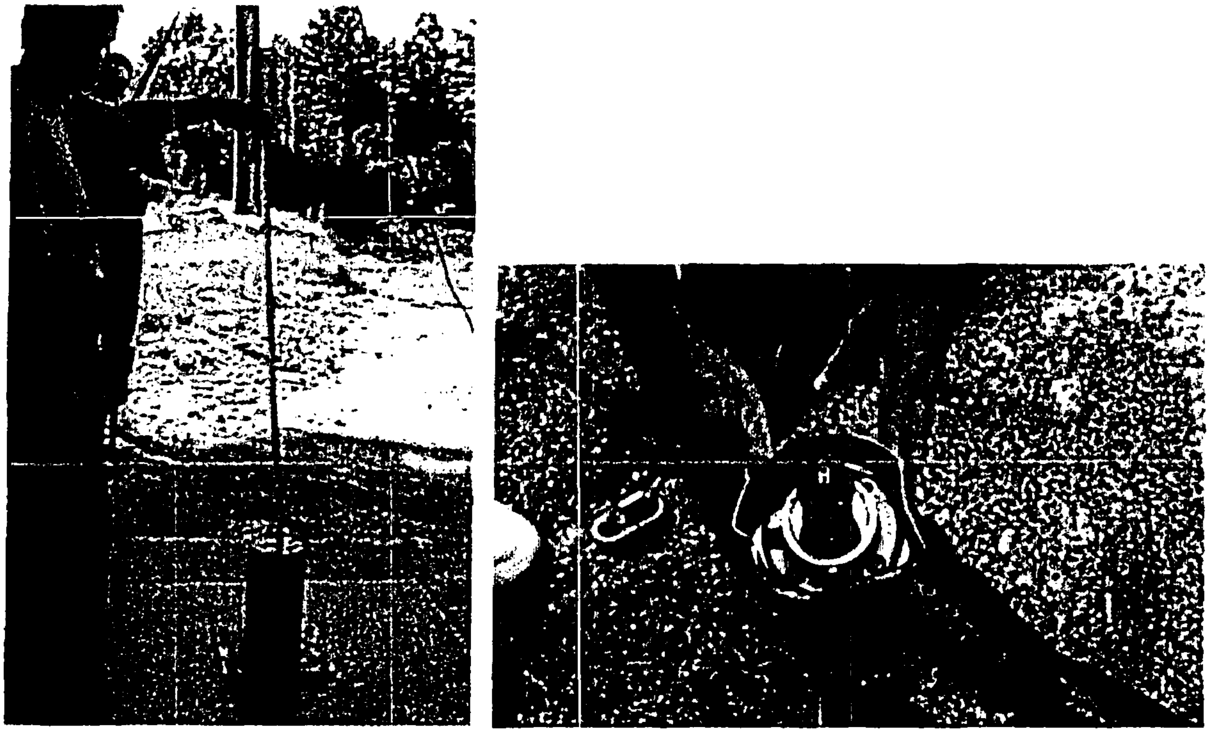


Figure 3: Puncture Test of Specimen (B)

Test Specimen (C)

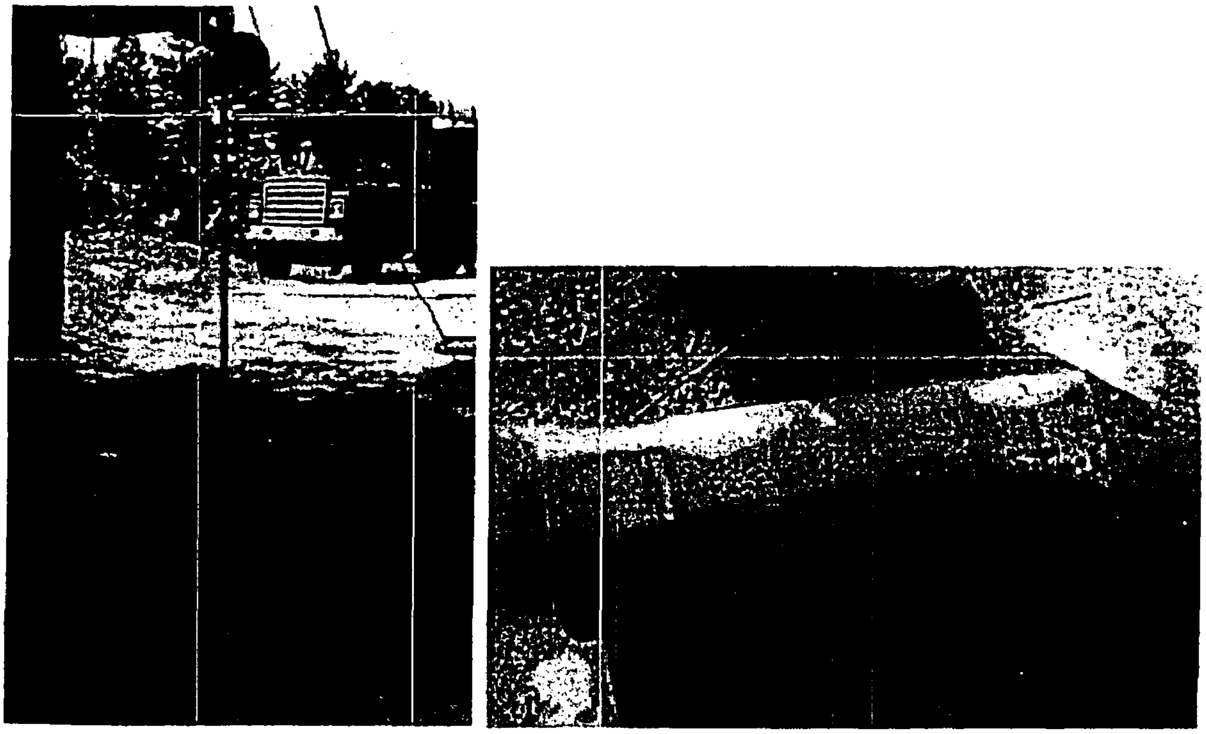


Figure 1: Four Foot Drop of Specimen (C)

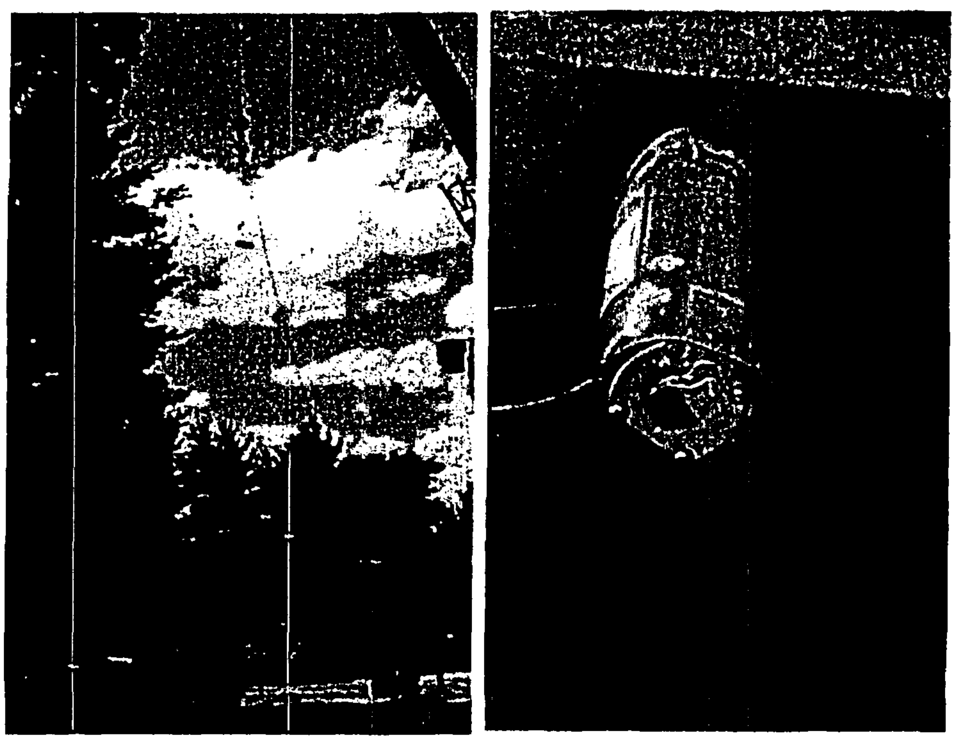


Figure 2: Thirty Foot Drop of Specimen (C)

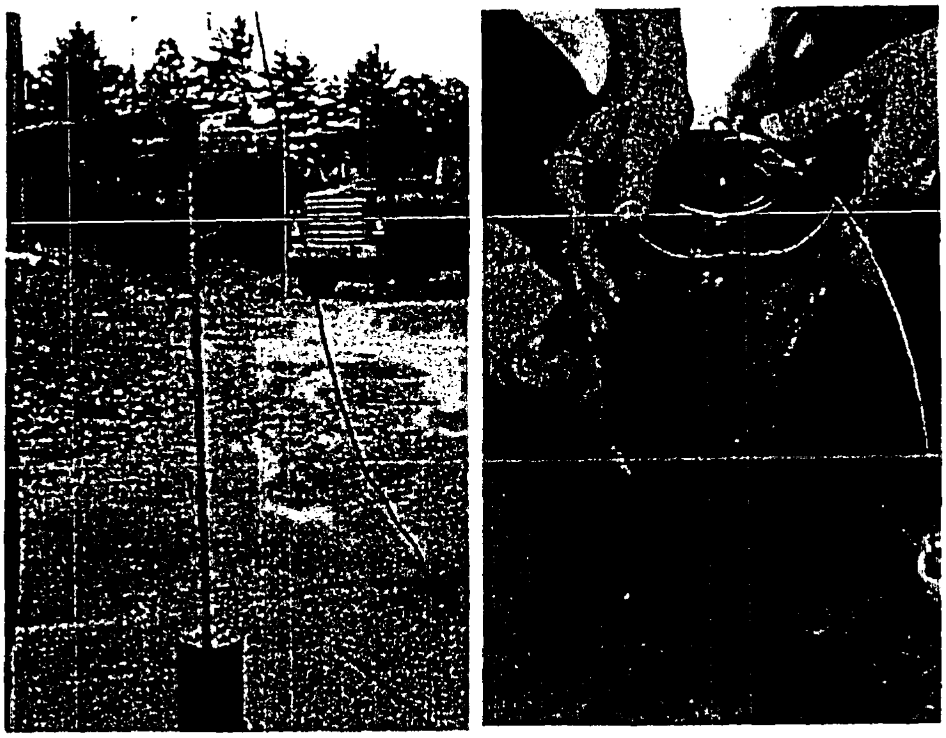


Figure 3: Puncture Test of Specimen (C)

Test Specimen (D)

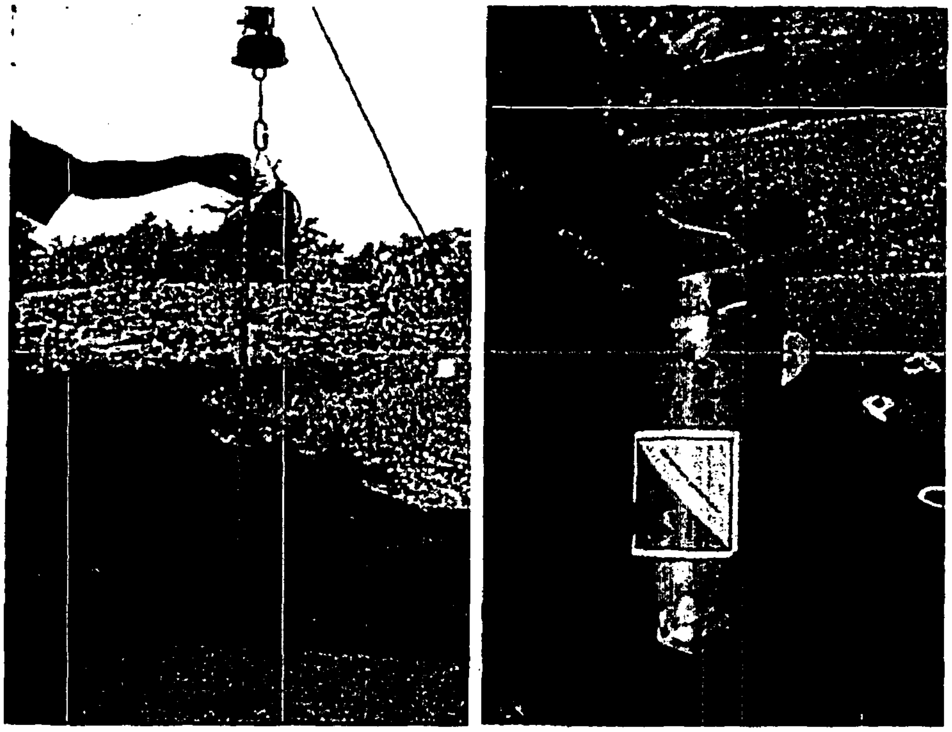


Figure 1: Four Foot Drop of Specimen (D)

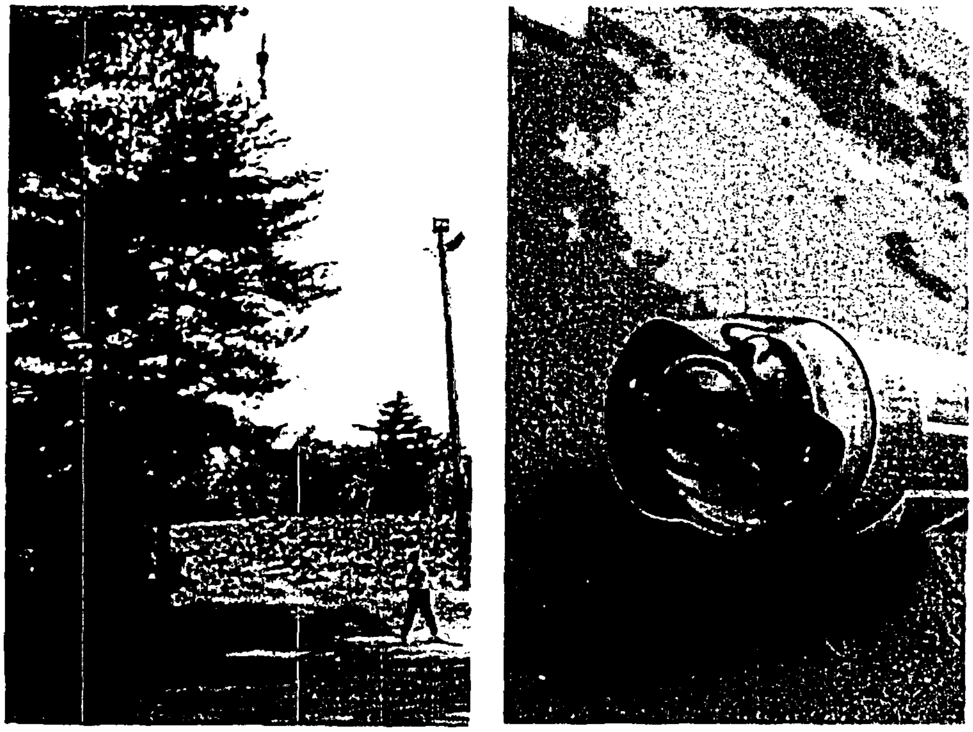


Figure 2: Thirty Foot Drop of Specimen (D)

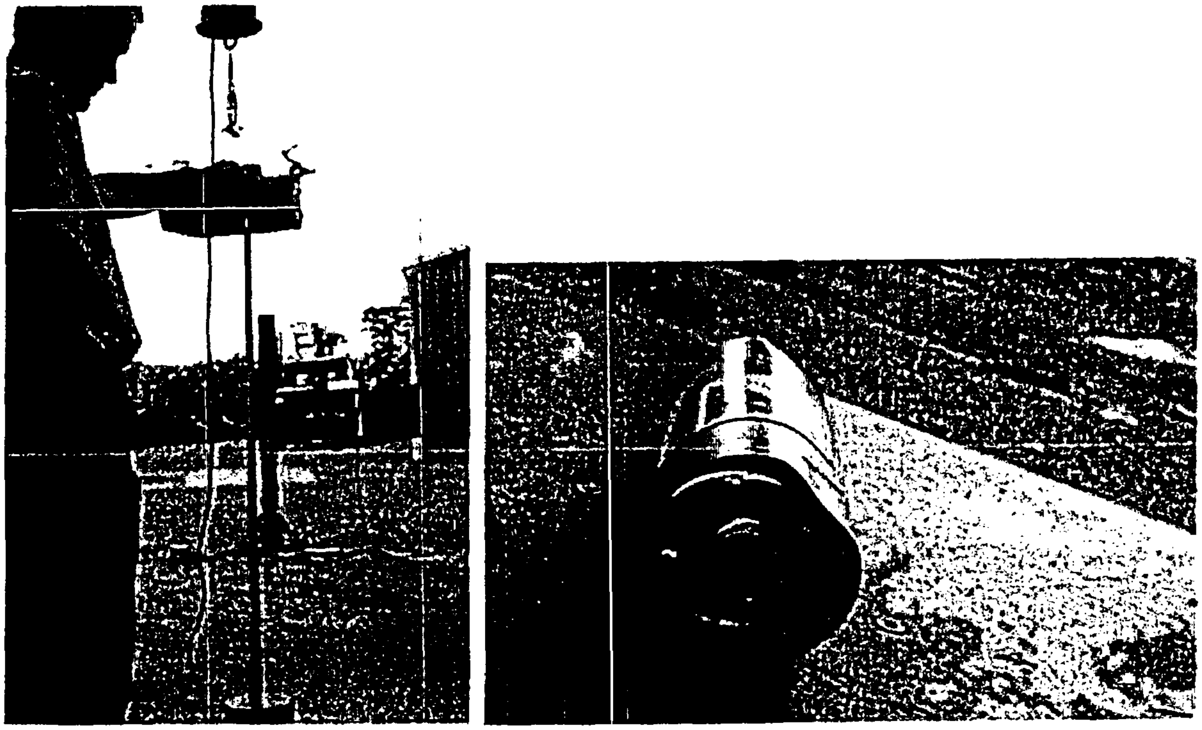


Figure 3: Puncture Test of Specimen (D)

Test Specimen (G)

Figure 1: Four Foot Drop of Specimen (G)

Figure 2: Thirty Foot Drop of Specimen (G)

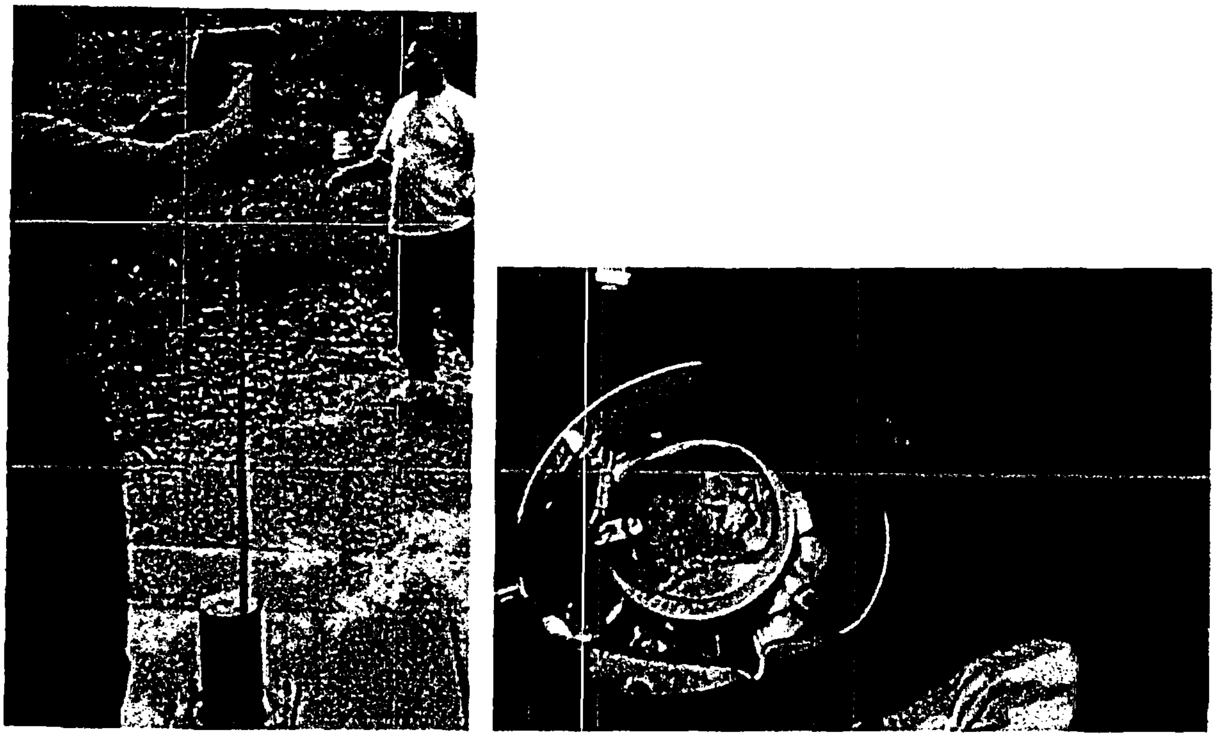


Figure 3: Puncture Test of Specimen (G)

Section 2.12.4 Appendix: Test Plan 115 (Feb 2001).

TEST PLAN 115

MODEL 880
RADIOGRAPHY PROJECTOR

ISO 3999-1:2000(E)
PERFORMANCE TESTS

Table of Contents

Test Plan No. 115

Section 1 Introduction

This test plan is intended to qualify the Model 880 Radiographic Projector to the performance requirements of ISO 3999-1:2000(E), "Radiographic protection – Apparatus for industrial gamma radiography – Part 1: Specifications for performance, design, and tests".

The ISO 3999-1:2000(E) tests covered under this plan are the following with their respective ISO 3999-1:2000(E) sections listed in parenthesis:

- Projection Test (6.2)
- Tensile Test for Source Assemblies (6.5)
- Shield Efficiency Test (6.4.1)
- Endurance Test (6.2)
- Horizontal Shock Test (6.4.6.1)
- Vertical Shock Test (6.4.6.2)
- Tensile Test for Guide Tubes (6.7.4)
- Tensile Test for Drive Cable Assembly (6.6.3)
- Kinking Test for Guide Tubes (6.7.3)
- Kinking Test for Drive Cable Assembly (6.6.2)
- Crushing and Bending Tests (6.6.1 & 6.7.2)
- Lock Breaking Test (6.4.2)
- Wrench Test (6.4.3)

This plan outlines the test procedure, describes the test specimen construction, identifies the test equipment, and provides worksheets for test data recording.

The vibration resistance test was evaluated and deemed unnecessary. The only parts that could come loose from vibration are the tamper-proof screws. However, tamper-proof screws have been used on similar devices over the past 25 years and field use of the screws has shown that the screws have never loosened as a result of vibration.

The accidental drop test was previously accomplished under Test Plan 104 in which the device was dropped from a height of 30 feet. After this drop, the dummy source remained secured in its fully shielded position within the source tube, attached to the source wire and was undamaged.

The design of the Model 880 Radiography Projector ensures that the device will operate continually under normal conditions. The Model 880 was designed ruggedly with non-corrosive materials, such as stainless steel, to prevent any harmful rusting or corrosion.

Only the Model 880-150 Ci device will be used to demonstrate compliance with ISO 3999-1:2000(E) performance tests. The Model 880-50 Ci device, by default, will perform the same or better than the Model 880-150 Ci device due to its lower weight and identical structural construction.

The test sequence to be used for the testing is listed in Section 6.

Section 2 Gamma Radiography Projector Description

The Model 880 projector, shown in Figure 2.1, is a portable (Class P), externally projecting source (Category II) device. The device consists of four major assemblies; the body assembly, the rear plate assembly, the front plate assembly, and the jacket assembly. A source assembly is also used and stored with the device.

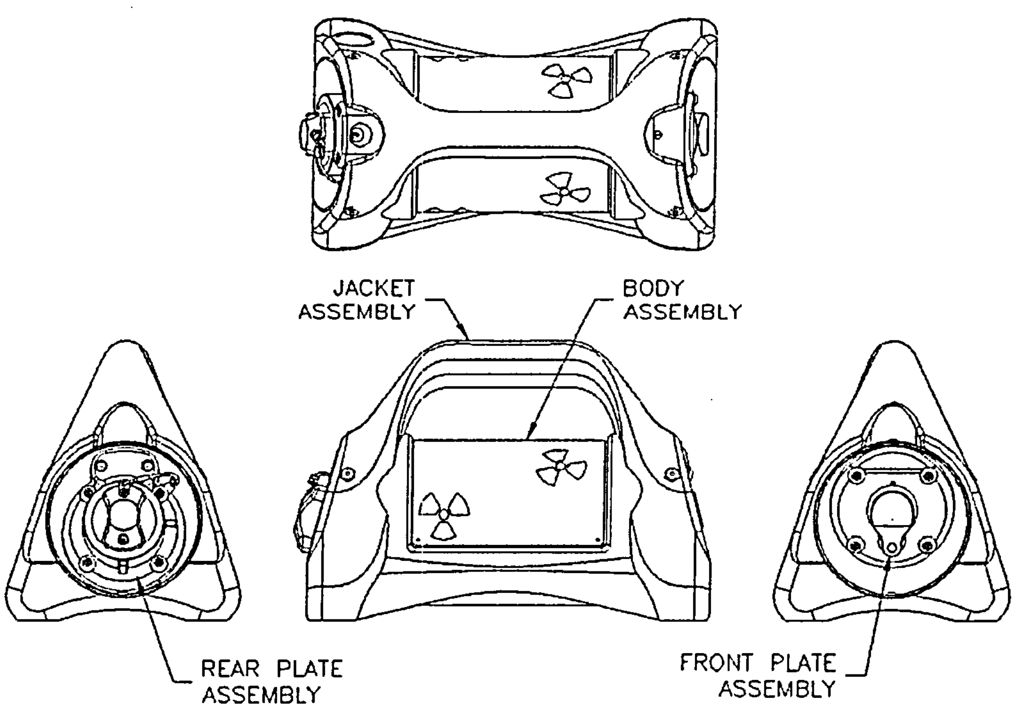


FIGURE 2.1: MODEL 880 PROJECTOR.

Section 3 Discussion on System Failure Modes of Interest

The tests in this test plan subject the test specimen to conditions likely to occur during use. The exposure device and integral safety features shall remain operational after the test and shall experience no loss of shielding efficiency.

A projection test is to be performed to determine the resistance to projection before and after the sequence of operational tests. The maximum force applied to the control handle must not increase by 25% after performing the operational tests. The projection test will be performed before and after the entire sequence of tests instead of each single test. Conducting the test in this manner will give a more conservative test result rather than smaller incremental increases in force from each single test. The test will be set up per Figure 6 in the ISO 3999-1:2000 standards. However, because of limited space, the cable paths used will have added difficulty and will actually be a more tortuous path than the one shown in the figure. The adjustment of this setup will only make the test more difficult and so will not make the test easier to pass. The operational tests include the endurance test, the shielding efficiency test, the horizontal and vertical shock tests, the tensile tests, the kinking tests, and the crushing and bending tests. A failure of the projection test would show an increase of over 125% of the force required to move the source assembly before the test to the force required after the test. A failure would indicate that a part of the exposure device, drive cable, drive cable housing, guide tube, or source assembly was damaged and is restricting movement of the source assembly or drive cable. This could result in an active source getting hung up in an unsecured location.

The source assembly tensile test is also to be performed before and after the sequence of operational tests. The purpose of the test is to ensure that the operational tests do not have any negative effects on the source wire assembly. The same dummy source assembly will be used with all of the operational tests requiring a source assembly except for the shielding efficiency test which requires an active source assembly. If there is enough wear on the swaged features of the assembly, the connections could fail when pulled.

The shielding efficiency test measures the performance of the shield when loaded with a maximum rated activity of 150 curies of Iridium-192. The shield efficiency test was completed on the test device after manufacture on November 10, 2000 and will not be completed again for this test. The results from this test will be included in the final test report at the conclusion of the tests in this test plan. The completion of the shielding efficiency test before the initial projection test and initial tensile test for source assemblies as shown in the test procedure in Section 6 of this test plan will not effect the testing in a negative manner. Performance of the shielding efficiency test does not have any effect on restricting the movement of a source assembly that is measured in the projection test. Also, the dummy source that is to be tested in the tensile test for source assemblies is not the same source assembly that would be used with the shield efficiency test because the shield efficiency test requires an active source. The source used with this test may not be the maximum rated source (150 Ci of Ir-192) that the device can handle but a correction factor will be used to determine the actual maximum dose rates if this is the case. The possible failure mode for this test would be high radiation levels over the exposure limits for a class P exposure device. Radiation levels over the limits may be the result of a number of factors. The following are possible factors:

1. Wrong source position within the shield tube.
2. Poor shield design or translation of the design to the manufacturing process.
3. Changes in distance of the container's exterior surface relative to the source position.

The endurance test demonstrates that the radiographic system will remain operational after 50,000 cycles. This test will use the same setup as the Projection Test. A failure could cause the source tube to wear resulting in depleted uranium contamination. Also, wear on the front and rear plate mechanisms may prevent the source wire assembly from becoming completely secure in the fully shielded position.

The horizontal shock test demonstrates the ability of the test specimen to withstand swing type impacts occurring during normal use. Three areas of the device that could cause the greatest effect on radiological safety if impacted were chosen for this. The areas include the front cover, the lock, and the rear cover test (see figures 11.1, 11.2, and 11.3). Possible failure would involve the inability to operate the front or rear plate mechanisms. Hitting the small protruding features on each end could cause deformation to the assembly mounting plates or shell endplates that may produce binding in the rotating parts of the mechanisms.

The vertical shock test demonstrates the ability of the test specimen to withstand many short drops expected during normal use. There are two normal carrying positions for this device; one with the jacket and the other without the jacket. Although the jacket would add a small amount of weight to the device, the jacket would also absorb some of the impact. This test will be performed without the jacket to prevent any impact absorption and give a more conservative test assessment. Possible failure could occur at the shield support structure, specifically at the pinned connection. If the connection were to fail, misalignment of the source tube could prevent the source wire from moving. Also, damage to the jacket could result in not being able to use the handle to carry the device.

The purpose of the tensile tests on the controls and guide tubes is to demonstrate that the they are able to withstand tensile stresses that may occur during normal use. The connections could fail if there is enough wear on the swaged features. Also, a failure could indicate that the design or manufacture of the controls or guide tubes is faulty.

The kinking tests on the control cable assembly and guide tubes are done to show that the sheaths are able to withstand the conditions they may likely encounter during use. After performing the kinking tests, the control cable assembly and guide tubes should remain operable without any loss of integrity. Also, a failure could indicate that the design or manufacture of the controls or guide tubes is faulty.

The crushing and bending tests are performed to demonstrate that the control cable assembly and guide tubes remain operational after being stepped on by the heel of a shoe. A mechanical device is used to simulate the crushing effect on the tubes from a shoe. After performing the crushing and bending test, the control cable assembly and guide tubes should remain operational without any loss to integrity.

The lock breaking test is performed to check the durability of the lock on the exposure device. A force of 400 N (90 lbs) is gradually applied to the lock and held for several seconds before being released. The force will be applied to where the key is inserted because this is the most exposed part of the lock and could become jammed or damaged by a force. The force is applied and released in this way eleven consecutive times at each position. A failure would occur if the exposure container could be opened without unlocking the device. A failure of the lock could develop into having an active source exposed without the operator's knowledge.

The wrench test is used to demonstrate that the handle of the exposure device is able to withstand forces that may be encountered during use. A static load of 25 times the weight of the device is placed at the most fragile part of the handle. A failure would be indicated by the handle becoming unattached from the device or becoming unstable. A failure could result in not being able to use the handle to carry the device or possibly an accidental drop.

Section 4 Construction and Condition of Test Specimens

All radiography system components listed in the table below and used in this test plan are manufactured in accordance with the AEA Technology QSA, Inc. Quality Assurance Program.

The Model 880, 150-Curie assembly, part number B88000 will be the device used in all tests requiring the use of a test projection device.

A Model 424-9 dummy source assembly will be loaded into the test specimen for all tests except the shield efficiency test and accidental drop test. An active Model 424-9 source assembly, part number A42409, with at least 75% of the maximum rated capacity (minimum of 112.5 curies of Iridium-192) shall be loaded into the test specimen for the shield efficiency test.

The radiography system consisting of the components in the table below will be used for the endurance test. The same Model 424-9 dummy source assembly used in the endurance test will be used in the tensile test.

Table of Model 880 Radiography System Components		
Part number	**Part Name**	**Quantity**
B88000 Rev.A	MODEL 880 150 Ci MAX ASSEMBLY	1
A42409XL Rev.A	MODEL 424-9 DUMMY SOURCE ASSEMBLY	1*
A42409 Rev.E	MODEL 424-9 SOURCE ASSEMBLY	1*
BTAN69250	PISTOL GRIP CONTROL SYSTEM, 50 FOOT	1
B48930-7 Rev.A	SOURCE GUIDE TUBE ASSEMBLY, 7 FOOT	1
B48907-7 Rev.T	SOURCE GUIDE TUBE ASSEMBLY, 7 FOOT	4
B48906-7 Rev.Q	SOURCE GUIDE TUBE ASSEMBLY, 7 FOOT	1

* Note: Either one of the Model 424-9 source assemblies, Dummy (XL) or Active may be used in the system, but not simultaneously.

Section 5 Material and Equipment List

The worksheets in section 24 identify the equipment and procedure required for the tests. Additional materials and equipment used to facilitate the tests will be listed as needed.

Section 6 Test Procedures

The testing shall follow the sequence below.

Device 1: Model 880, 150 Ci Assembly

1. Initial Projection Test
2. Initial Tensile Test for Source Assemblies
3. Shield Efficiency Test (See Section 3)
4. Endurance Test
5. Horizontal Shock Test
6. Vertical Shock Test
7. Tensile Test for Guide Tubes
8. Tensile Test for Control Cable Assembly
9. Kinking Test for Guide Tubes
10. Kinking Test for Control Cable Assembly
11. Crushing and Bending Tests for Control Cable Assembly and Guide Tubes
12. Final Tensile Test for Source Assemblies
13. Final Projection Test (See Section 3)
14. Lock Breaking Test
15. Wrench Test

Section 7 Testing Safety and Waste Disposal

Testing Safety

The shield efficiency test uses active radioactive material and the test specimen contains depleted uranium (low level radioactive material). Handling radioactive material shall be done with caution and only by qualified personnel.

The weight of the test specimen is approximately 50 pounds. Proper lifting techniques shall be used to prevent injury.

Some tests of this plan may result in heavy falling objects and flying debris. Safety glasses and a safe distance must be used.

The possibility of depleted uranium contamination could be present during and after the tests. Qualified personnel shall ensure all applicable surfaces are free of contamination.

Waste Disposal

The test specimen shall be stored in the low-level waste room until authorization by the regulatory department is given to properly dispose.

Section 8 Initial Projection Test

Requirements

The Projection Test demonstrates that the torque required at the controls to move the source assembly from the secured position to the working position and back to the secured position after certain tests remains within 125% of the torque before the tests. The minimum movement rate for projecting and retracting the source assembly shall be a constant 0.75 m/s (2.5 ft/s) of linear movement until the source stops after each cycle.

Equipment

1. The test projection device equipped with the largest diameter and greatest length dummy source assembly recommended for the device.
2. The largest recommended guide tube and controls (42 ft. guide tube and 50 ft. control cable) connected to the projection device set up in accordance with Figure 6 of the ISO 3999-1:2000 standards (see Section 3).
3. Motor and Controller with torque readout.
4. Cycle counter.
5. Pneumatic actuator for lock slide actuation.

Section 9 Initial Tensile Test for Source Assemblies

Requirements

The tensile tests demonstrate that the source assembly maintains its integrity after experiencing tensile loads that may be encountered during normal use. The Tensile Test for Source Assemblies is performed before and after the sequence of operational tests. The source assembly should remain operable and maintain its integrity.

Equipment

1. Dummy source assembly. (See Section 3)
2. Force gage for measuring the forces required from Section 6.5 of the ISO 3999-1:2000 standard.

Section 10 Endurance Test

Requirements

The Endurance Test demonstrates the gamma radiography system remains operational after 50,000 cycles of the source assembly moving from secure to working positions and back. This test is done to check the resistance due to fatigue and wear of the different components and accessories of the device during normal operation. The automatic securing mechanism and the lock should remain operational and effective.

Equipment

The equipment used for this test is equivalent to the equipment used in the initial projection test (see Section 8).

Section 11 Horizontal Shock Test

Requirements

The horizontal shock test demonstrates that the exposure device will withstand the horizontal impacts the device may encounter (see Section 3).

The exposure device and integral safety features shall remain operational after the test and the device shall experience no loss of shielding efficiency.

Equipment

1. The test projection device equipped with a dummy source assembly secured and locked in its most shielded position with all covers.
2. A target consisting of a steel bar with a flat vertical face 50 mm (1.97 in.) diameter by 300 mm (11.81 in.) long. The bar shall lie horizontally and be fixed or welded to a rigid mass at least 10 times the mass of the exposure device (500 lbs).
3. Suspension equipment for the test projection device that does not cause undesirable rotation around a vertical axis when suspended before being exposed to the shock.

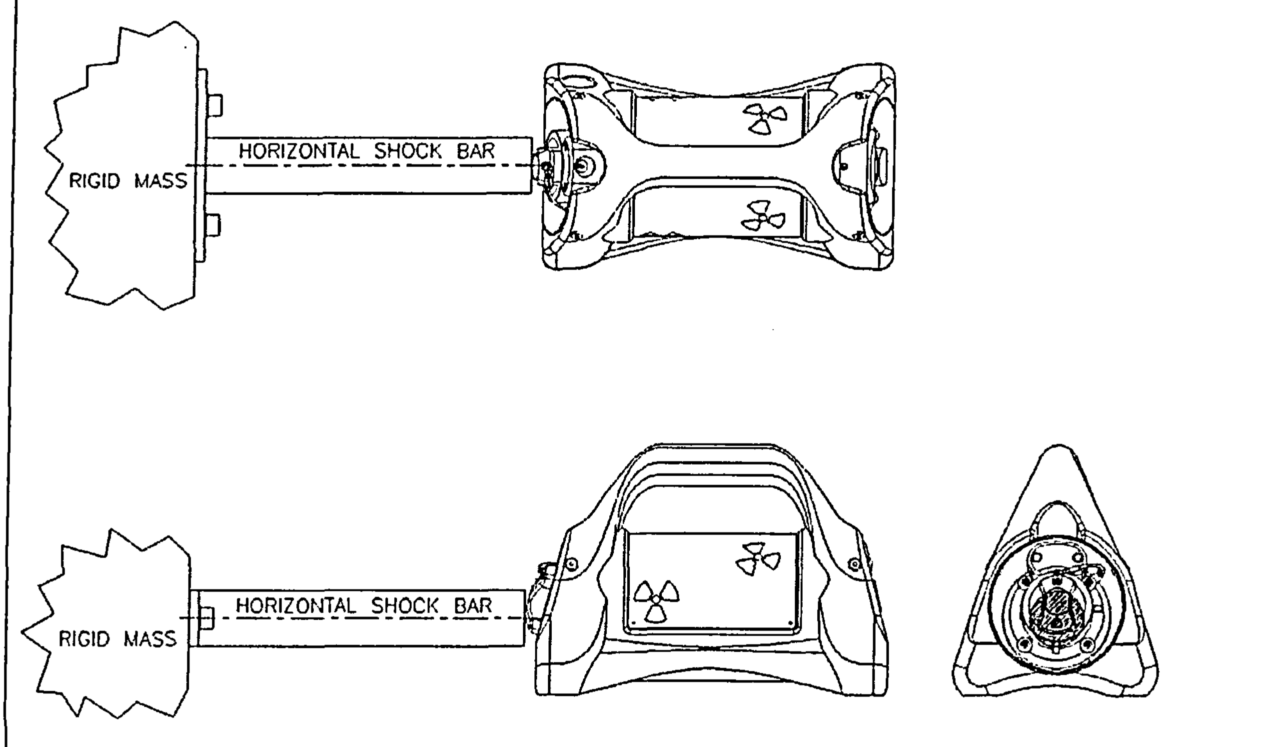


Figure 11.1 Setup for lock cover area.

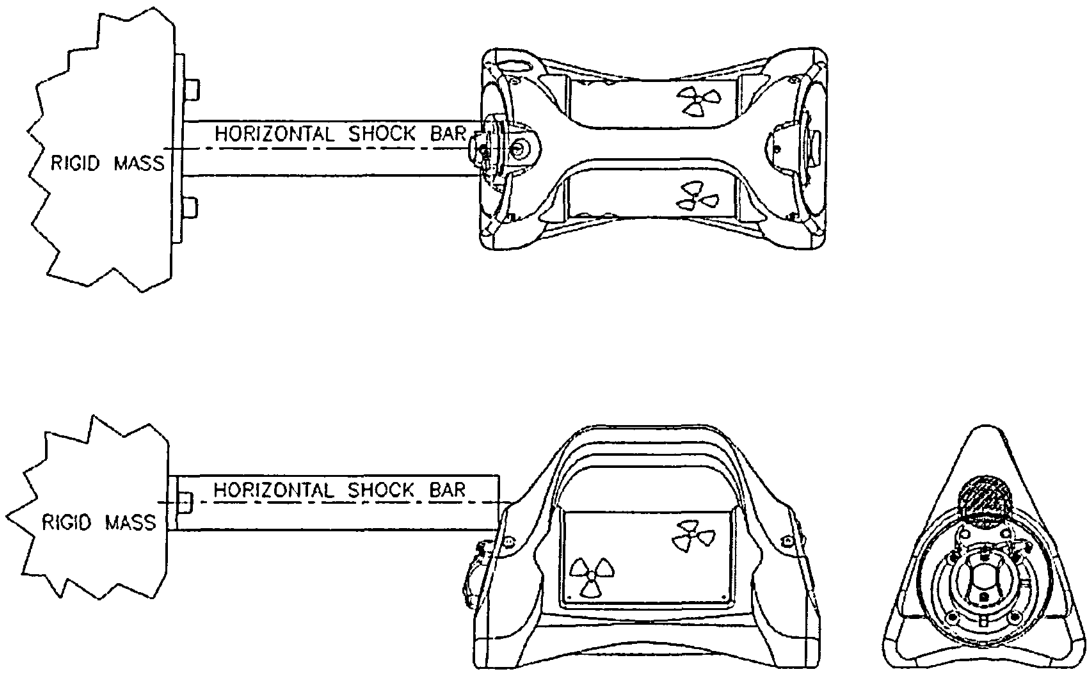


Figure 11.2 Setup for lock mount area.

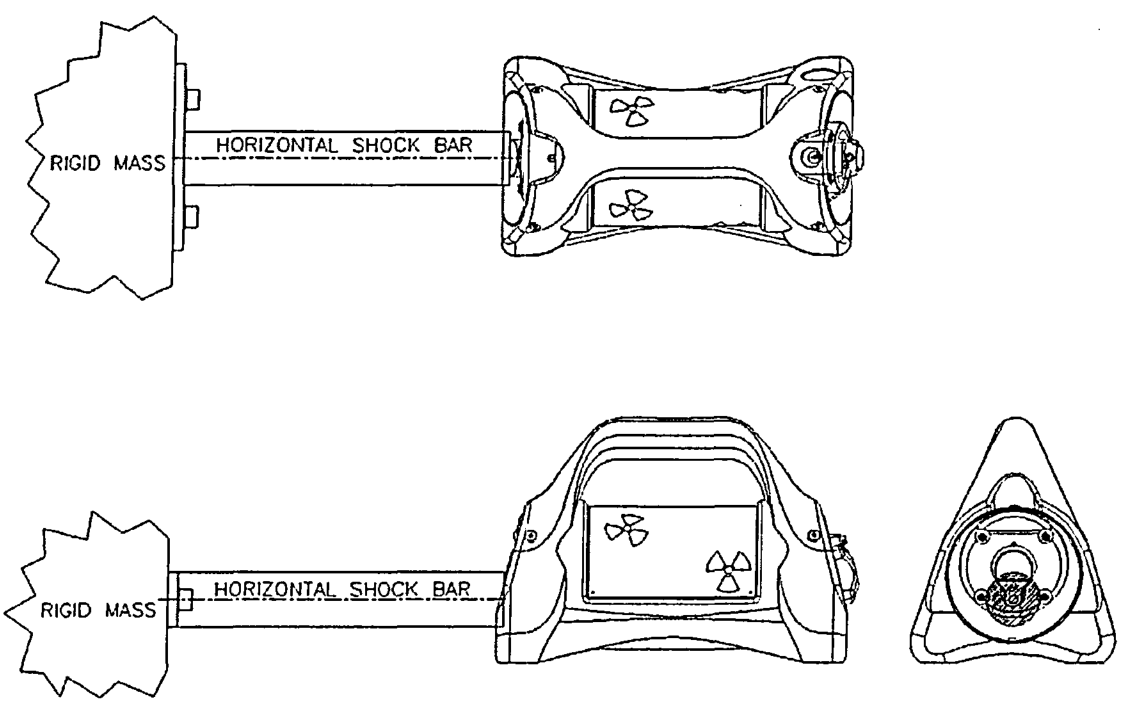


Figure 11.3 Setup for front knob area.

Section 12 Vertical Shock Test

Requirement

The vertical shock test demonstrates that the exposure device will withstand the vertical impacts the device may encounter. This test will be performed without the jacket as shown in Figure 12.1 (see Section 3).

The exposure device and integral safety features shall remain operational after the test and shall experience no loss of shielding efficiency.

Equipment

1. The test projection device equipped with a dummy source assembly secured and locked in its most shielded position with all covers but without the jacket.
2. A rigid target consisting of a flat horizontal surface of steel, concrete or solid timber having a mass at least 10 times the test specimen (500 lbs.). The surface shall be covered with a sheet of 7 or 9 ply (25mm thick) fir plywood or equivalent.

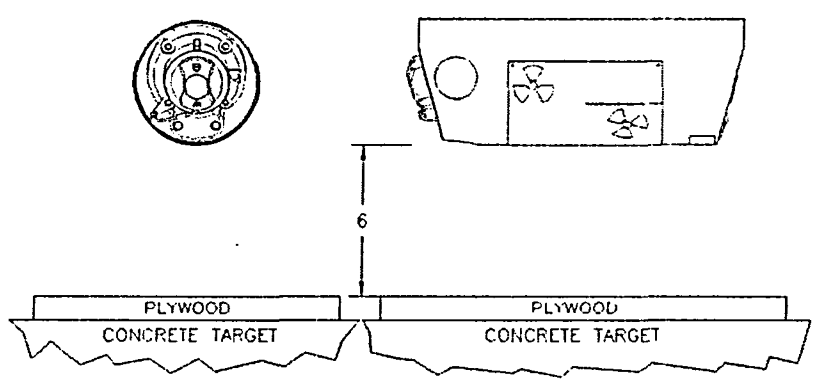


Figure 12.1

Section 13 Tensile Test for Guide Tubes

Requirements

The Tensile Tests demonstrate that the guide tube housing maintains its integrity after experiencing tensile loads that may be encountered during use as shown in Section 6.74 of the ISO 3999-1:2000 standard. The guide tube should remain completely operable without any damage that may restrict travel of the source assembly.

Equipment

1. The test projection device equipped with the dummy source assembly.
2. Test apparatus T10281 used to secure the guide tube.
3. A force or pressure gage for measuring the required loads.

Section 14 Tensile Test for Control Cable Assembly

Requirements

The Tensile Tests demonstrate that the control cable assembly maintains its integrity after experiencing tensile loads that may be encountered during use as shown in Section 6.74 of the ISO 3999-1:2000 standard. The control cable assembly will remain operational after the tests.

Equipment

1. The test projection device equipped with the dummy source assembly.
2. The test control cable assembly.
3. A force or pressure gage for measuring the required loads.

Section 15 Kinking Test for Guide Tube

Requirements

The kinking test demonstrates that the guide tube will withstand conditions that may be encountered during use as shown in Section 6.73 of the ISO 3999-1:2000 standard. The guide tube shall remain operational after the test without any damage that may restrict the travel of the source assembly.

Equipment

1. The test guide tube.
2. A flat test surface equipped with horizontal guides separated by less than or equal to 5 times the diameter of the guide tube.
3. A dynamometer.
4. A tape measure.

Section 16 Kinking Test for Drive Cable Assembly

Requirements

The kinking test demonstrates that the drive cable housing will withstand conditions that may be encountered during use as shown in Section 6.62 of the ISO 3999-1:2000 standard. The drive cable housing shall remain operational without any loss to structural integrity after the test.

Equipment

1. The test drive cable assembly.
2. A stop watch.
3. A tape measure.
4. A flat test surface.

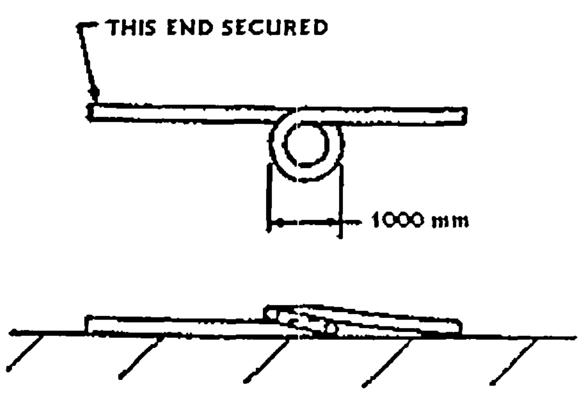


Figure 16.1

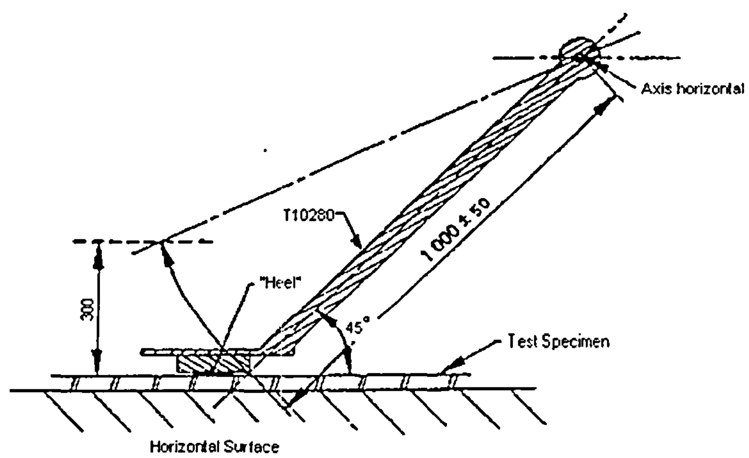
Section 17 Crushing and Bending Test

Requirements

The Crushing and Bending Test demonstrates that the drive cable and the guide tubes remain operational after being impacted by the heel of a shoe. The control cable assembly should remain operable without any loss to structural integrity.

Equipment

1. Test guide tube and control cable.
2. Test surface having a minimum mass of 150 kg (330 lb) and must be hard enough to not deform from the application of a steel punch without the presence of the drive cable housing or guide tube.
3. Steel guides to laterally hold housings with length greater than two heel lengths and a height between .5 and .75 times the sheath height for juxtaposed sheaths or single guide tube and between 1.5 and 1.75 times the sheath height for superimposed sheaths.
4. Steel punch tool T10280 as shown in figure 17.1.
5. Tape measure.



17.1 Crushing Test

Section 18 Final Tensile Test for Source Assemblies

Requirements

The tensile tests demonstrate that the source assembly maintains its integrity after experiencing tensile loads that may be encountered during normal use. The Tensile Test for Source Assemblies is performed before and after the sequence of operational tests. The source assembly should remain operable and maintain its integrity.

Equipment

1. Dummy source assembly. (See Section 3)
2. Force gage for measuring the forces required from Section 6.5 of the ISO 3999-1:2000 standard.

Section 19 Final Projection Test

Requirements

The Projection Test demonstrates that the torque required at the controls to move the source assembly from the secured position to the working position and back to the secured position after certain tests remains within 125% of the torque before the tests. The minimum movement rate for projecting and retracting the source assembly shall be a constant 0.75 m/s (2.5 ft/s) of linear movement until the source stops after each cycle.

Equipment

The equipment used for this test is equivalent to the equipment used in the initial projection test (see Section 8).

Section 20 Lock Breaking Test

Requirements

The Lock Breaking Test demonstrates that the locking mechanism can withstand a breaking force while in the locked position with the key removed. The lock must remain effective and operable after the test.

Equipment

1. The test projection device equipped with a dummy source assembly secured and locked in its most shielded position with all covers.
2. The lock breaking tool, Tool number T10345.
3. A stopwatch.
4. At least 90 lbs. of weights to be added gradually to lock breaking tool during test.

Section 21 Wrench Test

Requirements

The Wrench Test demonstrates that the exposure container handle is able to withstand a static force equal to 25 times the weight of the device (1250 lbs). The force is to be supplied to the most vulnerable part of the handle. The most vulnerable part of the handle is considered to be the middle of the handle the most bending stresses will occur.

Equipment

1. The test projection device equipped with a dummy source assembly secured and locked in its most shielded position with all covers.
2. A test plate with weights that, when strapped to the device, weighs at least 1250 lbs.
3. A scale to verify the weight of the test equipment.
4. Crane

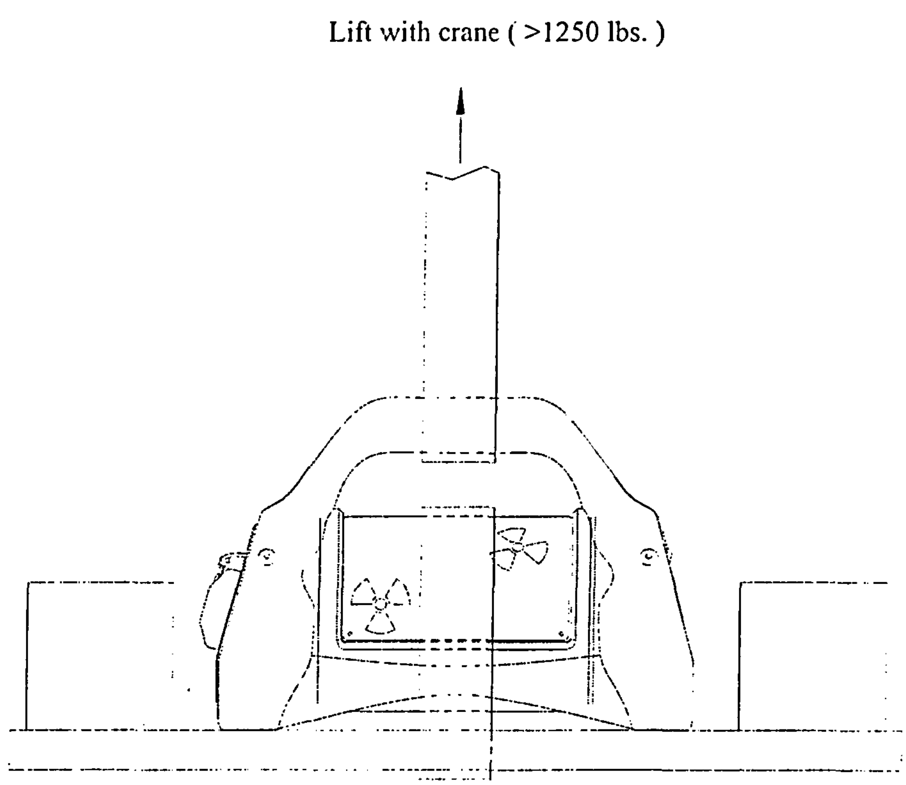


Fig. 21.1

Section 22 Final Test Assessment

After all the tests have been completed, evaluate the condition of the test specimen and assess its performance relative to the test requirements of standard ISO 3999-1:2000(E).

Section 23 Test Worksheets

Test Plan 115 Initial Projection Test

Material and Equipment:

Test device (Model 880) serial number: ____________________
Dummy source assembly serial number: ____________________
Drive control assembly and guide tubes.
Automatic cycling apparatus including motor, controller, pneumatic actuator, and counter.

Test Procedure:

1. Assemble system using Figure 6 of ISO 3999-1:2000 as a guide.
2. Assemble and connect the test specimen to the system.
3. Complete 10 full cycles.
4. Record the rotational speed (P177 rpm): ____________
5. Record the highest operational torque for each cycle. 1:_____ 2:_____ 3:_____ 4:_____ 5:_____

   6:_____ 7:_____ 8:_____ 9:_____ 10:_____

6. Record the average operational torque: _____

Damage and/or operational malfunctions:

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____
____
____

Test Assessment:

____
____
____

Recorded by: ____________________________________ Date: ______________

Witnessed by: ____________________________________ Date: ______________

Test Plan 115 Initial Tensile Test for Source Assemblies

Material and Equipment:

Dummy source assembly serial number: ____________________

Force gage serial number: ______________________________

Test Procedure:

1. Record stop ball to connector measurement: ____________
2. Attach control cable to the dummy source assembly.
3. Restrain end of source assembly opposite control cable connection.
4. Gradually apply 1000 N +44/-0 (225 lb +10/-0) force over 10 seconds, hold for 5 seconds, then release.
5. Complete test a total of 10 times.
6. Unrestrain source assembly.
7. Restrain source assembly at largest diameter and repeat steps 3-5.
8. Record stop ball to connector measurement: ____________.
9. Perform a complete functional operation of the device using the dummy source assembly.

Damage and/or operational malfunctions:

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Test Assessment:

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Recorded by: ______________________________ Date: ____________

Witnessed by: ______________________________ Date: ____________

Test Plan 115 Endurance Test

Material and Equipment:

Test device (Model 880) serial number: ____________________
Dummy source assembly serial number: ____________________
Drive control assembly and guide tubes.
Automatic cycling apparatus including motor, controller, pneumatic actuator, and counter.

Test Procedure:

1. Prepare test specimen by securing a dummy source into its fully shielded position, attaching all covers, and locking the device.
2. Assemble system using Figure 6 of ISO 3999-1:2000.
3. Set the cycle counter to zero.
4. Cycle the test specimen a minimum of 50,000 times.
5. Record the rotational speed (>2.5 ft/s): ____________________
6. Record the highest operational torque: ____________________
7. Record the total number of cycles (>50,000): ____________________
8. Clean the dummy source assembly.
9. Perform a complete functional operation of the device using the dummy source assembly used in the test.

Damage, maintenance, and/or operational malfunctions:

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Test Assessment:

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____

Recorded by: ______________________________ Date: ______________

Witnessed by: ______________________________ Date: ______________

Reviewed by:

Engineering: ______________________________ Date: ______________

Regulatory Affairs: ______________________________ Date: ______________

Quality Assurance: ______________________________ Date: ______________

Test Plan 115 Horizontal Shock Test

Material and Equipment:

Test device (Model 880) serial number: ________________

Target horizontal test bar: Tool Number T10333, serial number: __________

Target mass weight: ____________________ Weight scale used: ____________________

Test Procedure:

1. Prepare test specimen by securing a dummy source into its fully shielded position, attaching all covers, and locking the device.
2. Suspend the test specimen to the test apparatus.
3. Contact the area of impact to the target per figure 11.1.
4. Swing and raise the test specimen "center of gravity" up to at least 4 inches above the target center.
5. Release the test specimen.
6. Perform steps 4 & 5 for a total of twenty (20) times.
7. Perform a complete functional operation of the device using a dummy source assembly.

Damage and/or operational malfunctions:

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____

Test Assessment:

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____

Recorded by: ______________________________	Date: ____________
Witnessed by: ______________________________	Date: ____________

Test Plan 115 Horizontal Shock Test

Material and Equipment:

Test device (Model 880) serial number: ________________

Target horizontal test bar: Tool Number T10333, serial number: ________

Target mass weight: ____________________ Weight scale used: ____________________

Test Procedure:

1. Prepare test specimen by securing a dummy source into its fully shielded position, attaching all covers, and locking the device.
2. Suspend the test specimen to the test apparatus.
3. Contact the area of impact to the target per figure 11.2.
4. Swing and raise the test specimen "center of gravity" up to at least 4 inches above the target center.
5. Release the test specimen.
6. Perform steps 4 & 5 for a total of twenty (20) times.
7. Perform a complete functional operation of the device using a dummy source assembly.

Damage and/or operational malfunctions:

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Test Assessment:

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Recorded by: ______________________ Date: __________

Witnessed by: ______________________ Date: __________

Test Plan 115 Horizontal Shock Test

Material and Equipment:

Test device (Model 880) serial number: ______________

Target horizontal test bar: Tool Number T10333, serial number: ________

Target mass weight: ______________ Weight scale used: ______________

Test Procedure:

1. Prepare test specimen by securing a dummy source into its fully shielded position, attaching all covers, and locking the device.
2. Suspend the test specimen to the test apparatus.
3. Contact the area of impact to the target per figure 11.3.
4. Swing and raise the test specimen "center of gravity" up to at least 4 inches above the target center.
5. Release the test specimen.
6. Perform steps 4 & 5 for a total of twenty (20) times.
7. Perform a complete functional operation of the device using a dummy source assembly.

Damage and/or operational malfunctions:

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Test Assessment:

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Recorded by: ______________________ Date: __________

Witnessed by: ______________________ Date: __________

Test Plan 115 Vertical Shock Test

Material and Equipment:

Test device (Model 880) serial number: ______________

Target Used: ______________

Test Procedure:

1. Prepare test specimen by securing a dummy source into its fully shielded position, attaching all covers, and locking the device.
2. Suspend the test specimen at least 6 inches over the test target upside-down with the jacket removed.
3. Drop the test specimen onto target.
4. Perform steps 2 & 3 a total of one hundred (100) times.
5. Perform a complete functional operation of the device using a dummy source assembly.

Damage and/or operational malfunctions:

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Test Assessment:

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Recorded by: ______________________ Date: ____________

Witnessed by: ______________________ Date: ____________

Test Plan 115 Tensile Test for Guide Tubes

Material and Equipment:

Test device (Model 880) serial number: ____________________

Test apparatus T10281.

Force gage serial number: ______________________________

Test Procedure:

1. Prepare test specimen by securing a dummy source into its fully shielded position, attaching all covers, and locking the device.
2. Secure exposure device to prevent movement during test.
3. Attach one end of test specimen to apparatus, T10281.
4. Apply a tensile load of 500 N +44/-0 (112 lb +10/-0) for 30 seconds to the end of test specimen. The 112 lbf. tensile load will register as a minimum of 78.4 psi (84.3 psi with gauge tolerance allowance) on the pressure gauge.
5. Release the pressure.
6. Perform steps 4 & 5 a total of 10 times.

Damage and/or operational malfunctions:

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Test Assessment:

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____
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Recorded by: ____________________ Date: __________

Witnessed by: ____________________ Date: __________

Test Plan 115 Tensile Test for Control Cable Assembly

Material and Equipment:

Test device (Model 880) serial number: ________________

Force gage serial number: ____________________

Control Cable Assembly

Test Procedure:

1. Secure test device (Model 880) so that it cannot move during test.
2. Attach the controls to the test device.
3. Apply a tensile load of 500 N +44/-0 (112 lb +10/-0) for 30 seconds to the end of test specimen. The 112 lbf. tensile load will register as a minimum of 78.4 psi (84.3 psi with gauge tolerance allowance) on the pressure gauge.
4. Release the pressure.
5. Perform steps 3 & 4 a total of 10 times.
6. Secure the controls so they will not move during test.
7. Apply a force of 1000 N +44/-0 (225 lb +10/-0) tensile force to the free end of the source assembly for 10 seconds.
8. Perform step 7 a total of 10 times.

Damage and/or operational malfunctions:

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Test Assessment:

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____

Recorded by: ______________________ Date: __________

Witnessed by: ______________________ Date: __________

Test Plan 115 Kinking Test for Guide Tubes

Material and Equipment:

Guide Tube.

Dynamometer Ser. No. __________

Tape measure.

Test Procedure:

1. Secure test specimen without connection on a horizontal surface between two parallel plates.
2. Make a flat closed loop with guide tube.
3. Pull the free end of the loop with a force of 200 N +22/-0 (45 lb +5/-0) over 5 seconds and maintain for 10 seconds.
4. Repeat steps 2 through 4 for a total of 10 times using the same point of the guide tube.
5. Redo complete test 10 times with a connection in the loop opposite the crossing point.
6. Remove the test specimen from the clamp.
7. Verify that guide tube is operational.

Damage and/or operational malfunctions:

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Test Assessment:

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Recorded by: ______________________ Date: __________

Witnessed by: ______________________ Date: __________

Test Plan 115 Kinking Test for Control Cable Assembly

Material and Equipment:

Control Cable Assembly.

Tape Measure.

Stop Watch.

Test Procedure:

1. Secure the control housing rectilinearly on a horizontal surface and clamp one end of the housing to the tabletop.
2. Make a 1000mm (39.37 in) loop with the housing on the horizontal surface (see figure 17.1). Verify the diameter of the loop using a tape measure.
3. Pull the free end of the housing without allowing it to rotate along its original axis at a minimum speed of 2.0 m/s (6.6 ft/sec).
4. Repeat test for a total of 10 times at each of 10 equidistant points along the length of the control housing.
5. Remove control housing from the clamp.
6. Verify that control assembly is operational.

Damage and/or operational malfunctions:

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Test Assessment:

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Recorded by: ______________________ Date: __________

Witnessed by: ______________________ Date: __________

Test Plan 115 Crushing and Bending Test

Material and Equipment:

Steel Punch, Tool Number T10280.

Tape Measure.

Guide Tube and Control Cable Assembly.

Test Procedure:

1. Place the guide tube test specimen on a rigid horizontal test surface with a minimum mass of 150 kg between the lateral guides. The surface must be hard enough that it will not be deformed by a steel punch (heel) without the presence of the object to be tested.
2. Place the steel punch (T10280) at a point on the test specimen as shown in Figure 17.1
3. Lift the edge of the steel punch heel a minimum of 300mm (11-13/16 in).
4. Drop the steel punch onto the test specimen.
5. Perform steps 3 & 4 a total of ten (10) times on randomly selected points on the test specimen. One of these points shall be on a joint.
6. Verify that the guide tube is operational.
7. Place the control cable test specimen in the juxtaposed position on the same surface used with the guide tube and laterally support with guides 0.5 to 0.75 times the control cable housing height.
8. Repeat steps 2 through 4 on five randomly selected points on the housing making sure the punch heel hits both juxtaposed housings simultaneously.
9. Rotate the control cable test specimen on the surface to the superimposed position between lateral guides 1.5 to 1.75 times the height of a tube.
10. Repeat steps 2 through 4 on five randomly selected points making sure that the heel drops on the top tube.
11. Verify that the control cable assembly is operational.

Damage and/or operational malfunctions:

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Test Assessment:

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____

Recorded by: ______________________ Date: __________

Witnessed by: ______________________ Date: __________

Test Plan 115 Final Tensile Test for Source Assemblies

Material and Equipment:

Dummy source assembly serial number: ____________________

Force gage serial number: ________________________________

Test Procedure:

1. Record stop ball to connector measurement: ______________
2. Attach control cable to the dummy source assembly.
3. Restrain end of source assembly opposite control cable connection.
4. Gradually apply 1000 N +44/-0 (225 lb +10/-0) force over 10 seconds, hold for 5 seconds, then release.
5. Complete test a total of 10 times.
6. Unrestrain source assembly.
7. Restrain source assembly at largest diameter and repeat steps 3-5.
8. Record stop ball to connector measurement: ______________
9. Perform a complete functional operation check of the device using the dummy source assembly.

Damage and/or operational malfunctions:

____
____
____
____

Test Assessment:

____
____
____

Recorded by: ________________________________ Date: ____________

Witnessed by: ________________________________ Date: ____________

Test Plan 115 Final Projection Test

Material and Equipment:

Test device (Model 880) serial number: ___________________
Dummy source assembly serial number: ___________________
Drive control assembly and guide tubes.
Automatic cycling apparatus including motor, controller, pneumatic actuator, and counter.

Test Procedure:

1. Assemble system using Figure 6 of ISO 3999-1:2000 as a guide.
2. Assemble and connect the test specimen to the system.
3. Complete 10 full cycles.
4. Record the rotational speed (P 177 rpm): ___________
5. Record the highest operational torque for each cycle. 1:_____ 2:_____ 3:_____ 4:_____ 5:_____

   6:_____ 7:_____ 8:_____ 9:_____ 10:_____

6. Record the average operational torque: _____

Damage and/or operational malfunctions:

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____
____
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Test Assessment:

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____

Recorded by: ______________________________ Date: ____________

Witnessed by: ______________________________ Date: ____________

Test Plan 115 Lock Breaking Test

Material and Equipment:

Test device (Model 880) serial number: ________________

Lock Breaking Tool, Tool Number T10345

Stopwatch.

Weights.

Test Procedure:

1. Prepare test specimen by securing a dummy source into its fully shielded position, attaching all covers, and locking the device.
2. Secure test specimen to prevent movement during test.
3. Set up Lock Breaking Tool with rod end resting on lock.
4. Gradually apply a load of 400 N +44/-0 (90 lbs +10/-0) force to lock over 10 seconds by adding weights to the top of the Lock Breaking Tool. Max Force: ______
5. Maintain the force for 5 seconds.
6. Gradually remove weights over 10 seconds.
7. Repeat test 10 times.
8. Perform a complete functional operation of the device using the dummy source assembly.

Damage and/or operational malfunctions:

____

____

____

____

Test Assessment:

____

____

____

Recorded by: ______________________________ Date: ____________

Witnessed by: ______________________________ Date: ____________

Test Plan 115 Wrench Test

Material and Equipment:

Test device (Model 880) serial number: ________________

Weight of test device (Model 880): ________________

Total weight of test equipment: ______________

Scale: ______________

Test Procedure:

1. Prepare test specimen by securing a dummy source into its fully shielded position, attaching all covers, and locking the device.
2. Secure device to plate and add weight to 25 times weight of test specimen as shown in Fig. 22.1.
3. Lift test specimen and weight from middle of handle with crane.
4. Perform a complete functional operation of the device using the dummy source assembly.

Damage and/or operational malfunctions:

____

____

____

____

Test Assessment:

____

____

____

Recorded by: ______________________________ Date: ____________

Witnessed by: ______________________________ Date: ____________

Section 25 Appendix: ISO 3999-1:2000

Section 2.12.5 Appendix: Test Plan Report 115 Minus Appendices (March 2001).

TEST REPORT 115

MODEL 880
RADIOGRAPHY PROJECTOR

ISO 3999-1:2000
PERFORMANCE TESTS

Table of Contents

Test Report No. 115

Section 1 Introduction

This report documents the performance of the Model 880 Radiographic Projector to the test requirements of ISO 3999-1:2000, Radiological Safety for the Design and Construction of Apparatus for Gamma Radiography.

The ISO 3999-1:2000 tests were done in the following order:

- Initial Projection Test
- Initial Tensile Test for Source Assemblies
- Endurance Test
- Horizontal Shock Test
- Vertical Shock Test
- Tensile Test for Guide Tubes
- Tensile Test for Control Cable Assembly
- Kinking Test for Guide Tubes
- Kinking Test for Control Cable Assembly
- Crushing and Bending Tests
- Final Tensile Test for Source Assemblies
- Final Projection Test
- Lock Breaking Test
- Wrench Test

A test data worksheet was produced for each test detailing the material and equipment used for the test, the test procedure, a list of any damage or operational malfunctions as a result of the test, and the test assessment. Each test data worksheet is located in Appendix A. Copies of the route cards used in the production of the test device and dummy source assembly are located in Appendix B. In addition, a shield efficiency profile was completed before and after all of the above tests. Copies of the shield profile inspection forms are contained within Appendix C.

Section 2 Test Specimen Construction and Acceptance

All radiography system components listed in the table below and used in this test plan were manufactured and accepted in accordance with the AEA Technology QSA, Inc. Quality Assurance Program.

Except for the tensile test, the test specimen was the Model 880, 150-Curie projector. The projector was manufactured to drawing B88000 Rev. A and is serialized D1000.

A Model 424-9 dummy source assembly was loaded into the test specimen for all tests.

The radiography system consisting of the components in the table below was used for the endurance test. The same Model 424-9 dummy source assembly used in the endurance test was used in the tensile test for the source assembly.

Table of Model 880 Radiography System Components		
Part number	**Part Name**	**Quantity**
B88000 Rev. A	MODEL 880 150 Ci MAX ASSEMBLY	1
A42409XL Rev. A	MODEL 424-9 DUMMY SOURCE ASSEMBLY	1
BTAN69250 Rev. C	PISTOL GRIP CONTROL SYSTEM, 50 FOOT	1
B48930-7 Rev. A	SOURCE GUIDE TUBE ASSEMBLY, 7 FOOT	1
B48907-7 Rev. T	SOURCE GUIDE TUBE ASSEMBLY, 7 FOOT	4
B48906-7 Rev. Q	SOURCE GUIDE TUBE ASSEMBLY, 7 FOOT	1

Section 3 Test Objectives and Results

Initial Projection Test

The initial projection test is used to determine crank torque amounts before any other testing. A final projection test is done following all of the operational tests. ISO-3999:1-2000 standards state that the torque values cannot increase by more than 25% from the initial projection test to the final projection test. The setup for the test is the same as the setup for the endurance test.

The test resulted in an average torque of 41% of full motor torque (or 51 in-lbs).

Initial Tensile Test for Source Assembly

The tensile test demonstrates the source assembly maintains its integrity after experiencing tensile loads likely to occur during use.

The tensile tests resulted in an increase in the stop ball to connector measurement from 1.227 in. to 1.249 in. Inspection of the source assembly under a microscope revealed that the source wire stretched and unraveled slightly nearest the stop ball connector explains the increased measurement. However, a complete functional test with the test Model 880 projector showed that the source assembly was still completely functional. Therefore, the source assembly passed this test.

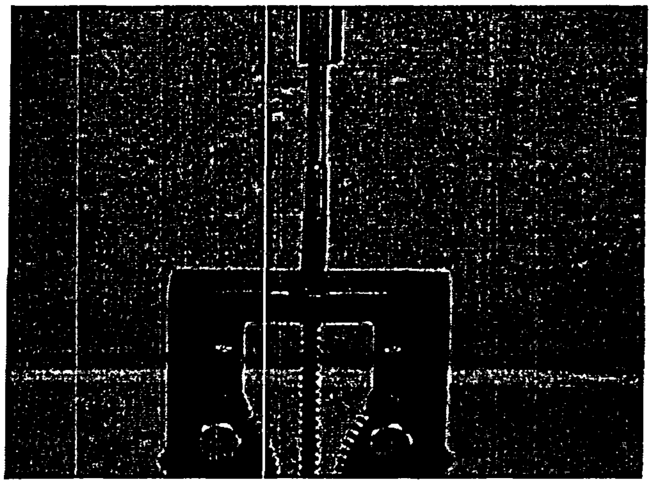


Figure 3.1 Source Assembly Tensile Test Connector and Ball Setup

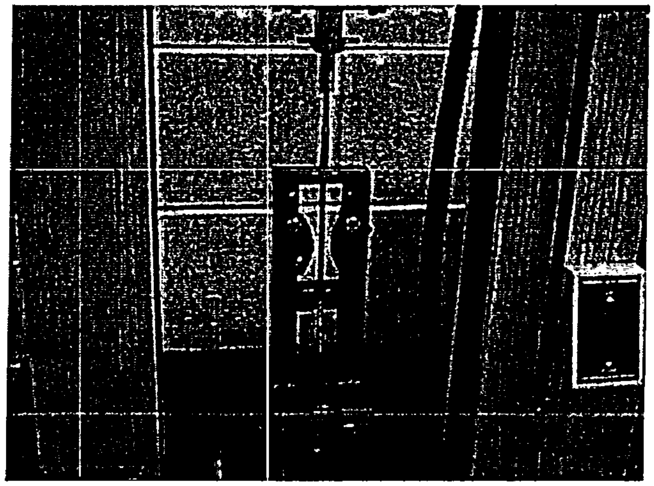


Figure 3.2 Source Assembly Tensile Test Connector and Capsule Setup

Endurance Test

The endurance test demonstrates that the gamma radiation system remains operational after 50,000 cycles of the source assembly moving from secure to working position and back while using the longest recommended guide tubes and controls. The exposure device and integral safety features shall remain operational after experiencing this test.

The device was put through 51,026 cycles at a speed of 3.28 ft/s. The highest operational torque observed was 41.4 % full load torque (or 51 in-lbs). There was no visible damage and there was only negligible wear to the device, drive cable, and guide tubes. One of the crank bearings was broken but the crank still turned freely. There were no functional or operational problems resulting from this test. Therefore, the device passed this endurance test.

Figure 3.3 Endurance Test Setup

Horizontal Shock Test

The horizontal shock test demonstrates the exposure device will withstand the horizontal impacts likely to occur during use. The exposure device and integral safety features shall remain operational after the test and the device shall experience no loss to shielding integrity.

The test was performed on three areas of the device: the lock cover area (Fig. 3.4), the lock mount area, and the front knob area (Fig. 3.5). The test was initially performed by measuring the 4 inch pendulum lift from the foot of the impact side of the device. This resulted in the center of gravity being lifted 4.5 inches which is more than the 4 inch lift required by ISO 3999-1:2000. The lock cover and lock mount areas became dented after the 4.5 inch center of gravity lift. However, the two areas did not lose any functionality.

The front knob area was tested twice using the 4.5 inch center of gravity lift. The impacts resulted in the front knob tightening enough to not be able to be pulled and turned by hand. Also, the front plate buckled inward slightly which prevented the fitting entering and turning the slider.

A new front plate assembly was installed and tested by lifting the center of gravity of the device only the required 4 inches. This test resulted only in minor dents to the front knob and very slight buckling of the front plate. The knob could be pulled and turned by hand and the fitting could enter and turn the slider proving that the device passes the minimum requirements of this test.

A further test was performed on the front knob by lifting the center of gravity of the device the 4 inches and allowing it to drop on the impact cylinder at an angle. This test was done to prove that the device could withstand an angled shock to the most fragile area of the device. The test produced only minor dents on the impact side of the front knob. The knob could be pulled and turned by hand and the fitting could enter and turn the slider.

After the tests, the device was put through a complete functional test that resulted in normal operation. Therefore, the device passed the horizontal shock test.

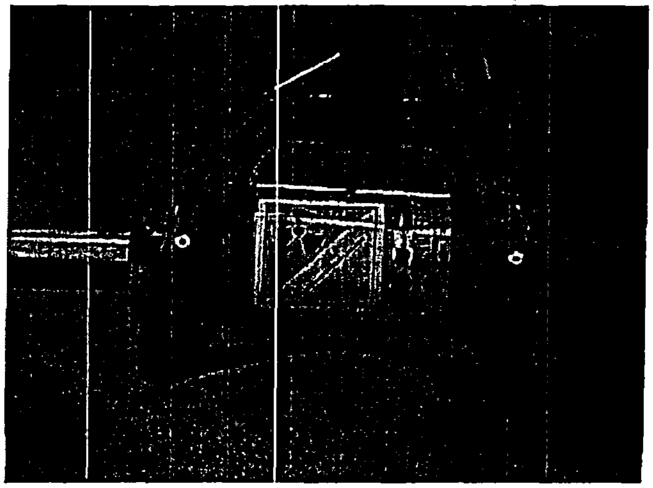


Figure 3.4 Horizontal Shock on Lock Cover

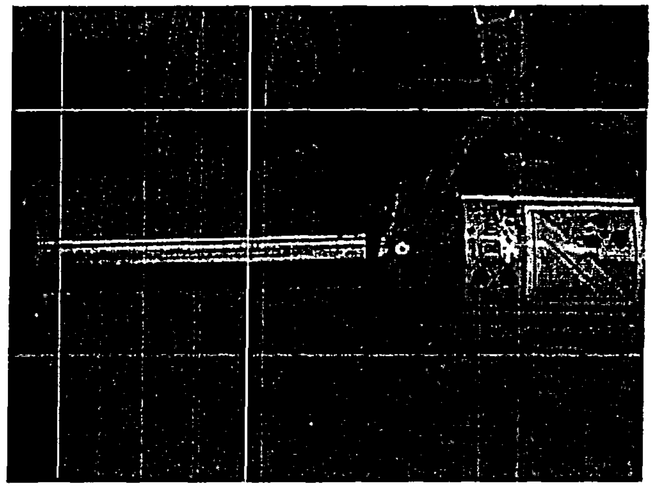


Figure 3.5 Horizontal Shock on Front Knob

Vertical Shock Test

The vertical shock test demonstrates the exposure device will withstand the vertical impacts likely to occur during use. The exposure device and integral safety features shall remain operational after the test and shall experience no loss of shielding integrity.

The test was performed on the device without the jacket in the normal carrying position. The device showed no visible damage after being dropped one hundred times from a height of 6 inches. The device functioned properly after having undergone a complete functional test. The device passed the vertical shock test.

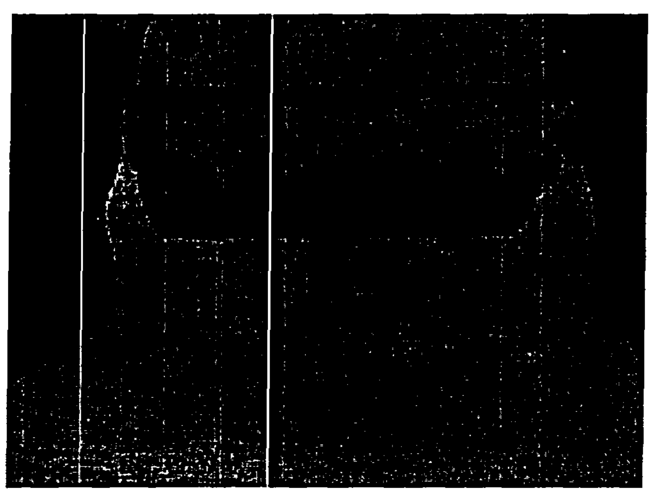


Figure 3.6 Vertical Shock Test

Tensile Test for Guide Tubes

The tensile test for guide tubes demonstrates that the guide tube housing maintains its integrity after experiencing tensile loads that may be encountered during regular use. The guide tube should remain operable after this test.

This test resulted in no apparent damage to the guide tube. The test dummy source assembly was not restricted while being passed through the guide tube during a functional test. Therefore, the guide tubes pass this test.

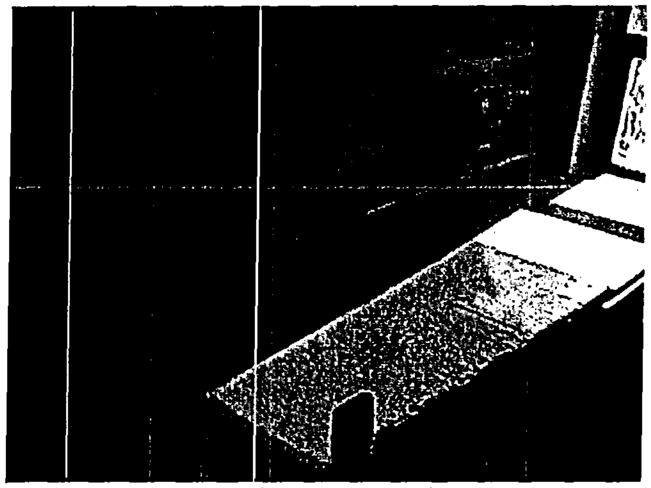


Figure 3.7 Tensile Test for Guide Tubes

Tensile Test for Control Cable Assembly

The tensile test for control cable assembly demonstrates that the control cable assembly maintains its integrity after experiencing tensile loads that may be encountered during regular use. The control cable assembly should remain operable after this test.

The test was conducted in two parts. The first part (Fig. 3.8 & 3.9) placed a tensile load on the control cable housing while connected to the device. The second part of the test (Fig. 3.10) placed a tensile load on the control cable itself while inside the control cable housing. This test resulted in no visible damage to the control cable assembly. The control cable was not restricted while being cranked through the control cable housing during a functional test. Therefore, the control cable assembly passes this test.

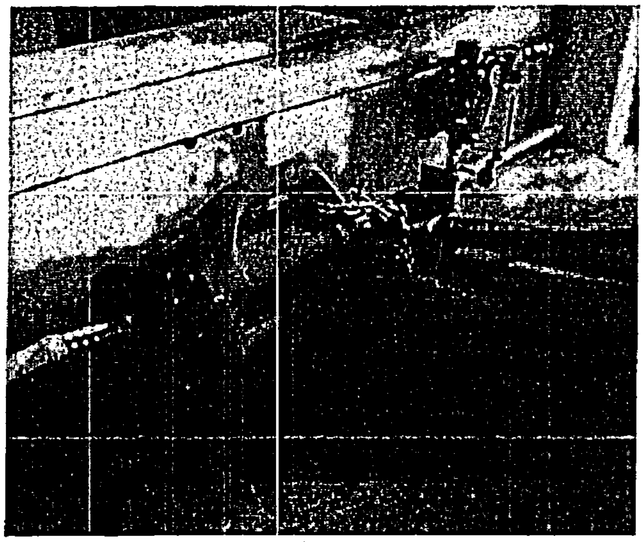


Figure 3.9 Tensile Test for Control Cable Housing

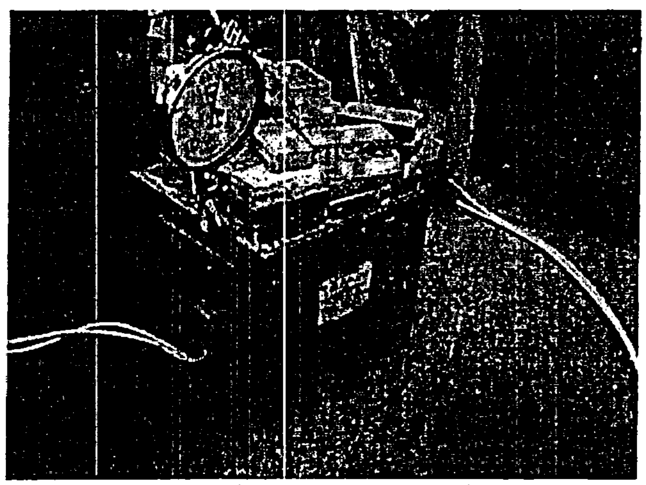


Figure 3.10 Tensile Test for Control Cable with Source Assembly

Kinking Test for Guide Tubes

The kinking test for the guide tube demonstrates that the guide tube withstands conditions that may be encountered during regular use. The guide tube should remain operational after experiencing this test.

The kinking test resulted in no visible damage to the guide tube. A complete functional test verified that the test dummy source assembly passed through the guide tube without any problems. Therefore, the guide tubes passed this test.

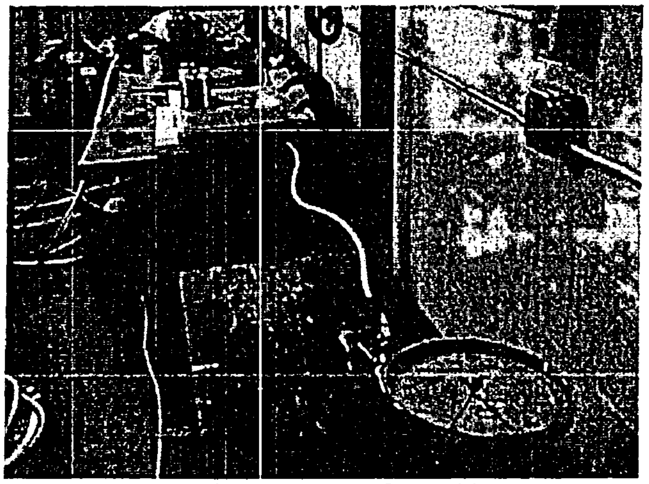


Figure 3.11 Kinking Test for Guide Tube

Kinking Test for Control Cable Assembly

The kinking test for the control cable assembly demonstrates that the control cable assembly can withstand kinking conditions that may occur during normal use. The control cable assembly should remain operational after performing this test.

After experiencing this test, the control cable assembly maintained its integrity without any apparent damage. A complete functional test was performed satisfactorily. The control cable assembly passed this kinking test.

Crushing and Bending Test

The crushing and bending demonstrates that the guide tubes and control cable assemblies can withstand a crushing test from a simulated heel (Fig. 3.12).

The control cable assembly showed some slight deformation from the impact of the simulated heel but the control cable had no problems passing through the control housings.

Three guide tubes were used in the crushing test. All of the guide tubes showed deformation from the heel impacts at each of the crushed points except for the connection point. The crushing test on the guide tube connection point resulted in no apparent damage. One of the ten crush points on each of the first two guide tubes tested resulted in enough deformation that the source assembly had trouble sliding through the area. Adding extra force to the hand crank allowed the source assembly to be forced through these tight areas. The test on the third guide tube did not require as much added force at the hand crank and the source assembly traveled through all ten crush points on the third guide tube much easier.

Although increased torque was required at the hand crank to push the source assembly through some of the crushed areas of the guide tubes, the source assembly was able to pass through all of the test samples during a functional test. Therefore, the guide tubes pass the crushing and bending test.

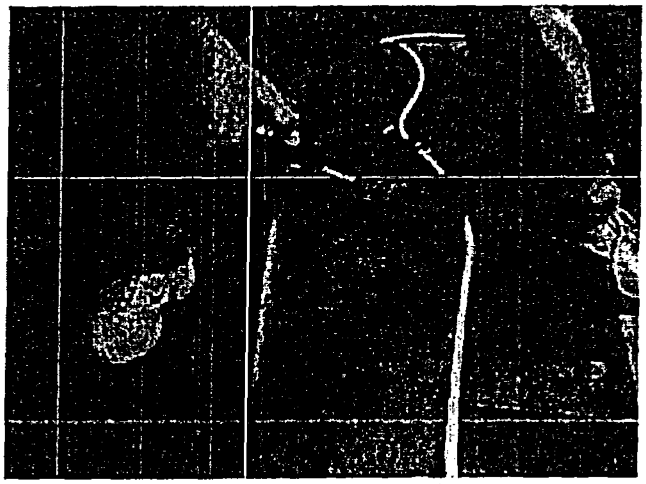


Figure 3.12 Crushing and Bending Test

Final Tensile Test

The final tensile test demonstrates the source assembly maintains its integrity after having undergone all of the other operational tests. The same dummy source assembly (Serial number TP115DEMO) that was used for this test is the same as used in all of the operational tests.

The tensile tests resulted in an increase in the stop ball to connector measurement from 1.240 in. to 1.250 in. A complete functional test with the test Model 880 projector showed that the source assembly was still completely functional. Therefore, the source assembly passed this test.

Final Projection Test

The final projection test demonstrates that the crank torque amount does not increase by more than 25% after the device and equipment have undergone all other operational tests. The setup that was used for this test is the same as the setup used for the initial projection test and the endurance test.

The test resulted in an average torque of 45% (or 56 in-lbs). The increase from the initial projection test was only approximately 10%. Therefore, the device passes the final projection test.

Lock Breaking Test

The lock breaking test demonstrates that the locking mechanism can withstand a breaking force while in the locked position with the key removed. The lock should remain operable after experiencing this test.

The locking mechanism had no visible damage after performance of the lock breaking test. The locking mechanism continued to be completely functional after this test. Therefore, the device passes the lock breaking test.

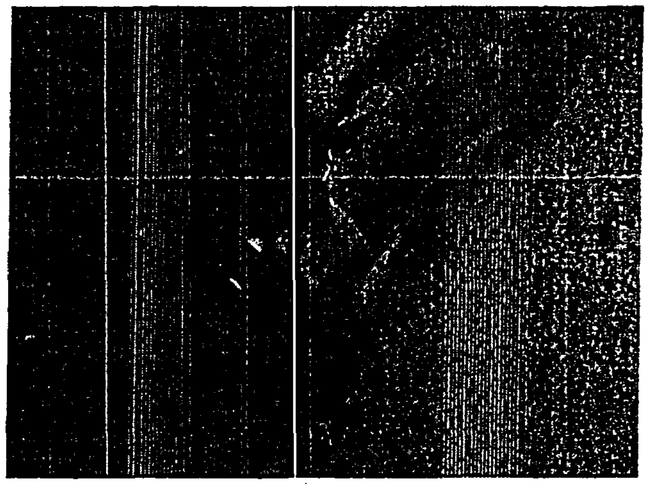


Figure 3.12 Lock Breaking Test

Wrench Test

The wrench test demonstrates that the handle of the exposure device is able to withstand a static force equal to at least 25 times the weight of the device (1250 lbs). This test was conducted on two different jackets with similar results. The first jacket contained metal wire wrapped around the device connected to a steel tube inside the handle for added support. The second device did not contain any added supports. Both handles lifted a load of 1288 lbs. with only slight bowing of the handle during the lift. The devices were inspected after the lift and showed no visible damage. Therefore, both handle options passed the wrench test.

Section 4 Conclusion

The Model 880 system consisting of the projector, control assembly, guide tubes and source assembly, satisfies the projection tests, the tensile tests for source assemblies, the endurance test, the horizontal shock test, the vertical shock test, the tensile and kinking tests for guide tubes and control cable assemblies, the crushing and bending tests, the lock breaking test, and the handle wrench test in accordance with ISO 3999-1:2000.

In addition to the tests performed under this test plan, ISO 3999-1:2000 also calls for a vibration resistance test and an accidental drop test.

A final shield profile was performed after the completion of all tests. There were only minor changes between the shield profile done previous to all the tests and the device remained within acceptable dose ranges. Both shield profile data sheets are located in Appendix C.

The vibration resistance test was evaluated and deemed unnecessary. The only parts that could come loose from vibration are the tamper proof screws. However, the tamper-proof screws are tightened to a prescribed torque to prevent unintentional release after repeated use or vibration. None of the tests performed resulted in a conditions that would increase chance that vibration could cause damage.

The accidental drop test was previously conducted under test plan 108 by dropping a Model 880 Projector from a height of 1.2 m (4 ft) three times to impact three different areas. There was no affect on the simulated source assembly from any of the impacts. Also, a shield profile did not show any increase in dose rate as a result of the impacts.

Section 2.12.6 Appendix: Test Plan Report 125 Rev B (Mar 2003).

TEST PLAN 125 (Rev. B) Report

MODEL 880
TYPE B CONTAINER
TRANSPORT CONDITIONS
With #88070 Foot Button Assembly
And #88022 Lock Mount Modification

AEA Technology QSA Inc.
40 North Avenue
Burlington
MA 01803

MARCH 2003

CONTENTS

Section 1. Purpose

The purpose of these tests were to assess the Model 880 transport container with the addition of the #88070 (F.C.B.A.) foot control button assembly. With the addition of this assembly and the modification of the #88022 lock mount, they will not adversely affect the packages ability as a "Type B" transport container.

Testing was performed on the 88070 F.C.B.A. to 10CFR71 regulations for 71.73(1) *free drop*, 71.73(3) *puncture*, and 71.71(10) *penetration*. These tests followed a random order except that the 71.73(3) puncture test was to follow the 71.73(1) free drop test if the specimen survived. Also, testing was performed according to ISO 3999-1 regulations for 6.4.6.1 *horizontal shock*. This horizontal shock test was relevant for both the 88070 F.C.B.A. and the 88022 lock mount assembly.

Section 2. Scope of Testing

Section 2.1 Normal Conditions of Transport and Accidental Drop

The tests for accidental drop described in ISO 3999-1, and normal conditions of transport in 10CFR71 are the tests. These tests will include a horizontal shock test, and penetration test.

Horizontal Shock Test

The 880 unit was oriented so the (1) F.C.B.A. and the (2) Lock Mount would impact the end-face of (T10333 SN01) 50 mm (2 in) diameter steel bar. The criteria is 300 mm (12 in) in length lying horizontally, that is fixed or welded to a rigid mass at least ten times the mass of the 880. The 880 was suspended from a fixed point so that, when at rest, the F.C.B.A. and Lock Mount just touches the target. The 880 was moved from its resting position until its center of gravity is 100 mm (4 in) higher than in the resting position and let loose, so that it swung in a pendulum movement against the target. This was carried out for a total of twenty (20) times.

Penetration Test

The 880 unit was oriented so as the foot control button assembly would be facing upward while the jacket will be supported on an unyielding surface. The hemispherical end of a vertical steel cylinder (AEA Technology QSA Drawing #BT10129) of 3.2 cm (1.25 in) diameter and 6 kg (13 lbs.) mass dropped from a height of 1 m (40 in) onto the surface of the F.C.B.A.

Section 2.2 Hypothetical Accident Conditions

The Hypothetical Accident Tests described in 10CFR71 are the 9m (30-foot) drop, the 1m (~3-foot) puncture drop.

9m (30-foot) Free Drop Test

The 880 radiographic unit was oriented so that the F.C.B.A. would be facing downward toward the test pad (T10261 SN01) for the 9m (30 ft.) drop test. This exposed the assembled unit so the F.C.B.A. received an impact similar to a slap down effect. One test was performed. It is described in the following sections.

Puncture Test

According to the Purpose (Section 1.0 paragraph 4) section of the test plan, an evaluation would be made before this test was to be performed. Normally, the 880 unit would be oriented in a similar angled fashion as above for the 1m (40 in.) drop test. The unit would be dropped onto a test billet (T10119 SN01) so as the F.C.B.A. sustains the full initial impact. This test was not performed. Reasons are described in the following sections.

Section 3. Test Unit Descriptions

Section 3.1 Test Unit 1 – Serial Number 01

The construction of this package is in accordance with the following AEA TECHNOLOGY QSA INC. documentation:

Assembly	Bill of Materials	Assembly Drawing
880 Delta Simulator Drawings	88017XLS TP125A Rev 1	B88017XLS Rev A BTP125A Rev 1
Foot Button Assy	BM 88070 Rev C	A88070 Rev B
Foot Control Shaft	N/A	A88070-4 Rev 3
Rear Plate Assy	BM 88020 Rev 5	B88020 Rev 5

The unit started construction to an earlier revision and Test Plan (See Appendix C Manufacturing Support Documentation). Changes to the unit during construction were recorded as mark-ups on the production prints and subsequently transferred to the above revisions.

As indicated above, the test unit was assembled with a modified rear plate assembly that includes changes to the *lock mount assembly*. Also, the *foot control button assembly* was modified with a G-10 shaft (Rev. 3) and installed onto the jacket for the testing. The test unit weighed approximately 49 pounds.

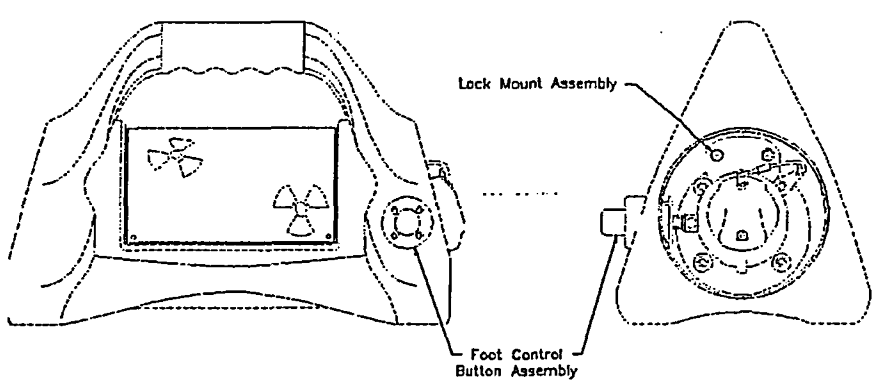


FIGURE 1. MODEL 880 (Test Unit #21) WITH FOOT BUTTON AND LOCK MOUNT ASSEMBLIES

Section 4. Changes to Test Conditions or Orientations

Section 4.1 Normal Conditions of Transport and Accidental Drop

No changes from plan were performed.

Section 4.2 Hypothetical Accident Conditions of Transport

No changes from plan were performed.

Section 5. Test Specimen Results

Section 5.1 Horizontal Shock Test – Foot Button Assembly

The test unit was set up on a portable crane type apparatus. Lead blocks were stacked around the base of the unit to keep it stationary and in position. The test unit was suspended (see figure 1) from the crane by means of its steel cable and a cloth rope around the test unit's handle. The 50mm 2 in diameter bar (T10333 SN01) was bolted to a Model 770 that weighted approx. 950 lbs.

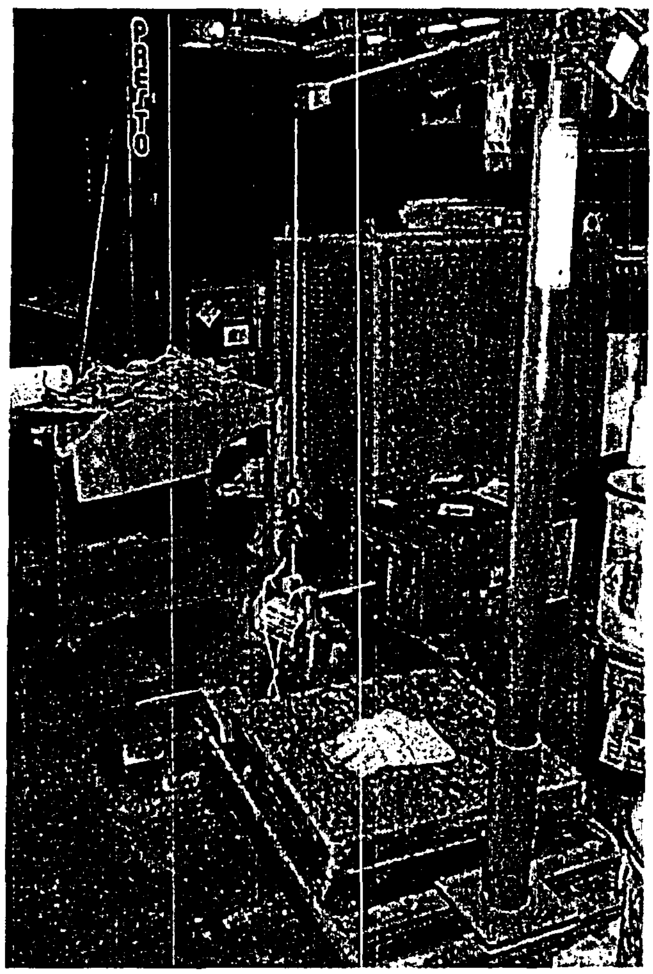


Figure 1

The test was then performed according to ISO 3999-1 regulations for 6.4.6.1 horizontal shock (see figure 2) test.

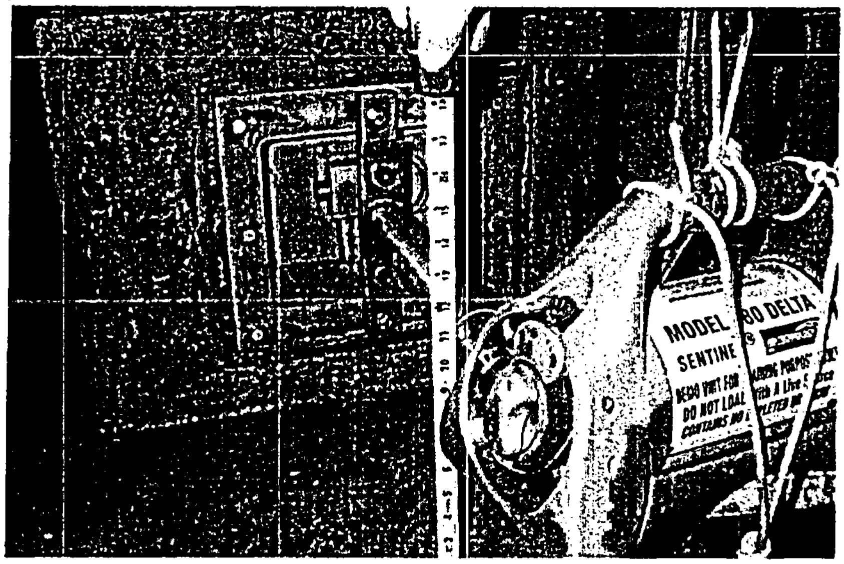


Figure 2

The unit was swung from the apparatus for a total of 20 times. The G-10 Shaft inside the F.C.B.A. broke, this was the piece that was expected to break. (see figure 3) The selector ring was not compromised. The unit passed the test.

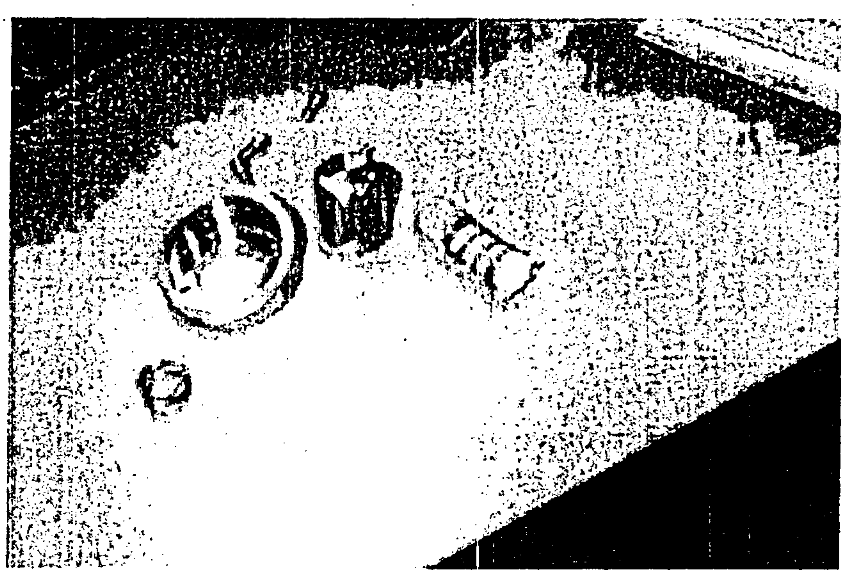


Figure 3

ction 5.2 Horizontal Shock Test – Lock Mount Assembly

The test unit was set up on the portable crane type apparatus as on the F.C.B.A. The same testing was performed. See figure 4.

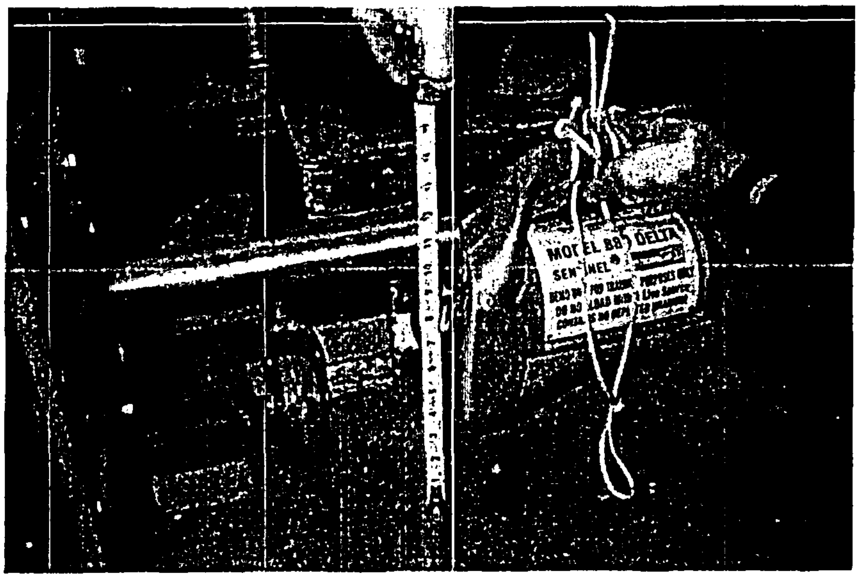


Figure 4

The unit was swung from the apparatus for a total of 20 times. The Lock Mount Assembly sustained minimal damage. Moreover, the corbin lock actuated smoothly and effortlessly. (See figure 5) The unit passed the test.

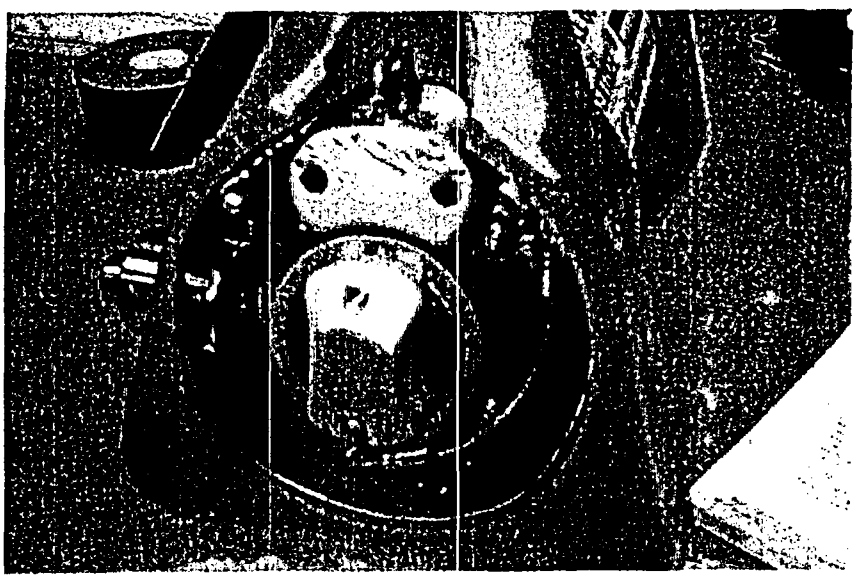


Figure 5

ection 5.3 Penetration Shock Test – Foot Button Assembly

The test unit was set up so the F.C.B.A. was facing upward. An aluminum angle was used to guide the test bar directly to the center of the F.C.B.A. (as shown in Figure 6).

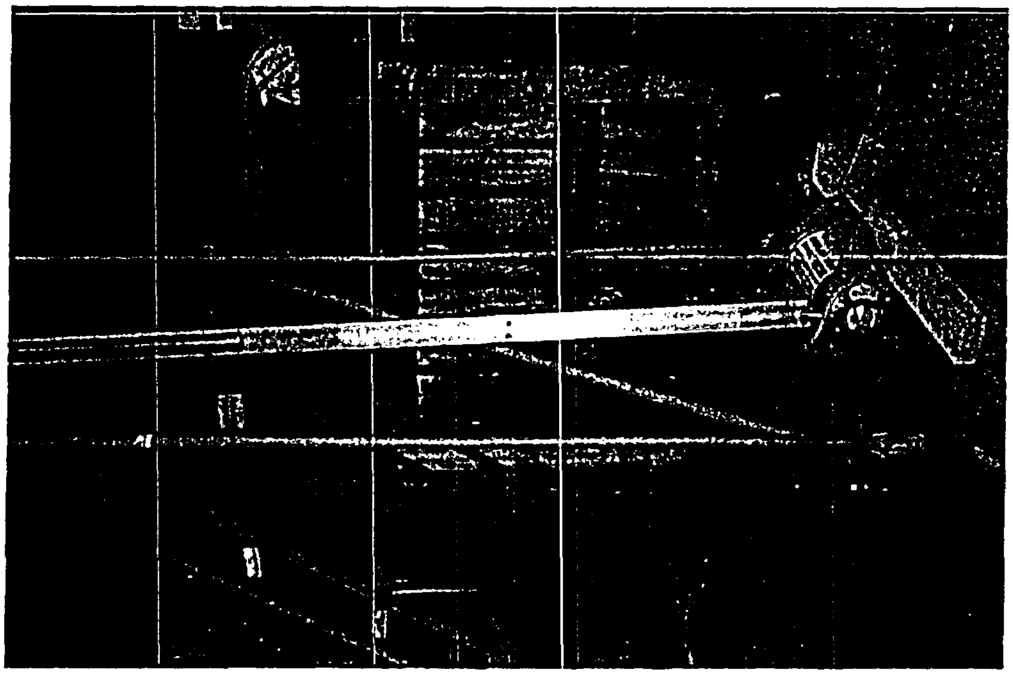


Figure 6 (rotated 90 degrees)

Upon dropping the bar, the G-10 Shaft broke. The button assembly needed to be disassembled to activate the selector ring and lock slide on the test unit. The test unit worked fine and passed the test.

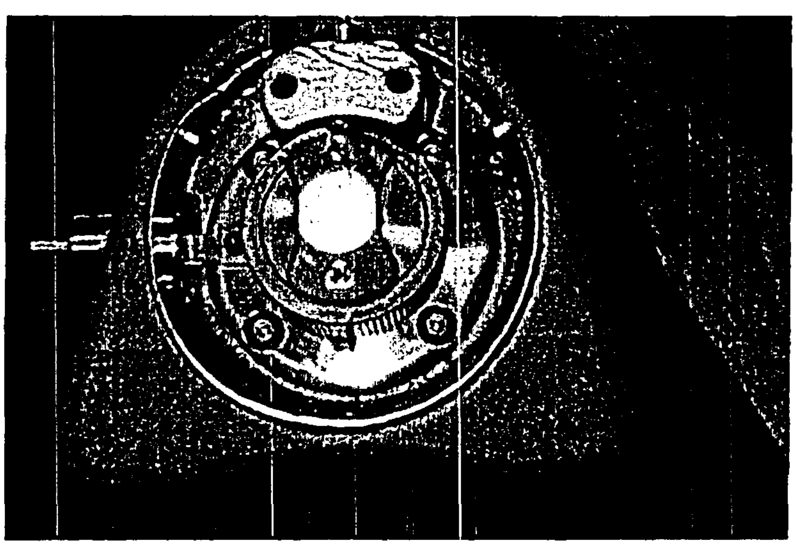


Figure 7

ection 5.4 9.m (30 ft.) Free Drop Test – Foot Button Assembly

The test unit was set up so that the F.C.B.A. was facing downward according to test plan instructions. The unit was dropped to induce the most rapid and damaging deceleration, which in this case had a slap down effect. See Test Plan 125B section 8.0 for setup orientation, and below (figure 8) for more information.

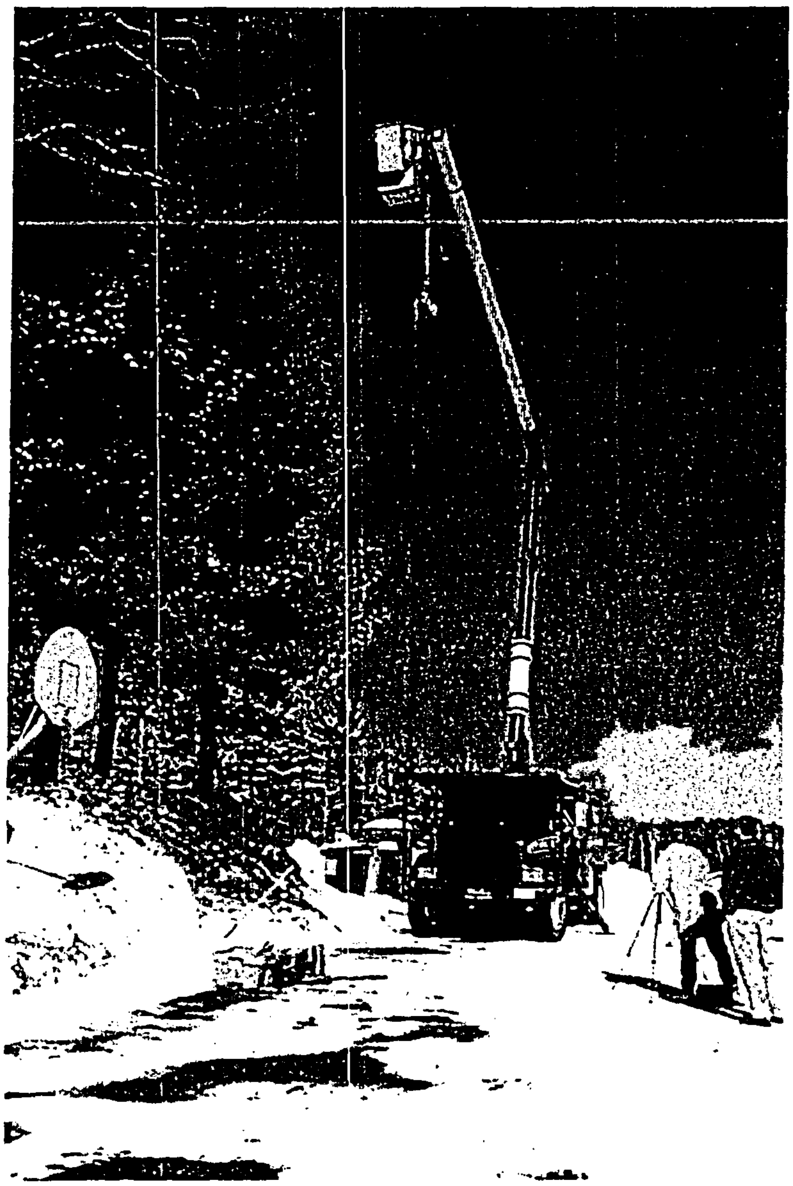


Figure 8

When the test unit was dropped, the unit fell as anticipated in the test plan. The polyurethane jacket and stainless steel canister deflected inward from the impact. The F.C.B.A. dented the side of the #88021 rear plate and the G-10 shaft contained within the button assembly shattered upon impact. Unfortunately due to the severe deflection of the components, the back of the F.C.B.A. hit the lock slide forcing it through the selector ring. The unit failed the test. See figure 9 and 10 for visual results. All testing was stopped at this time. Moreover, the Puncture Test was not performed.

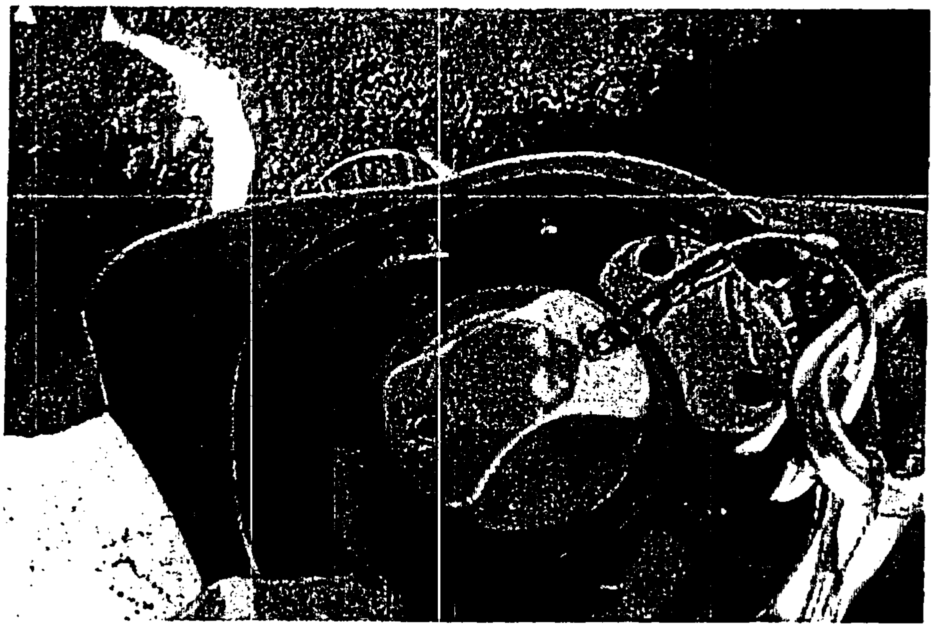


Figure 9

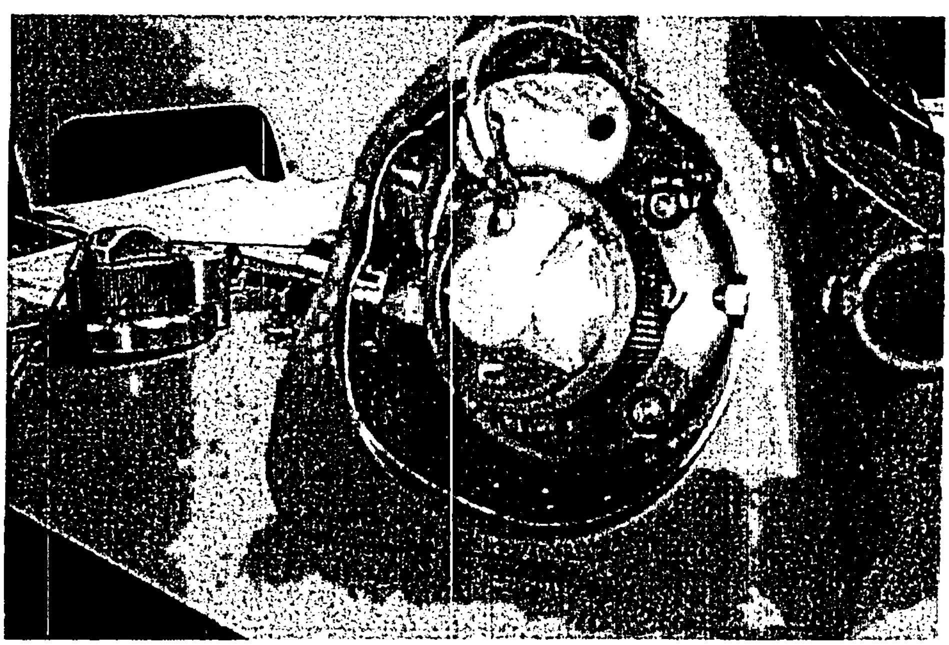


Figure 10

Section 6. Analysis, Summary, and Conclusions

Section 6.1 Analysis of testing not performed

Thermal Analysis
Because of the detailed assessment contained in TP108 a full weight "lead" dummy unit was used for this testing. Also, the melting temperature for all other materials of the internal support structure, rear plate assembly and source assembly is above the thermal test temperature of 800°C.

Moreover, the load condition for the thermal test is for the internal structure to support the static weight of the shield in suspension. The dynamic impact nature of the drop tests can subject the structure to a force over 100 times the static weight of the shield. This means the strength of the materials used in the structure would need to decrease by two orders of magnitude or to about 1% of their strength at room temperature. The 30-minute thermal test is not long enough for significant creep deformation to occur in the structure.

Puncture Test Analysis
This testing was performed on TP108. The testing passed when no damage occurred to the units. Therefore, testing was not performed on the Lock Mount Assembly. Also, the Lock Mount sits below the surface (with or without the jacket) of the radiographic camera and therefore would not be compromised. Moreover, the Lock Cover that is attached to the Rear Plate Assembly aids in the protection of the Lock Mount Assembly.

Vertical Shock Test Analysis
The vertical shock testing that was performed on TP115 for the model 880 unit showed no damage. The device functioned properly after having undergone a complete functional test. Therefore, vertical shock testing was not performed on this test unit.

Section 6.2 Summary and Conclusion

The Lock Mount Assembly with its addition of a stainless steel sleeve performed very well. The Lock Mount was also environmentally tested (see Technical Report #40) and performed superior. The design of the lock mount can be modified easily by enlarging its corbin lock retaining hole to accept the stainless sleeve. Moreover, the sleeve will be secured in place from the back with a 8-32 stainless set screw and a removable thread lock material.

The F.C.B.A. button assembly did pass the Horizontal Shock, and Penetration Test, but failed at the 9m (30ft.) Drop test. The G-10 fiberglass shaft reacted as designed, which shattered upon impact. As stated in the section 5.4, because of the severe force that was distributed through the F.C.B.A. stainless steel housing the lock slide was forced through the side of the selector ring.

From the test data, and the analysis contained within this report, we draw the following conclusions about the Model 880 (as tested):

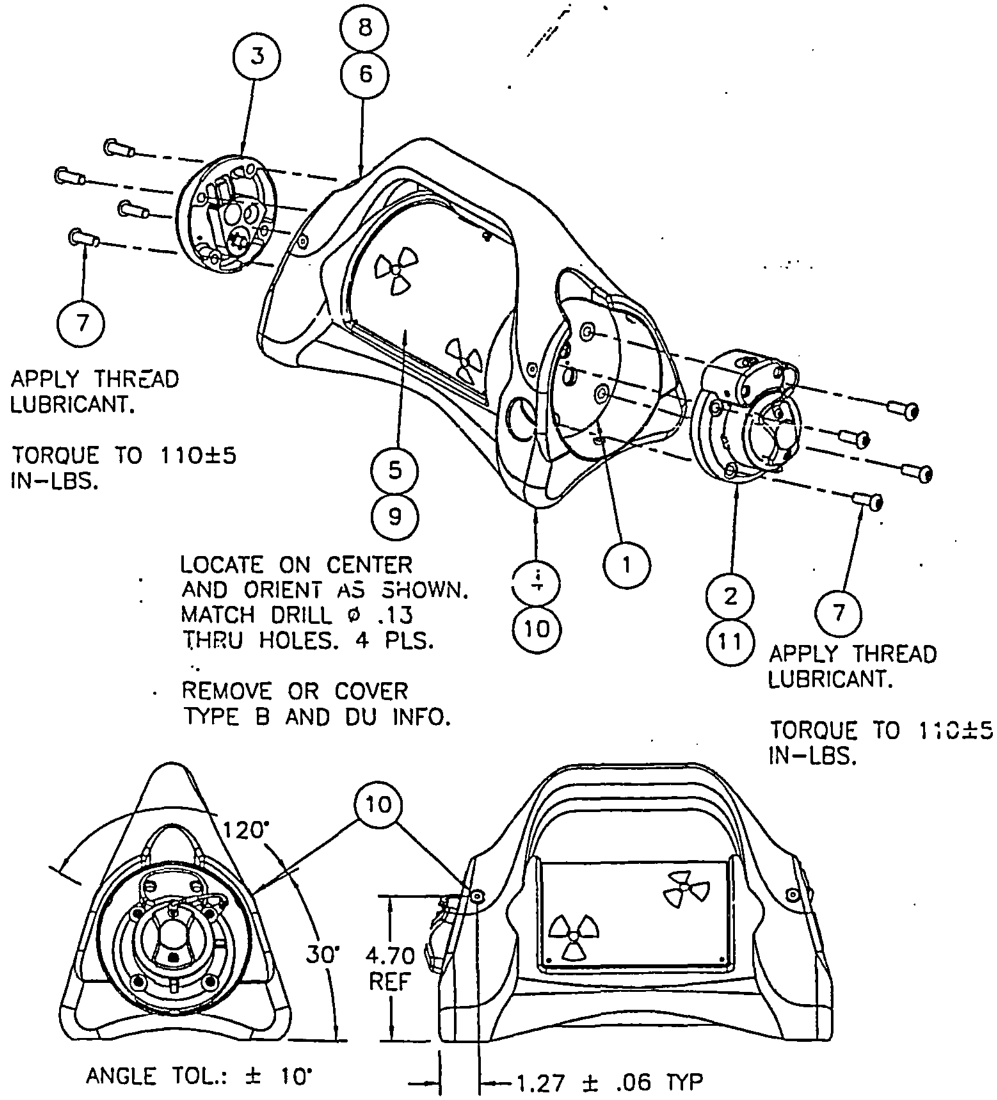
1. The lock mount and F.C.B.A. can withstand the *Normal Conditions of Transport* and *Accidental Drop Test* situations.
2. The lock mount can withstand the *Hypothetical Conditions of Transport*.

Section 7. APPENDIX A – DRAWINGS

REVISIONS				
REV.	ECO/TCR #	DESCRIPTION	APPROVALS	DATE
A	2731	INITIAL RELEASE	SEE TITLE	BLOCK

NOTES:

1. TOTAL PACKAGE WEIGHT TO BE 50 LBS. MAX.



11	A42409XL	1	DUMMY SOURCE WIRE
10	RIV093	4	RIVET
9	RIV003	4	POP RIVET
8	SCR137	1	BINDER HEAD SCREW, #6-32 X 3/16 LG.
7	SCR154	8	SECURITY SCREW, 5/16-18 X 1-1/2 LG.
6	A88043	1	SOURCE ID TAG
5	C88042-1	1	LABEL
4	B88041-1	1	JACKET
3	B88030	1	FRONT PLATE ASSEMBLY
2	B88020	1	REAR PLATE ASSEMBLY
1	B88011XLS	1	BODY WELDMENT, DELTA SIMULATOR
ITEM	DRAWING NO.	QTY.	DESCRIPTION

MATERIALS: SEE PARTS LIST

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 125
3. TOLERANCES APPLY AFTER PLATING.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64; MACHINED ANGLES ± 1°; .X ± 0.1; .XX ± 0.01; .XXX ± 0.005

USED ON:

DRAWN	[illegible]	[illegible]
CHECKED	[illegible]	[illegible]
APPR.	[illegible]	[illegible]

THIRD ANGLE PROJECTION

SAFETY CLASS C

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: MODEL 880 DELTA SIMULATOR ASSEMBLY

SIZE	DWG. NO.	REV
B	88017XLS	A

SCALE: NONE

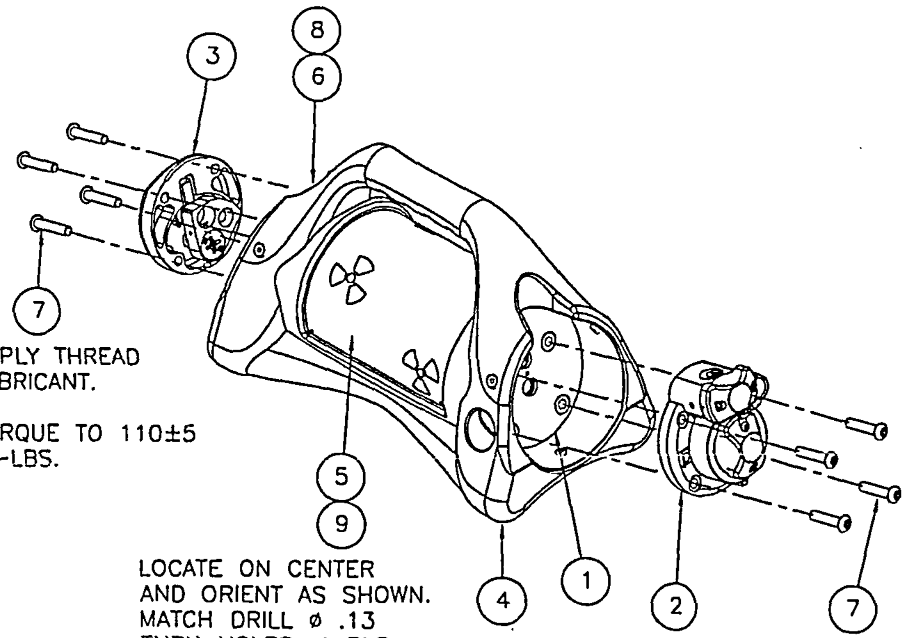
SHEET 1 OF 1

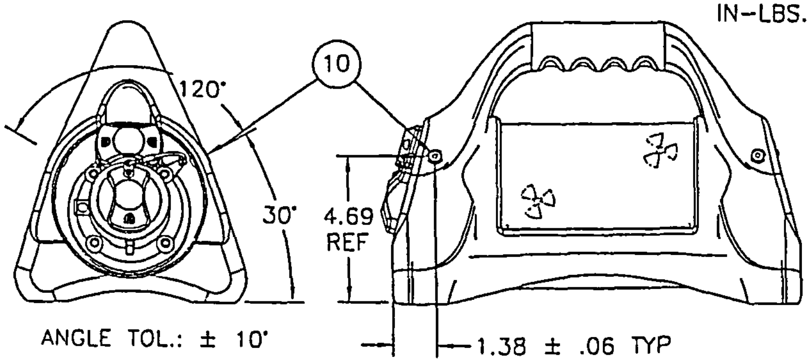
REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
1		PROTOTYPE	SEE TITLE	BLOCK

REVISIONS

NOTES:

1. TOTAL PACKAGE WEIGHT TO BE 50 LBS. MAX.





ITEM	DRAWING NO.	QTY.	DESCRIPTION
11	A4209XL	1	DUMMY SOURCE WIRE
10	RIV093	4	RIVET
9	RIV003	4	POP RIVET
8	SCR137	1	BINDER HEAD SCREW, #6-32 X 3/8LG.
7	SCR154	8	SECURITY SCREW, 5/16-18 X 1-1/2 LG.
6	88043	1	SOURCE ID TAG
5	88042-1	1	LABEL
4	88041-1	1	JACKET
3	88030	1	FRONT PLATE ASSEMBLY
2	88020	1	REAR PLATE ASSEMBLY
1	88011XLS	1	BODY WELDMENT, DELTA SIMULATOR

MATERIALS: SEE PARTS LIST

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 125
3. TOLERANCES APPLY AFTER PLATING.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64, MACHINED ANGLES ± 1°, .X ± 0.1, .XX ± 0.01, .XXX ± 0.005

USED ON:

DRAWN

CHECKED

APPR.

THIRD ANGLE PROJECTION

SAFETY CLASS A

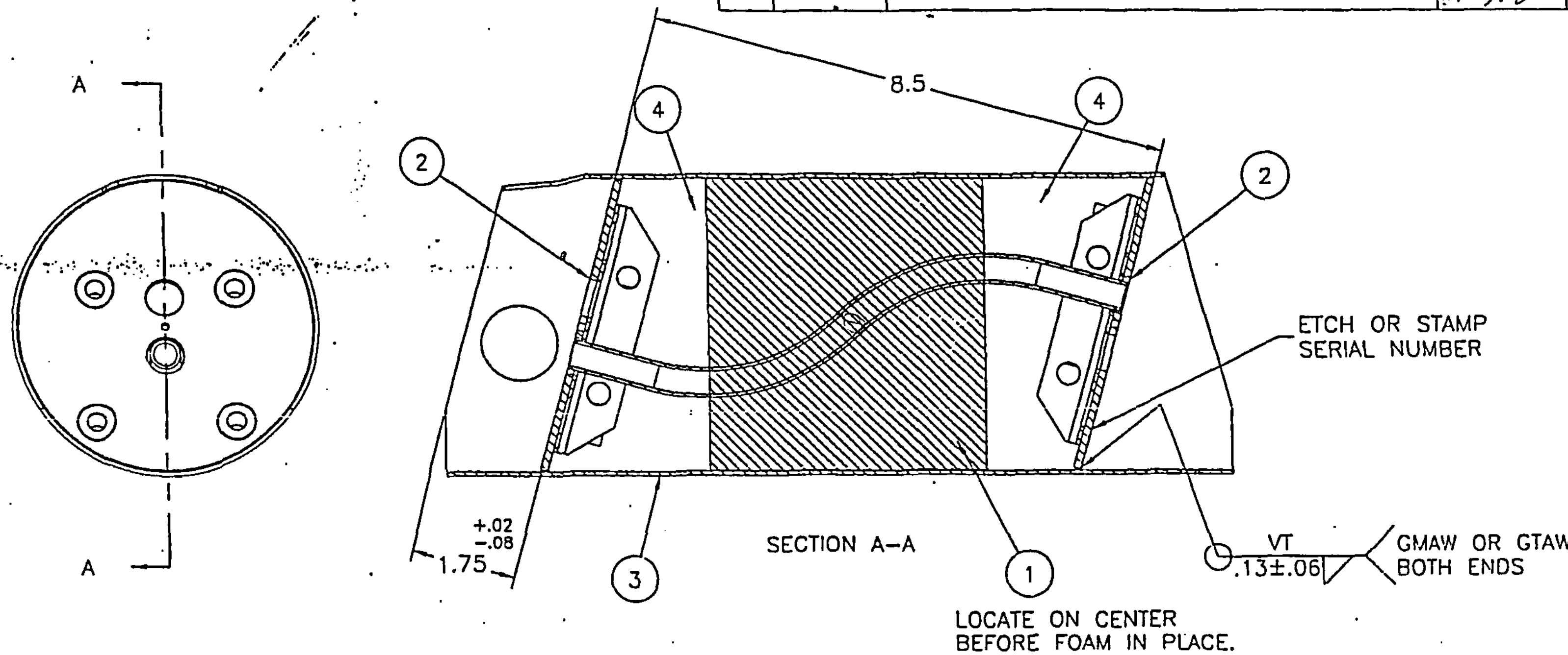
AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: MODEL 880 DELTA SIMULATOR ASSEMBLY

SIZE B | DWG. NO. TP125A | REV 1

SCALE: NONE | SHEET 1 OF 1

REVISIONS				
REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2731	INITIAL RELEASE	SEE TITLE	BLOCK
B	163	ADDED WELDING SYMBOL AND TOLERANCES	RAG/	14 DEC 01



NOTES:
1. TACK WELD EACH END MINIMUM OF 3 PLACES EQUALLY SPACED AROUND DIA. OF ENDPLATE.
2. FINISH WELD AS SHOWN.
3. FILL WITH ITEM 4 AFTER FINISH WELD.

ITEM	DRAWING NO.	QTY.	DESCRIPTION
4	FOM001	AR	VULTAFOAM, 8 PCF
3	B88003	1	SHELL
2	A88010	2	ENDPLATE WELDMENT
1	A88052-1	1	DELTA SHIELD SIMULATOR

MATERIALS: SEE PARTS LIST

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 125
3. TOLERANCES APPLY AFTER PLATING.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64, MACHINED ANGLES ± 1°, .X ± 0.1, .XX ± 0.01, .XXX ± 0.005

USED ON: 880

DRAWN	S.GRENIER	11SEP00
CHECKED	M.TREMBLAY	11SEP00
APPR.	M.TREMBLAY	11SEP00

THIRD ANGLE PROJECTION

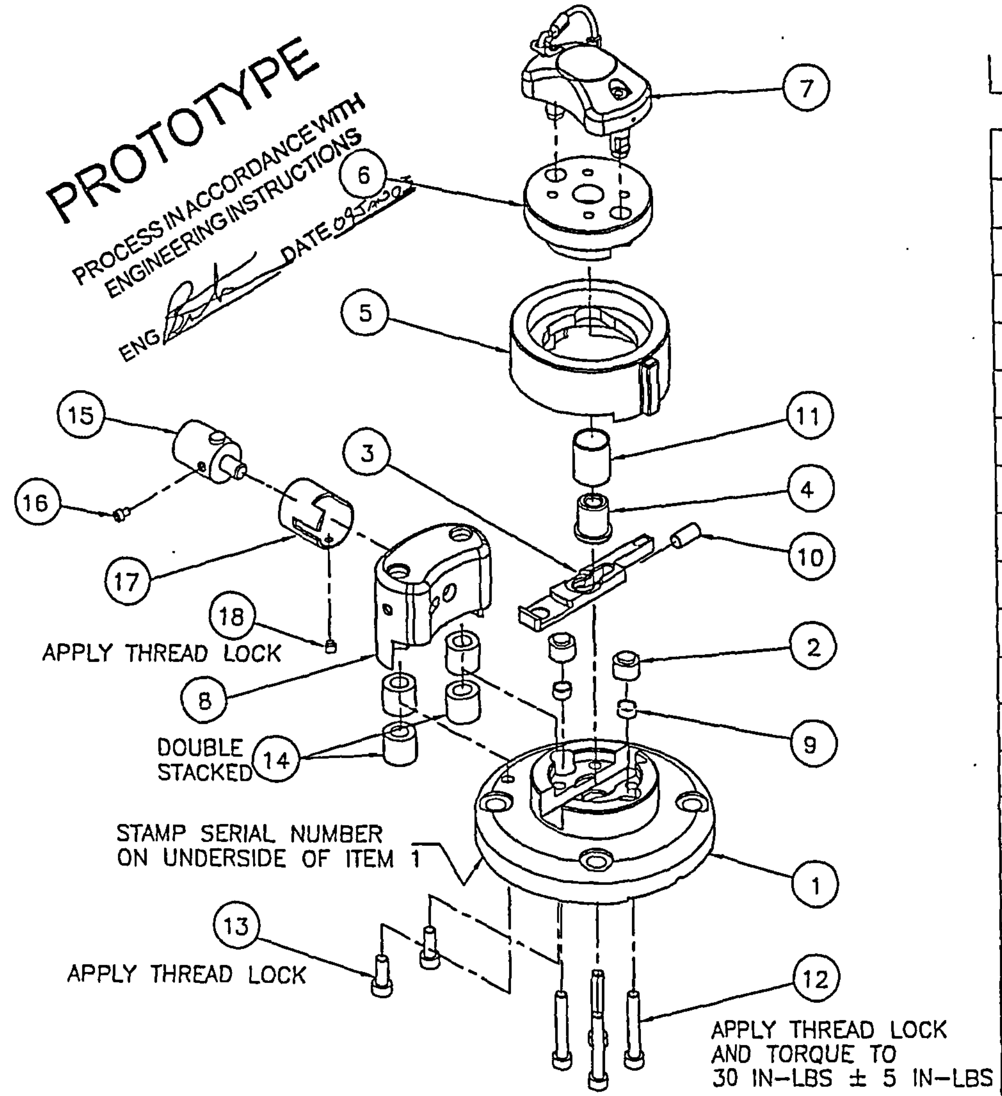
SAFETY CLASS C

AEA TECHNOLOGY OSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: BODY WELDMENT DELTA SIMULATOR

SIZE B | DWG. NO. 88011XLS | REV B

SCALE: 1/2 | SHEET 1 OF 1



REVISIONS

	ERF #	DESCRIPTION	APPROVAL	DATE
5		ADDED ITEMS 17 AND 18	SEE TITLE BLOCK	

ITEM	DRAWING NO.	QTY.	DESCRIPTION
16	SCR023	1	SOCKET HEAD SCREW
15	A66001-11	1	LOCK REWORK
14	SLV005	4	RUBBER SLEEVE
13	SCR072	2	SOCKET HEAD CAP SCREW
12	SCR002	4	SOCKET HEAD CAP SCREW
11	SPR005	1	COMPRESSION SPRING
10	SPR006	1	COMPRESSION SPRING
9	SPR004	2	COMPRESSION SPRING
8	A88022	1	LOCK MOUNT
7	B88014	1	LOCK COVER ASSEMBLY
6	B85701-5	1	SELECTOR RING RETAINER
5	A88026	1	SELECTOR RING
4	A88025	1	SLEEVE
3	A88024	1	LOCK SLIDE
2	A66001-6	2	ANTI-ROTATE LUGS
1	C88021	1	REAR PLATE

ITEM	DRAWING NO.	QTY.	DESCRIPTION
18	SCR225	1	DOG POINT SET SCREW
17	88022-1	1	STAINLESS STEEL SLEEVE

MATERIALS: SEE PARTS LIST

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64, ANGLES ± 1°, .X ± 0.1, .XX ± 0.01, .XXX ± 0.005

880

DRAWN	S.GRENIER	20JUL00
CHECKED	M.TREMBLAY	20JUL00
APPR.	M.TREMBLAY	20JUL00

THIRD ANGLE PROJECTION

QUALITY CLASS A

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: REAR PLATE ASSEMBLY

SIZE B | DWG. NO. 88020 | REV 5

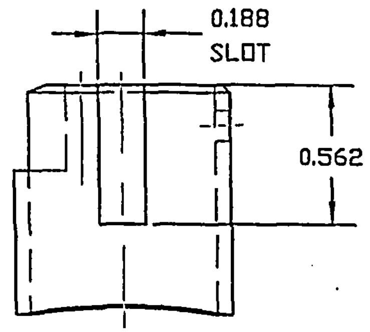
SCALE: 1/2 | SHEET 1 OF 1

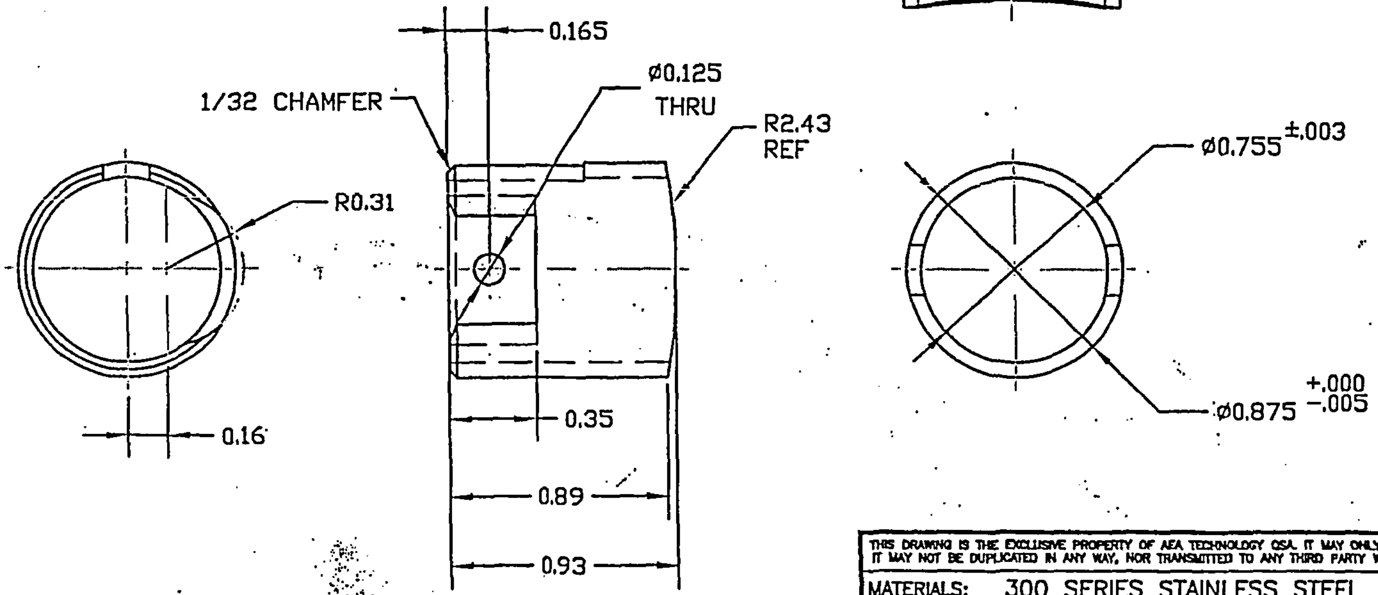
PROTOTYPE

PROCESS IN ACCORDANCE WITH ENGINEERING INSTRUCTIONS

ENG *Buttrick* DATE *07OCT02*

REVISIONS				
REV.	ERF #	DESCRIPTION	APPROVALS	DATE
3	N/A	PROTOTYPE RELEASE	SEE TITLE	BLOCK





MATERIALS: 300 SERIES STAINLESS STEEL

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED;
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64; ANGLES ± 1°; .X ± 0.1; .XX ± 0.01; .XXX ± 0.005

DRAWN	
CHECKED	NA
APPR.	

THIRD ANGLE PROJECTION

QUALITY CLASS B

AEA TECHNOLOGY QSA
40 NORTH AVE. BURLINGTON, MA 01803

TITLE: LOCK MOUNT S.S. INSERT

SIZE B | DWG. NO. 88022-1 | REV 3

SCALE: 1:1 | SHEET 1 OF 1

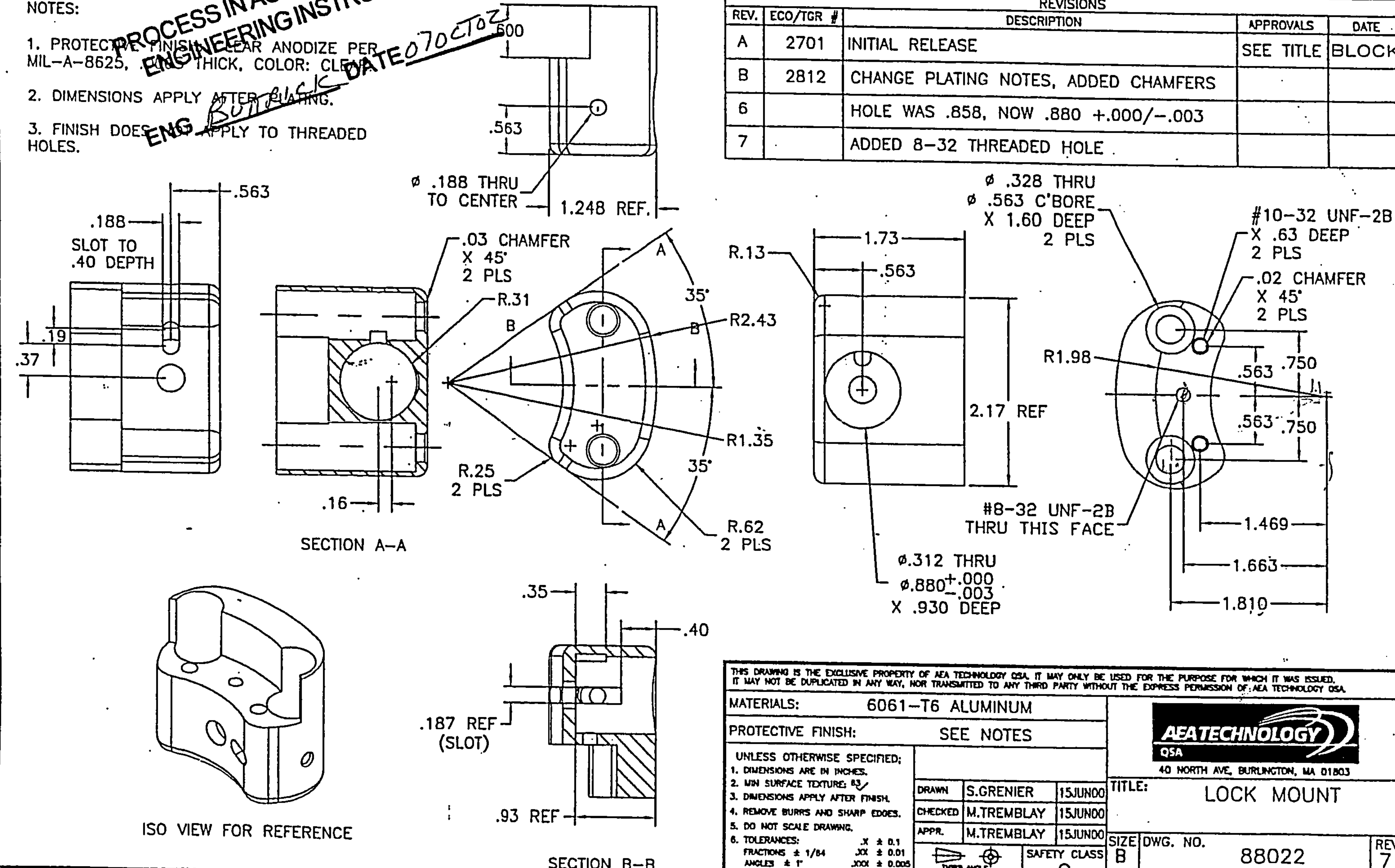
PROTOT...

PROCESS IN ACCORDANCE WITH ENGINEERING INSTRUCTIONS
ENG Butt/BLIC DATE 07OCT02

NOTES:

1. PROTECTIVE FINISH: CLEAR ANODIZE PER MIL-A-8625, .0005 THICK, COLOR: CLEAR.
2. DIMENSIONS APPLY AFTER PLATING.
3. FINISH DOES NOT APPLY TO THREADED HOLES.

REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2701	INITIAL RELEASE	SEE TITLE	BLOCK
B	2812	CHANGE PLATING NOTES, ADDED CHAMFERS		
6		HOLE WAS .858, NOW .880 +.000/-.003		
7		ADDED 8-32 THREADED HOLE		



MATERIALS: 6061-T6 ALUMINUM

PROTECTIVE FINISH: SEE NOTES

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64, ANGLES ± 1°, .X ± 0.1, .XX ± 0.01, .XXX ± 0.005

DRAWN	S.GRENIER	15JUN00
CHECKED	M.TREMBLAY	15JUN00
APPR.	M.TREMBLAY	15JUN00

THIRD ANGLE PROJECTION

SAFETY CLASS C

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: LOCK MOUNT

SIZE B | DWG. NO. 88022 | REV 7

SCALE: 1:1 | SHEET 1 OF 1

610
663
1.47

REVISIONS				
V.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
		PROTOTYPE RELEASE	SEE TITLE	BLOCK

SPECIFICATIONS:

1. TYPE: SOCKET SET SCREW, HALF DOG POINT.
2. SIZE: 8-32 UNC-2A X 3/16 LONG.
3. MATERIAL: 18-8 STAINLESS STEEL.

ERIALS: SPECIFICATION #3

TECTIVE FINISH: NONE

OTHERWISE SPECIFIED:
..NS ARE IN INCHES.
N SURFACE TEXTURE: 125
ERANCES APPLY AFTER PLATING.
MOVE BURRS AND SHARP EDGES.
NOT SCALE DRAWING.
LERANCES: .X ± 0.1
ACTIONS ± 1/64 .XX ± 0.01

USED ON: 880

DRAWN		
CHECKED		
APPR.		

SAFETY CLASS

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: 8-32 X 3/16 LONG DOG PT. SET SCREW

SIZE	DWG. NO.	REV
A	SCR225	1

AEA TECHNOLOGY QSA

FORM E001 rev A

Bill Of Materials

Part No.: 88070

Title: FOOT CONTROL BUTTON ASSY.

Rev: C

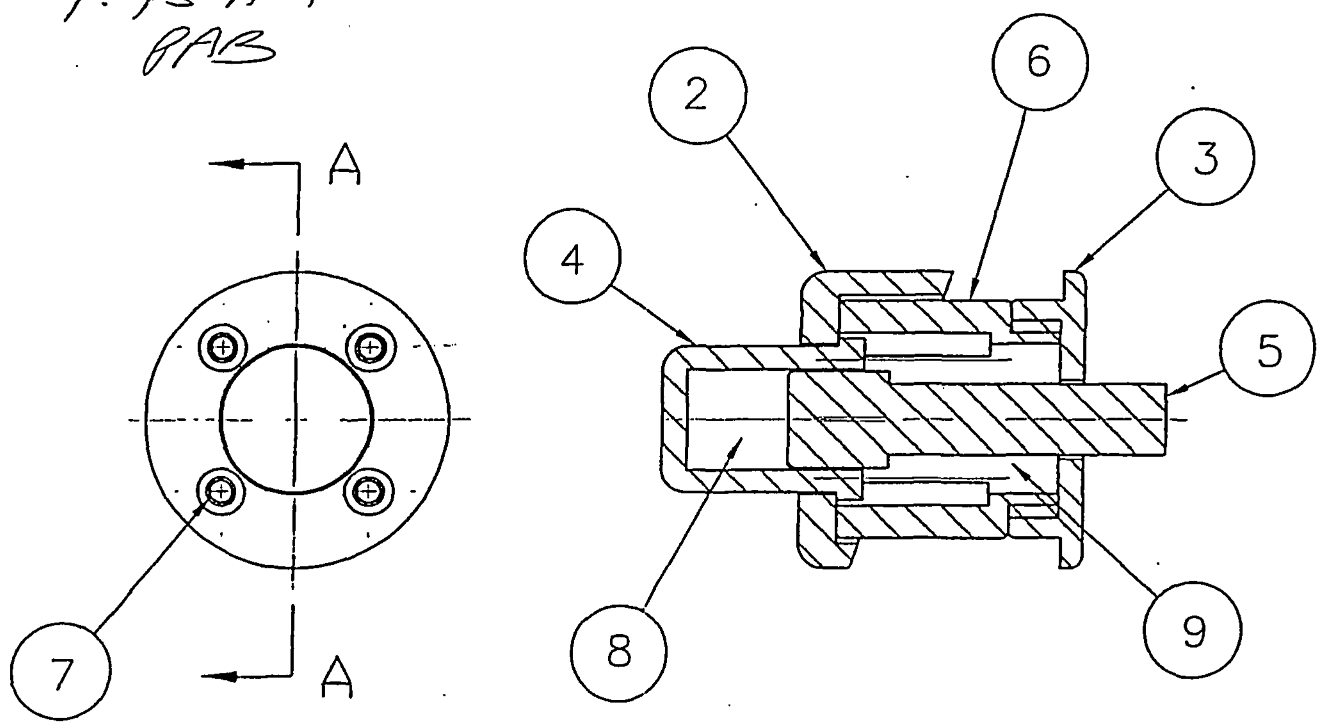
Page 1 of 1

Rev	ERF	Date	Ckd.	Appvd.	Rev	ECO	Date	Ckd.	Appvd.	Rev	ECO	Date	Ckd.	Appvd.
A	2871	6APR01	PAB	MT										
B	15	25Jun01	RLM	PAB										
C	27	11JUL01	PAB	[signature]										

Item	Qty	P/N	Description
1	0	A88070	FOOT CONTROL BUTTON ASSEMBLY
2	1	B88070-1	FOOT CONTROL SLEEVE
3	1	B88070-2	FOOT CONTROL END
4	1	A88070-3	FOOT CONTROL KNOB
5	1	B88070-4	FOOT CONTROL SHAFT
6	1	B88070-5	FOOT CONTROL CORE
7	4	SCR210	#6-32 SOCKET HEAD CAP SCREW 3/8" LONG
8	1	SPR040	SPRING, 3/8" LONG X .48" O.D. (61 lbs./in.)
9	1	SPR041	SPRING, 3/4" LONG X .48" O.D. (19 lbs./in.)
10	1	BAG003	7" x 9" zip lock bag
11	1	INST 02	Instruction Sheet - Foot Control Button
12	1	TOL009	7/64 Hex Key

REVISIONS				
:V.	ERF #	DESCRIPTION	APPROVALS	DATE
}	27	CHANGED SPRINGS/ ADDED BALLOONS	PAB / [illegible]	11JUL01

07-FEB-03
9:45 AM
PAB



SECTION A—A

NOTE: SEE BILL OF MATERIALS FOR PART INFORMATION.

'ERIALS: AISI TYPE 304 STAINLESS STEEL

)TECTIVE FINISH: NONE

LESS OTHERWISE SPECIFIED:
)NS ARE IN INCHES.
RFACE TEXTURE: 63
IMENSIONS APPLY AFTER FINISH.
EMOVE BURRS AND SHARP EDGES.
O NOT SCALE DRAWING.
OLERANCES: .X ± 0.1
RACTIONS ± 1/64 .XX ± 0.01
NGLES ± 1° .XXX ± 0.005

DRAWN	P.BUTTRICK	10APR01
CHECKED	M.TREMBLAY	10APR01
APPR.	M.TREMBLAY	10APR01

THIRD ANGLE PROJECTION

SAFETY CLASS B

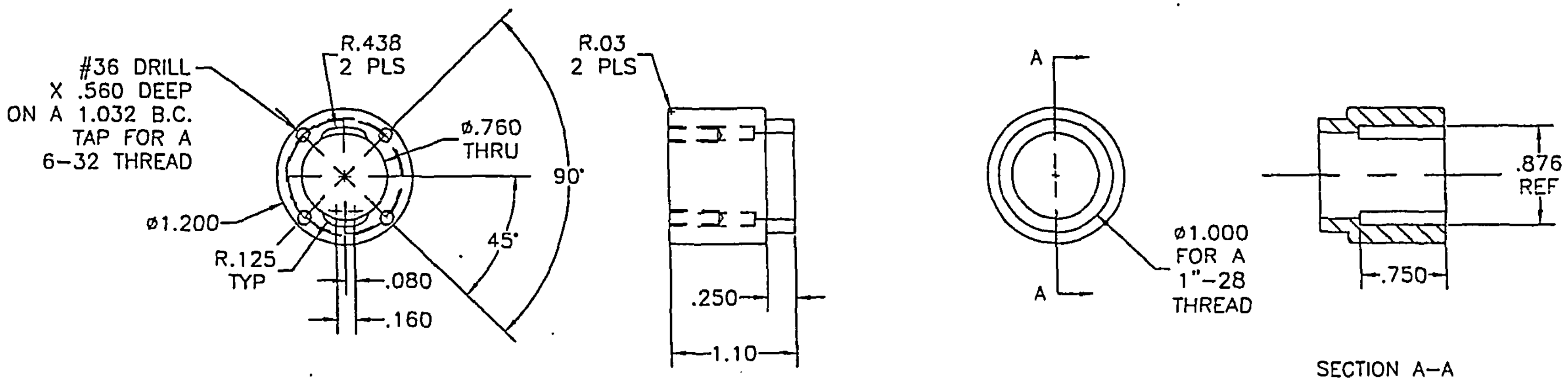
AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: FOOT CONTROL BUTTON ASSEMBLY

SIZE	DWG. NO.	REV
A	88070	B

SCALE: 1:1 SHEET 1 OF 1

REVISIONS				
REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2871	INITIAL RELEASE	SEE TITLE	BLOCK
B	2877	CHG. R.025 TO R.125, ADDED R.062	P.A.B./M.T	20APR01
C	2887	WAS 10-32 THREAD, NOW 6-32	PAB/MT	15MAY01



MATERIALS: AISI TYPE 304 STAINLESS STEEL

PROTECTIVE FINISH: PASSIVATE PER MILS-5002C

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: .X ± 0.1, .XX ± 0.01, .XXX ± 0.005; FRACTIONS ± 1/64; ANGLES ± 1°

DRAWN	P.BUTTRICK	10APR01
CHECKED	M.TREMBLAY	10APR01
APPR.	M.TREMBLAY	10APR01

THIRD ANGLE PROJECTION

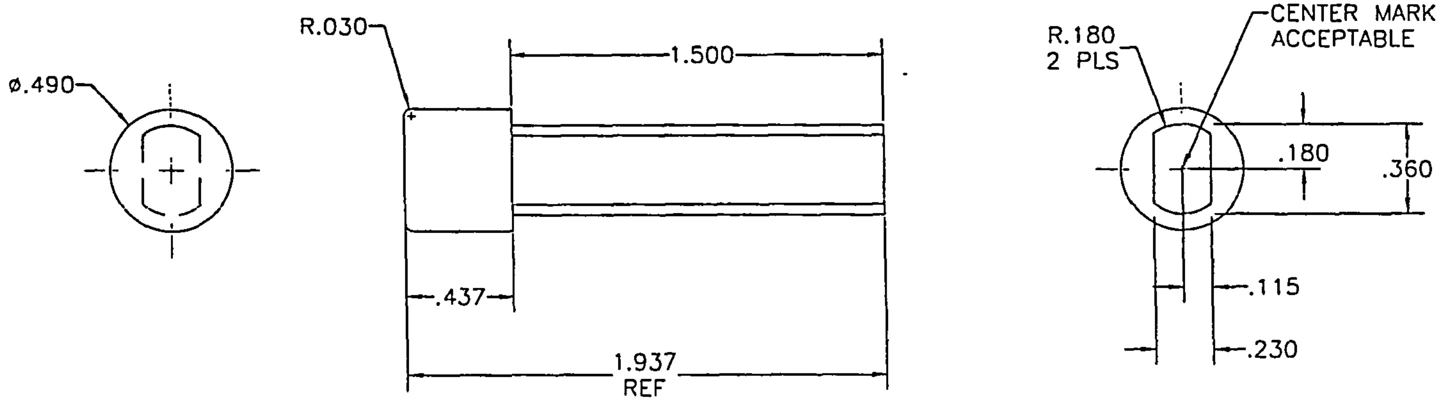
SAFETY CLASS B

TITLE: FOOT CONTROL CORE

SIZE B | DWG. NO. 88070-5 | REV C

SCALE: 1:1 | SHEET 1 OF 1

REVISIONS				
REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2871	INITIAL RELEASE	SEE TITLE	BLOCK
B	2877	ADDED CENTER MARK NOTE	PAB/M.T.	20APR01
C	2892	WAS .500,NOW .437 & WAS 1.38,NOW 1.500	PAB/[signature]	24MAY01



THIS DRAWING IS THE EXCLUSIVE PROPERTY OF AEA TECHNOLOGY QSA. IT MAY ONLY BE USED FOR THE PURPOSE FOR WHICH IT WAS ISSUED. IT MAY NOT BE DUPLICATED IN ANY WAY, NOR TRANSMITTED TO ANY THIRD PARTY WITHOUT THE EXPRESS PERMISSION OF AEA TECHNOLOGY QSA.

MATERIALS: AISI TYPE 304 STAINLESS STEEL

PROTECTIVE FINISH: PASSIVATE PER MILS-5002C

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: .X ± 0.1; .XX ± 0.01; .XXX ± 0.005; FRACTIONS ± 1/64; ANGLES ± 1°

DRAWN	P.BUTTRICK	10APR01
CHECKED	M.TREMBLAY	10APR01
APPR.	M.TREMBLAY	10APR01

THIRD ANGLE PROJECTION

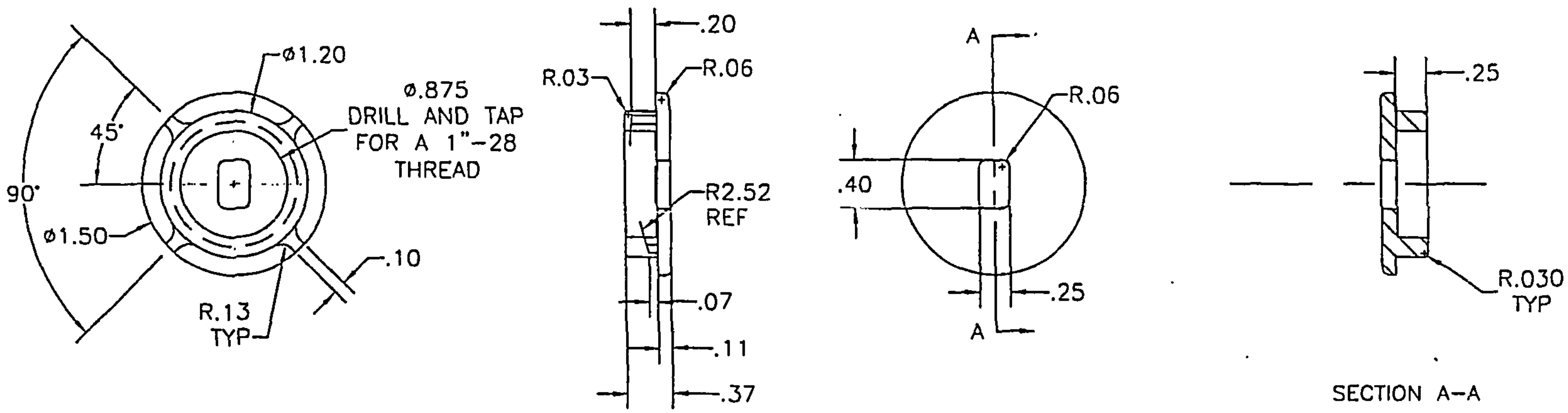
SAFETY CLASS B

TITLE: FOOT CONTROL SHAFT

SIZE B | DWG. NO. 88070-4 | REV C

SCALE: 1:1 | SHEET 1 OF 1

REVISIONS				
REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2871	INITIAL RELEASE	SEE TITLE	BLOCK
B	2885	PICTORIAL DRAWING CHANGE	PAB/MT	8MAY01
C	5	CHANGED TOERANCES	PAB/RLM	26JUN01



MATERIALS: AISI TYPE 304 STAINLESS STEEL

PROTECTIVE FINISH: PASSIVATE PER MILS-5002C

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63✓
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: .X ± 0.1
FRACTIONS ± 1/64 .XX ± 0.01
ANGLES ± 1° .XXX ± 0.005

DRAWN	P.BUTTRICK	10APR01
CHECKED	M.TREMBLAY	10APR01
APPR.	M.TREMBLAY	10APR01

THIRD ANGLE PROJECTION

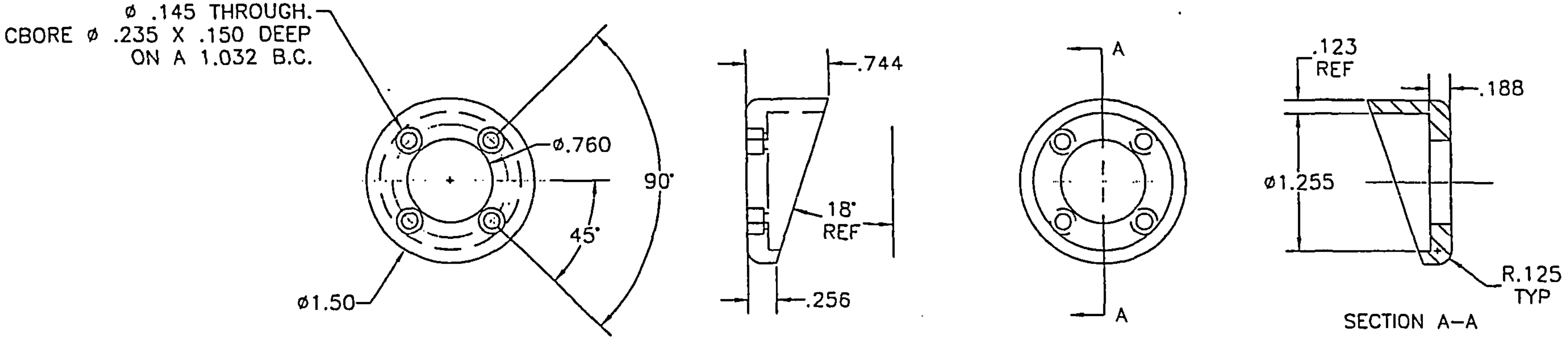
SAFETY CLASS B

TITLE: FOOT CONTROL END

SIZE B | DWG. NO. 88070-2 | REV C

SCALE: 1:1 | SHEET 1 OF 1

REVISIONS				
REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2871	INITIAL RELEASE	SEE TITLE	BLOCK



MATERIALS: AISI TYPE 304 STAINLESS STEEL

PROTECTIVE FINISH: PASSIVATE PER MILS-5002C

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63/
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64, ANGLES ± 1°, .X ± 0.1, .XX ± 0.01, .XXX ± 0.005

DRAWN [signature] 10/A/'21
CHECKED [signature]
APPR. [signature]

THIRD ANGLE PROJECTION

SAFETY CLASS B

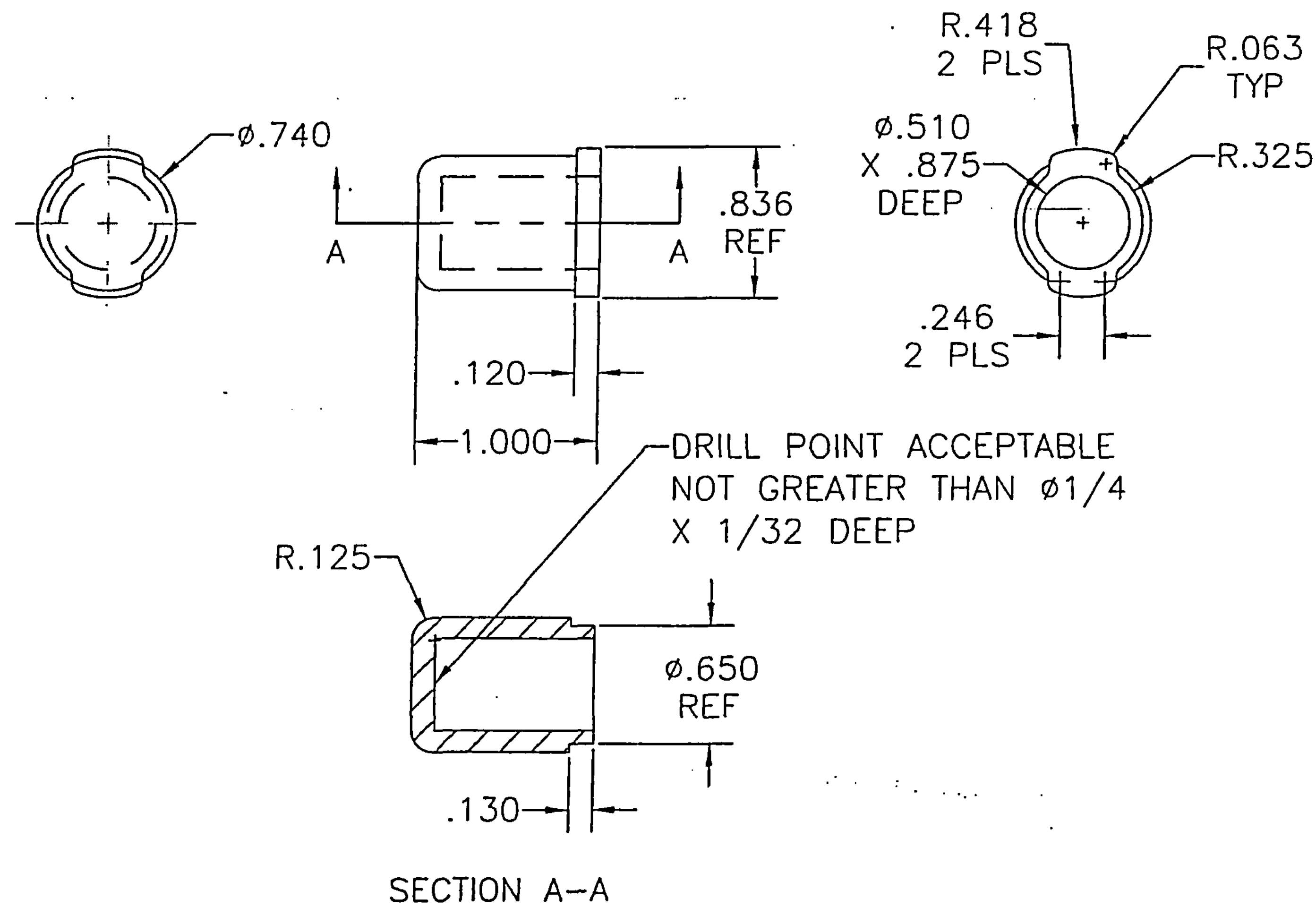
AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: FOOT CONTROL SLEEVE

SIZE B | DWG. NO. 88070-1 | REV A

SCALE: 1:1 | SHEET 1 OF 1

REVISIONS				
REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2871	INITIAL RELEASE	SEE TITLE	BLOCK
B	2877	CHG. R.025 TO R.063, ADDED DRILL NOTE	PB / [illegible]	20APR01



ATERIALS: AISI TYPE 304 STAINLESS STEEL

ROTECTIVE FINISH: PASSIVATE PER MILS-5002C

AEA TECHNOLOGY QSA

40 NORTH AVE, BURLINGTON, MA 01803

JNLESS OTHERWISE SPECIFIED:
- ...SIONS ARE IN INCHES.
- URFACE TEXTURE: 63
- ...NSIONS APPLY AFTER FINISH.
- REMOVE BURRS AND SHARP EDGES.
- DO NOT SCALE DRAWING.

TOLERANCES: .X ± 0.1
FRACTIONS ± 1/64 .XX ± 0.01
ANGLES ± 1° .XXX ± 0.005

DRAWN	P.BUTTRICK	10APR01
CHECKED	M.TREMBLAY	10APR01
APPR.	M.TREMBLAY	10APR01

THIRD ANGLE PROJECTION

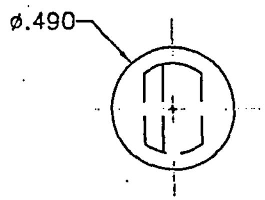
SAFETY CLASS: B

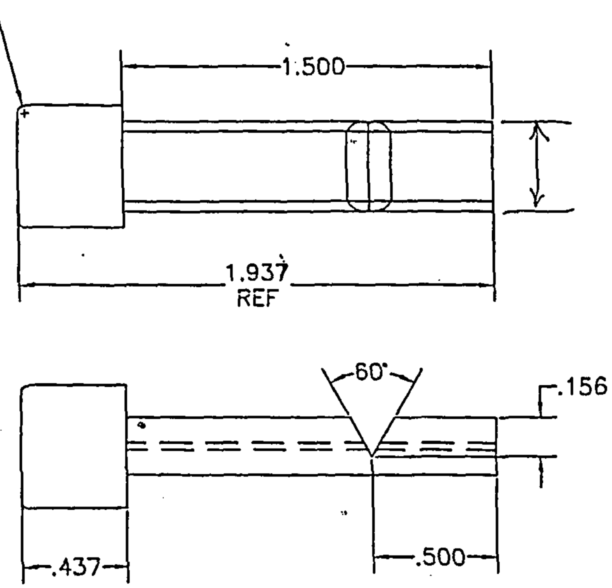
TITLE: FOOT CONTROL KNOB

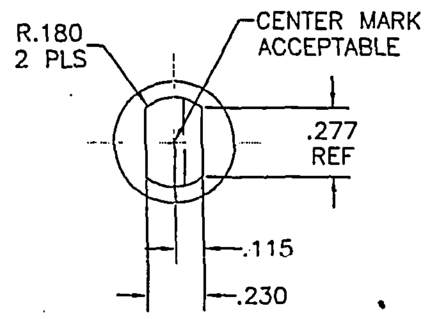
SIZE	DWG. NO.	REV
A	88070-3	B

SCALE: 1:1 | SHEET 1 OF 1

REVISIONS				
REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2871	INITIAL RELEASE	SEE TITLE	BLOCK
B	2877	ADDED CENTER MARK NOTE	PAB/M.T.	20APR01
C	2892	WAS .500,NOW .437 & WAS 1.38,NOW 1.500		
3	N/A	PROTOTYPE PART		







PROTOTYPE

PROCESS IN ACCORDANCE WITH
ENGINEERING INSTRUCTIONS

ENG Buttrick DATE 20SEP02

"Return Parts to Engineering"

MATERIALS: G-10 FIBERGLASS

PROTECTIVE FINISH: N/A

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64, ANGLES ± 1°, .X ± 0.1, .XX ± 0.01, .XXX ± 0.005

DRAWN	P.BUTTRICK	10APR01
CHECKED	M.TREMBLAY	10APR01
APPR.	M.TREMBLAY	10APR01

THIRD ANGLE PROJECTION — SAFETY CLASS B

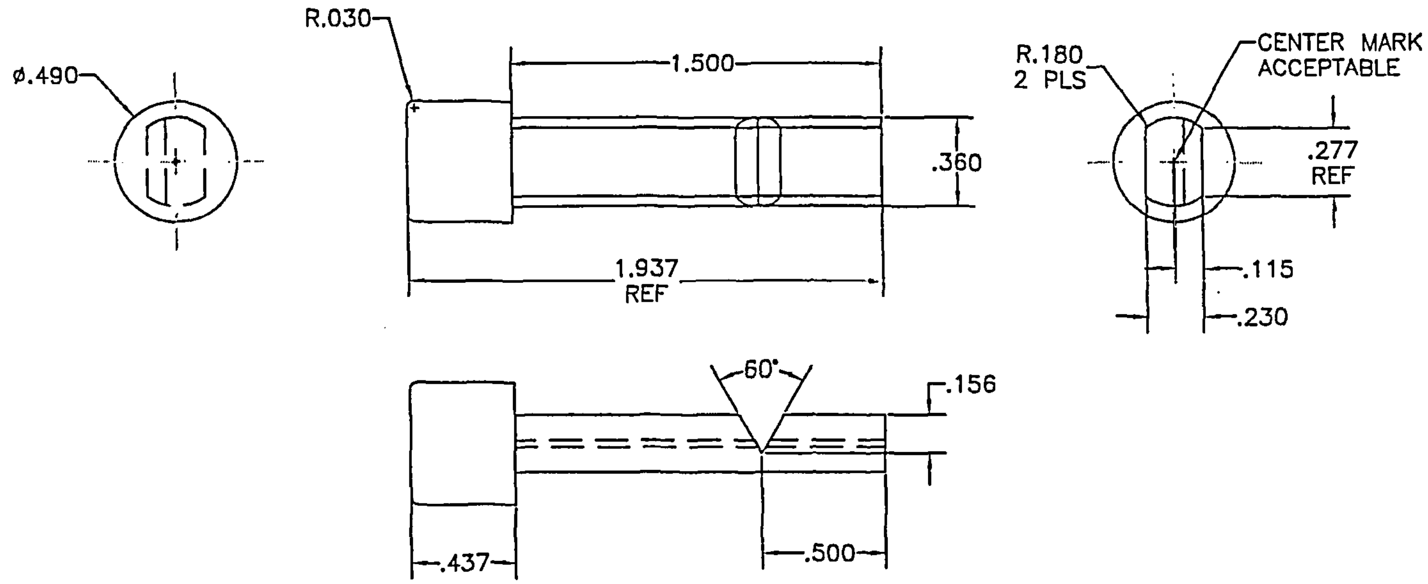
AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: FOOT CONTROL SHAFT

SIZE B | DWG. NO. 88070-4 | REV 3

SCALE: 1:1 | SHEET 1 OF 1

REVISIONS				
REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2871	INITIAL RELEASE	SEE TITLE	BLOCK
B	2877	ADDED CENTER MARK NOTE	PAB/M.T.	20APR01
C	2892	WAS .500,NOW .437 & WAS 1.38,NOW 1.500		
3	N/A	PROTOTYPE PART		



MATERIALS: G-10 FIBERGLASS

PROTECTIVE FINISH: N/A

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64, ANGLES ± 1°, .X ± 0.1, .XX ± 0.01, .XXX ± 0.005

DRAWN	P.BUTTRICK	10APR01
CHECKED	M.TREMBLAY	10APR01
APPR.	M.TREMBLAY	10APR01

THIRD ANGLE PROJECTION

SAFETY CLASS B

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: FOOT CONTROL SHAFT

SIZE B | DWG. NO. 88070-4 | REV 3

SCALE: 1:1 | SHEET 1 OF 1

Section 8. APPENDIX B – CALCULATIONS

(D)

F.C.B.A.

Horizontal Shock Test
ISO 3999-1

Test Specimen:

Drawing No. 88017XLS/TP125A Rev. B Serial Number: 12

Test weight 49 LBS Scale Used FWC DWM III
CAL DATE MAY 28 2003

Test Setup:

Set up per: ISO 3999-1 (6.4.6.1) horizontal shock test procedure.

Pictures: K:\TEST PLAN\TP125A

Notes:

Horizontal Test Bar:

Drawing No. T10333 S001 Rev. A Location: ENGR TEST CAGE

Test Period:

Date & time: 13FEB03 2:30 PM

Specimen Damage:

G-10 SHAFT BROKE AFTER 4TH HIT. FINISHED TEST OF 20 HITS. F.C.B.A. DID NOT WORK AT COMPLETION. UNIT (880) WAS NOT DAMAGED, WORKED FINE. PASSED TEST.

Post test assessment:

Recorded by: [signature]	Date: 14FEB03
Witnessed by: [signature]	Date: 13FEB03
Regulatory reviewed by: [signature]	Date: 13 Feb 03
Q.A. reviewed by: [signature]	Date: 13 Feb 03

(1)

LOCK MOUNT

Horizontal Shock Test
ISO 3999-1

Test Specimen:

Drawing No. 88117X/S/TP125A Rev. B Serial Number: 12

Test weight 49 LBS. Scale Used FWC DWM III
CAL. DATE MAY 28 2003

Test Setup:

Set up per: ISO 3999-1 (6.4.6.1) horizontal shock test procedure.

Pictures: K:\TEST PLAN\TP125A

Notes:

Horizontal Test Bar:

Drawing No. T10333 SN01 Rev. A Location: ENGR. STOCK CAGE

Test Period:

Date & time: 13FEB03 3PM

Specimen Damage:

ALUMINUM LOCK MOUNT W/S.S. INSERT WAS HIT 20 TIMES. FRONT OF LOCK MOUNT DAMAGED BUT FUNCTIONED PROPERLY. KEY ACTUATION WAS SMOOTH. PASSED TEST.

Post test assessment:

Recorded by: [signature]	Date: 13FEB03
Witnessed by: [signature]	Date: 13 Feb 03
Regulatory reviewed by: [signature]	Date: 13 Feb 03
Q.A. reviewed by: [signature]	Date: 13 Feb 04

2

Penetration Test
10CRF71

Test Specimen:

Drawing No. 88017XLS/TP125A Rev. B Serial Number: 12

Test weight 49 LBS. Scale Used FWC DWM IV
CAL. DATE 28 MAY 03

Test Setup:

Set up per: 10CR71 (71.71(10)) penetration test procedure.

Pictures: K:\TEST PLAN\TP125

Notes:

Drop surface:

Drawing No. T10129 SN01 Rev. A Location: ENG./SHIPPING

Test Period:

Date & time: 17 FEB03 9:30AM

Specimen Damage:

UPON DROPPING BAR ON THE F.C.B.A. THE 6-10 SHAFT BROKE. THE F.C.B.A. NEEDED TO BE DIS-ASSEMBLED TO ACTUATE THE SELECTOR RING AND LOCK SLIDE. UNIT WORKED FINE, PASSED TEST.

Post test assessment:

Recorded by: [signature]	Date:	17FEB03
Witnessed by: [signature]	Date:	17FEB03
Regulatory reviewed by: [signature]	Date:	17FEB03
Q.A. reviewed by: [signature]	Date:	17Feb03

Free Drop Test
10CRF71

Test Specimen:

Drawing No. 88017 XLS/TP125A Rev. B Serial Number: 12

Test weight 49 LBS. Scale Used PWC DWM III
CAL. DATE 28 MAY 03

Test Setup:

Set up per: 10CFR71 (71.73(1)) free drop test procedure.

Pictures: K:\TEST PLAN\TP125B

Notes:
SUSPENDED UNIT BY EYEHOOKS FROM A CRANE UNIT. VIDEO AND DIGITAL CAMERAS WERE USED TO DOCUMENT DROP.

Drop surface:

Drawing No. T10261 SN01 Rev. A Location: GROVELAND, MA.

Test Period:

Date & time: 07 MAR 03 9:42 AM

Specimen Damage:

UPON HITTING THE TEST PAD THE F.C.B.A.'S G-10 SHAFT BROKE AS DESIGNED. UNFORTUNATELY THE F.C.B.A.'S S.S. HOUSING ALSO CAME IN CONTACT WITH THE SELECTOR LOCK SLIDE, FORCING IT THROUGH THE SELECTOR RING.

Post test assessment:

IF THE REAR MOST COMPONENT (F.C.B.A.) WAS ALSO MADE OF G-10 MATERIAL, THAN THERE WOULD BE A CHANCE OF THE F.C.B.A. WOULD PASS THE TEST.

Recorded by: [signature]	Date: 14 MAR 03
Witnessed by: [signature]	Date: 17 MAR 03
Regulatory reviewed by: [signature]	Date: 18 Mar 03
Q.A. reviewed by: J. Beauchamp	Date: 19 March 03

Puncture Test 10CRF71	
Test Specimen: Drawing No. 88017XLS /TP125A Rev. A Serial Number: 12 Test weight 49 LBS. Scale Used FNC DWM IV CAL. DATE 28MAY03	
Test Setup: Set up per: 10CR71 (71.73(3)) puncture test procedure and assessed configuration. Pictures: N/A Notes (assessed configuration):	
Drop surface: Drawing No. T10261 SN01 Rev. A Location: GROVELAND, MA.	
Test Period: Date & time: 07MAR03 10:00 AM	
Specimen Damage: NOT PERFORMED. UNIT FAILED ON FREE DROP TEST. ALL TESTING STOPPED AT THIS TIME	
Post test assessment:	
Recorded by: [signature]	Date: 14MAR03
Witnessed by: [signature]	Date: 17MAR03
Regulatory reviewed by: [signature]	Date: 18MAR03
Q.A. reviewed by: [signature]	Date: 19MAR03

Final Test Assessment

Test Specimen:

Serial Number(s): 88017XLS/TP125 S/N Z1

Foot Control Button evaluation:

Spring (61lb.): IN GOOD WORKING ORDER
Spring (19lb.): IN GOOD WORKING ORDER
Stainless steel components: IN GOOD WORKING ORDER
F.C.B.A. working condition after Horizontal shock. YES *

Foot Control Button Assembly evaluation:

Is the F.C.B.A. in working condition?

THE ASSEMBLIES G-10 SHAFT BROKE ON IMPACT. THE F.C.B.A. HOUSING CAME IN CONTACT W/THE LOCK SLIDE, FORCING IT THROUGH THE SELECTOR RING

Comments:

* THE G-10 SHAFT WAS REPLACED AND THE ASSEMBLY WORKED FINE.

THE F.C.B.A. FAILED THE 9m FREE DROP.
THE PUNCTURE TEST WAS NOT PERFORMED.

Engineering Review by:	Date: 03 APR 03
SME Review by:	Date: 03 APR 03
Regulatory Review by:	Date: 3 Apr 03
Q.A. Review by:	Date: 4 April 03

Final Test Assessment

Test Specimen:

Serial Number(s): 88017XLS

Lock Mount Assembly evaluation:

Aluminum housing: DENTED AND SCRAPED (OK)
Stainless steel insert: NO DAMAGE
Corbin lock: NO DAMAGE
Lock Mount Assembly working condition after Horizontal shock. YES

Lock Mount evaluation:

Is the lock mount assembly in working condition?

THE LOCK MOUNT ASSY. STILL WORKS VERY SMOOTHLY.

Comments:

REFER TO TECHNICAL REPORT #40 FOR ADDITIONAL TEST OF THE LOCK MOUNT ASSY. WHICH ALSO FAVORS THE S.S. INSERT DESIGN.

Engineering Review by: [signature]	Date: 03APR03
SME Review by: [signature]	Date: 03APR03
Regulatory Review by: [signature]	Date: 3 Apr 03
Q.A. Review by: [signature]	Date: 4 April 03

Section 10. APPENDIX D – MANUFACTURING RECORDS

AEA TECHNOLOGY QSA

SPS-E-1724-1Rev1

ROUTE CARD

Part: 88017XLS	Rev: B
Desc: 880 DELTA "SIMULATOR" ASSEMBLY	
By: P Buttrick 9 JAN 03	Ckd: R. [illegible] 9 JAN 03
Safety Class: N/A	WO INDIRECT
Qty: 1	
Serial/Lot Number(s): 21	

OP#	Work Center	Operation	Part#	Rev	Lot or s/n	Reference Document	Tools	By	Date	Comments
010	Assy	Attach jacket	88041-1 88011XLS RIV093	C B A	S/n 21	B88017XLS	T10367 T10324	DA	9 JAN 03	
020	Assy	Attach front plate Torque screws ✓	88030 SCR154	C A		B88017XLS	Torque wrench S/n 182	DA	9 JAN 03	
030	Assy	Attach rear plate Torque screws ✓	88020 SCR154	5 A	S/n 1146	B88017XLS	Torque wrench S/n 182	DA	9 JAN 03	DA 7 FEB 03
040	Assy	Attach F.C.B.A.	88070	2		B88070		DA	9 JAN 03	
050	Assy	Label	88042-5 RIV003			B88017XLS		DA	9 JAN 03	
060	QC	Final inspection			Pass Fail X RE-INSPECT Acceptable D 7 Feb 03	B88017XLS		[illegible]	7 Feb 03	

AEA TECHNOLOGY QSA

SPS-E-1724-1Rev1

ROUTE CARD

Pa: 88017XLS	Rev: A	Page 1 of	
Desc: 880 DELTA "SIMULATOR" ASSEMBLY			
By: [signature] 17DEC01	Ckd: [signature] 17DEC01		
Safety Class: N/A	WO INDIRECT	Qty: 1	
Serial/Lot Number(s): 21			

OP#	Work Center	Operation	Part#	Rev	Lot or s/n	Reference Document	Tools	By	Date	Comments
010	Assy	Attach jacket	88041-1 88011XLS RIV093	C A A	S/n 21	B88017XLS	T10367 T10324	DAL	17 Dec 01	
020	Assy	Attach front plate Torque screws ✓	88030 SCR154	B A		B88017XLS	Torque wrench S/n 182	DAL	17 Dec 01	
030	Assy	Attach rear plate Torque screws ✓	88020 SCR154	B A	S/n 1146	B88017XLS	Torque wrench S/n 182	DAL	17 Dec 01	
040	Engr	Attach F.C.B.A.	88070	2		B88070		DAL	17 Dec 01	DAL 14 Nov 02
050	QC	Final inspection			Pass X Fail ___	B88017XLS	[initials]	[initials]	20 Dec 01	

AEA TECHNOLOGY QSA

17 JAN 02 5A PAB 17JAN02

Device for Test Pla.. 19

Sheet 1 of .

Inspection Instruction And Record	Originator/Date DW 18DEC01	Rev A	Part No. 88017XLS	Supplier
	QA Approval/Date 18DEC01	CM C	PIL N/A	Eng. Approval/Date 18DEC01

Item Description: Model 880 Delta Simulator Assembly

Characteristics	Tolerance	MTE	AQL	1	2	3	4	5	6	7	8	9
General Visual	N/A	N/A	C / 100%	0 / 1								
Verify all Items Present Per Drawing	N/A	N/A	C / 100%	0 / 1								
Verify Assembled per Drawing	N/A	N/A	C / 100%	0 / 1								
Total Weight 50 Lbs Max.	N/A	Scale	C / 100%	0 / 1								
Funtional Test With Dummy Source	N/A	N/A	C / 100%	0 / 1								
Verify Foot Control Button Assy Pt. # 88070 Installed	N/A	N/A	C / 100%	0 / 1								
Verify Foot Control Button Assy Functions Properly	N/A	N/A	C / 100%	0 / 1								
Less Name Plate & Source ID Tag	N/A	N/A	C / 100%	0 / 1								
Comments	PO / WO #			INDIRECT								
	Traveler / QCL #			N / A								
	Lot / Serial #			21								
	Lot Qty.			1								
	Qty. Rej / NCR			0 / NA								
	Qty. Acc.			1								
	Insp / Date			DW 20 DEC 01								

DC 17 JAN 02 17 JAN

AEA TECHNOLOGY QSA	ROUTE CARD	Part No.: 88011XLS	Rev: ~~A~~ B	Page 1 of 1
		Desc: Body Weldment "Delta Simulator"		
		By: [signature] 12 DEC 01	Ckd: R. [signature] 12 DEC 01	
		Safety Class: ~~N/A~~ C DC 17 JAN 02 WO INDIRECT	Qty: 1	
SPS-E-1724-3Rev1		Serial/Lot Number(s): 21		

Op #	Work Center	Operation	Part #	Lot or S/N	Reference Documents/Rev	Tools	by	Date	Comments
010	Assy	Stamp S/N	88010	S/N 21	B88011XLS		DAL	12 DEC 01	
020	Assy	Assemble shields & End plates	88052-1 88010 88003	Lot# 01171-1	B88011XLS		RDR	12 Dec 01	
030	Weld	Tack Weld	88011XLS WEL003	Lot# 01026-2	B88011XLS	T10318 S/N 02	E.P.	12 Dec 01	
040	Weld	Weld	88011XLS WEL003	Lot# 01026-2	B88011XLS		E.F.	12 Dec 01	
050	QC	Inspect weld (VT)		Pass X Fail	B88011XLS		DC	14 Dec 01	
060	Assy	Foam	FOM001		B88011XLS WI-P1712 SPS-P1712-1	T10329 S/N 04	DFW	15 DEC 01	
070	~~Assy~~ QC	Inspect			B88011XLS		DC	17 Dec 01	

Sheet 1 o

Inspection Instruction And Record	Originator/Date [signature] 17 Dec 01	Rev B	Part No. 88011XLS	Supplier	
	QA Approval/Date [signature] 17 Dec 01	CM C	PIL 3	Eng. Approval/Date [signature] 18 DEC 01	

Item Description: Body Weldment Delta Simulator

Characteristics	Tolerance	MTE	AQL	1	2	3	4	5	6	7	8	9
General Visual	N/A	N/A	MJ / 1.0	0 / 1								
Verify Assembled per Drawings Route Card Verification	N/A	N/A	MJ / 1.0	0 / 1								
1.75	+ .02 - .08	Micro Hite	MJ / 1.0	0 / 1								
8.5	+ / - .1	Micro Hite	MJ / 1.0	0 / 1								
Welded Per Dwg.	N/A	N/A	MJ / 1.0	0 / 1								
Stamp Serial # per Dwg.	N/A	N/A	MJ / 1.0	0 / 1								

Comments		1	2	3	4	5	6	7	8	9
	PO / WO #	INDIRECT								
	Traveler / QCL #	N / A								
	Lot / Serial #	21								
	Lot Qty.	1								
	Qty. Rej / NCR	0 / NA								
	Qty. Acc.	1								
	Insp / Date	DW / 17 Dec 01								

AEA TECHNOLOGY QSA

FIRST ARTICLE REPORT
Form F-Q1807-2

Supplier: MACHINE SHOP	Part No.: 88022-1	P.O. /W.O.
Item Description: LOCK MOUNT INSERT	Qty. 2	Qty./Insp. 2
Drawing No. 88022-1	Rev. 3	CM: B
Inspected by: Dave [signature]	Date: 18 Dec 02	Lot/Ser.#

Drawing Dimension	Actual Dimension	M&TE Used	SN & Cal. Due Date
SLOT .188	.188-.189	Caliper	#305 10-4-03
.562	.565 - .560	↓	" "
.755 ± .003	.756 - .758	Bore Gage	#111 4-5-03
.875 +.000 -.005	.875	Caliper	#305 10-4-03
.165	.164 - .166	Micro Hite	271 4-2-03
.125 Ø Thru	125	Pin gage	292 4-2-03
.35	.345 / .350	Micro Hite	#270 4-2-03
.89	.892 / .896	↓	↓ ↓
.93	.933	↓	↓ ↓
.16	.158 .160	Caliper	#305 10-4-03
.31 Rad	.31 Rad	Pin gage	293 4-2-03
300 Series S.S.	S.S	Visual / magnet	NA
	Results:	Accepted ☒	Rejected ☐

Comments:

QC Forward this inspection report along with the samples to Engineering for review and approval. *Retain a copy of the report in the file until approved.*

Approved ☒ Not Approved ☐

[signature] Date: 06 JAN 03
Engineering

Engineering return approved report to QC for records retention.

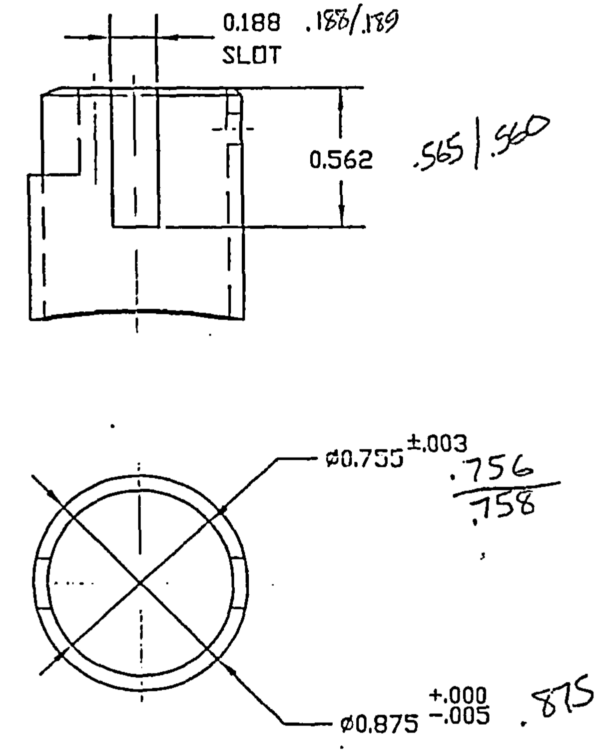
QCL# #12573

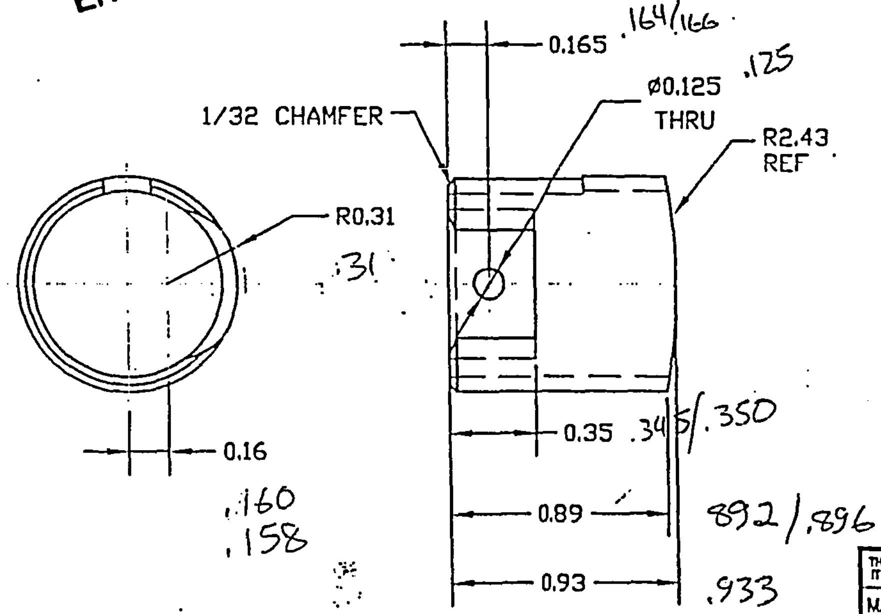
PROTOTYPE

PROCESS IN ACCORDANCE WITH ENGINEERING INSTRUCTIONS

ENG Buttrick DATE 07OCT02

REVISIONS				
REV.	ERF #	DESCRIPTION	APPROVALS	DATE
3	N/A	PROTOTYPE RELEASE	SEE TITLE	BLOCK





MATERIALS: 300 SERIES STAINLESS STEEL

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: .X ± 0.1, .XX ± 0.01, .XXX ± 0.005, FRACTIONS ± 1/64, ANGLES ± 1°

DRAWN	
CHECKED	NA
APPR.	

THIRD ANGLE PROJECTION — QUALITY CLASS B

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: LOCK MOUNT S.S. INSERT

SIZE	DWG. NO.	REV
B	88022-1	3

SCALE: 1:1 — SHEET 1 OF 1

AEA TECHNOLOGY QSA

FIRST ARTICLE REPORT
Form F-Q1807-2

Supplier: A.E.A MACHINE Shop	Part No.: 88070-4	P.O. /W.O: Indirect
Item Description: Foot Control Shaft	Qty. 10	Qty./Insp. 5
Drawing No.	Rev. 3	CM: B
Inspected by: Virgie Benitez	Date: 01 OCT 02	Lot/Ser.# N/A

Drawing Dimension	Actual Dimension	M&TE Used	SN & Cal. Due Date
General Visual	Conform	Visual	N/A
1.500	1.500	CALIPER	340 - 8/8/03
R.030	.030	RADIUS GAGE	QC-10- 4/1/03
Φ.490	.490	Caliper	340 - 8/8/03
.60°	.60°	OPTICAL COMP.	340 - 8/8/03
.437	.437	Caliper	↓
.500	.500	↓	↓
.156	.156	↓	↓
R.180 (2 PLS)	R.187	Radius Gage	QC-10 - 4/1/03
.115	.115	Caliper	340 - 8/8-03
.230	.230	Caliper	340 - 8/8 - 03
.360	.360	Caliper	340 - 8/8 - 03
	Results:	Accepted [ ]	Rejected [X]

Comments:

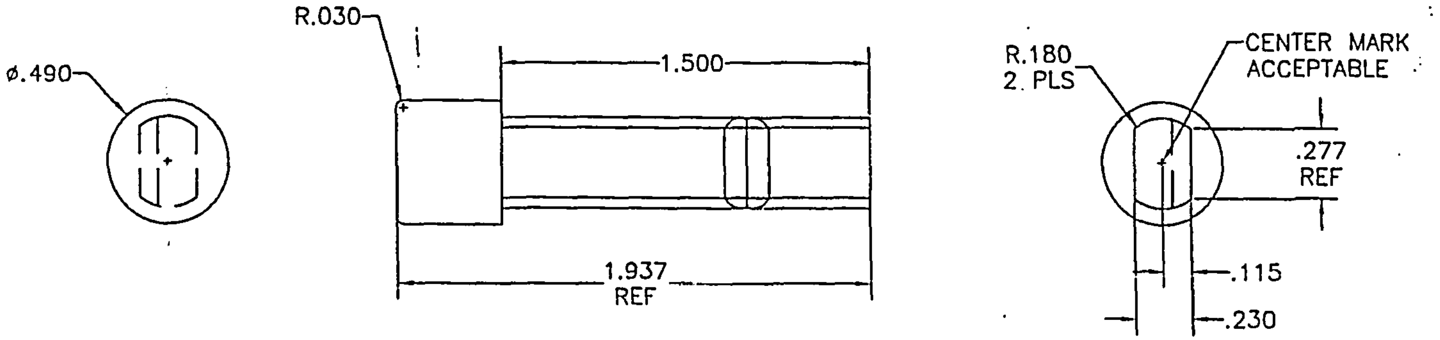
QC Forward this inspection report along with the samples to Engineering for review and approval. Retain a copy of the report in the file until approved.

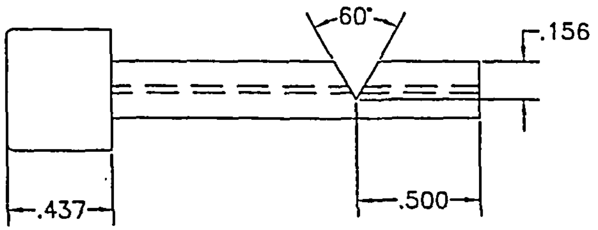
Approved [X]   Not Approved [ ]

[signature] Date: 03 OCT 02
Engineering

Engineering return approved report to QC for records retention.

REVISIONS				
REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2871	INITIAL RELEASE	SEE TITLE	BLOCK
B	2877	ADDED CENTER MARK NOTE	PAB/M.T.	20APR01
C	2892	WAS .500,NOW .437 & WAS 1.38,NOW 1.500		
3	N/A	PROTOTYPE PART		





PROTOTYPE

PROCESS IN ACCORDANCE WITH ENGINEERING INSTRUCTIONS

ENG Buttrick DATE 20SEP02

"RETURN PARTS TO ENGINEERING"

MATERIALS: G-10 FIBERGLASS

PROTECTIVE FINISH: N/A

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: .X ± 0.1, .XX ± 0.01, .XXX ± 0.005; FRACTIONS ± 1/64; ANGLES ± 1°

DRAWN	P.BUTTRICK	10APR01
CHECKED	M.TREMBLAY	10APR01
APPR.	M.TREMBLAY	10APR01

THIRD ANGLE PROJECTION

SAFETY CLASS B

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: FOOT CONTROL SHAFT

SIZE B | DWG. NO. 88070-4 | REV 3

SCALE: 1:1 | SHEET 1 OF 1

Section 11. APPENDIX E – TECHNICAL REPORTS

AEA TECHNOLOGY QSA, Inc.
Engineering Department
Technical Report

Title: 88022 Lock Mount "Environmental Test" evaluation

Prepared by: [signature] Date: 1/15JUN02
Checked by: [signature] Date: 1/15JUN02
Engineering Approval: [signature] Date: 1/20/1/02

1.0 PURPOSE

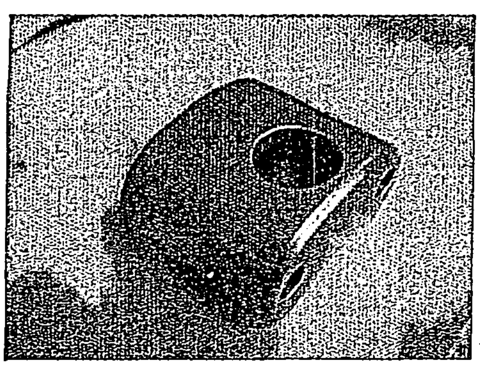
The purpose of the report is to set forth results on testing of the #88022 Lock Mount assembly, then propose and test new designs as to arrive at one that will not experience operating problems in the future.

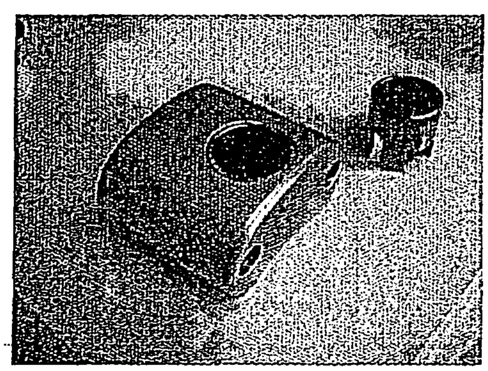
2.0 SCOPE

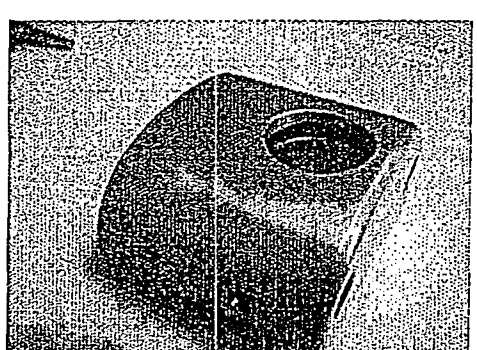
We have received customer concerns (see CR 151, CR177) about the aluminum #88022 lock mount and its brass #66001-11 lock plunger sticking (not unlocking) after being subjected to several days of marine environment and dark room exposure. Other concerns of mud and water submersion to the lock mount assembly during "normal" daily operations have been made in reference to faulty lock operations. Moreover, corrosion between the aluminum lock mount and the brass lock plunger will be evaluated when tested.

3.0 METHODS

The test method employed was performed on three different designs. The first design is the part as currently manufactured. The second design has a stainless steel sleeve inserted into the existing design's enlarged hole. The third, a rubber o-ring design incorporated into the existing design. Two complete assemblies of each of the three different configurations were used in the testing. The test was as follows.





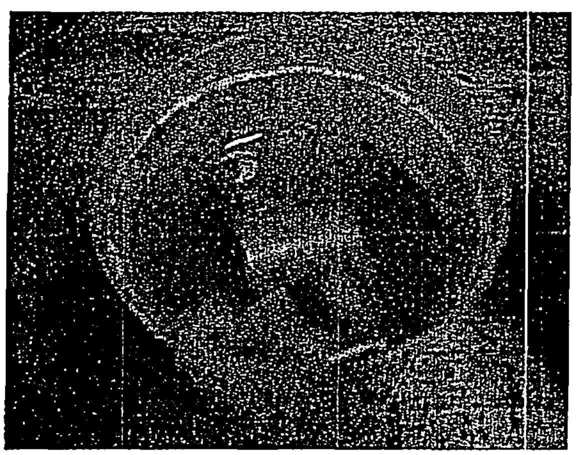


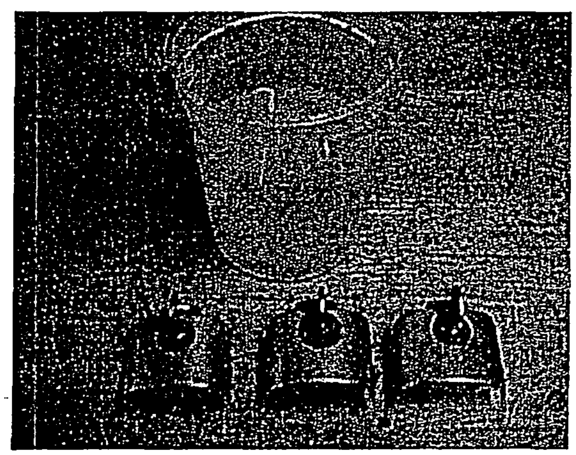
Two different tests were conducted:

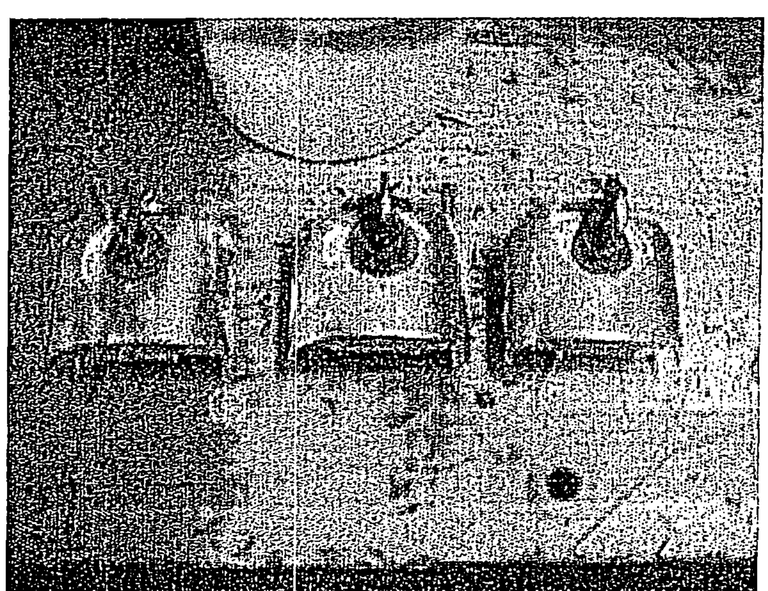
a. One each of the three different designs were submerged into a heavy salt water mixture for a period of 3 days. Each day the solution was stirred, as to fully coat the samples. On the fourth day the test samples were set on a table at ambient temperature to dry for a period of four hours. The samples were then placed in an oven and were subjected to a temperature of approximately 140 degrees Fahrenheit for a period of 4 hours.

The above process was to simulate exposure to a marine environment. The test samples did have some minor corrosion occur between the brass lock plunger and the aluminum housing. The brass lock plunger also had some discoloring around the key area but had little effect in operation.

See pictures below.......



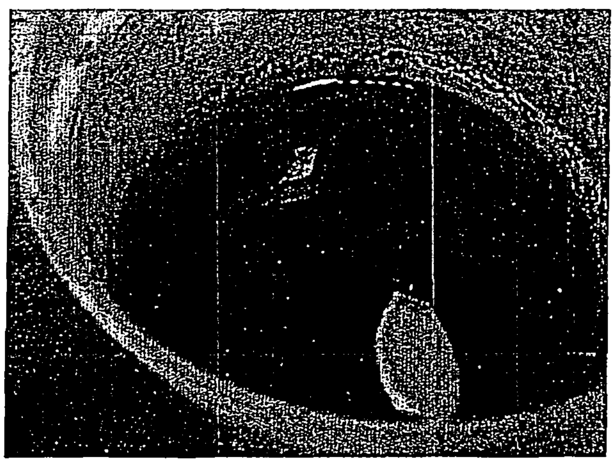


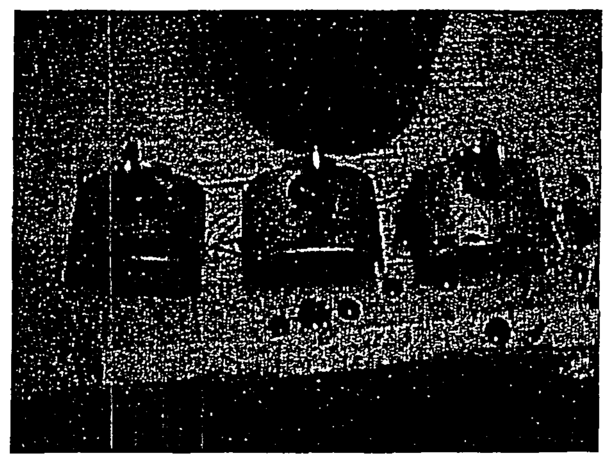


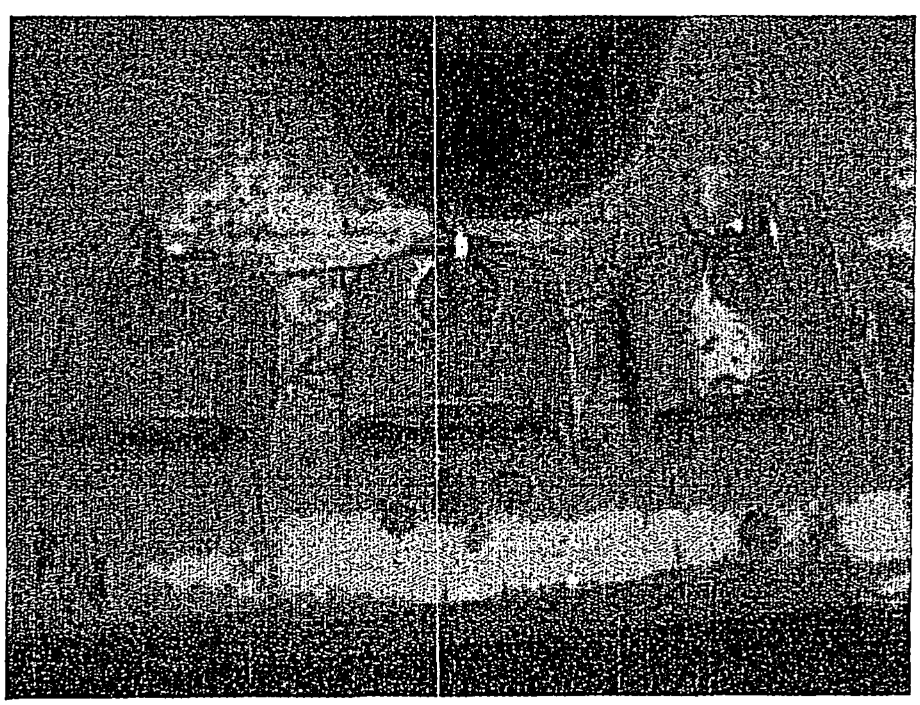
b. One each of the three different designs were submerged into a thick mud mixture for a period of 3 days. Each day the solution was stirred, as to fully coat the samples. On the fourth day the test samples were set on a table at ambient temperature to dry for a period of four hours. The samples were then placed in an oven and were subjected to a temperature of approximately 140 degrees Fahrenheit for a period of 4 hours.

The above process was to simulate exposure to dirt and mud for long periods of time. A drying cycle was introduced as a normal occurrence during storage or non-use.

See pictures below.......







4.0 INITIAL INPUT

The first sample, which is our normal production part was tested without any modifications. It was assembled by applying a petroleum (AEROSHELL Grease 7) lubricant to the perimeter of the hole on the aluminum lock mount. The brass plunger was than inserted into the hole and secured in place by a 6-32 hex slot machine screw through the side of the assembly.

The second sample, #88022 (Rev. 6) lock mount had the 0.858 diameter drill hole opened to .880 +.000/-.003 x .930 deep. A stainless steel sleeve #88022-1 (Rev. 1) with an outside diameter of 0.875 +.000/-.005 was bonded with a 5 minute epoxy into the .880 hole. The #66001-11 lock plunger was than inserted into the lubricated (AEROSHELL) stainless steel sleeve and secured in place with a 6-32 machine screw.

The third sample, #88022 (Rev. 5) lock mount was modified to accept an o-ring (Green Rubber #AS568-210) approximately 1/8" from the top edge of the .758 diameter hole. Upon insertion of the o-ring the 0.758 diameter hole was greased with the lubricant (AEROSHELL) and the brass lock plunger was secured in place as above.

See attached drawings for more information.

5.0 RESULTS / DISCUSSION

5.1 The parts were first evaluated (not cleaned) while still warm from the oven.

All the salt covered test sample's lock plungers were hard to turn with the key and did not actuate properly. The Stainless steel sleeve sample did however work the best after only a few iterations. The normal production sample was very stiff while turning the key and did not actuate fully. The o-ring sample did not turn or actuate at all.

The mud covered test sample's lock plungers turned easily with the key but did not actuate fully on the current design and the o-ring designed test sample. The stainless steel sample however actuated fully without any effort.

5.2 The parts were then cleaned (washed with water) while turning the key and actuating the lock plunger.

The salt covered stainless steel insert test sample and the o-ring test sample worked well after cleaning. The normal production sample however, never worked properly even after being rinsed thoroughly with water. The production sample was then disassembled, re-cleaned, and reassembled. At which point it worked as designed.

The mud samples were evaluated to find that the regular production sample's key turned fine but did not actuate completely. The o-ring design worked well. The o-ring kept out most of the mud and water enabling it to function properly. The sample with the stainless steel insert worked best. The key turned easily and the lock plunger actuated smoothly.

6.0 REFERENCES

Not applicable.

7.0 CONCLUSION

The overall conclusion is that the #88022 lock mount assembly should be kept clean as possible during normal operation. After use, the radiographic unit and it's lock mount assembly should be washed to remove any dirt, salt, and grime to insure proper functioning.

The conclusion from testing different designs is that the #88026 lock mount should be modified from it's original design to include the #88002-1 stainless steel insert. The stainless steel insert was quoted at approximately $5.00 each and will be incorporated at the time of assembly. The aluminum lock mount presently is being produced as a finished casting. The light weight aluminum design is both desirable and is a functional alternative to an all solid stainless steel design.

Section 12. APPENDIX F – ORIGINAL TEST PLAN

TEST PLAN 125 (Rev. B)
Model 880 Type B Container
With 88070 Foot Button Assembly
And 88022 Lock Mount Modification
10CFR71, ISO 3999-1
Transport Conditions

TABLE OF CONTENTS

1.0 Purpose

The purpose of these tests is to assess the Model 880 transport container with the addition of the #88070 foot control button assembly. With the addition of these components and the modification of the #88022 lock mount, they will not adversely affect the packages ability as a "Type B" transport container.

The tests will be conducted and witnessed by at least one Engineer (the originator), one Regulatory, and one Quality person. The results of the test will be written in a test report and distributed through the engineering, quality, and regulatory departments for review.

We will test to 10CFR71 regulations for 71.73(1) *free drop*, 71.73(3) *puncture*, and 71.71(10) *penetration*. These tests will follow a random order except that the 71.73(3) puncture test will follow the 71.73(1) free drop test. Also, testing will be performed according to ISO 3999-1 regulations for 6.4.6.1 *horizontal shock*.

This test is a revision to Test Plan 125A. In this test plan, AEA Technology QSA will revert back to the original test plan (TP125) for it's #88070 component design with the following exception. The #88070-4 Shaft which was made of 304 stainless steel will be manufactured from phenolic (G-10 fiberglass) rod stock.

In reference to TP125A, the test failed when the 88070-4 Shaft made impact with the 88024 Titanium lock slide, pushing it through the 88026 Selector ring causing a failure. By manufacturing the Shaft out of G-10 material it would fail first before any damage could occur to the lock slide or the selector ring. See drawing #88070-4 (Rev. 3) for details of the improved design.

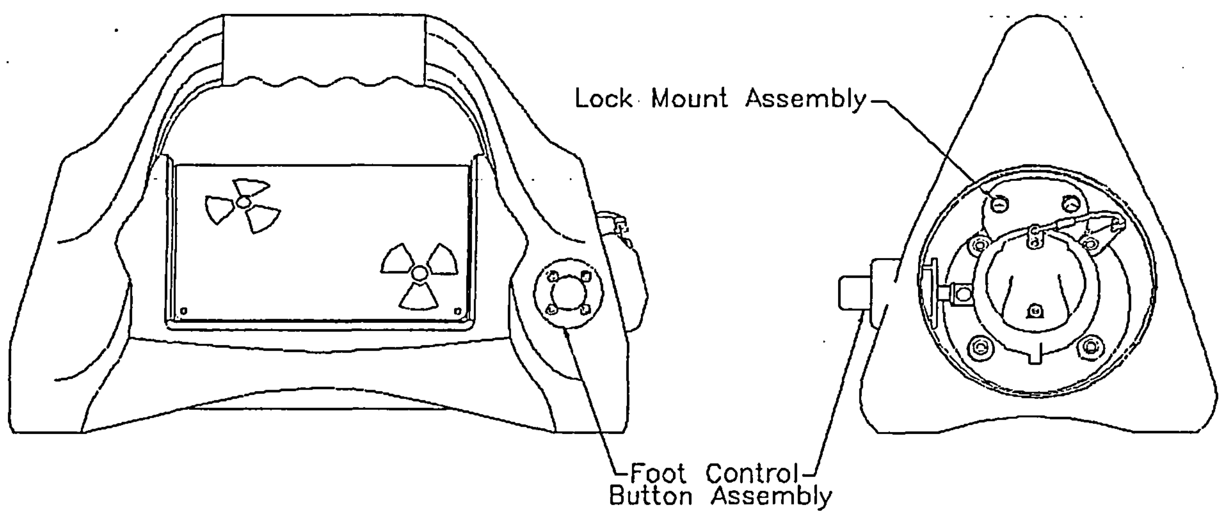
Testing not performed under this test (and necessary to demonstrate compliance with 10CFR71, ISO 3999-1, 49CFR and IAEA ~~TR-S-1~~) will be addressed in an assessment located in the final test report. TS-R-1

23 Oct 02

2.0 Product Design Description

The Model 880 "Delta" source projector, drawing #TP125A (weighted dummy unit) consists of the following components:

- 5" Dia. stainless steel body weldment with a "lead core" containing an S-tube.
- Stainless steel front and rear plate assemblies (with modified lock mount).
- #88041 Polyurethane jacket.
- #88070 foot control button assembly.



3.0 Failures of Interest

3.1 Foot Control Button Assembly

If the lock slide were to be forced from it's locked position, the source wire could become free to float inside the unit.

The drop test will show that the compressive load being transmitted through the 88070 foot control button assembly will not damage the 88024 lock slide located inside the 88020 rear plate assembly.

3.2 Lock Mount

If the aluminum lock mount receives a blow which damages this component and prevents the locking mechanism from actuating properly then the operator might be unable to use the radiographic camera as specified in the operations manual.

The ISO 3999-1 (6.4.6.1) horizontal shock test will show that with the addition of a stainless steel insert, that this will aid in better structural integrity to the lock mount assembly. See drawing 88022-1 for insert information.

Because the lock mount is designed not to extend beyond the surface of the camera body, the ISO 3999-1 (6.4.2) lock-breaking test, 10CFR 71 (71.73.1) free drop and (71.73.3) puncture test would not be relevant tests therefore will not performed.

Moreover, the ISO 3999-1 horizontal shock test is more severe than the 10CFR71 (71.71.10) penetration test. Because of this, the penetration test will not be performed.

4.0 Test Conditions and Orientations

The Foot Control Button Assembly (F.C.B.A.) was designed to thrust the lock slide into it's active position during operation. The F.C.B.A. was also designed to bottom out when the lock slide was fully actuated. With the new design (phenolic) of the lock slide, the force from actuating the F.C.B.A. cannot be translated directly to the lock slide.

4.1 Free Drop Test (3)

The 880 radiographic unit will be oriented so that the F.C.B.A. will be facing downward toward the test pad (T10261 SN01) for the 9m (30 ft.) drop test (see section 8.0). This will expose the assembled unit so the F.C.B.A. will receive an impact similar to a slap down effect. See section 3.2 for lock mount testing information.

4.2 Puncture Test (4)

According to the Purpose (Section 1.0 paragraph 4) section of this test plan an evaluation will be made before this test is performed. Unless stated in the test report, the following will most likely be performed. The 880 unit will be oriented in a similar angled fashion as above for the 1m (40 in.) drop test. The unit will be dropped onto a test billet (T10119 SN01) so as the F.C.B.A. sustains the full initial impact. See section 3.2 for lock mount testing information.

4.3 Penetration Test (2)

The 880 unit will be oriented so as the foot control button assembly will be facing upward while the jacket will be supported on an unyielding surface. The hemispherical end of a vertical steel cylinder (AEA Technology QSA Drawing #BT10129) of 3.2 cm (1.25 in) diameter and 6 kg (13 lbs.) mass will be dropped from a height of 1 m (40 in) onto the surface of the F.C.B.A. See section 3.2 for lock mount testing information.

4.4 Horizontal Shock Test (1)

The 880 unit will be oriented so the (1) F.C.B.A. and the (2) Lock Mount will impact the end-face of (T10333 SN01) 50 mm (2 in) diameter steel bar. The criteria is 300 mm (12 in) in length lying horizontally, that is fixed or welded to a rigid mass at least ten times the mass of the 880. The 880 will be suspended from a fixed point so that, when at rest, the F.C.B.A. and Lock Mount just touches the target. The 880 will be moved from its resting position until its center of gravity is 100 mm (4 in) higher than in the resting position and let loose, so that it swings in a pendulum movement against the target. This will be carried out for a total of twenty (20) times.

5.0 Pass and Fail Criteria

A final assessment shall be made upon the completion of the tests to evaluate the specimen's performance against the test requirements and determine a pass or fail judgement. The specimen(s) shall be considered passing the test requirement if the specimen meets the following criteria:

5.1 Foot Control Button Assembly

The lock slide must not be damaged in a way that the source wire assembly becomes free to move.

The radiographic unit must remain operational after the horizontal shock test. This means either with the actuation of the F.C.B.A. or by manual operation of the lock slide mechanism.

5.2 Lock Mount Assembly

The corbin lock mechanism must actuate freely after being subjected to the horizontal shock test. Also the stainless steel insert must stay in position. The Lock Mount and stainless steel insert will be secured in place with a dog point hex set screw. Loctite will also be added to a set screw prior to assembly. Moreover, the set screw in the Lock Mount assembly cannot back out of position after assembly because the Lock Mount seats up against the 88031 Front Plate.

Final assembly configuration will be noted on QC inspection/acceptance forms. The production unit will be assembled to comply with the tested configuration.

6.0 Test Specimen

The test specimen will be a fully weighted dummy "lead core" 880 Delta radiographic camera (reference AEA Technology QSA Drawing No. TP125A). The core will have no depleted uranium, however the lead core will encapsulate a titanium s-tube. The test specimen shall be examined after the test and any defects will be noted.

The test specimen was developed under drawing #88017XLS but stated that the unit was a Safety Class "C". The test unit should be a Safety Class "A" for traceability reasons. Therefore drawing TP125A was developed as a prototype drawing of the test unit with a Safety Class A.

AEA Technology QSA used a lead unit for this test for the soul evaluation of the Mechanical testing of exterior components. Therefore the unit did not need to be profiled.

Lead was also used to replicate the weight of the unit. The lead billet is orientated (center of gravity) in the same location as a DU unit. Moreover, the billet is mechanically attached with the same pins and hardware as a DU unit. Therefore the test unit will react in the same manner as the DU unit.

7.0 Testing Safety and Waste Disposal

Testing Safety

The tests will not be conducted with any radioactive sources. Instead, the testing of the Model 880 unit will use a dummy source wire assembly.

The weight of the testing will require lifting heavy objects. Proper lifting techniques shall be used to prevent injury.

Some tests of this plan may result in heavy falling objects and flying debris. Safety glasses and a safe distance must be used in these cases.

Waste Disposal

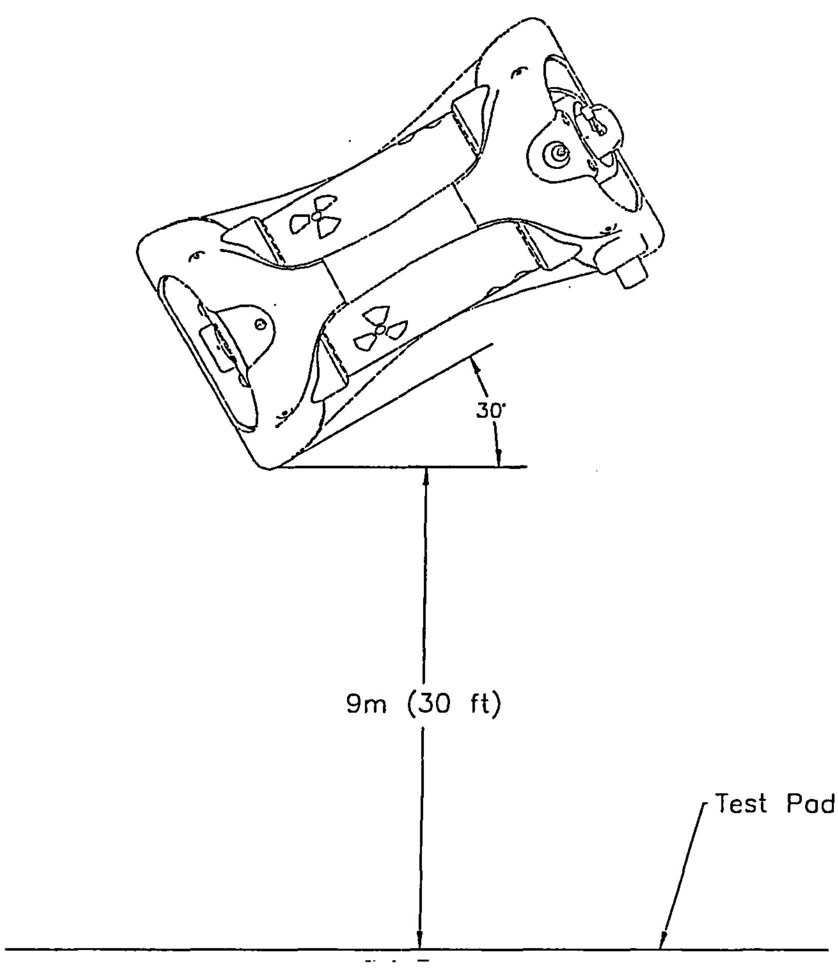
The test Model 880 and accessories will be kept and stored for reference until authorization by the engineering and regulatory department to dispose. No radioactive material will be used in the testing so the test specimens do not need to be kept in any special radiation storage areas.

Once approved for disposal by the engineering department and the regulatory department, the entire test units can be disposed of as standard garbage except for the lead shielding. The lead shall be removed from the Model 880 device and kept for the production department to melt down for other applications if applicable. If the unit remains in good condition, the unit will be repaired if necessary and used for future demo purposes.

8.0 Test Procedures

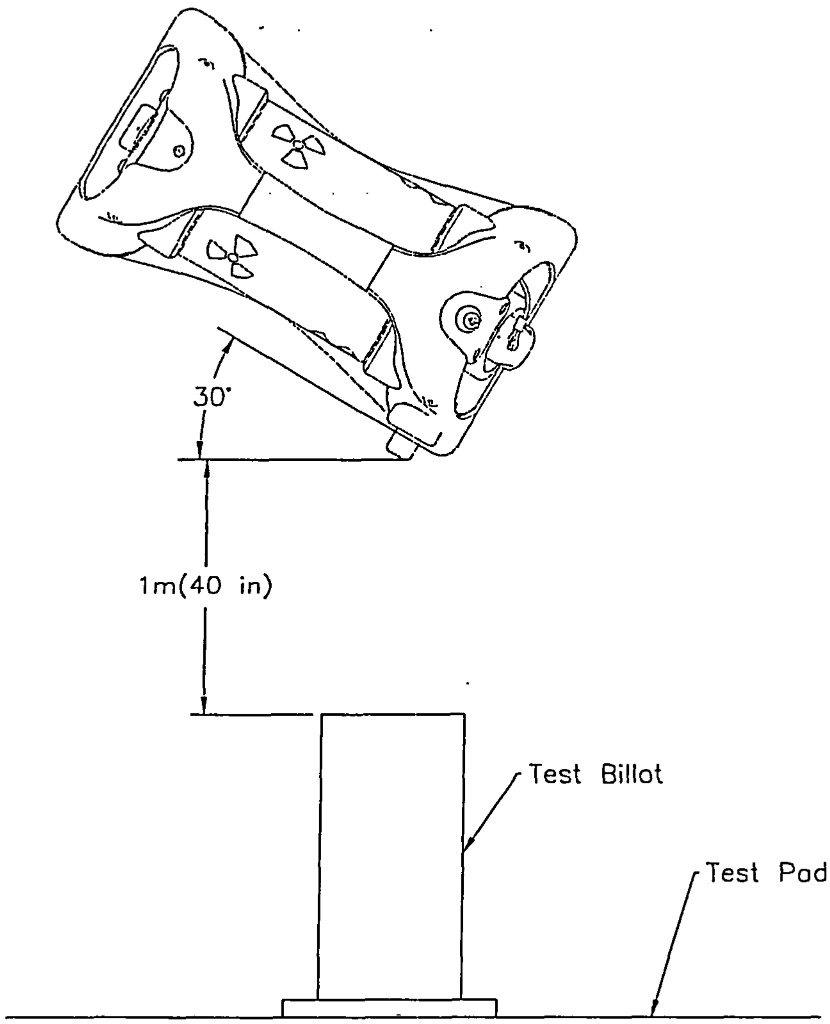
Free Drop Test 9m

1. Prepare test device by placing device into a sling device.
2. Hold test specimen orientated toward impact surface at a height of 9 m (30 ft) from the top of the drop pad surface to the bottom of the test specimen.
3. Drop the test specimen onto the rigid target surface.
4. Examine test specimen and evaluate to test requirements.
5. Record the results of the test.



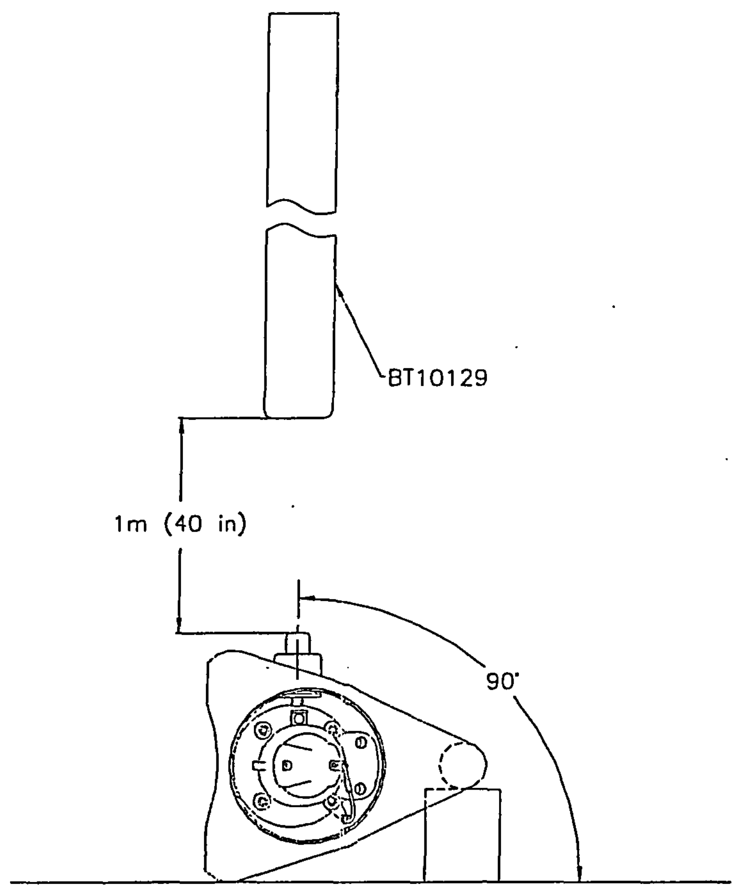
Puncture Test 1m

1. Prepare test device by placing device into sling device.
2. Hold test specimen orientated toward impact surface at a height of 1 m (40 in.) from the top of the test billet surface to the bottom of the test specimen.
3. Drop the test specimen onto the test billet surface.
4. Examine test specimen and evaluate to test requirements.
5. Record the results of the test.



Penetration Test

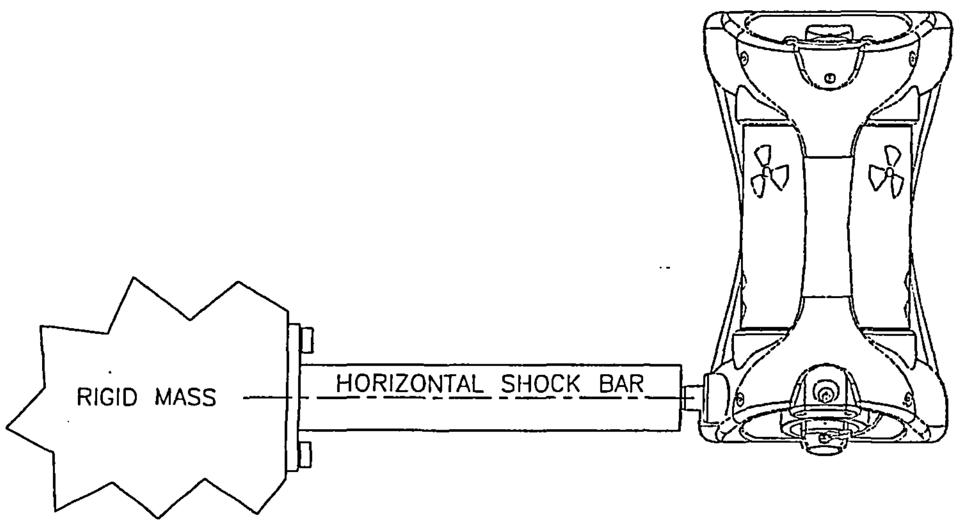
1. Prepare test device by placing device on an unyielding surface.
2. Orient F.C.B.A. in a vertical position while supporting handle of jacket.
3. Drop steel cylinder (T10129) from a height of 1m (40 in) onto the F.C.B.A.
4. Examine test specimen and evaluate to test requirements.
5. Record the results of the test.

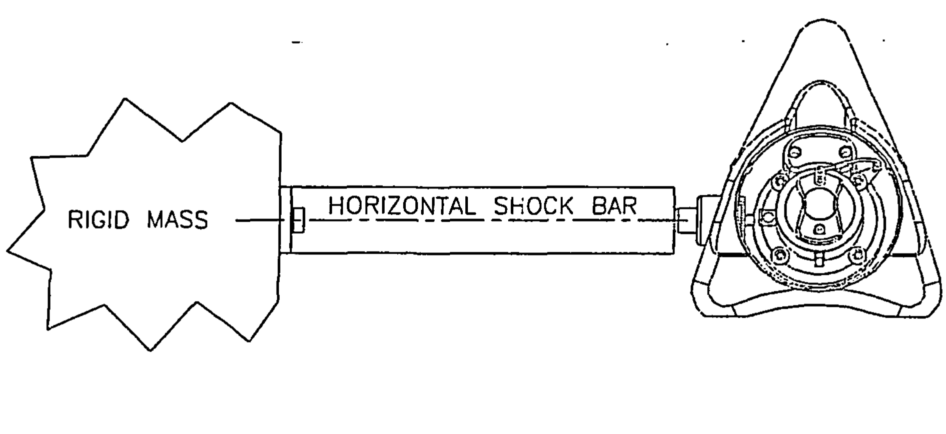


Horizontal Shock Test

1. Prepare test device by placing device into a sling device.
2. Orient by suspending the F.C.B.A. in a horizontal position while touching (T10333) horizontal shock bar.
3. Move the 880 unit until its center of gravity is 100 mm (4 in) higher than its resting position.
4. Let it loose, so that it swings in a pendulum movement against the target for a total of 20 times.
5. Examine test specimen and evaluate to the test requirements.
6. Record the results of the test.

Foot Button Assembly (1)

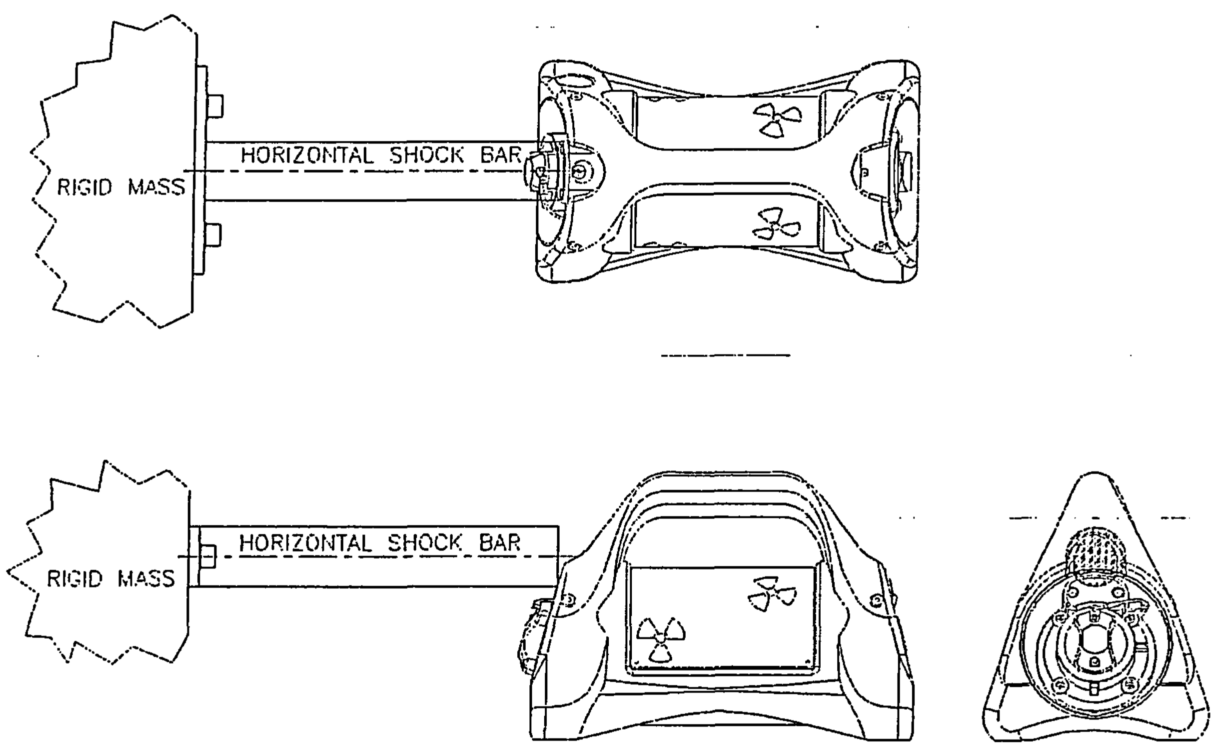




Horizontal Shock Test

1. Prepare test device by placing device into a sling device.
2. Orient by suspending the Lock Mount in a horizontal position while touching (T10333) horizontal shock bar.
3. Move the 880 unit until its center of gravity is 100 mm (4 in) higher than its resting position.
4. Let it loose, so that it swings in a pendulum movement against the target for a total of 20 times.
5. Examine test specimen and evaluate to the test requirements.
6. Record the results of the test.

Lock Mount (2)



Free Drop Test
10CRF71

Test Specimen:

Drawing No. ______________________ Rev. ______ Serial Number: ____________

Test weight __________________________ Scale Used ____________________

Test Setup:

Set up per: 10CFR71 (71.73(1)) free drop test procedure.

Pictures: ____________

Notes:

____

____

Drop surface:

Drawing No. ______________________ Rev. ______ Location: _________________

Test Period:

Date & time: ____________________

Specimen Damage:

____

____

____

Recorded by:	Date:
Witnessed by:	Date:
Regulatory reviewed by:	Date:
Q.A. reviewed by:	Date:

Puncture Test
10CRF71

Test Specimen:

Drawing No. ____________________ Rev. ______ Serial Number: ____________

Test weight ________________________ Scale Used ____________________

Test Setup:

Set up per: 10CR71 (71.73(3)) puncture test procedure and assessed configuration.

Pictures: ____________

Notes (assessed configuration):

____

____

Drop surface:

Drawing No. ____________________ Rev. ______ Location: ________________

Test Period:

Date & time: ____________________

Specimen Damage:

____

____

____

Post test assessment:

____

____

Recorded by:	Date:
Witnessed by:	Date:
Regulatory reviewed by:	Date:
Q.A. reviewed by:	Date:

Penetration Test
10CRF71

Test Specimen:

Drawing No. ______________________ Rev. ______ Serial Number: ____________

Test weight ___________________________ Scale Used ____________________

Test Setup:

Set up per: 10CR71 (71.71(10)) penetration test procedure.

Pictures: ____________

Notes:

____

____

Drop surface:

Drawing No. ______________________ Rev. ______ Location: _______________

Test Period:

Date & time: ____________________

Specimen Damage:

____

____

____

Post test assessment:

____

____

Recorded by:	Date:
Witnessed by:	Date:

Horizontal Shock Test
ISO 3999-1

Test Specimen:

Drawing No. ____________________ Rev. _______ Serial Number: ______________

Test weight ________________________ Scale Used ____________________

Test Setup:

Set up per: ISO 3999-1 (6.4.6.1) horizontal shock test procedure.

Pictures: ______________

Notes:

____

____

Horizontal Test Bar:

Drawing No. ____________________ Rev. _______ Location: ____________________

Test Period:

Date & time: ________________________

Specimen Damage:

____

____

____

Post test assessment:

____

____

Recorded by:	Date:
Witnessed by:	Date:
Regulatory reviewed by:	Date:
Q.A. reviewed by:	Date:

Final Test Assessment

Test Specimen:

Serial Number(s): ____

Foot Control Button evaluation:

Spring (61lb.): ______________________________________
Spring (19lb.): ______________________________________
Stainless steel components: ______________________________
F.C.B.A. working condition after Horizontal shock. _______________

Foot Control Button Assembly evaluation:

Is the F.C.B.A. in working condition?

Comments:

Engineering Review by:	Date:
SME Review by:	Date:
Regulatory Review by:	Date:
Q.A. Review by:	Date:

Final Test Assessment

Test Specimen:

Serial Number(s): ______________________________

Lock Mount Assembly evaluation:

Aluminum housing: ______________________________
Stainless steel insert: ______________________________
Corbin lock: ______________________________
Lock Mount Assembly working condition after Horizontal shock. ________________

Lock Mount evaluation:

Is the lock mount assembly in working condition?

Comments:

____
____
____
____
____
____
____
____
____
____
____
____

Engineering Review by:	Date:
SME Review by:	Date:
Regulatory Review by:	Date:
Q.A. Review by:	Date:

10.0 Appendix: 10CFR71, ISO 3999-1, Technical Report #40, and F.C.B.A. Instruction Sheet.

Section 2.12.7 Appendix: Test Plan Report 74 (Feb 1998).

SENTINEL

	TEST PLAN NO. 74
TEST PLAN COVER SHEET	
TEST TITLE: Model 660 Hypothetical Accident Condition Tests	
PRODUCT MODEL: 660 (with stainless steel screws)	
ORIGINATED BY: S. Glomei	DATE: 17 DEC 1997
TEST PLAN REVIEW	
ENGINEERING APPROVAL: [signature]	DATE: 17 Dec 97
QUALITY ASSURANCE APPROVAL: [signature]	DATE: 17 Dec 97
REGULATORY AFFAIRS APPROVAL: C. Rongman	DATE: 17 Dec 97
COMMENTS:	
TEST RESULTS REVIEW	
ENGINEERING APPROVAL: [signature]	DATE: 18 Feb 98
QUALITY ASSURANCE APPROVAL: [signature] Changes - CMR [illegible] KNA	DATE: 17 Feb 98 18 Feb 98
REGULATORY AFFAIRS APPROVAL: C. Rongman	DATE: 18 Feb 98

Amersham QSA

Test Plan #74 Results

This document describes the results of package design tests conducted for Hypothetical Accident Conditions (10 CFR 71.73) by Amersham to determine whether Model 660 Series projectors meet NRC requirements for Type B(U) packages.

The Model 660 Series includes the following models: 660, 660A, 660B, 660E, 660AE, and 660BE. Reference Certificate of Compliance 9033.

The tests were conducted in accordance with Amersham Test Plan #74 (dated December 16, 1997). The test plan also covers the criteria stated in IAEA, Safety Series 6 (1985, as amended 1990).

The purpose of the plan was to evaluate the performance of the Model 660 Series projectors that incorporate a proposed design change in which stainless steel end-plate screws are used instead of carbon steel screws.

This document reports on the manufacturing and acceptance of the test specimens, execution of the tests, test inspections, and assessment of the units as to their conformity with the requirements of 10 CFR 71.

Section 1 Transport Package Overview

The Model 660 Series projector consists of a source tube enclosed in a depleted-uranium shield, an end-plate with a lock assembly, a second end-plate with a storage plug assembly, four steel connecting rods, a sheet metal shell and foam packing material (Figure 1).

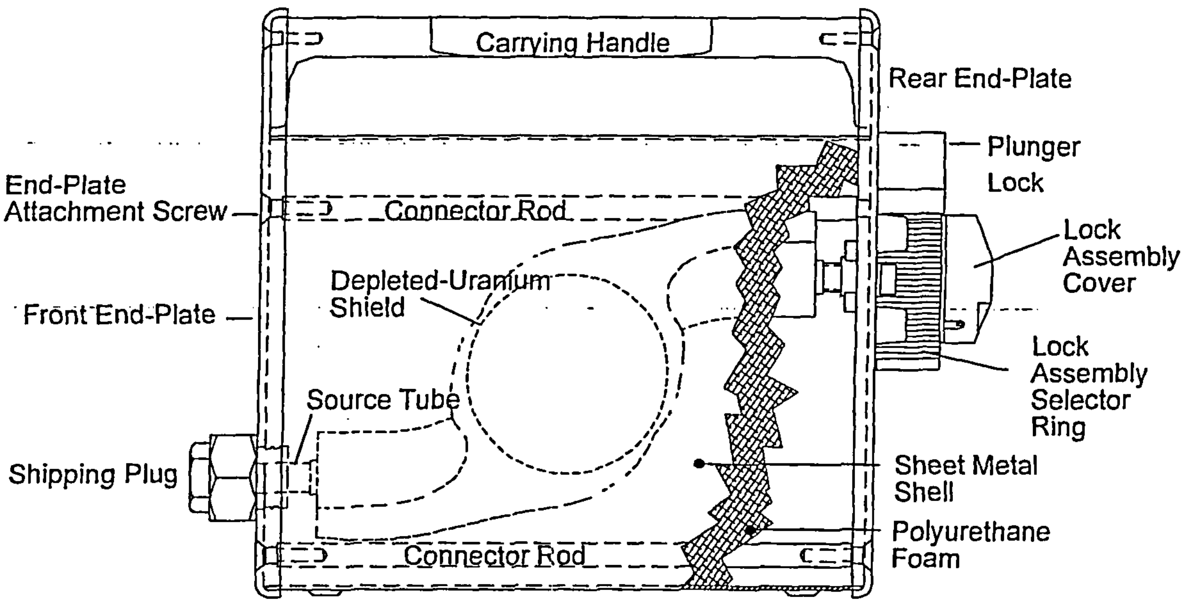


Figure 1: Side View of a Model 660 Series Projector

The shield consists of a 1/2-inch outside diameter source tube with its mid-section set in depleted uranium. One end of the source tube is inserted into a 1/2-inch hole in the lock assembly at the rear end-plate. The other end of the shield's source tube is inserted into another 1/2-inch hole in the shipping plug at the front end-plate. Both 1/2-inch holes allow enough radial clearance for a slip fitting attachment. There is approximately 1/8-inch axial clearance at the front end for assembly.

The source is contained in a special-form, encapsulated capsule assembly which is attached to the source wire assembly. This source wire assembly is secured in the package by the lock assembly. The lock assembly, in turn, is attached to the rear end-plate by four #10 stainless steel screws. There are two versions of the lock assembly used on the Model 660 series projectors. The size, material and location of the end-plate screws are identical on both versions.

The shield, end-plates and the sheet metal shell are connected by four 3/8-inch thick steel rods which are threaded at each end to accept 1/4-inch screws securing the end-plates to the rods.

A polyurethane foam is used to fill the space around the shield and to fill the void within the sheet metal shell. The foam acts as an impact absorber.

The depleted-uranium shield provides the primary radiation protection for the Model 660 Series projector. The shield accomplishes this by limiting the transmission of gamma rays to a dose level at or below 200 mR/hr at the package surface and limiting the dose level at or below 10 mR/hr at one meter from the surface of the package.

The location of the source relative to its stored position in the shield is also an important safety element. A large displacement of the source relative to its stored position could elevate the dose at the surface of the package above regulatory limits.

There are two possible scenarios to displace the source relative to its stored position:

- The shield could move away from the source if the source tubes were bent or fractured during testing.
- The source could move away from the shield if the lock assembly became loose or was removed from the end-plate or if the end-plates themselves became loose or were removed during testing.

The tests in this plan focused on damaging those components of the package which could cause the displacement of the source relative to its stored position within the shield.

Section 2 Test Specimen Production and Acceptance

The test units specified for this plan were seven test specimens manufactured for the Normal Transport Conditions testing under Test Plan #73.

The tests in Test Plan #74 were designed to further the damage inflicted on the units in Test Plan #73. The tests units were manufactured in the Amersham Burlington, Mass., facility in accordance with Amersham Drawing TP73, Rev. A.

As required in both test plans, the TP73 test units are standard Model 660B projectors with the following modifications:

- Shields weighing 37 to 39 pounds
- Supplemental lead added to the shield to increase shield assembly weight to 40 pounds
- Stainless steel screws used for end-plate fasteners instead of carbon steel screws
- End-plate screws with torque values set to either 10 in-lbs or 120 in-lbs

These modifications enabled us to produce test specimens that weighed at least 54 pounds, and to test the use of stainless steel end-plate screws as original equipment and as retrofit components.

Four test units (A, B, C and D) and three spares (S1, S2 and S3) were built according to the Drawing TP73, Rev. A. The units enabled us to test two different impact targets on units with end-plate screws set to different torque values (Table 1).

Table 1: TP73 Units

End-plate screw torque value	120 in-lbs (±10 in-lbs)	10 in-lbs (±2 in-lbs)
Impact bottom edge of rear plate	Specimens A, S1 and S3	Specimens C and S2
Impact top edge of front plate	Specimen B	Specimen D

The test specimens were manufactured in accordance with the Amersham Quality Assurance Program. The program provides for documentation of the manufacturing process, assures that the units comply with the relevant drawings and manufacturing instructions, and specifies radiological profiling of the completed product. Table 2 summarizes key manufacturing and profiling data.

Table 2: Test Specimen Manufacturing Data

Specimen	A	B	C	D	S1	S2	S3
Completion Date	12/16/97	12/16/97	12/16/97	12/16/97	12/16/97	12/16/97	1/6/98
Total Weight	55.1 lbs	54.9 lbs	55.3 lbs	54.9 lbs	54.8 lbs	55.1 lbs	55.3 lbs
Profile Data, Maximum Readings							
Package Surface (mR/hr)	142.5	142.5	133.0	133.0	152.0	152.0	147.0
At One Meter (mR/hr)	1.6	1.7	1.5	1.3	1.5	1.6	1.6

At the conclusion of Test Plan #73, representatives from Engineering, Quality Assurance and Regulatory Affairs reviewed test inspections and damage assessments on the test specimens. The assessment included radiation profiles on Specimens A, B, C, and D in accordance with Amersham Work Instruction Q09. The radiation profile worksheets are included in Appendix A. The maximum readings for each specimen are shown in Table 3. These readings, which are corrected for maximum capacity, demonstrate that the units met the requirements of 10 CFR 71.71 for normal conditions of transport.

Specimens S1, S2 and S3 were not subjected to Test Plan #73 testing until they were required as spares in Test Plan #74. The units were not profiled at the conclusion of the Normal Transport Conditions tests, as the purpose of the testing was to qualify the units for use in Test Plan #74 and profiling of A, B, C and D had already demonstrated conformity with 10 CFR 71.71 for all orientations.

Table 3: Maximum Readings from Test Plan #73 Final Test Inspection

Specimen	A	B	C	D	S1	S2	S3
Package Surface (mR/hr)	139.0	174.0	188.0	188.0	N/A	N/A	N/A
At One Meter (mR/hr)	1.4	1.2	1.5	1.3	N/A	N/A	N/A

Representatives from Engineering, Quality Assurance and Regulatory Affairs jointly confirmed that:

- The seven units selected for Test Plan #74 were adequately tested under Test Plan #73.
- There were no changes to the units since the final test inspections and assessments performed under Test Plan #73.
- No changes in orientation were required for the hypothetical accident conditions tests in Test Plan #74 because of damage sustained in Test Plan #73 testing.

Section 3 Hypothetical Accident Conditions

The TP73 test units underwent Hypothetical Accident Conditions tests in December 1997 and January 1998.

The testing demonstrated that the stainless steel end-plate screws maintained the end-plate connection throughout the tests. However, Specimen A had unacceptable radiation profile measurements after the thermal tests. Based on the data available, it is inconclusive whether the specimen failed because of a design flaw or because of damage incurred during handling and shipment.

This section describes the execution of the tests, results and the assessments made by representatives from Engineering, Regulatory Affairs and Quality Assurance.

3.1 Test Execution

The following Hypothetical Accident Conditions tests were conducted to meet the requirements of 10 CFR 71.73 and Test Plan #74:

- 30-foot free drop
- Puncture test
- Thermal test

Table 4 summarizes information about execution of the tests. In the table, package orientation is described as:

BRE where the impact surface is the bottom edge of the rear end-plate

TFE where the impact surface is the top edge of the front end-plate

NTP for normal transport position, that is, resting on the bottom

Table 4: Hypothetical Accident Conditions Tests (10 CFR 71.73)

Specimen	A	B	C	D	S1	S2	S3
30-foot Free Drop (Valley Tree, Groveland, Mass.)							
Test Date	12/23/97	12/24/97	12/23/97	12/24/97	1/8/98	12/24/97	1/11/98
Attempts	One	One	One	Two	One	One	Two
Orientation	BRE	TFE	BRE	TFE	BRE	BRE	BRE
Comments	Good hit	Good hit	Missed hit Replaced by S2	1st hit on right side; 2nd hit good	Missed hit Replaced by S3	Good hit	1st hit toward base; 2nd toward lock

Table 4: Hypothetical Accident Conditions Tests (10 CFR 71.73) (Continued)

Specimen	A	B	C	D	S1	S2	S3
Puncture Test (Valley Tree, Groveland, Mass)							
Test Date	12/23/97	12/23/97	Not Tested	12/24/97	Not Tested	12/24/97	1/11/98
Attempts	One	One		One		One	One
Orientation	BRE	TFE	BRE	TFE	BRE	BRE	BRE
Thermal Test (Manufacturing Science, Oak Ridge, Tenn.)							
Test Date	12/30/97	Not Tested	See Note1	12/30/97	Not Tested	12/30/97	1/13/98
Orientation	NTP			NTP		NTP	NTP

Note 1: Specimen C was subjected to the thermal test only to provide information to help in evaluating other specimens.

Testing began on December 23, 1997, with the four units that were used in the first round of Test Plan #73 testing. In the 30-foot free drop, Specimen C missed its intended impact surface, and was replaced by Specimen S2. S2 underwent normal testing under Test Plan #73 and on December 24, 1997, began testing under Test Plan #74.

The puncture test orientation for Specimens B and D was changed after the 30-foot drop to impact the top edge of the front end-plate to induce more damage, specifically to peel back the area of the end-plate left by the removed handle.

Specimen B did not undergo the thermal test because it was not as damaged as the other units. Specifically, there was no opening between the end-plate and the package, and therefore, it would sustain less damage from thermal testing.

Specimens A, D and S2 underwent thermal testing on December 30, 1997. The units were positioned in the normal transport position, that is, upright and resting on the bottom, to allow optimal airflow in and around the open gap created by damage to the shell and end-plates.

The units were shipped to Amersham's Burlington, Mass., facility on January 2, 1998, for radiographs and profiling. Amersham personnel were not on site in Oak Ridge to supervise the packaging and shipment of the test units.

The radiographs after the thermal tests showed displacement of the shield relative to the positions shown in radiographs taken after the puncture tests. In all three cases, a significant portion of the displacement was on the horizontal plane, indicating that the movement may have been caused during handling or shipment from Oak Ridge to Burlington. The thermal test orientation for these specimens would not have caused movement in the horizontal plane.

Profile results of Specimen A showed 9.3 R/hr at one meter. The other units (Specimens B and D) were within acceptable levels. To determine whether handling during transport caused the failure of Specimen A, we prepared Specimen S1 for testing and planned to measure the source position after the thermal test and before shipment.

In the 30-foot free drop, Specimen S1 missed its impact surface, creating the need for another substitution. A new unit, Specimen S3, was built and subjected to testing under Test Plan #73. The new unit underwent the 30-foot free drop and puncture test on January 11 and the thermal test on January 13.

The Specimen S3 was radiographed on site to determine source location before shipment and then radiographed upon receipt in Burlington. Comparison of the two radiographs showed no significant movement of the source. Subsequently the unit passed the radiation profile.

3.2 Damage Inspections

The test units incurred levels of mechanical damage as a result of the 30-foot free drop that were seen in previous testing:

- The rear end-plates were bowed on Specimens A, S2 and S3, producing a 3/16-inch (maximum) gap between the shell and end-plate.
- The tops of both end-plates were bent on Specimens B and D. No gap was produced on B; there was a 1/2-inch (maximum) gap on D.
- End-plate corners were crushed on Specimens S1 and C when these units missed their target impact surfaces. Both units were replaced.

In addition, the handle of Specimen B broke.

No additional mechanical damage to the tested units was evident as a result of the puncture test.

All of the stainless steel end-plate screws, including those set to 10 in-lb torque values, held the end-plates to the connecting rods, and there was no breakage.

Inspection of the units, including radiographs, showed that they maintained their structural integrity throughout the 30-foot drop and puncture test, that is, the source remained in the secured and shielded position and the end-plate screws held.

Four units were subjected to the thermal test: A, D, S2 and S3. As expected, the handle melted on each of the four units, and all or some of the foam burned off. There was no substantial oxidation of the shields as occurred in Test Plan #70. The end-plate-screws held the end-plates to the package throughout the testing and did not allow for increased airflow around the shield.

3.3 Test Assessment

The primary area of interest was the performance of the stainless steel end-plate screws. The test proved that the design change resolves the problem of shield performance caused by oxidation as occurred in Test Plan #70 and reported in the Test Plan #70 Test Results. In Test Plan #70, the oxidation occurred when the end-plate was not fully secured because of the breaks in the carbon steel end-plate screws.

Appendix A includes the worksheets for the radiation profiles taken as part of the final test inspection. Table 5 shows the maximum radiation measured in these profiles. The readings have been corrected for maximum capacity.

Table 5: Maximum Readings from Test Plan #74 Final Test Inspection

Specimen	A	B	C	D	S1	S2	S3
Profile date	1/5/98	1/5/98	Not profiled	1/7/98	Not profiled	Not profiled	1/19/98
Package Surface (mR/hr)	3000	390		281			1862
At One Meter (mR/hr)	9300	2.7		4.7			9.3

The evaluation of Specimen A and the subsequent testing of Specimen S3 did not resolve whether the movement of the source from its ideal shielded position was the result of a design flaw or the result of damage caused in handling and transport of the package. We were unable to exactly replicate the mechanical damage to Specimen A.

The measurement after the S3 thermal test showed that the source had moved only 0.2 inch, which resulted in acceptable levels of radiation. Test inspection revealed that the source wire had severed. The Specimen A source wire did not break and remained engaged in the lock assembly when the shield moved, pulling the source from the center of the shield which provides maximum shielding.

Although Specimen S3 satisfactorily met all of the test requirements, the damage was not identical to to Specimen A, and therefore, it could not be used as a replacement for Specimen A.

No conclusion can be drawn as to whether the Specimen A failed because of transport damage.

3.4 Conclusions

Based on the testing performed under Test Plan #74, the team concluded that:

- The stainless steel end-plate screws satisfactorily met all of the test requirements and the screws should be used on all Model 660 Series projectors.
- The torque value of the screws is not a significant factor in their performance and retrofitting of projectors with new screws can be accomplished in the field.
- Because of the difficulty of replicating specific mechanical damage, continued testing of TP73 units will probably not resolve the question of whether Specimen A failed because of design or damage from handling.
- Amersham should proceed with design evaluation *as if* Specimen A had failed because of its design, and examine design changes that would restrict shield movement during thermal testing.

Appendix A: Radiation Profile Worksheets

SENTINEL

660/660B DEVICE PROFILING FORM

B3587 (LMA) 12 Jan 98

Device Model No.: 660B   Device Serial No.: TP73"A" After Thermal

Model ~~424-9~~ T10163 Source Serial Number: X0016   Activity: 93.2 Ci

~~Surface~~ <500 mR/hr Survey Instrument: AN/PDR 27T   Serial No: SM-392401   Cal Due: 3/18/98

~~One Meter~~ ≥ 500 mR/hr Survey Instrument: Tech-50   Serial No: B-814-S   Cal Due: 7/22/98

Capacity Corr. Factor 1.5

SURFACE READINGS mR/hr	Extrapolated ~~Allowed~~ for Capacity only	Actual	ONE METER READINGS mR/hr	Extrapolated ~~Allowed~~	Actual
TOP	780	520*	TOP		
RIGHT	3 R/hr	2 R/hr*	RIGHT		
FRONT	40.5	27	FRONT	1.4	0.9
LEFT	3 R/hr	2 R/hr*	LEFT		
REAR	3 R/hr	2 R/hr*	REAR	9.3 R/hr	6.2 R/hr*
BOTTOM	1.8 R/hr	1.2 R/hr*	BOTTOM	18	12.0

>1 R/hr. No addl measurements taken on device.

INSPECTOR: [signature]   DATE: 5 Jan 98   NCR No.: ______

Comments:

- No surface corrections made. Actual surface enclosed in plastic bagging which varied in thickness from 1/2 - 1".

- Surface doses for general info only. Primary purpose of profile was for 1 meter readings. Surface levels on sides and rear may be higher than recorded. Radiation was a finely collimated beam from S-tube out the rear of the device which was difficult to quantify precisely without receiving

) 12 Jan 98

Amersham QSA

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SENTINEL

660/660B DEVICE PROFILING FORM

B3588 (KNA) 12 Jan 98

Device Model No.: 660B Device Serial No.: ~~After Thermal~~ TP73 "B" After 30 Ft & Puncture LP 5 Jan

Model ~~424-9~~ TI0163 Source Serial Number: X0016 Activity: 93.2C

Surface Survey Instrument: AN/PDR 27T Serial No: 5M-392401 Cal Due: 3/18/98

One Meter Survey Instrument: Same Serial No: – Cal Due: –

* Non-leaded plug used during profile.

Capacity Corr. factor 1.50

SURFACE READINGS mR/hr	Surf Corr. fact	Extrapolated (~~Allowed~~)	Actual
TOP	1.16	104.4	60
RIGHT	1.28	153.6	80
FRONT	1.13	389.9	230
LEFT	1.28	115.2	60
REAR	1.13	152.6	90
BOTTOM	1.19	107.1	60

ONE METER READINGS mR/hr	Extrapolate (~~Allowed~~)	Actual
TOP	1.0	0.7
RIGHT	0.9	0.6
FRONT	2.7	1.8
LEFT	0.75	0.5
REAR	1.5	1.0
BOTTOM	0.9	0.6

INSPECTOR: L. Pedrola DATE: 5 Jan 98 NCR No.: ______

Comments:

(KNA) 12 Jan 98

Amersham QSA

WI-Q05

SENTINEL

660/660B DEVICE PROFILING FORM

-B3590 (KNA) 12 Jan 98

Device Model No.: 660B   Device Serial No.: TP73 "D" After Thermal

Model ~~424-9~~ T10163 Source Serial Number: X0016   Activity: 89.7 Ci

Surface Survey Instrument: Bicron Tech-56   Serial No: B-814-5   Cal Due: 7/22/98

One Meter Survey Instrument: Same   Serial No: –   Cal Due: –

Capacity Corr. Factor

1.56

SURFACE READINGS mR/hr

	~~Allowed~~	Actual
TOP		130
RIGHT		180
FRONT		80
LEFT		50
REAR		90
BOTTOM		50

ONE METER READINGS mR/hr

	Extrapolated ~~Allowed~~	Actual
TOP	2.3	1.5
RIGHT	1.9	1.2
FRONT	2.7	1.7
LEFT	2.2	1.4
REAR	4.7	3.0
BOTTOM	1.7	1.1

INSPECTOR: [signature]   DATE: 9 Jan 98   NCR No.: ____

Comments:

* Surface of unit enclosed in multiple layers of plastic bags for contamination control of uranium oxide. Thickness varies from 1/4" to 1".

* Surface readings taken for exposure control and general information purposes only.

(KNA) 12 Jan 98

Amersham QSA

WI-Q05

SENTINEL

660/660B DEVICE PROFILING FORM

TP74 + TP73 "S3"

Serial# B3586 (KMA) 21 Jan 98

Device Model No.: 660B Device Serial No.: After Thermal

Model ~~424-9~~ TI0163 Source Serial Number: X0017 Activity: 105.c Ci

Surface Survey Instrument: AN/PDR-27T Serial No: SM-392401 Cal Due: 18 Mar 98

One Meter Survey Instrument: AN/PDR-27T Serial No: SM-392401 Cal Due: 18 Mar 98

Capacity Corr. Factor
1,33

	SURFACE READINGS mR/hr			ONE METER READINGS mR/hr	
	~~Allowed~~	Actual		Extrapolated ~~Allowed~~	Actual
TOP		70 mR/hr	TOP	1.9	1.4 mR/hr
RIGHT		80 mR/hr	RIGHT	1.5	1.1 mR/hr
FRONT		940 mR/hr Δ	FRONT	5.6	4.2 mR/hr
LEFT		110 mR/hr	LEFT	1.3	1.0 mR/hr
REAR		1400 mR/hr Δ	REAR	9.3	7.0 mR/hr
BOTTOM		130 mR/hr	BOTTOM	1.6	1.2 mR/hr

INSPECTOR: [signature] DATE: 19 Jan 98 NCR No.: NA

Comments:

* Surface readings taken for exposure control and general information purposes only

Δ Measurements taken with Model # ND 3000, S/N 9837 (Next cal date 23 Sept 98) [initials] 19 Jan 98

Amersham QSA

WI-Q05

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List of Figures and Tables

Amersham Test Plan #74

This document describes additional package design testing for Sentinel Model 660 Series projectors to meet NRC requirements for Type B(U) packages under Hypothetical Accident Conditions (10 CFR 71.73). Testing under Normal Transport Conditions (10 CFR 71.71) is described in Amersham Test Plan #73.

The test plan also covers the criteria stated in IAEA, Safety Series 6 (1985, as amended 1990). Quality Assurance will be involved in all aspects of this test plan and its execution.

The Model 660 Series includes the following models: 660, 660A, 660B, 660E, 660AE, and 660BE. Reference Certificate of Compliance 9033.

The tests in this plan evaluate a Model 660 Series design change that resulted from tests performed under Amersham Test Plan #70. In that testing, the 30-foot free drop caused failure of the end-plate screws on Specimen D, and subsequent oxidation and loss of the shield during the thermal test. The design change involves the use of stainless steel end-plate screws instead of the carbon steel screws used in the Test Plan #70 specimens.

We are specifying Military Standard screws, MS 51959-81 (1/4-20 x 3/4" long). The specification is included in Appendix B: Selected Fasteners. The tensile strength of these screws is twice that of the nominal strength of the carbon steel screws (110,000 psi versus 55,000 psi). In addition, at room temperature, the toughness of stainless steel is 40% greater than that of carbon steel; at -40° C, the stainless steel's toughness is four times greater than carbon steel's. Refer to the toughness versus temperature curve in Appendix B: Selected Fasteners.

As noted in the failure analysis by Packaging Technology, Inc. (November 25, 1997), the Specimen D shield experienced a deceleration of 200g in the 30-foot free drop in Test Plan #70. If the two end-plate screws closest to the lock assembly experience the full extent of the shield deceleration load, the tensile stress induced in these screws is calculated as follows:

$$\begin{aligned}\text{stress} &= \text{(shield mass) (impact deceleration) / tensile area}\\ &= \text{(40 lbs) (200g x cos 39°) / (2 x 0.0318 in}^2\text{)}\\ &= \text{97,800 psi}\end{aligned}$$

The induced stress is less than the ultimate strength of the two stainless steel screws (110,000 psi).

This document outlines the testing scenario, justifies the package orientations, and provides test worksheets to record key steps in the testing sequence.

1.0 Current Transport Package Overview

The Model 660 Series projector consists of a source tube enclosed in a depleted-uranium shield, an end plate with a lock assembly, a second end plate with a storage-plug assembly, four steel connecting rods, a sheet metal shell and foam packing material (Figure 1).

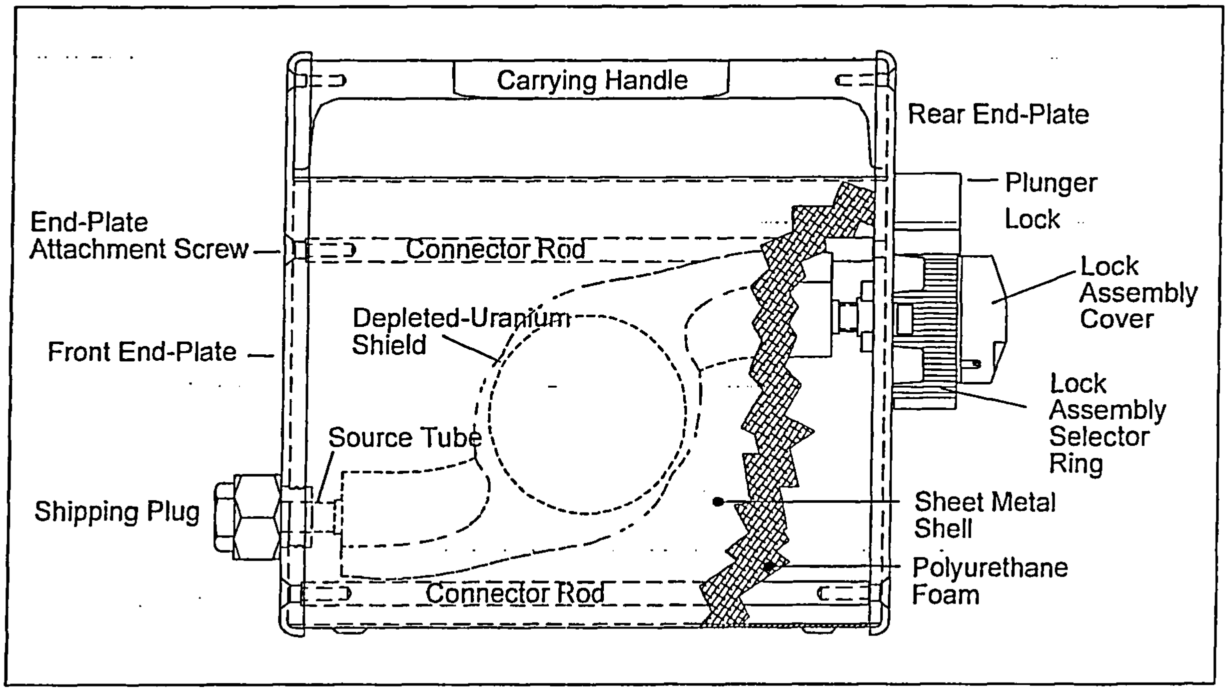


Figure 1: Side View of a Model 660 Series Projector

The shield consists of a 1/2-inch outside diameter source tube with its mid-section set in depleted uranium. One end of the source tube is inserted into a 1/2-inch hole in the lock assembly at the rear end-plate. The other end of the shield's source tube is inserted into another 1/2-inch hole in the shipping plug at the front end-plate. Both 1/2-inch holes allow enough radial clearance for a slip fitting attachment. There is approximately 1/8-inch axial clearance at the front end for assembly.

The source is contained in a special-form, encapsulated capsule assembly which is attached to the source wire assembly. This source wire assembly is secured in the package by the lock assembly. The lock assembly, in turn, is attached to the rear end-plate by four #10 stainless steel screws. There are two versions of the lock assembly used on the Model 660 series projectors. The size, material and location of the end-plate screws are identical on both versions.

The shield, end plates and the sheet metal shell are connected by four 3/8-inch thick steel rods which are threaded at each end to accept 1/4-inch screws securing the end plates to the rods.

A polyurethane foam is used to fill the space around the shield and fill void within the sheet metal shell. The foam acts as an impact absorber.

The depleted-uranium shield provides the primary radiation protection for the Model 660 Series projector. The shield accomplishes this by limiting the transmission of gamma rays to a dose level at or below 200 mR/hr at the package surface and limiting the dose level at or below 10 mR/hr at one meter from the surface of the package. A fracture of the shield could compromise this protection.

The location of the source relative to its stored position in the shield is also an important safety element. A large displacement of the source relative to its stored position could elevate the dose at the surface of the package above regulatory limits.

There are two possible scenarios to displace the source relative to its stored position:

- The shield could move away from the source if the source tubes were bent or fractured during testing.
- The source could move away from the shield if the lock assembly became loose or was removed from the end plate or if the end plates themselves became loose or were removed during testing.

The tests in this plan focus on damaging those components of the package which could cause the displacement of the source relative to its stored position within the shield and which affect the integrity of the shield itself.

2.0 Purpose

The purpose of this plan, which was developed in accordance with Amersham SOP-E005, is to test and evaluate modifications to the Model 660 Series projectors so that the Type B transport package requirements of 10 CFR 71 are met.

The series includes these models: 660, 660A, 660B, 660E, 660AE, and 660BE. Refer to Appendix A for descriptive drawings of these models.

The Normal Transport Conditions tests (10 CFR 71.71) have been performed on the test specimens as part of Amersham Test Plan #73. These tests included the compression test, penetration test and four-foot free drop.

The Hypothetical Accident Conditions tests (10 CFR 71.73) to be performed are the 30-foot free drop, puncture test, and thermal test.

The crush test (10 CFR 71.73(c)(2)) is not performed because the radioactive contents are special-form radioactive material.

The immersion test and all other conditions specified in 10 CFR 71 will be separately evaluated in accordance with Amersham Work Instruction WI-E08.

3.0 System Failure of Interest

The possible system failure tested in this plan is the failure of the end-plate screws. Failure of the end-plate screws on either plate could cause exposure of the shield to damage during the thermal test, especially if the foam burns.

Two package orientations are specified in this plan:

- Specimen D orientation in Test Plan #70, the orientation that caused the end-plate screw failure.
- Inversion of the Test Plan #70 Specimen D orientation. The impact surface is the top edge of the front plate.

Other orientations that were considered but rejected include:

- End plate sides. Because these surfaces are curved, they provide very small impact surfaces compared to the top or bottom edge of either plate.
- Top edge of the rear plate. The load on the screws provided by this orientation would be less than the load created by the orientation for Specimens B and D.

Figure 2 through Figure 5 show the four possible orientations to impact either the top or the bottom edge of an end-plate. With each figure is a calculation of the loading on the screws of interest. The calculations assume that the end plate is attached only at point a.

For sake of illustration, the calculations use 56 pounds for the vertical force. In the calculations:

f_x is the component force loading parallel with the axis of the screws.

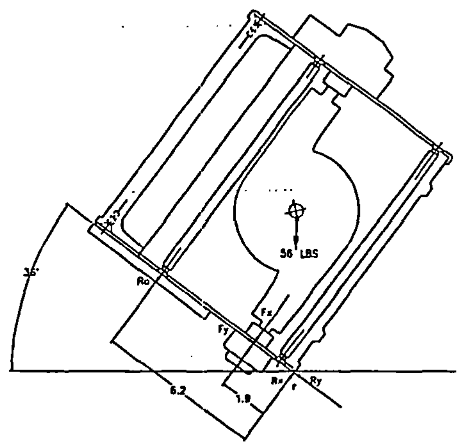
f_y is the component force loading perpendicular to the axis of the screws.

Summing the moments around the impact point (r) and equating it to zero determines the resultant force at the point of the screws (a).

Figures 3 and 4 demonstrate the worst-case loading on the end-plate screws of interests. These are the orientations selected for this test plan.

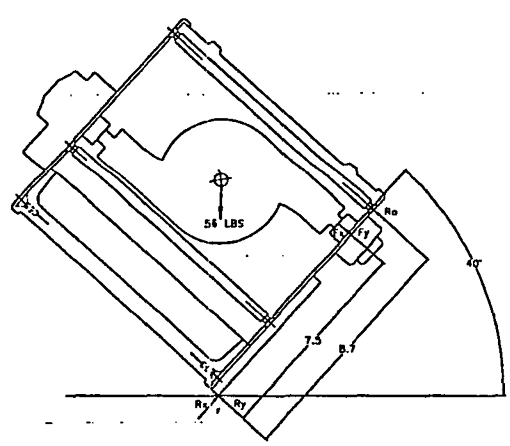
Two units are to be tested with each orientation, one with the end-plate screws torqued to 120 in-lbs (±10 in-lbs), the other with the end-plate screws tightened to 10 in-lbs (±2 in-lbs).

The orientations in this test plan are designed to further the damage to the end-plate screws caused during the execution of Test Plan #73.



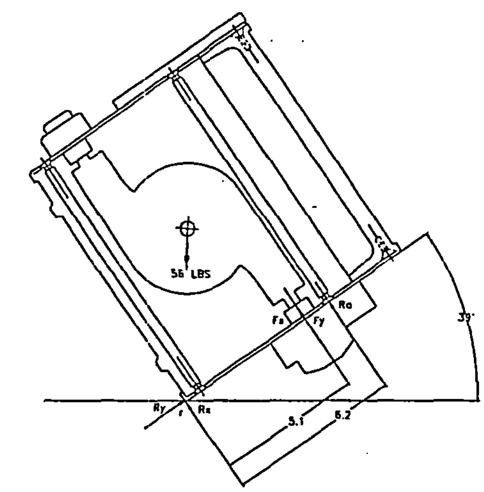
Fx = 56 COS (36°) = 45 LBS
Fy = 56 SIN (36°) = 33 LBS
Mr = 0 = (1.9)*(45) − (6.2)*(Ro) = 0
Ro = 13.8 LBS
IMPACT ON BOTTOM FRONT EDGE

Figure 2: Impact on Bottom Edge of Front End Plate



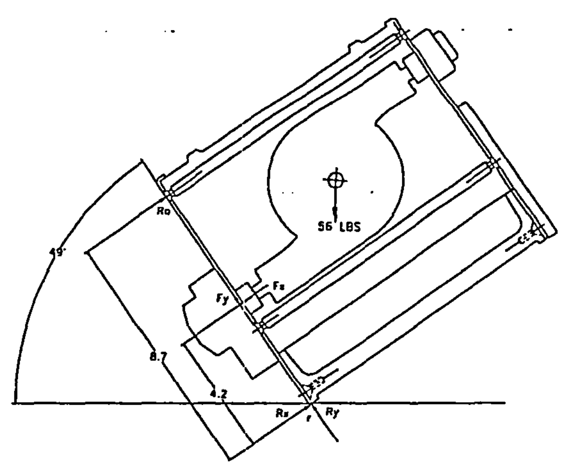
Fx = 56 COS (40°) = 43 LBS
Fy = 56 SIN (40°) = 36 LBS
Mr = 0 = (7.5)*(43) − (8.7)*(Ro) = 0
Ro = 37.1 LBS
IMPACT ON TOP FRONT EDGE
(ORIENTATION B&D)

Figure 3: Impact on Top Edge of the Front Plate



Fx = 56 COS (39°) = 44 LBS
Fy = 56 SIN (39°) = 35 LBS
Mr = 0 = (5.1)*(44) − (6.2)*(Ro) = 0
Ro = 36.2 LBS
IMPACT ON BOTTOM REAR EDGE
(ORIENTATION A&C)

Figure 4: Impact on Bottom Edge of Rear Plate



Fx = 56 COS (49°) = 37 LBS
Fy = 56 SIN (49°) = 42 LBS
Mr = 0 = (4.2)*(37) − (8.7)*(Ro) = 0
Ro = 17.9 LBS
IMPACT ON TOP REAR EDGE

Figure 5: Impact on Top Edge of the Rear Plate

4.0 Construction and Condition of Test Specimens

The test specimens will be the Model 660B units built for the Normal Transport Conditions tests in Test Plan #73. These units were constructed in accordance with Amersham Drawing TP73, Rev. A (Drawing TP73). With the exception of the stainless steel end-plate screws, the units specified in Drawing TP73 are in accordance with the NRC-approved design.

Drawing TP73, specifies the Model 660 Series in its worst-case transport condition, that is, with supplemental lead added to the shield. The added weight induces higher loads during dynamic testing.

For the 30-foot free drop and the puncture tests, the test temperature of specimen must be at or below -40° C at the time of each test, a minimum temperature required by IAEA, Safety Series 6 (1985, as amended 1990). The low temperature represents the worst-case condition for the package because of the potential for reduction in strength of the end-plate screws.

Four test units and two spares were built according to the Drawing TP73 and the Amersham Quality Assurance Program:

End-plate screw torque value	120 in-lbs (±10 in-lbs)	10 in-lbs (±2 in-lbs)
Impact bottom edge of rear plate	Specimen A	Specimen C
Impact top edge of front plate	Specimen B	Specimen D
Spare unit	Specimen S1	Specimen S2

- The tests for Specimens A and C attack the end-plate screws by targeting the bottom edge of the rear end-plate.
- The tests for Specimens B and D attack the top edge of the front plate.

The package orientations specified in this plan are designed to further the damage inflicted on the TP73 test units in testing under Normal Transport Conditions.

NOTE: *Because each test is designed to add to damage inflicted on a specific component or assembly in the preceding test, it is important that each specimen maintain its identity throughout the battery of tests and that the setup instructions specific to the specimen are strictly followed.*

Table 1 lists the differences between the test specimens and other 660 Series models.

Table 1: Model 660 Series Variations

Feature	Test Specimen per Drawing TP73	660 Series Models
Shell Material	Stainless steel	Models 660AE, 660BE and 660E have wires and connectors attached to ends plates for automatic actuation. Models 660, 660A and 660B do not have actuator wires and connectors.
Lock Assembly	Posilok™	The Model 660 and 660E use a non Posilok lock assembly. All other models feature the Posilok lock assembly.
Actuator Wires and Connectors	No actuator wires and connectors	Models 660AE, 660BE and 660E have wires and connectors attached to ends plates for automatic actuation. Models 660, 660A and 660B do not have actuator wires and connectors.
Shield Capacity	140 Curie	The following models have 120-Curie capacity shields: 660, 660A, 660AE and 660E. The following models have 140-Curie capacity shields: 660B and 660BE.
Body Width	Standard width (5 1/4 inches)	Some Model 660s and Model 660Es have a narrow-body design (4 3/4 inches wide). All other models only use the standard-width body (5 1/4 inches).
Source Tube Material	Titanium	Prior to 1980, the Models 660, 660A, 660AE and 660E were manufactured with zircaloy source tubes. All other units have titanium source tubes.
Use of Lead	Supplemental lead added	Prior to June 1992, some units in the Model 660 Series had lead added to supplement the shielding. The maximum amount of lead added was three pounds. The amount was also limited by a maximum shield weight of 40 pounds and a maximum package weight of 56 pounds.
Weight	54 pounds minimum	Over the last five years, the average package weight has been approximately 50 pounds. Earlier in the product history, the average weight was approximately 53 pounds.
End-plate fasteners	Stainless steel screws MS 51959-81	Standard Model 660 Series projectors have commercial carbon steel end-plate screws.

Table 1: Model 660 Series Variations (Continued)

Feature	Test Specimen per Drawing TP73	660 Series Models
End-plate screw torque value	Specimens A, B and S1 end-plate screws tightened to 120 in-lbs (±10 in-lbs) Specimens C, D and S2 end-plate screws tightened to 10 in-lbs (±2 in-lbs)	Carbon steel screws used in the standard Model 660 Series projectors are torqued to 80 in-lbs (±10 in-lbs)

The differences listed in Table 1 impact the testing or are made for the following reasons:

- **Shell Materials:** The shell thickness is 1/16-inch for the carbon steel and stainless steel versions. The likelihood of a crack or brittle flaw increases with the thickness of the section and is a problem in sections greater than 1/8-inch. Additionally, the temperature for transition from ductile to brittle failure is lower for the thinner sections. The thicker carbon steel end plates will reach the ductile-to-brittle transition temperature long before the shell does. The end plates are structural members, while the shell is not structurally significant.
- **Lock Style:** Damage to the Posilok lock assembly used on the test specimen would represent damage to any Model 660 Series lock assembly, including the non Posilok style assemblies used on the Model 660 and the Model 660E.

  The internal components of both lock assemblies are protected by the same lock assembly cover and practically the same selector ring. The cover and selector ring must be significantly damaged before an impact can disrupt the internal components' securement of the source. Because of the strength of the cover and the selector ring, damage to the source securement is more likely to occur from the failure of the lock assembly screws. All models use the same type and size screws in the same locations.
- **Actuator Wires and Connectors:** The additional parts used for automatic actuation provide no structural support.
- **Shield Capacity:** The lower-capacity shields are either lighter than or the same weight as the shield used on the Model 660B, making the 660B the worst case for shield failures of interest in these tests.
- **Body Width:** The end plates and shells of the narrow-body versions of the Model 660 and the Model 660E would provide smaller impact surfaces than the standard-width plates and shell used in the test specimen. The smaller impact surfaces would result in greater surface deformation and less deceleration on impact. As a result there would be less transfer of impact forces that could affect the integrity of the source securement.

- **Source Tube Material:** The Model 660 Series projectors have been manufactured with titanium source tubes exclusively since 1980. Because this represents our current manufacturing methods and because the majority of Model 660 Series units currently in use have titanium source tubes, the test specimens will be manufactured with titanium source tubes. Based on an evaluation of the damage caused by the tests, we will assess the implications for previously fabricated packages which utilized zircaloy.

  Note that although listed on the descriptive drawings, stainless steel source tubes have never been used in the fabrication of Model 660 Series units, nor do we intend to use them in future fabrication.

- **Supplemental Lead:** Prior to June 1992, supplemental lead was used in the production of Model 660 Series projectors with the depleted-uranium shield. Although the addition of supplemental lead is no longer a production technique, the test specimens will be fabricated with the supplemental lead to ensure the maximum device mass.

- **Package Weight:** Because of more efficient casting and the elimination of supplemental lead shielding, the average weight of Model 660 units produced in the last five years is three pounds less than the average weight for units produced in the early years of the series history. Two steps will be taken to build test specimens that will weigh at least 54 pounds:

  - Heavier depleted-uranium shields will be fabricated.
  - Supplemental lead will be added to the shield.

  The TP73 will be consistent with current manufacturing procedures and will represent the heavier units in the Model 660 population. Ninety-seven percent of all 660 units produced weigh 54 pounds or less.

- **End-plate screws:** Stainless steel end-plate screws are being used on the TP73 to test the ability of these fasteners to prevent the failure of the end-plate screws seen in TP70 Specimen D.

- **End-plate screw torque values:** The greater strength of the selected stainless steel end-plate screws allows tightening to a higher torque value than the carbon steel screws. The higher value is being tested with Specimens A and B to evaluate a new manufacturing standard. A low torque value is being tested with Specimens C and D to simulate an untorqued assembly.

5.0 Material and Equipment List

The test worksheets in Section 7.0 list the key materials and equipment specified in 10 CFR 71 and the necessary measurement instruments.

When video recording is specified in the following tests, select video cameras with the highest shutter speed practical to record testing.

Additional materials and equipment may be used to facilitate the tests.

6.0 Test Procedure

Four units are tested in parallel with the same sequence but with two different package orientations that test the use of stainless steel end-plate screws, as described in Section 3.0. The tests have the following sequence:

1. Test specimen preparation and inspection
2. 30-foot free drop (10 CFR 71.73(c)(1))
3. Puncture test (10 CFR 71.73(c)(3))
4. Intermediate test inspection
5. Thermal test (10 CFR 71.73(c)(4))
6. Final test inspection

6.1 Roles and Responsibilities

The responsibilities of the groups identified in this plan are:

- Engineering executes the tests according to the test plan and summarizes the test results. Engineering also provides technical input to assist Regulatory Affairs and Quality Assurance as needed.
- Regulatory Affairs monitors the tests and reviews test reports for compliance with regulatory requirements.
- Quality Assurance oversees test execution and test report generation to ensure compliance with 10 CFR 71, other regulatory requirements and the Amersham Quality Assurance Program.
- Engineering, Regulatory Affairs and Quality Assurance are jointly responsible for assessing test and specimen conditions relative to 10 CFR 71.
- Quality Control, a function that reports directly to Quality Assurance, is responsible for measuring and recording test and specimen data throughout the test cycle.
- The managers directly responsible for Engineering, Regulatory Affairs and Quality Assurance will identify and document personnel who are qualified to represent their departments in carrying out this test plan.

6.2 Test Specimen Preparation and Inspection

To prepare the test units:

1. Select the units tested under Amersham Test Plan #73.
2. Inspect the test units to ensure that they match the units described on the Test Plan #73 worksheets and attached damage assessments.
3. Confirm that a radiation profile was performed and recorded in accordance with Amersham Work Instruction WI-Q09 at the conclusion of Test Plan #70.
4. Measure and record the weight of each test specimen.
5. Prepare the packages for transport.

6.3 30-foot Free Drop Test (10 CFR 71.73(c)(1))

The first Hypothetical Accident Conditions test is the 30-foot free drop as described in 10 CFR 71.73(c)(1). This drop compounds any damage caused in the three Normal Transport Conditions tests in Test Plan #73.

Use *Checklist 1: 30-foot Free Drop* on page 27 to ensure that the test sequence is followed. Date and initial all action items, and record required data on the worksheet.

Figure 6 illustrates the orientation for Specimens A and C. Figure 7 shows the orientation for Specimen B and D. The orientations are the same as those for the four-foot free drop in Test Plan #73 except the package is raised 30 feet above the drop surface.

This test requires that test specimens be at or below -40° C at the time of the drop. Follow the Worksheet instructions for measuring and recording the specimen temperature before and after the drop.

6.3.1 30-foot Free Drop Setup

To set up a package for the 30-foot drop test:

1. Use the drop surface specified in Drawing AT10122, Rev B.
2. Measure and record the weight of test specimen.
3. Measure and record the specimen's internal and surface temperature, and ensure that the package is at or below -40° C.
4. Place the specimen on the drop surface and position it according to the appropriate orientation.

   Refer to Figure 6 for Specimens A and C.

   Refer to Figure 7 for Specimens B and D.
5. Align the selected center-of-gravity marker as shown in the referenced drawing.
6. Raise the package so that the impact target is 30 to 32 feet above the drop surface.

6.3.2 Orientation for the 30-foot Free Drop: Specimens A & C

Figure 6 shows the package orientation for Specimens A and C for the 30-foot free drop.

This orientation targets the bottom edge of the rear end-plate with the objective of loosening or shearing the end-plate screws which hold the plate to the steel connecting rods. The bottom edge of the plate provides the greatest surface area for a direct hit, and thus the most rapid deceleration, and was proven to be the most damaging to the unit during previous testing in Test Plan#70.

Make sure the center of gravity is directly over the point of impact.

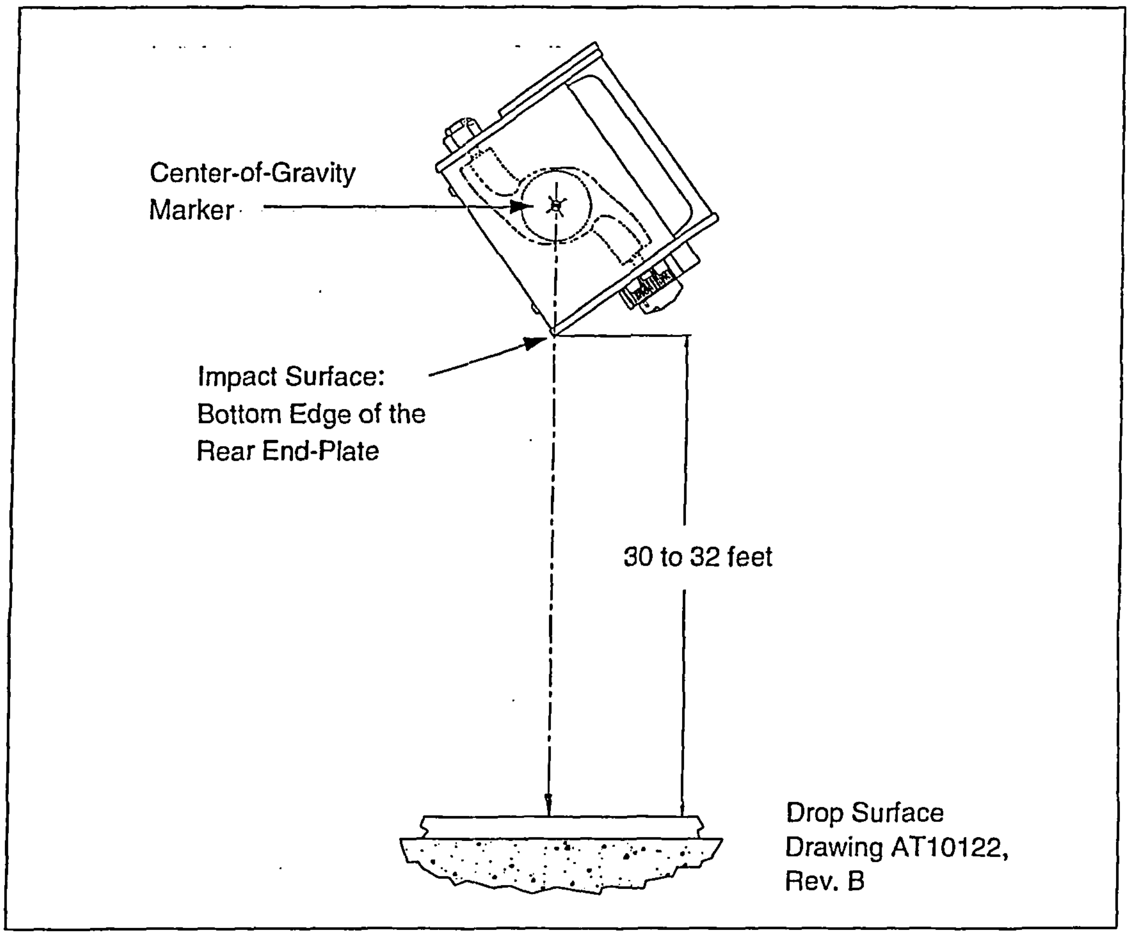


Figure 6: Orientation for the 30-foot Free Drop: Specimens A & C

6.3.3 Orientation for the 30-foot Free Drop: Specimens B & D

Figure 7 shows the package orientation for Specimens B and D for the 30-foot free drop.

This orientation targets the top edge of the front end-plate. The drop is designed to cause deformation of the end plate, which in turn will create multiple loads paths on the end-plate screws.

Make sure the center of gravity is directly over the point of impact.

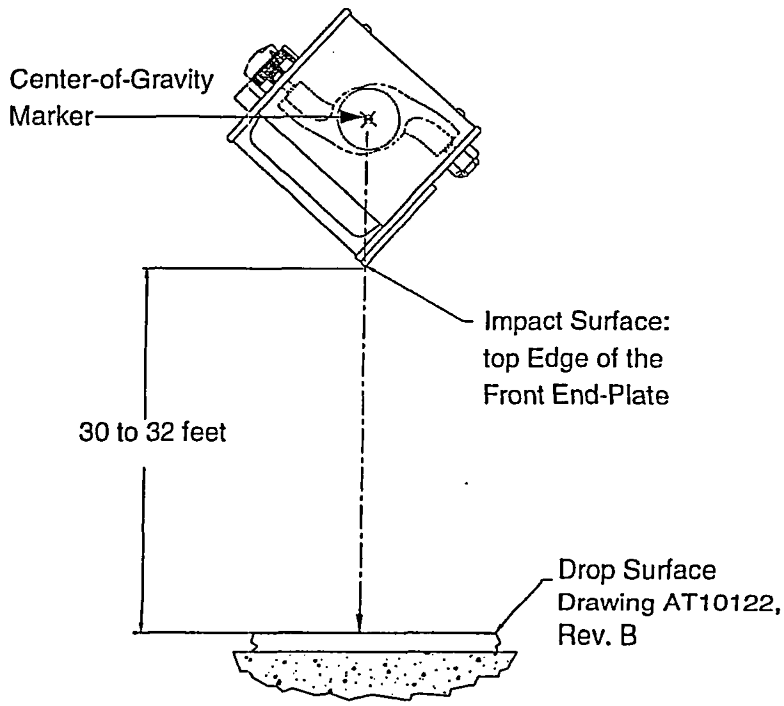


Figure 7: Orientation for the 30-foot Free Drop: Specimens B & D

6.3.4 30-foot Free Drop Test Assessment

Upon completion of the test, Engineering, Regulatory Affairs and Quality Assurance team members will jointly perform the following tasks:

- Review the test execution to ensure that the test was performed in accordance with 10 CFR 71. Units S1 and S2 may need to be tested, possibly with torque adjustments, to ensure test compliance.
- Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.
- Assess the damage to the specimen to decide whether testing of that specimen is to continue.
- Evaluate the condition of the specimen to determine what changes are necessary in package orientation in the puncture test to achieve maximum damage.

6.4 Puncture Test (10 CFR 71.73(c)(3))

The 30-foot free drop is followed by the puncture test per 10 CFR 71.73(c)(3), in which the package is dropped from a height of at least 40 inches onto the puncture billet specified in Drawing CT10119, Rev. C.

The billet is to be bolted to the drop surface used in the free drop tests (Figure 8).

Use *Checklist 2: Puncture Test* on page 31 to ensure that test sequence is followed. Date and initial all action items, and record required data.

6.4.1 Puncture Test Setup

There are two different package orientations for the puncture test. Each orientation assures that the package lands on the component or assembly of interest.

NOTE: *Because each test is designed to add to damage inflicted on a specific component or assembly in the preceding test, it is important that each specimen maintain its identity throughout the battery of tests and that the setup instructions specific to the specimen are strictly followed.*

This test requires that the test specimens be at or below -40° C at the time of the test. The worksheet calls for measuring and recording the specimen temperature before and after the test.

This test uses the 12-inch high puncture billet (Drawing CT10119, Rev. C). The billet meets the minimum height (8 inches) required in 10 CFR 71.73(c)(3). The specimen has no projections or overhanging members longer than 8 inches which could act as impact absorbers, thus allowing the billet to cause the maximum damage to the specimen.

To set up a package for the puncture test:

1. Measure and record the weight of the package.
2. Measure and record the specimen's internal and surface temperature, and ensure that the package is at or below -40° C.
3. Position the unit according to the appropriate orientation:

   For Specimens A and C, refer to Figure 8 on Page 18.

   For Specimens B and D, refer to Figure 9 on Page 19.
4. Check the alignment of the specified center-of-gravity marker with the targeted point of impact.
5. Raise the package so that there is 40 to 42 inches between the package and the top of the puncture billet.

6.4.2 Orientation for the Puncture Test: Specimens A & C

The orientation for Specimens A and C (Figure 8) targets the bottom edge of the rear end-plate to distort the end plate and possibly loosen or shear the end-plate screws.

The bottom edge provides the largest unobstructed flat surface on the plate. The impact will crush the bottom of the end plate into the polyurethane foam, the softest material in the package, and cause the maximum distortion of the plate. Attacking the top edge was rejected because the flat surface area is less than half that of the bottom edge and the carrying handle would deflect much of the energy.

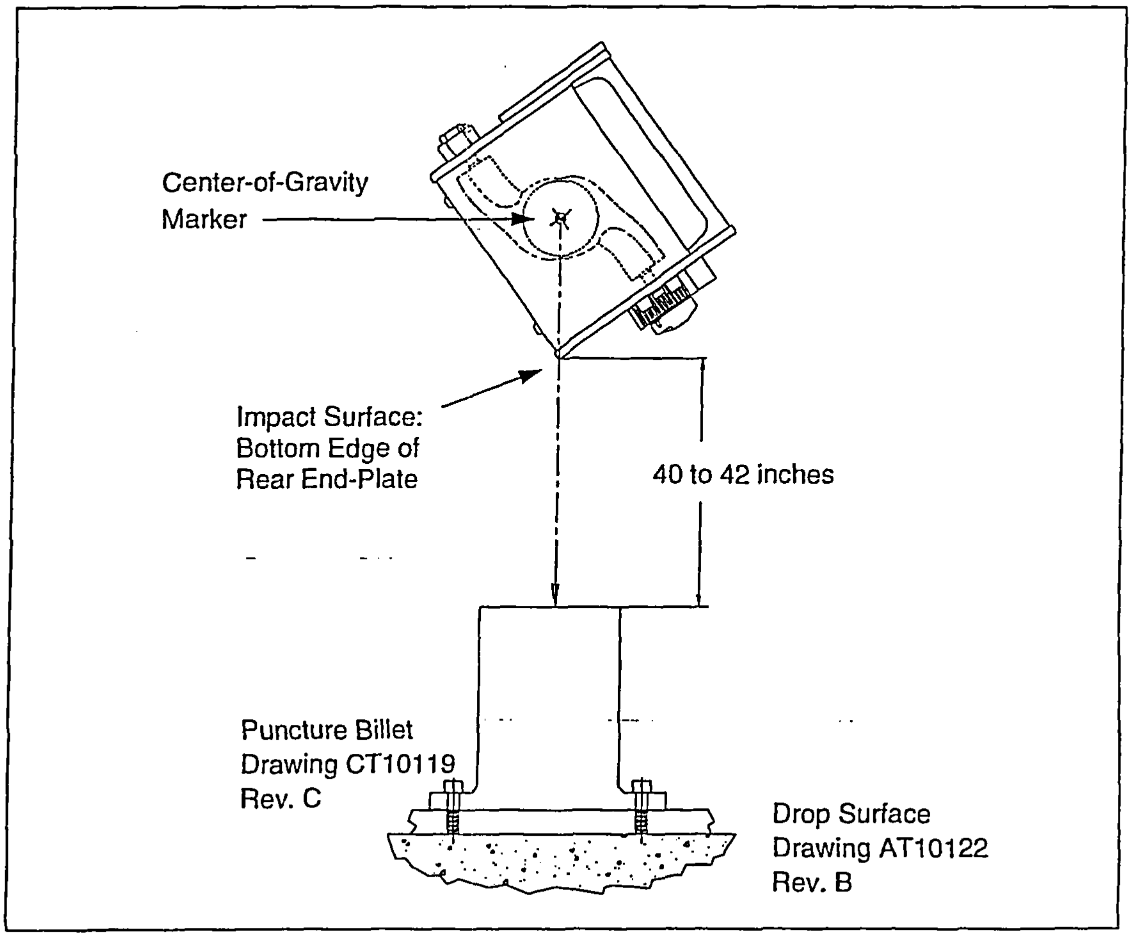


Figure 8: Orientation for the Puncture Test: Specimens A & C

6.4.3 Orientation for the Puncture Test: Specimens B & D

For Specimen B and D, the puncture test impact point is the lower left corner of the rear end-plate (Figure 9). This orientation continues the attack on the bottom left screw on the rear end plate that was inflicted with the penetration test and the two free drops. The impact will also have the effect of increasing any gap between the end plate and the shell caused by the previous tests.

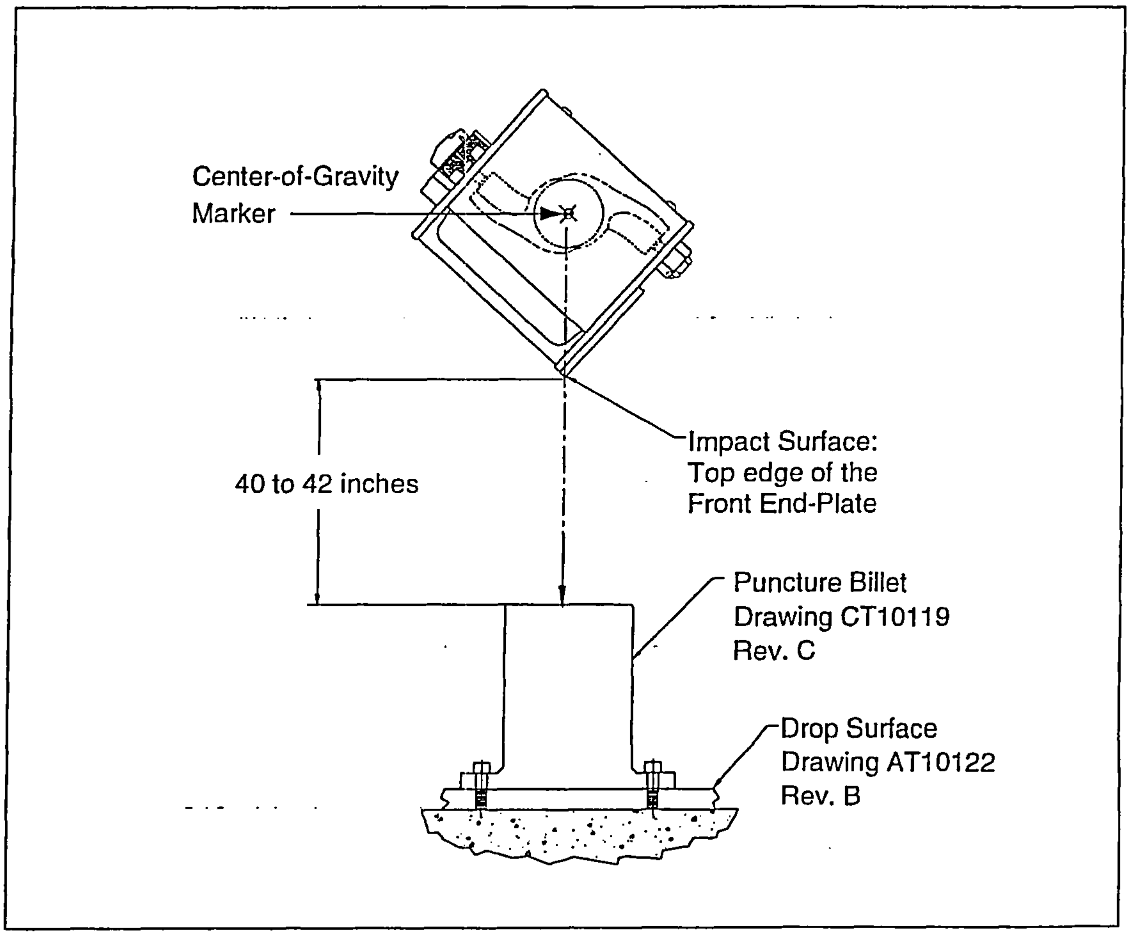


Figure 9: Orientation for the Puncture Test: Specimens B & D

6.4.4 Puncture Test Assessment

Upon completion of the test, Engineering, Regulatory Affairs and Quality Assurance team members will jointly perform the following tasks:

- Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.73.
- Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.73.
- Assess the damage to the specimen to decide whether testing of that specimen is to continue.
- Evaluate the condition of the specimen to determine whether the thermal test should be performed with the specimen.
- Evaluate the condition of the specimen to determine the package orientation for the thermal test to achieve maximum damage.

As part of the evaluation, measure the weight of the specimen.

6.5 Intermediate Test Inspection

Perform an intermediate test inspection after the puncture test.

1. Measure and record any damage to the test specimen.
2. If a source can be installed without affecting the integrity of the test specimen, profile the package using an active source in accordance with Amersham Work Instruction WI-Q09.
3. Assess the significance of any change in radiation at the surface or at one meter from the package.

6.6 Thermal Test (10 CFR 71.73(c)(4))

The final requirement is the thermal test specified in 10 CFR 71.73(c)(4).

To ensure sufficient heat input to the test specimens, each specimen will be pre-heated to a temperature of at least 800° C and held to at least that temperature for 30 minutes. This test condition provides heat input in excess of the requirements specified in 10 CFR 71.73(c)(4), which does not include a pre-heat condition. The pre-heat condition assures equivalent heat input regardless of emissivity and absorptivity coefficients.

The test environment is a vented electric oven operating greater than 800° C. There will be sufficient air flow to allow combustion. Air will be forced into the oven at a minimum rate of 9.6 cubic feet per minute to ensure sufficient oxygen to fully combust all package materials that are capable of burning. This rate is based on the following analysis:

1. The only combustible material in the TP73 is the polyurethane foam.
2. The chemical composition of polyurethane is $[C_{26}H_{33}NO_{13}]_n$.
3. The products of combustion are carbon dioxide (CO_2) and water (H_2O) and the molecular weights of the component materials are:

   C = 12 H = 1 O = 16 N = 14

4. The maximum mass of the polyurethane in a TP73 is 988 grams. The maximum amounts of carbon and hydrogen present in the polyurethane are computed as follows:

Polyurethane	C_{26}	H_{33}	N	O_{13}
Molecular Weight	(26x12) +	(33x1)+	(1x14)+	(13x16)
567 =	312 +	33 +	14 +	208
Percent by Mass	55.0%	5.8%	2.5%	36.7%
988 g =	543g +	57g +	25g +	363g

5. The amount of oxygen required to fully combust the carbon to carbon dioxide is computed as follows:

Carbon Dioxide	C	O_2
Molecular Weight	(1x12) +	(2x16)
44 =	12 +	32

For a given mass of carbon, 32/12 = 2.67 times that mass of oxygen is required to fully combust the carbon to carbon dioxide. For a TP73 containing 543 grams of carbon, full combustion would require 1450 grams of oxygen.

6. The amount of oxygen required to fully convert the hydrogen to water is computed as follows:

Water	H_2	O
Molecular Weight	(2x1) +	16
18 =	2 +	16

For a given mass of hydrogen, 16/2 = 8 times that mass of oxygen is required to fully convert the hydrogen to water. For a TP73 with 57 grams of hydrogen, full combustion would require 456 grams of oxygen.

7. The sum of these oxygen requirements (1450g + 456 g) less the oxygen supplied by the polyurethane (-363 g) equals 1543 grams of oxygen to assure sufficient oxygen to burn the polyurethane foam. At standard conditions, the composition of air is 23.2% oxygen by mass[1]. Therefore, 6650 grams of air are required.

8. The volume of air is computed at a density of 1.225 grams/liter to be 192 cubic feet:

   $6650g/1.225g/l = 5430\ l = 5.43m^3 = 192\ ft^3$

9. A 50% safety factor is added and the volume is distributed over the 30-minute test period to determine a minimum air flow rate of 9.6 cubic feet per minute:

   $(192\ ft^3)\ (1.5)\ /\ 30\ min. = 9.6\ ft^3/min.$

The air will be introduced as compressed air passing through a flowmeter and into the oven via metal tubing. A sufficient length of tubing will be inside the oven to ensure sufficient preheating.

The temperature of the package's exterior surface closest to the air entry point will be monitored throughout the test to ensure that the package remains above 800° C.

If the specimen is burning when it is removed, the unit is allowed to extinguish by itself and then cool naturally. The final evaluation of the package is performed when the specimen reaches ambient temperature.

1. Avallone, Eugene A., and Theodore Baumeister III, Editors, *Marks' Standard Handbook for Mechanical Engineers*, Ninth Edition (New York: McGraw-Hill Book Company, 1987), page 4-27

6.6.1 Thermal Test

To perform the thermal test:

1. Bring the oven temperature above 800° C.
2. Attach thermocouples to the package's internal and external measurement locations, and inside the oven.
3. Place the package in the oven and close the door.
4. When the internal temperature of the package goes above 800° C, start air flow and start a 30-minute timer.
5. Measure and record the oven temperature, test specimen internal and external temperatures, and the air flow rate. Record whether there is any combustion.
6. Monitor the specimen's internal and external temperatures, and the oven temperature throughout the 30-minute test period to ensure that all temperatures remain above 800° C.
7. Monitor the airflow rate throughout the test period to ensure that it remains above 9.6 ft^3/minute.
8. At the end of the 30 minutes, repeat Step 5.
9. Remove the test specimen from the oven.
10. Allow the package to self-extinguish and cool.

6.6.2 Thermal Test Assessment

Upon completion of the test, Engineering, Regulatory Affairs and Quality Assurance team members will jointly perform the following task:

- Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.

6.7 Final Test Inspection

Perform the following inspections after completion of the thermal test:

1. Measure and record any damage to the test specimen.
2. Profile the package using an active source in accordance with Amersham Work Instruction WI-Q09.
3. Assess the significance of any change in radiation at one meter from the package.
4. Determine whether it is necessary to dismantle the test specimen for inspection of hidden component damage or failure.
5. If you decide to proceed with the inspection, record and photograph the process of removing any component.
6. Measure and record any damage or failure found in the process of dismantling the test specimen.

6.8 Final Assessment

Engineering, Regulatory Affairs, and Quality Assurance team members will make a final assessment of the test specimen, and jointly determine whether the specimen meets the requirements of 10 CFR 71.73.

7.0 Worksheets

Use the following worksheets for executing these tests. There are two worksheets for each test: an equipment list and a test procedure checklist.

Use the test equipment list to record the serial number of each measurement device used. Attach a copy of the relevant inspection report or calibration certificate after you have verified the range and accuracy of the equipment.

Quality Control will initial each step on the checklist as it is executed and record data as required. The Engineering, Regulatory Affairs and Quality Assurance representatives must witness all testing to ensure the testing is performed in accordance with this test plan and 10 CFR 71.

Make copies of the forms for additional attempts. Maintain records of all attempts.

Equipment List 1: 30-foot Free Drop

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface, Drawing AT10122, Rev. B		
Weight Scale		
Thermometer		
Thermocouple flexible probe		
Thermocouple surface probe		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
Verified by:	Signature	Date
Engineering		
Regulatory Affairs		
Quality Assurance		

Checklist 1: 30-foot Free Drop

Test Location:

Attempt Number:

Step	Specimen A	Specimen B	Specimen C	Specimen D
1. Measure and record test specimen's weight.				
Record the specimen's weight:				
Note the instrument used:				
2. Immerse the test specimen in dry ice as needed to bring specimen temperature below -40° C.				
Steps 1 through 2 witnessed by:				
Engineering				
Regulatory Affairs				
Quality Assurance				
3. Measure the ambient temperature.				
Record ambient temperature:				
Note the instrument used:				
4. Attach the test specimen to the release mechanism.				
5. Begin video recording of test so that the impact is recorded.				
6. Measure the temperature of the specimen. Ensure that the specimen is below -40° C.				
Record the specimen's internal temperature:				
Note the instrument used:				
Record the specimen's surface temperature.				
Note the instrument used:				
7. Lift and orient the test specimen as shown in the referenced figure for the specimen.	Figure 6 on Page 14	Figure 7 on Page 15	Figure 6 on Page 14	Figure 7 on Page 15
8. Inspect the orientation setup and verify the drop height.				
9. Photograph the setup in at least two perpendicular planes.				

Checklist 1: 30-foot Free Drop (Continued)

Test Location: **Attempt Number:**

Step	Specimen A	Specimen B	Specimen C	Specimen D
Steps 3 through 9 witnessed by:				
Engineering				
Regulatory Affairs				
Quality Assurance				
10. Release the test specimen.				
11. Measure the surface temperature of the test specimen.				
Record the surface temperature:				
Note the instrument used:				
12. Measure and record the test specimen's weight.				
Record the specimen's weight:				
Note the instrument used:				
13. Pause the video recorder. Ensure that the point of impact and orientation specified in the plan have been achieved and recorded.				
14. Record damage to test specimen on a separate sheet and attach.				
Steps 10 through 14 witnessed by:				
Engineering				
Regulatory Affairs				
Quality Assurance				

Checklist 1: 30-foot Free Drop (Continued)

Test Location: **Attempt Number:**

Step	Specimen A	Specimen B	Specimen C	Specimen D
15. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes are necessary in package orientation for the puncture test to achieve maximum damage.				

Test Data Accepted by (Signature):	Date:
Engineering	
Regulatory Affairs	
Quality Assurance	

Equipment List 2: Puncture Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface, Drawing AT10122, Rev. B		
Puncture Billet, Drawing CT10119, Rev. C		
Weight Scale		
Thermometer		
Thermocouple flexible probe		
Thermocouple surface probe		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
Verified by:	Signature	Date
Engineering		
Regulatory Affairs		
Quality Assurance		

Checklist 2: Puncture Test

Test Location: **Attempt Number:**

Step	Specimen A	Specimen B	Specimen C	Specimen D
1. Immerse the test specimen in dry ice as need to bring the specimen's temperature below -40° C.				
Step 1 witnessed by:				
Engineering				
Regulatory Affairs				
Quality Assurance				
2. Measure the weight of the specimen.				
Record the specimen's weight:				
Note instrument used:				
3. Measure the ambient temperature.				
Record ambient temperature:				
Note the instrument used:				
4. Attach the test specimen to the release mechanism.				
5. Begin video recording of test so that the impact is recorded.				
6. Measure the surface temperature of the specimen. Ensure that the specimen is below -40° C.				
Record the specimen surface temperature:				
Note the instrument used:				
7. Lift and orient the test specimen as shown in the referenced figure for the specimen.	Figure 8 on Page 18	Figure 9 on Page 19	Figure 8 on Page 18	Figure 9 on Page 19
8. Inspect the orientation setup and verify drop height.				

Checklist 2: Puncture Test (Continued)

Test Location: **Attempt Number:**

Step	Specimen A	Specimen B	Specimen C	Specimen D
9. Photograph the setup in at least two perpendicular planes.				
Steps 2 through 9 witnessed by:				
Engineering				
Regulatory Affairs				
Quality Assurance				
10. Release the test specimen.				
11. Measure the surface temperature of the test specimen.				
Record the surface temperature:				
Note the instrument used:				
12. Measure and record the test specimen's weight.				
Record the specimen's weight:				
Note the instrument used:				
13. Pause the video recorder. Ensure that the point of impact and orientation specified in the plan have been achieved and recorded.				
14. Record damage to test specimen on a separate sheet and attach.				
Steps 10 through 14 witnessed by:				
Engineering				
Regulatory Affairs				
Quality Assurance				

Checklist 2: Puncture Test (Continued)

Test Location:

Attempt Number:

Step	Specimen A	Specimen B	Specimen C	Specimen D
15. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine the package orientation for the thermal test that will achieve maximum damage.				

Test Data Accepted by (Signature):	Date:
Engineering	
Regulatory Affairs	
Quality Assurance	

Equipment List 3: Thermal Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Air Flowmeter		
Thermocouple (internal)		
Thermocouple (external)		
Thermocouple (oven)		
Temperature recorder		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
Verified by:	Signature	Date
Engineering		
Regulatory Affairs		
Quality Assurance		

Checklist 3: Thermal Test

Test Location: **Attempt Number:**

Step	Specimen A	Specimen B	Specimen C	Specimen D
1. Pre-heat the oven to a temperature above 800° C.				
2. Attach the thermocouples the specimen's internal and external measuring points.				
3. Place the package in the oven and close the oven door.				
Record the date and time that the package is placed in oven.				
4. When the specimen's internal temperature exceeds 800° C, start the air flow into the oven. Record the time.				
Steps 1 through 4 witnessed by:				
Engineering				
Regulatory Affairs				
Quality Assurance				
5. Measure the oven temperature, the specimen's internal and external temperatures and the air flow rate.				
Record the oven temperature:				
Note instrument used:				
Record the specimen's internal temperature:				
Note instrument used:				
Record the specimen's external temperature:				
Note instrument used:				
Record airflow rate:				
Note instrument used:				
6. Monitor the internal and external temperatures of the specimen and the oven temperature throughout the 30-minute period to ensure that they are above 800° C.				

Checklist 3: Thermal Test (Continued)

Test Location: **Attempt Number:**

Step	Specimen A	Specimen B	Specimen C	Specimen D
7. Monitor the airflow throughout the 30-minute period to ensure a rate of at least 9.6 ft^3/min.				
8. At the end of the 30-minute period, repeat step 5 using the same measurement devices.				
Record the oven temperature:				
Record the specimen's internal temperature:				
Record the specimen's external temperature:				
Record intake air flow velocity:				
Steps 5 through 8 witnessed by:				
Engineering				
Regulatory Affairs				
Quality Assurance				
9. Remove test specimen from the oven.				
Record time the specimen is removed.				
Describe combustion when door is opened to remove specimen.				
NOTE: If specimen continues to burn, let it self-extinguish and cool naturally.				
10. Measure the ambient temperature.				
Record the ambient temperature:				
Note the instrument used:				
11. Photograph the test specimen and any subsequent damage				
12. Record damage to test specimen on a separate sheet and attach.				
Steps 9 through 12 witnessed by:				
Engineering				
Regulatory Affairs				
Quality Assurance				

Checklist 3: Thermal Test (Continued)

Test Location:

Attempt Number:

Step	Specimen A	Specimen B	Specimen C	Specimen D
13. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach.				

Test Data Accepted by (Signature):	Date:
Engineering	
Regulatory Affairs	
Quality Assurance	

Appendix A: Drawings

Test Specimen
TP73, Rev. A

Model 660 Gamma Ray Projector Shipping Container Descriptive Assembly
C66025, Rev. F (3 sheets)

Model 660 Gamma Ray Projector Shipping Container Descriptive Assembly
C66025, Rev. B (4 sheets)

Model 660 Gamma Ray Projector Shipping Container Descriptive Assembly
C66030, Rev. D (3 sheets)

Model 660 Gamma Ray Projector Shipping Container Descriptive Assembly
C66030, Rev. A (3 sheets)

Model 660 Gamma Ray Projector Shipping Container Descriptive Assembly
C66030, Rev. – (4 sheets)

REV	REVISED BY	DATE	DESCRIPTI	ECO#
A	SEE TITLE	BLOCK	RELEASE FOR PR	2382

NOTES

1. MATERIAL:

1.1. MANUFACTURE PER D66010 REV. D, EXCEPT REPLACE ENDPLATE SCREWS SCR001 WITH A66050-1 REV. A. AND SHIELD ASSEMBLY C66002, REV. O MAY BE REPLACED WITH C66040-5, REV. A.

1.2. INSTALL DUMMY SOURCE ASSEMBLY AT10161, REV. B

2. WEIGHT:

2.1. USE DU SHIELDS WEIGHING 37 TO 39 POUNDS.

2.2. TEST UNIT SHALL WEIGH 54 TO 56 POUNDS.

2.3. ADD 1 TO 2 POUNDS OF LEAD (1/4 THICK MAX) TO THE DU SHIELD. DISTRIBUTE THE LEAD SYMMETRICALLY AND ATTACH WITH GLASS TAPE. TOTAL SHIELD ASSEMBLY WEIGHT MUST NOT EXCEED 40 POUNDS.

2.4. PHOTOGRAPH COMPLETED SHIELD ASSEMBLY WITH LEAD APPLIED.

3. LABELING AND IDENTIFICATION:

3.1. COVER TYPE B(U) LABEL INFORMATION WITH AN OPAQUE LABEL. MARK THE OPAQUE LABEL "TP73 TEST SPECIMEN".

3.2. PERMANENT MARK BY HAND EACH: TEST SPECIMEN, SHIPPING PLUG AND DUMMY SOURCE ASSEMBLY WITH "TP73A", "TP73B", "TP73C", "TP73D", "TP73S1", & "TP73S2".

4. CENTER OF GRAVITY DETERMINATION INSTRUCTION. REF: MARKS' STANDARD HANDBOOK FOR MECHANICAL ENGINEERS, NINTH EDITION (MCGRAW-HILL BOOK COMPANY,1987), PAGE 3-8.

4.1 SUSPEND THE TEST SPECIMEN BY A CORD OR CABLE.

4.2. ATTACH A (PLUMB BOB) TO THE TEST SPECIMEN AT THE SUSPENDED ATTACHMENT POINT.

4.3. WAIT UNTIL THE TEST SPECIMEN COMES TO REST.

4.4. MARK A LINE ON THE TEST SPECIMEN ALONG THE PLUMB BOB.

4.5. REMOVE THE TEST SPECIMEN FROM ITS SUSPENSION POINT.

4.6. HANG THE TEST SPECIMEN FROM SOME OTHER ANGULAR ORIENTATION BUT IN THE SAME PLANE.

4.7. REPEAT STEPS 4.2 THROUGH 4.5.

4.8. INDICATE THE CENTER OF GRAVITY LOCATION AT THE INTERSECTION OF THE TWO MARKED LINES.

4.9. REPEAT STEPS 4.1 THROUGH 4.8 FOR ALL 4 SIDES OF THE TEST SPECIMEN (TOP & BOTTOM NOT REQUIRED).

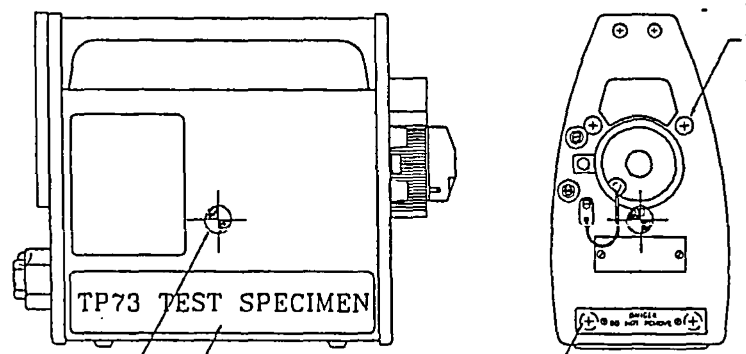
5. ATTACHMENT POINTS:

5.1. USE THE ORIENTATION FIGURES OF THE TEST PLAN TO LOCATE ANY ATTACHMENT POINTS ON THE TEST UNIT, IF NEEDED.

5.2. ATTACHMENT POINTS SHALL NOT INTERFERE WITH THE CENTER OF GRAVITY LOCATION OR AFFECT THE PERFORMANCE OF THE TEST UNIT DURING TESTING.

5.3. ATTACHMENT POINT SIZE AND LOCATION SHALL BE DOCUMENTED BEFORE TESTING CAN PROCEED.

5.4. ADHESIVE, HOOKS, AND STRAPS TO BE DETERMINED BY ENGINEERING PRIOR TO TEST.



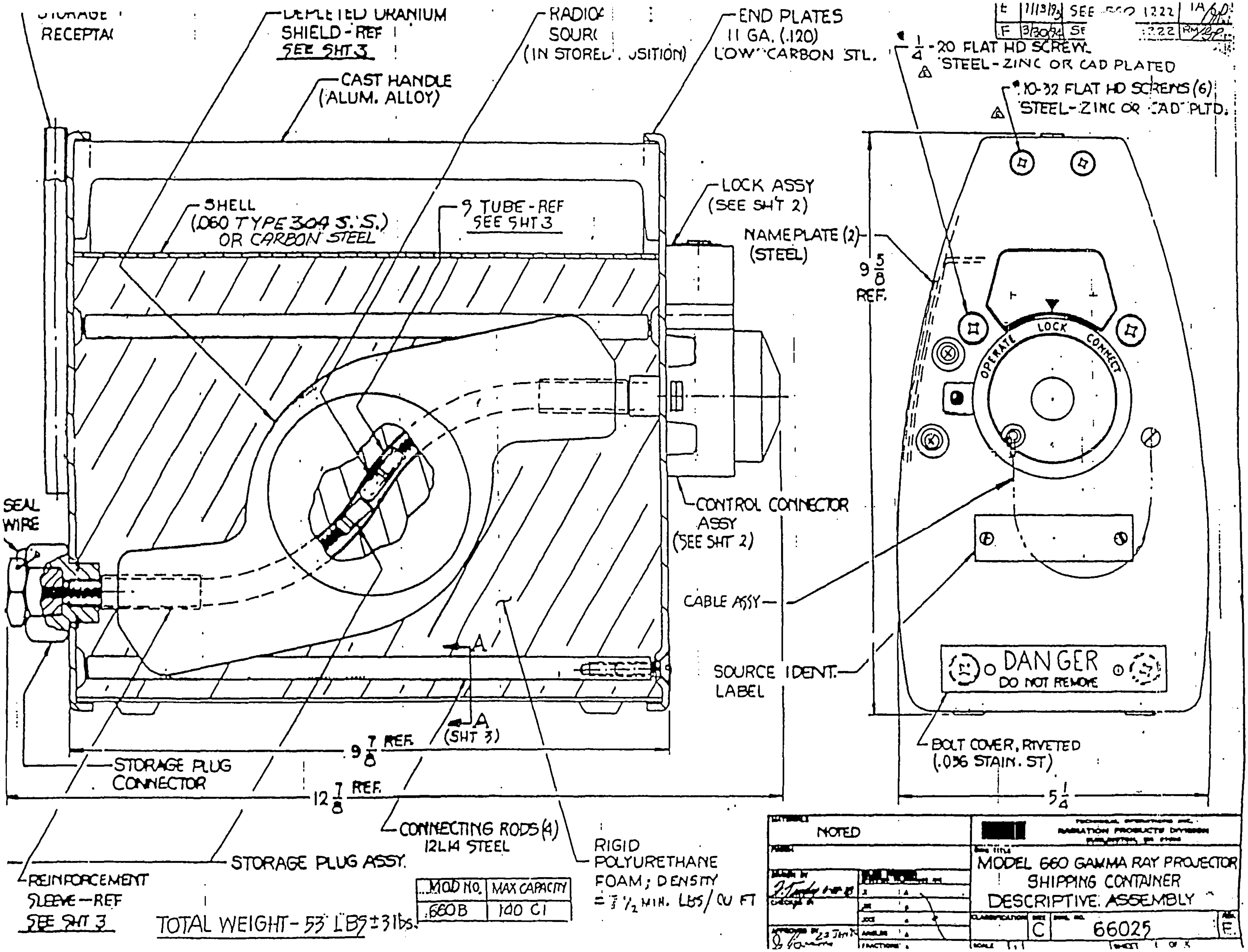
USED ON:	TEST PLAN #73
MATERIALS:	SEE NOTE 1
SURFACE TEXTURE:	UNLESS OTHERWISE STATED
FINISH: FINISH	UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
REMOVE ALL BURRS	.X ± 0.1
DRAWN / CHECKED / APPROVED: APPROVED DRAWING ON FILE	.XX ± 0.01; .XXX ± 0.005; ANGLES ± 1°; FRACT ± 1/64

AMERSHAM CORPORATION
BURLINGTON, MA 01803
SENTINEL

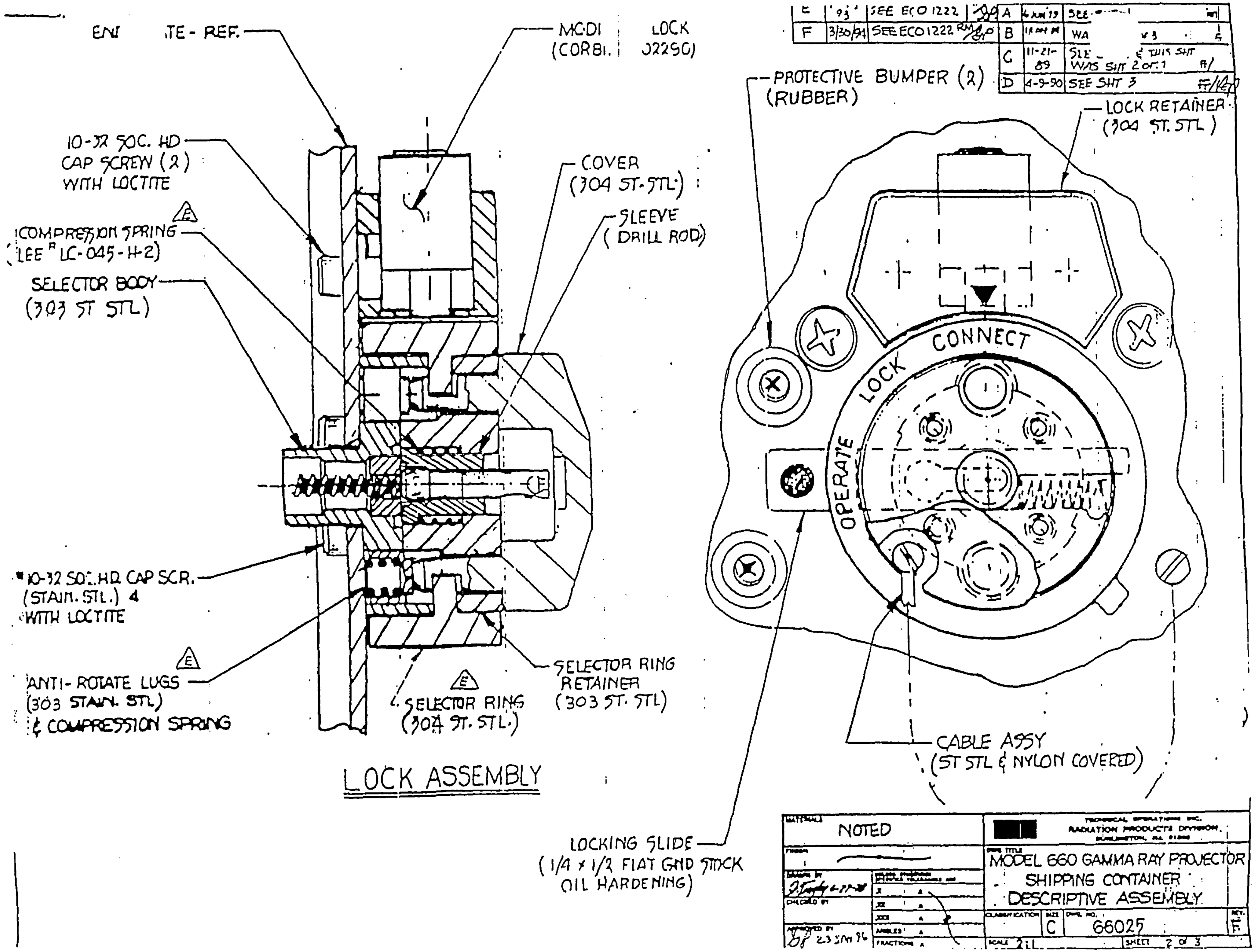
DWG. TITLE: MODEL 660 TEST SPECIMEN

SAFETY CLASS	SIZE	DWG. NO.	REV
A	C	TP73	A

SCALE NONE SHEET 1 OF 1

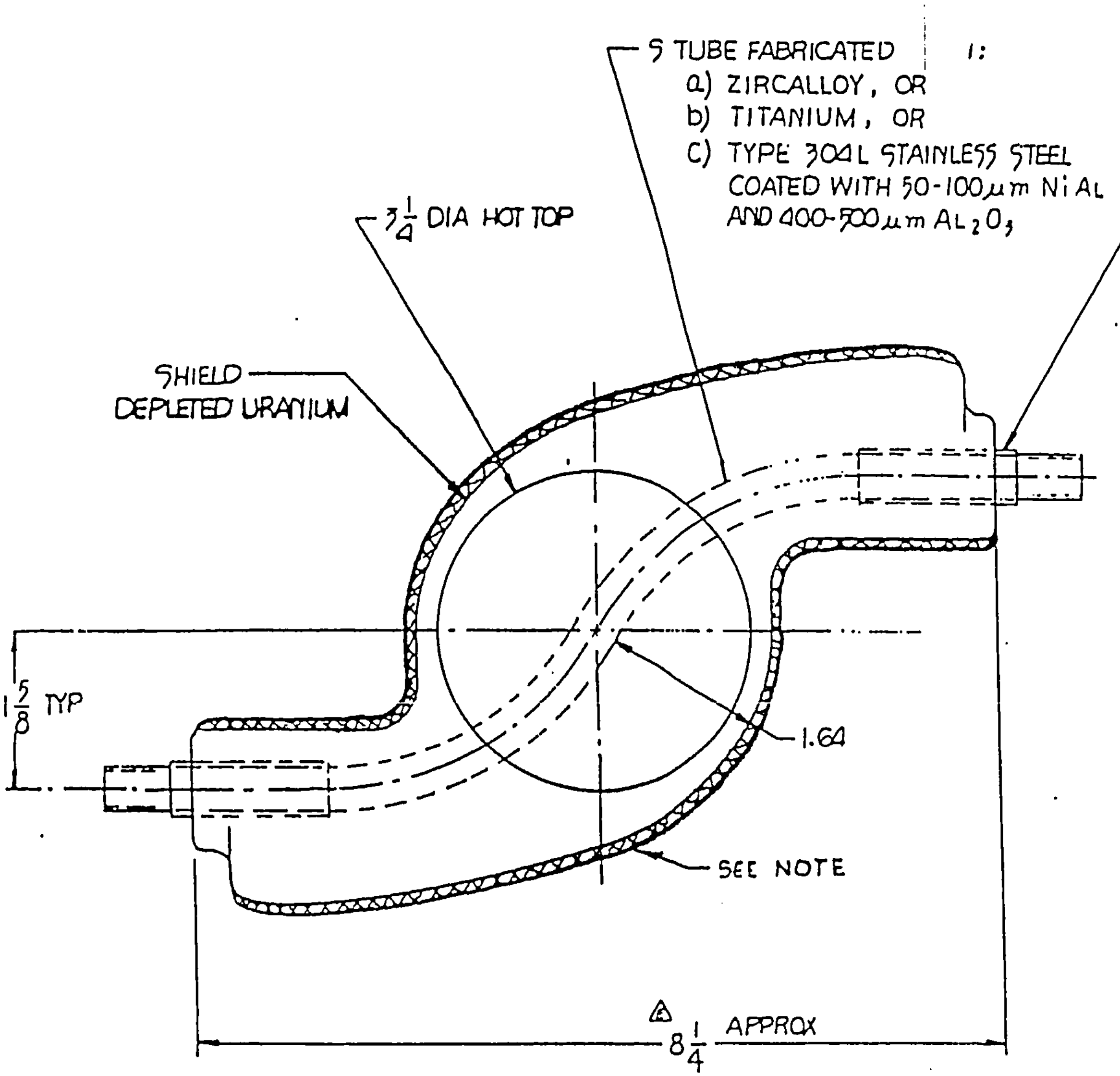


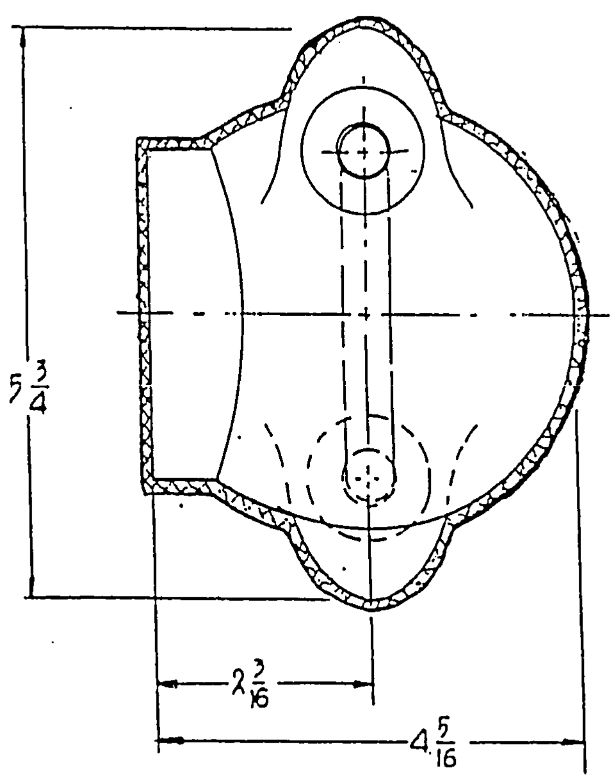
STORAGE RECEPTA(
DEPLETED URANIUM SHIELD - REF SEE SHT 3
RADIOA SOURC (IN STORED POSITION)
END PLATES 11 GA. (.120) LOW CARBON STL.
1/4 -20 FLAT HD SCREW. STEEL - ZINC OR CAD PLATED
10-32 FLAT HD SCREWS (6) STEEL - ZINC OR CAD PLTD.
CAST HANDLE (ALUM. ALLOY)
LOCK ASSY (SEE SHT 2)
SHELL (.060 TYPE 304 S.S.) OR CARBON STEEL
9 TUBE - REF SEE SHT 3
NAMEPLATE (2) (STEEL)
9 5/8 REF.
LOCK
OPERATE
CONNECT
SEAL WIRE
CONTROL CONNECTOR ASSY (SEE SHT 2)
CABLE ASSY
SOURCE IDENT. LABEL
DANGER
DO NOT REMOVE
A
A (SHT 3)
9 7/8 REF.
BOLT COVER, RIVETED (.036 STAIN. ST)
STORAGE PLUG CONNECTOR
12 7/8 REF.
5 1/4
CONNECTING RODS (4) 12L14 STEEL
RIGID POLYURETHANE FOAM; DENSITY = 3 1/2 MIN. LBS/CU FT
STORAGE PLUG ASSY.
REINFORCEMENT SLEEVE - REF SEE SHT 3
MOD NO. 660B
MAX CAPACITY 100 CI
TOTAL WEIGHT - 53 LBS ± 3 lbs.
NOTED
TECHNICAL OPERATIONS INC. RADIATION PRODUCTS DIVISION
MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
C
66025
E

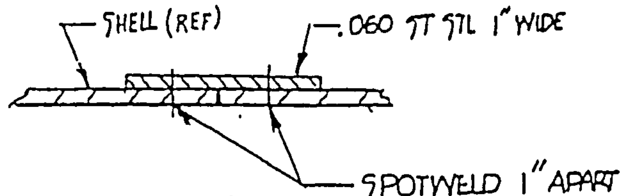


F 3/30/94 SEE ECO 1222
A
B
C 11-21-89
D 4-9-90 SEE SHT 3
PROTECTIVE BUMPER (2) (RUBBER)
LOCK RETAINER (304 ST. STL)
10-32 SOC. HD CAP SCREW (2) WITH LOCTITE
COVER (304 ST. STL)
SLEEVE (DRILL ROD)
COMPRESSION SPRING (LEE LC-045-H-2)
SELECTOR BODY (303 ST STL)
CONNECT
LOCK
OPERATE
10-32 SOC. HD CAP SCR. (STAIN. STL.) 4 WITH LOCTITE
ANTI-ROTATE LUGS (303 STAIN. STL) & COMPRESSION SPRING
SELECTOR RING (304 ST. STL.)
SELECTOR RING RETAINER (303 ST. STL)
CABLE ASSY (ST STL & NYLON COVERED)
LOCK ASSEMBLY
LOCKING SLIDE (1/4 x 1/2 FLAT GND STOCK OIL HARDENING)
NOTED
RADIATION PRODUCTS DIVISION
MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
C
66025
F
SHEET 2 OF 3

C	11-22 89	W-D ... 1 OF 4 & REV OF ... WAS — E.A. ... T-A-A	F/
D	9-4 90	ADDED "WELDED & INSPECTED IN ACCORDANCE WITH---" WAS "(MIL-W-6858)" E.C.O. # 718	F/
E	1-13 93	SEE ECO 1222	T/
F	3/30/94	ADDED LEAD TO NOTE PER ECO 1222	RM/







SECTION A-A

SCALE: 1/1

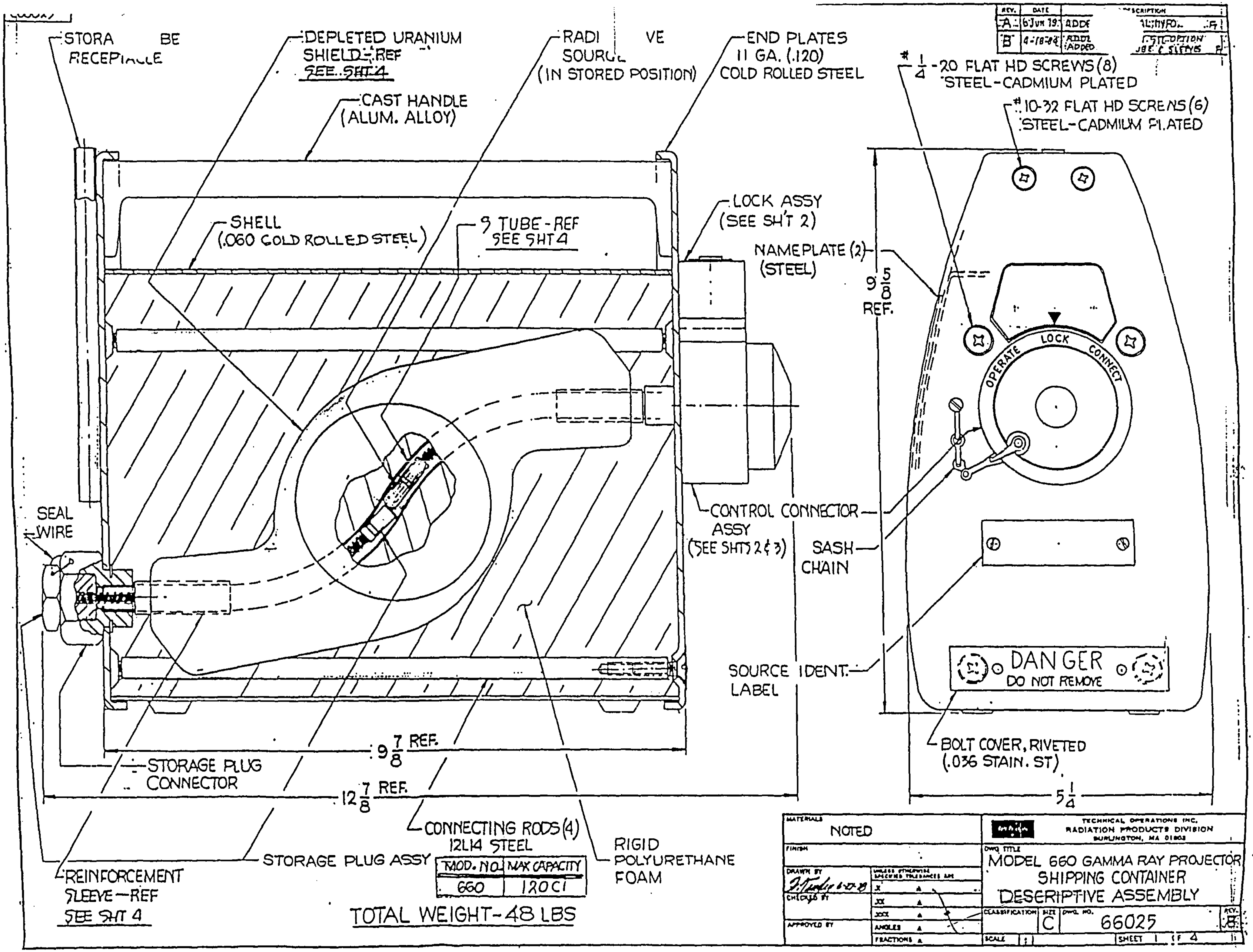
D

SHIELD DATA

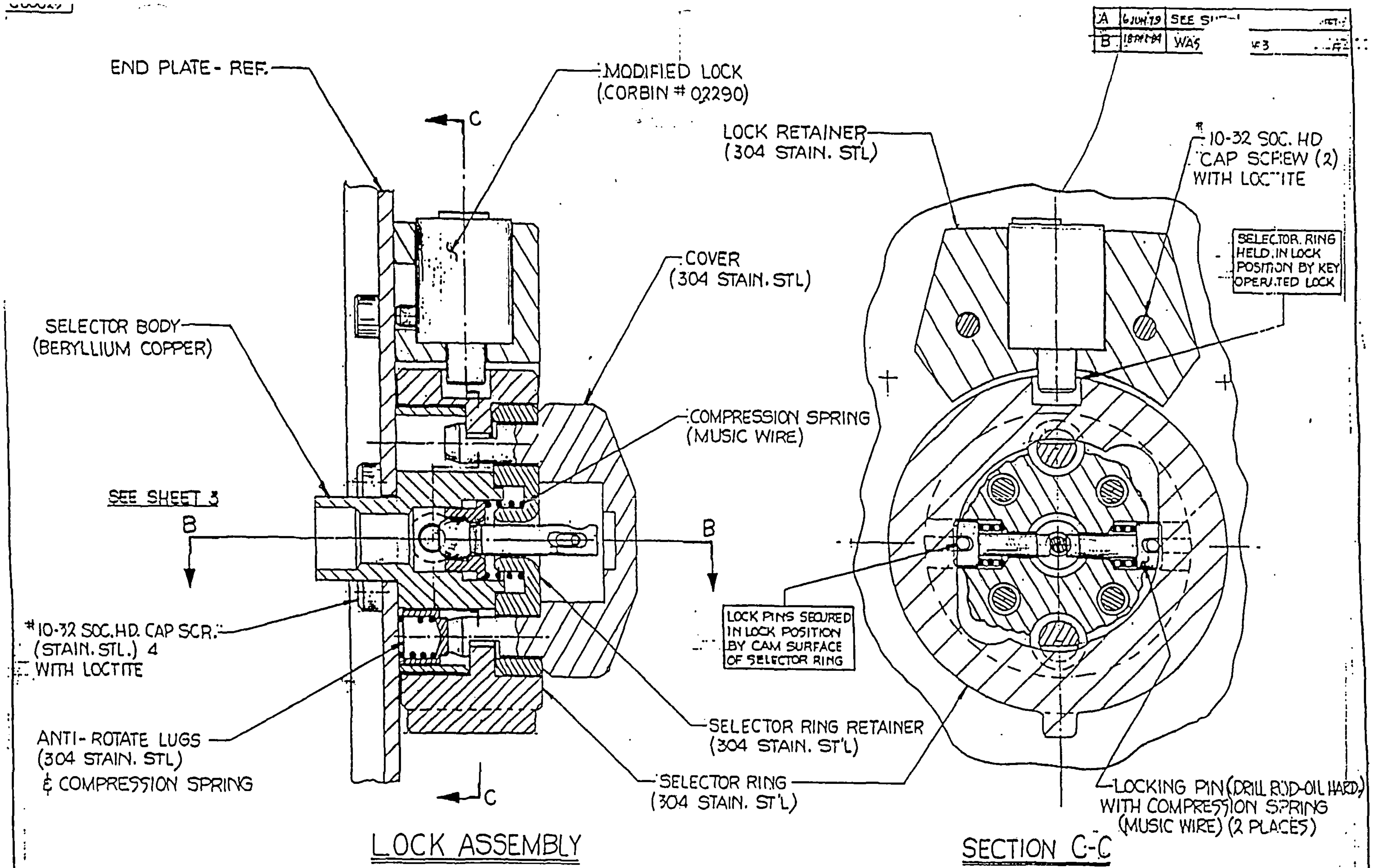
37 LBS ± 3 lbs. E

NOTE: ADDITIONAL LEAD SHIELDING NOT TO EXCEED 3 lbs. MAX. THICKNESS 1/4". TUNGSTEN NOT SHOWN. F

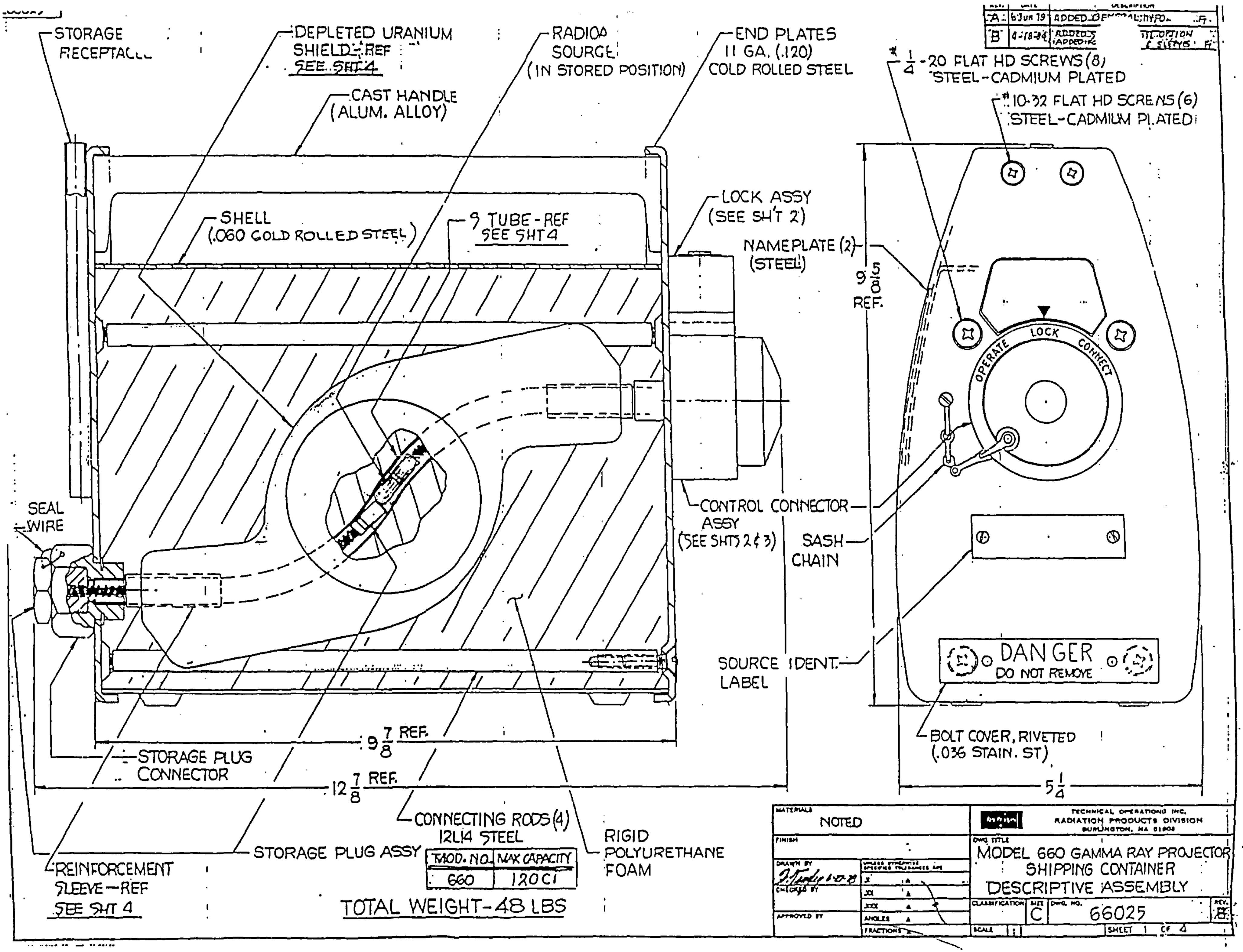
MATERIALS: AS NOTED	Tech/Ops, Inc. RADIATION PRODUCTS DIVISION BURLINGTON, MA 01803
FINISH	DWG TITLE: MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
DRAWN BY / CHECKED BY / APPROVED BY	CLASSIFICATION / SIZE C / DWG NO. 66025 / REV. E
	SCALE 1:1 / SHEET 3 OF 3



STORA BE RECEPIACLE
DEPLETED URANIUM SHIELD REF SEE SHT 4
RADI VE SOURCE (IN STORED POSITION)
END PLATES 11 GA. (.120) COLD ROLLED STEEL
CAST HANDLE (ALUM. ALLOY)
LOCK ASSY (SEE SH'T 2)
SHELL (.060 COLD ROLLED STEEL)
9 TUBE-REF SEE SHT 4
NAMEPLATE (2) (STEEL)
1/4-20 FLAT HD SCREWS (8) STEEL-CADMIUM PLATED
#10-32 FLAT HD SCREWS (6) STEEL-CADMIUM PLATED
9 5/8 REF.
OPERATE
LOCK
CONNECT
CONTROL CONNECTOR ASSY (SEE SHTS 2 & 3)
SASH CHAIN
SEAL WIRE
SOURCE IDENT. LABEL
DANGER DO NOT REMOVE
BOLT COVER, RIVETED (.036 STAIN. ST)
9 7/8 REF.
12 7/8 REF.
5 1/4
STORAGE PLUG CONNECTOR
CONNECTING RODS (4) 12L14 STEEL
RIGID POLYURETHANE FOAM
STORAGE PLUG ASSY
REINFORCEMENT SLEEVE-REF SEE SHT 4
MOD. NO | MAX CAPACITY
660 | 120 CI
TOTAL WEIGHT-48 LBS
REV. | DATE | DESCRIPTION
A | 6 JUN 79 | ADDE
B | 4-18-84 | ADDED
MATERIALS NOTED
FINISH
DRAWN BY
CHECKED BY
APPROVED BY
UNLESS OTHERWISE SPECIFIED TOLERANCES ARE
ANGLES
FRACTIONS
TECHNICAL OPERATIONS INC. RADIATION PRODUCTS DIVISION BURLINGTON, MA 01803
DWG TITLE
MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
CLASSIFICATION SIZE C
DWG NO. 66025
REV. B
SCALE 1:1
SHEET 1 OF 4

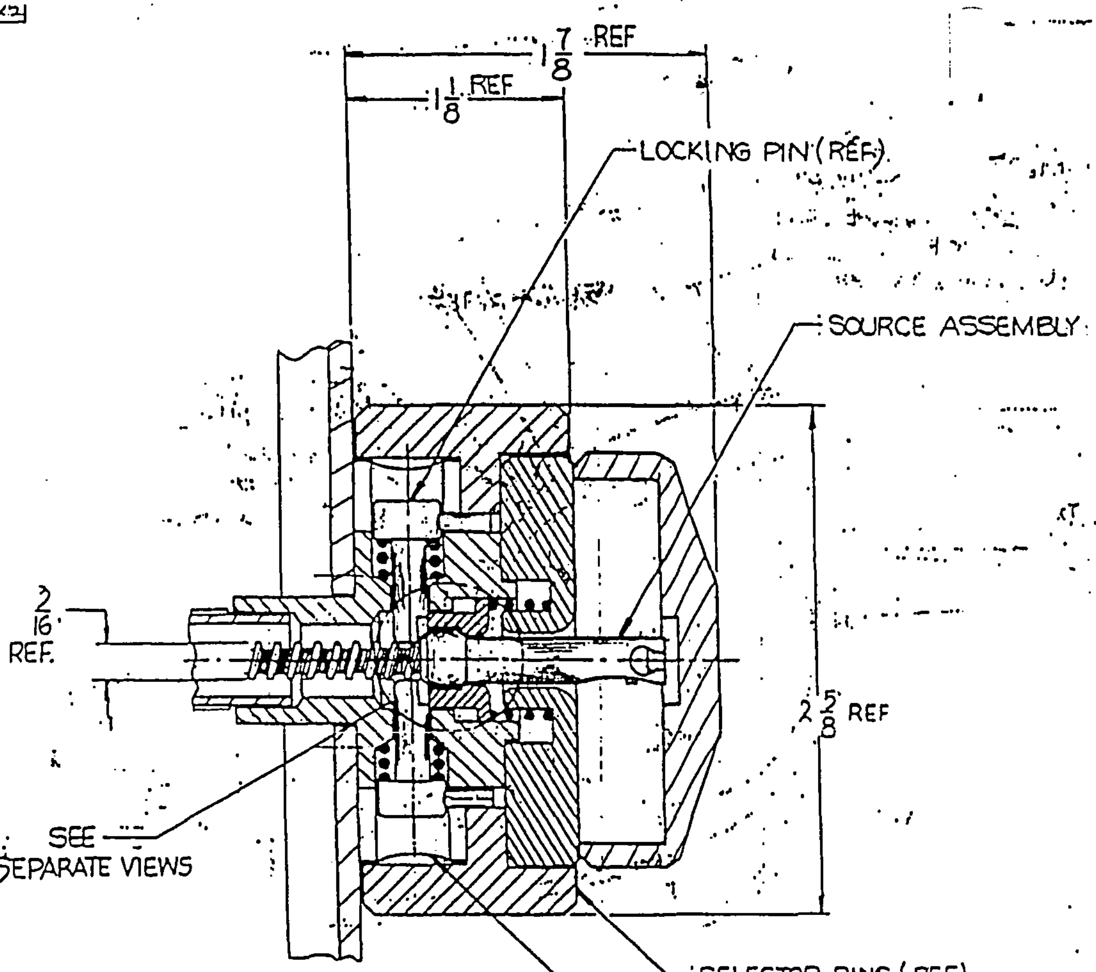


MATERIALS: NOTED	TECHNICAL OPERATIONS INC. RADIATION PRODUCTS DIVISION, BURLINGTON, MA 01803
FINISH:	DWG TITLE: MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
DRAWN BY: 6-27-78	CLASSIFICATION: · SIZE: C · DWG. NO. 66025 · REV. B
CHECKED BY:	
APPROVED BY:	SCALE 2:1 · SHEET 2 OF 4

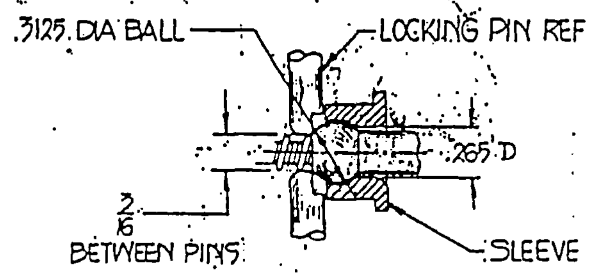


A | 6 JUN 79 | ADDED GENERAL INFO.
B | 4-18-86 | ADDED OPTION
STORAGE RECEPTALLL
DEPLETED URANIUM SHIELD - REF SEE SHT 4
RADIOA SOURCE (IN STORED POSITION)
END PLATES 11 GA. (.120) COLD ROLLED STEEL
1/4 -20 FLAT HD SCREWS (8) STEEL-CADMIUM PLATED
10-32 FLAT HD SCREWS (6) STEEL-CADMIUM PLATED
CAST HANDLE (ALUM. ALLOY)
LOCK ASSY (SEE SH'T 2)
SHELL (.060 COLD ROLLED STEEL)
S TUBE - REF SEE SHT 4
NAMEPLATE (2) (STEEL)
9 5/8 REF.
LOCK
OPERATE
CONNECT
CONTROL CONNECTOR ASSY (SEE SHTS 2 & 3)
SASH CHAIN
SEAL WIRE
SOURCE IDENT. LABEL
DANGER
DO NOT REMOVE
BOLT COVER, RIVETED (.036 STAIN. ST)
9 7/8 REF.
12 7/8 REF.
5 1/4
STORAGE PLUG CONNECTOR
CONNECTING RODS (4) 12L14 STEEL
RIGID POLYURETHANE FOAM
STORAGE PLUG ASSY
REINFORCEMENT SLEEVE - REF SEE SHT 4
MOD. NO. | MAX CAPACITY
660 | 120 CI
TOTAL WEIGHT - 48 LBS
MATERIALS NOTED
FINISH
DRAWN BY
CHECKED BY
APPROVED BY
TECHNICAL OPERATIONS INC. RADIATION PRODUCTS DIVISION BURLINGTON, MA 01803
DWG TITLE
MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
SIZE C
DWG. NO. 66025
REV. B
SCALE 1:1
SHEET 1 OF 4

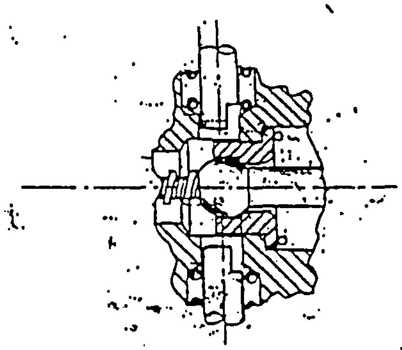
REV.	DATE	DESCRIPTION
A	6JUN79	SEE S...
B	18APR84	WAS 5 ... 3



SECTION B-B

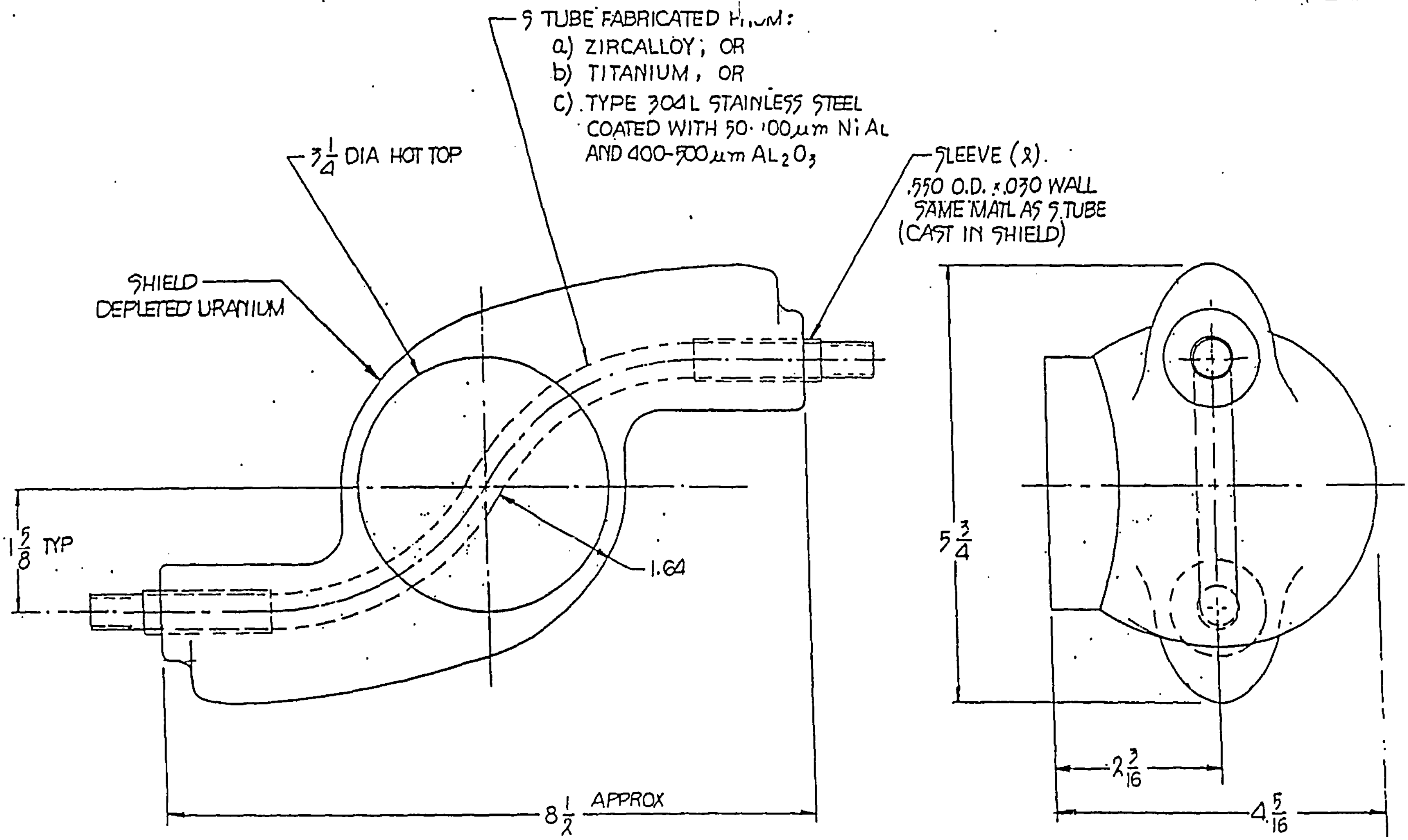


LOCKED POSITION



UNLOCKED POSITION

MATERIALS: NOTED	TECHNICAL OPERATIONS INC. RADIATION PRODUCTS DIVISION BURLINGTON, MA 01803
FINISH	DWG TITLE: MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
DRAWN BY	CLASSIFICATION / SIZE: C / DWG NO.: 66025 / REV: B
CHECKED BY / APPROVED BY	SCALE: 2:1 / SHEET 3 OF 4



SHIELD DATA

35 LBS

REV.	DATE	DESCRIPTION
B	4-18-84	SEE

MATERIALS: AS NOTED

FINISH: "

DRAWN BY: [signature] 4-12-84

CHECKED BY: [signature] 13Apr84

APPROVED BY: [signature] 13Apr84

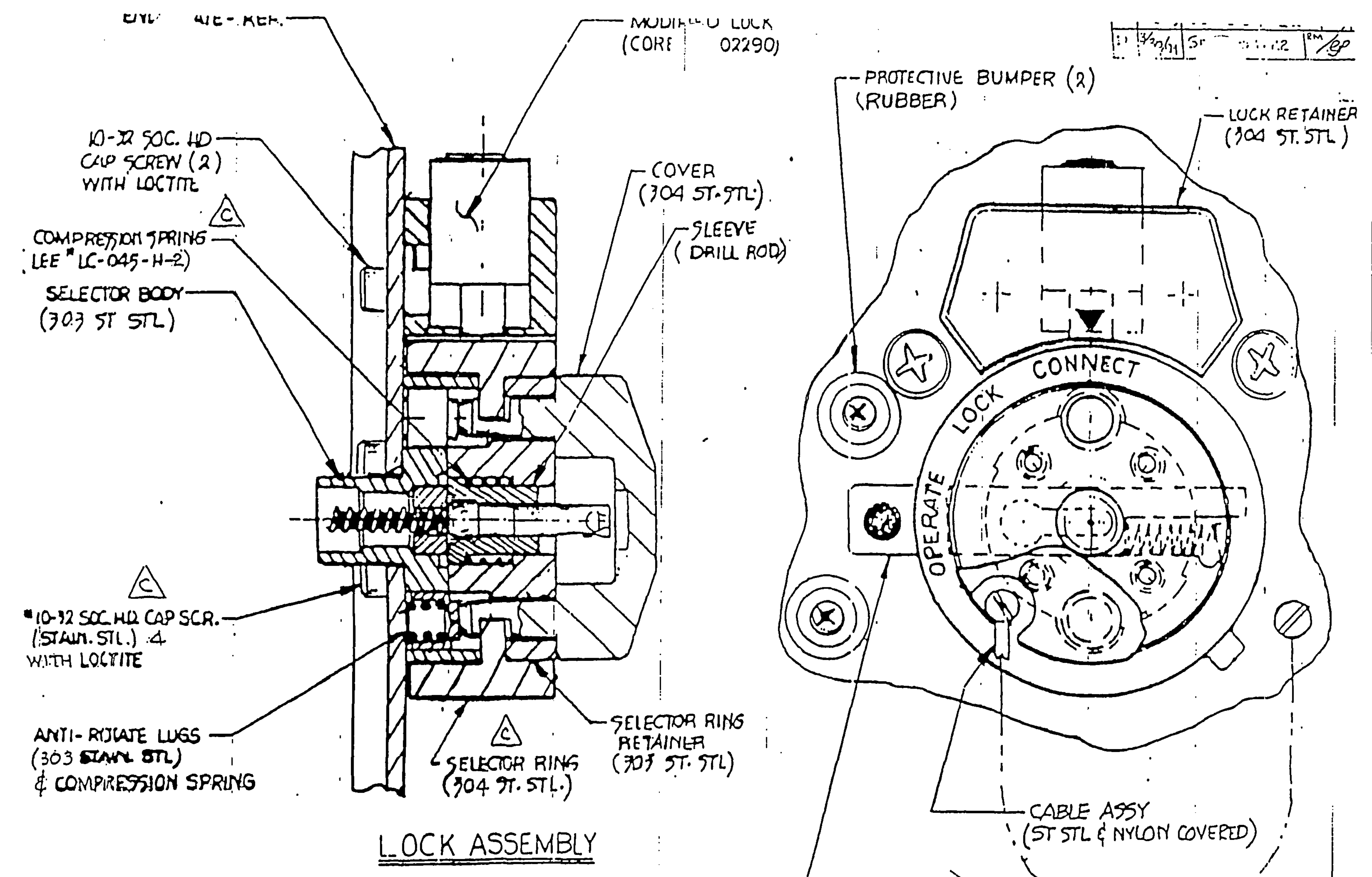
UNLESS OTHERWISE SPECIFIED TOLERANCES ARE: .X ±, .XX ±, .XXX ±, ANGLES ±, FRACTIONS ±

Tech Ops — Tech/Ops, Inc. RADIATION PRODUCTS DIVISION BURLINGTON, MA 01803

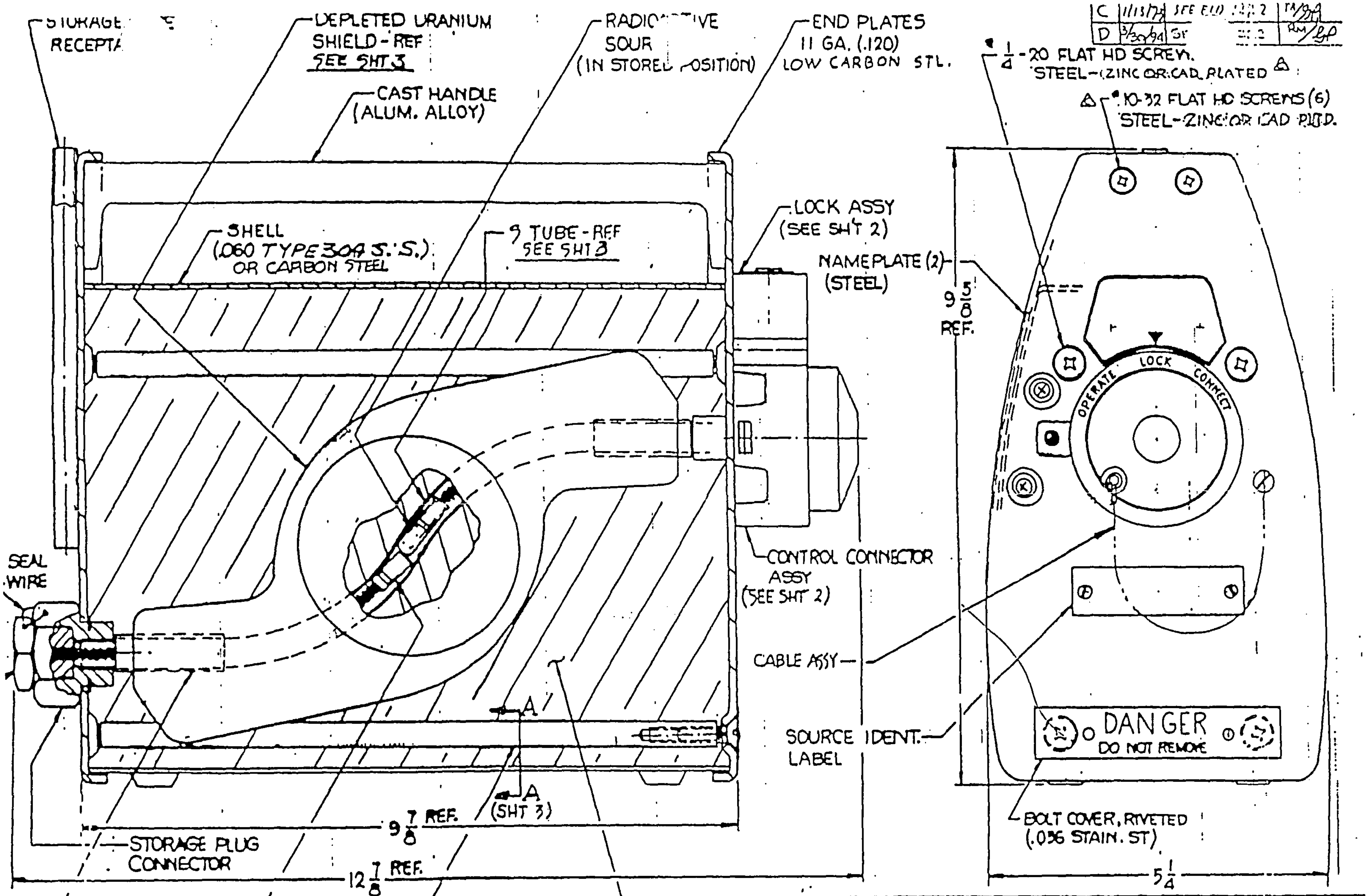
DWG TITLE: MODEL 660 GAMMA RAY PROJECT SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY

CLASSIFICATION | SIZE C | DWG. NO. 66025 | B

SCALE 1:1 | SHEET 4 OF 4



MATERIALS: NOTED	TECHNICAL OPERATIONS, INC. RADIATION PRODUCTS DIVISION BURLINGTON, MA
	MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER: DESCRIPTIVE ASSEMBLY
SIZE: C	DWG. NO. 66030
SCALE 2:1	SHEET 2 OF 3



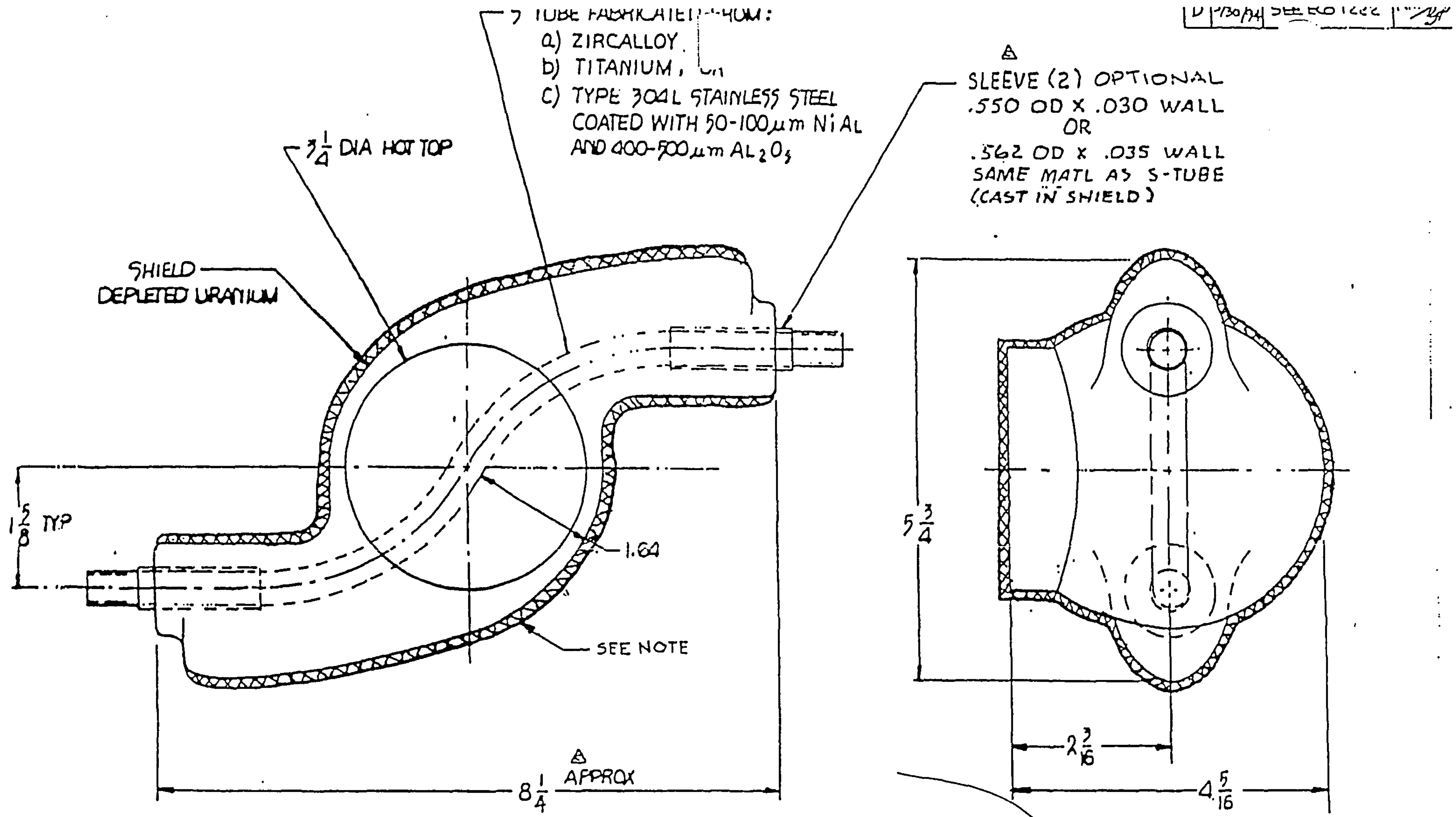
MOD NO	MAX CAPACITY
660A	120 Ci

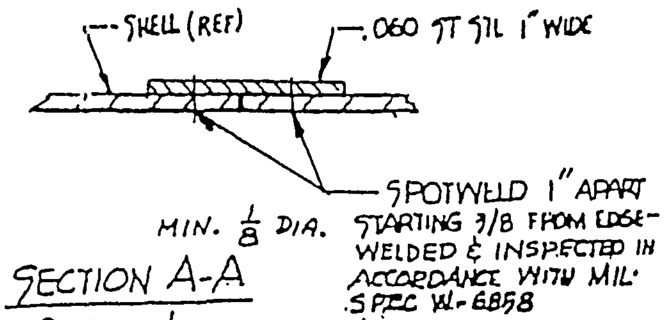
TOTAL WEIGHT - 53 LBS ± 3 lbs. (C)

MATERIALS: NOTED

MODEL 660 GAMMA RAY PROJECTOR
SHIPPING CONTAINER
DESCRIPTIVE ASSEMBLY

C | 66030 | D





SECTION A-A

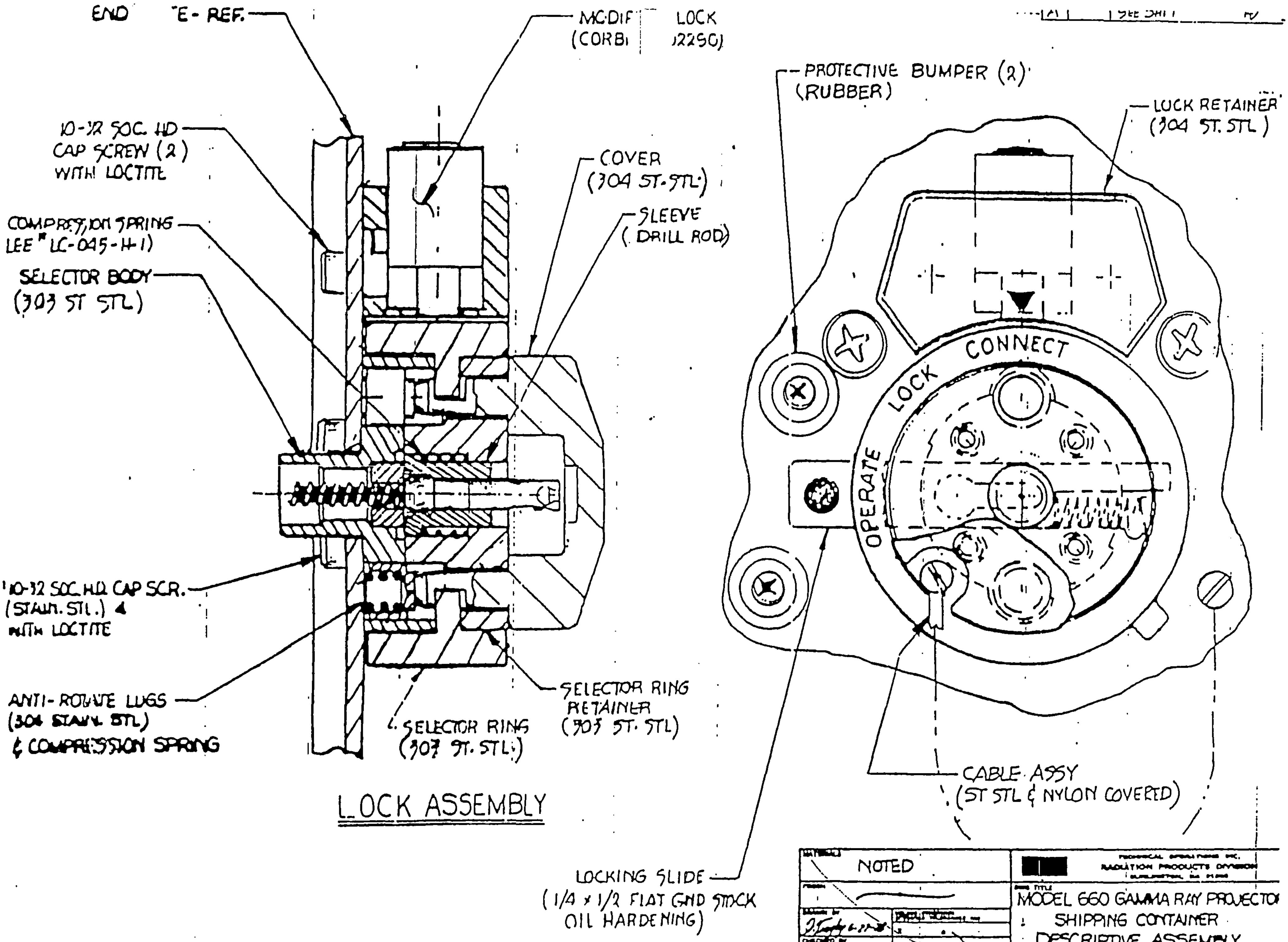
SCALE: 1/1

SHIELD DATA

37 LBS ± 3 lbs.

NOTE: ADDITIONAL LEAD SHIELDING NOT TO EXCEED 3 lbs. MAX. THICKNESS 1/4". TUNGSTEN NOT SHOWN. (F)

MATERIAL: AS NOTED	RADIATION PRODUCTS DIVISION
	MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
	SIZE C — 66030
	SCALE 1:1 — SHEET 3 OF 3

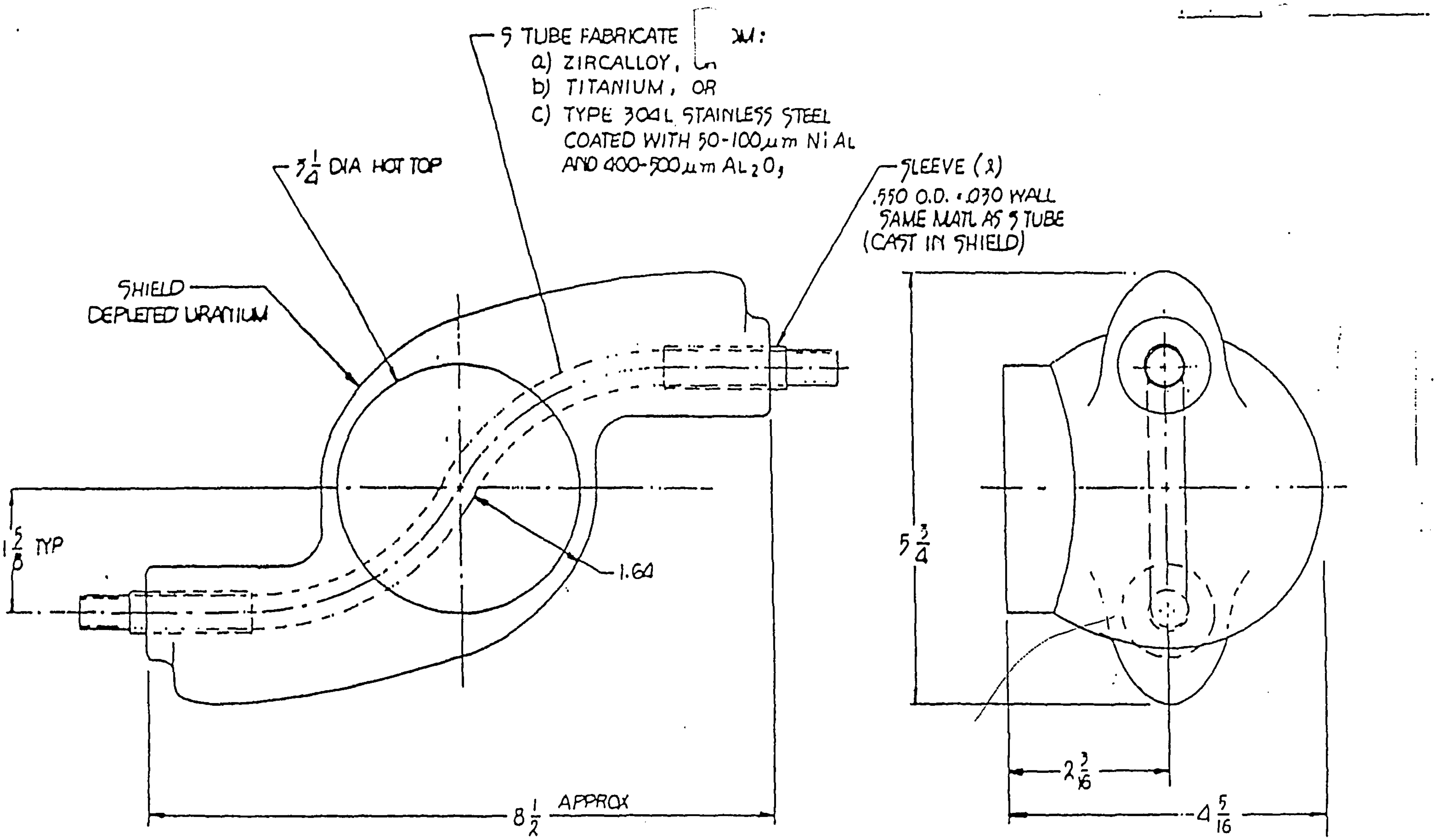


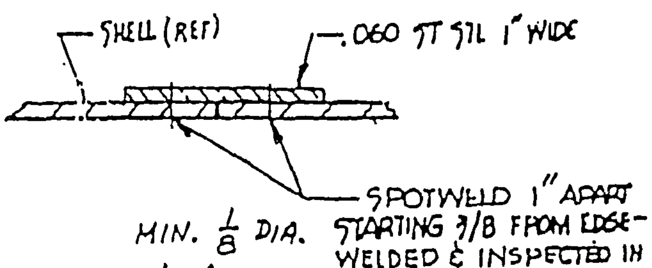
MATERIAL: NOTED

TECHNICAL OPERATIONS INC.
RADIATION PRODUCTS DIVISION
BURLINGTON, MA

MODEL 660 GAMMA RAY PROJECTOR
SHIPPING CONTAINER
DESCRIPTIVE ASSEMBLY

SIZE: C
DWG NO: 66030
SCALE 2:1
SHEET 2 OF 3





SECTION A-A

SCALE: 1/1

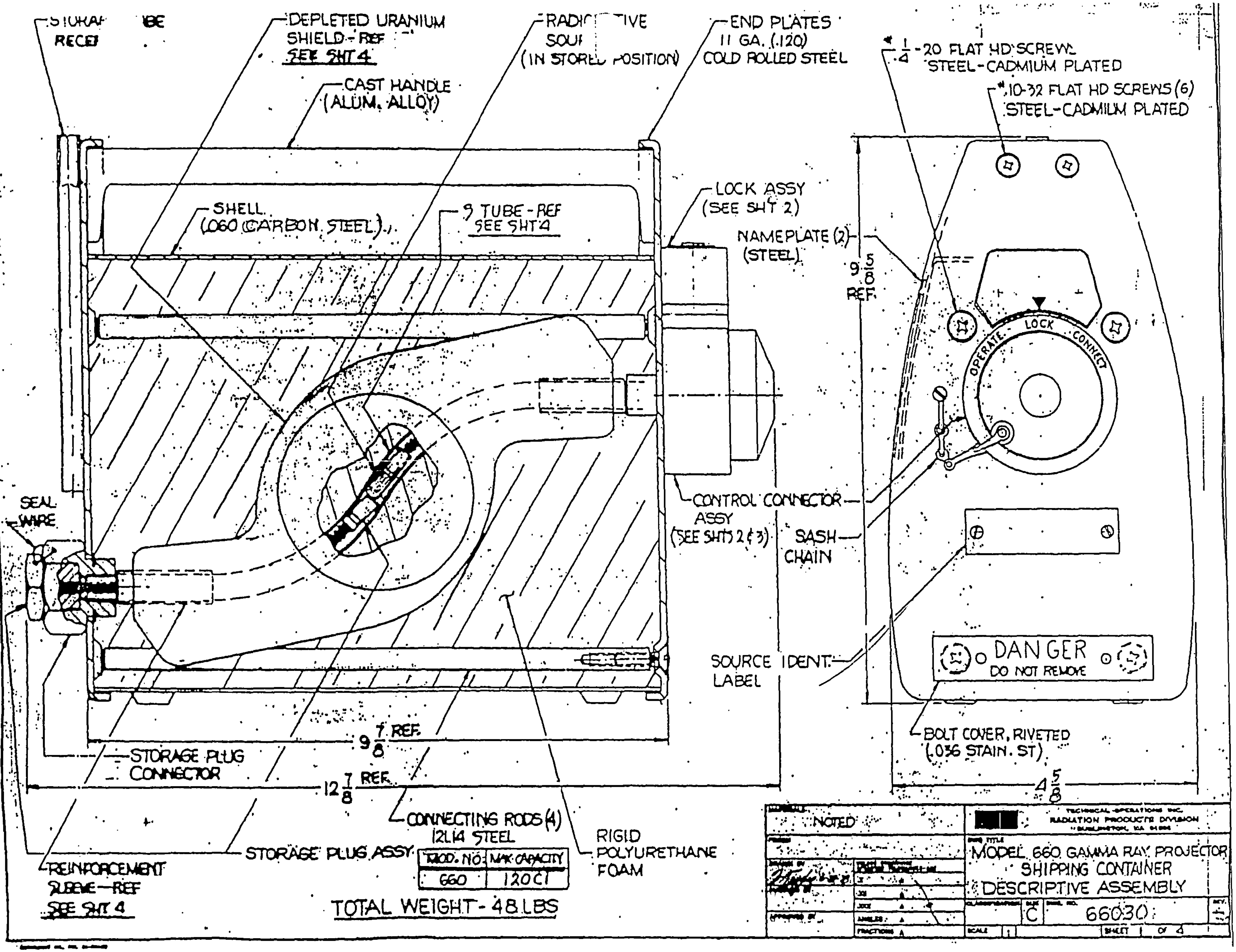
SHIELD DATA

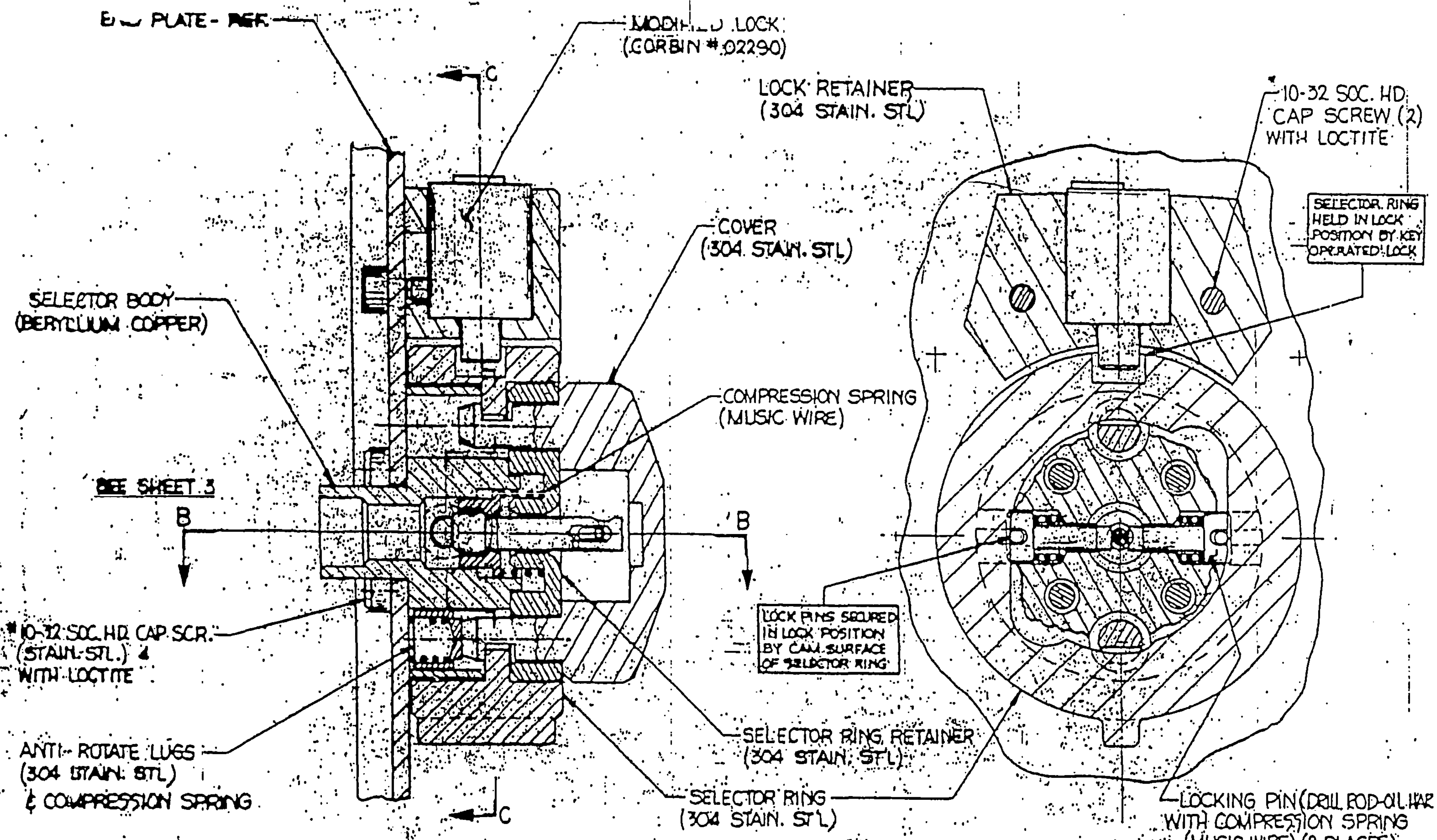
38 LBS

SHT. 3 of

AS NOTED

MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY

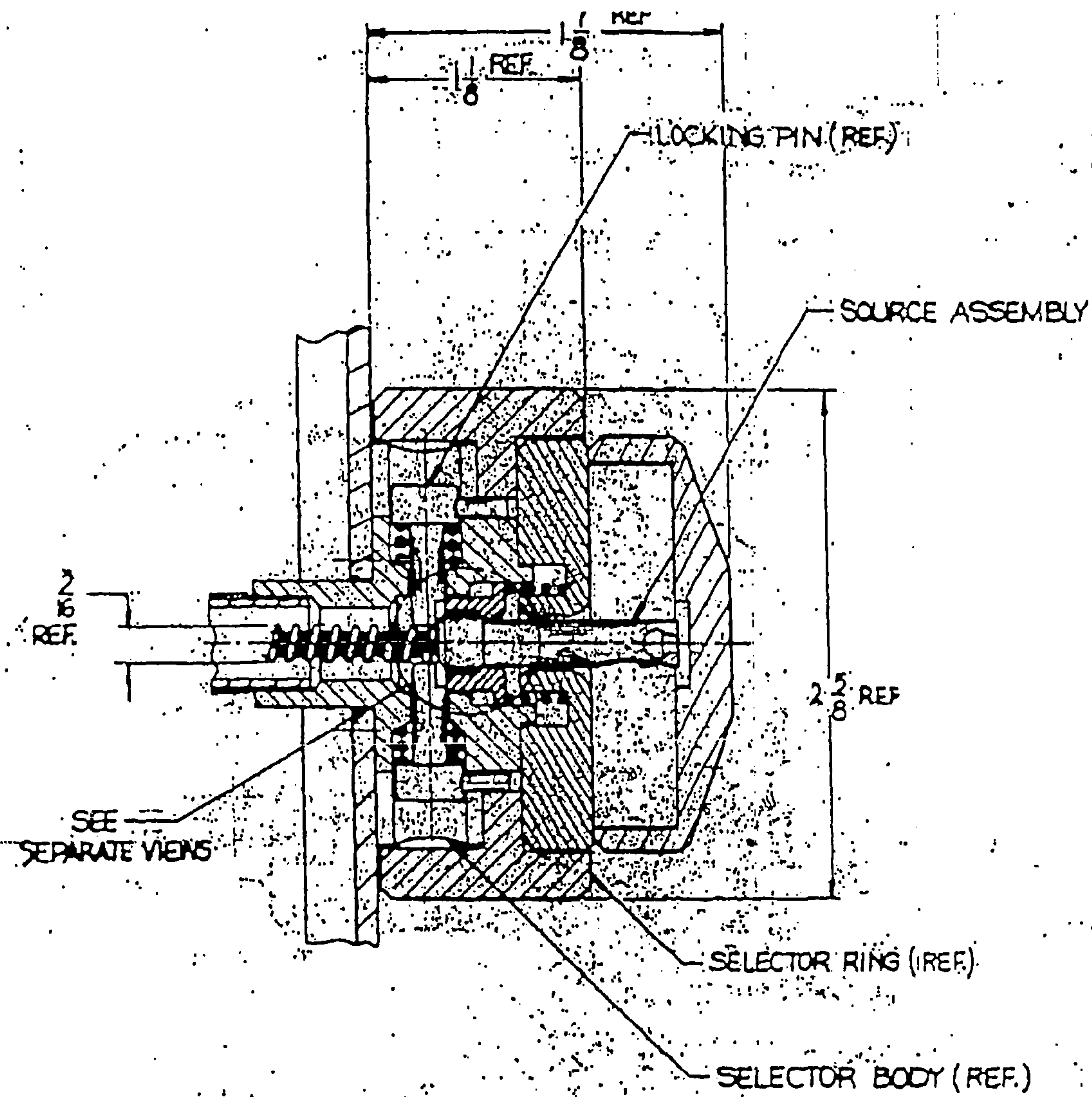

STORAGE TUBE RECEPTACLE
DEPLETED URANIUM SHIELD - REF
SEE SHT 4
RADIOACTIVE SOURCE (IN STORED POSITION)
END PLATES
11 GA. (.120)
COLD ROLLED STEEL
CAST HANDLE (ALUM. ALLOY)
SHELL (.060 CARBON STEEL)
S TUBE - REF
SEE SHT 4
LOCK ASSY (SEE SHT 2)
NAMEPLATE (2) (STEEL)
$\frac{1}{4}$-20 FLAT HD SCREWS
STEEL-CADMIUM PLATED
#10-32 FLAT HD SCREWS (6)
STEEL-CADMIUM PLATED
$9\frac{5}{8}$ REF.
LOCK
OPERATE
CONNECT
SEAL WIRE
CONTROL CONNECTOR ASSY (SEE SHTS 2 & 3)
SASH CHAIN
SOURCE IDENT. LABEL
DANGER
DO NOT REMOVE
$9\frac{7}{8}$ REF.
$12\frac{7}{8}$ REF.
STORAGE PLUG CONNECTOR
BOLT COVER, RIVETED (.036 STAIN. ST)
$4\frac{5}{8}$
CONNECTING RODS (4)
12L14 STEEL
RIGID POLYURETHANE FOAM
STORAGE PLUG ASSY
REINFORCEMENT SLEEVE - REF
SEE SHT 4
MOD. NO. | MAX CAPACITY
660 | 120 Ci
TOTAL WEIGHT - 48 LBS
NOTED
TECHNICAL OPERATIONS INC.
RADIATION PRODUCTS DIVISION
BURLINGTON, MA
MODEL 660 GAMMA RAY PROJECTOR
SHIPPING CONTAINER
DESCRIPTIVE ASSEMBLY
C
66030
SHEET 1 OF 4



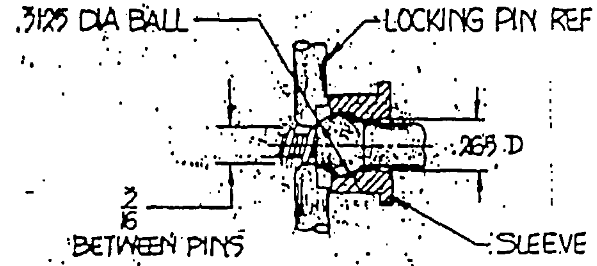
LOCK ASSEMBLY

SECTION C-C

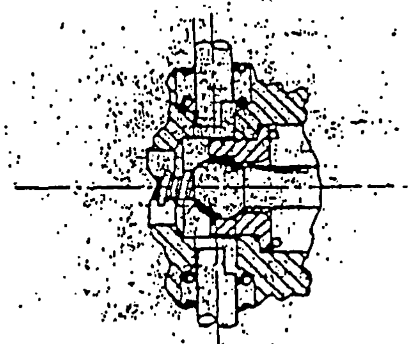
NOTED	TECHNICAL OPERATIONS, INC. RADIATION PRODUCTS DIVISION BURLINGTON, MA
	MODEL 660 GAMMA RAY PROJECTO SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
	C 66030
	SCALE 2:1 SHEET 2 OF 4



SECTION B-B



LOCKED POSITION



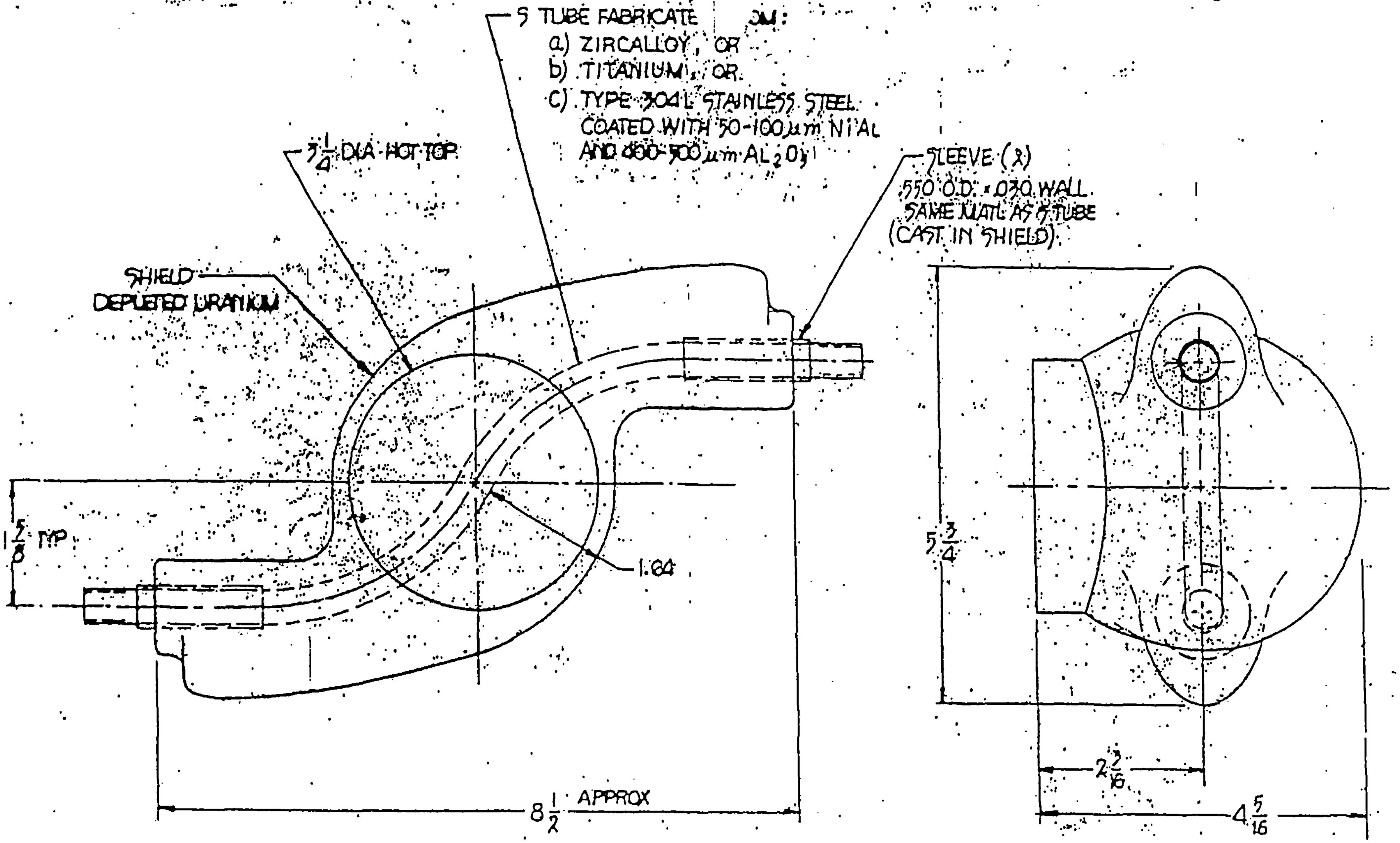
UNLOCKED POSITION

NOTED

MODEL 660 GAMMA RAY PROJECTOR
SHIPPING CONTAINER
DESCRIPTIVE ASSEMBLY

C 66030

SHEET 3 OF 4



SHIELD DATA

35 LBS

AS NOTED	RADIATION PRODUCTS DIVISION, BURLINGTON, MA
	MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
SIZE C	DWG. NO. 66030
SCALE 1:1	SHEET 4 OF 4

Appendix B: Selected Fasteners

The stainless steel screw selected for the end-plate fasteners is 51959-81 as specified in Military Standard 51959, a copy of which is included in this appendix. The item is highlighted on page 2 of the specification.

The toughness versus temperature curve below shows the consistent toughness of stainless steel over a wide range of temperatures. The curve is excerpted from Deutschman, Aaron D, Walter J. Michels, and Charles E. Wilson, *Machine Design: Theory and Practice* (New York: Macmillan Publishing Co., Inc. 1975), page 136.

Low temperature effects

As the temperature is lowered, there is an increase in yield strength, tensile strength, elastic modulus, and hardness and a decrease in ductility for metals such as aluminum and aluminum alloys, nickel alloys, austenitic steels, lead, and copper. Carbon and low alloy steels tend to become embrittled at much higher temperatures than the aforementioned metals. Embrittlement is measured by loss of toughness over a small temperature range (for example, see Section 3.21) when tested by the Charpy or Izod machines. The transition temperature is taken to be that for which the impact energy is reduced by 50% of its ductile value. Figure 3-43 shows some average value curves of toughness (energy in foot-pounds) versus temperature for a variety

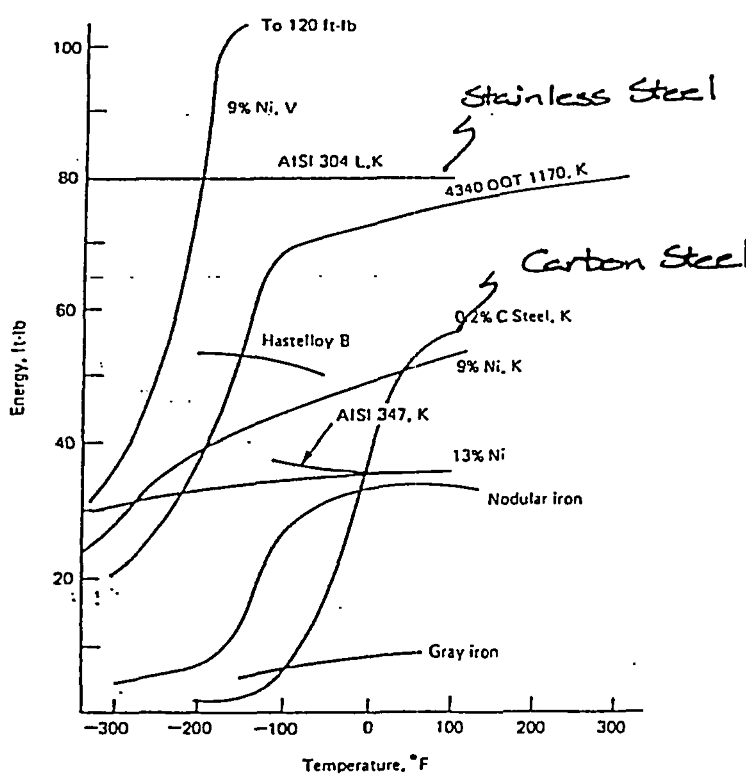


Figure 3-43 Toughness versus temperature for several metals. Note the sharp drop in toughness that takes place within a narrow temperature range. [From V. M. Faires: *Design of Machine Elements*, 4th ed. The Macmillan Company, New York, 1965.]

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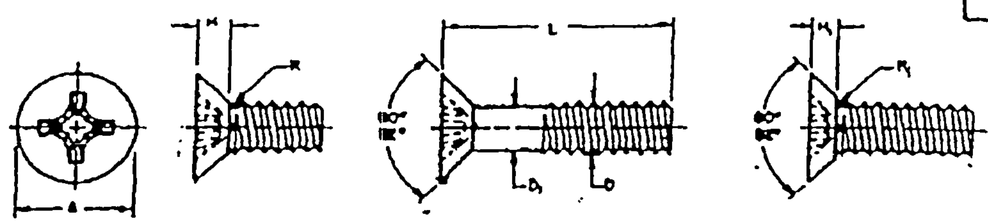

TABLE I

			#2	#4	#6	#8
D NOMINAL SIZE			.0860	.1120	.1380	.1640
THREADS PER INCH			56UNC	40UNC	32UNC	32UNC
D_1 BODY DIAMETER		Max	.0860	.1120	.1380	.1640
		Min	.0727	.0925	.1141	.1399
A HEAD DIAMETER		Max Sharp	.172	.225	.279	.332
		Min Sharp	.156	.207	.257	.308
		Abs Min	.147	.195	.244	.292
H HEAD HEIGHT-FULL HEAD		Ref	.051	.067	.083	.100
H_1 HEAD HEIGHT-UNDERCUT HEAD		Max	.036	.047	.059	.070
		Min	.028	.038	.048	.058
R RADIUS-FULL HEAD		Max	.034	.045	.055	.066
R_1 RADIUS-UNDERCUT HEAD		Max	.013	.017	.021	.025
DRIVER SIZE			1	1	2	2
** MINIMUM TENSILE STRENGTH LOAD LBS.			300	480	730	1,120
L	LENGTH	Tolerance	Dash Number	Dash Number	Dash Number	Dash Number
Threads shall extend to within 2 threads of the bearing surface of the head, or closer if practicable.	1/8		1	11	24	39
	3/16		2	12	25	40
	1/4		3	13	26	41
	5/16		4	14	27	42
	3/8	+0 -1/32	5	15	28	43
	7/16		6	16	29	44
	1/2		7	17	30	45
	5/8		8	18	31	46
	3/4		9	19	32	47
	7/8		10*	20	33	48
	1			21	34	49
	1-1/4			22*	35	50
	1-1/2	+0 -1/16		23*	36	51
	1-3/4				37	52
	2				38	53
Minimum complete thread length of 1-3/4	2-1/4					54*
	2-1/2	+0 -3/32				55*
	2-3/4					56*
	3					57*

* Indicates manufacturer's non-stock production items.

** Based on 80,000 PSI minimum tensile strength. Load pounds are calculated by the stress areas indicated in Screw-Thread Standards for Federal Services, Handbook H-28.

1. MATERIAL: Steel, Corrosion-Resisting in accordance with Fed. Std. No. 66, AISI 302, 303, 304 and 305, or equal to or interchangeable with the 18-8 chrome-nickel alloy steel.
2. PROTECTIVE COATING: Passivated in accordance with QQ-P-35.
   (B) Black oxide coated in accordance with MIL-C-13924, class 4. (When black oxide coating is required the dash number shall be followed by a "B".)
3. MAGNETIC PERMEABILITY: These fasteners have a magnetic permeability of 2.0 maximum (air = 1.0) for a field strength of H = 200 oersteds using a magnetic indicator per MIL-I-17214.
4. THREADS: The threads shall be in accordance with Screw-Thread Standards for Federal Services, Handbook H28.
5. RECESS: The recess shall conform with MS9006.
6. DIMENSIONS: All dimensions are in inches, unless otherwise specified.
7. PART NUMBER: The MS part number consists of the MS number, plus the dash number.
   (B) Example: MS51959-1: Passivated.
   MS51959-1B: Black oxide coated.
8. Referenced documents shall be of the issue in effect on date of invitations for bid.
9. For design feature purposes, this standard takes precedence over procurement documents referenced herein.
10. Sizes above dotted line have undercut head.

(B) For changes see sheet 1.

RETRIEVER: AV, EL, CL, IS, MI, SSA, US, AT, MC, ME, MC, CS, YD
USER:

APPROVED 15 DECEMBER 1963 REVISED (A) 15 OCTOBER 1965 (B) 5 DEC 1968

P.A. WC Other Cust SH, AR	TITLE SCREW, MACHINE-FLAT COUNTERSUNK HEAD, 82°, CROSS-RECESSED, CORROSION RESISTING STEEL, UNC-2A	MILITARY STANDARD MS 51959
PROCUREMENT SPECIFICATION FF-S-92	SUPERSEDES: MS35200 and in part: MS35249, MS35358, MS35363 and AN505	SHEET 1 OF 4

DD FORM 672-1

FED. SUP CLASS
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REVIEWER: AV, EL, CL, ZS, MI, NSA, AS, AT, MC, MC, MC, OS, YD
USER:

TABLE I (CONTINUED)

D NOMINAL SIZE			#10 .1900	1/4 .2500	5/16 .3125	3/8 .3750
THREADS PER INCH			24UNC	20UNC	18UNC	16UNC
D_1 BODY DIAMETER		Max Min	.1900 .1586	.2500 .2127	.3125 .2712	.3750 .3287
A HEAD DIAMETER		Max Sharp Min Sharp Abs Min	.385 .359 .340	.507 .477 .452	.635 .600 .568	.762 .722 .685
H HEAD HEIGHT-FULL HEAD		Ref	.116	.153	.191	.230
H_1 HEAD HEIGHT-UNDERCUT HEAD		Max Min	.081 .068	.107 .092	.134 .116	.161 .140
R RADIUS-FULL HEAD		Max	.074	.100	.125	.150
R_1 RADIUS-UNDERCUT HEAD		Max	.029	.038	.047	.056
DRIVER SIZE			2	3	4	4
** MINIMUM TENSILE STRENGTH LOAD LBS.			1,400	2,540	4,190	6,700
L	LENGTH	Tolerance	Dash Number	Dash Number	Dash Number	Dash Number
Threads shall extend to within 2 threads of the bearing surface of the head, or closer if practicable.	1/8	+0 -1/32				
	3/16		58*			
	1/4		59			
	5/16		60	76		
	3/8		61	77	92	
	7/16		62	78	93	
	1/2		63	79	94	107
	5/8		64	80	95	108
	3/4		65	81	96	109
	7/8		66	82	97	110
	1		67	83	98	111
	1-1/4	+0 -1/16	68	84	99	112
	1-1/2		69	85	100	113
	1-3/4		70	86	101	114
	2		71	87	102	115
Minimum complete thread length of 1-3/4	2-1/4		72	88	103	116
	2-1/2	+0 -3/32	73	89	104	117
	2-3/4		74*	90*	105*	118
	3		75*	91*	106*	119

* Indicates manufacturer's non-stock production items.
** Based on 80,000 PSI minimum tensile strength. Load pounds are calculated by the stress areas indicated in Screw-Thread Standards for Federal Services, Handbook H-28.
NOTE: For illustration, material, treatment, and other pertinent data, see sheet 3.

APPROVED 19 DECEMBER 1963 REVISED (A) 15 OCT 1965 (B) FOR CHANGES SEE SHEET 1.

P.A. VC Other Cust SH 82	TITLE SCREW, MACHINE-FLAT COUNTERSUNK HEAD, 82°, CROSS-RECESSED, CORROSION RESISTING STEEL, UNC-2A	MILITARY STANDARD MS 51959
PROCUREMENT SPECIFICATION FF-S-92	SUPERSEDES: MS35200 and in part: MS35249, MS35358, MS35363 and AN505	SHEET 2 OF

DD FORM 672-1 (Continued)

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

FED. SUP CLASS 5305

TABLE II
INTERCHANGEABILITY TABLE

The screws covered by dash numbers given MS35200 and in part MS35249 and AN505 are cancelled/inactivated after the dates indicated on the documents. Use the dash numbers given in the preceding sheets for nominal sizes thru 3/8 inch, and MS24671 for larger sizes. The cancelled screws cannot always replace the new screws and should be used until existing stocks are depleted. Use only the new screws for design and replacement. Replacement shall be in accordance with this table and MS24671.

CROSS REFERENCE OF PART NUMBERS

CANCELLED				NEW
MS35249	MS35200	AN505		MS51959
Dash Number				Dash Number
1				No Replacement
2				No Replacement
3				No Replacement
4				No Replacement
5				No Replacement
6				No Replacement
7				No Replacement
8	1			1
9	2	C2R3	C2-3	2
10	3	C2R4	C2-4	3
11	4	C2R5	C2-5	4
12	5	C2R6	C2-6	5
13	6	C2R7	C2-7	6
14	7	C2R8	C2-8	7
		C2R9	C2-9	No Replacement
15	8	C2R10	C2-10	8
		C2R11	C2-11	No Replacement
16	9	C2R12	C2-12	9
17				10
		C3R3	C3-3	No Replacement
		C3R4	C3-4	No Replacement
		C3R5	C3-5	No Replacement
		C3R6	C3-6	No Replacement
		C3R7	C3-7	No Replacement
		C3R8	C3-8	No Replacement
		C3R9	C3-9	No Replacement
		C3R10	C3-10	No Replacement
		C3R11	C3-11	No Replacement
		C3R12	C3-12	No Replacement
		C3R13	C3-13	No Replacement
		C3R14	C3-14	No Replacement
		C3R15	C3-15	No Replacement
		C3R16	C3-16	No Replacement
18	10			11
19	11	C4R3	C4-3	12
20	12	C4R4	C4-4	13
21	13	C4R5	C4-5	14
22	14	C4R6	C4-6	15
23	15	C4R7	C4-7	16
24	16	C4R8	C4-8	17
		C4R9	C4-9	No Replacement
25	17	C4R10	C4-10	18
		C4R11	C4-11	No Replacement
26	18	C4R12	C4-12	19
		C4R13	C4-13	No Replacement
27	19	C4R14	C4-14	20
		C4R15	C4-15	No Replacement
28	20	C4R16	C4-16	21
		C4R18	C4-18	No Replacement
29		C4R20	C4-20	22
		C4R22	C4-22	No Replacement
30		C4R24	C4-24	23
		C5R3	C5-3	No Replacement
		C5R4	C5-4	No Replacement
		C5R5	C5-5	No Replacement
		C5R6	C5-6	No Replacement
		C5R7	C5-7	No Replacement
		C5R8	C5-8	No Replacement
		C5R9	C5-9	No Replacement
		C5R10	C5-10	No Replacement
		C5R11	C5-11	No Replacement
		C5R12	C5-12	No Replacement
		C5R13	C5-13	No Replacement

CANCELLED				NEW
MS35249	MS35200	AN505		MS51959
Dash Number				Dash Number
		C5R14	C5-14	No Replacement
		C5R15	C5-15	No Replacement
		C5R16	C5-16	No Replacement
		C5R18	C5-18	No Replacement
		C5R20	C5-20	No Replacement
		C5R22	C5-22	No Replacement
		C5R24	C5-24	No Replacement
31	21			24
32	22	C6R3	C6-3	25
33	23	C6R4	C6-4	26
34	24	C6R5	C6-5	27
35	25	C6R6	C6-6	28
36	26	C6R7	C6-7	29
37	27	C6R8	C6-8	30
		C6R9	C6-9	No Replacement
38	28	C6R10	C6-10	31
		C6R11	C6-11	No Replacement
39	29	C6R12	C6-12	32
		C6R13	C6-13	No Replacement
40	30	C6R14	C6-14	33
		C6R15	C6-15	No Replacement
41	31	C6R16	C6-16	34
		C6R18	C6-18	No Replacement
42	32	C6R20	C6-20	35
		C6R22	C6-22	No Replacement
43	33	C6R24	C6-24	36
		C6R26	C6-26	No Replacement
44	34	C6R28	C6-28	37
		C6R30	C6-30	No Replacement
45	35	C6R32	C6-32	38
		C6R34	C6-34	No Replacement
		C6R36	C6-36	No Replacement
		C6R38	C6-38	No Replacement
		C6R40	C6-40	No Replacement
		C6R42	C6-42	No Replacement
		C6R44	C6-44	No Replacement
		C6R46	C6-46	No Replacement
		C6R48	C6-48	No Replacement
46	36			39
47	37			40
48	38	C8R4	C8-4	41
49	39	C8R5	C8-5	42
50	40	C8R6	C8-6	43
51	41	C8R7	C8-7	44
52	42	C8R8	C8-8	45
		C8R9	C8-9	No Replacement
53	43	C8R10	C8-10	46
		C8R11	C8-11	No Replacement
54	44	C8R12	C8-12	47
		C8R13	C8-13	No Replacement
55	45	C8R14	C8-14	48
		C8R15	C8-15	No Replacement
56	46	C8R16	C8-16	49
		C8R18	C8-18	No Replacement
57	47	C8R20	C8-20	50
		C8R22	C8-22	No Replacement
58	48	C8R24	C8-24	51
		C8R26	C8-26	No Replacement
59	49	C8R28	C8-28	52
		C8R30	C8-30	No Replacement
60	50	C8R32	C8-32	53
		C8R34	C8-34	No Replacement
61		C8R36	C8-36	54

(Continued on Sheet 4)

REVIEWER: AV, EL, CL, IS, MI, SSA, YD
USER: AS, AT, KC, MC, MC, OS

APPROVED 19 DECEMBER [illegible] REVISED (A) 15 OCT 1965 (B) FOR CHANGES SEE SHEET 4

P.A. VC
Other Cust SH 82

TITLE
SCREW, MACHINE-FLAT COUNTERSUNK HEAD, 82°, CROSS-RECESSED, CORROSION RESISTING STEEL, UNC-2A

MILITARY STANDARD
MS 51959

PROCUREMENT SPECIFICATION FF-S-92

SUPERSEDES: MS35200 and in part: MS35249, MS35358, MS35363 and AN505

SHEET 3 OF

FED. SUP CLASS
5305

TABLE II (CONTINUED)

INTERCHANGEABILITY TABLE (CONTINUED)

CROSS REFERENCE OF PART NUMBERS

CANCELLED				NEW
MS35249	MS35200	AN505		MS51959
Dash Number				Dash Number
		C8R38	C8-38	No Replacement
62		C8R40	C8-40	55
		C8R42	C8-42	No Replacement
63		C8R44	C8-44	55
		C8R46	C8-46	No Replacement
64		C8R48	C8-48	57
65				58
66	51			59
67	52	C10R5	C10-5	60
68	53	C10R6	C10-6	61
69	54	C10R7	C10-7	62
70	55	C10R8	C10-8	63
		C10R9	C10-9	No Replacement
71	56	C10R10	C10-10	64
		C10R11	C10-11	No Replacement
72	57	C10R12	C10-12	65
		C10R13	C10-13	No Replacement
73	58	C10R14	C10-14	66
		C10R15	C10-15	No Replacement
74	59	C10R16	C10-16	67
		C10R18	C10-18	No Replacement
75	60	C10R20	C10-20	68
		C10R22	C10-22	No Replacement
76	61	C10R24	C10-24	69
		C10R26	C10-26	No Replacement
77	62	C10R28	C10-28	70
		C10R30	C10-30	No Replacement
78	63	C10R32	C10-32	71
		C10R34	C10-34	No Replacement
79	64	C10R36	C10-36	72
		C10R38	C10-38	No Replacement
80	65	C10R40	C10-40	73
		C10R42	C10-42	No Replacement
81		C10R44	C10-44	74
		C10R46	C10-46	No Replacement
82		C10R48	C10-48	75
83	66	C416R5	C416-5	76
84	67	C416R6	C416-6	77
85	68	C416R7	C416-7	78
86	69	C416R8	C416-8	79
		C416R9	C416-9	No Replacement
87	70	C416R10	C416-10	80
		C416R11	C416-11	No Replacement
88	71	C416R12	C416-12	81
		C416R13	C416-13	No Replacement
89	72	C416R14	C416-14	82
		C416R15	C416-15	No Replacement
90	73	C416R16	C416-16	83
		C416R18	C416-18	No Replacement
91	74	C416R20	C416-20	84
		C416R22	C416-22	No Replacement
92	75	C416R24	C416-24	85
		C416R26	C416-26	No Replacement
93	76	C416R28	C416-28	86
		C416R30	C416-30	No Replacement
94	77	C416R32	C416-32	87
		C416R34		No Replacement
95	78	C416R36		88
		C416R38		No Replacement

CANCELLED				NEW
MS35249	MS35200	AN505		MS51959
Dash Number				Dash Number
96	79	C416R40	C416-40	89
		C416R42	C416-42	No Replacement
97		C416R44	C416-44	90
		C416R46	C416-46	No Replacement
98		C416R48	C416-48	91
99	80			92
100	81			93
101	82	C516R8	C516-8	94
		C516R9	C516-9	No Replacement
102	83	C516R10	C516-10	95
		C516R11	C516-11	No Replacement
103	84	C516R12	C516-12	96
		C516R13	C516-13	No Replacement
104	85	C516R14	C516-14	97
		C516R15	C516-15	No Replacement
105	86	C516R16	C516-16	98
		C516R18	C516-18	No Replacement
106	87	C516R20	C516-20	99
		C516R22	C516-22	No Replacement
107	88	C516R24	C516-24	100
		C516R26	C516-26	No Replacement
108	89	C516R28	C516-28	101
		C516R30	C516-30	No Replacement
109	90	C516R32	C516-32	102
		C516R34	C516-34	No Replacement
110	91	C516R36	C516-36	103
		C516R38	C516-38	No Replacement
111	92	C516R40	C516-40	104
		C516R42	C516-42	No Replacement
112		C516R44	C516-44	105
		C516R46	C516-46	No Replacement
113		C516R48	C516-48	106
114	93	C616R8	C616-8	107
		C616R9	C616-9	No Replacement
115	94	C616R10	C616-10	108
		C616R11	C616-11	No Replacement
116	95	C616R12	C616-12	109
		C616R13	C616-13	No Replacement
117	96	C616R14	C616-14	110
		C616R15	C616-15	No Replacement
118	97	C616R16	C616-16	111
		C616R18	C616-18	No Replacement
119	98	C616R20	C616-20	112
		C616R22	C616-22	No Replacement
120	99	C616R24	C616-24	113
		C616R26	C616-26	No Replacement
121	100	C616R28	C616-28	114
		C616R30	C616-30	No Replacement
122	101	C616R32	C616-32	115
		C616R34	C616-34	No Replacement
123	102	C616R36	C616-36	116
		C616R38	C616-38	No Replacement
124	103	C616R40	C616-40	117
		C616R42	C616-42	No Replacement
125	104	C616R44	C616-44	118
		C616R46	C616-46	No Replacement
126	105	C616R48	C616-48	119
127 thru 138				*Use MS24671

* Diameters over 3/8" covered by MS24671.

APPROVED 19 DECEMBER 1963 REVISED (A) 15 OCT 1965 (C) FOR CHANGES SEE SHEET 1

P.A. VC Other Cust SH F2	TITLE SCREW, MACHINE-FLAT COUNTERSUNK HEAD, 82°, CROSS-RECESSED, CORROSION RESISTING STEEL, UNC-2A	MILITARY STANDARD MS 51959
PROCUREMENT SPECIFICATION FF-S-92	SUPERSEDES: MS35200 and in part: MS35249, MS35354, MS35363 and AN505	SHEET 4 OF

DD FORM 672-1 (Continued)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1964 341-514/A-3540

Appendix C: Referenced Materials

The following is an excerpt from Avallone, Eugene A., and Theodore Baumeister III, Editors, *Marks' Standard Handbook for Mechanical Engineers*, Ninth Edition (New York: McGraw-Hill Book Company, 1987), page 4-27.

Table 4.1.5 Approximate Inversion-Curve Locus for Air

p, bar	0	25	50	75	100	125	150	175	200	225
T_L, K	(112)*	114	117	120	124	128	132	137	143	149
T_U, K	653	641	629	617	606	594	582	568	555	541
p, bar	250	275	300	325	350	375	400	425	432	
T_L, K	156	164	173	184	197	212	230	265	300	
T_U, K	526	509	491	470	445	417	386	345	300	

*Hypothetical low-pressure limit.

Loss Due to Throttling A throttling process in a cycle of operations always introduces a loss of efficiency. If T_0 is the temperature corresponding to the back pressure, the loss of available energy is the product of T_0 and the increase of entropy during the throttling process. The following example illustrates the calculation in the case of ammonia passing through the expansion valve of a refrigerating machine.

EXAMPLE. The liquid ammonia at a temperature of 70°F passes through the valve into the brine coil in which the temperature is 20 deg and the pressure is 48.21 psia. The initial enthalpy of the liquid ammonia is $h_{f1} = 120.5$, and therefore the final enthalpy is $h_{f2} + x_2 h_{fg2} = 64.7 + 553.1 x_2 = 120.5$, whence $x_2 = 0.101$. The initial entropy is $s_{f1} = 0.254$. The final entropy is $s_{f2} + (x_2 h_{fg2}/T_2) = 0.144 + 0.101 \times 1.153 = 0.260$. $T_0 = 20 + 460 = 480$; hence the loss of refrigerating effect is $480 \times (0.260 - 0.254) = 2.9$ Btu.

COMBUSTION

REFERENCES: Chigier, "Energy, Combustion and Environment," McGraw-Hill, 1981. Campbell, "Thermodynamic Analysis of Combustion Engines," Wiley, 1979. Glassman, "Combustion," Academic Press, New York, 1977. Lefebvre, "Gas Turbine Combustion," McGraw-Hill, New York, 1983. Strehlow, "Combustion Fundamentals," McGraw-Hill, New York, 1984. Williams et al., "Fundamental Aspects of Solid Propellant Rockets," *Agardograph*, 116, Oct. 1969. Basic thermodynamic table type information needed in this area is found in Glushko et al., "Thermodynamic and Thermophysical Properties of Combustion Products," Moscow, and IPST translation; Gordon, NASA Technical Paper 1906, 1982; "JANAF Thermochemical Tables," NSRDS-NBS-37, 1971.

Fuels For special properties of various fuels, see Sec. 7. In general, fuels may be classed under three heads: (1) gaseous fuels, (2) liquid fuels, and (3) solid fuels.

The combustible elements that characterize fuels are carbon, hydrogen, and, in some cases, sulphur. The complete combustion of carbon gives, as a product, carbon dioxide, CO_2; the combustion of hydrogen gives water, H_2O.

Combustion of Gaseous and Liquid Fuels

Combustion Equations The approximate molecular weights of the important elements and compounds entering into combustion calculations are:

Material	C	H_2	O_2	N_2	CO	CO_2	H_2O	CH_4	C_2H_4	C_2H_6O	S	NO	NO_2	SO_2
Molecular weight	12	2	32	28	28	44	18	16	28	46	32	30	46	64

For the elements C and H, the equations of complete combustion are

$$\begin{cases} C + O_2 = CO_2 & H_2 + \tfrac{1}{2}O_2 = H_2O \\ 12\text{ lb} + 32\text{ lb} = 44\text{ lb} & 2\text{ lb} + 16\text{ lb} = 18\text{ lb} \end{cases}$$

For a combustible compound, as CH_4, the equation may be written

$$CH_4 + x \cdot O_2 = y \cdot CO_2 + z \cdot H_2O$$

Taking, as a basis, 1 molecule of CH_4 and making a balance of the atoms on the two sides of the equation, it is seen that

$$y = 1 \qquad z = 2 \qquad 2x = 2y + z \qquad \text{or} \qquad x = 2$$

Hence,

$$\begin{cases} CH_4 + 2O_2 = CO_2 + 2H_2O \\ 16\text{ lb} + 64\text{ lb} = 44\text{ lb} + 36\text{ lb} \end{cases}$$

The coefficients in the combustion equation give the combining volumes of the gaseous components. Thus, in the last equation 1 ft³ of CH_4 requires for combustion 2 ft³ of oxygen and the resulting gaseous products of combustion are 1 ft³ of CO_2 and 2 ft³ of H_2O. The coefficients multiplied by the corresponding molecular weights give the combining weights. These are conveniently referred to 1 lb of the fuel. In the combustion of CH_4, for example, 1 lb of CH_4 requires $64/16 = 4$ lb of oxygen for complete combustion and the products are $44/16 = 2.75$ lb of CO_2 and $36/16 = 2.25$ lb of H_2O.

Air Required for Combustion The composition of air is approximately 0.232 O_2 and 0.768 N_2 on a pound basis, or 0.21 O_2 and 0.79 N_2 by volume. For exact analyses, it may be necessary sometimes to take account of the water vapor mixed with the air, but ordinarily this may be neglected.

The minimum amount of air required for the combustion of 1 lb of a fuel is the quantity of oxygen required, as found from the combustion equation, divided by 0.232. Likewise, the minimum volume of air required for the combustion of 1 ft³ of a fuel gas is the volume of oxygen divided by 0.21. For example, in the combustion of CH_4 the air required per pound of CH_4 is $4/0.232 = 17.24$ lb and the volume of air per cubic foot of CH_4 is $2/0.21 = 9.52$ ft³. Ordinarily, more air is provided than is required for complete combustion. Let a denote the minimum amount required and xa the quantity of air admitted; then $x - 1$ is the excess coefficient.

Products of Combustion The products arising from the complete combustion of a fuel are CO_2, H_2O, and, if sulphur is present, SO_2. Accompanying these are the nitrogen brought in with the air and the oxygen in the excess of air. Hence the products of complete combustion are principally CO_2, H_2O, N_2, and O_2. The presence of CO indicates incomplete combustion. In simple calculations the reaction of nitrogen with oxygen to form noxious oxides, often termed NO_x, such as nitric oxide (NO), nitrogen peroxide (NO_2), etc., is neglected. In practice, an automobile engine is run at a lower compression ratio to reduce NO_x formation. The reduced pollution is bought at the

Specimen S1 Serial #B3591

Equipment List 1: 30-foot Free Drop

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface, Drawing AT10122, Rev. B	01	SEE ATTACH
Weight Scale	OHAUS / 35014	SEE ATTACH
Thermometer	OMEGA / ENG-12	SEE ATTACH
Thermocouple flexible probe	OMEGA / ENG-11	SEE ATTACH
Thermocouple surface probe	OMEGA / ENG-13	SEE ATTACH
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
THERMOCOUPLE STRAIGHT PROBE	OMEGA / ENG-14	SEE ATTACH
Verified by:	Signature	Date
Engineering	S. Grani	12 JAN 98
Regulatory Affairs	L. [illegible]	12 Jan 98
Quality Assurance	K. [illegible]	12-Jan 98

Checklist 1: 30-foot Free Drop

Test Location: VALLEY TREE GROVELAND MA **Attempt Number:** 1

Step	Specimen A (Serial # B3591, S1)	Specimen B	Specimen C	Specimen D
1. Measure and record test specimen's weight.	DW 8 JAN 98	N/A	N/A	N/A
Record the specimen's weight:	54.5 lbs			
Note the instrument used:	35014	35014	35014	35014
2. Immerse the test specimen in dry ice as needed to bring specimen temperature below -40° C.	DW 8 JAN 98			
Steps 1 through 2 witnessed by:				
Engineering	SD 12 JAN 98			
Regulatory Affairs	LP 12 Jan 98			
Quality Assurance	KAA 12 Jan 98			
3. Measure the ambient temperature.	DW 8 JAN 98			
Record ambient temperature:	36.9° F			
Note the instrument used:	ENG-12 / ENG-14	ENG-12 / ENG-14	ENG-12 / ENG-14	ENG-12 / ENG-14
4. Attach the test specimen to the release mechanism.	DW 8 JAN 98			
5. Begin video recording of test so that the impact is recorded.	DW 8 JAN 98			
6. Measure the temperature of the specimen. Ensure that the specimen is below -40° C.	DW 8 JAN 98			
Record the specimen's internal temperature:	-71.4° C			
Note the instrument used:	ENG-12 / ENG-11	ENG-12 / ENG-11	ENG-12 / ENG-11	ENG-12 / ENG-11
Record the specimen's surface temperature.	-64.7° C			
Note the instrument used:	ENG-12 / ENG-13	ENG-12 / ENG-13	ENG-12 / ENG-13	ENG-12 / ENG-13
7. Lift and orient the test specimen as shown in the referenced figure for the specimen.	Figure 6 on Page 14	Figure 7 on Page 15	Figure 6 on Page 14	Figure 7 on Page 15
8. Inspect the orientation setup and verify the drop height.	DW 8 JAN 98			
9. Photograph the setup in at least two perpendicular planes.	DW 8 JAN 98			

Checklist 1: 30-foot Free Drop (Continued)

Test Location: GROVELAND, MA. **Attempt Number:** 1

Step	Specimen A S1	Specimen B	Specimen C	Specimen D
Steps 3 through 9 witnessed by:		N/A	N/A	N/A
Engineering	12 JAN 98			
Regulatory Affairs	12 Jan 98			
Quality Assurance	KNA 12 Jan 98			
10. Release the test specimen.	DW 8 JAN 98			
11. Measure the surface temperature of the test specimen.	DW 8 JAN 98			
Record the surface temperature:	-39.6 °C			
Note the instrument used:	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13
12. Measure and record the test specimen's weight.	DW 8 JAN 98			
Record the specimen's weight:	54.5 lbs			
Note the instrument used:	35014	35014	35014	35014
13. Pause the video recorder. Ensure that the point of impact and orientation specified in the plan have been achieved and recorded.	DW 8 JAN 98			
14. Record damage to test specimen on a separate sheet and attach.	DW 8 JAN 98			
Steps 10 through 14 witnessed by:				
Engineering	12 JAN 98			
Regulatory Affairs	12 Jan 98			
Quality Assurance	KNA 12 Jan 98			

Checklist 1: 30-foot Free Drop (Continued)

Test Location: GROVELAND, MA. Attempt Number: 1

Step	Specimen A	Specimen B	Specimen C	Specimen D
15. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes are necessary in package orientation for the puncture test to achieve maximum damage.	See attached	N/A	N/A	N/A

Test Data Accepted by (Signature):		Date:
Engineering	S. Gran	18 FEB 98
Regulatory Affairs	[signature]	22 Jan 98
Quality Assurance	C. [signature]	18 Feb 98

Serial #B3591

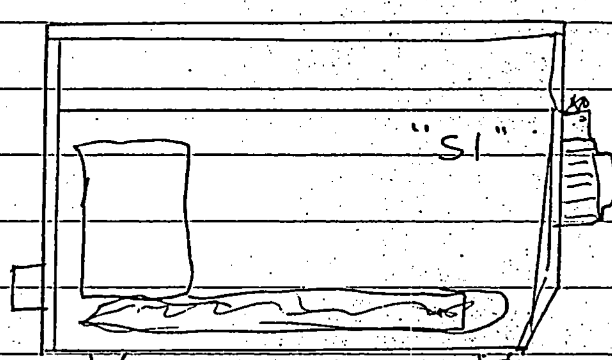
30 FOOT FREE DROP. (JO) 9 JAN 97

SPECIMEN "A" ORIENTATION S1: HIT ON ANGLE REAR END PLATE BOTTOM RIGHT SIDE

DENTED IN 35°

.165 GAP BETWEEN SHELL & REAR END PLATE

FRONT NUT WILL NOT ROTATE



(KNA) 14 Jan 98

ASSESSMENT: S1, 30 FOOT FREE DROP.

TEST EXECUTED PER TEST PLAN #74, therefore it was performed in accordance with 10 CFR 71.

Drop ~~[illegible]~~ (SJ) 14 FEB 98 missed impact hit orientation.

Based on damage and missed hit, the Group agreed to not proceed to next ~~TESTS~~ (SJ) 18 FEB 98 TESTS.

(SJ) 18 FEB 98

Equipment List 1: 30-foot Free Drop

Specimen S2 Serial#B35

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface, Drawing AT10122, Rev. B	01	SEE ATTACH
Weight Scale	35014	SEE ATTACH
Thermometer	ENG-12	SEE ATTACH
Thermocouple flexible probe	ENG-11	SEE ATTACH
Thermocouple surface probe	ENG-13	
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
THERMOCOUPLE STRAIGHT PROBE	ENG-14	SEE ATTACH
Verified by:	Signature	Date
Engineering	[signature]	14 Jan 98
Regulatory Affairs	[signature]	12 Jan 98
Quality Assurance	[signature]	12 Jan 98

Checklist 1: 30-foot Free Drop

Test Location: VALLEY TREE GROVELAND MA

Attempt Number: 1

Step	Specimen A (MB 24Dec97) Spec S 2 DW	Specimen B	Specimen C	Specimen D
1. Measure and record test specimen's weight.	DW 24 DEC 97	NA	NA	NA
Record the specimen's weight:	55.5 lb			
Note the instrument used:	35014	35014	35014	35014
2. Immerse the test specimen in dry ice as needed to bring specimen temperature below -40° C.	DW 24 DEC 97			
Steps 1 through 2 witnessed by:				
Engineering	[signature] 14 Jan 98			
Regulatory Affairs	[signature] 12 Jan 98			
Quality Assurance	KMA 12 Jan 98			
3. Measure the ambient temperature.	24 Dec 97 MB			
Record ambient temperature:	35.6° F			
Note the instrument used:	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14
4. Attach the test specimen to the release mechanism.	DW 24 DEC 97			
5. Begin video recording of test so that the impact is recorded.	DW 24 DEC 97			
6. Measure the temperature of the specimen. Ensure that the specimen is below -40° C.	24 Dec 97 MB			
Record the specimen's internal temperature:	-65.6° C			
Note the instrument used:	~~ENG-12~~ ENG-11	~~ENG-12~~ ENG-11	~~ENG-12~~ ENG-11	~~ENG-12~~ ENG-11
Record the specimen's surface temperature.	-57.1° C			
Note the instrument used:	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13
7. Lift and orient the test specimen as shown in the referenced figure for the specimen.	Figure 6 on Page 14	Figure 7 on Page 15	Figure 6 on Page 14	Figure 7 on Page 15
8. Inspect the orientation setup and verify the drop height.	DW 24 DEC 97			
9. Photograph the setup in at least two perpendicular planes.	DW 24 DEC 97			

Equipment List 1: 30-foot Free Drop

Specimen D Serial #B3590

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface, Drawing AT10122, Rev. B	01	SEE ATTACH
Weight Scale	35014	SEE ATTACH
Thermometer	ENG-12	SEE ATTACH
Thermocouple flexible probe	ENG-11	SEE ATTACH
Thermocouple surface probe	ENG-13	
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
THERMOCOUPLE STRAIGHT PROBE	ENG-14	SEE ATTACH

Verified by:	Signature	Date
Engineering	[signature]	14 Jan 98
Regulatory Affairs	[signature]	12 Jan 98
Quality Assurance	[signature]	12 Jan 98

Checklist 1: 30-foot Free Drop

Test Location: VALLEY TREE GROVELAND MA

Attempt Number: 2nd

Step	Specimen A	Specimen B	Specimen C	Specimen D (Serial #B2590)
1. Measure and record test specimen's weight.	NA	NA	NA	24 Dec 97 MBB
Record the specimen's weight:				54.84 lb
Note the instrument used:	35014	35014	35014	35014
2. Immerse the test specimen in dry ice as needed to bring specimen temperature below -40° C.				DW 24 DEC 97
Steps 1 through 2 witnessed by:				
Engineering				[illegible] Jan 98
Regulatory Affairs				[illegible] 12 Jan 98
Quality Assurance				KNA 12 Jan 98
3. Measure the ambient temperature.				24 Dec 97 MBB
Record ambient temperature:				38.6° F
Note the instrument used:	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14
4. Attach the test specimen to the release mechanism.				DW 24 DEC 97
5. Begin video recording of test so that the impact is recorded.				DW 24 DEC 97
6. Measure the temperature of the specimen. Ensure that the specimen is below -40° C.				24 Dec 97 MBB
Record the specimen's internal temperature:				-72.5° C
Note the instrument used:	~~ENG-12~~ ENG-11	~~ENG-12~~ ENG-11	~~ENG-12~~ ENG-11	~~ENG-12~~ ENG-11
Record the specimen's surface temperature.				-56.3° C
Note the instrument used:	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13
7. Lift and orient the test specimen as shown in the referenced figure for the specimen.	Figure 6 on Page 14	Figure 7 on Page 15	Figure 6 on Page 14	Figure 7 on Page 15
8. Inspect the orientation setup and verify the drop height.				DW 24 DEC 97
9. Photograph the setup in at least two perpendicular planes.				DW 24 DEC 97

Checklist 1: 30-foot Free Drop (Continued)

Test Location: GROVELAND, MA. Attempt Number: 2

Step	Specimen A		Specimen B		Specimen C		Specimen D
Steps 3 through 9 witnessed by:		NA		NA		NA	
Engineering							[signature] 14 Jan 98
Regulatory Affairs							[signature] 12 Jan 98
Quality Assurance							KNA 12 Jan 98
10. Release the test specimen.							[initials] 24 DEC 97
11. Measure the surface temperature of the test specimen.							24 Dec 97 [initials]
Record the surface temperature:							-48.3°C
Note the instrument used:	ENG-12 ENG-13		ENG-12 ENG-13		ENG-12 ENG-13		ENG-12 ENG-13
12. Measure and record the test specimen's weight.							24 Dec 97 [initials]
Record the specimen's weight:							53.75 lb
Note the instrument used:	35014		35014		35014		35014
13. Pause the video recorder. Ensure that the point of impact and orientation specified in the plan have been achieved and recorded.							[initials] 24 DEC 97
14. Record damage to test specimen on a separate sheet and attach.							[initials] 24 DEC 97
Steps 10 through 14 witnessed by:							
Engineering							[signature] 14 Jan 98
Regulatory Affairs							[signature] 12 Jan 98
Quality Assurance							KNA 12 Jan 98

Specimen A Serial# B3587
B #B3588
C #B3589
D #B35

Equipment List 1: 30-foot Free Drop

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface, Drawing AT10122, Rev. B	01	See Attach.
Weight Scale	35014	See Attach.
Thermometer	ENG-12	See Attach.
Thermocouple flexible probe	ENG-11	See Attach.
Thermocouple surface probe	ENG-13	
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
Thermocouple Straigt Probe	ENG-14	See Attach.

Verified by:	Signature	Date
Engineering	[signature]	14 Jan 98
Regulatory Affairs	[signature]	12 Jan 98
Quality Assurance	[signature]	12 Jan 98

Checklist 1: 30-foot Free Drop

Test Location: Valley Tree Groveland MA **Attempt Number:** 1

Step (Serial #)	#3587 Specimen A	#3588 Specimen B	#3589 Specimen C	#3590 Specimen D
1. Measure and record test specimen's weight.	23 Dec 97 MAB	24 Dec 97 MAB	23 Dec 97 MAB	24 Dec 97 MAB
Record the specimen's weight:	55.20 lb	54.90 lb	55.60 lb	54.85 lb
Note the instrument used:	35014	35014	35014	35014
2. Immerse the test specimen in dry ice as needed to bring specimen temperature below -40° C.	DW 23 DEC 97	DW 24 DEC 97	DW 23 DEC 97	DW 24 DEC 97
Steps 1 through 2 witnessed by:				
Engineering	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98
Regulatory Affairs	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98
Quality Assurance	KNA 12 Jan 98	KNA 12 Jan 98	KNA 12 Jan 98	KNA 12 Jan 98
3. Measure the ambient temperature.	23 Dec 97 MAB	24 Dec 97 MAB	23 Dec 97 MAB	24 Dec 97 MAB
Record ambient temperature:	32.2°F	35.4°F	35.1°F	38.6°F
Note the instrument used:	ENG 12 ENG 114	ENG 12 ENG 14	ENG 12 ENG 14	ENG 12 ENG 14
4. Attach the test specimen to the release mechanism.	DW 23 DEC 97	DW 24 DEC 97	DW 23 DEC 97	DW 24 DEC 97
5. Begin video recording of test so that the impact is recorded.	DW 23 DEC 97	DW 24 DEC 97	DW 23 DEC 97	DW 24 DEC 97
6. Measure the temperature of the specimen. Ensure that the specimen is below -40° C.	DW 23 DEC 97	24 Dec 97 MAB	DW 23 DEC 97	24 Dec 97 MAB
Record the specimen's internal temperature:	-74.1°C	-54.6°C	-71.6°C (*)	-72.5°C
Note the instrument used:	ENG 12 ENG 11	ENG 12 ENG 11	ENG 12 ENG 11	ENG 12 ENG 11
Record the specimen's surface temperature.	-52.9°C	-56.9°C	-70.6°C	-67.5°C
Note the instrument used:	ENG 12 ENG 13	ENG 12 ENG 13	ENG 12 ENG 13	ENG 12 ENG 13
7. Lift and orient the test specimen as shown in the referenced figure for the specimen.	Figure 6 on Page 14	Figure 7 on Page 15	Figure 6 on Page 14	Figure 7 on Page 15
8. Inspect the orientation setup and verify the drop height.	DW 23 DEC 97	DW 24 DEC 97	DW 23 DEC 97	DW 24 DEC 97
9. Photograph the setup in at least two perpendicular planes.	23 Dec 97 MAB	24 Dec 97 MAB	23 Dec 97 MAB	DW 24 DEC 97

(*) KNA for M [illegible] 12 Jan

Checklist 1: 30-foot Free Drop (Continued)

Test Location: VALLEY TREE GROVELAND MA **Attempt Number:** 1

Step	Specimen A	Specimen B	Specimen C	Specimen D
Steps 3 through 9 witnessed by:				
Engineering	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98
Regulatory Affairs	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98
Quality Assurance	KNA 12 Jan 98	KNA 12 Jan 98	KNA 12 Jan 98	KNA 12 Jan 98
10. Release the test specimen.				
11. Measure the surface temperature of the test specimen.	DW 23 DEC 97	24 Dec 97 MAB	DW 23 DEC 97	24 Dec 97 MAB
Record the surface temperature:	-44.2°C	-54.9°C	-42.6°C	-60.0°C
Note the instrument used:	ENG 12 ENG 13	ENG 12 ENG 13	ENG 12 ENG 13	ENG 12 ENG 13
12. Measure and record the test specimen's weight.	DW 23 DEC 97	24 Dec 97 MAB	DW 23 DEC 97	24 Dec 97 MAB
Record the specimen's weight:	55.25 lb	54.50 lb	55.50 lb	54.84 lb
Note the instrument used:	35014	35014	35014	35014
13. Pause the video recorder. Ensure that the point of impact and orientation specified in the plan have been achieved and recorded.	DW 23 DEC 97	DW 24 DEC 97	DW 23 DEC 97	DW 24 DEC 97
14. Record damage to test specimen on a separate sheet and attach.	DW 29 DEC 97	DW 29 DEC 97	DW 29 DEC 97	DW 29 DEC 97
Steps 10 through 14 witnessed by:				
Engineering	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98
Regulatory Affairs	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98
Quality Assurance	KNA 12 Jan 98	KNA 12 Jan 98	KNA 12 Jan 98	KNA 12 Jan 98

Checklist 1: 30-foot Free Drop (Continued)

Test Location: Valley Tree Groveland, MA **Attempt Number:** 1

Step	Specimen A	Specimen B	Specimen C	Specimen D
15. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes are necessary in package orientation for the puncture test to achieve maximum damage.	see	Attached	[signature] 14 Jan 98	

Test Data Accepted by (Signature):	Date:
Engineering [signature]	14 Jan 98
Regulatory Affairs [signature]	22 Jan 98
Quality Assurance [signature]	14 Jan 98

30-foot Free Drop Test Assessment

The test was executed per test plan #74, therefore it was performed in accordance with 10 CFR 71.

Unit S2 was needed for replacing Unit C, since Unit C did not hit the target impact point. There was no adjustment to the torque values of the end plate screws. The penetration test and 4-foot free drop test was performed on S2 before the 30-foot free drop test.

Unit D was dropped twice since it did not hit the target impact point. Second attempt hit same impact point as previous. This produced worst damage of all attempts.

Based on assessment of damage, there is no indication of any damage that would alter original acceptance of test specimens to meet requirements of 10 CFR 71.

As there is no structural damage to the dropped units, conclude that testing will continue as described in test plan 74.

Except for specimen B and D, there was no change in orientation for the puncture test. Orientations for specimen B and D was changed to try to peel back the area of the end plate left by the removed handle.

[signature] 14 Jan 98

KMA 14 Jan 98

[signature] 22 Jan 98

Intermediate Test Inspection

Damage recorded for each test specimen. See attached.

It was decided to delay the radiation profile of the test specimen, since it could possibly affect their structural integrity and affect the outcome of the thermal test.

[signature] 14 Jan 98

KNA 14Jan98

[signature] 22 Jan 98

30 FOOT FREE DROP & PUNCTURE TEST

DW 29 DEC 97

SPECIMEN A	VISUAL: BOTTOM SHELL CONVEXED (DW 29 DEC 97) 1/4" CENTER OF SHELL (BOTTOM)
	LEFT SIDE
	.168 GAP OPENING BETWEEN SHELL & REAR PLATE, CROWN OF REAR PLATE 3 3/4"
HIT REAR PLATE BOTTOM	RIGHT SIDE
	.149 GAP BETWEEN SHELL & REAR PLATE · CROWN OF REAR PLATE 4" 10.280 W FRONT TO REAR
Serial #B3587	
SPECIMEN B	VISUAL: HANDLE BROKEN OFF, FRONT PLATE TOP BENT IN 45°
	REAR END PLATE BENT OUT 13° (1/8 GAP ON TOP REAR)
HIT FRONT PLATE TOP	NO GAP ON SHELL & FRONT, OR REAR PLATES 10" W FRONT TO REAR
Serial #B3588	CROWN FRONT PLATE 3 1/2 HIGH CONVEX 1/16, FRONT NUT DOESNT SPIN
[illegible]EN [illegible]S2	GAP .147 BOTH SIDES CROWN 4" HIGH (CONVEXED)
	BOTTOM SHELL CONVEXED 1/4" ~~[illegible]~~ 1/2" FROM MID POINT TO REAR
[illegible]T REAR PLATE BOTTOM	FRONT NUT SPINS FREELY 10.255/10.270 ~~W~~ FRONT TO REAR
Serial #B3592	
SPECIMEN "D"	GAP .480 FRONT PLATE TO SHELL 4 1/8" TO CROWN FROM BASE
	.094 GAP TOP SHELL TO REAR PLATE.) SHELL TWIST APPROX 1/8"
HIT FRONT PLATE TOP RIGHT SIDE	
Serial #B3590	

KNA 12 Jan 98

[signature] 12 Jan 98

[signature] 14 Jan 98

30 FT FREE DROP 29 DEC 97

SPECIMEN C | VISUAL: DAMAGE TO BOTTOM LEFT CORNER OF REAR PLATE & SHELL

HIT BOTTOM REAR PLATE CORNER

DIDN'T HIT ON TARGET

.200 GAP BETWEEN SHELL & REAR PLATE

Serial #B35889

DENT APPROX 1" REAR PLATE LEFT BOTTOM

(KNA) 12 Jan 98

LLP 12 Jan 98

[signature] 14 Jan 98

Specimen A serial #B3587
B #B3588
D #B3590
S2 #B3592

Equipment List 2: Puncture Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface, Drawing AT10122, Rev. B	SN-01	SEE ATTACH
Puncture Billet, Drawing CT10119, Rev. C	SN-01	SEE ATTACH
Weight Scale	OHAUS DS10 #35014	SEE ATTACH
Thermometer	OMEGA HH21 # ENG-12	SEE ATTACH
Thermocouple flexible probe	#ENG-11	SEE ATTACH
Thermocouple surface probe	#ENG-13	SEE ATTACH
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
Thermocouple Straight Probe	#ENG-14	SEE ATTACH

Verified by:	Signature	Date
Engineering	[signature]	14 Jan 98
Regulatory Affairs	[signature]	12 Jan 98
Quality Assurance	[signature]	12 Jan 98

Checklist 2: Puncture Test

Test Location: GROVE LAND MA   Attempt Number: 1

Step	Specimen A (Serial # B3587)	Specimen B (B3588)	Specimen C (B3592) S-2	Specimen D (B3590)
1. Immerse the test specimen in dry ice as need to bring the specimen's temperature below -40° C.	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97
Step 1 witnessed by:				
Engineering	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98
Regulatory Affairs	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98
Quality Assurance	KNA 12-Jan 98	KNA 12-Jan 98	KNA 12-Jan 98	KNA 12-Jan 98
2. Measure the weight of the specimen.	24 Dec 97 MAB	24 Dec 97 MAB	24 Dec 97 MAB	24 Dec 97 MAB
Record the specimen's weight:	55.20 lb	54.50 lb	55.01 lb	54.84 lb
Note instrument used:	#35014	#35014	#35014	#35014
3. Measure the ambient temperature.	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97
Record ambient temperature:	36.8 °F	35.6 °F	35.3 °F	31.6 °F
Note the instrument used:	ENG-12 #ENG-14	ENG-12 #ENG-14	ENG-12 #ENG-14	ENG-12 #ENG-14
4. Attach the test specimen to the release mechanism.	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97
5. Begin video recording of test so that the impact is recorded.	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97
6. Measure the surface temperature of the specimen. Ensure that the specimen is below -40° C.	24 Dec 97 MAB	24 Dec 97 MAB	24 Dec 97 MAB	24 Dec 97 MAB
Record the specimen surface temperature:	-70.4 °C	-42.2 °C	-57.2 °C	-58.5 °C
Note the instrument used:	ENG-12 #ENG-13	ENG-12 #ENG-13	ENG-12 #ENG-13	ENG-12 #ENG-13
7. Lift and orient the test specimen as shown in the referenced figure for the specimen.	Figure 8 on Page 18	Figure 9 on Page 19	Figure 8 on Page 18	Figure 9 on Page 19
8. Inspect the orientation setup and verify drop height.	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97

Checklist 2: Puncture Test (Continued)

Test Location: VALLEY TREE GROVELAND, MA. **Attempt Number:** 1

Step	Specimen A	Specimen B	Specimen ~~C~~ S-2 (MAB 24 DEC 97)	Specimen D
9. Photograph the setup in at least two perpendicular planes.	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97
Steps 2 through 9 witnessed by:				
Engineering	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98
Regulatory Affairs	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98
Quality Assurance	KNA 12 Jan 98	KNA 12 Jan 98	KNA 12 Jan 98	KNA 12 Jan 98
10. Release the test specimen.	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97
11. Measure the surface temperature of the test specimen.	24 Dec. 97 MAB	24 Dec 97 MAB	24 Dec 97 MAB	24 Dec. 97 MAB
Record the surface temperature:	-65.2 °C	-42.2 °C	-40.1 °C	-48.7 °C
Note the instrument used:	ENG-12 #ENG-13	ENG-12 #ENG-13	ENG-12 #ENG-13	ENG-12 #ENG-13
12. Measure and record the test specimen's weight.	24 Dec. 97 MAB	24 Dec. 97 MAB	24 Dec. 97 MAB	24 Dec. 97 MAB
Record the specimen's weight:	55.05 lb	53.91 lb	55.05 lb	55.20 lb
Note the instrument used:	#35014	#35014	#35014	#35014
13. Pause the video recorder. Ensure that the point of impact and orientation specified in the plan have been achieved and recorded.	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97	DW 24 DEC 97
14. Record damage to test specimen on a separate sheet and attach.	DW 29 DEC 97	DW 29 DEC 97	DW 29 DEC 97	DW 29 DEC 97
Steps 10 through 14 witnessed by:				
Engineering	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98	[signature] 14 Jan 98
Regulatory Affairs	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98	[signature] 12 Jan 98
Quality Assurance	KNA 12 Jan 98	KNA 12 Jan 98	KNA 12 Jan 98	KNA 12 Jan 98

Checklist 2: Puncture Test (Continued)

Test Location: VALLEY TREE GROVELAND, MA. Attempt Number: 1

Step	Specimen A	Specimen B	Specimen C	Specimen D
15. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine the package orientation for the thermal test that will achieve maximum damage.	see	attached	[signature] 14 Jan 98	

Test Data Accepted by (Signature):	Date:
Engineering [signature]	14 Jan 98
Regulatory Affairs [signature]	22 Jan 98
Quality Assurance [signature]	14 Jan 98

Puncture Test Assessment

The puncture test was executed per test plan #74, therefore it was performed in accordance with 10 CFR 71.

Based on assessment of damage, there is no indication of any damage that would alter original acceptance of test specimens to meet requirements of 10 CFR 71.

As there is no structural damage to the dropped units, conclude that testing will continue as described in test plan 74.

Since the damage for specimen B did not produce a gap in the shell or end plates, It was decided to not perform the thermal test on this specimen.

There is no special orientation for the thermal test. All specimen to be oriented on their feet. This will allow optimal air flow in and around open gap areas of the damaged shell and end plates.

14 Jan 98

KMA 14 Jan 98

22 Jan 98

Specimen A -- Serial #B3587
D #B3590
S2 #B3592

Equipment List 3: Thermal Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Air Flowmeter	3367 / ENG-08	SEE ATTACH
Thermocouple (internal)	ENG-18A	SEE ATTACH
Thermocouple (external)	ENG-17A	SEE ATTACH
Thermocouple (oven)	ENG-16A	SEE ATTACH
Temperature recorder	ENG-16/ENG-17/ENG-18	SEE ATTACH
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
THERMOMETER	ENG-12	SEE ATTACH
THERMOCOUPLE PROBE	ENG-14	SEE ATTACH
Verified by:	Signature	Date
Engineering	[signature]	14 Jan 98
Regulatory Affairs	[signature]	12 Jan 98
Quality Assurance	[signature]	12 Jan 98

Checklist 3: Thermal Test

Test Location: MFG SCIENCES OAKRIDGE, TN.   Attempt Number: 1

Step	Specimen A #B3587	Specimen B	Specimen C #B3592	Specimen D #B3590
1. Pre-heat the oven to a temperature above 800° C.	DW 3:24 PM 902.2°C		DW 3:24 PM 902.2	DW 3:24 PM 902.2°c
2. Attach the thermocouples the specimen's internal and external measuring points.	DW 30 DEC 97		DW 30 DEC 97	DW 30 DEC 97
3. Place the package in the oven and close the oven door.	DW 30 DEC 97		DW 30 DEC 97	DW 30 DEC 97
Record the date and time that the package is placed in oven.	3:25 PM 844°c		6:16 PM 807.9°c	4:50 PM 852°c
4. When the specimen's internal temperature exceeds 800° C, start the air flow into the oven. Record the time.	4:06 PM DW 30 DEC 97		7:25 PM DW 30 DEC 97	5:34 PM DW 30 DEC 97
Steps 1 through 4 witnessed by:				
Engineering	[signature] 14 Jan 98		[signature] 14 Jan 98	[signature] 14 Jan 98
Regulatory Affairs	[signature] 12 Jan 98		[signature] 12 Jan 98	[signature] 12 Jan 98
Quality Assurance	KMA 12 Jan 98		KMA 12 Jan 98	KMA 12 Jan 98
5. Measure the oven temperature, the specimen's internal and external temperatures and the air flow rate.	DW 30 DEC 97		DW 30 DEC 97	DW 30 DEC 97
Record the oven temperature:	904°c		900.7°c	900.0°c
Note instrument used:	~~ENG-16~~ ENG-16A		~~ENG-16~~ ENG-16A	~~ENG-16~~ ENG-16A
Record the specimen's internal temperature:	800°c		800.1°c	801.1°c
Note instrument used:	~~ENG-18~~ ENG-18A		~~ENG-18~~ ENG-18A	~~ENG-18~~ ENG-18A
Record the specimen's external temperature:	844.3°c		823.8°c	842.2°c
Note instrument used:	~~ENG-17~~ ENG-17A		~~ENG-17~~ ENG-17A	~~ENG-17~~ ENG-17A
Record airflow rate:	10 CFM		10 CFM	10 CFM
Note instrument used:	~~3367~~ ENG-08		~~3367~~ ENG-08	~~3367~~ ENG-08
6. Monitor the internal and external temperatures of the specimen and the oven temperature throughout the 30-minute period to ensure that they are above 800° C.	DW 30 DEC 97		DW 30 DEC 97	DW 30 DEC 97

Checklist 3: Thermal Test (Continued)

Test Location: MFG SCIENCES OAKRIDGE, TN. **Attempt Number:** 1

Step	Specimen A	Specimen B	Specimen C	Specimen D
7. Monitor the airflow throughout the 30-minute period to ensure a rate of at least 9.6 ft^3/min.	DW 30 DEC 97		DW DEC 97	DW 30 DEC 97
8. At the end of the 30-minute period, repeat step 5 using the same measurement devices.	DW 30 DEC 97		DW DEC 97	DW 30 DEC 97
Record the oven temperature:	905.2°C		901.5°C	907.1°C
Record the specimen's internal temperature:	841.2°C		857.0°C	842.5°C
Record the specimen's external temperature:	856.4°C		843.0°C	850.4°C
Record intake air flow velocity:	10 CFM		10 CFM	10 CFM
Steps 5 through 8 witnessed by:				
Engineering	[signature] Jan 98		[signature] Jan 98	[signature] Jan 98
Regulatory Affairs	[signature] 12 Jan 98		[signature] 12 Jan 98	[signature] 12 Jan 98
Quality Assurance	KNA 12 Jan 98		KNA 12 Jan 98	KNA 12 Jan 98
9. Remove test specimen from the oven.	DW 30 DEC 97		DW 30 DEC 97	DW 30 DEC 97
Record time the specimen is removed.	4:36 PM		7:55 PM	6:04
Describe combustion when door is opened to remove specimen.	RED HOT NO FLAMES		RED HOT FLAMES INSIDE	RED HOT SOME FLAMES IN REAR
NOTE: If specimen continues to burn, let it self-extinguish and cool naturally.				
10. Measure the ambient temperature.	DW 30 DEC 97		DW	DW 30 DEC 97
Record the ambient temperature:	62.3°F		62.3°F	61.9°F
Note the instrument used:	ENG-12 / ENG-14		ENG-12 / ENG-14	ENG-12 / ENG-14
11. Photograph the test specimen and any subsequent damage	DW 30 DEC 97		DW 30 DEC 97	DW 30 DEC 97
12. Record damage to test specimen on a separate sheet and attach.	See Photos + Videos			
Steps 9 through 12 witnessed by:				
Engineering	[signature] 18 Feb 98		[signature] 18 Feb 98	[signature] 18 Feb 98
Regulatory Affairs	[signature] 12 Jan 98		[signature] 12 Jan 98	[signature] 12 Jan 98
Quality Assurance	KNA 12 Jan 98		KNA 12 Jan 98	KNA 12 Jan 98

Checklist 3: Thermal Test (Continued)

Test Location: MFG SCIENCES OAK RIDGE, TN. **Attempt Number:** 1

Step	Specimen A	Specimen B	Specimen C ~~C~~ 52	Specimen D
13. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach.	see attached		see attached	see attached

Test Data Accepted by (Signature):		Date:
Engineering	S. Ge[illegible]	18 FEB 98
Regulatory Affairs	C. [illegible]	18 Feb 98
Quality Assurance	[illegible]	02-MAR-98

Post Thermal Temp. at Mfg. Sources

8:35 AM 31 Dec 97 Room Temp 17.8

Serial #B3587 Specimen A: Internal temp 17.6°C

Serial #B3590 Specimen D: Internal temp ~~54.1~~ [initials] 31 Dec 97
541.3°C

Serial #B3592 Specimen S2: Internal temp ~~417.3°C~~ [initials] 31 Dec 97
417.5°C

[initials] 31 DEC 97
Spec

(KNA) 31 Dec 97

Assessment - Specimen A (thermal results)
Serial #B3587

Based on physical appearance of Specimen A, it is probable that additional movement of the shield was due to transport / handling.

The shield in Specimen A appears (based on radiographs) to have experienced lateral movement from time of concluding puncture test to arrival back at Amersham after thermal testing. The evidence of lateral movement is the distance the front S tube was displaced from the front nut. Comparisons of this position after thermal (and transport) to radiographs taken after puncture indicate an approximate 1/4 inch movement. As the thermal test was performed with the 660 flat, there were no forces or loads produced during thermal that could have produced this degree of lateral movement.

In order to validate that the lateral movement was a result of handling and transport, additional specimens will be subject to the thermal test.

In addition observations of the unpacking operation at Amersham of the test units indicate that the test specimens had been packaged with an end plate down, i.e. not in its normal resting position on the feet.

The additional test specimens include:

(1) S_3 - This is a specimen that was originally
Serial #B3586

edge dip. Based on the orientation miss, the puncture test was not performed. Upon examination of C through radiographs and visual observation and mechanical measurements, it was determined that although the damage was not exactly as in Specimen A prior to B thermal test, it would provide information on the ~~xx~~ amount of possible movement as a result of the thermal test. The S tube location in the front nut was similar to that seen on Specimen A. The rear plate on C was not bowed out in the same location as on A, but as the strike was disengaged from the boss of the lock assembly it appeared that the shield would have room to move downward. The teleflex engagement of C was severed.

(initials) 18 FEB 98
CMR 18 Feb 98
(KMA) 02 MAR 98

was corrupted during transport/ handling.

If it doesn't pass profile, information will not be used as it was subjected to four 30 foot drop tests and had the excessive damage. Other test specimens subjected to 1 or 2 30 foot drops did not exhibit the extent of damage shown by EX-1

radiographs of all three specimens were taken prior to transport to thermal testing. Source position was also taken prior to transport. The source position was taken upon receipt at Manufacturing Sciences to determine actual position prior to thermal.

Radiographs and lt source position will be taken when units are cooled down after thermal test to record source position prior to any movement or transport.

(GE) 18 FEB 98

CMR 19 Feb 98

(KMM) 02 MAR 98

TEST PLAN # 74

SPECIMEN "D" - PROFILE RESULTS INDICATE THIS TEST SPECIMEN PASSED THE TEST REQUIREMENTS OF 10 CFR 71.73.

Serial# B3590

SPECIMEN "S2" - THE TEAM AGREED TO NOT PROFILE THIS TEST SPECIMEN. THIS IS BECAUSE THE RESULTS PROBABLY WOULD NOT HAVE MATTERED SINCE THE RESULTS OF SPECIMEN "A" WAS QUESTIONABLE. ALSO, ~~PRESONAL~~ PERSONAL (SD 18FEB98) SAFETY WAS CONSIDERED IN THE DECISION NOT TO PROFILE "S2".

Serial# B3592

(SD) 18 FEB 98
CMR 18 Feb 98
(KMA) 02 MAR 98

SENTINEL

WORKSHEET

I. Device Model ~~Stylo~~ 660 Capacity 140 Ci Isotope IR-192 Source Model 424-9 T10763

II. Maximum acceptable surface reading: 200 mR/hr * If used to show compliance w/ normal transport requirements

Maximum acceptable meter reading: 10 mR/hr * For normal transport

1 R/hr * For hypothetical accident conditions of 10 CFR 71.

III. Surface Correction Factors:

(applicable for normal transport only).

Top	1.16
Right	1.28
Front	1.13
Left	1.28
Rear	1.13
Bottom	1.19

IV. Specific Instructions for loading/unloading:

See Attachment

V. Approved By:

S. Gr[illegible]	9 Jan 98
Engineering	Date
[illegible signature]	9 Jan 98
Regulatory	Date
C. Longhan	9 Jan 98
Quality Assurance	Date

Amersham QSA

Profile Worksheet Supplement (PEF-003/97)	Supplement # PWS-1/98
4.	ALARA Justification

4. ALARA Justification

Step 1:

Assuming surface intensity of 5 R/hr, source securement/unsecurement time of 2 minute and working behind supplemental shielding to reduce body intensities to less than 500 mR/hr, exposure estimates for operation as follows:

$$E_{WB} = \left(500\ \frac{mR}{hr} \times 0.033\ hr\right) = 17\ mR$$

$$E_{Hand} = \left(5{,}000\ \frac{mR}{hr} \times 0.033\ hr\right) = 165\ mR$$

Step 2 and 3:

Dose to personnel the same as general cutting cell work.

Profile Operation:

5 minutes for assessment of surface dose rates and general handling/adjustment at average intensity of 1 R/hr, whole body average dose rate of 200 mR/hr for 15 minutes for one meter dose rate readings.

$$E_{WB} = \left(200\ \frac{mR}{hr} \times 0.25\ hr\right) = 50\ mR$$

$$E_{Hand} = \left(1{,}000\ \frac{mR}{hr} \times 0.083\ hr\right) = 83\ mR$$

RHP Approval Initials & Date: [signature] 9 Jan 98

Profile Worksheet Supplement (PEF-003/97)	Supplement # PWS-1/98
5.	**Authorized Individuals:** Profile: ☐ RT Qualified & Operationally Approved for Device Profiles ☒ Others: RSO, RAM, E. Shaffer, R. Kelly Steps 2 & 3: ☐ RT Qualified & Operationally Approved for Cutting Cell Procedure ☒ Others: E. Shaffer, R. Kelly, RSO, RAM
6.	**Operational Hold-points:** None.
7.	**Other Applicable Comments/Criteria:** None.

RHP Approval Initials & Date: [signature] 9 Jan 98

SENTINEL

660/660B DEVICE PROFILING FORM

B3588 (KNA) 12 Jan 98

Device Model No.: 660B Device Serial No.: TP73 "B" ~~After Thermal~~ After 30 Ft & Puncture LR 5 Jan

Model ~~424-9~~ TI0163 Source Serial Number: X0016 Activity: 93.2C

Surface Survey Instrument: AN/PDR 27T Serial No: SM-392401 Cal Due: 3/18/98

One Meter Survey Instrument: Same Serial No: — Cal Due: —

* Non-leaded plug used during profile.

Capacity Corr. Factor 1.50

SURFACE READINGS mR/hr

	Surf Corr. Fact	Extrapolated ~~Allowed~~	Actual
TOP	1.16	104.4	60
RIGHT	1.28	153.6	80
FRONT	1.13	389.9	230
LEFT	1.28	115.2	60
REAR	1.13	152.6	90
BOTTOM	1.19	107.1	60

ONE METER READINGS mR/hr

	Extrapolate ~~Allowed~~	Actual
TOP	1.0	0.7
RIGHT	0.9	0.6
FRONT	2.7	1.8
LEFT	0.75	0.5
REAR	1.5	1.0
BOTTOM	0.9	0.6

INSPECTOR: L. Pedrolat DATE: 5 Jan 98 NCR No.: ______

Comments:

(KNA) 12 Jan 98

Amersham QSA

SENTINEL

660/660B DEVICE PROFILING FORM

B3587 (LMA) 12 Jan 98

Device Model No.: 660B Device Serial No.: ~~After~~ TP73"A" Thermal

Model ~~424-9~~ T10163 Source Serial Number: X0016 Activity: 93.2 Ci

~~Surface~~ <500 mR/hr Survey Instrument: AN/PDR 27T Serial No: SM-392401 Cal Due: 3/18/98

~~One Meter~~ k) ≥ 500 mR/hr Survey Instrument: Tech-50 Serial No: B-814-S Cal Due: 7/22/98

Capacity Corr. Factor 1.5

SURFACE READINGS mR/hr

	~~Allowed~~ Extrapolated For Capacity only	Actual
TOP	780	520*
RIGHT	3 R/hr	2 R/hr*
FRONT	40.5	27
LEFT	3 R/hr	2 R/hr*
REAR	3 R/hr	2 R/hr*
BOTTOM	1.8 R/hr	1.2 R/hr*

ONE METER READINGS mR/hr

	~~Allowed~~ Extrapolated	Actual
TOP		
RIGHT		
FRONT	1.4	0.9
LEFT		
REAR	9.3 R/hr	6.2 R/hr*
BOTTOM	18	12.0

→ >1 R/hr. No add'l measurements taken on device.

INSPECTOR: L. [signature] DATE: 5 Jan 98 NCR No.: ______

Comments:

- No surface corrections made. Actual surface enclosed in plastic bagging which varied in thickness from 1/2 - 1".

- Surface doses for general info only. Primary purpose of profile was for 1 meter readings. Surface levels on sides and rear may be higher than recorded. (1A) 12 Jan 98 Radiation was a finely collimated beam from S-tube out the rear of the device which was difficult to quantify precisely without receiving add'l. extremity exposure

Amersham QSA

WI-Q05

SENTINEL

660/660B DEVICE PROFILING FORM

B3590 (KNA) 12 Jan 98

Device Model No.: 660B Device Serial No.: TP73 "D" After Thermal

Model ~~424-9~~ T10163 Source Serial Number: X0016 Activity: 89.7 Ci

Surface Survey Instrument: Bicron Tech-50 Serial No: B-814-S Cal Due: 7/22/98

One Meter Survey Instrument: Same Serial No: – Cal Due: –

Capacity Corr. Factor
1.56

SURFACE READINGS mR/hr

	~~Allowed~~	Actual
TOP		130
RIGHT		180
FRONT		80
LEFT		50
REAR		90
BOTTOM		50

ONE METER READINGS mR/hr

	Extrapolated ~~Allowed~~	Actual
TOP	2.3	1.5
RIGHT	1.9	1.2
FRONT	2.7	1.7
LEFT	2.2	1.4
REAR	4.7	3.0
BOTTOM	1.7	1.1

INSPECTOR: L. Pedersen[illegible] DATE: 9 Jan 98 NCR No.: ______

Comments:

* Surface of unit enclosed in multiple layers of plastic bags for contamination control of uranium oxide. Thickness varies from 1/4" to 1".

* Surface readings taken for exposure control and general information purposes only.

(KNA) 12-Jan 98

Amersham QSA

WI-Q05

Equipment List 1: 30-foot Free Drop S3 Serial#B3586

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface, Drawing AT10122, Rev. B	01	SEE ATTACH
Weight Scale	OHAUS / 35014	SEE ATTACH
Thermometer	OMEGA / ENG-12	SEE ATTACH
Thermocouple flexible probe	OMEGA / ENG-11	SEE ATTACH
Thermocouple surface probe	OMEGA / ENG-13	SEE ATTACH
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
THERMOCOUPLE STRAIGHT PROBE	OMEGA / ENG-14	SEE ATTACH

Verified by:	Signature	Date
Engineering	[signature]	14 Jan 98
Regulatory Affairs	L. [signature]	12 Jan 98
Quality Assurance	C. [signature]	14 Jan 98

Checklist 1: 30-foot Free Drop

Test Location: VALLEY TREE GROVELAND MA serial # B3586 Attempt Number: *

Step	*1 Specimen A F 11 JAN 98 53	*2 Specimen B F 11 JAN 98 53	Specimen C	Specimen D
1. Measure and record test specimen's weight.	55.3 lbs	55.25 lbs	N/A	N/A
Record the specimen's weight:	DW 11 JAN 98	DW 11 JAN 98		
Note the instrument used:	35014	35014	35014	35014
2. Immerse the test specimen in dry ice as needed to bring specimen temperature below -40° C.	DW 11 JAN 98	DW 11 JAN 98		
Steps 1 through 2 witnessed by:				
Engineering	[signature] 11 Jan 98	[signature] 11 Jan 98		
Regulatory Affairs	[signature] 12 Jan 98	[signature] 12 Jan 98		
Quality Assurance	[signature] 14 Jan 98	[signature] 14 Jan 98		
3. Measure the ambient temperature.	F 11 JAN 98	F 11 JAN 98		
Record ambient temperature:	42.6°F	42.6F		
Note the instrument used:	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14
4. Attach the test specimen to the release mechanism.	DW 11 JAN 98	DW 11 JAN 98		
5. Begin video recording of test so that the impact is recorded.	DW 11 JAN 98	DW 11 JAN 98		
6. Measure the temperature of the specimen. Ensure that the specimen is below -40° C.	F 11 JAN 98	F 11 JAN 98		
Record the specimen's internal temperature:	-77.1°C	-77.1°C		
Note the instrument used:	~~ENG-12~~ ENG-11	~~ENG-12~~ ENG-11	~~ENG-12~~ ENG-11	~~ENG-12~~ ENG-11
Record the specimen's surface temperature.	-58.2°C	-51.1°C		
Note the instrument used:	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13
7. Lift and orient the test specimen as shown in the referenced figure for the specimen.	Figure 6 on Page 14	Figure 7 on Page ~~15~~ 14 cmp	Figure 6 on Page 14	Figure 7 on Page 15
8. Inspect the orientation setup and verify the drop height.	DW 11 JAN 98	DW 11 JAN 98		
9. Photograph the setup in at least two perpendicular planes.	DW 11 JAN 98	DW 11 JAN 98		

Checklist 1: 30-foot Free Drop (Continued)

Test Location: GROVELAND, MA. Attempt Number: *

Step	Specimen S3 A*1 (DO 11 JAN 98)	Specimen S3 B*2 (DO 11 JAN 98)	Specimen C	Specimen D
Steps 3 through 9 witnessed by:			N/A	N/A
Engineering	[signature] 14 Jan 98	[signature] 14 Jan 98		
Regulatory Affairs	[signature] 12 Jan 98	[signature] 12 Jan 98		
Quality Assurance	CMR 14 Jan 98	CMR 14 Jan 98		
10. Release the test specimen.	DO 11 JAN 98	DO 11 JAN 98		
11. Measure the surface temperature of the test specimen.	F 11 JAN 98	F 11 JAN 98		
Record the surface temperature:	-45.4°C	-26.2°C		
Note the instrument used:	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13
12. Measure and record the test specimen's weight.	F 11 JAN 98	F 11 JAN 98		
Record the specimen's weight:	55.25 lbs	55.4 lbs		
Note the instrument used:	35014	35014	35014	35014
13. Pause the video recorder. Ensure that the point of impact and orientation specified in the plan have been achieved and recorded.	DO 11 JAN 98	DO 11 JAN 98		
14. Record damage to test specimen on a separate sheet and attach.	DO 11 JAN 98	DO 11 JAN 98		
Steps 10 through 14 witnessed by:				
Engineering	[signature] 14 Jan 98	[signature] 14 Jan 98		
Regulatory Affairs	[signature] 12 Jan 98	[signature] 12 Jan 98		
Quality Assurance	CMR 14 Jan 98	CMR 14 Jan 98		

Checklist 1: 30-foot Free Drop (Continued)

Test Location: GROVELAND, MA.

Attempt Number: *

Step	Specimen 53 A*1 DO 11 JAN 98	Specimen 53 B*2 DO 11 JAN 98	Specimen C	Specimen D
15. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes are necessary in package orientation for the puncture test to achieve maximum damage.	DO 11 JAN 98	DO 11 JAN 98	N/A	N/A

Test Data Accepted by (Signature):	Date:
Engineering [signature]	14 Jan 98
Regulatory Affairs [signature]	22 Jan 98
Quality Assurance C. [signature]	17 Feb 98

TP 74 - S3   11 Jan 98

30 foot drop 1st attempt

Impact was on rear plate bottom, (with a following slap down effect from towards the front plate along the bottom of the device) but did not produce the bowing of rear plate seen with previous specimen A and S1 of TP 74. Visually the specimen S3 has minor deformation at bottom edge, bottom of shell bent upwards into rear plate

Will attempt another 30 foot drop to try and recreate damage seen from specimen A, as CoG was not directly over planned impact point.

30 foot drop 2nd Attempt

Impact was on the rear plate bottom, with a secondary impact on the lock cover, ~~following~~ followed ~~by a full rotation and a third impact on the rear plate bottom~~. The rear end plate bowed and the bottom of the plate and shell deformed further.

The temperature after this 2nd attempt was -26.2°C (above the -40°C requirement). However, the team did not see this as detrimental to the test because brittle fracture of the screws,

14 Jan

TP 74 11 Jan 98
S3

Assessment:

Orientation For Puncture Test -

Team assessed condition of specimen to determine worst case orientation for puncture - An alternate orientation was suggested on the front plate bottom. The intent of this drop would be to try and drive tube out of boss of rear plate, ie disengaging tube to rear plate connection.

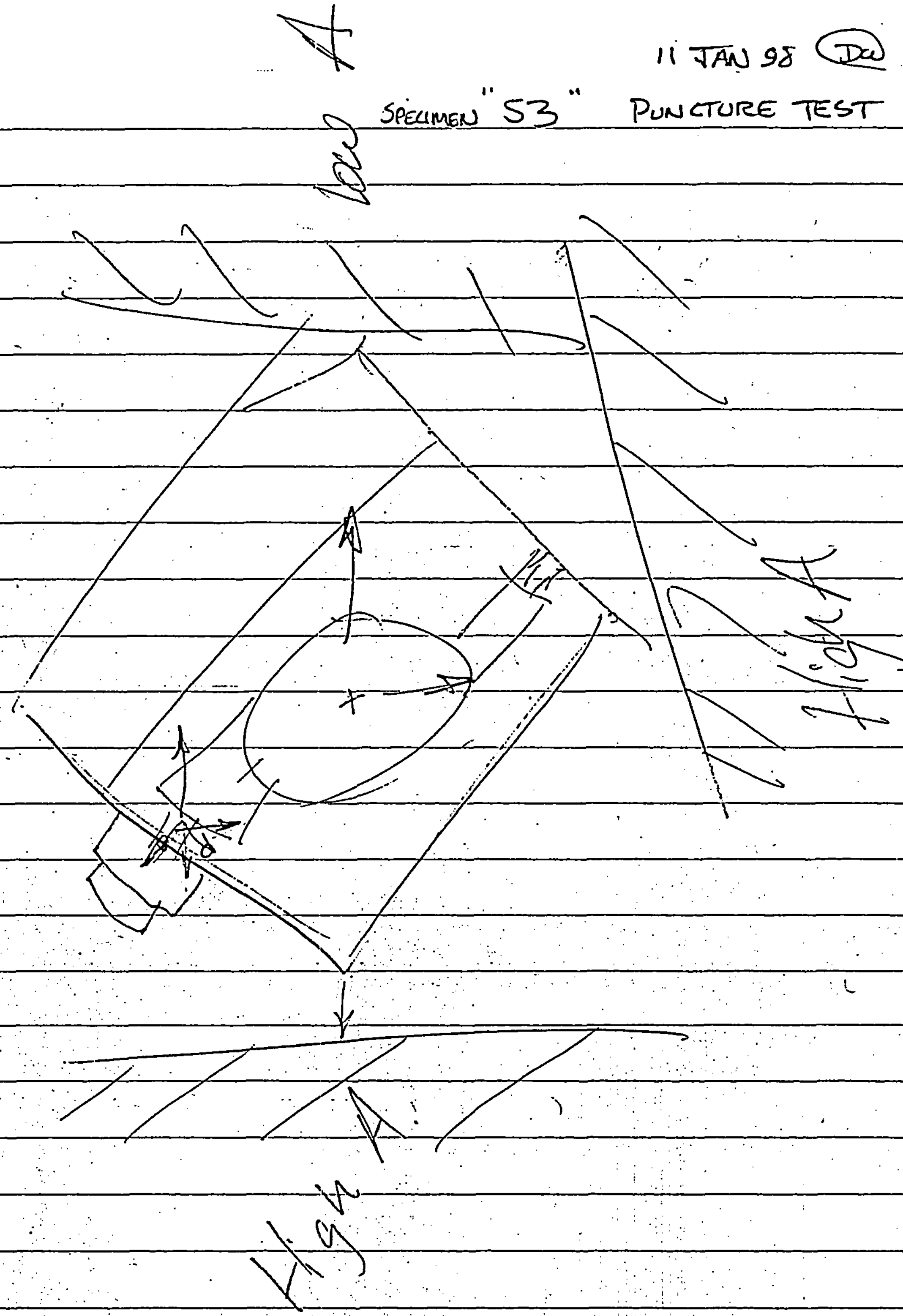
The team evaluated and ~~cont~~ unanimously determined that the bottom edge drop orientation (ie continue on with original orientation) would be worse to continue on with already incurred damage.

The worst case for thermal would be to disengage connection of rear plate to shield, continuing on damage to the tube, based on radiographs from earlier test specimens ie A, S, - Tube was damaged from 30 foot and puncture.

As puncture is only a one meter drop, any minor damage to the front would not result in worst case for thermal. The drop on

11 JAN 98 (DW)

SPECIMEN "53" PUNCTURE TEST



Equipment List 2: Puncture Test S3 Serial#B3586

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface, Drawing AT10122, Rev. B	01	SEE ATTACH
Puncture Billet, Drawing CT10119, Rev. C	01	SEE ATTACH
Weight Scale	#35014 / OHAUS	SEE ATTACH
Thermometer	ENG-12 / OMEGA	SEE ATTACH
Thermocouple flexible probe	ENG-11 / OMEGA	SEE ATTACH
Thermocouple surface probe	ENG-13 / OMEGA	SEE ATTACH
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
THERMOCOUPLE STRAIGHT PROBE	ENG-14 / OMEGA	SEE ATTACH
Verified by:	Signature	Date
Engineering	[signature]	14 Jan 98
Regulatory Affairs	[signature]	12 Jan 98
Quality Assurance	C. Rousman	14 Jan 98

Checklist 2: Puncture Test

Test Location: VALLEY TREE GROVELAND MA

Attempt Number: 1

Serial #B3586

Step	Specimen A (DW 11 JAN 98) S3	Specimen B	Specimen C	Specimen D
1. Immerse the test specimen in dry ice as need to bring the specimen's temperature below -40° C.	DW 11 JAN 98	N/A	N/A	N/A
Step 1 witnessed by:				
Engineering	[signature] Jan 98			
Regulatory Affairs	[signature] 12 Jan 98			
Quality Assurance	[signature] 14 Jan 98			
2. Measure the weight of the specimen.	DW 11 JAN 98			
Record the specimen's weight:	55.40 lbs			
Note instrument used:	#35014	#35014	#35014	#35014
3. Measure the ambient temperature.	42.6° F			
Record ambient temperature:	DW 11 JAN 98			
Note the instrument used:	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14
4. Attach the test specimen to the release mechanism.	DW 11 JAN 98			
5. Begin video recording of test so that the impact is recorded.	DW 11 JAN 98			
6. Measure the surface temperature of the specimen. Ensure that the specimen is below -40° C.	DW 11 JAN 98			
Record the specimen surface temperature:	-66.7°C			
Note the instrument used:	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-13	~~ENG-12~~ ENG-14	~~ENG-12~~ ENG-14
7. Lift and orient the test specimen as shown in the referenced figure for the specimen.	Figure 8 on Page 18	Figure 9 on Page 19	Figure 8 on Page 18	Figure 9 on Page 19
8. Inspect the orientation setup and verify drop height.	DW 11 JAN 98			

Checklist 2: Puncture Test (Continued)

Test Location: VALLEY TREE GROVELAND MA **Attempt Number:** 1

Step	Specimen DW 11 JAN 98 A-53	Specimen B	Specimen C	Specimen D
9. Photograph the setup in at least two perpendicular planes.	DW 11 JAN 98	N/A	N/A	N/A
Steps 2 through 9 witnessed by:				
Engineering	[signature] 14 Jan 98			
Regulatory Affairs	[signature] 12 Jan 98			
Quality Assurance	[signature] 14 Jan 98			
10. Release the test specimen.	DW 11 JAN 98			
11. Measure the surface temperature of the test specimen.	DW 11 JAN 98			
Record the surface temperature:	-58.2°C			
Note the instrument used:	ENG-12 / ENG-13	ENG-12 / ENG-13	ENG-12 / ENG-13	ENG-12 / ENG-13
12. Measure and record the test specimen's weight.	DW 11 JAN 98			
Record the specimen's weight:	55.3 lbs			
Note the instrument used:	#35014	#35014	#35014	#35014
13. Pause the video recorder. Ensure that the point of impact and orientation specified in the plan have been achieved and recorded.	DW 11 JAN 98			
14. Record damage to test specimen on a separate sheet and attach.	DW 11 JAN 98			
Steps 10 through 14 witnessed by:				
Engineering	[signature] 14 Jan 98			
Regulatory Affairs	[signature] 12 Jan 98			
Quality Assurance	[signature] 14 Jan 98			

Checklist 2: Puncture Test (Continued)

Test Location: VALLEY TREE GROVELAND MA **Attempt Number:** 1

Step	Specimen A 53	Specimen B	Specimen C	Specimen D
15. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine the package orientation for the thermal test that will achieve maximum damage.	[signature] 14 Jan 98	N/A	N/A	N/A

Test Data Accepted by (Signature):	Date:
Engineering [signature]	14 Jan 98
Regulatory Affairs [signature]	22 Jan 98
Quality Assurance C. [signature]	17 Feb 98

Puncture Test Assessment - Specimen 53 Serial # B3586

Impacted in accordance with Test Plan 74. Little damage noted.

Orientation for thermal test should be normal upright position. This will allow the shield to move downward due to the force of gravity.

[signature] 14 Jan 98

CMR 14 Jan 98
RLB 22 Jan 98

Serial #B3586

SPECIMEN S3 [signature]

"A" ORIENTATION 11 JAN 98

PENETRATION TEST

SIX ATTEMPTS BEFORE TARGET HIT LIGHT DENT ABOVE TARGET AND ON TARGET, NO DAMAGE TO SCREW

FOUR FOOT FREE DROP

DROP ON TARGET 1ST DROP PAINT CHIPPED ON BOTTOM OF REAR PLATE, NO ADDITIONAL DAMAGE VISIBLE.

30' FREE DROP

1ST DROP HIT ON BOTTOM OF REAR PLATE EVENLY ON EACH SIDE

CENTER OF GRAVITY SLIGHTLY TO BOTTOM OF DEVICE,

BOTTOM OF REAR PLATE & SHELL DENTED IN, NO GAP BETWEEN SHELL & REAR PLATE

2ND DROP 30' HIT ON BOTTOM OF REAR PLATE ON TARGET

BOTTOM OF REARPLATE & SHELL DENTED,

SHELL CONVEXED ON BOTTOM,

FRONT NUT DOESN'T TURN,

DW 12 JAN 89 REL PUNCTURE TEST

NO ADDITIONAL DAMAGE VISIBAL.

SENTINEL

660/660B DEVICE PROFILING FORM

TP74 + TP73 "S3" Serial# B3586 (KMA) 21 Jan 98

Device Model No.: 660B Device Serial No.: After Thermal

Model ~~424-9~~ TI0163 Source Serial Number: X0017 Activity: 105 Ci

Surface Survey Instrument: AN/PDR-77T Serial No: SM-392401 Cal Due: 18 Mar 98

One Meter Survey Instrument: AN/PDR-77T Serial No: SM-392401 Cal Due: 18 Mar 98

Capacity Corr. Factor
1,33

	SURFACE READINGS mR/hr		ONE METER READINGS mR/hr	
	~~Allowed~~	Actual	Extrapolated ~~Allowed~~	Actual
TOP		70 mR/hr	1.9	1.4 mR/hr
RIGHT		80 mR/hr	1.5	1.1 mR/hr
FRONT		940 mR/hr Δ	5.6	4.2 mR/hr
LEFT		110 mR/hr	1.3	1.0 mR/hr
REAR		1400 mR/hr Δ	9.3	7.0 mR/hr
BOTTOM		130 mR/hr	1.6	1.2 mR/hr

INSPECTOR: [signature] DATE: 19 Jan 98 NCR No.: NA

Comments:

* Surface readings taken for exposure control and general information purposes only.

Δ Measurements taken with Model # ND 3000, S/N 9837 (Next cal date 23 Sept 98) [initials] 19 Jan 98

Amersham QSA

WI-Q05

19 Jan 98

Smit# 83586

S3 Source position measurement

0,362 unthreaded ship plug length
6,802 teleflex wire off tool!

Removed section from shield = 4 3/8"
(Source dummy wire from "S3" specimen)

[signature] 19 Jan 98

Serial #B3586 and #B3589

Equipment List 3: Thermal Test S3 and C

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Air Flowmeter	HEDLAND / 3367 / WINTERS ENG-08	SEE ATTACH
Thermocouple (internal)	OMEGA / ENG-18 A	SEE ATTACH
Thermocouple (external)	OMEGA / ENG-17 A	SEE ATTACH
Thermocouple (oven)	OMEGA / ENG-16 A	SEE ATTACH
Temperature recorder	OMEGA / ENG-16, 17, 18	SEE ATTACH
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
THERMOMETER	OMEGA / ENG-12	SEE ATTACH
THERMOCOUPLE STRAIGHT PROBE	OMEGA / ENG-14	SEE ATTACH
SOURCE LOCATION TOOL / DIGITAL CALIPER	710142 / # 277	SEE ATTACH
Verified by:	Signature	Date
Engineering	[signature]	13 Jan 98
Regulatory Affairs	C. Rou[signature]	14 Jan 98
Quality Assurance	[signature]	13 Jan 98

SOURCE LOCATION BEFORE THERMAL TEST "S3" 5.922 / "C" 5.824

Checklist 3: Thermal Test

Test Location: MFG SCIENCES OAK RIDGE TN Serial #B3586 **Attempt Number:** 1 Serial #B3589

Step	Specimen A	Specimen ~~B~~ S3 (DO 13 JAN 98)	Specimen C	Specimen D
1. Pre-heat the oven to a temperature above 800° C.	N/A	DO 13 JAN 98	DO 13 JAN 98	N/A
2. Attach the thermocouples the specimen's internal and external measuring points.		DO 13 JAN 98	DO 13 JAN 98	
3. Place the package in the oven and close the oven door.		DO 13 JAN 98	DO 13 JAN 98	
Record the date and time that the package is placed in oven.		13 JAN 98 424 pm	13 JAN 98 2:51PM	
4. When the specimen's internal temperature exceeds 800° C, start the air flow into the oven. Record the time.		453pm 13 JAN 98	347PM DO 13 JAN 98	
Steps 1 through 4 witnessed by:				
Engineering		[signature] 13 Jan 98	[signature] 13 Jan 98	
Regulatory Affairs		C. Roughan 13 Jan 98	C. Roughan 13 Jan 98	
Quality Assurance		KNA 13 Jan 98	KNA 13 Jan 98	
5. Measure the oven temperature, the specimen's internal and external temperatures and the air flow rate.		DO 13 JAN 98	DO 13 JAN 98	
Record the oven temperature:		891.4°c	896.7°c	
Note instrument used:	~~ENG-16~~ ENG-16A	~~ENG-16~~ ENG-16A	~~ENG-16~~ ENG-16A	~~ENG-16~~ ENG-16A
Record the specimen's internal temperature:		803.5°c	800.9°c	
Note instrument used:	~~ENG-18~~ ENG-18A	~~ENG-18~~ ENG-18A	~~ENG-18~~ ENG-18A	~~ENG-18~~ ENG-18A
Record the specimen's external temperature:		838.3°c	834.9°c	
Note instrument used:	~~ENG-17~~ ENG-17A	~~ENG-17~~ ENG-17A	~~ENG-17~~ ENG-17A	~~ENG-17~~ ENG-17A
Record airflow rate:		11 CFM	11 CFM	
Note instrument used:	~~3367~~ ENG-08	~~3367~~ ENG-08	~~3367~~ ENG-08	~~3367~~ ENG-08
6. Monitor the internal and external temperatures of the specimen and the oven temperature throughout the 30-minute period to ensure that they are above 800° C.		DO 13 JAN 98	DO 13 JAN 98	

Checklist 3: Thermal Test (Continued)

Test Location: MFG SCIENCES OAK RIDGE TN   Attempt Number: 1

Step	Specimen A	Specimen ~~B~~ 53	Specimen C	Specimen D
7. Monitor the airflow throughout the 30-minute period to ensure a rate of at least 9.6 ft^3/min.	N/A	DC 13 JAN 98	DC 13 JAN 97	N/A
8. At the end of the 30-minute period, repeat step 5 using the same measurement devices.		DC 13 JAN 98	DC 13 JAN 97	
Record the oven temperature:		904.7°c	902.8°c	
Record the specimen's internal temperature:		844.1°	853.5°c	
Record the specimen's external temperature:		836.2°c	850.9°c	
Record intake air flow velocity:		11 CFM	11 CFM	
Steps 5 through 8 witnessed by:				
Engineering		[signature] 13 Jan 98	[signature] 13 Jan 98	
Regulatory Affairs		C. Langhan 13 Jan 98	C. Langhan 13 Jan 98	
Quality Assurance		KNA 13 Jan 98	KNA 13 Jan 98	
9. Remove test specimen from the oven.		DC 13 JAN 98	DC 13 JAN 98	
Record time the specimen is removed.		5 25 PM	4:17 PM	
Describe combustion when door is opened to remove specimen.		DC 13 JAN 98 RED HOT	DC 13 JAN 98 RED HOT	
NOTE: If specimen continues to burn, let it self-extinguish and cool naturally.				
10. Measure the ambient temperature.	N/A	DC 13 JAN 98	DC 13 JAN 98	N/A
Record the ambient temperature:		65.7°F	67.2°F	
Note the instrument used:	ENG-12 / ENG-14	ENG-12 / ENG-14	ENG-12 / ENG-14	ENG-12 / ENG-14
11. Photograph the test specimen and any subsequent damage		DC 13 JAN 98	DC 13 JAN 98	
12. Record damage to test specimen on a separate sheet and attach.		DC 15 JAN 98	DC 15 JAN 98	
Steps 9 through 12 witnessed by:				
Engineering		[signature] 17 Feb 98	[signature] 17 Feb 98	
Regulatory Affairs		C. Langhan 17 Feb 98	C. Langhan 17 Feb 98	
Quality Assurance				

Checklist 3: Thermal Test (Continued)

Test Location: **Attempt Number:**

Step	Specimen A	Specimen B	Specimen C	Specimen D
13. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach.	NA	see attached		NA

Test Data Accepted by (Signature):	Date:
Engineering S. Gr[illegible]	18FEB98
Regulatory Affairs C. [illegible]	18 Feb 98
Quality Assurance [illegible]	02MAR98

15 Jan 98
at Mfg. Sciences

Specimen Ex-1

max length 10.534 (right side)
gap (rt side) .378
height to gap 3.220 right - to crown
height to gap - 3.105 left - to crown
max length 10.450 (left side)
gap (left side) - .272

observation - Oxide is soft on left side

Specimen S3 Serial# B3586

Max length 10.132" (left side)
No gap
Max length 10.138" (Right side)
Bowing height (crown) 3.438" left
Bowing (crown) height 3.505" Right

15 Jan 98
at Mfg. Sciences

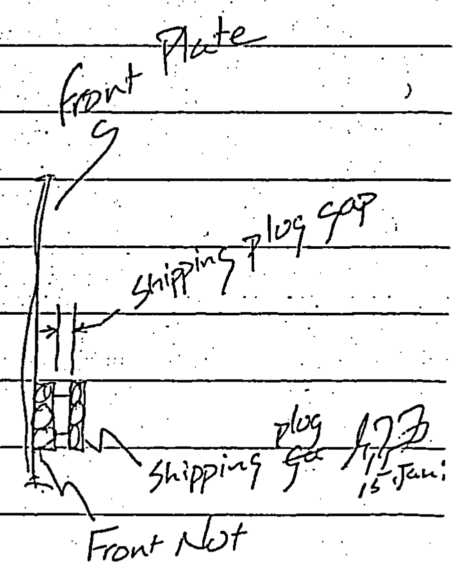
Specimen C #B3589

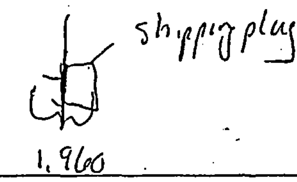
gap	.288"	Right
Max length	16.397"	Right
Height [Crown]	2.705"	Right
Max length	9.936"	left
NO gap	———	left
Height (Crown)	3.234"	left

~~Shipping plug~~ (KMA) 15 Jan 98
Specimen "C", #B3589
Source location (Partial measurement) 2.580"
due to obstruction in the "S-tube".

Specimen S3 #B3586

Front plate - loose
Source location 6.610" - .150 = 6.460"
Shipping plug gap = .150"





Ex-1

wire inserted through front nut
went in 1.960 (~~front~~ from-outside of front
nut (Shipping plug)

<u>Specimen C</u> #B3589

Distance from face of front Nut to dummy Source = 7.822" [initials] 15 Jan 98
(Measured with piece of wire)

(DA) 12 JAN 98

SOURCE LOCATION

	C	S3	~~EX1~~ EX1 (DA 14 JAN 98)
Amersham 12 JAN 98	5.829	5.897	5.620
Mfg. Sam[illegible] 13 JAN 98	5.824	~~5.921~~ 5.922 (DA 13 JAN 98)	5.650

14 Jan 98 Unit Temp

	"C"		17.3°C
?:47	"S3"	* "1 inch [illegible]"	17.4°C
?:49	"EX-1"	* "1/4 inch [illegible]"	60.6°C

Note: Surface Thermocouple was used to measure the internal ^& surface Temp. (KNA) 14 Jan 98

~~* Surface temp~~ (KNA) 14 Jan 98

OMR 19Feb98

SD 18FEB98.

KMD 02MAR98

17 Feb 98

Assessment - Part 71

53 / Specimen C after Thermal Test

Serial #B3586 Serial #B3589

As specimen C has not gone through all the testing, i.e. no puncture test, the thermal was performed for informational purposes only and is not a valid test specimen. Therefore no assessment to 10 CFR 71 is required.

Specimen 53 underwent the full range of testing and successfully passed the radiation profile, indicating this specific unit passes all the Type B tests.

However the specimen 53 was tested to try and exactly mimic the damage seen in specimen of A of TP 73/74 in order to validate/assess the likelihood of transport damage to Specimen A.

53 damage from all testing was not an exact replica of damage seen from A, and therefore cannot conclusively determine that Specimen A from TP 73/TP 74 would have passed the tests if it had not been subjected to transport damage.

Conclusion is ~~that~~ 53 passes the Type B testing but cannot conclude that Specimen A would have passed all the Type B test.

Equipment List 3: Thermal Test

EX-1 R+D Unit

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Air Flowmeter	HEDLAND / 3367 / WINTERS ENG-08	SEE ATTACH
Thermocouple (internal)	OMEGA / ENG-18 A	SEE ATTACH
Thermocouple (external)	OMEGA / ENG-17 A	SEE ATTACH
Thermocouple (oven)	OMEGA / ENG-16 A	SEE ATTACH
Temperature recorder	OMEGA / ENG - 16, 17, 18	SEE ATTACH
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
THERMOMETER	OMEGA / ENG-12	SEE ATTACH
THERMOCOUPLE STRAIGHT PROBE	OMEGA / ENG-14	SEE ATTACH
SOURCE LOCATION TOOL / DIGITAL CALIPER	T10142 / #277	SEE ATTACH
Verified by:	Signature	Date
Engineering	[signature]	13 Jan 98
Regulatory Affairs	C. Rongman	14 Jan 98
Quality Assurance	[signature]	13 Jan 98

EX 1 SOURCE LOCATION BEFORE THERMAL TEST 5.650 [initials] 14 JAN 98

Checklist 3: Thermal Test

Test Location: MFG Sciences OAK RIDGE TN RFD Unit **Attempt Number:** 1

Step	Specimen A EX1	Specimen B	Specimen C	Specimen D
1. Pre-heat the oven to a temperature above 800° C.	DW 13 JAN 98			
2. Attach the thermocouples the specimen's internal and external measuring points.	DW 13 JAN 98			
3. Place the package in the oven and close the oven door.	DW 13 JAN 98			
Record the date and time that the package is placed in oven.	DW 13JAN98 5:35 PM			
4. When the specimen's internal temperature exceeds 800° C, start the air flow into the oven. Record the time.	13 JAN 98 608PM			
Steps 1 through 4 witnessed by:				
Engineering	[signature] 13 Jan 98			
Regulatory Affairs	C [signature] 14 Jan 98			
Quality Assurance	KMA 13Jan98			
5. Measure the oven temperature, the specimen's internal and external temperatures and the air flow rate.	DW 13 JAN 98			
Record the oven temperature:	898.9°C			
Note instrument used:	ENG-16 / ENG-16A	ENG-16 / ENG-16A	ENG-16 / ENG-16A	ENG-16 / ENG-16A
Record the specimen's internal temperature:	803.9			
Note instrument used:	ENG-18 / ENG-18A	ENG-18 / ENG-18A	ENG-18 / ENG-18A	ENG-18 / ENG-18A
Record the specimen's external temperature:	845.2°			
Note instrument used:	ENG-17 / ENG-17A	ENG-17 / ENG-17A	ENG-17 / ENG-17A	ENG-17 / ENG-17A
Record airflow rate:	10 CFM			
Note instrument used:	3367 / ENG-08	3367 / ENG-08	3367 / ENG-08	3367 / ENG-08
6. Monitor the internal and external temperatures of the specimen and the oven temperature throughout the 30-minute period to ensure that they are above 800° C.	DW 13 JAN 98			

Checklist 3: Thermal Test (Continued)

Test Location: MFG Skeaxes **Attempt Number:** 1

R&D UNIT

Step	Specimen A (DO 13 JAN 98 EX1)	Specimen B	Specimen C	Specimen D
7. Monitor the airflow throughout the 30-minute period to ensure a rate of at least 9.6 ft^3/min.	DO 13 JAN 98	N/A	N/A	N/A
8. At the end of the 30-minute period, repeat step 5 using the same measurement devices.	DO 13 JAN 98			
Record the oven temperature:	904.0° c			
Record the specimen's internal temperature:	849.9° c			
Record the specimen's external temperature:	856.5° c			
Record intake air flow velocity:	10.5 CFM			
Steps 5 through 8 witnessed by:				
Engineering	[signature] 18 Feb 98			
Regulatory Affairs	C. Rouyne [signature] 18			
Quality Assurance	KMF 13 Jan 98			
9. Remove test specimen from the oven.	13 JAN 98 6:38 PM ~~6:04~~ DO			
Record time the specimen is removed.	DO 6:38 pm			
Describe combustion when door is opened to remove specimen.	NO FLAME - RED HOT DO 13 JAN 98			
NOTE: If specimen continues to burn, let it self-extinguish and cool naturally.				
10. Measure the ambient temperature.	DO 13 JAN 98			
Record the ambient temperature:	63.1° F			
Note the instrument used:	ENG-12 / ENG-14	ENG-12 / ENG-14	ENG-12 / ENG-14	ENG-12 / ENG-14
11. Photograph the test specimen and any subsequent damage	DO 13 JAN 98			
12. Record damage to test specimen on a separate sheet and attach.	DO 15 JAN 98			
Steps 9 through 12 witnessed by:				
Engineering	[signature] 18 Feb 98			
witnessed on 15 Jan 98 Regulatory Affairs	CMR 18 Feb 98			
Quality Assurance				

Checklist 3: Thermal Test (Continued)

Test Location: MFG SIENLES OAK RIDGE TN R&D **Attempt Number:** 1

Step	Specimen A BJAL 58 EX-1	Specimen B	Specimen C	Specimen D
13. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach.	NA*	N/A	N/A	N/A

Test Data Accepted by (Signature):	Date:
Engineering	
Regulatory Affairs	
Quality Assurance	

* NA - as test unit was experimental and not a valid test specimen in the TP 74

CMR 18FEB98

Section 2.12.8 Appendix: Test Plan 80 Rev 1 (Mar 1999).

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 16, 1999

Mr. William M. McDaniel,
Facility Manager
AEA Technology, QSA Inc.
40 North Avenue
Burlington, MA 01803

Dear Mr. McDaniel:

This is to acknowledge receipt of your plan No. 80, Revision 1, dated March 12, 1999, for testing the Model No. 650L package. This plan was submitted in response to our Confirmatory Action Letter No. 97-7-005, dated June 10, 1997.

We have reviewed your test plan and found it to be acceptable.

If you have any questions regarding this matter, please contact me at (301)-415-8510.

Sincerely,

Cass R. Chappell

Cass R. Chappell, Chief
Package Certification Section
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

cc: 71-9269

AEA TECHNOLOGY
QSA

	TEST PLAN NO. 80, REV. 1
TEST PLAN COVER SHEET	
TEST TITLE: TEST PLAN 80, REVISION 1, MODEL 650L SOURCE CHANGER TYPE B TRANSPORT TESTS	
PRODUCT MODEL: 650L	
ORIGINATED BY: [signature] (MPR)	DATE: 12 MAR 99
TEST PLAN REVIEW	
ENGINEERING APPROVAL: Nicholas J. Mavros	DATE: 12 MAR 99
QUALITY ASSURANCE APPROVAL: Daniel W. Kurtz	DATE: 12 Mar 99
REGULATORY APPROVAL: [signature]	DATE: 12 Mar 99
COMMENTS:	
TEST RESULTS REVIEW	
ENGINEERING APPROVAL:	DATE:
QUALITY ASSURANCE APPROVAL:	DATE:
REGULATORY APPROVAL:	DATE:

SENTINEL

Test Plan 80

Revision 1

Model 650L

Source Changer

Type B Transport Tests

March 1999

Prepared By: [signature] Date 12 MAR 99

C. SCHLASEMAN
MPR

Checked By: Date 12 MAR 99

E. CLAUDE [signature]
MPR

Approved By: Date

N. MARRONE [signature] 12 MAR 99
MPR

Test Plan 80

Revision 1

Model 650L
Source Changer
Type B Transport Tests

March 1999

Prepared By: Date

C. SCHLASEMAN
MPR

Checked By: Date

E. CLAUDE
MPR

Approved By: Date

N. MARRONE
MPR

Contents

List of Figures, Tables and Worksheets

AEA Technology/QSA Test Plan 80

1.0 Introduction

This document describes Type B(U) transport package testing of the SENTINEL Model 650L Source Changer, Certificate of Compliance Number 9269. The purpose of the testing is to demonstrate that the package meets the NRC requirements for Type B(U) packages under Normal Conditions of Transport (10 CFR 71.71), Hypothetical Accident Conditions (10 CFR 71.73), and the criteria stated in IAEA, Safety Series 6 (1985, as amended 1990).

The test plan specifies the test package configurations, testing equipment and scenarios, justifies the package orientations, and provides test worksheets to record key steps in the testing sequence.

Refer to Appendix A for a drawing of the test specimen.

2.0 Transport Package Description

The Model 650L source changer shown in Appendix A is 13 ¼" high, 10" long, and 8 ¼" wide in overall dimension, and has a maximum weight of 90 lb. The package consists of the following components:

- Source Capsule and Shield Assembly: The Special Form Source is contained in a capsule and is attached to the source wire assembly. The source is shielded by a Titanium "U" tube that is enclosed in a depleted uranium (DU) shield.

- Outer Casing: The shield assembly is encased in two Carbon Steel shells. The inner shell is rectangular and is 0.135" thick. The outer shell is circular and is 0.048" thick. The shells are positioned between two, Stainless Steel, 0.135" thick top and bottom plates. The plates are secured with four 5/16-18 hex head stainless steel through-bolts. The voids between the depleted uranium shield and the inner and outer shells are filled with a rigid 8 pound Polyurethane foam.

- Protective Lid: During transport, the locking assembly is protected by a 0.135" thick, Carbon Steel lid. The lid is secured to the top plate by four 3/8-16 hex head strain-hardened stainless steel bolts.

- Source Locking Assembly: Model 650L has two Stainless Steel locking assemblies that keep the source inside the Titanium "U" tube. Each locking assembly is secured to the top plate by four ¼-20 Stainless Steel screws.

The 650L package is shown below in Figure 1.

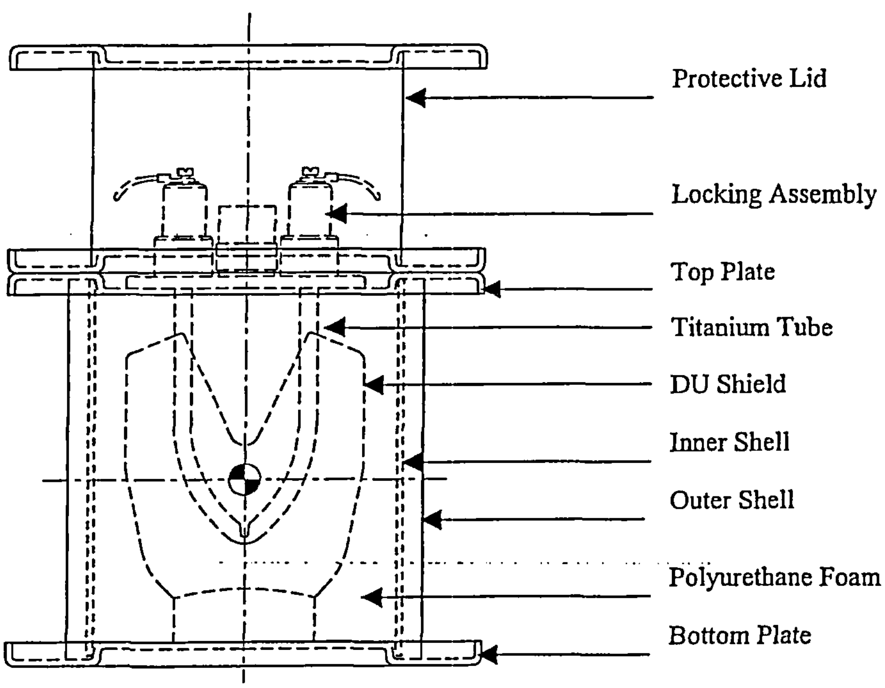


Figure 1. Side View of Model 650L Package

3.0 Regulatory Compliance

The purpose of this plan, which was developed in accordance with AEAT/QSA SOP-E005, is to ensure that the Model 650L Source Changer shown in the descriptive drawing provided in Appendix A meets the Type B(U) transport package requirements of 10 CFR 71 and IAEA Safety Series No. 6 (1985, as amended 1990).

The Normal Conditions of Transport tests (10 CFR 71.71) to be performed are the compression test, penetration test, and 1.2 meter (4 foot) free drop.

Water spray preconditioning of the package is not performed as the Model 650L packages are constructed of waterproof materials throughout. The water spray would not contribute to any degradation in structural integrity.

The Hypothetical Accident Tests (10 CFR 71.73) to be performed are the 9 meter (30 foot) free drop, puncture test, and thermal test.

The crush test (10 CFR 71.73(c)(2)) is not performed because the radioactive contents are special-form radioactive material.

The immersion test and all other conditions specified in 10 CFR 71 will be evaluated separately.

4.0 System Failures and Package Orientations

The location of the source relative to its stored position in the shield is an important safety element. Displacement of the source and/or shield from its original stored position could elevate the dose rate at the surface of the package above regulatory limits. Tests in this plan focus on damaging those components of the package which could cause displacement of the source, relative to its stored position, within the shield and which affect the integrity of the shield itself.

System failures that could affect package integrity and cause radiological dose rates to exceed the regulatory limits include:

- Oxidation of DU Shield during the thermal test could occur if either distortion/local buckling of the inner and outer shells, or failure of the through-bolts during drop testing results in a large, open path to the DU shield.

- Source Pull-Out from Shield could occur if there is significant relative displacement between the shield and the top cover plate penetration and locking assembly.

Three orientations are considered most likely to cause damage during the 1.2 meter and 9 meter drop tests, i.e., the most likely to cause unacceptable external dose rates. For all three orientations, the worst case temperature is the lower limit of -40°C due to embrittlement of the DU and Carbon Steel components.

- Case 1, Horizontal, Long-Side Down: The DU shield could move through the foam during impact, which could result in source pullout from titanium tubes. Also, due to the low testing temperature, brittle failure of the inner and outer shells could occur. The failure(s) may be sufficient to open a significant path to the depleted uranium shield during thermal test and cause burning of the DU shield. The Long-Side Down orientation is selected because the long side of the package has a stiffer configuration than the short side, which will result in a shorter deceleration and a higher impact load.

- Case 2, Vertical, Upside Down: Deformation of the lid weldment, crushing of the foam between the depleted uranium shield and top plate, deformation (bowing upward) of the top plate due to the impact load of the DU shield applied through titanium source tubes and foam, failure of the through-bolts, and failure of the locking assembly could occur. When the package is turned upright for the thermal test, the DU shield and its integral titanium tubes could drop down to their original positions while the source is pulled out of the tubes by the bowed top plate or failed locking assembly. Also, a lead shim (which will melt during thermal testing) under the DU shield could cause additional source pullout.

- Case 3, Vertical, Top Corner Down: Failure of lid or lid closure bolts could expose the locking assembly to damage during the puncture bar test. Failure of the locking assembly could result in source pullout. Additionally, this orientation will load the through-bolts in tension, and could cause them to fail.

The following orientations are planned for the puncture tests. These orientations will be modified, if necessary, based on the results of the engineering assessments conducted after the 9 meter drop tests. The puncture test orientations will be selected to maximize damage to the test specimens.

- Case 1, Horizontal, Long-Side Down: This orientation is the same as for the Case 1, 1.2 meter and 9 meter drop tests.

- Case 2, Underside of Top Plate at Lid Bolt: The top plate could be pried up, and, as a minimum, load the through-bolts in tension. The impact on the lid bolt rivnut could damage the lid bolt connection.

- Case 3, Bottom of Package: Impact on the four Stainless Steel rivnuts could damage the through-bolt connection. If the lid is removed during the Case 3 9 meter drop, the test specimen will be dropped upside down such that the lock assemblies strike the puncture bar.

The limiting orientation for the penetration bar test is discussed in Section 8.6.2.

5.0 Assessment of Package Conformance

The Model 650L Source Changer must meet the Type B(U) transport package requirements of 10 CFR 71. The conformance criteria are detailed in the following two sections.

5.1 Regulatory Requirements

- Normal Conditions of Transport Tests (71.43(f)): There should be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels and no substantial reduction in the effectiveness of the packaging.

- Hypothetical Accident Conditions (71.51(a)(2)): There should be no escape of radioactive materials greater than A_2 in one week and no external dose rate greater than 1 R/hr at 1 meter from the external surface when the package contains its maximum design radioactive contents.

5.2 Test Package Contents

The Model 650L is designed to carry Special Form Sources. Containment of the radioactive source is tested at manufacture. The source capsules have been certified by the Competent Authority in accordance with the performance requirements for Special Form as specified in 10 CFR Part 71 and 49 CFR.

The test plan therefore does not discuss/specify tests of the containment of the radioactive source. The purpose of the tests is to demonstrate that the shielding remains effective within the limits specified by the regulations, and that the source capsule remains contained within the source changer.

A simulated source will be used during testing of the package. The radiation levels after the test will be monitored by replacing the simulated source with an active source.

6.0 Construction and Condition of Test Specimens

The Test Plan 80 (TP 80) test specimens will be Model 650L units constructed in accordance with AEAT/QSA Drawing R-TP80, Revision D.

Drawing TP650L specifies the Model 650L package in its worst case transport conditions, which vary depending on the Test Case. Lead shielding placement should be as described below:

Test Case	Lead Shielding Placement	Rationale
1—Horizontal, Long-Side Down Specimen TP80(A)	No lead between DU shield and long side of inner shell.	Lead between DU and shell or through-bolts might stop DU from travelling through foam during drop impact.
2—Vertical, Upside Down Specimen TP80(B)	Thickest lead under DU shield, use heavy package.	Lead under DU may melt during thermal test and could allow DU to settle, which could allow source pullout. Impact force will be larger for heavier packages, which would result in larger top plate deflection.
3—Top Corner Down Specimen TP80(C)	Any location, use heavy package.	Lead placement will not affect lid failure, and impact force will be larger for heavier packages.

For all Drop Test Cases the temperature of the specimen must be below -40°C at the time of each test, a minimum temperature required by IAEA, Safety Series 6 (1985, as amended 1990). The low temperature represents the worst-case condition for the package because of the potential for brittle fracture of the shield and Carbon Steel lid.

7.0 Material and Equipment List

The equipment checklists, test worksheets, and data sheets in Section 9.0 list the key materials and equipment specified in 10 CFR 71 and the necessary measurement instruments.

When video recording is specified, select video cameras with the highest shutter speed practical to record testing.

Additional materials and equipment may be used to facilitate the tests.

8.0 Test Procedure

Three specimens are to be tested to determine the transport integrity of the package. The testing sequence is shown below:

1. Test specimen preparation and inspection
2. Compression test (10 CFR 71.71(c)(9))
3. Penetration test (10 CFR 71.71(c)(10))
4. 1.2 Meter (4 foot) free drop test (10 CFR 71.71(c)(7))
5. First intermediate test inspection
6. 9 Meter (30 foot) free drop test (10 CFR 71.73(c)(1))
7. Puncture test (10 CFR 71.73(c)(3))
8. Second intermediate test inspection
9. Thermal test (10 CFR 71.73(c)(4)) (If applicable, see Section 8.12.1)
10. Final test inspection

Each specimen must be put through the entire test sequence, unless the thermal test is considered unnecessary based on the test specimen condition after the puncture test and the assessment by Engineering, Quality Assurance and Regulatory Affairs. If test conditions such as the orientation at impact are not met during the test of a particular specimen, it may be replaced with a specimen of equivalent construction. The replacement must go through the entire test sequence.

8.1 Roles and Responsibilities

The responsibilities of the groups identified in this plan are:

- **Engineering** executes the tests according to the test plan and summarizes the test results. **Engineering** also provides technical input to assist Regulatory Affairs and Quality Assurance as needed.

- **Regulatory Affairs** monitors the tests and reviews test reports for compliance with regulatory requirements.

- **Quality Assurance** oversees test execution and test report generation to ensure compliance with AEAT/QSA Quality Assurance Program.

- **Engineering, Regulatory Affairs,** and **Quality Assurance** are jointly responsible for assessing test and specimen conditions relative to 10 CFR 71.

- **Quality Control,** a function that reports directly to Quality Assurance, is responsible for measuring and recording test and specimen data throughout the test cycle.

8.2 Specimen Temperature Measurement

The penetration, drop, and puncture tests are to be carried out while the package is at or below -40°C. Temperature measurements will be made by positioning thermocouples on the package surface and the shield (inside the source tube).

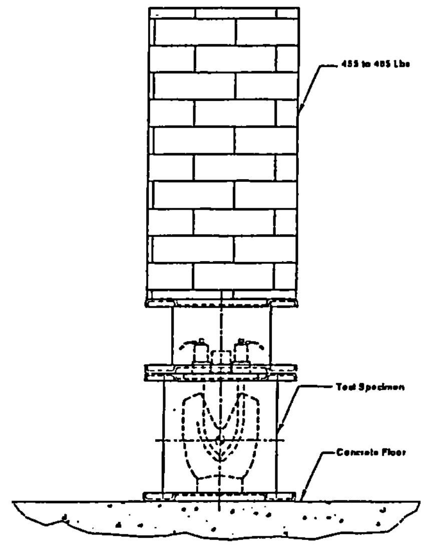
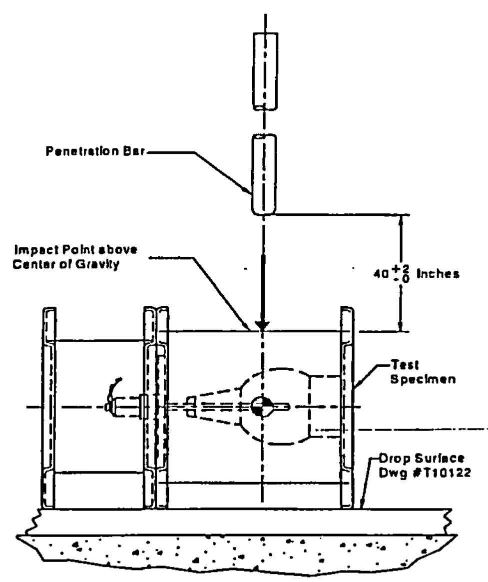
8.3 Test Specimen Preparation and Inspection

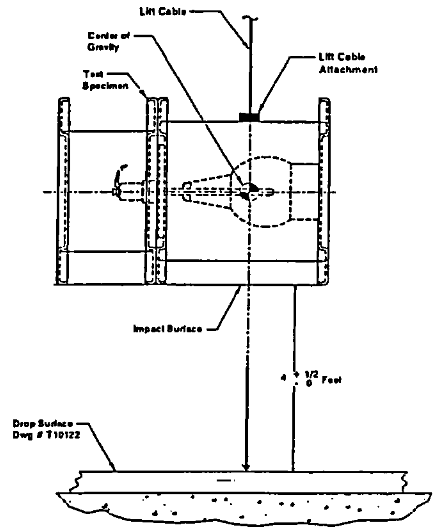
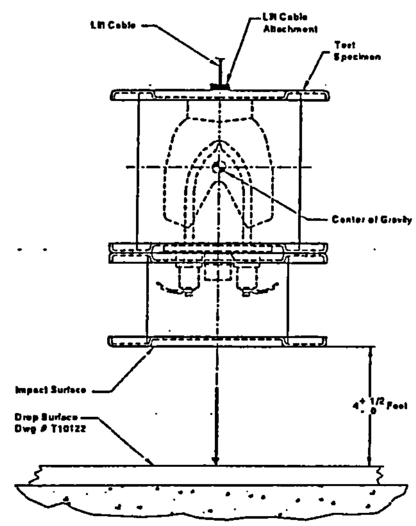
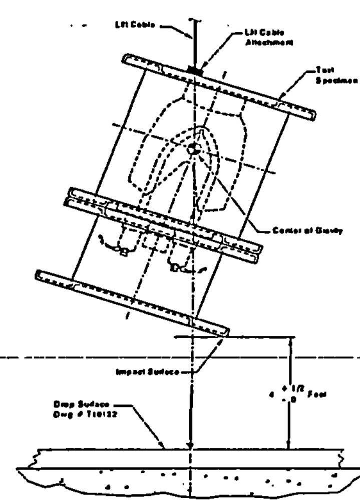
Refer to the *Specimen Preparation List* in Section 9.0 to ensure that test sequence is followed. Sign and date the list when completed.

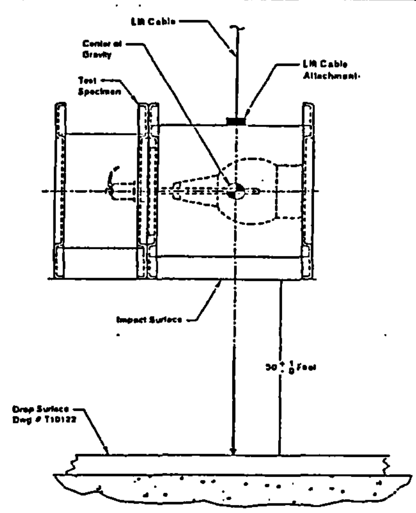
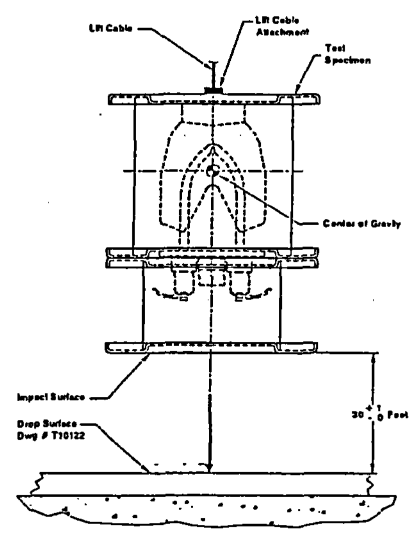
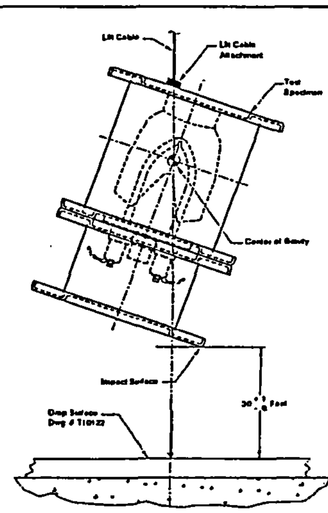
To prepare the test units:

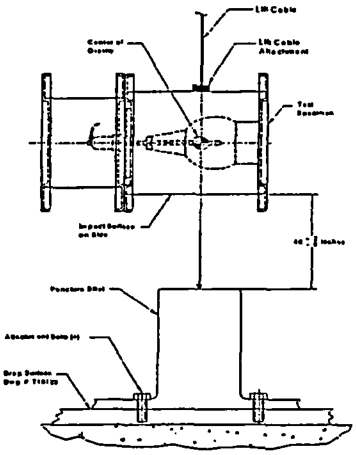
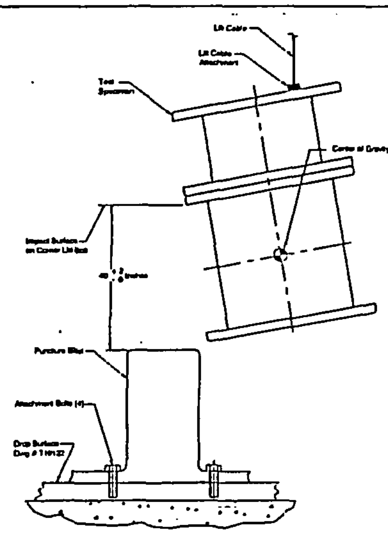
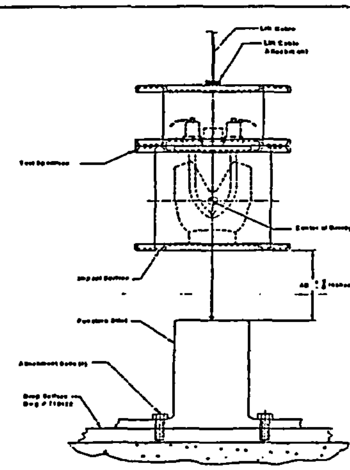
1. Inspect the test units to ensure that they comply with the requirements of Drawing R-TP80, Revision D.
2. Weigh the test package, including the lid.
3. Perform and record the radiation profile in accordance with AEAT/QSA Work Instruction WI-Q09.
4. **Quality Control, Engineering, Regulatory Affairs,** and **Quality Assurance** will jointly verify that the test specimens comply with Drawing R-TP80, Revision D, and the AEAT/QSA Quality Assurance Program.
5. Measure and record the location of the simulated source.
6. Place thermocouples on package surface and inside one of the source tubes.
7. Prepare the package for transport.
8. Clearly and indelibly mark the units with identification.

8.4 Summary of Test Schedule

Test	Paragraph	Specimen	Diagram
Compression	71.71(c)(9)	ALL	
Penetration	71.71(c)(10)	ALL	

Test	Paragraph	Specimen	Diagram
1.2 Meter (4 Foot) Free Drop, Case 1, Horizontal, Long Side Down	71.71(c)(7)	TP80(A)	
1.2 Meter (4 Foot) Free Drop, Case 2, Vertical, Upside Down	71.71(c)(7)	TP80(B)	
1.2 Meter (4 Foot) Free Drop, Case 3, Top Corner Down	71.71(c)(7)	TP80(C)	

Test	Paragraph	Specimen	Diagram
9 Meter (30 Foot) Free Drop, Case 1, Horizontal, Long Side Down	71.73(c)(1)	TP80(A)	
9 Meter (30 Foot) Free Drop, Case 2, Vertical, Upside Down	71.73(c)(1)	TP80(B)	
9 Meter (30 Foot) Free Drop, Case 3, Top Corner Down	71.73(c)(1)	TP80(C)	

Test	Paragraph	Specimen	Diagram
Puncture, Case 1, Horizontal, Long Side Down	71.73(c)(3)	TP80(A)	
Puncture, Case 2, Underneath Corner of Top Plate	71.73(c)(3)	TP80(B)	
Puncture, Case 3, Vertical Upright	71.73(c)(3)	TP80(C)	
Thermal	71.73(c)(4)	ALL	Requirement for thermal test to be determined for each unit following completion of drop and puncture tests.

8.5 Compression Test (10 CFR 71.71(c)(9))

The first test is the compression test, per 10 CFR 71.71(c)(9), in which the package is placed under a load of 455 pounds which is greater than five times the maximum package weight and greater than 2 lbf/in^2 multiplied by the vertically projected area:

5 x 90 lbf = 450 lbf

8 ¼" wide x 10" long x 2 lbf/in^2 = 165 lbf

Refer to *Equipment List 1* for information about required tools. Use *Checklist 1* to ensure that the test sequence is followed. Use *Data Sheet 1* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

8.5.1 Compression Test Setup

To prepare a specimen for the compression test:

1. Review the setup shown in Figure 2.
2. Place the specimen on a concrete surface oriented in its normal, upright transport position.
3. *Gradually place 455 to 465 pounds uniformly distributed onto the specimen* as shown in Figure 2.
4. Test specimen in accordance with *Checklist 1.*

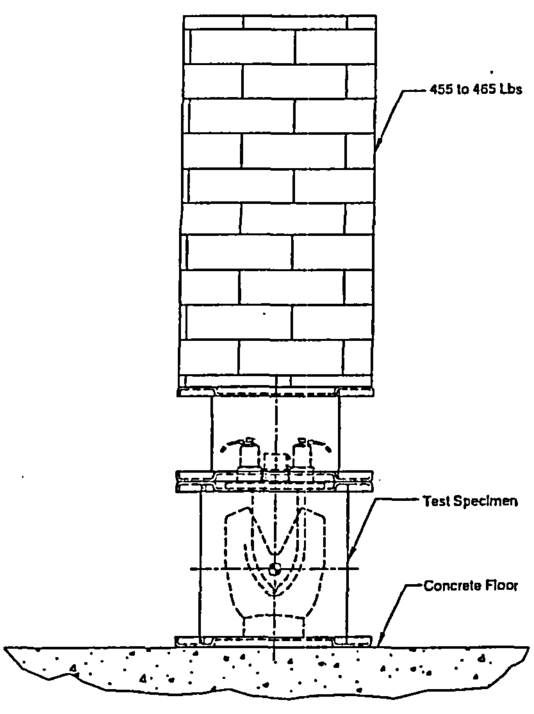


Figure 2. Compression Test Setup

8.5.2 Compression Test Assessment

Upon completion of the test, Engineering, Regulatory Affairs, and Quality Assurance team members will jointly take the following actions:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.

2. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.

3. Assess the damage to the specimen to decide whether testing of that specimen is to continue.

4. Evaluate the condition of the specimen to determine if changes are necessary in the package orientation for the penetration test to achieve maximum damage.

8.6 Penetration Test (10 CFR 71.71(c)(10))

The compression test is followed by the penetration test, per 10 CFR 71.71(c)(10), in which a penetration bar is dropped from a height of at least 40 inches to impact a specified point on the package. The bar is dropped through free air.

Refer to *Equipment List 2* for information about required tools. Use *Checklist 2* to ensure that the test sequence is followed. Use *Data Sheet 2* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

8.6.1 Penetration Test Setup

This test requires that the test specimen be at -40°C or below at the time of the penetration bar release. The worksheet calls for measuring and recording the specimen temperature before and after the test.

To set up a package for the penetration test:

1. Place the specimen on the drop surface (Drawing AT10122, Revision B) and position it according to the orientation described in the next section. Use shims to position the package, if necessary.

2. Position the penetration bar shown in Drawing BT10129, Revision B, directly above the specified point of impact, and raise the bar 40 to 42 inches above the target.

3. Measure the specimen's internal and surface temperature to ensure that the package is at the required temperature.

4. Test specimen in accordance with *Checklist 2*.

8.6.2 Penetration Test Orientation

The 650L package is placed horizontally, long side down on the drop surface specified in Drawing AT10122, Revision B. The orientation of the package is shown in Figure 3. The desired impact point is on the long side of the outer shell, directly above the center of gravity of the package, to try to penetrate the shells.

Other orientations for this specimen were considered including the normal transport position. In the normal transport orientation, the lock assembly is protected by the 0.135" thick steel outer lid. The penetration bar dropped from four feet would cause only minor damage to the outer lid.

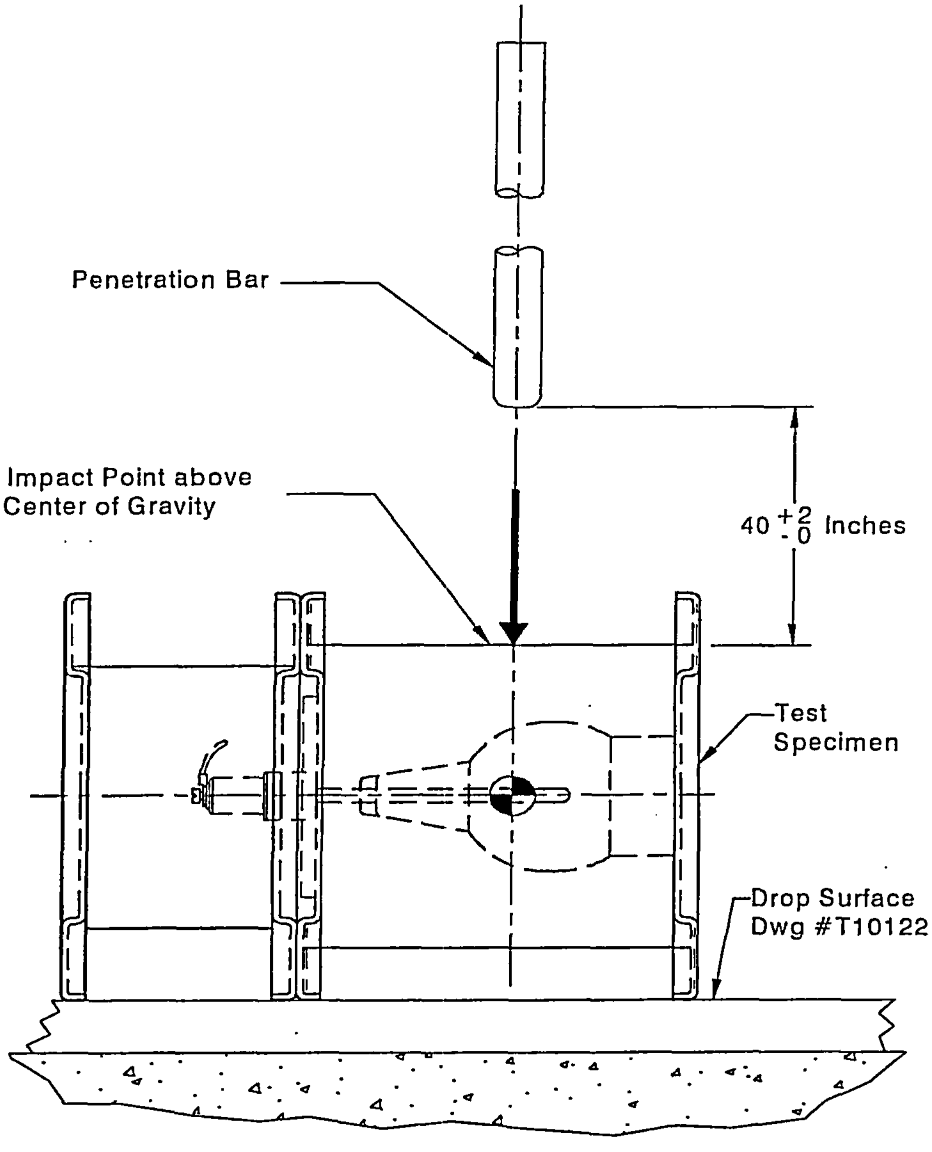


Figure 3. Penetration Test Orientation

8.6.3 Penetration Test Assessment

Upon completion of the test, **Engineering**, **Regulatory Affairs**, and **Quality Assurance** team members will jointly take the following actions:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.

2. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.

3. Assess the damage to the specimen to decide whether testing of that specimen is to continue.

4. Evaluate the condition of the specimen to determine if changes are necessary in the package orientation for the 1.2 meter (4 foot) free drop test to achieve maximum damage.

8.7 1.2 Meter (4 Foot) Free Drop Test (10 CFR 71.71(c)(7))

The final Normal Transport Conditions test is the 1.2 meter (4 foot) free drop as described in 10 CFR 71.71(c)(7). The drop compounds any damage caused in the first two tests. Upon completion of this step, the first intermediate test inspections will be performed.

Refer to *Equipment List 3* for information about required tools. Use *Checklist 3* to ensure that the test sequence is followed. Use *Data Sheet 3* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

8.7.1 1.2 Meter (4 Foot) Free Drop Test Setup

In this test, the package is released from a height of four feet and lands on the steel drop surface specified in Drawing AT10122, Revision B.

This test requires that all test specimen be at -40°C or below at the time of impact. Follow the instructions in the appropriate checklist for measuring and recording the test specimen temperature before and after the drop.

To set up a package for the 1.2 meter (4 foot) free drop test:

1. Use the drop surface specified in Drawing AT10122, Rev. B.

2. Measure and record the test specimen temperature to ensure that the package is at the specified temperature.

3. Place the specimen on the drop surface and position it according to the appropriate orientation:

   - Refer to Figure 4 for the Specimen TP80(A) package orientation

   - Refer to Figure 5 for the Specimen TP80(B) package orientation

   - Refer to Figure 6 for the Specimen TP80(C) package orientation

4. Align the selected center-of-gravity as shown in the referenced drawing.

5. Raise the package so that the impact target is 4.0 to 4.5 feet above the drop surface.

6. Test specimen in accordance with *Checklist 3*.

8.7.2 1.2 Meter (4 Foot) Free Drop Test Orientation, Specimen TP80(A)

The impact surface of Specimen TP80(A) is horizontal, long-side down.

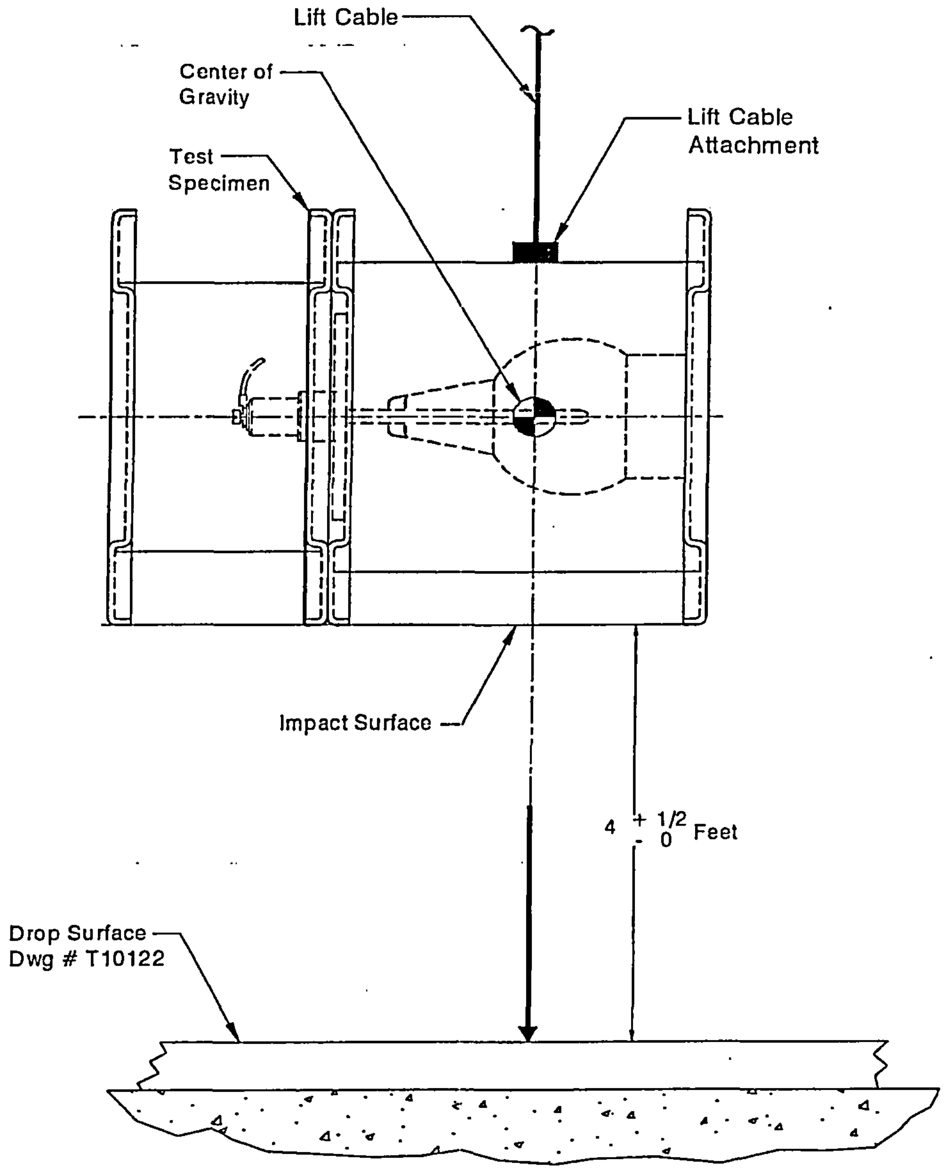


Figure 4. 1.2 Meter (4 Foot) Free Drop Orientation, Specimen TP80(A)

8.7.3 1.2 Meter (4 Foot) Free Drop Test Orientation, Specimen TP80(B)

The impact surface for Specimen TP80(B) is vertical, upside down.

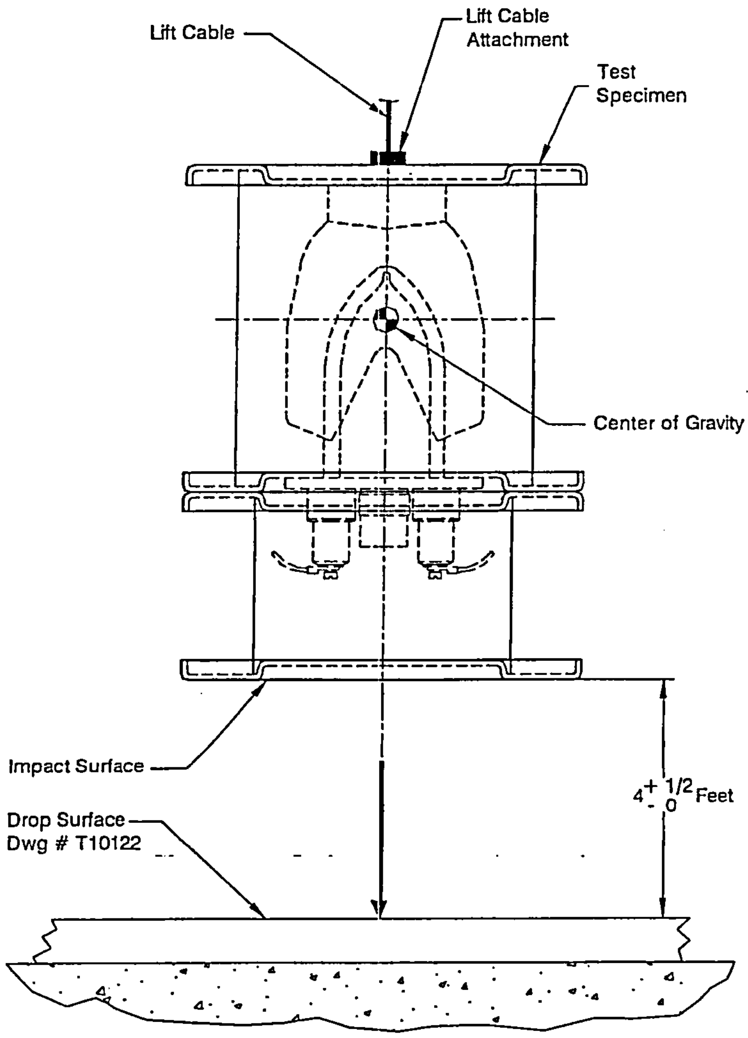


Figure 5. 1.2 Meter (4 Foot) Free Drop Orientation, Specimen TP80(B)

8.7.4 1.2 Meter (4 foot) Free Drop Test Orientation, Specimen TP80(C)

The impact surface for Specimen TP80(C) is the top (lid) corner.

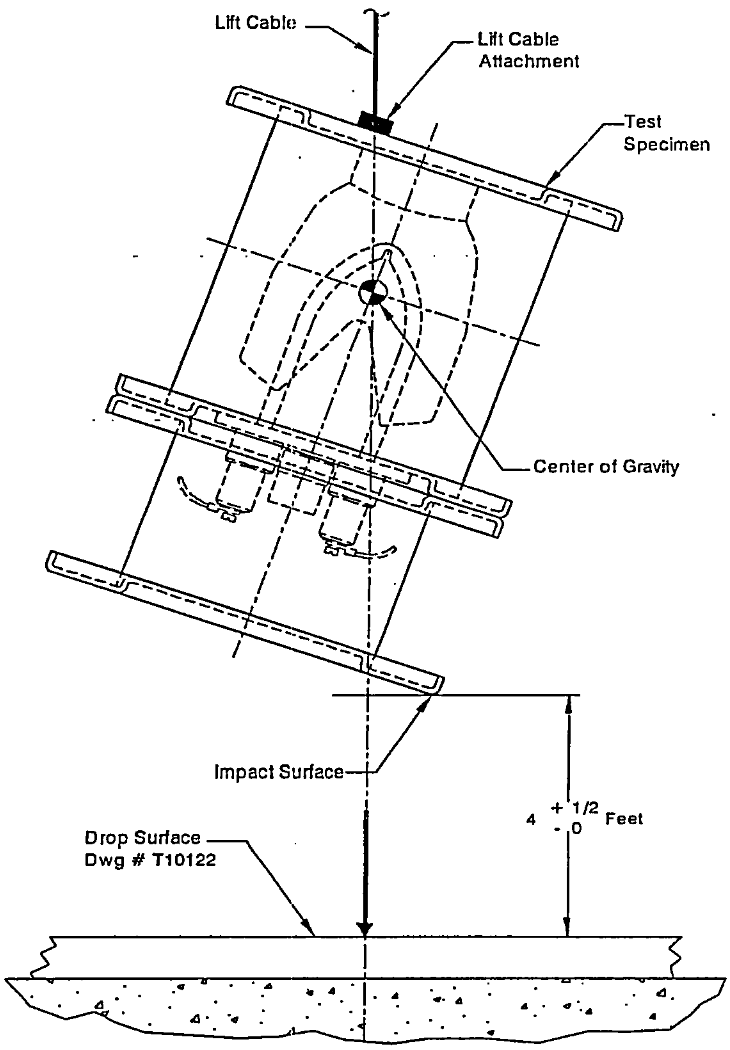


Figure 6. 1.2 Meter (4 Foot) Free Drop Orientation, Specimen TP80(C)

8.7.5 1.2 Meter (4 Foot) Free Drop Test Assessment

Upon completion of the test, **Engineering, Regulatory Affairs,** and **Quality Assurance** team members will jointly perform the following tasks:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.71.

2. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.71.

3. Assess the damage to the specimen to decide whether testing of that specimen is to continue.

4. Evaluate the condition of the specimen to determine if changes are necessary in package orientation for the 9 meter (30 foot) free drop to achieve maximum damage.

5. Measure and record any damage to the test specimen.

6. Measure and record a radiation profile of the test specimen in accordance with AEAT/QSA Work Instruction WI-Q09.

8.8 First Intermediate Test Inspection

Engineering, Regulatory Affairs, and **Quality Assurance** team members will make an assessment of the test specimen and jointly determine whether the specimen meets the requirements of 10 CFR 71.71.

8.9 9 Meter (30 Foot) Free Drop Test (10 CFR 71.73(c)(1))

The first Hypothetical Accident Conditions test is the 9 meter (30 foot) free drop as described in 10 CFR 71.73(c)(1). This drop uses the same orientations as the 1.2 meter (4 foot) free drop and compounds any damage caused in that test.

Refer to *Equipment List 4* for information about required tools. Use *Checklist 4* to ensure that the test sequence is followed. Use *Data Sheet 4* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

8.9.1 9 Meter (30 Foot) Free Drop Test Setup

In this test, the package is released from a height of thirty feet and lands on the steel drop surface specified in Drawing AT10122, Revision B.

This test requires that the test specimen be at -40°C or below at the time of impact. Follow the instructions in the appropriate checklist for measuring and recording the test specimen temperature before and after the drop.

To set up a package for the 9 meter (30 foot) free drop test:

1. Use the drop surface specified in Drawing AT10122, Rev. B.

2. Measure and record the test specimen temperature to ensure that the package is at the specified temperature.

3. Place the specimen on the drop surface and position it according to the appropriate orientation:

   - Refer to Figure 7 for the Specimen TP80(A) package orientation
   - Refer to Figure 8 for the Specimen TP80(B) package orientation
   - Refer to Figure 9 for the Specimen TP80(C) package orientation

4. Align the selected center-of-gravity marker as shown in the referenced drawing.

5. Raise the package so that the impact target is 30 to 31 feet above the drop surface.

6. Test the specimen in accordance with *Checklist 4*.

8.9.2 9 Meter (30 Foot) Free Drop Test Orientation, TP80(A)

The impact surface for Specimen TP80(A) is horizontal, long-side down. This orientation is the same as the orientation for the 1.2 meter (4 foot) drop for Specimen TP80(A).

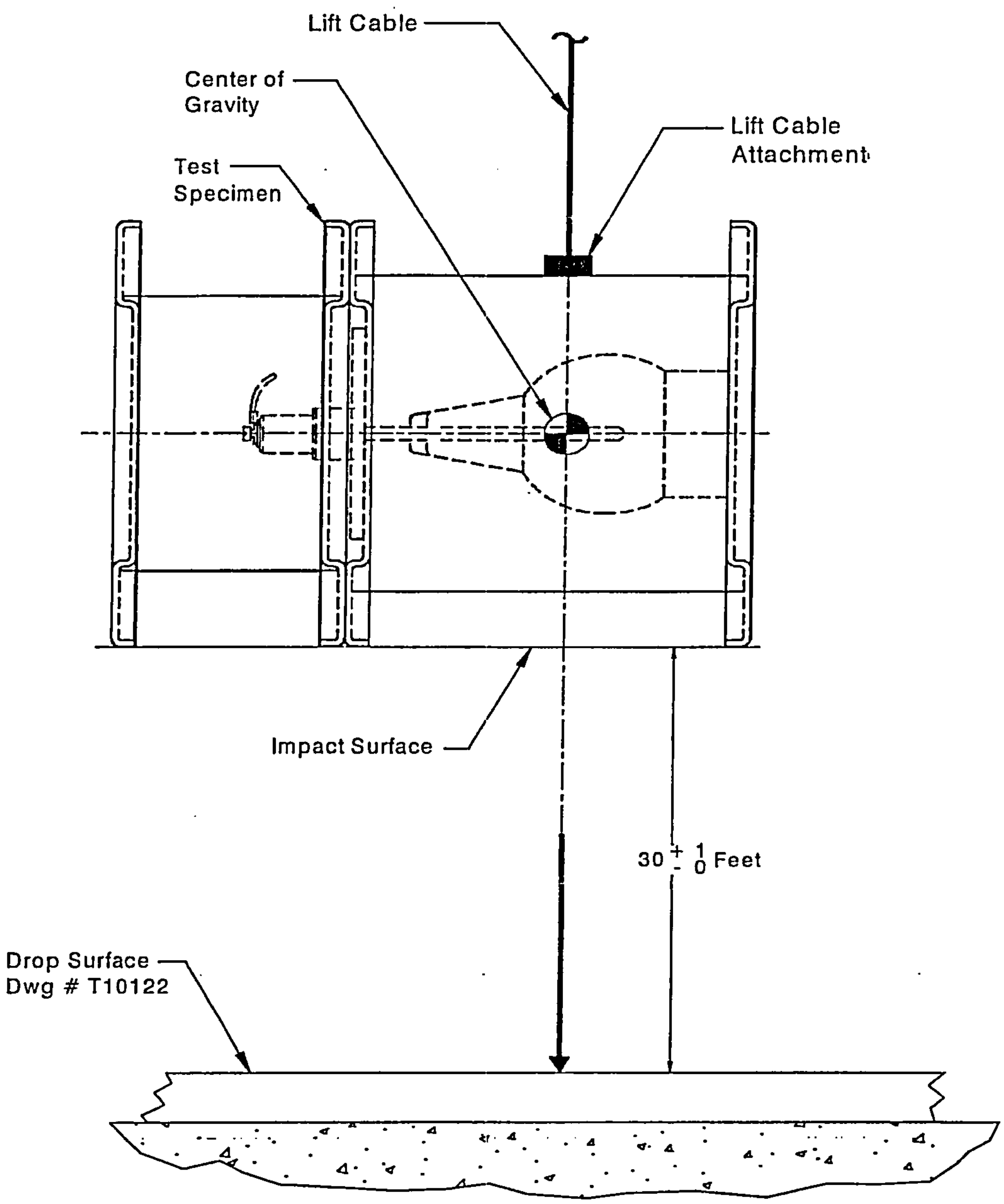


Figure 7. 9 Meter (30 Foot) Free Drop Orientation, Specimen TP80(A)

8.9.3 9 Meter (30 Foot) Free Drop Test Orientation, Specimen TP80(B)

The impact surface for Specimen TP80(B) is vertical, upside down. This orientation is the same as the orientation for the 1.2 meter (4 foot) drop for Specimen TP80(B).

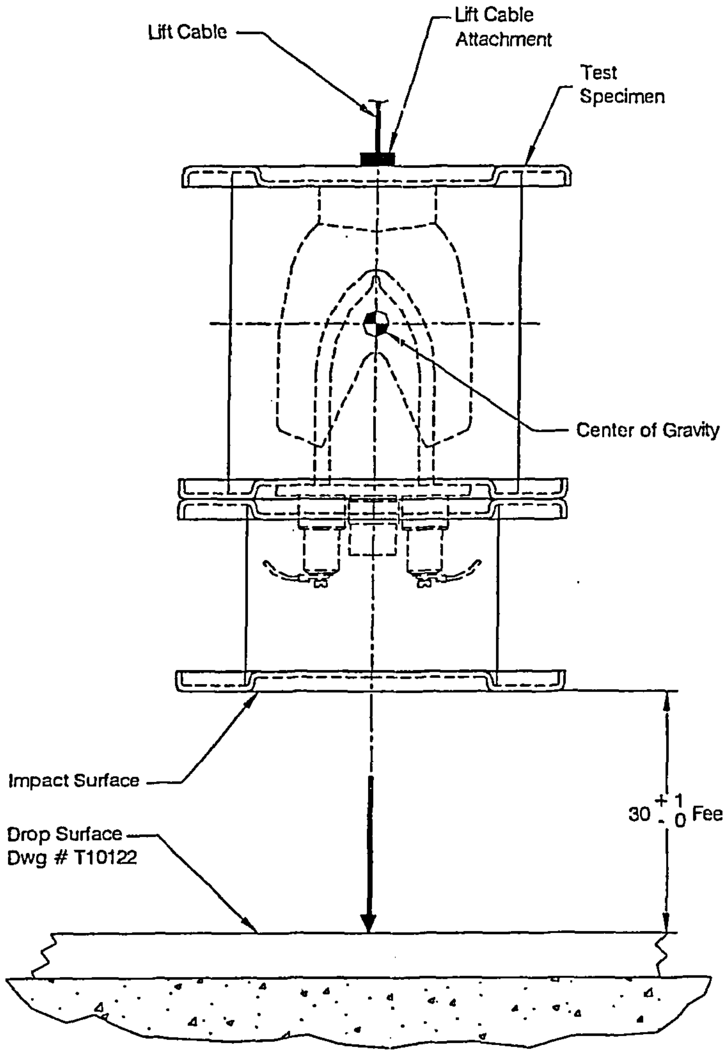


Figure 8. 9 Meter (30 Foot) Free Drop Orientation, Specimen TP80(B)

8.9.4 9 Meter (30 Foot) Free Drop Test Orientation, Specimen TP80(C)

The impact surface for Specimen TP80(C) is the top (lid) corner. This orientation is the same as the orientation for the 1.2 meter (4 foot) drop for Specimen TP80(C).

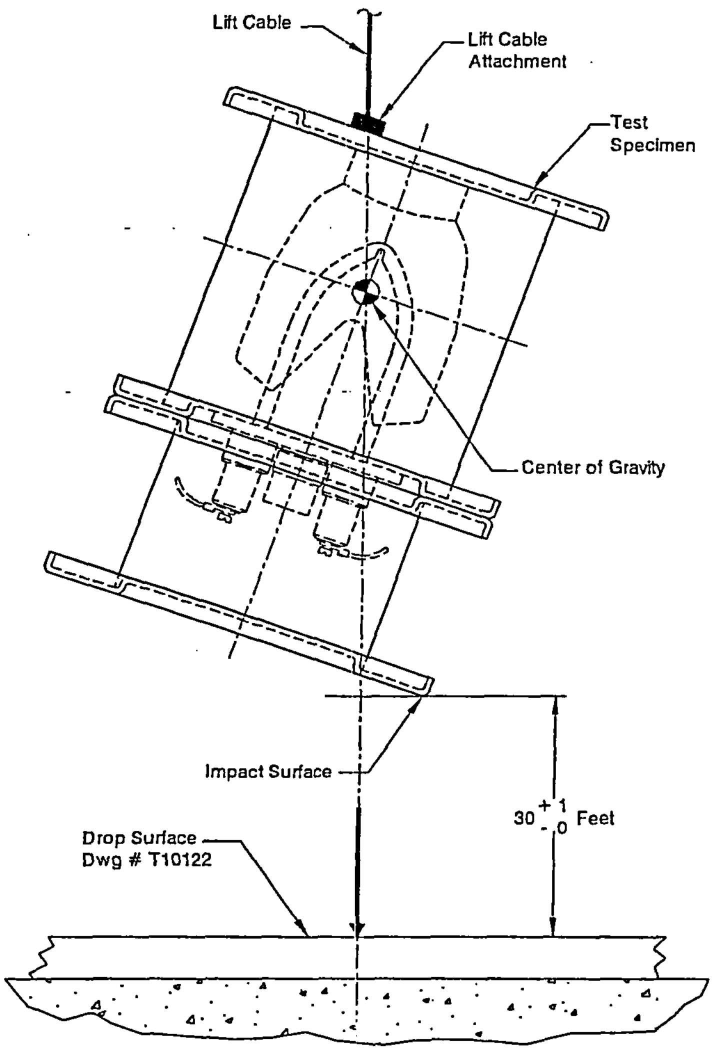


Figure 9. 9 Meter (30 Foot) Free Drop Orientation, Specimen TP80(C)

8.9.5 9 Meter (30 Foot) Free Drop Test Assessment

Upon completion of the test, Engineering, Regulatory Affairs, and Quality Assurance team members will jointly perform the following tasks:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.73, and in accordance with the impact orientation and other conditions specified in this plan.

2. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.73.

3. Perform an assessment to determine if any change in puncture test orientation is necessary in order to sustain maximum specimen damage during the Puncture Test, and document.

8.10 Puncture Test (10 CFR 71.73(c)(3))

The 9 meter (30 foot) free drop is followed by the puncture test, per 10 CFR 71.73(c)(3), in which the package is dropped from a height of at least 40 inches onto the puncture billet specified in the Drawing CT10119, Revision C.

The billet is to be bolted to the drop surface used in the free drop tests. The 12-inch high puncture billet meets the minimum height (8 inches) required in 10 CFR 71.73(c)(3). The specimen has no projections or overhanging members longer than 8 inches, which could act as impact absorbers, thus allowing the billet to cause the maximum damage to the specimen.

Refer to *Equipment List 5* for information about required tools. Use *Checklist 5* to ensure that the test sequence is followed. Use *Data Sheet 5* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

This test requires that the test specimen be at -40°C or below at the time of impact. Follow the instructions in the appropriate checklist for measuring and recording the test specimen temperature before and after the drop.

8.10.1 Puncture Test Setup

To set up a test specimen for the puncture test:

1. Measure and record the test specimen temperature to ensure that the package is at the specified temperature.

2. Place the specimen on the drop surface and position it according to the appropriate orientation (unless the 9 meter Test Assessment selects different orientations):

   - Refer to Figure 10 for the Specimen TP80(A) package orientation
   - Refer to Figure 11 for the Specimen TP80(B) package orientation
   - Refer to Figure 12 for the Specimen TP80(C) package orientation

3. Check the alignment of the specified center-of-gravity marker with the targeted point of impact.

4. Raise the package so that there are 40 to 42 inches between the package and the top of the puncture billet.

5. Test the specimen in accordance with *Checklist 5.*

8.10.2 Puncture Test Orientation, Specimen TP80(A)

The impact surface for Specimen TP80(A) is the horizontal, long-side of the outer shell.

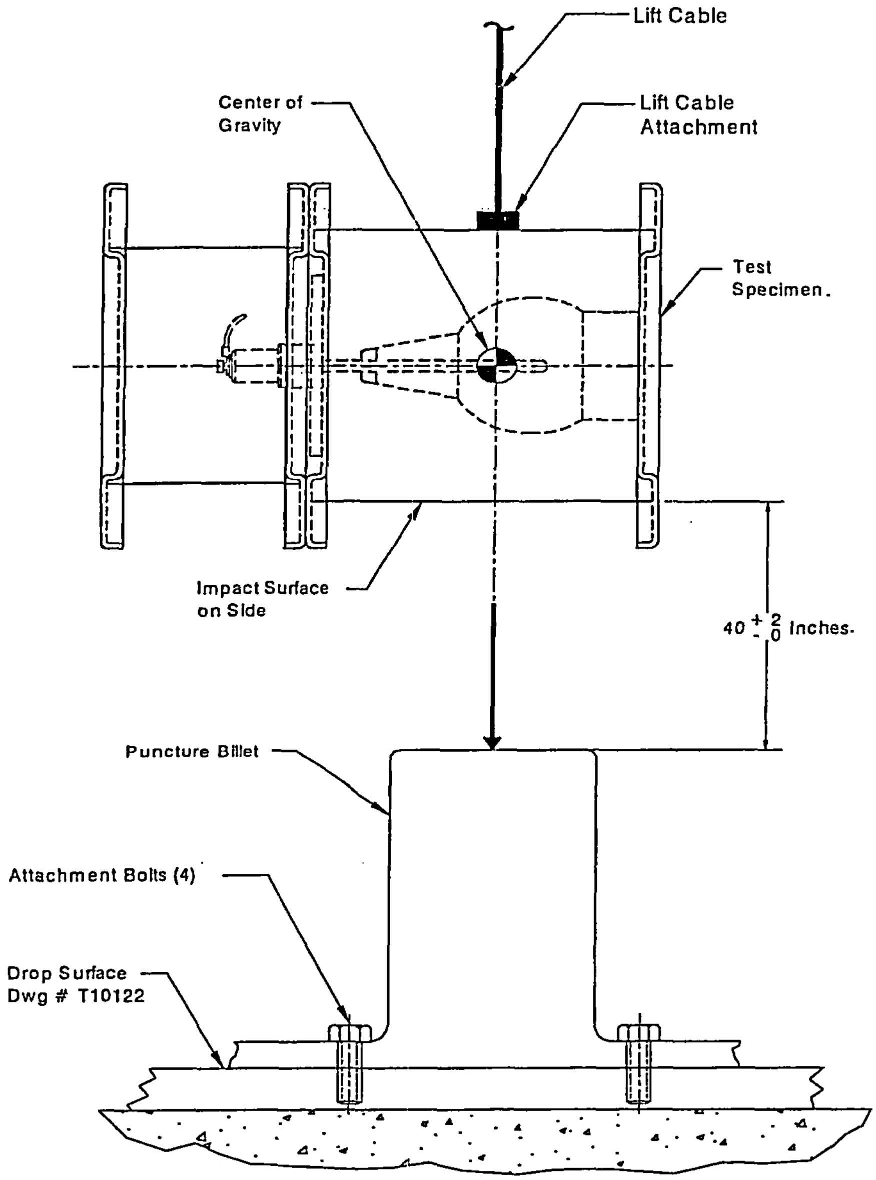


Figure 10. Puncture Test Orientation, Specimen TP80(A)

8.10.3 Puncture Test Orientation, Specimen TP80(B)

The impact surface for Specimen TP80(B) is the underside of the top plate. The puncture bar should impact the corner of the plate on the lid bolt.

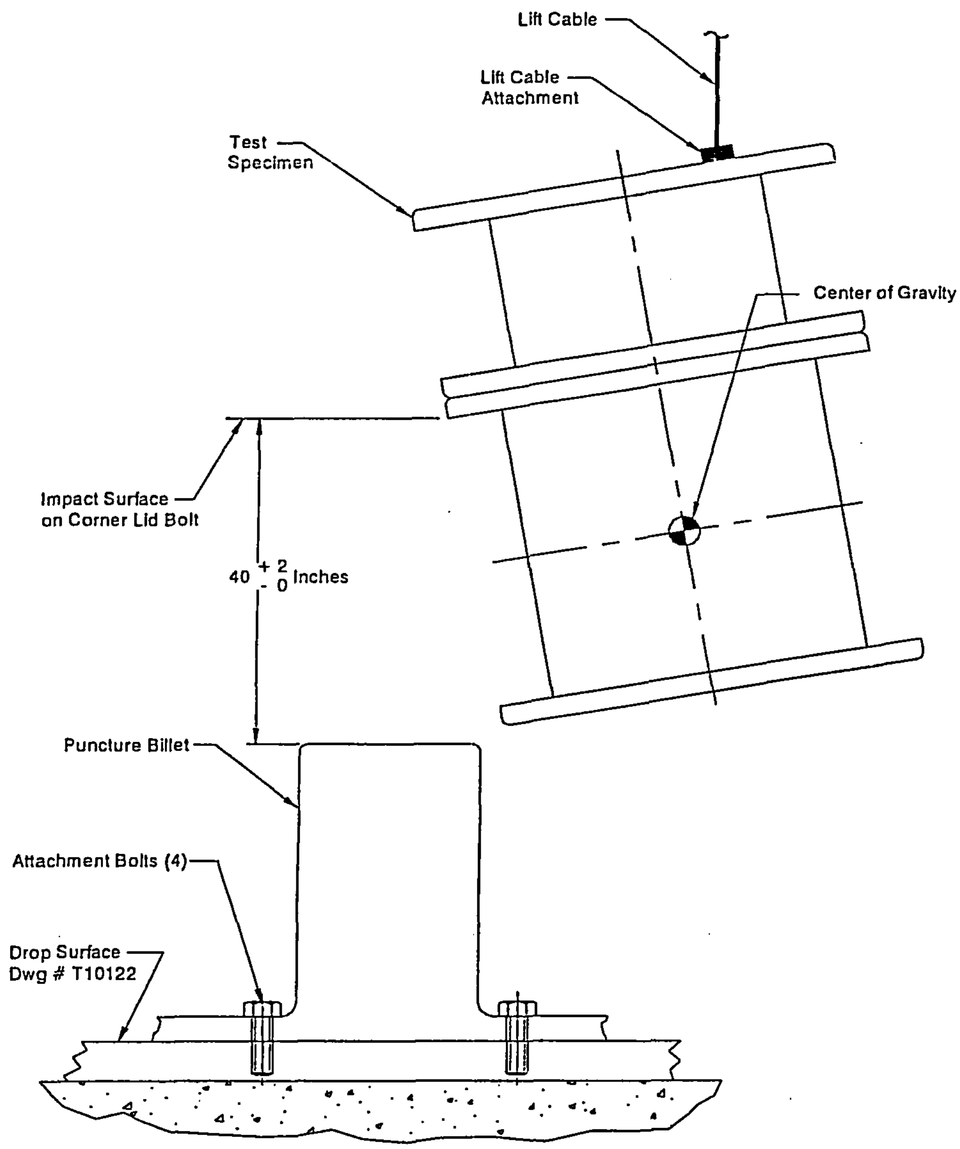


Figure 11. Puncture Test Orientation, Specimen TP80(B)

8.10.4 Puncture Test Orientation, Specimen TP80(C)

The impact surface for Specimen TP80(C) is the bottom of the package.

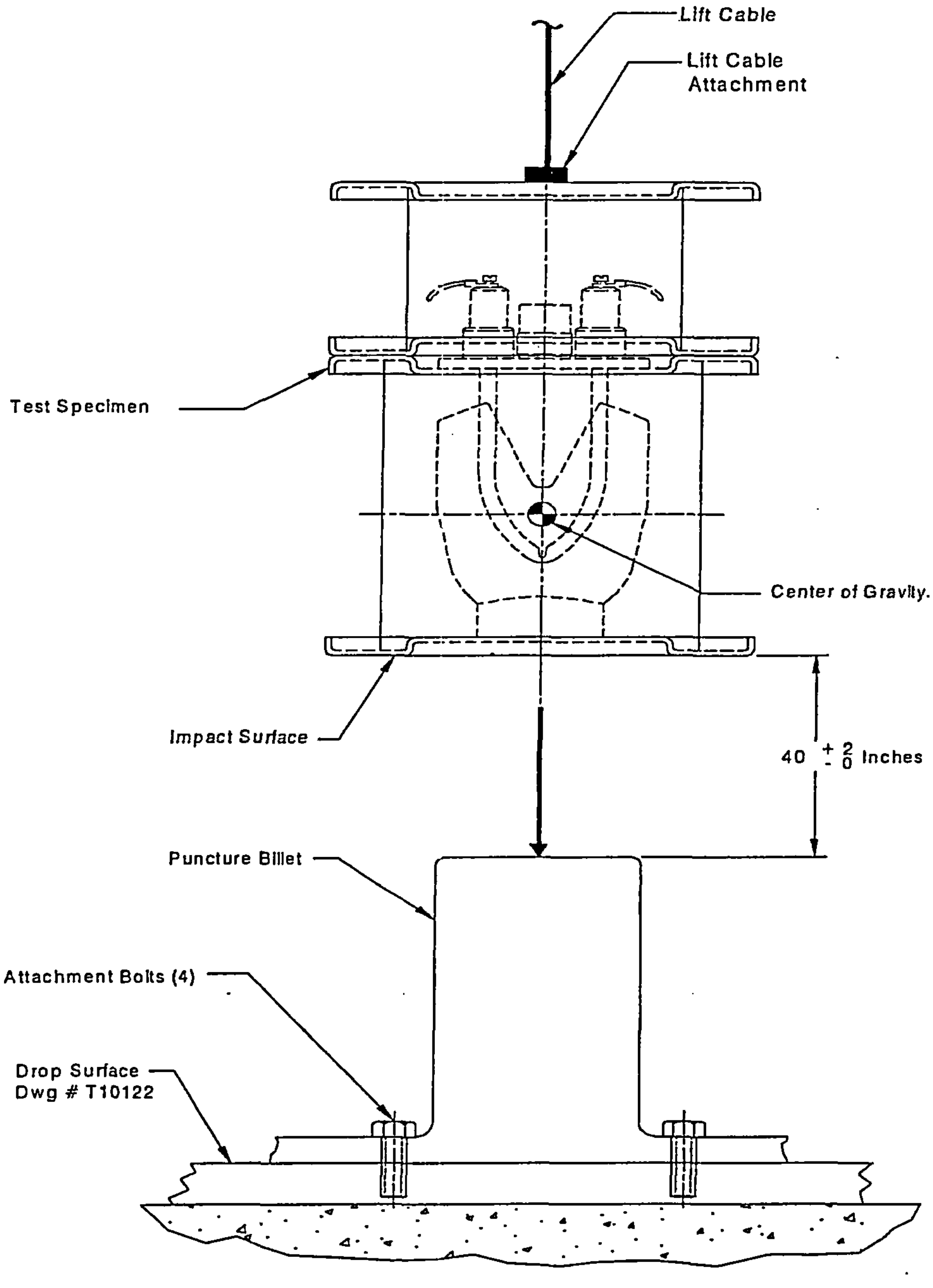


Figure 12. Puncture Test Orientation, Specimen TP80(C)

8.10.5 Puncture Test Assessment

Upon completion of the test, **Engineering**, **Regulatory Affairs**, and **Quality Assurance** team members will jointly perform the following tasks:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.73, and in accordance with any other conditions specified in this plan.
2. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.73.
3. Assess the damage to the specimen to decide whether testing of the specimen is to continue.

8.11 Second Intermediate Test Inspection

Perform a second intermediate test inspection of all specimens after the puncture test and before the thermal test.

1. Measure and record any damage to the test specimen.
2. Determine and record the location of the source.
3. Remove and assess the condition of the simulated source.
4. Reassemble the package using an active source, making sure that the source wire position and the package configuration are the same as they were immediately after the puncture test.
5. Measure and record a radiation profile of the test specimen in accordance with AEAT/QSA Work Instruction WI-Q09.
6. Reassemble the package using the same simulated source used in the specimen during the previous tests.
7. Make sure that the source wire position and the package configuration are the same as they were immediately after the puncture test.
8. Weigh package.

8.12 Thermal Test (10 CFR 71.73(c)(4))

The final requirement is the thermal test specified in 10 CFR 71.73(c)(4).

Refer to *Equipment List 6* for information about required tools. Use *Checklist 6* to ensure that the test sequence is followed. Use *Data Sheet 6* to record testing results. Sign and date all action items and record required data on the appropriate worksheets.

8.12.1 Test Specimen Selection

The specimen(s) selected for thermal testing will be based on an assessment of the damage sustained by the packages following the puncture test. The selected package testing orientation will also be determined based on an assessment of the test specimen condition. As a minimum requirement, the vertical, upside down drop orientation (TP80(B)) will be tested in a vertical, right side up orientation for the thermal test. The TP80(B) specimen is most likely to have the source pull out from its shielded position due to deflection of the top plate during the drop tests and melting of lead shielding/shims below the DU shield during the thermal test.

8.12.2 Thermal Test Setup

To ensure sufficient heat input to the test specimens, the oven will be pre-heated to a temperature of not less than 810°C. This temperature, above the required 800°C, includes an allowance for measurement uncertainty.

The test environment is a vented electric oven capable of creating a time weighted average temperature of 800°C.

Thermocouples will be attached to the specimen top, bottom, and 2 side surfaces. The 2 side surface thermocouples will be positioned 180° apart, facing the front and back of the oven. A fifth thermocouple will be inserted into one of the source tubes to measure source changer internal temperature. The external thermocouples will be shielded from the radiant heat of the oven so that the surface temperature of the source changer can be accurately measured.

When the oven has been pre-heated to 810°C, the package will be placed in the oven in the orientation determined to be worst case, per Section 8.10.2. When the temperature of the source changer surface has risen to no less than 810°C, the test will start. The package will remain in the oven for a period of 30 minutes after the start of the test.

To allow for combustion of the foam during the thermal test, the oven door will remain slightly open. It has been determined that a gap of one inch at the top and bottom of the oven door allows airflow into the oven and allows the oven to maintain its temperature. The oven door is 36 inches long. As a result, there will be about a 36 square inch opening at both the top and bottom of the furnace door. This allows for the natural convection of air into the furnace.

If the specimen is burning when the oven is opened, the unit will be allowed to extinguish by itself and then cool naturally. Although solar radiation assumed during a hypothetical accident could reduce the rate of package cooldown, such a reduction in cooldown rate is considered to have a negligible effect on the package compared with the 30 minutes of exposure to 810°C. This test plan, therefore, does not require insolation effects to be explicitly modeled during package cooldown. Appropriate measures should be taken to avoid the radiological risks associated with this potential hazard. The final evaluation of the package is performed when the specimen reaches ambient temperature.

8.12.3 Thermal Test Procedure

To perform the thermal test:

1. Attach the thermocouples to the test specimen's measurement locations.
2. Preheat the oven temperature to not less than 810°C.
3. When the oven temperature is stable at above 810°C, place the specimen in the oven, and partially close the door.
4. When the temperature of the surface of the specimen rises above 810°C, start the 30-minute time interval.

5. Throughout the test, measure and record the oven and the test specimen temperatures.

6. At the end of the 30 minute time interval, open the oven door and shut off the oven.

WARNING: **If the package is burning, appropriate safety measures must be in place to avoid the risks associated with burning polyurethane foam and/or depleted uranium. Consult with the oven operator and other appropriate personnel.**

7. Allow the package to self-extinguish and cool.

8. Record any damage to the package and make a photographic and radiographic record of shield position and damage.

8.12.4 Thermal Test Assessment

Upon completion of the test, Engineering, Regulatory Affairs, and Quality Assurance team members will jointly perform the following task:

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.73 and the test conditions specified in this plan.

2. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.73.

8.13 Final Test Inspection

Perform the following inspections after completion of all the required testing:

1. Measure and record any damage to the test specimen.

2. Determine and record the location of the source.

3. Remove and assess the condition of the simulated source.

4. Reassemble the package using an active source, making sure that the source wire position and the package configuration are the same as they were immediately after the thermal test.

5. Measure and record a radiation profile of the test specimen in accordance with AEAT/QSA Work Instruction WI-Q09.

6. Document and assess the radiation level at one meter from the surface of the package.

7. Determine whether it is necessary to dismantle the test specimen for inspection of hidden component damage or failure.

8. If proceeding with the inspection, record and photograph the process of removing any component.

9. Measure and record any damage or failure found in the process of dismantling the test specimen.

Engineering, Regulatory Affairs, and Quality Assurance team members will make a final assessment of the test specimen and jointly determine whether the specimen meets the testing requirements of 10 CFR 71.

9.0 Worksheets

Use the following worksheets for executing these tests. There are three worksheets for each test: an equipment list, a test procedure checklist, and a data sheet.

Use the test equipment list to record the serial number of each measurement device used. Attach a copy of the relevant inspection report or calibration certificate after verifying the range of accuracy of the equipment.

Quality Control will initial each step on the checklist as it is executed and record data as required. The **Engineering, Regulatory Affairs,** and **Quality Assurance** representatives must witness all testing to ensure the testing is performed in accordance with this test plan and 10 CFR 71.

Make copies of the forms for additional attempts. Maintain records of all attempts.

Specimen Preparation List

Step		TP80(A)	TP80(B)	TP80(C)
1.	Serial Number:			
2.	Total weight of package (lb):			
3.	Location of simulated source from top plate (in):			
4.	Location of lead shielding:			
5.	All fabrication and inspection records documented in accordance with the AEAT QA Program?			
6.	Does the unit comply with the requirements of Drawing R-TP80, Revision D?			
7.	Has the radiation profile been recorded in accordance with AEAT QSA Work Instruments WI-Q09?			
8.	Is the package prepared for transport?			

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Equipment List 1: Compression Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Weight Scale		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 1: Compression Test

Step	TP80(A)	TP80(B)	TP80(C)
1. Position the specimen on concrete surface, per the appropriate drawing.	Figure 2	Figure 2	Figure 2
2. Measure the ambient temperature.			
Note the instrument used:			
3. Apply a uniformly distributed weight of 455 to 465 pounds on the top of the lid for a period of 24 hours.			
Record the actual weight:			
Note the instrument used:			
Record start time and date:			
4. After 24 hours, remove the weight.			
Record end time and date:			
5. Measure the ambient temperature.			
Note the instrument used:			
6. Photograph the test specimen and record any damage on Data Sheet 1.			
7. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71. Record the assessment on Data Sheet 1. Determine what changes are necessary in package orientation for the penetration test to achieve maximum damage.			

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 1: Compression Test

Test Unit Model and Serial Number:		Test Specimen:
Test Date:	Test Time:	Test Plan 80 Step No.: 8.5

Describe test orientation and setup:

Describe on-site inspection (damage, broken parts, etc.):

On-site assessment:

Engineering: ____________________ Regulatory: ____________________ QA: ____________________

Describe any post-test disassembly and inspection:

Describe any change in source position:

Describe results of any pre- or post-test radiography:

Completed by:	Date:

Equipment List 2: Penetration Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Penetration Bar	Drawing BT10129, Rev. B	
Drop Surface	Drawing AT10122, Rev. B	
Thermometer		
Thermocouple		
Thermocouple		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 2: Penetration Test

Step	TP80(A)	TP80(B)	TP80(C)
1. Immerse the test specimen in dry ice or cool in freezer as needed to bring specimen temperature below –40°C.			
2. Position the package as shown in the referenced figure, or by Step 7, Checklist 1.	Figure 3	Figure 3	Figure 3
3. Begin video recording of the test.			
4. Inspect the orientation setup and verify the bar height.			
5. Photograph the set-up in at least two perpendicular planes.			
6. Measure the ambient temperature and the specimen's internal and surface temperatures. Ensure that the specimen is at the specified temperature.			
Record the ambient temperature:			
Note the instrument used:			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
7. Drop the penetration bar.			
8. Check to ensure that penetration bar hit the specified area.			
9. Measure the specimen's surface temp. Ensure that specimen is at specified temp.			
Note the instrument used:			
10. Photograph the test specimen and record any damage on Data Sheet 2.			
11. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71. Record the assessment on Data Sheet 2. Determine what changes are necessary in package orientation for the 1.2 meter (4 foot) free drop to achieve maximum damage.			

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 2: Penetration Test

Test Unit Model and Serial Number:		Test Specimen:
Test Date:	Test Time:	Test Plan 80 Step No.: 8.6
Describe test orientation and setup:		
Describe impact (location, rotation, etc.):		
Describe on-site inspection (damage, broken parts, etc.):		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Equipment List 3: 1.2 Meter (4 Foot) Free Drop

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface	Drawing AT10122, Rev. B	
Thermometer		
Thermocouple		
Thermocouple		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 3: 1.2 Meter (4 Foot) Free Drop

Step	TP80(A)	TP80(B)	TP80(C)
1. Immerse specimen in dry ice or cool in freezer to bring specimen below –40°C.			
2. Measure the ambient temperature.			
Note the instrument used:			
3. Attach the test specimen to the release mechanism.			
4. Begin video recording of the test.			
5. Measure specimen internal and surface temps. Ensure specimen is at specified temp.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
6. Lift and orient the test specimen as shown in the specified referenced figure.	Figure 4	Figure 5	Figure 6
7. Inspect the orientation setup and verify drop height.			
8. Photograph the set-up in at least two perpendicular planes.			
9. Release the test specimen.			
10. Measure specimen internal and surface temps. Ensure specimen is at specified temp.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
11. Photograph the test specimen and record any damage on Data Sheet 3.			
12. Measure and record a radiation profile of the test specimen in accordance with AEAT/QSA Work Instruction WI-Q09.			
13. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71, and record on Data Sheet 3. Determine package orientation for the 9 meter free drop to achieve maximum damage.			

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 3: 1.2 Meter (4 Foot) Free Drop

Test Unit Model and Serial Number:		Test Specimen:
Test Date:	Test Time:	Test Plan 80 Step No.: 8.7
Describe drop orientation and drop height:		
Describe impact (location, rotation, etc.):		
Describe on-site inspection (damage, broken parts, etc.):		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Equipment List 4: 9 Meter (30 Foot) Free Drop

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface	Drawing AT10122, Rev. B	
Thermometer		
Thermocouple		
Thermocouple		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 4: 9 Meter (30 Foot) Free Drop

Step	TP80(A)	TP80(B)	TP80(C)
1. Immerse test specimen in dry ice or cool in freezer to bring specimen temperature below –40°C.			
2. Measure the ambient temperature.			
Note the instrument used:			
3. Attach the test specimen to the release mechanism.			
4. Begin Video Recording of the test.			
5. Measure specimen's internal and surface temps. Ensure specimen is at the specified temperature.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
6. Lift and orient the test specimen as shown in the specified referenced figure.	Figure 7	Figure 8	Figure 9
7. Inspect the orientation setup and verify drop height.			
8. Photograph the setup in at least two perpendicular planes.			
9. Release the test specimen.			
10. Measure specimen's internal and surface temps. Ensure specimen is at specified temperature.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
11. Photograph the test specimen and record any damage on Data Sheet 4.			
12. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71. Record assessment on Data Sheet 4. Determine what changes are necessary in package orientation for the puncture test to achieve maximum damage.			

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 4: 9 Meter (30 Foot) Free Drop

Test Unit Model and Serial Number:		Test Specimen:
Test Date:	Test Time:	Test Plan 80 Step No.: 8.9
Describe drop orientation and drop height:		
Describe impact (location, rotation, etc.):		
Describe on-site inspection (damage, broken parts, etc.):		
On-site assessment: Engineering: ________ Regulatory: ________ QA: ________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Equipment List 5: Puncture Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface	Drawing AT10122, Rev. B	
Puncture Billet	Drawing CT10119, Rev. C	
Thermometer		
Thermocouple		
Thermocouple		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 5: Puncture Test

Step	TP80(A)	TP80(B)	TP80(C)
1. Immerse specimen in dry ice or cool in freezer to bring specimen temp. below –40°C.			
2. Measure the ambient temperature.			
Note the instrument used:			
3. Attach the test specimen to the release mechanism.			
4. Begin Video Recording of the test.			
5. Measure specimen's internal and surface temps. Ensure that specimen is at specified temp.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
6. Lift and orient the test specimen as shown in the specified referenced figure, or as determined during the assessment of the 9 Meter (30 Foot) Drop Test.	Figure 10	Figure 11	Figure 12
7. Inspect the orientation setup and verify drop height.			
8. Photograph the set-up in at least two perpendicular planes.			
9. Release the test specimen.			
10. Measure the specimen's internal and surface temperatures.			
Record the specimen's internal temperature:			
Note the instrument used:			
Record the specimen's surface temperature:			
Note the instrument used:			
11. Photograph the test specimen and record any damage on Data Sheet 5.			
12. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71. Record assessment on Data Sheet 5. Determine what changes are necessary in package orientation for thermal test to achieve maximum damage.			

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 5: Puncture Test

Test Unit Model and Serial Number:		Test Specimen:
Test Date:	Test Time:	Test Plan 80 Step No.: **8.10**

Describe drop orientation and drop height:

Describe impact (location, rotation, etc.):

Describe on-site inspection (damage, broken parts, etc.):

On-site assessment:

Engineering: ____________________ Regulatory: ____________________ QA: ____________________

Describe any post-test disassembly and inspection:

Describe any change in source position:

Describe results of any pre- or post-test radiography:

Completed by:	Date:

Equipment List 6: Thermal Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Bottom Surface Thermocouple 1		
Top Surface Thermocouple 2		
Side Surface Facing Oven Front Thermocouple 3		
Side Surface Facing Oven Rear Thermocouple 4		
Source Tube Thermocouple 5		
Oven		
Oven thermostat		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:			
Verified by:			

Checklist 6: Thermal Test

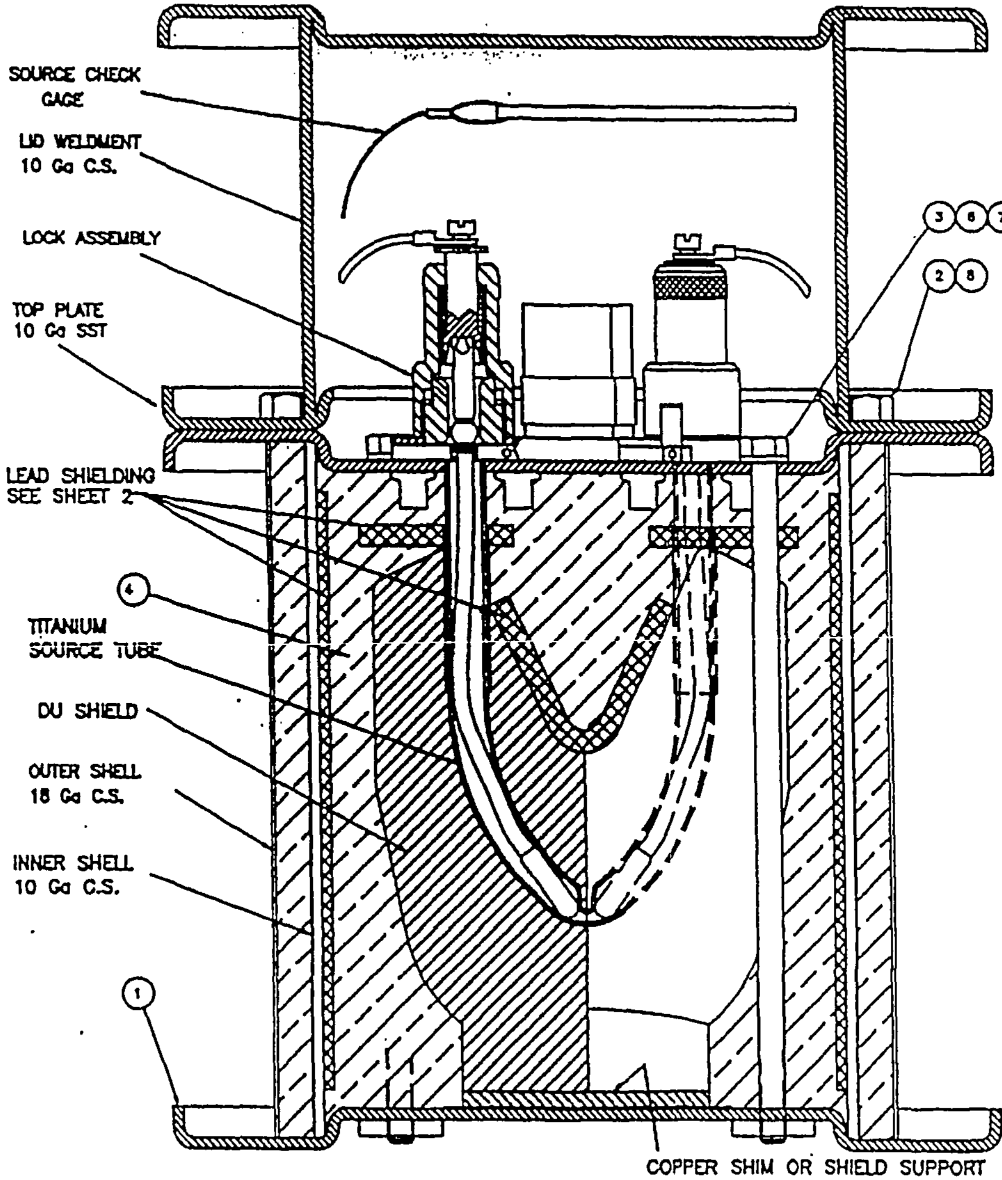
Step	TP80(A)	TP80(B)	TP80(C)
1. Record Test Specimen Serial Number.			
2. Preheat the oven to 810°C.			
3. Attach the thermocouples as described in Equipment List 6. Ensure the recording devices are active, and that the external thermocouples are shielded.			
4. Place the package in the oven in the worst case orientation and partially close the oven door such that a 1 inch by 36 inch opening is provided. Record the time.			
5. When all of the test specimen's surface temperatures exceed 810°C, begin the 30-minute time interval. Record the time.			
6. Monitor and record the test specimen and the oven temperatures throughout the 30-minute period to ensure that they are above 810°C			
7. At the end of the 30-minute test period, shut off the oven and open the door. Record the time.			
8. Describe combustion when door is opened.			
9. Allow the specimen to cool, then remove the specimen from the oven. Record the time.			
NOTE: If specimen continues to burn, let it self-extinguish and cool naturally.			
10. Measure and record the ambient temperature.			
11. Photograph the test specimen and record any damage on data sheet 6.			
12. Radiograph the unit to determine the shield location.			
13. Measure and record the source location.			
14. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71. Record assessment on Data Sheet 6.			

Verified by:	Print Name:	Signature:	Date:
Engineering			
Regulatory Affairs			
Quality Assurance			

Data Sheet 6: Thermal Test

Test Unit Model and Serial Number:		Test Specimen:
Test Date:	Test Time:	Test Plan 80 Step No.: **8.12**
Describe test orientation and setup:		
Describe package during testing:		
Describe on-site inspection (damage, broken parts, etc.):		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Appendix A: Drawing R-TP80, Revision D



Notes:

1. Refer to Drawing C65009 for construction of original unit.

2. Modify unit as follows:
   a) Remove lid and discard bolts.
   b) Remove through bolts and discard.
   c) If bottom plate is carbon steel, remove existing plate. Patch missing or damaged foam with new Vultafoam., Item (4). Install new stainless steel bottom plate, Item (1).
   d) Install new through bolts, Item (3), with lock washers, torque through bolts to 100±5 in-lbs and install safety wire for security.
   e) Install two (2) dummy source assembly 424-9's, one in each side.

3. Verify marking on new lid bolts, Item (2), is "B8".

4. Install lid with new lid bolts, Item (2), and install seal wire for shipment tamper indicator.

ITEM	QTY	DESCRIPTION
8	AR	TAMPER PROOF SEAL WIRE
7	AR	SAFETY WIRE
6	4	LOCK WASHER 5/16 DIA
4	AR	VULTAFOAM #16-L-708
3	4	HEX HEAD BOLT 5/16-18 X 8 LG. DRILLED HEAD, 300 SERIES (18-8) STAINLESS STEEL
2	4	HEX HEAD BOLT 3/8-16 X 7/8 LG. DRILLED HEAD, A193 GR B8 CL 2
1	1	BOTTOM PLATE

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES AND REFERENCE

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

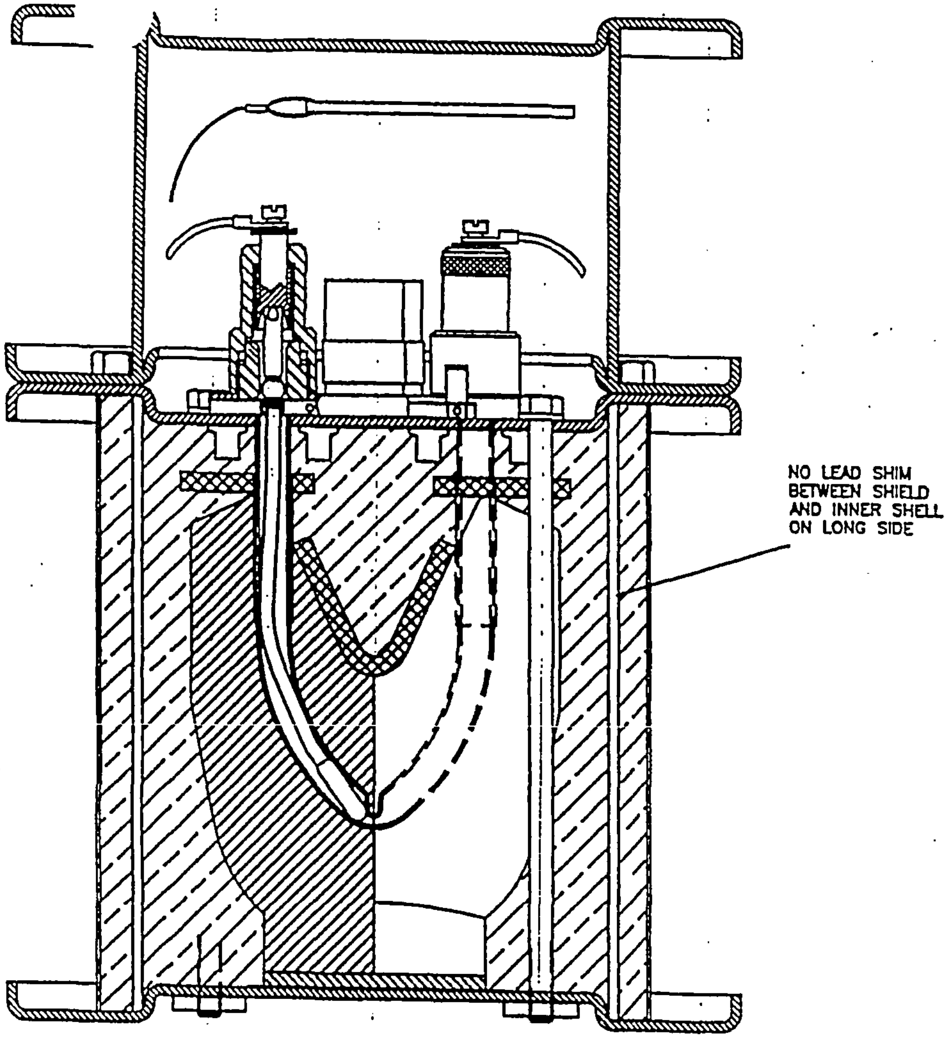
DESCRIPTIVE DRAWING

TITLE 650L SOURCE CHANGER TEST UNITS

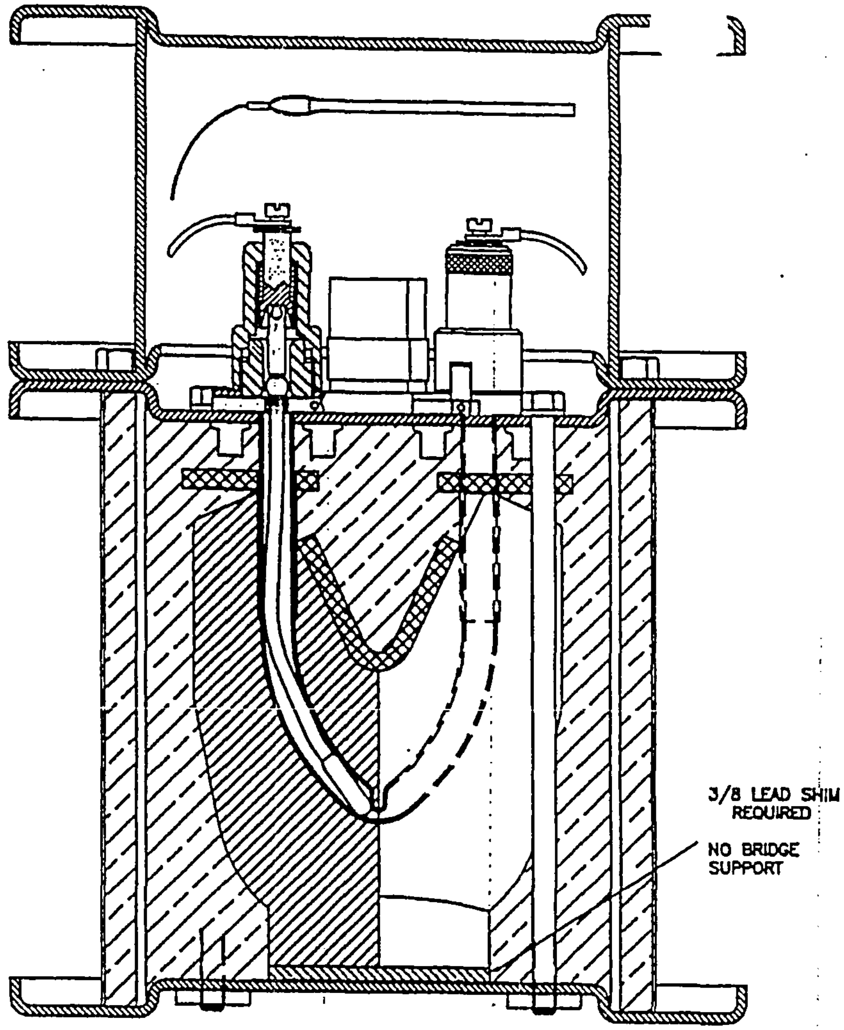
DESCRIPTION	APPROVALS	DATE	LTR
DDCO#33 SEE DDCO	LR / (SO)	12 MAR 99	D
DDCO#32 REMOVE LOCK WASHER (ITEM 5)	LR/MT	4MAR99	C
DDCO#31 FORMAT CORRECTED	MT/TL	25FEB99	B

REVISIONS

SIZE	DWG. NO.	SCALE	SHEET	REV
A	R-TP80	NONE	1 OF 2	D



TP 80 (A)



TP 80 (B)

NOTE:
NO SPECIAL REQUIREMENTS
FOR
LEAD LOCATION IN TP80(C)

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE REFERENCE			
SIZE A	DWG. NO. R–TP80		REV D
	SCALE: NONE	SHEET 2 OF 2	

Section 2.12.9 Appendix: Test Plan 80 Report Minus Manufacturing Records (Jun 1999).

AEA TECHNOLOGY QSA

TEST PLAN NO. 80, REV. 1	
TEST PLAN COVER SHEET	
TEST TITLE: TEST PLAN 80, REVISION 1, MODEL 650L SOURCE CHANGER TYPE B TRANSPORT TESTS	
PRODUCT MODEL: 650L	
ORIGINATED BY: [signature] (MPR)	**DATE:** 12 MAR 99
TEST PLAN REVIEW	
ENGINEERING APPROVAL: [signature]	**DATE:** 12 MAR 99
QUALITY ASSURANCE APPROVAL: Daniel W. Kurtz	**DATE:** 12 Mar 99
REGULATORY APPROVAL: [signature]	**DATE:** 12 Mar 99
COMMENTS:	
TEST RESULTS REVIEW	
ENGINEERING APPROVAL: [signature]	**DATE:** 12 JUL 99
QUALITY ASSURANCE APPROVAL: Daniel W. Kurtz	**DATE:** 13 Jul 99
REGULATORY APPROVAL: C. [signature]	**DATE:** 13 Jul 99

SENTINEL

TEST PLAN 80 REPORT

MODEL 650L

June 1999

Prepared By: Laura Ridzon — Date: 28 JUN 99
Laura Ridzon, MPR Associates, Inc.

Reviewed By: Nicholas J. Marrone — Date: 28 June 99
Nicholas J. Marrone, MPR Associates, Inc.

Approved By: Caroline S. Schlaseman — Date: 28 JUN 99
Caroline S. Schlaseman, MPR Associates, Inc.

AEA Technology QSA, Inc.
Burlington, MA

TABLE OF CONTENTS

APPENDICES

1. PURPOSE

This report describes the Type B test results for the Model 650L source changer. These tests were performed in accordance with Test Plan 80 and were conducted March 15 through 20, 1999. The Test Plan specified testing necessary to demonstrate compliance with the requirements in 10 CFR Part 71 and IAEA Safety Series No. 6 (1985 as amended 1990) for "Normal Conditions of Transport" and "Hypothetical Accident Conditions." Evaluation of the compliance of the Model 650L with these requirements is provided in the Safety Analysis Report (SAR).

2. SCOPE OF TESTING

Test Plan 80 identified three orientations that could potentially cause the most significant damage to the Model 650L source changer in the 9 meter (30 foot) drop tests. Therefore, the test plan required three test specimens. Each of these test specimens was subjected to the tests described below.

1. Normal Conditions of Transport Tests per 10 CFR 71.71, including the following for each test specimen:

   a) Compression test, with the test specimen under a load greater than or equal to five times the Model 650L maximum weight for at least 24 hours.

   b) Penetration test, in which a 13.4 lb (6.08 kg) penetration bar is dropped from at least 1 meter (40 inches) onto the test specimen in the most vulnerable location.

   c) 1.2 meter (4 foot) drop test, in which the test specimen is dropped in an orientation expected to cause maximum damage.

   Water spray preconditioning of the test specimens prior to testing was not required in the test plan and is evaluated separately.

2. Hypothetical Accident Condition Tests per 10 CFR 71.73, including the following for each of the test specimens:

   a) 9 meter (30 foot) drop test, in which the test specimen is dropped in an orientation expected to cause maximum damage.

   b) Puncture test, in which the test specimen is dropped from at least 1 meter (40 inches) onto a 6 inch (152.4 mm) diameter vertical bar in an orientation expected to compound damage from the 9 meter (30 foot) drop test.

   c) Thermal test, in accordance with 10 CFR71.73(c)(4), in which the test specimen is exposed for 30 minutes to an environment which provides a time-averaged environmental temperature of at least 800°C (1472°F), and an emissivity coefficient of at least 0.9. For the Model 650L, the test plan specified that the thermal test would be performed for only one of the three test specimens, unless other test units suffered significant damage in the drop and puncture tests. This requirement was based on the evaluation of the construction of the unit, and on the potential failure modes, which are discussed in the following section.

   The crush test specified in 10 CFR 71.73(c)(2) was not required because the source capsules are qualified as Special-Form radioactive material.

   The water immersion test specified in 10 CFR 71.73(c)(6) and other tests specified in 10 CFR 71 are evaluated separately.

   For all tests, sufficient margin was included in test parameters to account for measurement uncertainty. These test parameters included test specimen weight, temperature, and drop height.

3. FAILURE MODES

For the Model 650L source changer, the key function important to safety is the positive retention of the radioactive source in its stored position within the depleted uranium shield. Displacement of either the source or the shield from the design position or failure of the shield could cause radiation from the package to increase above regulatory limits. Mechanisms, which could cause these modes of failure, include:

- Oxidation of the DU Shield - During the thermal test, oxidation of the DU shield could lead to reduced shielding effectiveness and higher radiation exposure. This could occur if failure of the inner and outer shells or failure of the through-bolts during drop testing results in a large, open path to the DU shield.

- Source Pull-Out from the Shield - During drop testing or during the thermal test, source pull-out could lead to higher radiation exposure. This could occur if there is significant relative displacement between the shield and the lock assembly on the top cover plate. Such displacement could occur if the top plate is deformed outward, and the shield moves laterally or downward through the polyurethane foam.

The drop orientations for the normal and hypothetical accident tests were selected to challenge the components that are intended to prevent these failures. For the 1.2 meter (4 foot) and 9 meter (30 foot) drop tests, these orientations include the following:

- Horizontal with the long side of the unit down - This orientation could cause movement of the shield or failure of the inner and/or outer shells.
- Vertical upside down - This orientation could cause deformation of the top plate, failure of the through-bolts, or failure of the lock assembly which would all lead to source pull-out from the shield. Additionally, movement of the shield through the foam in the upper part of the unit would put a large lateral load on the upper portion of the inner shell, which is subject to brittle failure.
- Top corner down - This orientation could cause failure of the bolts holding the protective lid in place, exposing the lock assembly to damage during the puncture test. This orientation also loads the through-bolts, top plate, and inner shell similar to the vertical upside down orientation.

Because of the potential for brittle failure of carbon steel components, all test units were packed in dry ice and cooled to less than -40°C (-40°F) (the minimum temperature required by IAEA Safety Series 6) for the penetration, 1.2 meter (4 foot) drop, 9 meter (30 foot) drop, and puncture tests.

In selecting test units for the thermal test, it was concluded that an undamaged unit would not be significantly affected by exposure to the conditions of the thermal test. In particular, for an undamaged unit, the depleted uranium shield would still be completely enclosed within the inner and outer shells and be supported by foam and a shim of either copper, steel, or lead. Under the thermal test conditions, degradation of the foam and melting of the shim, if it is lead, will allow the shield to move by a small amount. This could result in limited movement of the source relative to the shield, but not enough to significantly increase radiation levels.

Therefore, the thermal test is only expected to have a significant effect on those units which sustained damage relating to the two modes of failure described above, specifically: (1) an opening in the inner and outer shells to allow oxidation of the shield, or (2) relative displacement of the lock assembly and shield which could be compounded by shield movement during the thermal test. Since relative displacement of the lock assembly was expected in the vertical upside down drop orientation, it was planned to perform the thermal test with the unit dropped in this orientation. The test plan required thermal tests of the other test specimens only if they sustained damage that could lead to failure during the thermal test.

4. TEST UNIT DESCRIPTION

The Model 650L test specimens, identified below, were originally constructed in accordance with drawing C65009 and were prepared for testing in accordance with drawing R-TP80, Rev. E. The manufacturing route cards for the units document the compliance of these units with the AEA Technology QSA Inc. QA program (see Appendix B).

Specimen	Serial No.	Total Weight	Lead Configuration
TP80(A)	2243	80.0 lb (36.3 kg)	No lead between DU shield and long side of inner shell.
TP80(B)	182	83.6 lb (37.9 kg)	Thickest lead under DU shield (total 3/8" thick).
TP80(C)	195	89.0 lb (40.4 kg)	Any location.

Important features of the test unit construction include the following:

- The configuration of lead added to each unit for supplemental shielding was specified as shown above to provide the worst case for the each drop orientation.
- For TP80(B), the original steel shim used in the unit was replaced with a solid 3/8" thick lead shim.
- The original carbon steel through-bolts were replaced with stainless steel bolts.
- The original carbon steel lid bolts were replaced with high strength, strain hardened stainless steel bolts.
- The weights of the test specimens are representative of the heaviest 650L units in use. The range of weights of 650L units is 75 lb to 90 lb (34.0 kg to 40.8 kg).

The test specimens were radiographed to document the lead configuration and the position of the internal components. Also, the position of the "dummy" source used in the units was measured prior to testing.

5. SUMMARY AND CONCLUSIONS

All test specimens met the requirements for 10 CFR 71 Type B(U) Transport Testing, as shown in the following table of Radiation Profile results.

Specimen	Specimen Surface	At Surface, Before Test	At One Meter, Before Test	At Surface, After 4 ft Drop Test	At One Meter, After 4 ft Drop Test	At One Meter, After Final Test (Notes 1,2)
	Reg. Limits	200 mR/hr	10 mR/hr	200 mR/hr	10 mR/hr	1000 mR/hr
TP80(A)	Top	84	3.2	94	2.4	2.7
	Right	47	0.6	47	0.7	0.8
S/N 2243	Front	88	0.7	89	0.8	1.0
	Left	56	0.6	65	0.7	0.7
	Rear	74	0.7	89	0.8	0.9
	Bottom	51	0.4	94	0.7	0.6
TP80(B)	Top	60	3.1	71	2.0	28
	Right	56	0.4	53	0.6	5.6
S/N 182	Front	84	0.8	83	0.8	5.6
	Left	88	0.6	83	0.6	7.9
	Rear	79	0.8	77	0.8	7.9
	Bottom	74	0.5	83	0.7	1.1
TP80(C)	Top	72	2.2	59	2.0	2.2
	Right	105	0.7	71	0.7	0.9
S/N 195	Front	50	0.6	47	0.5	0.6
	Left	127	0.7	106	0.8	1.0
	Rear	50	0.6	53	0.6	0.6
	Bottom	61	0.6	59	0.5	0.5

Notes:
1. The final Hypothetical Accident Condition test for test specimens TP80(A) and TP80(C) was the Puncture Test. The final test for specimen TP80(B) was the Thermal Test.
2. Radiation profile at the surface is not required for the Hypothetical Accident Condition test (see 10 CFR 71.51(a)(2)).

Results of each test are summarized in the table below, in the sequence in which the tests were completed. Detailed results are provided in the following sections of this report, test data sheets are in Appendix C, and photographs are included in Appendix D.

Specimen	Test Performed	Test Results (Note 1)
TP80(A)	Compression Test	No damage
	1 meter (40 inch) penetration bar on side	Impact mark; no visible damage
	1.2 meter (4 foot) drop, horizontal on long side	• Impact mark on edge of plates • Small change in radiation profile
	9 meter (30 foot) drop, horizontal on long side	Bent bottom plate flange inward
	1 meter (40 inch) puncture, horizontal on long side (dropped twice to ensure specimen temperature was below-40°C (-40°F))	Shallow dent on outer shell at impact point
	Post-Drop Inspection	• Lid secured in place • Locks undamaged; source secured • No significant change in source position • Small change in radiation profile
TP80(B)	Compression Test	No damage
	1 meter (40 inch) penetration bar on side	Impact mark; no visible damage
	1.2 meter (4 foot) drop, vertical upside down	• Impact mark on top of lid • Small change in radiation profile
	9 meter (30 foot) drop, vertical upside down	• Outer shell split open from top to bottom • Inner shell cracked, creating a 3 inch (76.2 mm) high by 0.5 inch (12.7 mm) wide opening • Small upward deflection of top plate • Top and bottom plates remained secured by the through bolts.
	1 meter (40 inch) puncture on crack in shell	Bent shell inward slightly in area of crack

Specimen	Test Performed	Test Results (Note 1)
TP80(B) (con't)	Post-Drop Inspection	• Lid secured in place • Locks undamaged; source secured • Top plate deflection at center about 0.16 inch (4.1 mm). • No damage to through bolts • No significant change in source position. • Outer and inner shells cracked; opening about 3 inch (76.2 mm) by 0.5 inch (12.7 mm).
	Thermal test	• Some oxidation of DU shield near crack in shell • Shield moved down (as expected) • Polyurethane foam burned off, exposing the shield • Some oxidation of shield near crack in shell • Shield self-extinguished after removal from oven • Source pullout less than 0.5 inch (12.7 mm). • Max. radiation level at one meter was 28 mR/hr (which is much less than 1000mR/hr allowable)
TP80(C)	Compression Test	No damage
	1 meter (40 inch) penetration bar on side	Impact mark; no visible damage
	1.2 meter (4 foot) drop on top edge of lid	• Bent corner of lid and cracked top plate of lid (brittle failure) • Small change in radiation profile
	9 meter (30 foot) drop on top edge of lid	• Increased lid top plate crack length in vicinity of impact point • Locks still protected by lid
	1 meter (40 inch) puncture vertical upside down on lid and on underside of top plate	Broke inside of lid top plate (locks still protected)
	Post-Drop Inspection	• Locks undamaged; source secured • No significant change in source position • Small change in radiation profile

Note 1: None of the new stainless steel bolts installed in the test specimens failed.

Specimen TP80(A) was not significantly damaged in the testing. On specimen TP80(C), the top plate of the protective lid was substantially cracked and portions broke away; however, the rectangular tube section which surrounds the locks was undamaged and still attached to the lower portion which in turn was secured to the body of the changer. As such, the locks remained protected. The post-test radiation profiles showed a slight increase in radiation levels for these units, but these radiation levels were well below the allowable values.

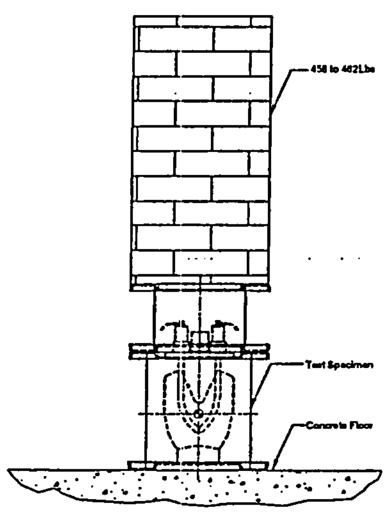
The only significant damage to any unit was the cracked shell in specimen TP80(B). Because of this crack, the depleted uranium shield was exposed to air during the thermal test, and portions of the shield near the crack opening were oxidized. In addition, after the lead shim melted, the shield was free to move downward, pulling the dummy source out of its fully inserted position in the shield. However, even with the oxidized shield and source pull-out, the post-test radiation profile showed a maximum radiation level of 28 mR/hr at one meter. This is well below the maximum allowable level of 1,000 mR/hr at one meter following the hypothetical accident conditions.

6. TP80 NORMAL TESTS

Compression Test

All three test specimens were loaded as shown in the figure below. Lead weights were placed on a steel plate, which was positioned on top of each test specimen.

The vertical projected area of the unit is 8.25 inch (209 mm) x 10 inch (254 mm) or 82.5 square inches (531 square centimeters), yielding a total load of 165 lb (74.8 kg) for an applied pressure of 2 psi. Since the maximum weight of the Model 650L source changer is 90 lb (40.8 kg), a load of 5 times the weight, or 450 lb (204 kg), is more conservative. The total compressive load actually used was 458 lb to 462 lb (208 kg to 210 kg).



Compression Test Orientation – All Specimens

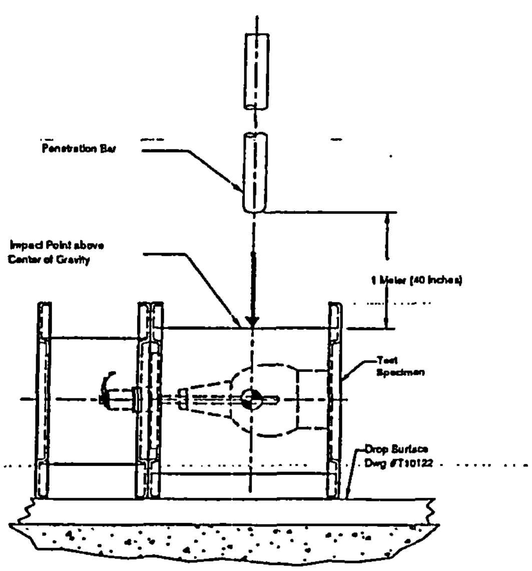
After a period of 24 hours, the weights were removed. No visible deformation or buckling occurred and no other damage was observed for any of the test specimens.

Penetration Test

The three test specimens were subjected to the penetration test. Temperature readings taken just before the test are summarized below.

Specimen	Ambient	Surface	Internal
TP80(A)	10°C (50°F)	-96°C (-141°F)	-95°C (-139°F)
TP80(B)	9°C (48°F)	-93°C (-135°F)	-83°C (-117°F)
TP80(C)	10°C (50°F)	-90°C (-130°F)	-90°C (-130°F)

The penetration bar target was the side of the unit in an attempt to damage the shell. For this test, each specimen was positioned with its horizontal long side down, as shown below.



Penetration Test Orientation – All Specimens

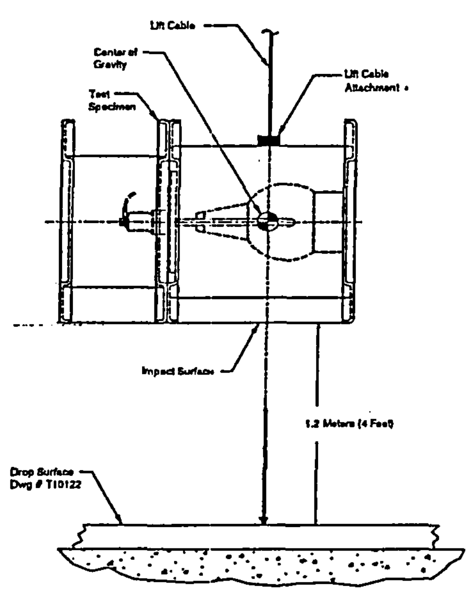
The penetration bar was dropped from a height of at least 1 meter (40 inches) above the impact point. The bar hit as intended on each package, leaving a visible impact mark, but no other damage.

1.2 Meter (4 Foot) Drop Test

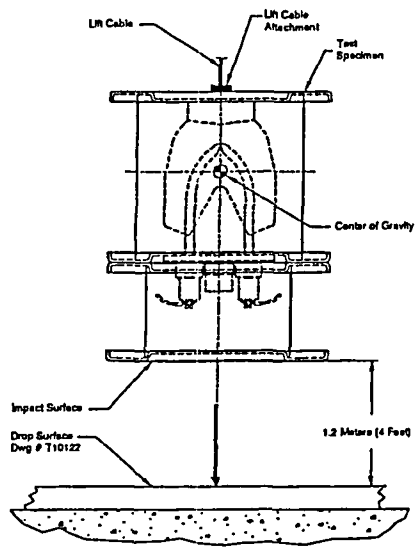
The three test specimens were then subjected to the 1.2 meter (4 foot) drop test. Temperature readings taken just before the test are summarized below.

Specimen	Ambient	Surface	Internal
TP80(A)	13°C (55°F)	-92°C (134°F)	-90°C (-130°F)
TP80(B)	13°C (55°F)	-87°C (-125°F)	-89°C (-128°F)
TP80(C)	13°C (55°F)	-95°C (-139°F)	-92°C (-134°F)

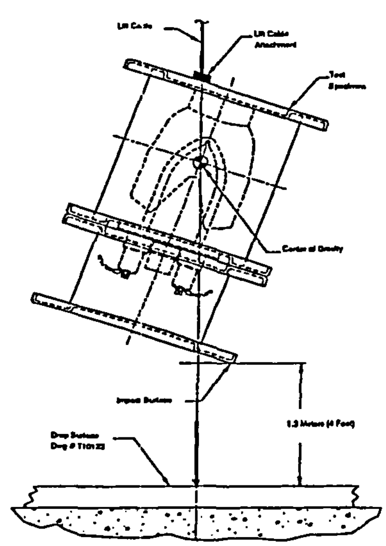
The drop orientations for each unit are shown below and on the next page. These orientations are the same as those used for each specimen in the 9 meter (30 foot) drop tests.



1.2 Meter (4 Foot) Drop Orientation for Specimen TP80(A)



1.2 Meter (4 Foot) Drop Orientation for Specimen TP80(B)



1.2 Meter (4 Foot) Drop Orientation for Specimen TP80(C)

Each test specimen impacted as intended. Visual inspections showed impact marks but no significant damage to either TP80(A) or TP80(B). For TP80(C), a 2 inch (50.8 mm) long crack in the top of the protective lid was observed, and the flange corner was bent.

Post-Test Inspection and Assessment

Results of the first intermediate inspections and assessments are summarized below. The radiation profile of each specimen was measured, and data sheets are provided in Appendices B and C.

Specimen	Damage	Source Movement	Radiation Profile (Note 1)
TP80(A)	No visible damage, locks functional	No significant change observed	Largest change at bottom surface: 51mR/hr to 94 mR/hr (Note 2)
TP80(B)	No visible damage, locks functional	No significant change observed	Largest change at top surface: 60 mR/hr to 71 mR/hr
TP80(C)	Cracked top lid, locks functional	No significant change observed	Largest change at rear surface: 50 mR/hr to 53 mR/hr

Note 1: Radiation levels at one meter were 2.4 mR/hr or less after Normal Condition Tests.

Note 2: All other surfaces measured remained essentially the same, exhibiting no corresponding shift in radiation levels. Additionally, no source movement was measured. Therefore, this change was considered insignificant.

7. TP80 ACCIDENT DROP TESTS – TP80(A)

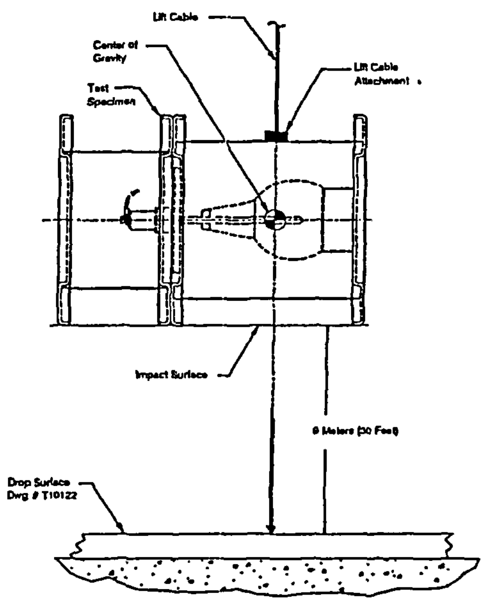
Specimen TP80(A) was subjected to a 9 meter (30 foot) drop test and a puncture test in accordance with Test Plan 80. The results are described below.

<u>9 Meter (30 Foot) Drop Test</u>

Just before the drop test, thermocouple readings for Specimen TP80(A) were as follows:

- Internal (source tube): -93°C (-135°F)
- Surface (shell): -92°C (-134°F)

The orientation for Specimen TP80(A), shown below, was the same as for the 1.2 meter (4 foot) drop. The intention was to cause the shield to move relative to the lock assembly and/or to cause failure of the inner and outer shells.

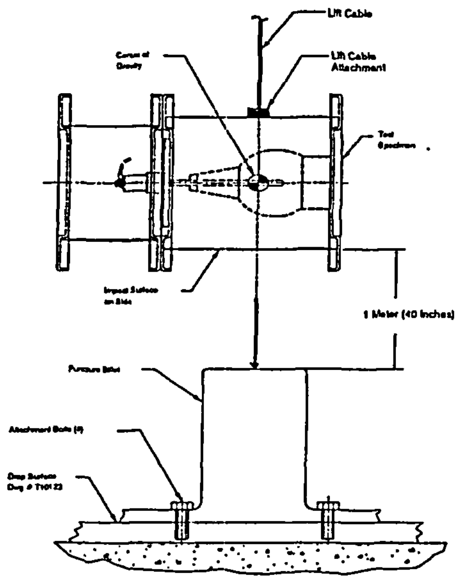


9 Meter (30 Foot) Drop Orientation for Specimen TP80(A)

The package rotated very slightly causing the edge of the bottom plate to impact first. However, the impact was sufficiently close to ideal as to impart the desired force into the package. Visual inspections showed that the edge of the bottom plate had bent inward to the point where it contacted and dented the outer shell. The edge of the top plate of the lid also bent inward slightly.

Puncture Test

For the puncture test, TP80(A) was dropped, as planned, on its side with the center of gravity over the impact area, as shown below. The intention of this orientation was to inflict further damage to the shell. The thermocouple reading on the surface of the unit before the puncture test was -69°C (-92°F) but warmed to -26°C (-15°F) just after the test due to delays in rigging the unit for the drop. Consequently, the unit was cooled again and dropped a second time. For the second test, the surface temperature was -46°C (-51°F) before the test and -42°C (-44°F) after the test.



Puncture Drop Orientation for Specimen TP80(A)

For both drops, the unit impacted on its side as intended. Each impact caused the side of the shell to deform inward slightly, but no significant damage was observed.

Post-Test Inspection and Assessment

Following the test, the protective lid was removed and the unit was inspected. No damage to the lock assembly was observed, and no significant source movement was measured. Radiographs of the unit showed no discernable change in the position of the shield. The post-test radiation profile showed no significant change in radiation levels from the pre-test profile (see Appendices B and C). Because no significant damage occurred to the unit, the thermal test was not considered necessary (see Section 3). In addition, Specimen TP80(B) was considered worst case.

8. TP80 ACCIDENT DROP TESTS – TP80(B)

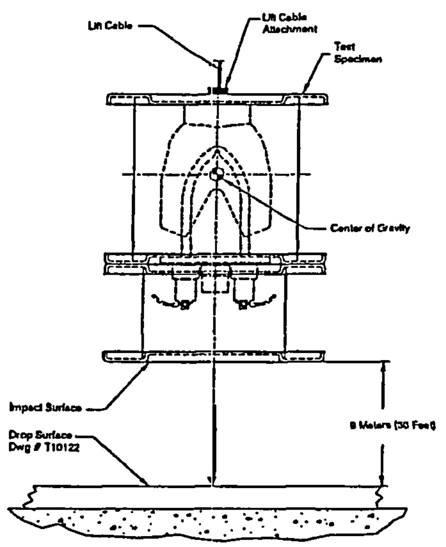
Specimen TP80(B) was subjected to a 9 meter (30 foot) drop test and a puncture test in accordance with Test Plan 80. The results are described below.

<u>9 Meter (30 Foot) Drop Test</u>

Just before the drop test, thermocouple readings for Specimen TP80(B) were as follows:

- Internal (source tube): -94°C (-137°F)
- Surface (shell): -93°C (-135°F)

The package orientation for Specimen TP80(B), shown below, was the same as for the 1.2 meter (4 foot) drop. The intention was to cause deformation of the top plate, failure of the through-bolts, and failure of the lock assembly, leading to source pull-out from the shield.



9 Meter (30 Foot) Drop Orientation for Specimen TP80(B)

The package impacted as intended. The impact caused the depleted uranium shield to move into the foam below the top plate, putting a large lateral load on the inner shell, and causing the shell to crack. The cracking of the inner shell resulted in a transfer of the lateral load to the outer shell, breaking the spot welds that hold the outer shell together. The outer stainless steel wrap also failed and sprung open. One of the rivnuts in the top plate broke, but its associated bolt and the all the other lid bolts were undamaged and the lid remained secured to the package.

Puncture Test

For the puncture test, the planned orientation was changed in order to inflict the greatest damage, based on the on-site assessment of Engineering, Regulatory and QA. As such, TP80(B) was dropped so that the cracked shell was aligned with the top edge of the puncture bar. The intention was to open up the crack or cause additional cracking in the damaged area. The thermocouple reading on the outside surface of the unit was -57°C (-71°F) before the puncture test and -44°C (-47°F) after the test.

The unit impacted directly on the crack. The outer shell was deformed inward at the impact area, but additional cracking was not observed.

Post-Test Inspection and Assessment

Following the test the protective lid was removed and the unit was inspected. The through-bolts were all intact. One of the locks had broken out, but the dummy source remained securely retained (i.e., the lock slide was still secure). The top plate (with the lock assembly) deflected outward by about 0.16 inch (4.1 mm). The resulting source pull-out was measured to be 0.027 inch (0.69 mm) in one side and 0.064 inch (1.6 mm) in the other side. Radiographs showed the crack in the inner shell extended from the top plate to the bottom plate.

9. TP80 ACCIDENT DROP TESTS – TP80(C)

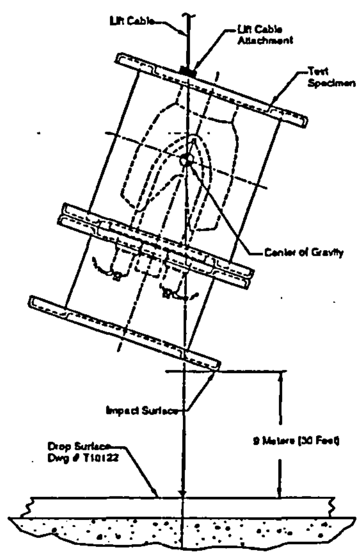
Specimen TP80(C) was subjected to a 9 meter (30 foot) drop test and a puncture test in accordance with Test Plan 80 and results are described below.

9 meter (30 Foot) Drop Test

Just before the drop test, thermocouple readings for Specimen TP80(C) were as follows:

- Internal (source tube): -97°C (-143°F)
- Surface (shell): -98°C (-144°F)

The package orientation for Specimen TP80(C), shown below, was the same as for the 1.2 meter (4 foot) drop. The intention was to fail the bolts holding the protective lid to the rest of the unit. This would expose the lock assembly to further damage during the puncture test.



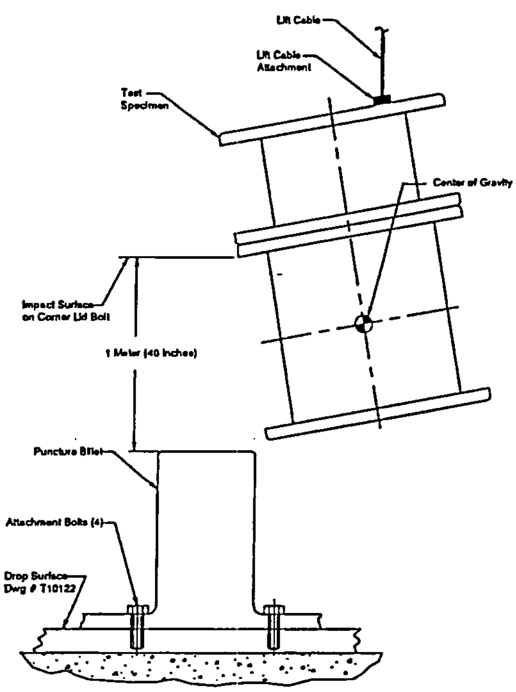
9 Meter (30 Foot) Drop Orientation for Specimen TP80(C)

The package impacted as intended. Visual inspections showed that none of the lid bolts failed, but the lid crack initiated in the 1.2 meter (4 foot) drop increased in both directions. The crack went around the top plate at its interface with the rectangular tube section that protects the locks. The crack went about halfway around the lid, and the top plate was deflected downward about 0.5 inch (13 mm). Portions of the top plate flange also broke off.

Puncture Test

Specimen TP80(C) was subjected to two puncture tests. An additional puncture drop was added as two possible orientations were deemed "worst case". In the first test, the unit was dropped vertically upside down, with the intention of breaking through the lid and damaging the locks. The thermocouple reading on the surface of the unit was -53°C (-63°F) before the puncture test and -50°C (-58°F) after the test.

For the second test, the unit was dropped such that the impact was on the underside of the top plate, as shown below. The objective of this drop was to damage the rivnuts, which hold the lid to the top plate, and to pry the top plate off of the unit by overloading the through-bolts. The initial surface temperature was -47°C (-53°F).



Second Puncture Drop Orientation for Specimen TP80(C)

The unit impacted as intended in both drops. In the first drop, the top of the lid was damaged further, however, the lid remained intact and the puncture bar did not impact the lock assembly. In the second drop, the top plate deformed slightly, but no significant damage was observed.

Post-Test Inspection and Assessment

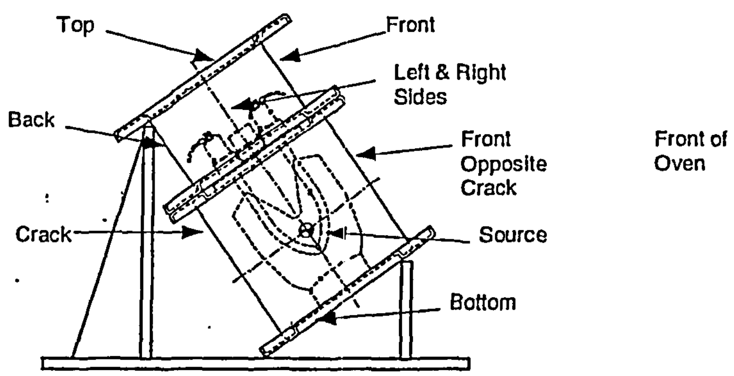
Following the test, the protective lid was removed and the unit was inspected. No damage to the locks was observed and no significant movement of the source was measured. The post-test radiation profile showed no significant change in radiation levels from the pre-test profile (see Appendix B). Because no significant damage occurred to the unit, the thermal test was not considered necessary (see Section 3). In addition, Specimen TP80(B) was considered worst case.

10. TP80 THERMAL TEST – TP80(B)

Based on the results of the drop tests, a thermal test was performed with specimen TP80(B). The damage to this unit was such that the maximum source pull-out, as well as oxidation of the depleted uranium shield, could occur during the thermal test. The thermal test was not considered necessary for the other test specimens since the results are bounded by those for TP80(B).

Orientation and Setup

Based on the damage observed in the drop tests, it was concluded that worst orientation for the thermal test was to have the unit at an angle such that the center of gravity of the shield was over the bottom corner edge of the inner shell. The cracked side of the unit was oriented downward, so that the shield would move toward the crack as the lead shim melted and the shield dropped down. The worst case angle was determined to be 53° based on the internal geometry of the unit. This would allow the maximum amount of shield movement relative to the top plate, pulling the source out of position. To hold the specimen in this orientation, a steel jig was constructed as shown below.



TP80(B) Orientation and Thermocouple Locations

Seven thermocouples were attached to the specimen on the top, bottom, and four side surfaces (two thermocouples on the front side). An eighth thermocouple was inserted into one of the source tubes to measure the internal temperature. A ninth thermocouple was used to measure the ambient oven temperature.

To allow for combustion during the thermal test, the oven door was blocked open with a gap of 1 inch (25.4 mm) at the top and bottom of the door, permitting airflow into the oven while allowing the oven to maintain its temperature. Since the oven door is 36 inches (914 mm) long, each opening was approximately 36 square inches (232 square centimeters).

Test Chronology

Temperatures were recorded from the time the specimen was inserted in the oven until after it had cooled and was moved to a temporary storage area. The total duration of this period was about 1,000 minutes (16 hours). Plots of the temperature data are included in Appendix C. The overall test chronology is as follows:

- Zero to 32 minutes – heat up of the specimen from ambient to over 810°C (1490°F). The 30 minute test started when all surfaces of the specimen exceeded 810°C (1490°F). The thermocouple on the bottom of the unit was the last to reach the target temperature, and the test was started when it reached 813°C (1495°F).

- 32 to 64 minutes – 30 minute test period, with all temperatures maintained above 810°C (1490°F). The maximum temperature was 996°C (1825°F) on the side of the unit facing the rear of the oven, while the minimum temperature was 813°C (1495°F) on the bottom of the unit. The initial and final temperatures of all thermocouples over the 30 minute period are shown below. Flames due to combustion of the foam were observed, however these diminished and stopped before the end of the 30 minute test.

Location	Initial Temp.	Final Temp.	Average Temp.
Bottom	813°C (1495°F)	861°C (1582°F)	872°C (1602°F)
Top	980°C (1796°F)	879°C (1614°F)	913°C (1675°F)
(Lid) Front Oven	934°C (1713°F)	848°C (1558°F)	879°C (1614°F)
(Lid) Back Oven	995°C (1823°F)	884°C (1623°F)	923°C (1693°F)
(Lid) Left Side	949°C (1740°F)	865°C (1589°F)	899°C (1650°F)
(Lid) Right Side	979°C (1794°F)	872°C (1602°F)	909°C (1668°F)
Side (Opposite Crack)	830°C (1526°F)	810°C (1490°F)	823°C (1513°F)
Source Tube	906°C (1663°F)	865°C (1589°F)	886°C (1627°F)
Oven/Ambient	940°C (1724°F)	839°C (1542°F)	877°C (1611°F)

- 64 minutes – removal from oven. The depleted uranium shield was visible, with a slightly red glow in areas. Some depleted uranium oxide (black power) was observed coming out of the crack and onto the surface below, indicating the shield was oxidizing.

- 64 to 700 minutes – cool down to below 100°C (212°F). During this time, the shield was allowed to self-extinguish.

During the cool down period, the unit was allowed to cool via natural convection with no additional heat input. The hypothetical accident conditions specified in the IAEA Safety Series 6 regulations include a requirement to account for heat input due to insolation during the cool down period. This heat input could reduce the cool down rate. However, the reduction was not considered to have any effect on the damage sustained by the test specimen, particularly compared with the 30 minute exposure to 810°C (1490°F) in the oven.

Post-Test Inspection and Assessment

The initial on-site assessment of the test specimen included the following observations:

- A cracked piece of the inner shell was dislodged and had dropped out of position.
- Most paint had vaporized. Radiation labels were still legible.
- All the foam had burned off, leaving a small amount of carbon char.
- The lead shielding and shim melted and some lead had dripped out the bottom of the unit.
- Radiography showed the shield moved laterally and downward as expected. The resulting source pull-out was measured to be 0.436 inch (11.1 mm) on one side and 0.480 inch (12.2 mm) on the other side.
- The lock assemblies were functional; however, the source tubes had completely pulled out of the top plate and had shifted laterally. This caused an interference between the source wire and the top plate, and required that the top plate be machined to enlarge the holes before the unit could be profiled.

After the thermal test, visual observations indicated that the shield had come to rest on the through bolts and bottom plate. However, to securely fix the shield in position for shipping and extensive handling, holes were drilled in the shell of the unit so that foam could be poured in, and the shield was foamed in place. A radiation profile was then done on site with the source located to replicate the amount of observed source pull-out. The highest radiation measurement was 28 mR/hr at one meter (when scaled to the 240 Ci licensed capacity of the unit) at the top of the unit. The small amount of shield oxidation experienced in the test had a minimal effect on the overall effectiveness of the shielding.

APPENDIX A

CALIBRATION RECORDS

METTLER TOLEDO

SCALE CALIBRATION RECORD

Date: 11-16-98

SCALE LOCATION Shipping + Rec.
MANUFACTURER FAIRBANKS
MODEL NUMBER Port Beam
CAPACITY 2000 X 1/2
TEST PROCEDURE HB44

TAG NO. ASSY II
SERIAL NUMBER L482397
DIVISIONS 4000
CSWA#

TEST PROCEDURE REFERENCE: METTLER TOLEDO MANUAL FOR CALIBRATIONS SERVICES, HANDBOOK 44 FIELD MANUAL

Shift Test	Weights Applied	Scale Reading	Error (+/-)	Scale Reading After Adjustment		
Position 1	500 lb	501 lb	+1 lb		(Acc.)	Rej.
Position 2	500	500	0		(Acc.)	Rej.
Position 3	500	500 1/2	+1/2		(Acc.)	Rej.
Position 4	500	500 1/2	+1/2		(Acc.)	Rej.

Test Load	Weights Applied	Scale Reading	Error (+/-)	Scale Reading After Adjustment		
Zero Balance	0 lb	0 lb	0 lb		(Acc.)	Rej.
	500	500 1/2	+1/2		(Acc.)	Rej.
	1000	999 1/2	-1/2		(Acc.)	Rej.
	1500	1501	+1		(Acc.)	Rej.
Maximum Test Load	2000	1998	-2		(Acc.)	Rej.
					Acc.	Rej.
	1000		-1/2		(Acc.)	Rej.
					Acc.	Rej.
Zero Balance	0		0		(Acc.)	Rej.

EST WEIGHT ID NUMBERS: 01 thru 28

OMMENTS/ACTIONS:

JSTOMERS SIGNATURE (FOR OFF TOLERANCE):

ECHNICIANS SIGNATURE: J. Draper + B. Clarke

TEKSERV

127 Riverneck Road
Chelmsford, MA 01824
Telephone: 978 - 459-9480
FAX: 978 - 453-6336
WEBSITE: http://www.tekserv.com

Do 8 OCT 98

CALIBRATION REPORT

NQA ISO9002 REGISTERED COMPANY — ANSI-RAB ACCREDITED — Certificate No. 10154

NQA ISO9002 REGISTERED COMPANY — BS EN ISO 9002 Certificate No. 8229

SERVICE NUMBER:	SN-0226210
CONTRACT NUMBER:	SENTINEL

A59847

AEA TECHNOLOGIES
40 NORTH AVENUE

BURLINGTON MA 01803

DATE RECEIVED	CUSTOMER P.O.	ASSET NUMBER
10/08/98	2887	ENG-12

MANUFACTURER
OMEGA

MODEL	SERIAL NUMBER
HH-21	T-179139

DESCRIPTION
THERMOMETER

TEMP	HUMIDITY	PRIOR CAL	CAL CYCLE	DATE OF TEST	NEXT TEST DUE
23.00C	30.00%	9/25/97	12 MO	10/08/98	10/08/99

WORK REQUESTED	SERVICES RENDERED	REMARKS
CALIBRATE/CERTIFY	CALIBRATED/CERTIFIED	IN TOLERANCE AS RCV'D

PROCEDURE USED	N.I.S.T. TEST NUMBER	TECHNICIAN
MANUFACTURER'S	413348-433349-259071-LRAN	POULIN

CALIBRATION CHECKED TO: MANUFACTURER'S SPECIFICATIONS ADJUSTED TO: MANUFACTURER'S SPECIFICATIONS

MANUFACTURER	MODEL	SERIAL	ACCURACY	DATE CALIBRATED
ANALOGIC	AN6520	8904010	MFG.	7/03/98

TEKSERV CERTIFIES THAT ALL CALIBRATION EQUIPMENT USED IN THE TEST IS TRACEABLE TO N.I.S.T. AND THE TEST WAS PERFORMED IN ACCORDANCE WITH MIL-STD-45662A, ISO9002, Z-10012-1, ANSI/NCSL-Z540-1-1994.

CERTIFIED BY ____________

IN TOLERANCE AS RECEIVED

TEKSERV
CALIBRATION DATA

OMEGA Model HH-21
Serial Number: T 179139
Date of test: 10-8-98
Prior Cal: 9-25-97
Technician: M.P.

Data as Received ✓
Data After Adjustment ______
Data After Repair ______
Asset Number: ENG-12

Range	Reading	Specification
Deg.C Type J		
- 100.0	-99.6	+/-(0.1%rdg+0.5'C)
0.0	0.3	"
100.0	100.3	"
500.0	500.0	"
Deg.F Type J		
- 100.0	-99.3	+/-(0.1%rdg+1.0'F)
32.0	32.6	"
200.0	200.5	"
650.0	650.4	"
1200.0	1199.9	"
Deg.C Type K		
- 100.0	-99.5	+/-(0.1%RDG+0.5'C)
0.0	0.4	"
100.0	100.4	"
600.0	599.9	"
1000.0	1000.2	"
Deg.F Type K		
- 100.0	-99.1	+/-(0.1%rdg+1.0'F)
32.0	32.9	"
200.0	200.7	"
600.0	600.4	"
1600.0	1600.5	"
Deg.C Type T		
- 100.0	-99.5	+/-(0.1%rdg+0.5'C)
0.0	0.3	"
100.0	100.2	"
350.0	350.1	"
Deg.F Type T		
- 100.0	-99.4	+/-(0.1%rdg+1.0'F)
32.0	32.5	"
100.0	100.3	"
500.0	500.3	"

Established in 1972

HUNT METROLOGY SERVICE, INC.
175 Jackson St. Methuen, Ma. 01844-5042
Phone: (978) 688-7278 Fax: (978) 794-4632

Calibration Certificate

Company Name: SENTINEL
Address: 40 NORTH AVENUE
BURLINGTON, MA. 01803

Calibration No: HMSCC-08487
Dated: APR 1-2, 1998
Pages: 28

Department:

Phone No.: (781) 272-2000 Ext:
Fax No: (781) 273-2216
Attention: DAVE ANNIS
P.O. No.:
Technician: PAUL RABS

The calibration performed on the following measuring and test equipment (M&TE) of this document are traceable to the National Institute of Standards and Technology (N.I.S.T.) through N.I.S.T. test number 821/256504-96; Dated February 26, 1997 for dimensional calibration, and/or through N.I.S.T. test number 822/254480 dated February 26, 1997 for mass calibration.

The M&TE have been cleaned and lubricated, as needed. Our technician(s) have calibrated, adjusted and/or reset the M&TE, affixed a calibration label to the M&TE, updated the corresponding record(s), and provided this calibration certificate.

The standard(s) utilized to perform the calibration have been calibrated, certified and maintained in our laboratory which sustains a temperature of 68 degrees (+/- 2 degrees F.) and less than 50% relative humidity. All records pertaining to our standards, and the masters utilized to calibrate them, are kept on file in our laboratory for a period of no less than 3 years.

The services provided, traceability to the N.I.S.T., and Hunt Metrology Service's calibration system comply with the requirements of ANSI/NCSL Z540-1-1994 and ISO 10012-1:1994(E).

The reported value is both "as found" and "as left" data, unless otherwise specified. A calibration uncertainty ratio of at least 4:1 is maintained unless otherwise stated.

Keith R. Young
Technical Manager

omer: AMERSHAM CORPORATION - SENTINEL DIVISION P.O. No.:

ID.No.: 183	Manufacturer: CHATILLON	Date Cal: 04/01/98
2 ID.No.:	Serial No.: 17938	Date Due: 04/01/99
epartment: QC	Model No.: DPP-10	Technician: PR
		Cal. Proc. No: 22
viation u.:	Standard No.: 018 Cal.: 03/06/98	Due: 03/31/99
Accuracy: +/-1% OF FS	Standard No.: Cal.:	Due:
Accuracy:	Standard No.: Cal.:	Due:
	Standard No.: Cal.:	Due:

Gage Type: 10 lb FORCE GAGE

Required:	1	2	4	6	8	10	lb
Deviation:	0	0	0	0	0	0	lb
Measured:	1.0	2.0	4.0	6.0	8.0	10.0	lb

Customer: AMERSHAM CORPORATION - SENTINEL DIVISION P.O. No.:

ID.No.: 186	Manufacturer: CHATILLON	Date Cal: 04/01/98
2 ID.No.:	Serial No.: 19108	Date Due: 04/01/99
Department: RI LAB	Model No.: DPP-10	Technician: PR
		Cal. Proc. No: 22
Deviation u.:	Standard No.: 018 Cal.: 03/06/98	Due: 08/31/98
Accuracy: +/-1% OF FS	Standard No.: Cal.:	Due:
Accuracy:	Standard No.: Cal.:	Due:
	Standard No.: Cal.:	Due:

Gage Type: 10 lb FORCE GAGE

Required:	1	2	4	6	8	10	lb
Deviation:	0	0	0	0	0	0	lb
Measured:	1.0	2.0	4.0	6.0	8.0	10.0	lb

comer: AMERSHAM CORPORATION - SENTINEL DIVISION P.O. No.:

ID.No.: 236 (1)	Manufacturer: MITUTOYO	Date Cal: 04/01/98
2 ID.No.:	Serial No.: 314390	Date Due: 04/01/99
Department: QC	Model No.:	Technician: PR
		Cal. Proc. No: 16
Deviation u.:	Standard No.: 026 Cal.: 02/04/98	Due: 08/31/98
Accuracy: +/-0.0010"/12"	Standard No.: 088 Cal.: 02/04/98	Due: 02/28/99
Accuracy:	Standard No.: 137 Cal.: 02/02/98	Due: 02/28/99
	Standard No.: Cal.:	Due:

Gage Type: 0-18" VERNIER PART 1 OF 2

~~Required:~~	~~0~~	~~PARA~~	~~ID~~	~~OD~~	~~1.0~~	~~2.0~~	~~4.0~~
Deviation:	REF	.001	0		0	0	0
Measured:	REF	.001	1.0000		1.0000	2.0000	4.0000

Customer: AMERSHAM CORPORATION - SENTINEL DIVISION P.O. No.:

ID.No.: 236 (2)	Manufacturer: MITUTOYO	Date Cal: 04/01/98
2 ID.No.:	Serial No.: 314390	Date Due: 04/01/99
Department: QC	Model No.:	Technician: PR
		Cal. Proc. No: 16
Deviation u.:	Standard No.: 026 Cal.: 02/04/98	Due: 08/31/98
Accuracy: +/-0.0010"/12"	Standard No.: 088 Cal.: 02/02/98	Due: 02/28/99
Accuracy:	Standard No.: 137 Cal.: 02/02/98	Due: 02/28/99
	Standard No.: Cal.:	Due:

Gage Type: 0-18" VERNIER PART 2 OF 2

quired:	6.0	8.0	10.0	12.0	18.0
viation:	0	0	0	0	0
Measured:	6.0000	8.0000	10.0000	12.0000	18.0000

AND RE RD

T10129

PERIODIC MAINTENANCE

DESCRIPTION: PENETRATION TEST BAR

NA

CHARACTERISTICS	TOLERANCE	AQL	1	2	3	4	5	6	7	8	9	10	11	12
GENERAL VISUAL	N/A	C/100%	0/1	0/1										
VERIFY WEIGHT	13/13.5 lbs.	C/100%	0/1	0/1										

ORIGINATOR [signature] DATE 2 SEPT 97	~~P.O. / W.O.~~ FREQ. DAYS	365											
ENGINEERING APPROVAL N/A DATE	~~RECEIVING RECORD #~~ DUE DATE	2 Sep 98	2 Sep 99										
REGULATORY APPROVAL N/A DATE	LOT / SERIAL NO.	01	01										
Q A APPROVAL [signature] DATE 3 Sep 97	LOT QTY.	1	1										
COMMENTS:	QTY REJ / NCR NO.	0 / NA	0 / NA										
	QTY ACC.	1	1										
	INSP / DATE	DW / 2 Sep 97	DW / 2 Sep 98										

INSPECTION INSTRUCTION AND RECORD

PART/DWG. NO.	REV.	VENDOR:	Page 1 of
T10122	B	PERIODIC MAINTENANCE	1
		DESCRIPTION: DROP TEST SURFACE	CM - NA

CHARACTERISTICS	TOLERANCE	AQL	1	2	3	4	5	6	7	8	9	10	11	12
GENERAL VISUAL SURFACE SECURE & NOT DAMAGED	N/A	C/100%	0 / 1											
REMOVE 4 ½-13 SCREWS LUBRICATE AND REINSTALL	N/A	C/100%	0 / 1											

			1	2	3	4	5	6	7	8	9	10	11	12
ORIGINATOR Dave Annis	DATE 29 SEPT 97	~~P.O. / W.O.~~ DAYS; FREQ	365											
ENGINEERING APPROVAL N/A	DATE	~~RECEIVING RECORD #~~ DATE DUE	25 SEPT 98											
REGULATORY APPROVAL N/A	DATE	LOT / SERIAL NO.	01											
Q A APPROVAL [signature]	DATE 29 Sep 97	LOT QTY.	1											
COMMENTS:		QTY REJ / NCR NO.	0 / N/A											
		QTY ACC.	1											
		INSP / DATE	DW / 25 SEPT 95											

Simpson Gumpertz & Heger Inc.

Consulting Engineers
Arlington, MA
San Francisco, CA

297 Broadway
Arlington, MA
02174-5310

Telephone:
617 643 2000
Fax:
617 643 2009

9 June 1997

Sentinel Amersham Corporation
40 North Avenue
Burlington, Massachusetts 01803

Attention: Steven J. Grenier

Tel: 617-272-2000
Fax: 617-273-2216

Comm. 97276 – Test Foundation Study, Sentinel Amersham Test Site, Groveland, MA

Gentlemen:

At your request we studied a test foundation located on the property of Valley Tree Service, Inc. at 1210 Salem Street, Groveland, Massachusetts. The purpose of our study was to determine if the test foundation provides an essentially unyielding horizontal surface for purposes of a drop test.

Scope

The scope of our study included: visiting the site to examine the foundation; reviewing documents provided by you that describe the construction of the foundation; reviewing drawings describing the housing of your Model 676 Projector; and computing the performance characteristics of the foundation in a drop test of the Model 676 Projector.

Background and Information From Others

We understand from our discussions with Sentinel Amersham representatives that the test foundation is used as a reaction support in a drop test for the Model 676 Projector. The projector is dropped from a height of 30 ft onto the center portion of the foundation. The drawings for the Model 676 Projector show that the weight is 625 lbs, and the end plates are fabricated from 1 in. thick steel plate.

We understand from discussions with Sentinel Amersham representatives and from construction records that the test foundation was built in 1982. The delivery tickets show that 2-1/2 cubic yards of 3,000 psi concrete were utilized. We were also told that a 1 in. thick steel plate is embedded in the top surface of the foundation and welded to reinforcing steel in the foundation.

Observations

On 5 June 1997, Joseph J. Zona of Simpson Gumpertz & Heger Inc. visited the test facility and observed the following:

- The test foundation is 7 ft 4 in. x 7 ft 5 in.
- A steel plate is embedded in the top of the foundation so that the top of the plate is approximately flush with the top of the concrete. The plate is 47 in. x 48 in. At one

side of the plate, the concrete is chipped away exposing part of the plate edge. The bottom of the plate is not visible, but 7/8 in. of plate is exposed to view.

- The top surface of the steel plate is approximately horizontal. The plate slopes a maximum of 1/8 in. per 2 ft.
- The top surface of the concrete is weathered, but sound.
- Four cracks are visible in the foundation, each emanating from a corner of the steel plate. The cracks appear stable and show no signs of recent movement.
- The concrete is flush with the adjoining bituminous pavement. There is no evidence of settlement or heaving of the foundation.
- The exposed soil in the vicinity of the foundation is firm and sandy.

Results of Analysis

We estimated the depth of the foundation as 15 in. based on the measured plan dimensions and the reported volume of concrete delivered. We characterized the supporting soil as medium dense coarse grained material.

We used simple analytical models to estimate the response of the foundation in a drop test. A conservation of momentum approach that models the test as a plastic impact provides an upper bound estimate of the kinetic energy taken by the foundation. This approach predicts that 6 percent of the kinetic energy of the Model 676 Projector is taken by the foundation upon impact.

Arya et al present a relevant method of analysis in "Design of Structures & Foundations For Vibrating Machines." The approach accounts for the participation of an effective soil mass in resisting a dynamic loading. This method predicts less than 1 percent of the kinetic energy is taken by the foundation. Arya el al also present a method of estimating the foundation deflection. We computed a deflection upon impact of 0.014 in.

We estimated the flexibility of the concrete foundation as a plate on an elastic foundation using a method presented in "Theory of Plates and Shells" by Timoshenko & Woinowsky-Krieger. This approach shows that the foundation is rigid relative to the soil, and virtually all of the foundation deflection is the result of soil response.

Discussion

The plastic impact approach provides an upper bound estimate of the energy transmitted to the foundation. In an actual test, energy is absorbed in the device being tested in both plastic deformation and rebound energy that is not accounted for in this analysis.

The Arya approach is fully applicable to foundations that support vibrating equipment. This approach may somewhat overstate the participation of the soil in a single impact loading. However, we expect the influence of the participating soil mass will be significant and, therefore, we expect the percent of kinetic energy taken by the foundation is closer to 1 percent than 6 percent.

The four cracks near the corners of the foundation intersect corners of the embedded steel plate. This suggests that the plate restrained the free shrinkage of the foundation and caused these cracks. The cracks are obviously old, yet they remain tight and there is no sign of recent movement at the cracks. This strongly indicates that the cracks have not compromised the monolithic behavior of the foundation. Any loss of stiffness in the foundation related to these cracks is insignificant within the limits of our simple analytical models.

Conclusion

Based on the study described above, we conclude that the existing test foundation absorbs between 1 and 6 percent of the kinetic energy at impact during a 30·ft drop test of a Model 676 Projector. In our opinion the foundation provides an essentially unyielding horizontal surface for the purpose of this test. For items of lesser mass, the foundation also provides an essentially unyielding horioznta! surface.

Sincerely yours,

Joseph J. Zona, P.E.
Principal
JJZ32-97.ras

Atis A. Liepins, P.E.
Senior Associate

OMEGA ENGINEERING, INC.
An OMEGA Technologies Company

Certificate of Conformance

for

AEA TECHNOLOGY

40 NORTH AVE

BURLINGTON MA 01803

Cust. P.O. #: 3291 **OMEGA W.O. #** 812995304

CAL-1

OMEGA Engineering, Inc. certifies that the items comprising the above order have been manufactured in accordance with all applicable instructions and specifications as published in the OMEGA TEMPERATURE MEASUREMENT HANDBOOK AND ENCYCLOPEDIA®. OMEGA Engineering Inc. further certifies that all thermocouple base and noble metal materials conform to ANSI Limits of Error (ANSI Standard MC96.1)

Certified by: Stephen Cardone **Date:** 12-04-98

Quality Assurance Inspector

Omega Engineering, Inc., One Omega Drive, Box 4047, Stamford, CT 06907
Telephone: (203) 359-1660 · FAX: (203) 359-7811
Internet Address: http://www.omega.com E-Mail: info@omega.com

OMEGA ENGINEERING, INC.
An OMEGA Technologies Company

Certificate of Conformance

for

AEA TECHNOLOGY

40 NORTH AVE

BURLINGTON MA 01803

Cust. P.O. #: 3226 OMEGA W.O. # 811973359

CAL-1

OMEGA Engineering, Inc. certifies that the items comprising the above order have been manufactured in accordance with all applicable instructions and specifications as published in the OMEGA TEMPERATURE MEASUREMENT HANDBOOK AND ENCYCLOPEDIA®. OMEGA Engineering Inc. further certifies that all thermocouple base and noble metal materials conform to ANSI Limits of Error (ANSI Standard MC96.1)

Certified by: Stephen Cardone Date: 11-04-98

Quality Assurance Inspector

Omega Engineering, Inc., One Omega Drive, Box 4047, Stamford, CT 06907
Telephone: (203) 359-1660 · FAX: (203) 359-7811
Internet Address: http://www.omega.com E-Mail: info@omega.com

AND RE RD

T10119

PERIODIC MAINTENANCE

DESCRIPTION: PUNCTURE TEST BILLET

NA

CHARACTERISTICS	TOLERANCE	AQL	1	2	3	4	5	6	7	8	9	10	11	12
GENERAL VISUAL	N/A	C/100%	0 / 1	0 / 1										

ORIGINATOR Dave [signature] DATE 3 SEPT 97	~~P.O. / W.O.~~ FREQ. DAYS	365 →												
ENGINEERING APPROVAL N/A DATE	~~RECEIVING RECORD #~~ DUE DATE	3 SEPT 98	3 Sep 99											
REGULATORY APPROVAL N/A DATE	LOT / SERIAL NO.	01	01											
Q A APPROVAL [signature] DATE 3Sep97	LOT QTY.	1	1											
COMMENTS:	QTY REJ / NCR NO.	0 / N/A	0 / NA											
	QTY ACC.	1	1											
	INSP / DATE	DW / 3 SEPT 97	DW / 3 Sep 98											

OMEGA ENGINEERING, INC.
An OMEGA Technologies Company

Certificate of Conformance

for

MPR ASSOCIATES

320 KING ST

ALEXANDRIA VA 22314

Cust. P.O. #: 420002BRB **OMEGA W.O. #** 901934179

CAL-1

OMEGA Engineering, Inc. certifies that the items comprising the above order have been manufactured in accordance with all applicable instructions and specifications as published in the OMEGA TEMPERATURE MEASUREMENT HANDBOOK AND ENCYCLOPEDIA®. OMEGA Engineering Inc. further certifies that all thermocouple base and noble metal materials conform to ANSI Limits of Error (ANSI Standard MC96.1)

Certified by: Stephen Cardone **Date:** 01-28-99

Quality Assurance Inspector

Omega Engineering, Inc., One Omega Drive, Box 4047, Stamford, CT 06907
Telephone: (203) 359-1660 · FAX: (203) 359-7811
Internet Address: http://www.omega.com E-Mail: info@omega.com

TEKSERV

127 Riverneck Rd.
Chelmsford, MA 01824
Telephone: 978-459-9480

D@ 1 Dec 98

Calibration Report

[illegible]	[illegible]	[illegible]
A51106	AEA	SN269
[illegible]	[illegible]	[illegible]
11/23/98	3303	ENG-21

[illegible]

COLE PARMER

[illegible]	[illegible]
92000-00	L98003314

Description

12 CHANNEL THERMOCOUPLE SCANNER

AEA
40 NORTH AVENUE

BURLINGTON MA 01803-

Temperature	Humidity	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	30		12	Monthly	11/23/98	11/23/99

Work Requested	Service Rendered	Remarks
CALIBRATE/CERTIFY	CALIBRATED/CERTIFIED	IN TOLERANCE AS RECEIVED

Procedure Used	NIST Test Number	Technician
Manufacturer	413348-433349-259071-LRAN	POULIN

Calibration Checked To: Manufacturer *Spec* *Adjusted To:* Manufacturer *Spec*

Manufacturer Name	Model Number	Serial Number	Accuracy	Calibration Date	Cal Due Date
ANALOGIC	AN6520	8904010	MFG	7/3/98	7/3/99

TEKSERV CERTIFIES THAT ALL CALIBRATION EQUIPMENT USED IN THE TEST IS TRACEABLE TO N.I.S.T. AND THE TEST WAS PERFORMED IN ACCORDANCE TO ANSI/NCSL-Z540-1994, ISO-10012-1, ISO9002 AND MIL-STD-45662A

ISO9002 ISO9002

Certified By:

IN TOLERANCE
AS RECEIVED

TEKSERV
CALIBRATION DATA

CP 92000-00
Serial Number: L98 V0 3314
Date of test: 11-23-98
Prior Cal: —
Technician: MP

Data as Received ✓
Data After Adjustment
Data After Repair
Asset Number: ENG-21

Thermocouple Scanner
Type "K"

Channel	Standard Input (Deg F)			Tolerance
	32.0	1000	2000	
1	31.9	1000	2000	+/-(0.1%+0.8F)
2	31.7	999.4	2001	"
3	31.5	999.7	1999	"
4	32.0	999.6	2002	"
5	31.7	1000	2001	"
6	31.6	999.8	2001	"
7	32.0	999.7	2000	"
8	31.8	999.4	2000	"
9	31.8	1000	2000	"
10	31.9	999.7	1999	"
11	32.1	999.7	2000	"
12	31.7	999.9	2000	"

cp92000

TEKSERV 127 Riverneck Rd. Chelmsford, MA 01824 Telephone: 978-459-9480 Fax: 978-453-6336

Bill To:	AEA 40 NORTH AVENUE ATTN ACCT PAYABLE BURLINGTON MA 01803-	*Ship To:*	AEA 40 NORTH AVENUE BURLINGTON MA 01803-

Service Report Invoice

Invoice Number
INV143

Item ID
A51106

PO Number	Ship Via	PPD	Col	Invoice Date	Contact	Phone Number	[illegible]
3303	TEKSERV	Yes	No	11/23/98			

Model Number	Manufacturer	Serial Number	Accessories Received With Equipment
92000-00	COLE PARMER	L98003314	ENG-21 W/MANUAL SOFTCASE AN AC ADAPTER

Work Requested	Quantity	Part No	Description	Unit Price	Total Price	[illegible]
CALIBRATE/CERTIFY						

[illegible]

Results

IN TOLERANCE AS RECEIVED

TEKSERV
127 Riverneck Road
Chelmsford, MA 01824
Telephone: 978 - 459-9480
FAX # 978 - 453-6336
WEB SITE: http://www.tekserv.com

F.O.B. Chelmsford MA
Terms: Net 30 Days

Calibration Regular Hours: 0		*Charge:*	$45.00	*Material:*	$0.00
Calibration Overtime Hours: 0		*Labor:*	$0.00	*% Discount:*	0
Repair Regular Hours: 0		*Cost:*	$0.00	*% Tax:*	0
Repair Overtime Hours: 0		*Labor/Hour:*	$0.00	*Shipping:*	$0.00
Contract #:	AEA	*Sub Total:*	$45.00		
Warranty:				***Total Due:***	$45.00

APPENDIX B

MANUFACTURING ROUTE CARDS AND PRE-TEST RADIATION PROFILE DATA SHEETS

SENTINEL

TP80 (A)

ROUTE CARD

10352	Complete Lot:______	Total WO Qty.: 3	Serial No: 2243
CM.. A	Split Lot : ✓	Rte. Cd. Qty.: 1	Lot No: NA

Part # TP80	Description 650L SOURCE CHANGER TEST UNITS	Dwg C TP80	Rev A	WO Q89650

Oper. Seq.	Department	Operation Description	By	Date	Qty Acc	Qty Rej	Reference	Comments
0010	ASSY	MODIFY PER NOTES 3-11	RWC	15 Mar 99			TP80	QC VERIFY NOTE 6
			DW	15 MAR 99	~~0~~	1		
0020	QC	INSPECTION	DW	15 MAR 99	1	0	SOP-Q015	SEE DISPOSITION BACK
								80 lbs
0030	QA	QA REVIEW	F	15 Mar 99			SOP-Q025 & TP80	
0040	IC	STOCKROOM PROCESSING	QC	15 MAR 99			SOP-M002	
		DELIVER TO QC FOR						
		TESTING						

WI-Step	Checklist	Initials	WI-Step	Checklist	Initials	WI-Step	Checklist	Initials

ENGINEERING: S. Grani 15 MAR 99	REGULATORY: C. Lenfman 15 Mar 99	MATERIALS: Alan Cain 15 MAR 99
PRODUCTION: RW Evans 15 Mar 99	QUALITY ASSURANCE: D.W. Kurtz 15 MAR 99	ISSUE NUMBER: 1

NO	DESCRIPTION OF NONCONFORMANCE	DISPOSITION	INDIV/ DATE	INSP/DATE
1	THRU' BOLT TORQUE	*	RWE 15Mar99	D 15 MAR 99
	135 IN LBS (4 PL)			
	*USE AS IS - TORQUE OF 135 in-lbs			
	ENSURES TOP AND BOTTOM PLATES ARE			
	PROPERLY SEATED - ECO WILL BE			
	ISSUED TO CHANGE SPECIFIED TORQUE			
	ON DRAWING TO 135 ±5 in-lbs			
	NAM 15MAR99			
	DWK 15MAR99			
	[illegible] 16 Mar 99			
	MLS 16 March 99			

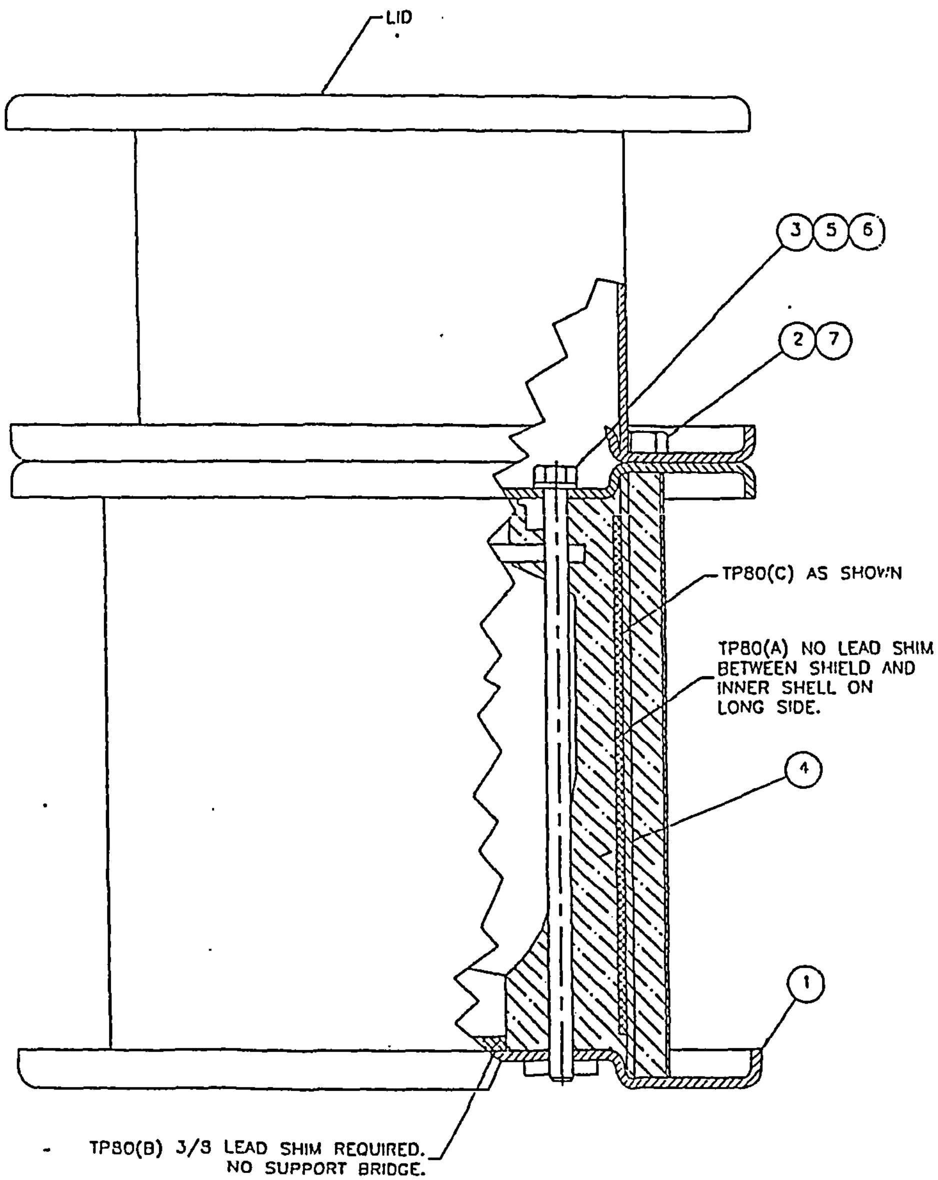
PART NUMBER	DESCRIPTION	CM	SERIAL/ LOT NO.	INITIALS	DATE
650L	SOURCE CHANGER	A	2243	RWE	15Mar99
* SCR200	5/16-18 HEX BOLT	A	99072-1	RWE	15Mar99
* BOLT #4					
#5				RWE	15Mar99
#6					
#7					

MTE SN	MTE DESCRIPTION	CAL DUE DATE	INITIALS	DATE
1126131	SCALE	16 MAY 99	D	15 MAR 99
171	TORQUE WRENCH	8/7/99	RWE	15Mar99

CHANGE VERIFICATION

PART NUMBER	DESCRIPTION	REV	ECO	INDIVIDUAL	VERIFIED

REV.	ECO/TCR #	DESCRIPTION	APPROVALS	DATE
A	2552	INITIAL RELEASE	SEE TITLE	BLOCK



NOTES:

1. UNIT DESCRIBED ON DRAWING C65009 TO BE MODIFIED AS FOLLOWS:
2. REMOVE LID AND DISCARD LID BOLTS (ITEM 2).
3. REMOVE THROUGH BOLTS (ITEM 3) AND DISCARD.
4. IF BOTTOM PLATE (ITEM 1) IS CARBON STEEL, THEN:
   A. REMOVE BOTTOM PLATE AND DISCARD.
   B. PATCH MISSING OR DAMAGED FOAM (ITEM 4) WITH NEW VULTAFOAM (ITEM 4).
   C. INSTALL NEW STAINLESS STEEL BOTTOM PLATE (ITEM 1).
5. INSTALL NEW THROUGH BOLTS (ITEM 3) WITH LOCKWASHERS (ITEM 5).
6. APPLY THREAD LUBRICANT AND TORQUE EACH THROUGH BOLT (ITEM 3) TO 100±5 in-lbs.
7. INSTALL SAFETY WIRE (ITEM 6) THROUGH EACH BOLT IN PAIRS.
8. INSTALL AND LOCK BOTH DUMMY SOURCE ASSEMBLIES (ITEM 8) INTO EACH PORT (NOT SHOWN).
9. VERIFY MARKING ON NEW LID BOLTS (ITEM 2) IS "B8".
10. INSTALL LID WITH NEW LID BOLTS (ITEM 2).
11. INSTALL TAMPER INDICATING SEAL WIRE (ITEM 7) THROUGH TWO LID BOLTS (ITEM 2).

ITEM	QTY	NAME	DESCRIPTION
8	2	42409XL	DUMMY SOURCE WIRE ASSEMBLY
7	AR		TAMPER INDICATING SEAL WIRE
6	AR	WRS032	SAFETY WIRE
5	4		LOCK WASHER 5/16 DIA
4	AR	FOM001	VULTAFOAM #16-L-708
3	4	SCR200	HEX HEAD BOLT 5/16-18 X 8 LG. DRILLED HEAD, 300 SERIES (18-8) STN STL
2	4	SCR201	HEX HEAD BOLT 3/8-16 X 7/8 LG. DRILLED HEAD, A198 GR B8 CL 2
1	1	C65000-6	BOTTOM PLATE

MATERIALS: C65009 & PARTS LIST ABOVE

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MAX SURFACE TEXTURE 125
3. TOLERANCES APPLY AFTER PLATING.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64, .X ± 0.1, .XX ± 0.01, .XXX ± 0.005, MACHINED ANGLES ± 1°

USED ON:

DRAWN	S. [signature]	15 MAR 97
CHECKED	[signature]	15 MAR 97
APPR.	S. [signature]	15 MAR 97

THIRD ANGLE PROJECTION

SAFETY CLASS A

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: MODEL 650L TEST SPECIMEN

SIZE C | DWG. NO. TP80 | REV A

SCALE: NA | SHEET 1 OF 1

SENTINEL

Specimen Copy 2 ... TP80(A)

ROUTE CARD

#10243 Complete Lot:____ Total WO Qty.: 3 Serial No: 2243

A Split Lot: ✓ Rte. Cd. Qty.: 1 Lot No: NA

Part# TP80	Description 650L SOURCE CHANGER TEST UNITS	Dwg TP80 R-	Rev B	WO Q89650

Oper. Seq.	Department	Operation Description	By	Date	Qty Acc	Qty Rej	Reference	Comments
0010	ASSY	MODIFY PER NOTES 2-4	RWE	25Feb99			TP80	
0020	QC	INSPECTION	DW	25Feb99	1	0	SOP-Q015	
0030	QC	FINAL PROFILE	DW FOR MRB	25Feb99	1	0	WI-Q09	TOTAL WEIGHT 800#
0040	QA	QA REVIEW	F	25Feb99			SOP-Q025 & TP80	
	IC	STOCKROOM PROCESSING	AC	25Feb99			SOP-M002	
		DELIVER TO QC FOR TESTING						

WI-Step	Checklist	Initials	WI-Step	Checklist	Initials	WI-Step	Checklist	Initials

ENGINEERING: [signature] 25Feb99 REGULATORY: C. Ra[signature] 25Feb99 MATERIALS: [signature] 25Feb

PRODUCTION: RW Evans 25Feb99 QUALITY ASSURANCE: D.W. Kurtz 25Feb99 ISSUE NUMBER: 1

QP2

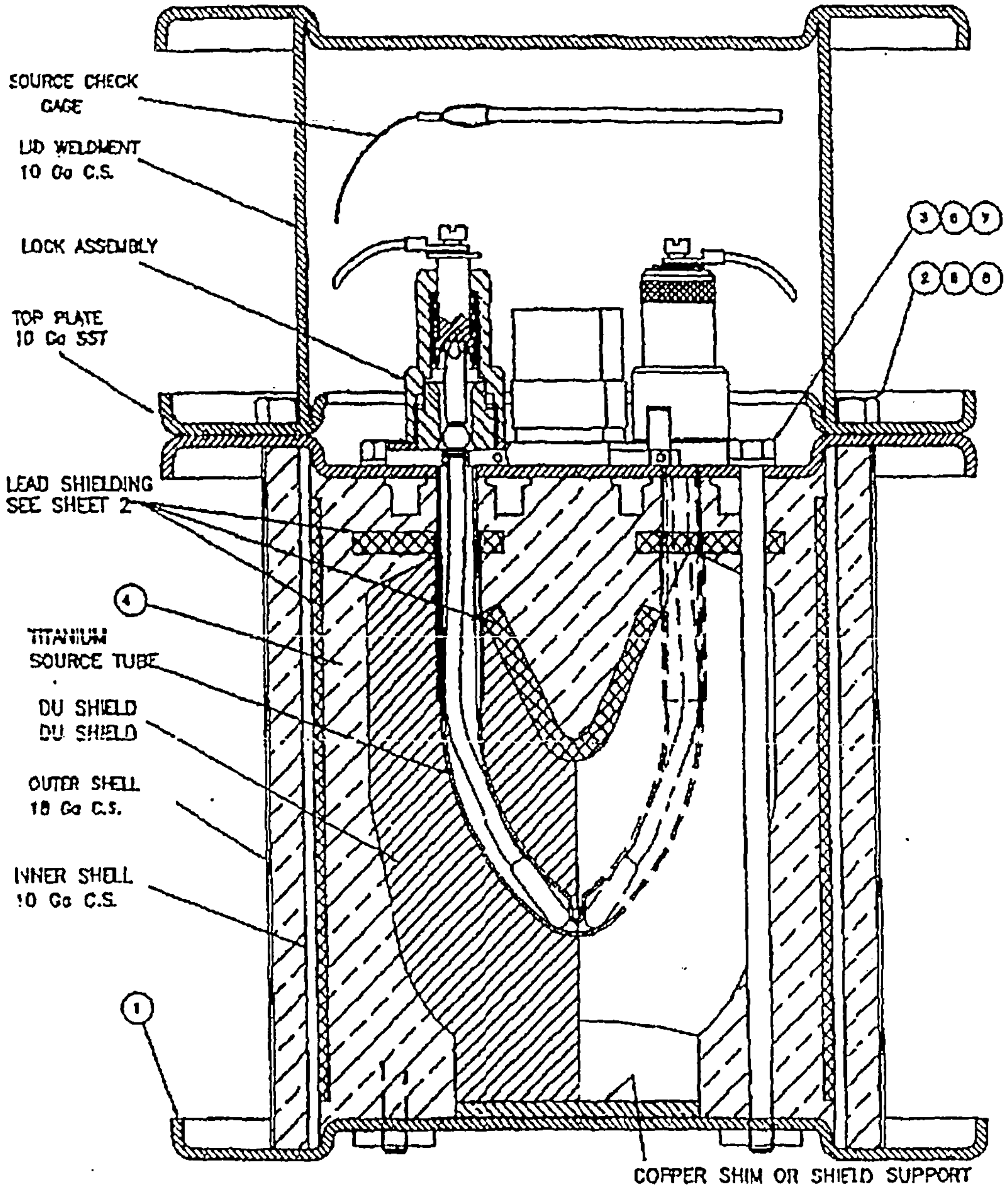
DESCRIPTION OF NONCONFORMANCE	DISPOSITION	INDIV/ DATE	INSP/DATE

PART NUMBER	DESCRIPTION	CM	SERIAL/ LOT NO.	INITIALS	DATE
650L	SOURCE CHANGER	A	2243	RWE	25Feb99
SCR200	5/16-18 HEX BOLT	A	99054-1	RWE	25Feb99

MTE SN	MTE DESCRIPTION	CAL DUE DATE	INITIALS	DATE
112631	SCALE	16May99	RWE	25Feb99

CHANGE VERIFICATION

PART NUMBER	DESCRIPTION	REV	ECO	INDIVIDUAL	VERIFIED



Notes:

1. Refer to Drawing C65009 for construction of original unit.

2. Modify unit as follows:
 a) Remove lid and discard bolts.
 b) Remove through bolts and discard.
 c) If bottom plate is carbon steel, remove existing plate. Patch missing or damaged foam with new Vultafoam., Item (4). Install new stainless steel bottom plate, Item (1).
 d) Install new through bolts, Item (3), with lock washers and install safety wire for security.
 e) Install two (2) dummy source assembly 424-9's, one in each side.

3. Verify marking on new lid bolts, Item (2), is "B8".

4. Install lid with new lid bolts, Item (2), and lock washers, and install seal wire for shipment tamper indicator.

ITEM	QTY	NAME	DESCRIPTION
8	AR		TAMPER PROOF SEAL WIRE
7	AR	WRS032	SAFETY WIRE
6	4		LOCK WASHER 5/'6 DIA
5	4		LOCK WASHER, 3/8 DIA
4	AR	FOM001	VULTAFOAM #16-L-708
3	4	SCR200	HEX HEAD BOLT 5/16-18 X 8 LG. DRILLED HEAD, STAINLESS STEEL 304
2	4	SCR201	HEX HEAD BOLT 3/8-16 X 7/8 LG. DRILLED HEAD, A198 GR B8 CL 2
1	1	C65000-6	BOTTOM PLATE

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES AND REFERENCE

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

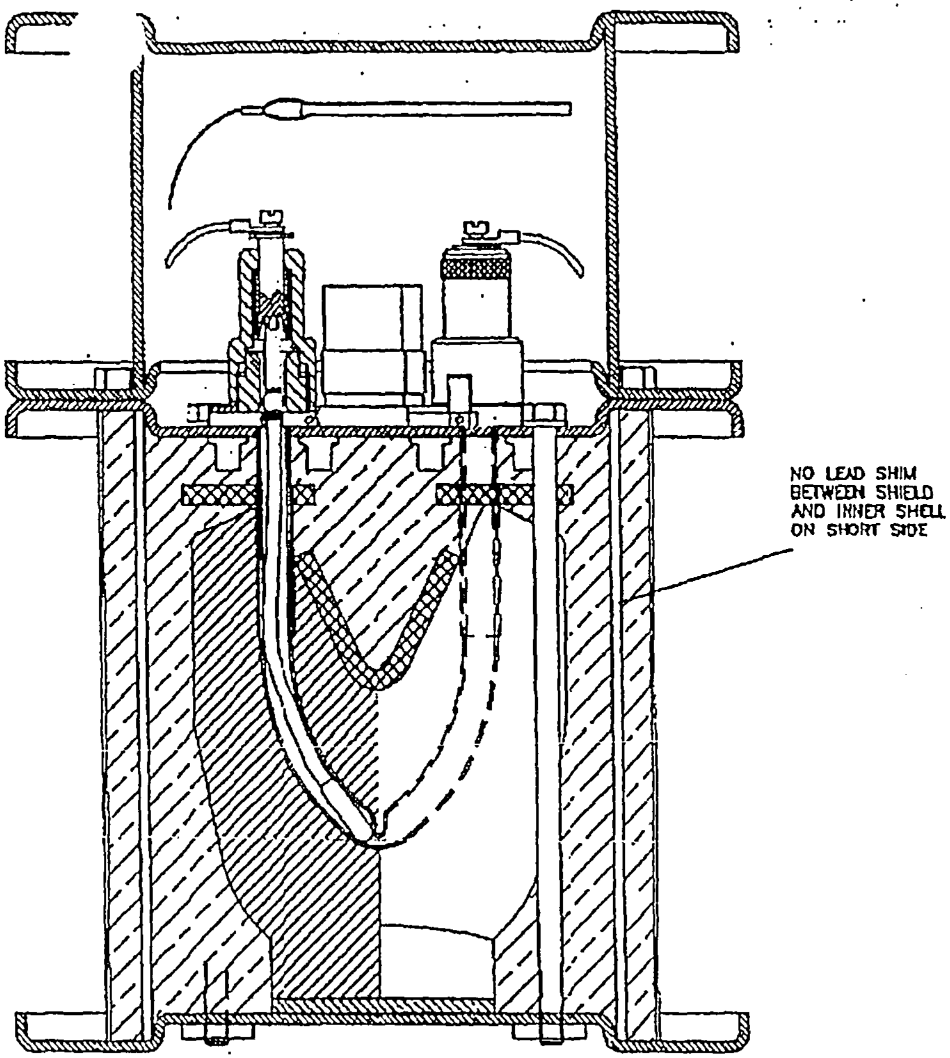
DESCRIPTIVE DRAWING

TITLE 650L SOURCE CHANGER TEST UNITS

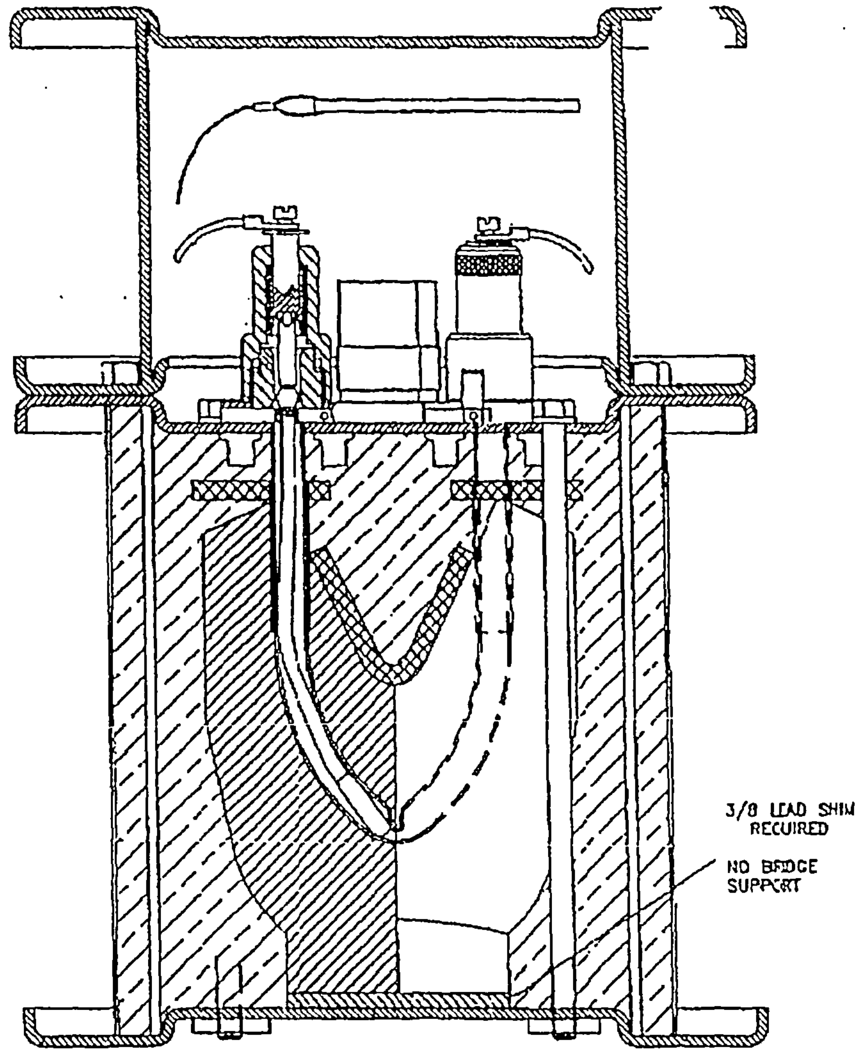
SIZE A | DWG. NO. R-TP80 | SCALE: NONE | SHEET 1 OF 2

DESCRIPTION	APPROVALS	DATE	LTR
FORMAT CORRECTED DDCO#31	W.T.L.	25FEB99	B

REVISIONS



TP 80 (A)



TP 80 (B)

NOTE:
NO SPECIAL REGUIREMENTS
FOR
LEAD LOCATION N TP80(C)

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE REFERENCE			
SIZE A	DWG. NO. R–TP80		REV B
	SCALE: NONE	SHEET 2 OF 2	

SENTINEL TP80 (B)

ROUTE CARD

Q 10352 Complete Lot:______ Total WO Qty.: 3 Serial No: ~~2243~~ 182 DW 15 MAR 99

CM: A Split Lot: ✓ Rte. Cd. Qty.: 1 Lot No: NA

Part # TP80	Description 650L SOURCE CHANGER TEST UNITS	Dwg C TP80	Rev A	WO Q89650

Oper. Seq.	Department	Operation Description	By	Date	Qty Acc	Qty Rej	Reference	Comments
0010	ASSY	MODIFY PER NOTES 3-11	KWE	15 Mar 99			TP80	QC VERIFY NOTE 6
			~~DW~~	15 MAR 99	~~0~~	1		
0020	QC	INSPECTION	DW	15 MAR 99	1	~~0~~	SOP-Q015	SEE DISPOSITION BACK
								83.6 lbs
030	QA	QA REVIEW	[illegible]	15 MAR 99			SOP-Q025 & TP80	
040	IC	STOCKROOM PROCESSING	AC	15 MAR 99			SOP-M002	
		DELIVER TO QC FOR						
		TESTING						

WI–Step	Checklist	Initials	WI–Step	Checklist	Initials	WI–Step	Checklist	Initials

ENGINEERING: S. [illegible] 15 MAR 99	REGULATORY: C. [illegible] 15 MAR 99	MATERIALS: Alan Cain 15 MAR 99
PRODUCTION: KW Evans 15 Mar 99	QUALITY ASSURANCE: D.W. Kurtz 15 MAR 99	ISSUE NUMBER: 1

QP25-1/2

NO	DESCRIPTION OF NONCONFORMANCE	DISPOSITION	INDIV/ DATE	INSP/DATE
1	THRU BOLT TORQUE 135 IN LBs (4 PL)	*	RWE 15 Mar 99	DW 15 MAR 99
	*USE AS IS - Torque of 135 in-lbs ensures top and bottom plates are properly seated - ECO will be issued to change specified torque on drawing to 135 ± 5 lbs			
	NAM 15 MAR 99 BWK 15 MAR 99 [illegible] 16 Mar 99 MLS 16 MAR 99			

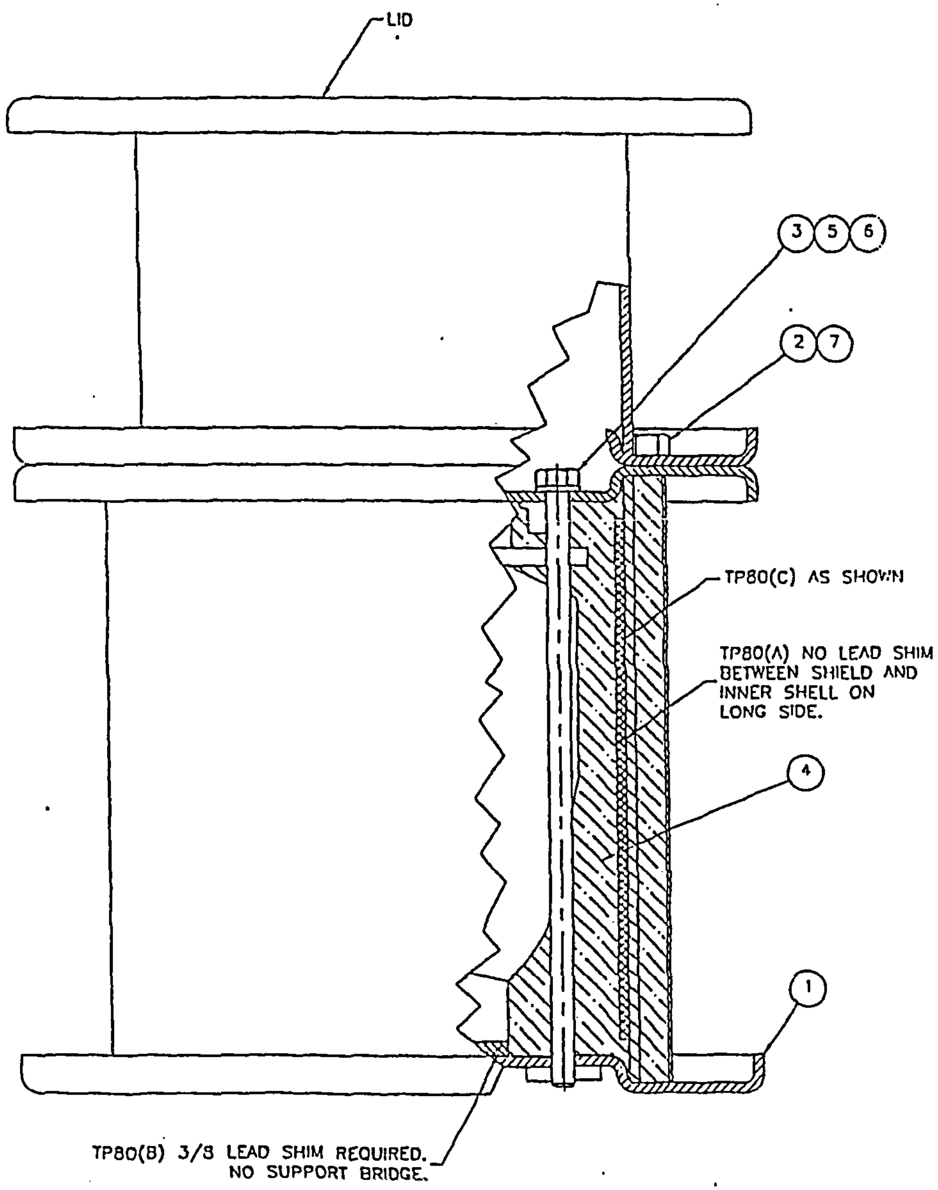
PART NUMBER	DESCRIPTION	CM	SERIAL/ LOT NO.	INITIALS	DATE
650L	SOURCE CHANGER	A	182	RWE	15 Mar 99
* SCR200	5/16-18 HEX BOLT	A	99072-1	RWE	15 Mar 99
*Bolt #8, #9, #10, #11				RWE	15 Mar 99

MTE SN	MTE DESCRIPTION	CAL DUE DATE	INITIALS	DATE
1126131	SCALE	16 MAY 99	DW	15 MAR 99
171	TORQUE WRENCH	8/7/99	RWE	15 Mar 99

CHANGE VERIFICATION

PART NUMBER	DESCRIPTION	REV	ECO	INDIVIDUAL	VERIFIED

REV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
A	2552	INITIAL RELEASE	SEE TITLE	BLOCK



NOTES:

1. UNIT DESCRIBED ON DRAWING C65009 TO BE MODIFIED AS FOLLOWS:
2. REMOVE LID AND DISCARD LID BOLTS (ITEM 2).
3. REMOVE THROUGH BOLTS (ITEM 3) AND DISCARD.
4. IF BOTTOM PLATE (ITEM 1) IS CARBON STEEL, THEN:
   A. REMOVE BOTTOM PLATE AND DISCARD.
   B. PATCH MISSING OR DAMAGED FOAM (ITEM 4) WITH NEW VULTAFOAM (ITEM 4).
   C. INSTALL NEW STAINLESS STEEL BOTTOM PLATE (ITEM 1).
5. INSTALL NEW THROUGH BOLTS (ITEM 3) WITH LOCKWASHERS (ITEM 5).
6. APPLY THREAD LUBRICANT AND TORQUE EACH THROUGH BOLT (ITEM 3) TO 100±5 in-lbs.
7. INSTALL SAFETY WIRE (ITEM 6) THROUGH EACH BOLT IN PAIRS.
8. INSTALL AND LOCK BOTH DUMMY SOURCE ASSEMBLIES (ITEM 8) INTO EACH PORT (NOT SHOWN).
9. VERIFY MARKING ON NEW LID BOLTS (ITEM 2) IS "B8".
10. INSTALL LID WITH NEW LID BOLTS (ITEM 2).
11. INSTALL TAMPER INDICATING SEAL WIRE (ITEM 7) THROUGH TWO LID BOLTS (ITEM 2).

ITEM	QTY	NAME	DESCRIPTION
8	2	42409XL	DUMMY SOURCE WIRE ASSEMBLY
7	AR		TAMPER INDICATING SEAL WIRE
6	AR	WRS032	SAFETY WIRE
5	4		LOCK WASHER 5/16 DIA
4	AR	FOM001	VULTAFOAM #16-L-708
3	4	SCR200	HEX HEAD BOLT 5/16-18 X 8 LG. DRILLED HEAD, 300 SERIES (18-8) STN STL
2	4	SCR201	HEX HEAD BOLT 3/8-16 X 7/8 LG. DRILLED HEAD, A198 GR B8 CL 2
1	1	C65000-6	BOTTOM PLATE

MATERIALS: C65009 & PARTS LIST ABOVE

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MAX SURFACE TEXTURE 125
3. TOLERANCES APPLY AFTER PLATING.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64; MACHINED ANGLES ± 1°; .X ± 0.1; .XX ± 0.01; .XXX ± 0.005

USED ON:

DRAWN	S. G.	15 ... 97
CHECKED	[signature]	15 MAR 97
APPR.	S. G.	15 ... 97

THIRD ANGLE PROJECTION

SAFETY CLASS A

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: MODEL 650L TEST SPECIMEN

SIZE C | DWG. NO. TP80 | REV A

SCALE: NA | SHEET 1 OF 1

SENTINEL

TP80 (B) [illegible] 2 Mar 99

ROUTE CARD

10243 | Complete Lot: ____ | Total WO Qty.: 3 | Serial No: 182

CM: A | Split Lot: ✓ | Rtc. Cd. Qty.: 1 | Lot No: NA

Part # TP80	Description 650L SOURCE CHANGER TEST UNITS	Dwg # TP80	Rev B	WO 989650

Oper. Seq.	Department	Operation Description	By	Date	Qty Acc	Qty Rej	Reference	Comments
0010	ASSY	MODIFY PER NOTES 2-4	RWE	25 Feb 99			TP80	
0020	QC	INSPECTION	(initials)	25 Feb 99	1	0	SOP-Q015	
0030	QC	FINAL PROFILE	DO for MPB	25 Feb 99	1	0	WI-Q09	TOTAL WEIGHT 83.6 #
0040	QA	QA REVIEW	(initials)	25 Feb 99			SOP-Q025 & TP80	
00[illegible]	IC	STOCKROOM PROCESSING DELIVER TO QC FOR TESTING	AC	25 Feb 99			SOP-M002	

WI-Step	Checklist	Initials	WI-Step	Checklist	Initials	WI-Step	Checklist	Initials

ENGINEERING: [signature] 25 Feb 99 | REGULATORY: C. [signature] 25 Feb 99 | MATERIALS: [signature] 25[illegible]

PRODUCTION: RW [signature] 25 Feb 99 | QUALITY ASSURANCE: D.W. [signature] 25 Feb 99 | ISSUE NUMBER: 1

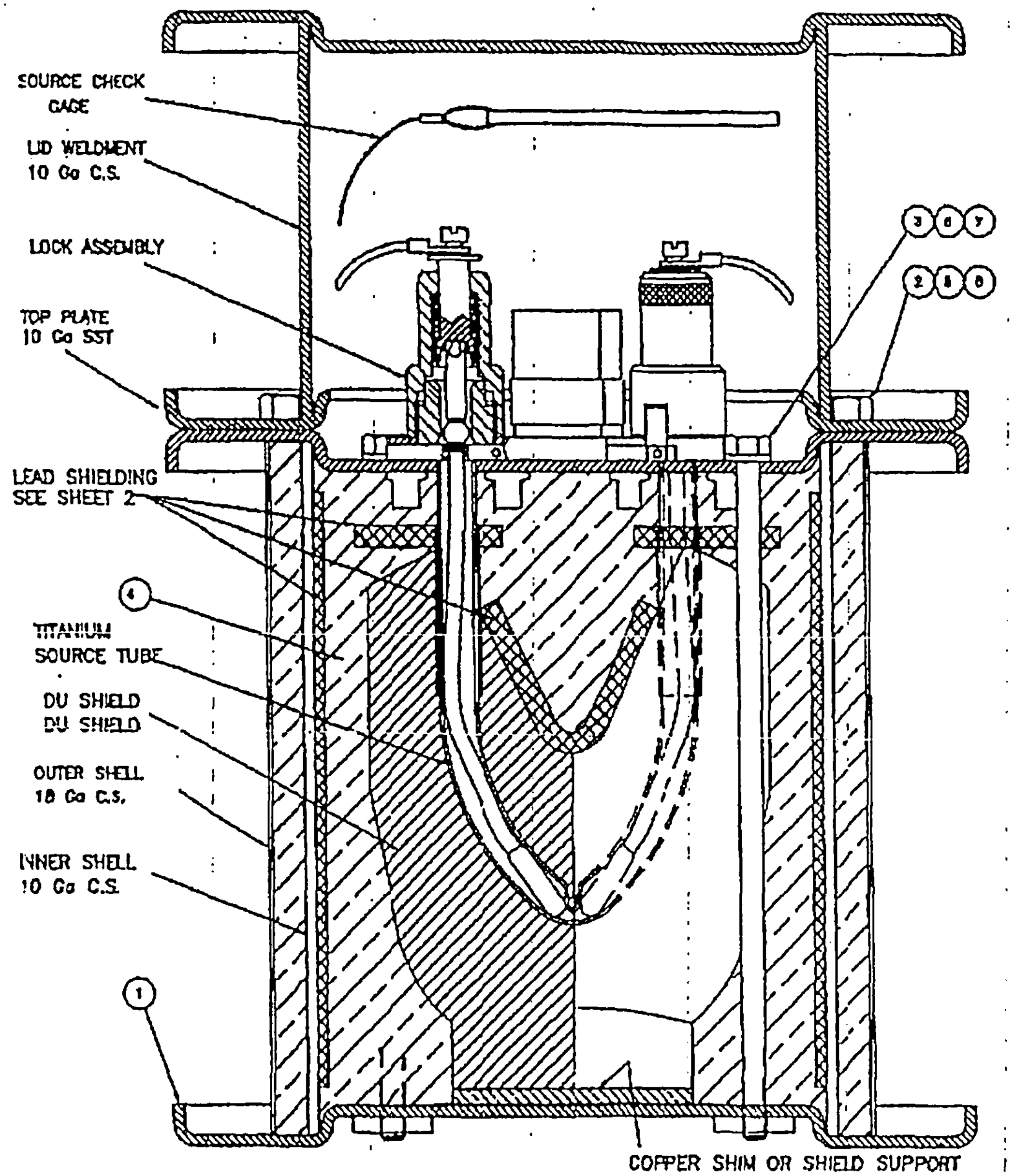
DESCRIPTION OF NONCONFORMANCE	DISPOSITION	INDIV/ DATE	INSP/DATE

PART NUMBER	DESCRIPTION	CM	SERIAL/ LOT NO.	INITIALS	DATE
650L	SOURCE CHANGER	A	182	KWE	25 Feb 99
SCR200	5/16-18 HEX BOLT	A	99054-1	KWE	25 Feb 99

MTE SN	MTE DESCRIPTION	CAL DUE DATE	INITIALS	DATE
1126131	SCALE	16 May 99	KWE	25 Feb 99

CHANGE VERIFICATION

PART NUMBER	DESCRIPTION	REV	ECO	INDIVIDUAL	VERIFIED



Notes:

1. Refer to Drawing C65009 for construction of original unit.

2. Modify unit as follows:
 a) Remove lid and discard bolts.
 b) Remove through bolts and discard.
 c) If bottom plate is carbon steel, remove existing plate. Patch missing or damaged foam with new Vultafoam., Item (4). Install new stainless steel bottom plate, Item (1).
 d) Install new through bolts, Item (3), with lock washers and install safety wire for security.
 e) Install two (2) dummy source assembly 424-9's, one in each side.

3. Verify marking on new lid bolts, Item (2), is "B8".

4. Install lid with new lid bolts, Item (2), and lock washers, and install seal wire for shipment tamper indicator.

ITEM	QTY	NAME	DESCRIPTION
8	AR		TAMPER PROOF SEAL WIRE
7	AR	WRS032	SAFETY WIRE
6	4		LOCK WASHER 5/16 DIA
5	4		LOCK WASHER, 3/8 DIA
4	AR	FOM001	VULTAFOAM #16-L-708
3	4	SCR200	HEX HEAD BOLT 5/16-18 X 8 LG. DRILLED HEAD, STAINLESS STEEL 304
2	4	SCR201	HEX HEAD BOLT 3/8-16 X 7/8 LG. DRILLED HEAD, A193 GR B8 CL 2
1	1	C65000-6	BOTTOM PLATE

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES AND REFERENCE

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

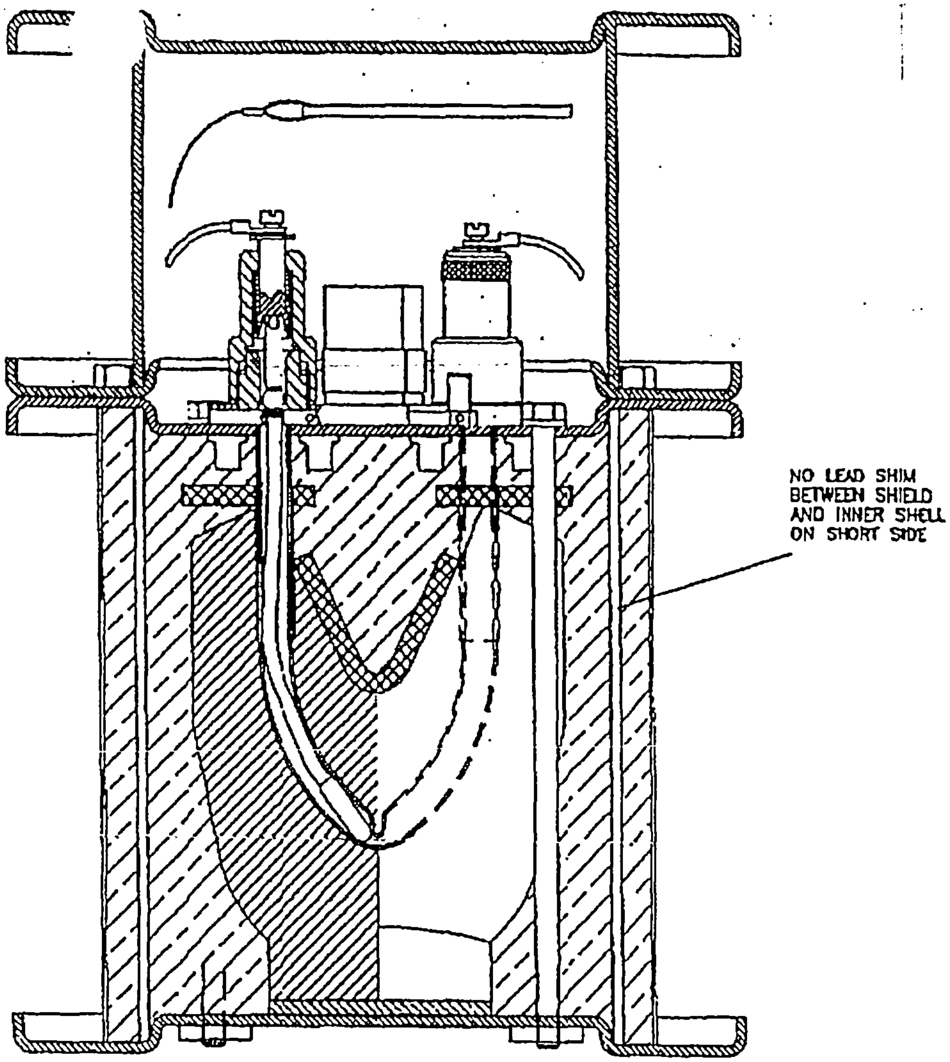
DESCRIPTIVE DRAWING

TITLE 650L SOURCE CHANGER TEST UNITS

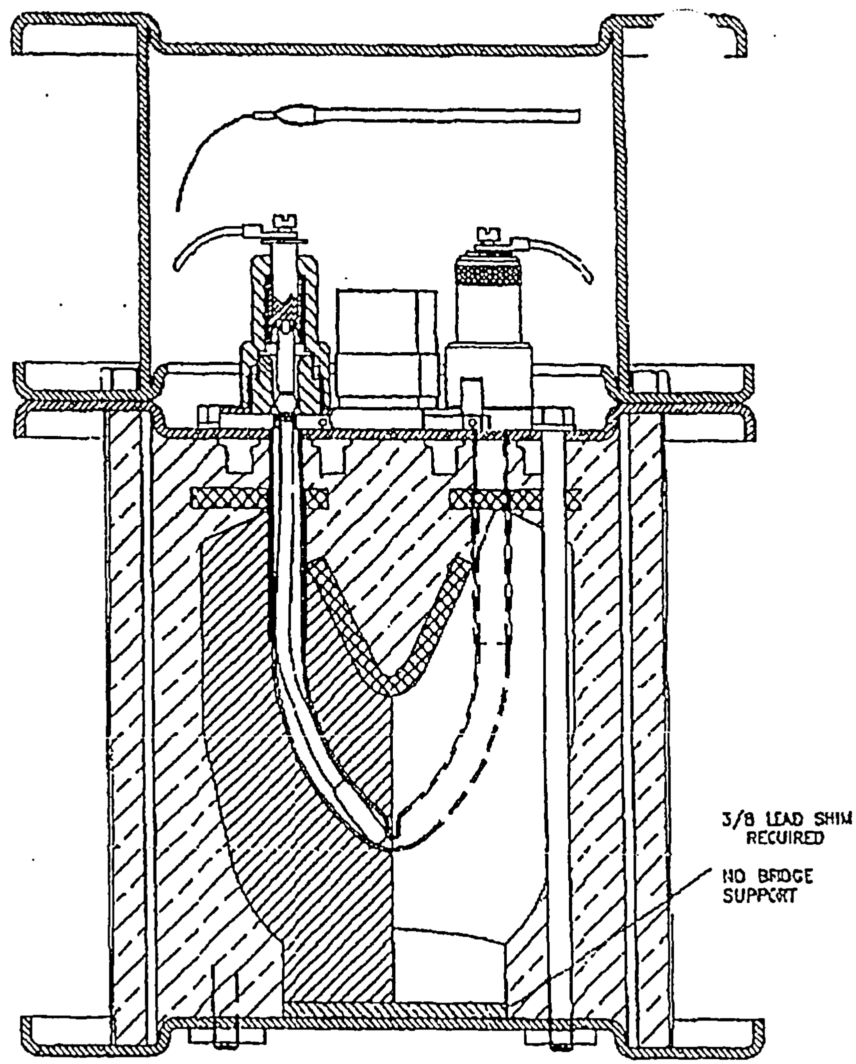
DESCRIPTION	APPROVALS	DATE	LTR
FORMAT CORRECTED DDCO#31	[signature] T.L.	25FEB99	B

REVISIONS

SIZE A | DWG. NO. R-TP80 | REV B
SCALE: NONE | SHEET 1 OF 2



TP 80 (A)



TP 80 (B)

NOTE:
NO SPECIAL REQUIREMENTS
FOR
LEAD LOCATION N TP80(C)

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE REFERENCE			
SIZE A	DWG. NO. R-TP80		REV B
	SCALE: NONE	SHEET 2 OF 2	

SENTINEL TP80 (c)

ROUTE CARD

QC '0352 Complete Lot: ~~✓~~ (DW 15 MAR 99) Total WO Qty.: 3 Serial No: 195

CM: Split Lot: ✓ Rte. Cd. Qty.: 1 Lot No: NA

Part # TP80		Description 650L SOURCE CHANGER TEST UNITS					Dwg C TP80	Rev A	WO Q89650
Oper. Seq.	Department	Operation Description	By	Date	Qty Acc	Qty Rej	Reference		Comments
010	ASSY	MODIFY PER NOTES 3-11	RVE	15 Mar 99			TP80		QC VERIFY NOTE 6 (DW 15 MAR 99)
			DW	15 MAR 99	0	1			
020	QC	INSPECTION	DW	15 MAR 99	1	0	SOP-Q015		SEE DISPOSITION BACK
									89 lbs
030	QA	QA REVIEW	$	15 MAR 99			SOP-Q025 & TP80		
40	IC	STOCKROOM PROCESSING	AC	15 MAR 99			SOP-M002		
		DELIVER TO QC FOR							
		TESTING							

WI-Step	Checklist	Initials	WI-Step	Checklist	Initials	WI-Step	Checklist	Initials

ENGINEERING: S. Gr[illegible] 15 MAR 99	REGULATORY: C. Lenfran 15 MAR 99	MATERIALS: Alan Cain 15 MAR 99
PRODUCTION: RW Evans 15 Mar 99	QUALITY ASSURANCE: D.W. Kurtz 15 MAR 99	ISSUE NUMBER: 1

NO	DESCRIPTION OF NONCONFORMANCE	DISPOSITION	INDIV/ DATE	INSP/DATE
1	THRU BOLT TORQUE	*	RWE 15 Mar 99	DW 15 MAR 99
	135 IN LBS (4 PC)			
	*USE AS IS - Torque of 135 in-lbs			
	ensures top and bottom plates are			
	properly seated - ECO will be			
	issued to change specified torque			
	on drawing to 135 ± 5 in-lbs			
	NDM 15 MAR 99			
	BWK 15 MAR 99			
	RBB 16 Mar 99			
	MLS 16 Mar 99			

PART NUMBER	DESCRIPTION	CM	SERIAL/ LOT NO.	INITIALS	DATE
650L	SOURCE CHANGER	A	195	RWE	15 Mar 99
* SCR200	5/16-18 HEX BOLT	A	99072-1	RWE	15 Mar 99
* BOLT # 12					
# 13				RWE	15 Mar 99
# 14					
# 15					

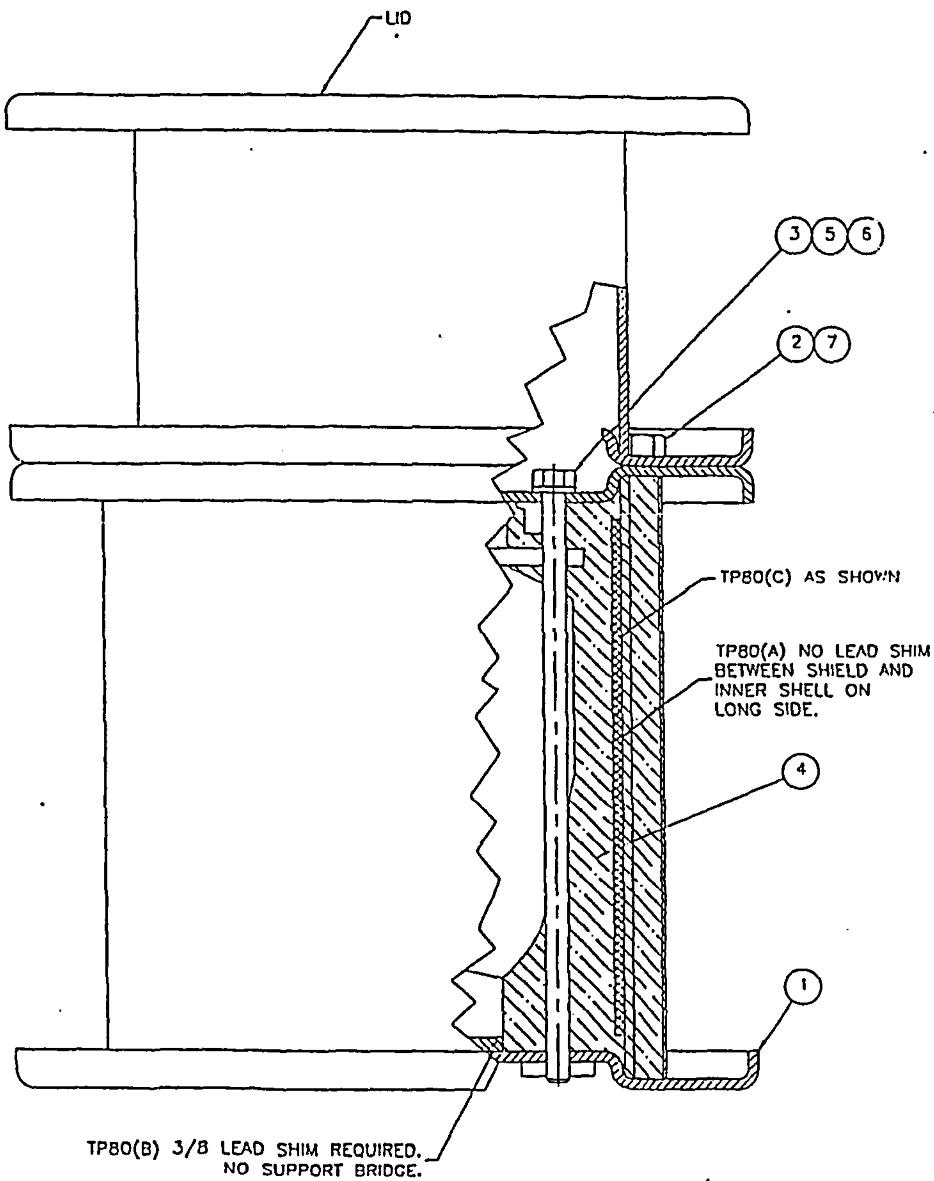
MTE SN	MTE DESCRIPTION	CAL DUE DATE	INITIALS	DATE
F16383	SCALE	16 MAY 99	DW	15 MAR 99
171	TORQUE WRENCH	8/7/99	RWE	15 Mar 99

CHANGE VERIFICATION

PART NUMBER	DESCRIPTION	REV	ECO	INDIVIDUAL	VERIFIED

REV.	ECO/IGR #	DESCRIPTION	APPROVALS	DATE
A	2552	INITIAL RELEASE	SEE TITLE	BLOCK

REVISIONS



NOTES:

1. UNIT DESCRIBED ON DRAWING C65009 TO BE MODIFIED AS FOLLOWS:
2. REMOVE LID AND DISCARD LID BOLTS (ITEM 2).
3. REMOVE THROUGH BOLTS (ITEM 3) AND DISCARD.
4. IF BOTTOM PLATE (ITEM 1) IS CARBON STEEL, THEN:
   A. REMOVE BOTTOM PLATE AND DISCARD.
   B. PATCH MISSING OR DAMAGED FOAM (ITEM 4) WITH NEW VULTAFOAM (ITEM 4).
   C. INSTALL NEW STAINLESS STEEL BOTTOM PLATE (ITEM 1).
5. INSTALL NEW THROUGH BOLTS (ITEM 3) WITH LOCKWASHERS (ITEM 5).
6. APPLY THREAD LUBRICANT AND TORQUE EACH THROUGH BOLT (ITEM 3) TO 100±5 in-lbs.
7. INSTALL SAFETY WIRE (ITEM 6) THROUGH EACH BOLT IN PAIRS.
8. INSTALL AND LOCK BOTH DUMMY SOURCE ASSEMBLIES (ITEM 8) INTO EACH PORT (NOT SHOWN).
9. VERIFY MARKING ON NEW LID BOLTS (ITEM 2) IS "B8".
10. INSTALL LID WITH NEW LID BOLTS (ITEM 2).
11. INSTALL TAMPER INDICATING SEAL WIRE (ITEM 7) THROUGH TWO LID BOLTS (ITEM 2).

ITEM	QTY	NAME	DESCRIPTION
8	2	42409XL	DUMMY SOURCE WIRE ASSEMBLY
7	AR		TAMPER INDICATING SEAL WIRE
6	AR	WRS032	SAFETY WIRE
5	4		LOCK WASHER 5/16 DIA
4	AR	FOM001	VULTAFOAM #16-L-708
3	4	SCR200	HEX HEAD BOLT 5/16-18 X 8 LG. DRILLED HEAD, 300 SERIES (18-8) STN STL
2	4	SCR201	HEX HEAD BOLT 3/8-16 X 7/8 LG. DRILLED HEAD, A198 GR 88 CL 2
1	1	C65000-6	BOTTOM PLATE

MATERIALS: C65009 & PARTS LIST ABOVE

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED:
1. DIMENSIONS ARE IN INCHES.
2. MAX SURFACE TEXTURE 125
3. TOLERANCES APPLY AFTER PLATING.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64, MACHINED ANGLES ± 1°, .X ± 0.1, .XX ± 0.01, .XXX ± 0.005

USED ON:

DRAWN	S. [signature]	15 Mar 97
CHECKED	[signature]	15 MAR 97
APPR.	S. [signature]	15 Mar 97

THIRD ANGLE PROJECTION

SAFETY CLASS A

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: MODEL 650L TEST SPECIMEN

SIZE C | DWG. NO. TP80 | REV A

SCALE: NA | SHEET 1 OF 1

SENTINEL

ROUTE CARD

#10283 Complete Lot: N/A Total WO Qty.: 3 4 DW 3 MAR 99 Serial No: 195

A Split Lot: ✓ Rte. Cd. Qty.: 1 Lot No: NA

Part # TP80	Description 650L SOURCE CHANGER TEST UNITS	Dwg # TP80 R-	Rev B	WO Q89650

Oper. Seq.	Department	Operation Description	By	Date	Qty Acc	Qty Rej	Reference	Comments
0010	ASSY	MODIFY PER NOTES 2-4	RWE	3Mar99			TP80	
0020	QC	INSPECTION	DW	3MAR 99	1	0	SOP-Q015	
0030	QC	FINAL PROFILE	MDB	4 March99	1	0	WI-Q09	TOTAL WEIGHT 89 #LG
0040	QA	QA REVIEW	F	4MAR99			SOP-Q025 & TP80	
[illegible]	IC	STOCKROOM PROCESSING DELIVER TO QC FOR TESTING	AC	4MAR99			SOP-M002	

WI-Step	Checklist	Initials	WI-Step	Checklist	Initials	WI-Step	Checklist	Initials

ENGINEERING: [signature] 25Feb99 REGULATORY: [signature] 25Feb99 MATERIALS: [signature] 25Feb

PRODUCTION: RW Evans 25Feb99 QUALITY ASSURANCE: D.W. Kurtz 25Feb99 ISSUE NUMBER: 1

QP2

TOTAL P.23

RMAT CC

DESCRIPTION OF NONCONFORMANCE	DISPOSITION	INDIV/ DATE	INSP/DATE

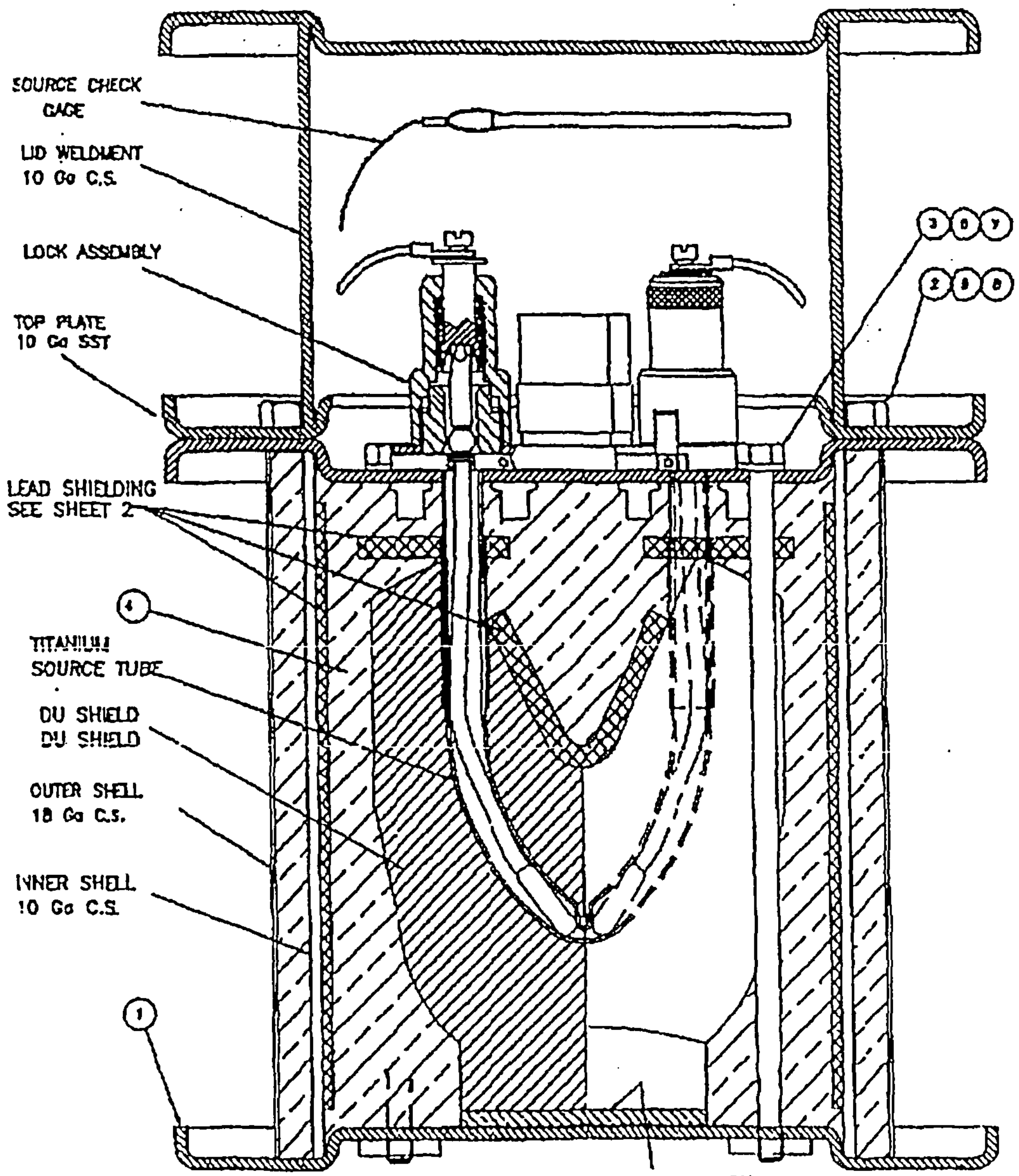
PART NUMBER	DESCRIPTION	CM	SERIAL/ LOT NO.	INITIALS	DATE
650L	SOURCE CHANGER	A	195	RWE	3 Mar 99
SCR200	5/16-18 HEX BOLT	A	99054-1	RWE	3 Mar 99

MTE SN	MTE DESCRIPTION	CAL DUE DATE	INITIALS	DATE
F16383	SCALE	16 May 99	RWE	3 Mar 99

CHANGE VERIFICATION

PART NUMBER	DESCRIPTION	REV	ECO	INDIVIDUAL	VERIFIED

QP25-2/2



Notes:

1. Refer to Drawing C65009 for construction of original unit.

2. Modify unit as follows:
 a) Remove lid and discard bolts.
 b) Remove through bolts and discard.
 c) If bottom plate is carbon steel, remove existing plate. Patch missing or damaged foam with new Vultafoam., Item (4). Install new stainless steel bottom plate, Item (1).
 d) Install new through bolts, Item (3), with lock washers and install safety wire for security.
 e) Install two (2) dummy source assembly 424-9's, one in each side.

3. Verify marking on new lid bolts, Item (2), is "B8".

4. Install lid with new lid bolts, Item (2), and lock washers, and install seal wire for shipment tamper indicator.

ITEM	QTY	NAME	DESCRIPTION
8	AR		TAMPER PROOF SEAL WIRE
7	AR	WRS032	SAFETY WIRE
6	4		LOCK WASHER 5/16 DIA
5	4		LOCK WASHER, 3/8 DIA.
4	AR	FOM001	VULTAFOAM #16-L-708
3	4	SCR200	HEX HEAD BOLT 5/16-18 X 8 LG. DRILLED HEAD, STAINLESS STEEL 304
2	4	SCR201	HEX HEAD BOLT 3/8-16 X 7/8 LG. DRILLED HEAD, A198 GR B8 CL 2
1	1	C65000-6	BOTTOM PLATE

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES AND REFERENCE

AEATECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

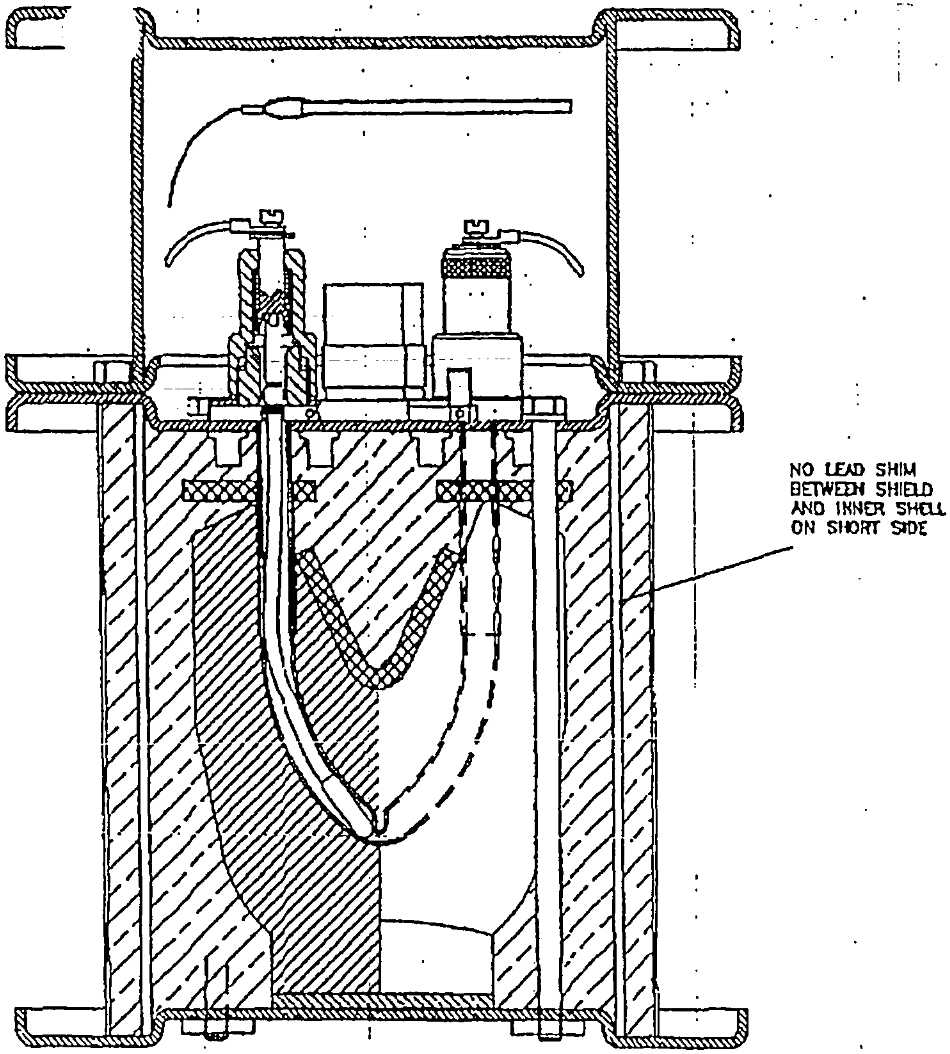
DESCRIPTIVE DRAWING

TITLE 650L SOURCE CHANGER TEST UNITS

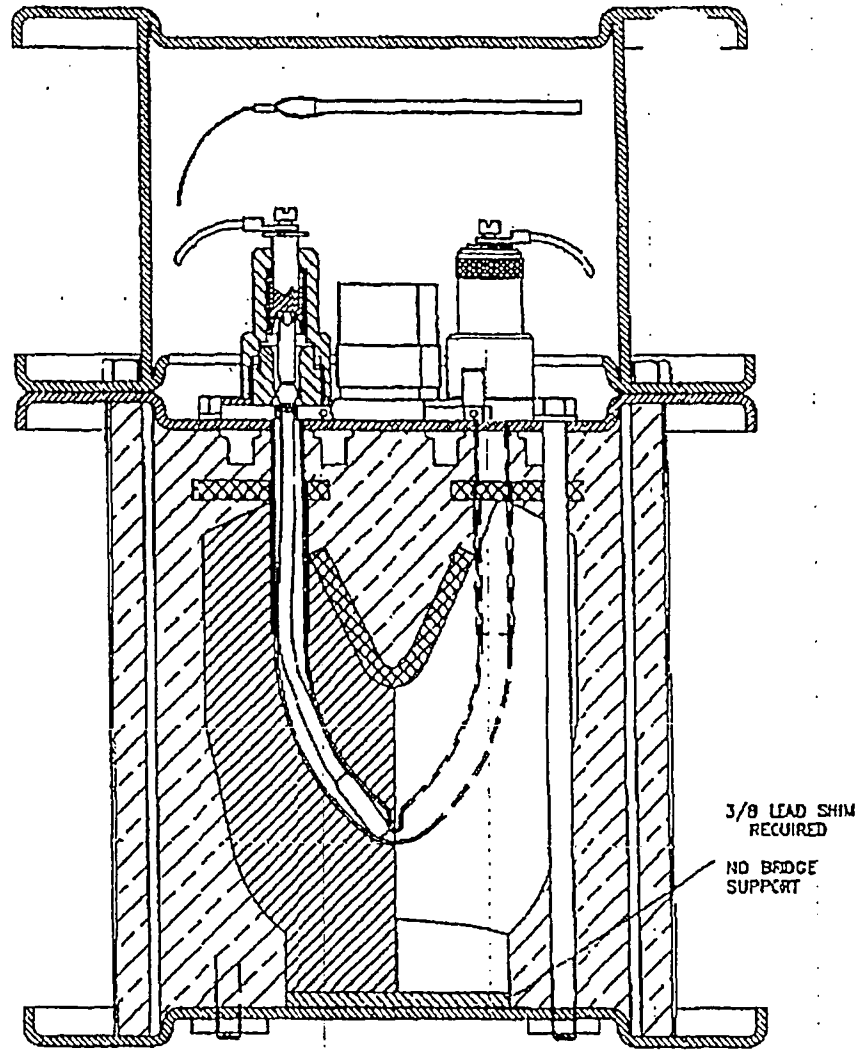
DESCRIPTION	APPROVALS	DATE	LTR
FORMAT CORRECTED DDCO#31		25FEB99	B

REVISIONS

SIZE A | DWG. NO. R-TP80 | REV E
SCALE: NONE | SHEET 1 OF 2



TP 80 (A)



TP 80 (B)

NOTE:
NO SPECIAL REQUIREMENTS
FOR
LEAD LOCATION N TP80(C)

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE REFERENCE			
SIZE A	DWG. NO. R–TP80		REV B
	SCALE: NONE	SHEET 2 OF 2	

SENTINEL

TP80 (A) - BEFORE TEST

SHIELDING PROFILE AND INSPECTION FORM

Model: 650L Serial Number: 2243 Radionuclide: IR192 Max.Capacity: 240 Ci

Shield Data

Shield Heat#: ______ Mass of Shield: ______ Lbs. Lot #: ______

Initial Profile

Source Model: ______ Source SN: ______ Activity: ______ Ci

Survey Inst.: ______ SN: ______ Date Cal.: ______ Date Due: ______

Surface	Observed Intensity mR/hr	Surface Correction Factor	Capacity Correction Factor:	Adjusted Intensity mR/hr
Top				
Right				
Front				
Left				
Rear				
ttom				

..spector: ______ Date: ______ NCR #: ______

Final Profile

Source Model: 424-9 Source SN: C8931: 131.2Ci. C9001: 124.9Ci. Activity: 256.1 Ci Mass of Device: ______ Lbs.

Survey Inst.: AN/PDR27T SN: 392402 Date Cal.: 8Oct98 Date Due: 8Oct99

Surface	Observed Intensity mR/hr: At Surface	Surface Corr. Factor	At One Meter		Adjusted Intensity mR/hr: At Surface	At One Meter
Top	90	*N/A	3.5	Capacity Correction Factor: .93	84	3.2
Right	50	↓	.7		47	.6
Front	95	↓	.8		88	.7
Left	60	↓	.7		56	.6
Rear	80	↓	.8		74	.7
Bottom	55	↓	.5		51	.4

Inspector: [signature] Date: 24 Feb 99 NCR #: N/A

Q16-1/1

ments: * Per WT-009 worksheet

Amersham QSA

SENTINEL

TP80(B) - BEFORE TEST

SHIELDING PROFILE AND INSPECTION FORM

Model: 650L Serial Number: 182 Radionuclide: IR192 Max.Capacity: 240 Ci

Shield Data

Shield Heat#: ____ Mass of Shield: ____ Lbs. Lot #: ____

Initial Profile

Source Model: ____ Source SN: ____ Activity: ____ Ci

Survey Inst.: ____ SN: ____ Date Cal.: ____ Date Due: ____

Surface	Observed Intensity mR/hr	Surface Correction Factor		Adjusted Intensity mR/hr
Top			Capacity Correction Factor: ____	
Right				
Front				
Left				
Rear				
Bottom				

Inspector: ____ Date: ____ NCR #: ____

Final Profile

Source Model: 424-9 Source SN: C8981-131.2ci. C9001-124.9ci Activity: 256.1 Ci | Mass of Device: ____ Lbs.

Survey Inst.: AN/PDR 27T SN: SM392402 Date Cal.: 8 Oct 98 Date Due: 8 Oct 99

Surface	Observed Intensity mR/hr: At Surface	Surface Corr. Factor	At One Meter		Adjusted Intensity mR/hr: At Surface	At One Meter
Top	65	*N/A	3.3	Capacity Correction Factor: .93	60	3.1
Right	60	↓	.5		56	.4
Front	~~85~~ 90 MRB 24Feb99	↓	.9		84	.8
Left	95	↓	.7		88	.6
Rear	85	↓	.9		79	.8
Bottom	80	↓	.6		74	.5

Inspector: MRBoyd Date: 24 Feb 99 NCR #: N/A

Q16-1/1

Comments: * Per WI-Q09 worksheet

Amersham QSA

ENTINEL

TP 80 (C) - BEFORE TEST
Drop Test Unit

SHIELDING PROFILE AND INSPECTION FORM

Model: 650L Serial Number: 195 Radionuclide: IR192 Max.Capacity: 240 Ci

Shield Data

Shield Heat#: ______ Mass of Shield: ______ Lbs. Lot #: ______

Initial Profile

Source Model: ______ Source SN: ______ Activity: ______ Ci

Survey Inst.: ______ SN: ______ Date Cal.: ______ Date Due: ______

Surface	Observed Intensity mR/hr	Surface Correction Factor		Adjusted Intensity mR/hr
Top			Capacity Correction Factor: ______	
Right				
Front				
Left				
Rear				
Bottom				

Inspector: ______ Date: ______ NCR #: ______

Final Profile

Source Model: 424-9 Source SN: C8931 = 121.7 ci. C9113 = 105.0 ci. Activity: 226.7 Ci Mass of Device: ______ Lbs.

Survey Inst.: AN/PDR27T SN: SM392407 Date Cal.: 8 Oct 98 Date Due: 8 Oct 99

	Observed Intensity mR/hr				Adjusted Intensity mR/hr	
Surface	At Surface	Surface Corr. Factor	At One Meter		At Surface	At One Meter
Top	65	* N/A	2.0	Capacity Correction Factor: 1.10	72	2.2
Right	95	↓	.6		105	.7
Front	45	↓	.5		50	.6
Left	115	↓	.6		127	.7
Rear	45	↓	.5		50	.6
Bottom	55	↓	.5		61	.6

Inspector: MBoyd Date: 4 March 99 NCR #: N/A

Q16-1/1

Comments: * Per WT-009 worksheet
See Attached Doc.

Amersham QSA

APPENDIX C

TEST CHECKLISTS AND DATA SHEETS

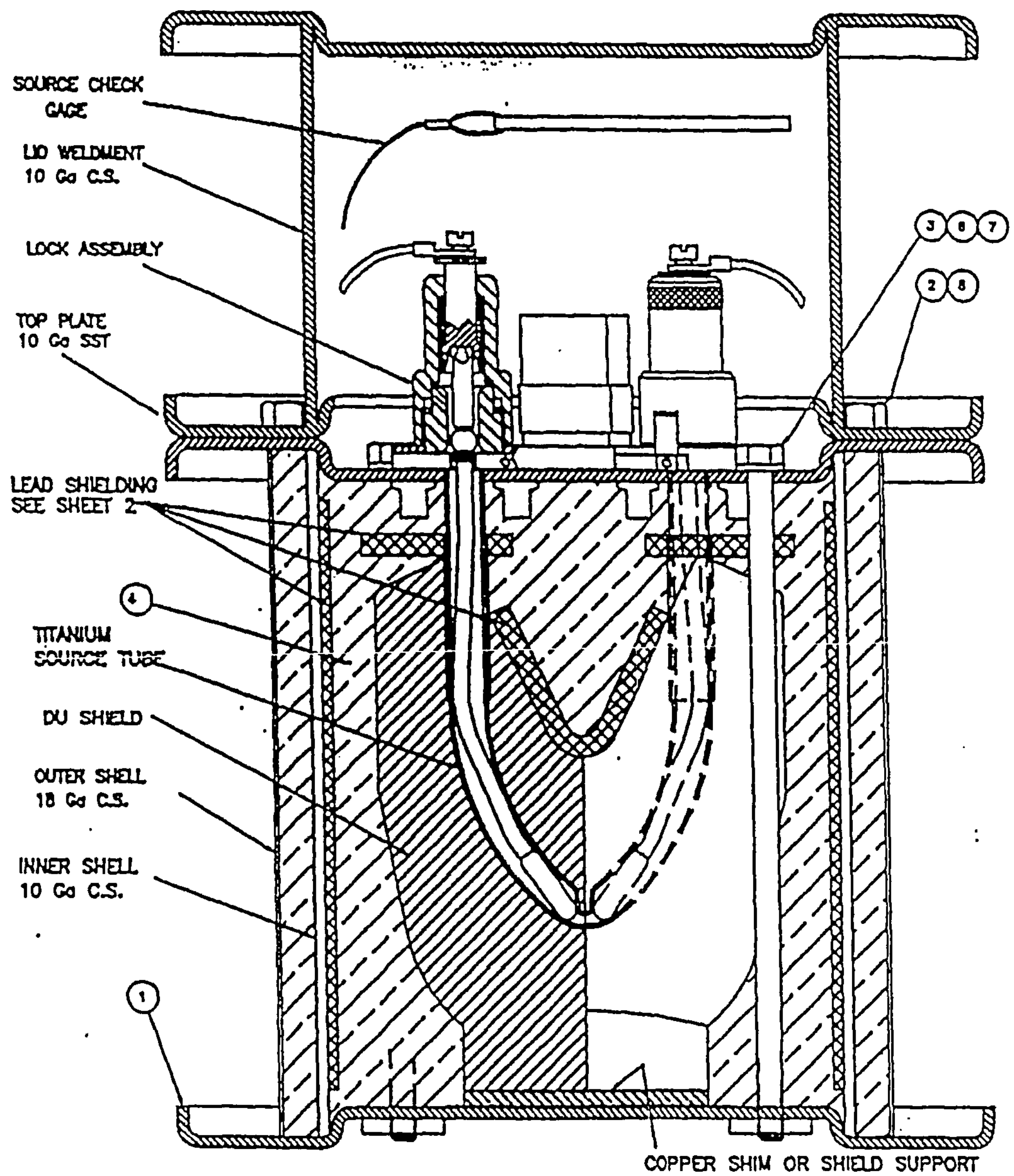
Specimen Preparation List

Step		TP80(A)	TP80(B)	TP80(C)
1.	Serial Number:	2243	182	195
2.	Total weight of package (lb):	80.0 lb.	83.6 lb	89.0 lb
3.	Location of simulated source from top plate (in):	(A) 6.318 (B) 6.359	(A) 6.556 (B) 6.430	(A) 6.304 (B) 6.256
4.	Location of lead shielding:	SEE X-RAYS	SEE X-RAYS & ROUTE CARD PKG.	SEE X-RAYS
5.	All fabrication and inspection records documented in accordance with the AEAT QA Program?	DK 16 MAR 99	DK 16 MAR 99	DK 16 MAR 99
6.	Does the unit comply with the requirements of Drawing R-TP80, Revision D?	*	*	*
7.	Has the radiation profile been recorded in accordance with AEAT QSA Work Instruments WI-Q09?	YES DK	YES DK	YES DK
8.	Is the package prepared for transport?	yes DK	yes DK	yes DK

Verified by:	Print Name:	Signature:	Date:
Engineering	Nicholas J. Marano	[signature]	16 MAR 99
Regulatory Affairs	Marc S. Nadeau	[signature]	16 MAR 99
Quality Assurance	Daniel W. Kurtz	Daniel W. Kurtz	16 MAR 99

*As noted on the route cards for the devices, the units were assembled with through bolt torques of 135±5 in-lbs. instead of the 100±5 in-lb torque specified on R-TP80, Rev D. This change was approved by engineering, regulatory and QA and was implemented on Rev E of R-TP80.

NJM 16 MAR 99
DWK 16 MAR 99
[initials] 16 MAR 99



Notes:

1. Refer to Drawing C65009 for construction of original unit.

2. Modify unit as follows:
 a) Remove lid and discard bolts.
 b) Remove through bolts and discard.
 c) If bottom plate is carbon steel, remove existing plate. Patch missing or damaged foam with new Vultafoam., Item (4). Install new stainless steel bottom plate, Item (1).
 d) Install new through bolts, Item (3), with lock washers, torque through bolts to 100±5 in-lbs and install safety wire for security.
 e) Install two (2) dummy source assembly 424-9's, one in each side.

3. Verify marking on new lid bolts, Item (2), is "B8".

4. Install lid with new lid bolts, Item (2), and install seal wire for shipment tamper indicator.

ITEM	QTY	DESCRIPTION
8	AR	TAMPER PROOF SEAL WIRE
7	AR	SAFETY WIRE
6	4	LOCK WASHER 5/16 DIA
4	AR	VULTAFOAM #16-L-708
3	4	HEX HEAD BOLT 5/16-18 X 8 LG. DRILLED HEAD, 300 SERIES (18-8) STAINLESS STEEL
2	4	HEX HEAD BOLT 3/8-16 X 7/8 LG. DRILLED HEAD, A198 GR B8 CL 2
1	1	BOTTOM PLATE

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES AND REFERENCE

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

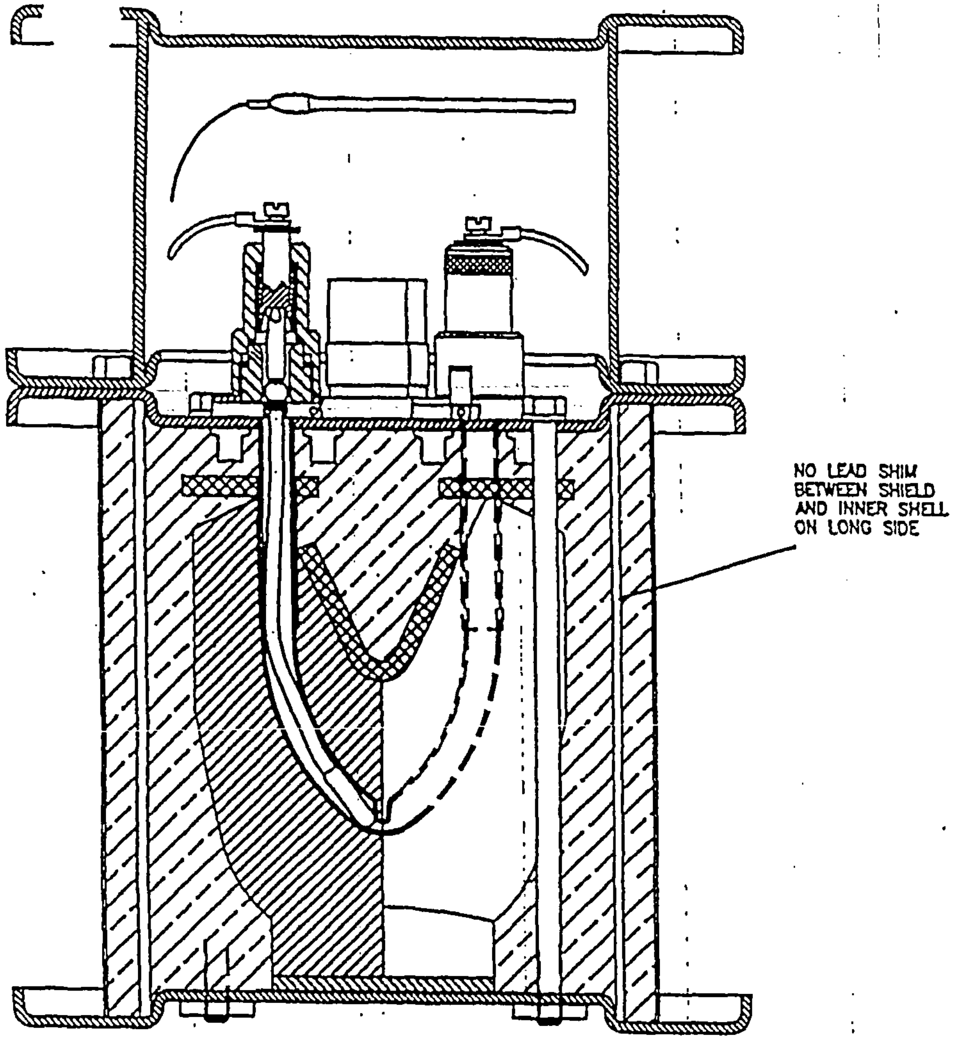
DESCRIPTIVE DRAWING

TITLE 650L SOURCE CHANGER TEST UNITS

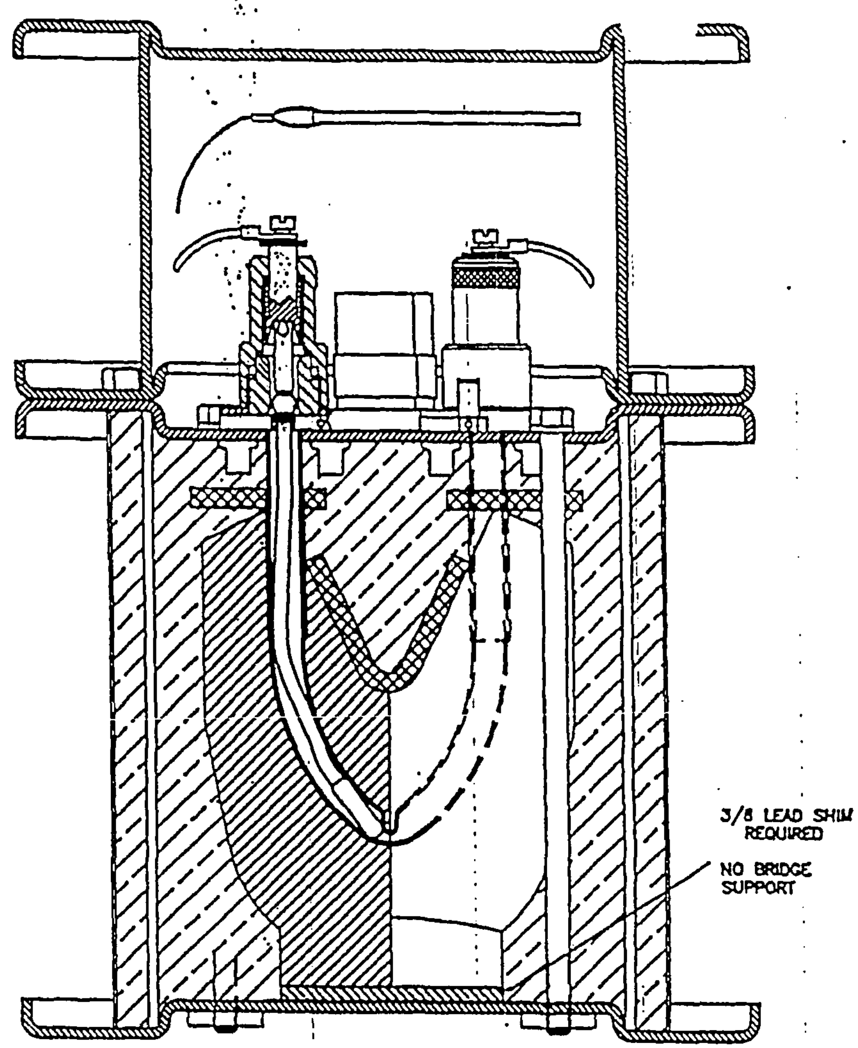
SIZE A | DWG. NO. R-TP80 | REV D
SCALE: NONE | SHEET 1 OF 2

DESCRIPTION		APPROVALS	DATE	LTR
DDCO#33	SEE DDCO	LR / (SD)	12 MAR 99	D
DDCO#32	REMOVE LOCK WASHER (ITEM 5)	LR/MT	4MAR99	C
DDCO#31	FORMAT CORRECTED	MT/TL	25FEB99	B

REVISIONS



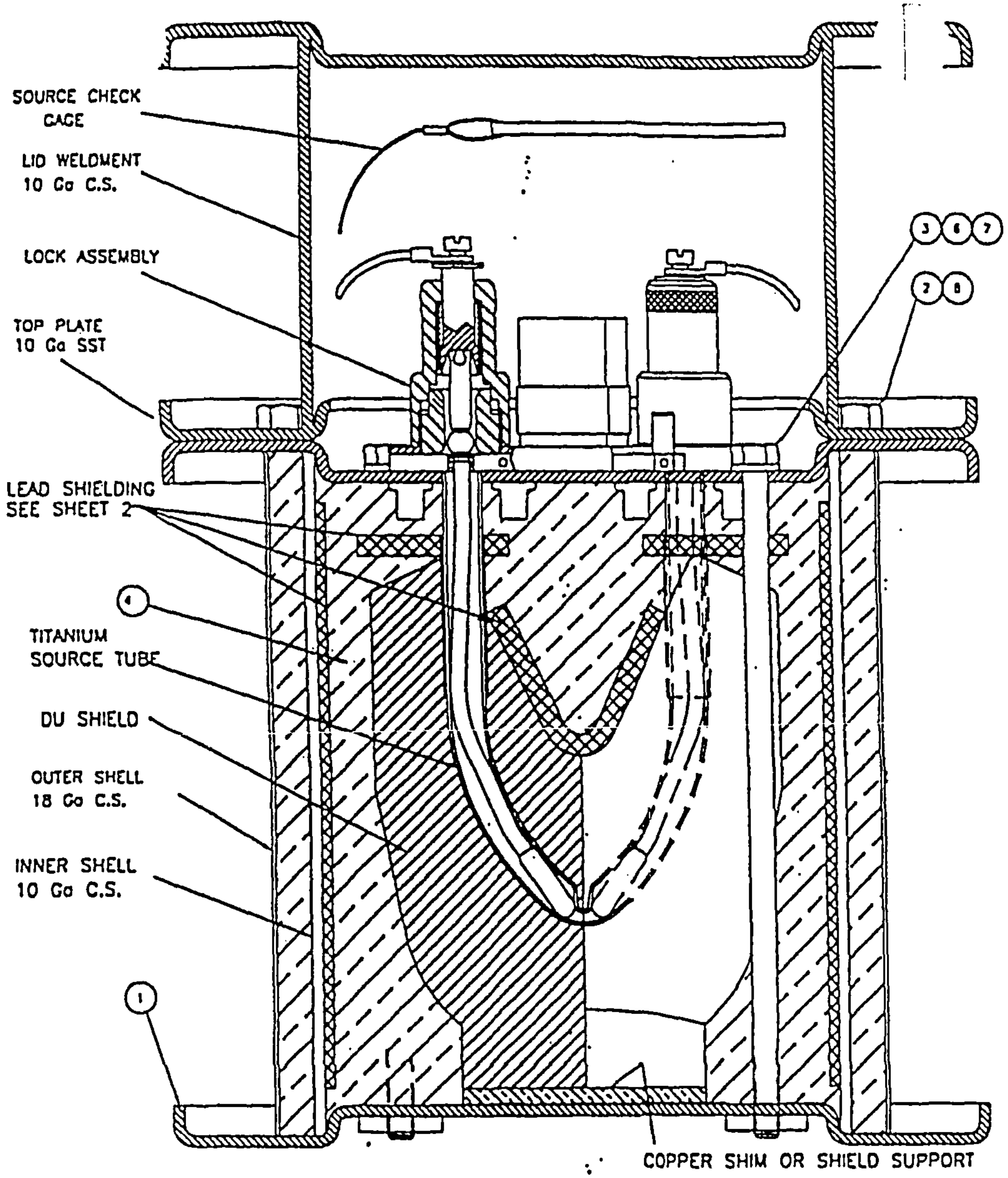
TP 80 (A)



TP 80 (B)

NOTE:
NO SPECIAL REQUIREMENTS FOR
LEAD LOCATION IN TP80(C)

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE REFERENCE		
SIZE A	DWG. NO. R-TP80	REV D
	SCALE: NONE / SHEET 2 OF 2	



Notes:

1. Refer to Drawing C65009 for construction of original unit.

2. Modify unit as follows:
   a) Remove lid and discard bolts.
   b) Remove through bolts and discard.
   c) If bottom plate is carbon steel, remove existing plate. Patch missing or damaged foam with new Vultafoam., Item (4). Install new stainless steel bottom plate, Item (1).
   d) Install new through bolts, Item (3), with lock washers, torque through bolts to 135±5 in-lbs and install safety wire for security.
   e) Install two (2) dummy source assembly 424-9's, one in each side.

3. Verify marking on new lid bolts, Item (2), is "B8".

4. Install lid with new lid bolts, Item (2), and install seal wire for shipment tamper indicator.

ITEM	QTY	DESCRIPTION
8	AR	TAMPER PROOF SEAL WIRE
7	AR	SAFETY WIRE
6	4	LOCK WASHER 5/16 DIA
4	AR	VULTAFOAM #16-L-708
3	4	HEX HEAD BOLT 5/16-18 X 8 LG. DRILLED HEAD, 300 SERIES (18-8) STAINLESS STEEL
2	4	HEX HEAD BOLT 3/8-16 X 7/8 LG. DRILLED HEAD, A193 GR B8 CL 2
1	1	BOTTOM PLATE

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES AND REFERENCE

DESCRIPTION		APPROVALS	DATE	LTR
DDCO#34	CHANGE TORQUE FROM 100±5 TO 135±5	TL / (illegible initials)	16MAR99	E
DDCO#33	SEE DDCO	LR/SG	12MAR99	D
DDCO#32	REMOVE LOCK WASHER (ITEM 5)	LR/MT	4MAR99	C
DDCO#31	FORMAT CORRECTED	MT/TL	25FEB99	B

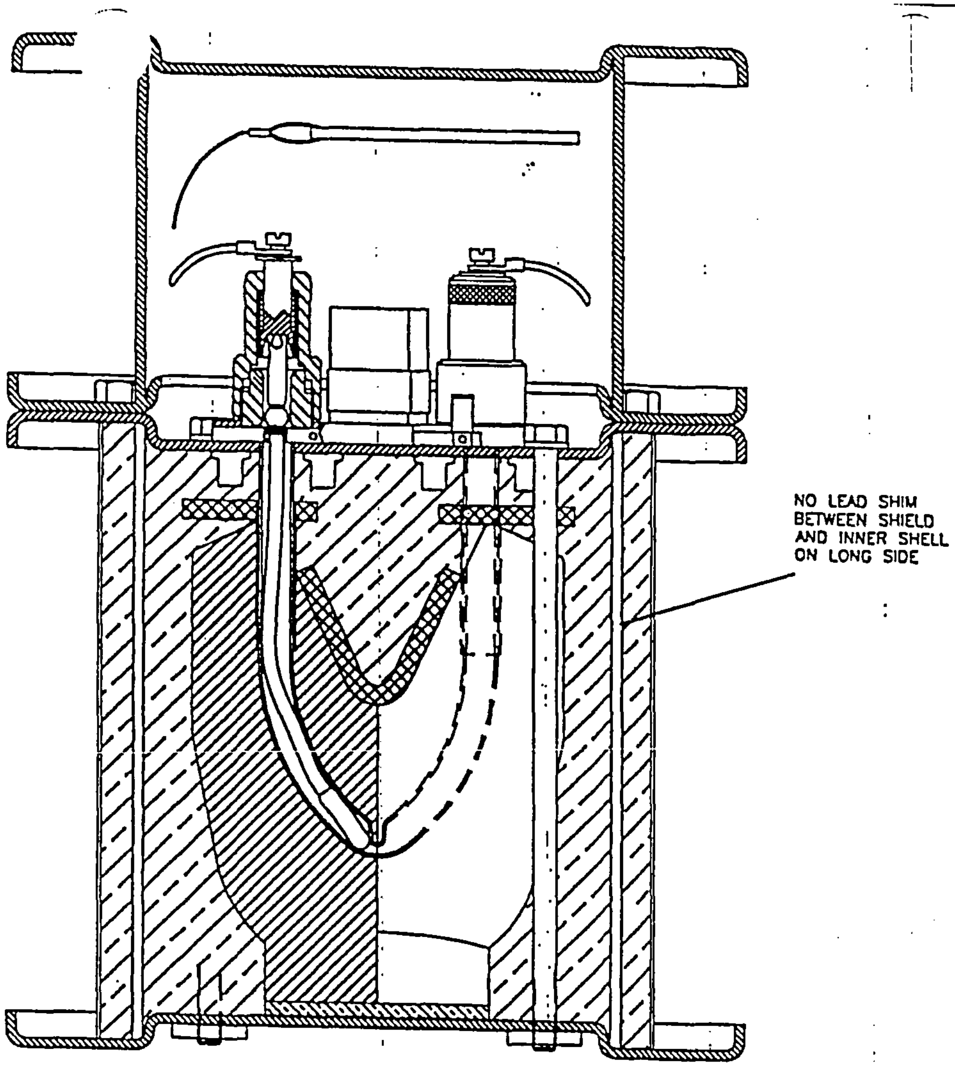
REVISIONS

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

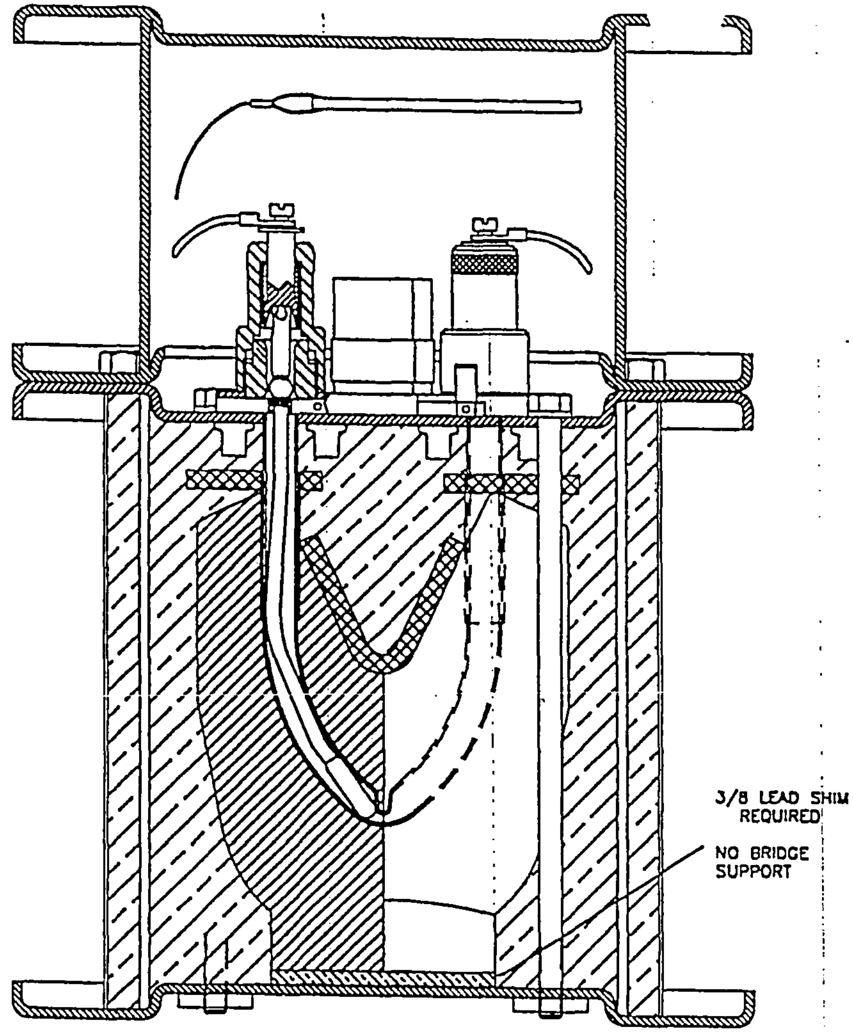
DESCRIPTIVE DRAWING

TITLE 650L SOURCE CHANGER TEST UNITS

SIZE A | DWG. NO. R-TP80 | REV E
SCALE: NONE | SHEET 1 OF 2



TP 80 (A)



TP 80 (B)

NOTE:
NO SPECIAL REQUIREMENTS
FOR
LEAD LOCATION IN TP80(C)

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE REFERENCE			
SIZE A	DWG. NO. R-TP80		REV E
	SCALE: NONE	SHEET 2 OF 2	

Equipment List 1: Compression Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Weight Scale	ASSY -11	DUE 16 MAY 99
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
THERMOCOUPLE READER	ENG-12	DUE 8 OCT 99
18" CALIPER	# 236	1 Apr 99

	Print Name:	Signature:	Date:
Completed by:	DAVE ANNIS	Dave Annis	15 MAR 99
Verified by:	Nicholas J. Marzo	Nicholas J. MARZO	15 MAR 99

Checklist 1: Compression Test

Step	TP80(A)	TP80(B)	TP80(C)
1. Position the specimen on concrete surface, per the appropriate drawing.	Figure 2	Figure 2	Figure 2
2. Measure the ambient temperature.	20.5 °C	20.5°C	20.5°C
Note the instrument used:	ENG-12	ENG-12	ENG-12
3. Apply a uniformly distributed weight of 455 to 465 pounds on the top of the lid for a period of 24 hours.	DW 15 MAR 99	DW 15 MAR 99	DW 15 MAR 99
Record the actual weight:	462 lb	458 lb	459 lb
Note the instrument used:	ASY-11	ASY-11	ASY-11
Record start time and date:	7:15 pm 15 MAR 99	7:15 pm 15 MAR 99	7:15 pm 15 MAR 99
4. After 24 hours, remove the weight.	DW 16 MAR 99 ~~7:18 PM~~	DW	DW
Record end time and date:	16 MAR 99 7:18 PM	16 MAR 99 7:18 PM	16 MAR 99 7:18 pm
5. Measure the ambient temperature.	22°C	22°C	22°C
Note the instrument used:	ENG-12	ENG-12	ENG-12
6. Photograph the test specimen and record any damage on Data Sheet 1.	DW	DW	DW
7. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71. Record the assessment on Data Sheet 1. Determine what changes are necessary in package orientation for the penetration test to achieve maximum damage.	DW 16 MAR 99	DW 16 MAR 99	DW 16 MAR 99

Verified by:	Print Name:	Signature:	Date:
Engineering	Nicholas J. Marrone	[signature]	16 MAR 99
Regulatory Affairs	Marc S. Nason	[signature]	16 MAR 99
Quality Assurance	Daniel W. Kurtz	Daniel W. Kurtz	16 MAR 99

SUPPLEMENTAL SHT. FOR TP80, REV. 1

650L COMPRESSION TEST

TEST WT.: 455 - 465 lb.

TP80(A)	TP80(B)	TP80(C)
LATE WT. = 14 lb.	PLATE WT. = 13.8 lb.	PLATE WT. = 14 lb.
NGOT WT. = —	INGOT WT. = —	INGOT WT. = —
TAL WT. = 462 lb	TOTAL WT. = 458	TOTAL WT. = 459
(DW) 15 MAR 99	(DW) 15 MAR 99	(DW) 15 Mar 99
AGE HEIGHT BEFORE COMPRESSION TEST:		
.367	13.465 IN	13.620 IN
(DW) 15 MAR 99	(DW) 15 Mar 99	(DW) 15 MAR 99
AGE HEIGHT AFTER COMPRESSION TEST:		
13.365	13.463	13.616
(DW) 16 MAR 99	(DW) 16 MAR 99	(DW) 16 MAR 99

Data Sheet 1: Compression Test

Test Unit Model and Serial Number: 650L S/N 2243 S/N 182 S/N 195		Test Specimen: TP80(A) TP80(B) TP80(C)
Test Date: 15-16MAR99	Test Time: 7:15PM - 7:15PM	Test Plan 80 Step No.: 8.5

Describe test orientation and setup:
- Cert ingots stacked on top of each unit per Fig 2 of TP80

Describe on-site inspection (damage, broken parts, etc.):
No Damage to units

On-site assessment:
No DAMAGE

Engineering: [signature] 16MAR99 Regulatory: [signature] 16MAR99 QA: D.W. Kurtz 16MAR99

Describe any post-test disassembly and inspection:
N/A

Describe any change in source position:
N/A

Describe results of any pre- or post-test radiography:
N/A

Completed by: Nicholas J. Marino [signature]	Date: 16 MAR99

Equipment List 2: Penetration Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Penetration Bar	Drawing BT10129, Rev. B	See ATTACH
Drop Surface	Drawing AT10122, ~~Rev. B~~	DA ↓
Thermometer	OMEGA MODEL HH21 # ENG-12	↓
Thermocouple	OMEGA MODEL# 5TL-GG-K-20-36	↓
Thermocouple	OMEGA MODEL# WTK-10-36	↓
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:	DAVE ANNIS	Dave Annis	17 mar 99
Verified by:	Daniel W. Kurtz	D.W. Kurtz	17 mar 99

Checklist 2: Penetration Test

Step	TP80(A)	TP80(B)	TP80(C)
1. Immerse the test specimen in dry ice or cool in freezer as needed to bring specimen temperature below –40°C.	DW	DW	DW
2. Position the package as shown in the referenced figure, or by Step 7, Checklist 1.	Figure 3	Figure 3	Figure 3
3. Begin video recording of the test.	DW	DW	DW
4. Inspect the orientation setup and verify the bar height.	DW	DW	DW
5. Photograph the set-up in at least two perpendicular planes.	DW	DW	DW
6. Measure the ambient temperature and the specimen's internal and surface temperatures. Ensure that the specimen is at the specified temperature.	DW	DW	DW
Record the ambient temperature:	"A" 10°C	9°C	10°C
Note the instrument used:	ENG-12	ENG-12	ENG-12
Record the specimen's internal temperature:	-95°C	-83°C	-90°C
Note the instrument used:	ENG-12	ENG-12	ENG-12
Record the specimen's surface temperature:	-96°C	-93°C	-90°C
Note the instrument used:	ENG-12	ENG-12	ENG-12
7. Drop the penetration bar.	DW	DW	DW
8. Check to ensure that penetration bar hit the specified area.	DW	DW	DW
9. Measure the specimen's surface temp. Ensure that specimen is at specified temp.	-74°C	-62°C	-71°C
Note the instrument used:	ENG-12	ENG-12	ENG-12
10. Photograph the test specimen and record any damage on Data Sheet 2.	DW	DW	DW
11. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71. Record the assessment on Data Sheet 2. Determine what changes are necessary in package orientation for the 1.2 meter (4 foot) free drop to achieve maximum damage.	DW	DW	DW

Verified by:	Print Name:	Signature:	Date:
Engineering	Nicholas S. Marrone	[signature]	17 MAR 99
Regulatory Affairs	Marc S. Nadeau	[signature]	17 MAR 99
Quality Assurance	Daniel W. Kurtz	D.W. Kurtz	17 MAR 99

Data Sheet 2: Penetration Test

...t Unit Model and Serial Number: 650L SN 2243		Test Specimen: TP80(A)
Test Date: 17 MAR 99	Test Time: 9:40 am	Test Plan 80 Step No.: 8.6

Describe test orientation and setup:
-In accordance with Fig 3 of test Plan

Describe impact (location, rotation, etc.):
-Impact on side of source changer

Describe on-site inspection (damage, broken parts, etc.):
-No damage - small indentation at point of impact

On-site assessment:
-CONTINUE WITH ~~TEST~~ OTHER PLANNED TEST SEQUENCE AND ORIENTATIONS

Engineering: [signature] 17MAR99 Regulatory: [signature] 17 MAR 99 QA: D.N. Kurtz 17 MAR 99

Describe any post-test disassembly and inspection:
NA

Describe any change in source position:
NA

Describe results of any pre- or post-test radiography:
NA

Completed by: [signature]	Date: 17 MAR 99

Data Sheet 2: Penetration Test

:st Unit Model and Serial Number: 650L SN 182	Test Specimen: TP80(B)

Test Date: 17 MAR 99	Test Time: 9:50 AM	Test Plan 80 Step No.: 8.6

Describe test orientation and setup:
IN ACCORDANCE WITH FIGURE 3 OF TEST PLAN

Describe impact (location, rotation, etc.):
IMPACT ON SIDE OF SOURCE CHANGER

Describe on-site inspection (damage, broken parts, etc.):
NO DAMAGE - SMALL INDENTATION AT POINT OF CONTACT

On-site assessment:
CONTINUE WITH PLANNED TEST SEQUENCE AND ORIENTATIONS.

Engineering: [signature] 17 MAR 99 Regulatory: [signature] 17 MAR 99 QA: D.W. Kurtz 17 MAR 99

Describe any post-test disassembly and inspection:
NA

Describe any change in source position:
NA

Describe results of any pre- or post-test radiography:
NA

Completed by: [signature]	Date: 17 MAR 99

Data Sheet 2: Penetration Test

est Unit Model and Serial Number: 650L SN 195		Test Specimen: TP80 (C)
Test Date: 17 MAR 99	Test Time: 10:01	Test Plan 80 Step No.: 8.6

Describe test orientation and setup:
IN ACCORDANCE WITH FIGURE 3 OF TEST PLAN.

Describe impact (location, rotation, etc.):
IMPACT ON SIDE OF SOURCE CHANGER

Describe on-site inspection (damage, broken parts, etc.):
NO DAMAGE - SMALL INDENTATION AT POINT OF CONTACT.

On-site assessment:
CONTINUE WITH PLANNED TEST SEQUENCE AND ORIENTATIONS.

Engineering: [signature] 17 MAR 99 Regulatory: [signature] 17 MAR 99 QA: D.N. Kurtz 17 MAR 99

Describe any post-test disassembly and inspection:
NA

Describe any change in source position:
NA

Describe results of any pre- or post-test radiography:
NA

Completed by:	Date:
[signature]	17 MAR 99

Equipment List 3: 1.2 Meter (4 Foot) Free Drop

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface	Drawing AT10122, Rev. B	SEE ATTACH
Thermometer	OMEGA ENG-12	↓
Thermocouple	OMEGA STC-GG-K-20-36	↓
Thermocouple	OMEGA WTK-10-36	↓
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:	DAVE ANNIS	[signature]	17 MAR 99
Verified by:	Daniel W. Kurtz	D.W. Kurtz	17 MAR 99

Checklist 3: 1.2 Meter (4 Foot) Free Drop

Step	TP80(A)	TP80(B)	TP80(C)
1. Immerse specimen in dry ice or cool in freezer to bring specimen below –40°C.	DW	DW	DW
2. Measure the ambient temperature.	13°c	13°c	13°c
Note the instrument used:	ENG-12	ENG-12	ENG-12
3. Attach the test specimen to the release mechanism.	DW	DW	DW
4. Begin video recording of the test.	DW	DW	DW
5. Measure specimen internal and surface temps. Ensure specimen is at specified temp.	DW	DW	DW
Record the specimen's internal temperature:	-90°c	-89°c	-92°c
Note the instrument used:	ENG-12	ENG-12	ENG-12
Record the specimen's surface temperature:	-92°c	-87°c	-95°c
Note the instrument used:	ENG-12	ENG-12	ENG-12
6. Lift and orient the test specimen as shown in the specified referenced figure.	Figure 4	Figure 5	Figure 6
7. Inspect the orientation setup and verify drop height.	DW	DW	DW
8. Photograph the set-up in at least two perpendicular planes.	DW	DW	DW
Release the test specimen.	DW	DW	DW
10. Measure specimen internal and surface temps. Ensure specimen is at specified temp.	DW	DW	DW
Record the specimen's internal temperature:	-71°c	-53°c	-90°c
Note the instrument used:	ENG-12 DW	ENG-12	ENG-12
Record the specimen's surface temperature:	-76°c	-90°c	-61°c
Note the instrument used:	ENG-12	ENG-12	ENG-12
11. Photograph the test specimen and record any damage on Data Sheet 3.	DW	DW	DW
12. Measure and record a radiation profile of the test specimen in accordance with AEAT/QSA Work Instruction WI-Q09.	DW	DW	DW
13. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71, and record on Data Sheet 3. Determine package orientation for the 9 meter free drop to achieve maximum damage.	DW	DW	DW

Verified by:	Print Name:	Signature:	Date:
Engineering	Nick Marrone	[signature]	17 MAR 99
Regulatory Affairs	Marc S. Nathan	[signature]	17 MAR 99
Quality Assurance	Daniel W. Kurtz	D.W. Kurtz	17 March 99

Data Sheet 3: 1.2 Meter (4 Foot) Free Drop

Test Unit Model and Serial Number: 650L SN 2243		Test Specimen: TP80 (A)
Test Date: 17 MAR 99	Test Time: 10:15 AM	Test Plan 80 Step No.: 8.7

Describe drop orientation and drop height:
HORIZONTAL - LONG SIDE DOWN. HEIGHT OF DROP WAS 1.2 m

Describe impact (location, rotation, etc.):
IMPACT FLAT AS SHOWN IN FIGURE 4

Describe on-site inspection (damage, broken parts, etc.):
IMPACT WITNESS MARKS ON BOTTOM PLATE, TOP PLATE AND BOTH LID FLANGES.
NO DAMAGED OR BROKEN PARTS.

On-site assessment:
CONTINUE WITH PLANNED TEST SEQUENCE AND ORIENTATIONS.

Engineering: [signature] 17 MAR 99 Regulatory: [signature] 17 MAR 99 QA: D.N. Kurtz 17 MAR 99

Describe any post-test disassembly and inspection:
- LID REMOVED TO ALLOW FOR PROFILING OF DEVICE, NO DAMAGE TO TOP PLATE/LOCKING ASSEMBLIES WAS OBSERVED
- LOCK ASSEMBLIES REMAIN FUNCTIONAL

Describe any change in source position:
(A) 6.295 after drop vs. 6.318 before drop
(B) 6.375 after drop vs. 6.357 before drop
} No change within the accuracy of the measurement

Describe results of any pre- or post-test radiography:
NA

Completed by: [signature]	Date: 17 Mar 99

Data Sheet 3: 1.2 Meter (4 Foot) Free Drop

Test Unit Model and Serial Number: 650L SN 182		Test Specimen: TP80(B)
Test Date: 17 MAR 99	Test Time: 10:30 AM	Test Plan 80 Step No.: 8.7

Describe drop orientation and drop height:
~~HORIZONTAL - LONG SIDE DOWN~~ - HEIGHT OF DROP WAS 1.2 m
FLAT ON TOP DWK 17MAR99

Describe impact (location, rotation, etc.):
IMPACT FLAT ON TOP OF LID - VERTICAL UPSIDE DOWN AS SHOWN IN FIGURE 5

Describe on-site inspection (damage, broken parts, etc.):
IMPACT WITNESS MARKS ON TOP OF LID. NO DAMAGE OBSERVED.

On-site assessment:
CONTINUE WITH PLANNED TEST SEQUENCE AND ORIENTATIONS.

Engineering: [signature] 17MAR99 Regulatory: [signature] 17MAR99 QA: D.N. Kurtz 17MAR99

Describe any post-test disassembly and inspection:
- LID REMOVED TO ALLOW FOR PROFILING OF DEVICE - NO DAMAGE TO TOP PLATE/LOCKING ASSEMBLY WAS OBSERVED
- LOCK ASSEMBLIES REMAIN FUNCTIONAL

Describe any change in source position:
(B) 6.533 after drop vs 6.556 before drop
(B) 6.348 after drop vs 6.430 before drop
} No CHANGE - Measurements unchanged within the accuracy of the measurement technique

Describe results of any pre- or post-test radiography:
NA

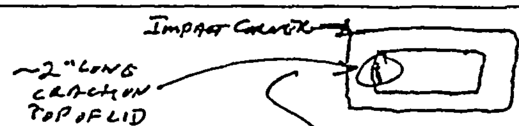
Completed by: [signature]	Date: 17 MAR 99

Data Sheet 3: 1.2 Meter (4 Foot) Free Drop

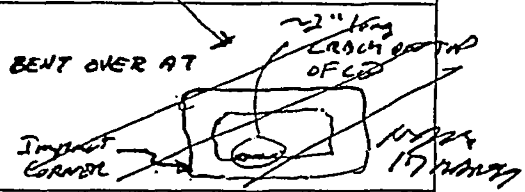
Test Unit Model and Serial Number: 650L SN 195		Test Specimen: TP80(C)
Test Date: 17MAR99	Test Time: 10:45	Test Plan 80 Step No.: 8.7

Describe drop orientation and drop height:
TOP CORNER DOWN - HEIGHT OF DROP WAS 1.2 m

Describe impact (location, rotation, etc.):
IMPACT ON CORNER OF LID TOP.



Describe on-site inspection (damage, broken parts, etc.):
IMPACT WITNESS MARKS ON TOP CORNER OF LID. FLANGE BENT OVER AT IMPACT POINT. APPROX. 2" CRACK OBSERVED ON TOP OF LID AS SHOWN IN SKETCH. No damage observed on lid bolts or Rivnuts



On-site assessment:
CONTINUE WITH PLANNED TEST SEQUENCE AND ORIENTATIONS

Engineering: [signature] 17MAR99 Regulatory: [signature] 17MAR99 QA: D.W. Kurtz 17MAR99

Describe any post-test disassembly and inspection:
- LID REMOVED TO ALLOW FOR PROFILING OF DEVICE - NO DAMAGE TO TOP PLATE/LOCKING ASSEMBLIES WAS OBSERVED
- Lock Assemblies Remain Functional

Describe any change in source position:
(A) 6.328 after drop vs 6.304 before drop
(B) 6.291 after drop vs 6.256 before drop
} No change - Measurements unchanged within the accuracy of the measurement technique

Describe results of any pre- or post-test radiography:
NA

Completed by: [signature]	Date: 17 MAR 99

SENTINEL TP80(A) - AFTER 1.2M (4 FOOT) DROP TEST

DROP TEST UNIT

SHIELDING PROFILE AND INSPECTION FORM

odel: 650L Serial Number: 2243 Radionuclide: IR192 Max.Capacity: 240 Ci

Shield Data

hield Heat#: ______ Mass of Shield: ______ Lbs. Lot #: ______

Initial Profile

ource Model: ______ Source SN: ______ Activity: ______ Ci

urvey Inst.: ______ SN: ______ Date Cal.: ______ Date Due: ______

Surface	Observed Intensity mR/hr	Surface Correction Factor	Capacity Correction Factor: ______	Adjusted Intensity mR/hr
op				
ight				
ont				
eft				
ear				
ottom				

r: ______ Date: ______ NCR #: ______

Final Profile

ource Model: 424-9 Source SN: C8931-107.8 C9232-44.8 ci. Activity: 202.6 Ci Mass of Device: ______ Lbs.

urvey Inst.: AN/PDR27T SN: ~~SM39704~~ 392402 MAB 13 Apr. 99 Date Cal.: 8Oct98 Date Due: 8Oct99

Surface	Observed Intensity mR/hr At Surface	Surface Corr. Factor	At One Meter	Capacity Correction Factor: 1.18	Adjusted Intensity mR/hr At Surface	At One Meter
p	80	*N/A	2.0		94	2.4
ght	40	↓	.6		47	.7
ont	75	↓	.7		89	.8
ft	55	↓	.6		65	.7
ar	75	↓	.7		89	.8
ttom	80	↓	.6		94	.7

pector: MBBoyd Date: 17 March 99 NCR #: N/A

Q16-1/1

mments: * Per WT-Q09 worksheet

Amersham QSA

SENTINEL TP80(B) - AFTER 1.2M (4 FOOT) DROP TEST

DROP TEST UNIT

SHIELDING PROFILE AND INSPECTION FORM

Model: 650L Serial Number: 182 Radionuclide: IR192 Max.Capacity: 240 Ci

Shield Data

Shield Heat#: ______ | Mass of Shield: ______ Lbs. | Lot #: ______

Initial Profile

Source Model: ______ Source SN: ______ Activity: ______ Ci

Survey Inst.: ______ SN: ______ Date Cal.: ______ Date Due: ______

Surface	Observed Intensity mR/hr	Surface Correction Factor	Capacity Correction Factor: ______	Adjusted Intensity mR/hr
Top				
Right				
Front				
Left				
Rear				
Bottom				

Inspector: ______ Date: ______ NCR #: ______

Final Profile

Source Model: 424-9 Source SN: C9232 – 44.8 Ci, C8931 – 107.8 Activity: 202.6 Ci | Mass of Device: ______ Lbs.

Survey Inst.: AN/PDR27T SN: SM 392402 (corrected, MRB 13Apr99) Date Cal.: 8Oct98 Date Due: 8Oct99

Surface	Observed Intensity mR/hr: At Surface	Observed Intensity mR/hr: Surface Corr. Factor	Observed Intensity mR/hr: At One Meter	Capacity Correction Factor: 1.18	Adjusted Intensity mR/hr: At Surface	Adjusted Intensity mR/hr: At One Meter
Top	60	* N/A	1.7		71	2.0
Right	45	↓	.5		53	.6
Front	70	↓	.7		83	.8
Left	70	↓	.5		83	.6
Rear	65	↓	.7		77	.8
Bottom	70	↓	.6		83	.7

Inspector: MRBoyd Date: 17March99 NCR #: N/A

Q16-1/1

Comments: * Per WI-Q09 worksheet

Amersham QSA

SENTINEL TP80(c) - AFTER 1.2M (4 FOOT) DROP TEST

DROP TEST UNIT

SHIELDING PROFILE AND INSPECTION FORM

odel: 650L Serial Number: 195 Radionuclide: IR192 Max.Capacity: 240 Ci

Shield Data		
hield Heat#:	Mass of Shield: Lbs.	Lot #:

Initial Profile

ource Model: Source SN: Activity: Ci

urvey Inst.: SN: Date Cal.: Date Due:

Surface	Observed Intensity mR/hr	Surface Correction Factor		Adjusted Intensity mR/hr
op			Capacity Correction Factor:	
ight				
ont				
eft				
ear				
ottom				

or: Date: NCR #:

Final Profile

ource Model: 424-9 Source SN: C9232 - 94.8 ci, C8931 - 107.8 Activity: 202.6 Ci Mass of Device: Lbs.

urvey Inst.: AN/PDR27T SN: 392402 ~~SIM39204~~ MB 31 Apr 99 Date Cal.: 8Oct98 Date Due: 8Oct99

Surface	Observed Intensity mR/hr At Surface	Surface Corr. Factor	At One Meter		Adjusted Intensity mR/hr At Surface	At One Meter
op	50	*N/A	1.7	Capacity Correction Factor: 1.18	59	2.0
ght	60	↓	.6		71	.7
ont	40	↓	.4		47	.5
ft	90	↓	.7		106 ~~53~~ MB 17 March 99	.8
ear	45	↓	.5		53	.6
ottom	50	↓	.4		59	.5

spector: MBgd Date: 17 March 99 NCR #: N/A

Q16-1/1

nts: * Per WI-Q09 worksheet

Amersham QSA

Equipment List 4: 9 Meter (30 Foot) Free Drop

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface	Drawing AT10122, Rev. B	SEE ATTACH DW ↓
Thermometer	OMEGA HH21 ENG-12	↓
Thermocouple	OMEGA 5TC-GG-K-20-36	↓
Thermocouple	OMEGA WTK-10-36	↓
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:	DAVE ANNIS	[signature]	18 Mar 99
Verified by:	Daniel W. Kurtz	D.W. Kurtz	18 Mar 99

Checklist 4: 9 Meter (30 Foot) Free Drop

Step	TP80(A)	TP80(B)	TP80(C)
1. Immerse test specimen in dry ice or cool in freezer to bring specimen temperature below –40°C.	DW	DW	DW
2. Measure the ambient temperature.	11°c	13°c	15°c
Note the instrument used:	ENG-12	ENG-12	ENG-12
3. Attach the test specimen to the release mechanism.	DW	DW	DW
4. Begin Video Recording of the test.	DW	DW	DW
5. Measure specimen's internal and surface temps. Ensure specimen is at the specified temperature.	DW	DW	DW
Record the specimen's internal temperature:	NOTE ①	-94°c	-97°c
Note the instrument used:	ENG-12	ENG-12	ENG-12
Record the specimen's surface temperature:	-92°c	-93°c	-98°c
Note the instrument used:	ENG-12	ENG-12	ENG-12
6. Lift and orient the test specimen as shown in the specified referenced figure.	Figure 7	Figure 8	Figure 9
7. Inspect the orientation setup and verify drop height.	DW	DW	DW
.. Photograph the setup in at least two perpendicular planes.	DW	DW	DW
9. Release the test specimen.	DW	DW	DW
10. Measure specimen's internal and surface temps. Ensure specimen is at specified temperature.	DW	DW	DW
Record the specimen's internal temperature:	-92°c	-94°c	-94°c
Note the instrument used:	ENG-12	ENG-12	ENG-12
Record the specimen's surface temperature:	-54°c	-69°c	-64°c
Note the instrument used:	ENG-12	ENG-12	ENG-12
11. Photograph the test specimen and record any damage on Data Sheet 4.	DW	DW	DW
12. **Engineering, Regulatory Affairs and Quality Assurance** make a preliminary assessment relative to 10 CFR 71. Record assessment on Data Sheet 4. Determine what changes are necessary in package orientation for the puncture test to achieve maximum damage.	DW	DW	DW

Verified by:	Print Name:	Signature:	Date:
Engineering	Nick Marroni	[signature]	18 MAR 99
Regulatory Affairs	Marc S. Nadeau	[signature]	18 MAR 99
Quality Assurance	Daniel W. Kurtz	D.W. Kurtz	18 March 99

① ATC UNIT READING -93°c

Data Sheet 4: 9 Meter (30 Foot) Free Drop

Test Unit Model and Serial Number: 650L SN 2243		Test Specimen: TP80(A)
Test Date: 18 MAR 99	Test Time: 9:45	Test Plan 80 Step No.: 8.9

Describe drop orientation and drop height:
HORIZONTAL LONG SIDE DOWN FROM 30 ft

Describe impact (location, rotation, etc.):
- PACKAGE ROTATED SLIGHTLY DURING DROP - EDGE OF BOTTOM PLATE STRUCK FIRST (IMPACT ON LONG EDGE OF PLATE)

Describe on-site inspection (damage, broken parts, etc.):
- LONG EDGE OF BOTTOM PLATE DEFORMED (NO CRACKING OBSERVED); WITNESS MARKS ON
- EDGE OF TOP PLATE AND BOTTOM LID FLANGE - SMALL DEFORMATION OF LID TOP FLANGE
- DEFORMATION OF OUTER SHELL AT INTERFACE WITH BOTTOM ~~FLANGE~~ ALUMINUM PLATE (WHERE BOTTOM PLATE DEFORMED)

On-site assessment:
- CONTINUE WITH PLANNED DROP SEQUENCE AND ORIENTATION

Engineering: [signature] 18 MAR 99 Regulatory: [signature] 18 MAR 99 QA: D.W. Kurtz 18 MAR 99

Describe any post-test disassembly and inspection:
NA

Describe any change in source position:
NA

Describe results of any pre- or post-test radiography:
NA

Completed by:	Date:
[signature]	18 MAR 99

Data Sheet 4: 9 Meter (30 Foot) Free Drop

Test Unit Model and Serial Number: 650L SN 182		Test Specimen: TP80(B)
Test Date: 18 MAR 99	Test Time: 10:30	Test Plan 80 Step No.: 8.9

Describe drop orientation and drop height:
- VERTICAL UPSIDE DOWN FROM 30 ft

Describe impact (location, rotation, etc.):
- Impact was flat on top

Describe on-site inspection (damage, broken parts, etc.):
- One Rivet broken – lid bolt still holding – No other ~~damage~~ damage to lid bolts
- No damage to lid (only witness marks on top
- SS over wrap (i.e. label) UNZIPPED AND OPENED UP
- CS Outer shell (18 gage) UNZIPPED ALONG SPOT WELD LINE AND OPENED UP ~1½"

On-site assessment:
- FOAM CRACKED SEVERAL SMALL PIECES CAME OUT
- CS INNER SHELL (16 gage) (in middle of short side) FAILED (BRITTLE FRACTURE) - opened CRACK ~ 3" High; ~½ WIDE ; ~~ALSO AT~~ THIS CRACK STARTS AT TOP END - AT BOTTOM OF THIS OPENING THE CRACK TURNS AND CONTINUES BEHIND FOAM
- FOAM BEHIND INNER SHELL CRACKED

* SEE BELOW

Engineering: [signature] 19 MAR 99 Regulatory: [signature] 18 MAR 99 QA: D. W. Kurtz 18 MAR 99

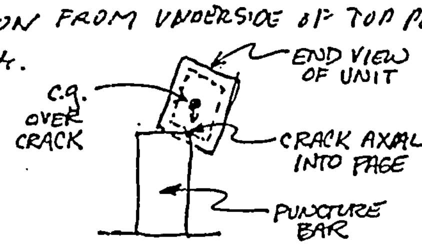
Describe any post-test disassembly and inspection:
NA

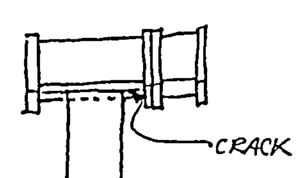
Describe any change in source position:
NA

Describe results of any pre- or post-test radiography:
NA

Completed by: [signature]	Date: 18 MAR 99

CHANGE PUNCTURE BAR DROP ORIENTATION FROM UNDERSIDE OF TOP PLATE TO HORIZONTAL WITH IMPACT TO OPEN AXIAL CRACK.
- PROCEED WITH PUNCTURE BAR DROP





Data Sheet 4: 9 Meter (30 Foot) Free Drop

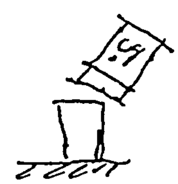
Test Unit Model and Serial Number: 650L SN 195		Test Specimen: TP 80 (C)
Test Date: 18 MAR 99	Test Time: 11:20	Test Plan 80 Step No.: 8.9

Describe drop orientation and drop height:
TOP CORNER DOWN FROM 30 ft

Describe impact (location, rotation, etc.):
IMPACT ON TOP CORNER OF LID

Describe on-site inspection (damage, broken parts, etc.):
- TOP PLATE OF LID CRACKED (BRITTLE FAILURE) IN VICINITY OF IMPACT POINT. TOP SURFACE LID DEFLECTED INTO "COLUMN" SECTION OF LID ~½" - COLUMN SECTION AND BOTTOM FLANGE OF LID INTACT
- NO DAMAGE TO LID BOLTS OR RIVNUTS
- BOTTOM PLATE DEFORMED AT CORNER (HIT ON BOUNCE)

On-site assessment:
- CHANGE PUNCTURE BAR DROP ORIENTATION FROM HIT ON BOTTOM PLATE TO IMPACT ON TOP OF LID TO TRY TO GET TO LOCKS.
- PROCEED W/ PUNCTURE BAR DROP



Engineering: [signature] 18 MAR 99 Regulatory: [signature] 18 MAR 99 QA: D.N. Kurtz 18 MAR 99

Describe any post-test disassembly and inspection:
NA

Describe any change in source position:
NA

Describe results of any pre- or post-test radiography:
NA

Completed by: [signature]	Date: 18 MAR 99

Equipment List 5: Puncture Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Drop Surface	Drawing AT10122, Rev. B	DW SEE ATTACH
Puncture Billet	Drawing CT10119, Rev. C	↓
Thermometer	OMEGA HH21 ENG-12	↓
Thermocouple	OMEGA 5TC-GG-K-20-36	↓
Thermocouple	OMEGA WTK-10-36	↓
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		

	Print Name:	Signature:	Date:
Completed by:	DAVE ANNIS	[signature]	18 Mar 99
Verified by:	Daniel W. Kurtz	D.W. Kurtz	18 MAR 99

Checklist 5: Puncture Test

Step		TP80(A)	TP80(B)	TP80(C)	TP80(C) 2nd ORIENTATION
1. Immerse specimen in dry ice or cool in freezer to bring specimen temp. below –40°C.		D	Dw	Dw	Dw
2. Measure the ambient temperature.		15°C / 15°C	18°C	15°C	15°C
Note the instrument used:		ENG-12	ENG-12	ENG-12	ENG-12
3. Attach the test specimen to the release mechanism.		Dw	Dw	Dw	Dw
4. Begin Video Recording of the test.		Dw	Dw	Dw NOTE *	Dw
5. Measure specimen's internal and surface temps. Ensure that specimen is at specified temp.		Dw	Dw	Dw	Dw
Record the specimen's internal temperature:	② -81°C	-87°C / -81	-83°C	-83°C	-80°C
Note the instrument used:		ENG-12	ENG-12	ENG-12	ENG-12
Record the specimen's surface temperature:	② -46°C	-69°C	-57°C	-53°C	-47°C
Note the instrument used:		ENG-12	ENG-12	ENG-12	ENG-12
6. Lift and orient the test specimen as shown in the specified referenced figure, or as determined during the assessment of the 9 Meter (30 Foot) Drop Test.		Figure 10	Figure 11	Figure 12 Dw	Dw
7. Inspect the orientation setup and verify drop height.		Dw	Dw	Dw	Dw
8. Photograph the set-up in at least two perpendicular planes.		Dw	Dw	Dw	Dw
9. Release the test specimen.		Dw	Dw	Dw	Dw
10. Measure the specimen's internal and surface temperatures.		Dw	Dw	Dw	Dw
Record the specimen's internal temperature:	② -79°C	-88°C	-82°C	-81°C	-70°C
Note the instrument used:		ENG-12	ENG-12	ENG-12	ENG-12
Record the specimen's surface temperature:	② -42°C	-26°C	-44°C	-50°C	-37°C
Note the instrument used:		ENG-12	ENG-12	ENG-12	ENG-12
11. Photograph the test specimen and record any damage on Data Sheet 5.		Dw	Dw	Dw	
12. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record assessment on Data Sheet 5. Determine what changes are necessary in package orientation for thermal test to achieve maximum damage.		Dw	Dw	Dw	

Verified by:	Print Name:	Signature:	Date:
Engineering	Nick Marrone	[signature]	18 MAR 99
Regulatory Affairs	Marc S. Nasson	[signature]	18 MAR 99
Quality Assurance	Daniel W. Kurtz	D.W. Kurtz	18 March 99

* TEST SIGN WAS FOR "B" UNIT, NOT "C"

Data Sheet 5: Puncture Test

Test Unit Model and Serial Number: 650L SN 2243		Test Specimen: TP80(A)
Test Date: 19 MAR 99	Test Time: 12:05	Test Plan 80 Step No.: **8.10**

Describe drop orientation and drop height:
HORIZONTAL LONG SIDE ONTO PUNCTURE BAR FROM 4 ft

Describe impact (location, rotation, etc.):
IMPACT ON LONG SIDE OF PACKAGE

Describe on-site inspection (damage, broken parts, etc.):
- WITNESS MARK ON TOP PLATE FLANGE
- SMALL DENT ON SIDE JUST ABOVE BOTTOM PLATE
- NO DAMAGE TO LID BOLTS OR RIVETS

On-site assessment:
- PACKAGE INTACT — NO DAMAGE TO LID
- NOTE: LID TEMP AFTER DROP ~~30°C~~ 26°C HIGHEST (i.e. below 40°C) – Therefore drop 2nd TIME IN SAME ORIENTATION
- 2nd DROP HIT ON LONG SIDE – IMPACT ~~AGS~~ NJM 18MAR99 RESULTED IN DENT ON SIDE OF PACKAGE — NO OTHER DAMAGE
- PROCEED WITH DISASSEMBLY INSPECTION OF TOP PLATE AND LOCK AND SOURCE POSITION
- There are NO OPENINGS IN THE PACKAGE. Therefore there is no need to change the plan to NOT PERFORM A THERMAL TEST ON THE PACKAGE

Engineering: [signature] 18MAR99 Regulatory: [signature] 18MAR99 QA: D.W. Kurtz 18 MAR 99

Describe any post-test disassembly and inspection:
SEE ATTACHED SHEET

Describe any change in source position:

	BEFORE	AFTER	Δ
(A)	6.318	6.303	− 0.015
(B)	6.359	6.378	+ 0.019

Describe results of any pre- or post-test radiography:
No change in shield position — No damage to internal structure identified in radiographs

Completed by: [signature]	Date: 22 MAR 99

650L - TEST SPECIMEN TP80(A)

18 MAR 99

- REMOVED COVER - BOLTS & RIVNUTS OK

- SOURCE LOCATION
  - (A) 6.303
  - (B) 6.378

- SOURCES SECURED IN LOCKED POSITION
- NO DAMAGE TO LOCKS, LOCK SCREWS OR THROUGH BOLTS
- No Deflection of top plate

NJM
18 MAR 99

Data Sheet 5: Puncture Test

Test Unit Model and Serial Number: 650L SN 182		Test Specimen: TP80 (B)
Test Date: 18 MAR 99	Test Time: 1:20	Test Plan 80 Step No.: 8.10

Describe drop orientation and drop height:
4 ft DROP ON PUNCTURE BAR - TARGET ~~ER~~ AXIAL CRACK (NM 18MAR99)

Describe impact (location, rotation, etc.):
Impact Point directly on axial crack ~~at~~ (NM 18MAR99)

Describe on-site inspection (damage, broken parts, etc.):
- SMALL INDENTATION ON EITHER SIDE OF CRACK WERE BAR IMPACTED
- NO FURTHER OPENING OF CRACK WAS OBSERVED

On-site assessment:
- Radiograph device to further assess cracking and determine how to proceed.
- Radiographs were taken which showed cracking of inner sleeve only on the one side. [The crack ~~has~~ appears to ~~run the~~ ENTIRE LENGTH OF THE INNER SHELL. (NM 18MAR99)]
- Based on above it was determined that it is appropriate to proceed with inspection of top plate, lock mechanism and source position. IN ADDITION IT WAS DETERMINED THAT THE THERMAL TEST OF THE UNIT SHOULD BE PERFORMED WITH THE CRACK SIDE DOWN AND THE UNIT ROTATED FROM HORIZONTAL TO ALLOW THE SHIELD TO MOVE AS MUCH AS POSSIBLE (NM 18MAR99)

Engineering: N. Murray 18MAR99 Regulatory: [signature] 18MAR99 QA: D.N. Kent 18MAR99

Describe any post-test disassembly and inspection:
SEE ATTACHED SHEET

Describe any change in source position:
- Deflection of top plate resulted in a very small change in source position as follows
  (A) Δ is 0.027 in
  (B) Δ is 0.064 in

Describe results of any pre- or post-test radiography:
SEE ABOVE

Completed by: [signature]	Date: 18 MAR 99

18 MAR 99

650L - TEST SPECIMEN TP80(B) - SN 182
DISASSEMBLY NOTES (POST PUNCTURE BAR DROP)

- PART OF RIVNUT - ADJACENT TO SEAM - BROKEN OFF
- LID BOLTS UNDAMAGED, BUT RIVNUTS TURNED OUT
- LOCK B BROKEN OUT; SOURCE STILL LOCKED IN PLACE
- NO SIGNIFICANT DEFLECTION OF THROUGH-BOLT HEADS
- LOCK SCREWS INTACT; SOURCES LOCKED IN POSITION
- LOCKS ARE STILL FUNCTIONAL
- SOURCE POSITION:

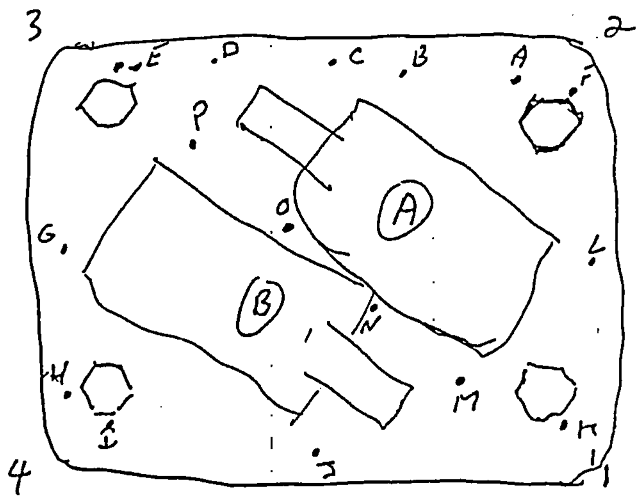
		ORIG. SOURCE POS.	Δ
(A)	6.583	6.556	0.027
(B)	6.494	6.430	0.064

[signature]
18 MAR 99

TP8U(13)
Post-Grm Drwo

18 MAR99

Dave Amnis



PT	
A	0.000
B	.032
C	.032
D	.019
E	-.005
F	-.005
G	.023
H	.013
I	.012
J	.019
K	.020
L	.003
M	.034
N	.154
O	.162
P	.070

Data Sheet 5: Puncture Test

Test Unit Model and Serial Number: 650L SN 195

Test Specimen: TP80(C)

Test Date: 18 MAR 99 | **Test Time:** 12:45p | **Test Plan 80 Step No.:** 8.10

Describe drop orientation and drop height:
① – UPSIDE DOWN ON LID CENTER, AT A SLIGHT ANGLE.

② 2ND DROP ORIENTATION – TARGET UNDERNEATH CORNER OF TOP PLATE PER Fig 11

Describe impact (location, rotation, etc.):
② Impact at same corner on 2nd attempt
① – EDGE OF PUNCTURE BAR HIT TOP PLATE OF LID WITHIN THE TUBE/COLUMN OF THE LID.

Describe on-site inspection (damage, broken parts, etc.):
① – DAMAGE TO LID INCREASED ONLY SLIGHTLY

② 2ND DROP ORIENTATION – SMALL DEFORMATION OF TOP PLATE AT IMPACT POINT – NO DAMAGE TO BOLTS – NO GAPS WERE CREATED AT TOP plate/SHELL INTERFACE

On-site assessment:
① – LOCK MECHANISMS NOT EXPOSED OR DIRECTLY IMPACTED IN DROP SEQUENCE
– LID BOLTS REMAINED INTACT
– ~~PACKAGING~~ NJM 18MAR99 NO OPENINGS IN PACKAGE CREATED IN ANY OF THE DROPS.

② NOTE: IT WAS DECIDED ON-SITE TO PERFORM AN ADDITIONAL PUNCTURE BAR DROP USING THE TP80(C) TEST SPECIMEN. THE 2ND DROP ORIENTATION WILL TARGET UNDERNEATH CORNER OF TOP PLATE AS SHOWN IN FIGURE 11 OF THE TEST PLAN. [THIS DROP ORIENTATION WAS PLANNED FOR ITEM TP 80(A)]

* SEE BELOW

Engineering: NJ Mary 18MAR99 Regulatory: [signature] 18 MAR 99 QA: D. W. Kurtz 18 MAR 99

Describe any post-test disassembly and inspection:
SEE ATTACHED SHEET

Describe any change in source position:

	BEFORE	AFTER	Δ
A	6.304	6.342	+0.038
B	6.256	6.259	+0.003

Describe results of any pre- or post-test radiography:
No damage to internals identified in radiography

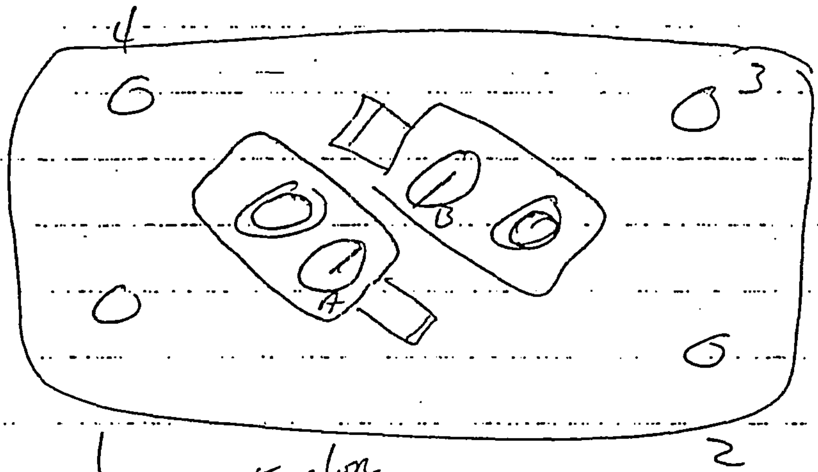
Completed by: [signature] | **Date:** 22 MAR 99

* THERE ARE NO OPENING IN THE PACKAGES THEREFORE THERMAL TESTING OF THE UNIT IS NOT REQUIRED (PER THE TEST PLAN) NJM 18 MAR 99

1635
18 March 99

650L Test
TP80(C) - Top Corner Drop
#195

Removed Cover → Bolts & RivNuts OK.
→ Top plate slightly warped due to puncture impact on Corner # 2
(i.e. slight upward bend in plate at corner #2)



→ Lock tumbler B slightly higher than normal
(Lock B works)
→ Locks & Lock Slides work properly though difficult to move
(Due possible to ice)

Source → 6.342 Side A
6.259 Side B

→ Sources secured in locked position
→ Through bolts & lock holddown screws show no sign of any deformation
→ No deflection or dishing of top plate

NPM
18 Mar 99

SENTINEL TP80(A) - AFTER 9M (30 FOOT) DROP TEST & PUNCTURE TEST

SHIELDING PROFILE AND INSPECTION FORM

odel: 650L Serial Number: 2243 Radionuclide: IR192 Max.Capacity: 240 Ci

Shield Data

hield Heat #: ______ Mass of Shield: ______ Lbs. Lot #: ______

Initial Profile

ource Model: ______ Source SN: ______ Activity: ______ Ci

urvey Inst.: ______ SN: ______ Date Cal.: ______ Date Due: ______

Surface	Observed Intensity mR/hr	Surface Correction Factor	N/A Capacity Correction Factor: ______	Adjusted Intensity mR/hr
op				
ight				
ont				
eft				
ear				
ottom				

or: ______ Date: ______ NCR #: ______

Final Profile

ource Model: 424-9 Source SN: C9274-112.3ci. C9232-93.1ci Activity: 205.4 Ci Mass of Device: ______ Lbs.

urvey Inst.: AN/PDR27T SN: SM392402 Date Cal.: 8Oct98 Date Due: 8Oct99

Surface	Observed Intensity mR/hr At Surface	Surface Corr. Factor	At One Meter	Capacity Correction Factor: 1.16	Adjusted Intensity mR/hr At Surface	At One Meter
p	80	*N/A	2.3		93	2.7
ght	55	↓	.7		64	.8
ont	80	↓	.9		93	1.0
ft	50	↓	.6		58	.7
ar	70	↓	.8		81	.9
ttom	80	↓	.5		93	.6

pector: MWBoyd Date: 19 March 99 NCR #: N/A

016-1/1

ments: * Per WI-Q09 worksheet

Amersham QSA

SENTINEL TP80(c) - AFTER 9M (30 FOOT) DROP TEST & PUNCTURE TEST

SHIELDING PROFILE AND INSPECTION FORM

odel: 650L Serial Number: 195 Radionuclide: IR192 Max.Capacity: 240 Ci

Shield Data		
hield Heat#:	Mass of Shield: Lbs.	Lot #:

Initial Profile (N/A)

ource Model: Source SN: Activity: Ci

urvey Inst.: SN: Date Cal.: Date Due:

Surface	Observed Intensity mR/hr	Surface Correction Factor		Adjusted Intensity mR/hr
op			N/A Capacity Correction Factor:	
ght				
ont				
ft				
ear				
ttom				

: Date: NCR #:

Final Profile

urce Model: 424-9 Source SN: C9274-112.3 ci. / C9232-93.1 ci Activity: 205.4 Ci Mass of Device: Lbs.

rvey Inst.: AN/PDR27T SN: SM392402 (MAB 13 Apr 99) Date Cal.: 8 Oct 98 Date Due: 8 Oct 99

	Observed Intensity mR/hr				Adjusted Intensity mR/hr	
urface	At Surface	Surface Corr. Factor	At One Meter		At Surface	At One Meter
p	60	*N/A	1.9	Capacity Correction Factor: 1.16	70	2.2
ht	85	↓	.8		99	.9
nt	45	↓	.5		52	.6
t	100	↓	.9		116	1.0
ar	50	↓	.5		58	.6
tom	60	↓	.4		70	.5

pector: M.E. Boyd Date: 19 March 99 NCR #: N/A

Q16-1/1

ments: * Per WT-Q09 worksheet

Amersham QSA

Equipment List 6: Thermal Test

Description	Enter the Model and Serial Number	Attach Inspection Report or Calibration Certificate
Bottom Surface Thermocouple 1	XCIB-K OMEGA	DW
Top Surface Thermocouple 2	OMEGA XCIB-K	DW
Side Surface Facing Oven Front Thermocouple 3	OMEGA XCIB-K	DW
Side Surface Facing Oven Rear Thermocouple 4	XCIB-K	DW
Source Tube Thermocouple ~~5~~ 8 DA 19MAR99	XCIB-K	DW
Oven	GE 60KW RESISTANT HEATED BOX FURNACE	DW N/A
Oven thermostat	OMEGA #XCIB-K-	DW
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
SIDE SURFACE FACING LEFT TC 5	XCIB-K	DA
SIDE SURFACE FACING RIGHT TC 6	XCIB-K	DA
SIDE OF UNIT FACING OVEN FRONT TC 7	XCIB-K	DA
AMBIENT THERMOCOUPLE 9	XCIB-K	DA
THERMOCOUPLE THERMOMETER ~~[illegible]~~ DA 19 MAR 99	#ENG-21 Cole-Parmer (12 CH)	DA

	Print Name:	Signature:	Date:
Completed by:	Dave Annis	Dave Annis	19 mar 99
Verified by:	Daniel W. Kurtz	D.W. Kurtz	19 Mar 99

Checklist 6: Thermal Test

Step	TP80(A)	TP80(B)	TP80(C)
1. Record Test Specimen Serial Number.		182	
2. Preheat the oven to 810°C.		DW	
3. Attach the thermocouples as described in Equipment List 6. Ensure the recording devices are active, and that the external thermocouples are shielded.	NJM 19MAR99	DW	NJM 19MAR99
4. Place the package in the oven in the worst case orientation and partially close the oven door such that a 1 inch by 36 inch opening is provided. Record the time.		DW 19 MAR 99 7:35 PM	
5. When all of the test specimen's surface temperatures exceed 810°C, begin the 30-minute time interval. Record the time.		DW 19 MAR 99 8:05 PM	
6. Monitor and record the test specimen and the oven temperatures throughout the 30-minute period to ensure that they are above 810°C		DW	
7. At the end of the 30-minute test period, shut off the oven ~~and~~ open the door, AND REMOVE THE TEST SPECIMEN Record the time.		DW 19 MAR 99 8:37 PM	
8. Describe combustion when door is opened. NJM 19MAR99 19MAR99 DWK 19MAR99		CHERRY RED NO FLAME	
9. Allow the specimen to cool, ~~then remove the specimen from the oven~~. Record the time. NJM 19MAR99 19MAR99 DWK 19MAR99		8:37 PM	
NOTE: If specimen continues to burn, let it self-extinguish and cool naturally.			
10. Measure and record the ambient temperature.		DW 25°C	
11. Photograph the test specimen and record any damage on data sheet 6.		DW	
12. Radiograph the unit to determine the shield location.		DW	
13. Measure and record the source location.		DW 24 MAR 99	
14. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record assessment on Data Sheet 6.		DW	

Verified by:	Print Name:	Signature:	Date:
Engineering	*NICHOLAS MARRONE CAROLINE S. SCHLASEMAN	[signature] [signature]	~~20MAR99~~ 24 MAR 99
Regulatory Affairs	* MARC J. NAVONO Cathleen Roughan	[signature] Cathleen Roughan	~~20MAR99~~ 24 mar 99
Quality Assurance	*Daniel W. Kurtz Daniel W. Kurtz	D.W. Kurtz D.W. Kurtz	20 MAR 99 26 MAR 99

*COMPLETION OF ALL STEPS EXCEPT STEP 13 (Source location). Source location will be determined at the time of profiling NJM 20MAR99

Data Sheet 6: Thermal Test

Test Unit Model and Serial Number: 650L SN 182		Test Specimen: TP80(B)
Test Date: 19 MAR 99	Test Time: 7:35 pm	Test Plan 80 Step No.: 8.12

Describe test orientation and setup: PACKAGE ON JIG TO RAISE SIDE FACE OF UNIT TO AN ANGLE 53° ABOVE HORIZONTAL. SIDE WITH CRACK FACING DOWN (@ 53° ANGLE). SEE FIGURE – ATTACHED.

Describe package during testing: POLYURETHANE FOAM BURNED OFF, CAUSING SOME RED FLAMES TO SHOOT OUT ABOVE OVEN DOOR. FLAMES DIMINISHED AND STOPPED COMPLETELY BEFORE 30 MINUTE INTERVAL COMPLETED.

Describe on-site inspection (damage, broken parts, etc.): WHEN OVEN DOOR FIRST OPENED, UNIT GLOWED BRIGHT RED (INCLUDING JIG). AFTER EXTERIOR HAD COOLED TO GREY COLOR, INSPECTION SHOWED: (1) NO CHANGE IN CONFIGURATION OF PACKAGE EXTERIOR, INCLUDING INNER SHELL -- e.g., CRACK WIDTH DID NOT CHANGE, (2) ALL FOAM IN TOP OF UNIT WAS GONE, SO DU SHIELD AND SOURCE TUBE CLOSEST TO CRACK WERE VISIBLE THROUGH CRACK OPENING, (3) DU SHIELD WAS GLOWING RED IN A FEW SPOTS AND OXIDE (BLACK POWDER) WAS BUILDING UP ON SHIELD SURFACE, (4) DU OXIDE WAS FALLING OUT OF UNIT PERIODICALLY AND FORMING A SMALL PILE BELOW FACE OF CRACK ON JIG'S BASE. NEXT MORNING (~10 HOURS LATER), INSPECTION SHOWED: (1) A CRACKED PIECE OF INNER SHELL HAD DROPPED OUT OF POSITION, ~~AND PARTIALLY COVERED CRACK OPENING,~~ [initials] 20 MAR 99 (2) PILE OF DU OXIDE BELOW CRACK WAS MUCH LARGER – AT LEAST 2" TALL, 3"Ø. ~~(3) DU OXIDE FILLING IN CRACK OPENING.~~ [initials] 20 MAR 99

On-site assessment: – CONTINUE WITH PROFILE & SOURCE POSITION MEASUREMENTS

Engineering: [signature] 20 MAR 99 Regulatory: [signature] 20 MAR 99 QA: D.W. Kurtz 20 MAR 99

Describe any post-test disassembly and inspection: SEE ATTACHED SHEETS.

Describe any change in source position: ~~LATER?~~ [initials] 24 MAR 99 SEE ATTACHED SHEETS.

Describe results of any pre- or post-test radiography: POST-TEST RADIOGRAPHS TAKEN FROM LONG SIDE & SHORT SIDE SHOWED SOURCE TUBES PULLED OUT FROM [initials] 20 MAR 99 ~~ENGAGE (OR AT LEAST TOUCHING)~~ TOP PLATE. ~~IN POSITION.~~ [initials] 20 MAR 99 DU SHIELD WAS SHIFTED DOWN (TOWARD CRACK FACE) & SOURCE TUBE CLOSEST TO CRACK HAD BENT SLIGHTLY ~~DOWN~~ TO FOLLOW SHIELD. SHIELD DID NOT PASS BEYOND INTERFERENCE WITH → THROUGH BOLTS. THE D.U. SHIELD "EAR" (MATERIAL AROUND SOURCE TUBE) CLOSEST TO CRACK WAS MISSING MATERIAL, DUE TO OXIDATION. THE SOURCE TUBE PULLOUT AND SHIELD [SH]IFT CAUSED THE TOP OF THE SOURCE TUBES TO BE MISALIGNED WITH THE LOCK [A]SSEMBLIES. THE GAP BETWEEN THE TOP OF THE SOURCE TUBE AND THE BOTTOM OF THE [TO]P PLATE IS LARGER FOR THE TUBE FARTHER FROM THE CRACK.
[initials] 20 MAR 99

Completed by: [signature]	Date: 24 MAR 99

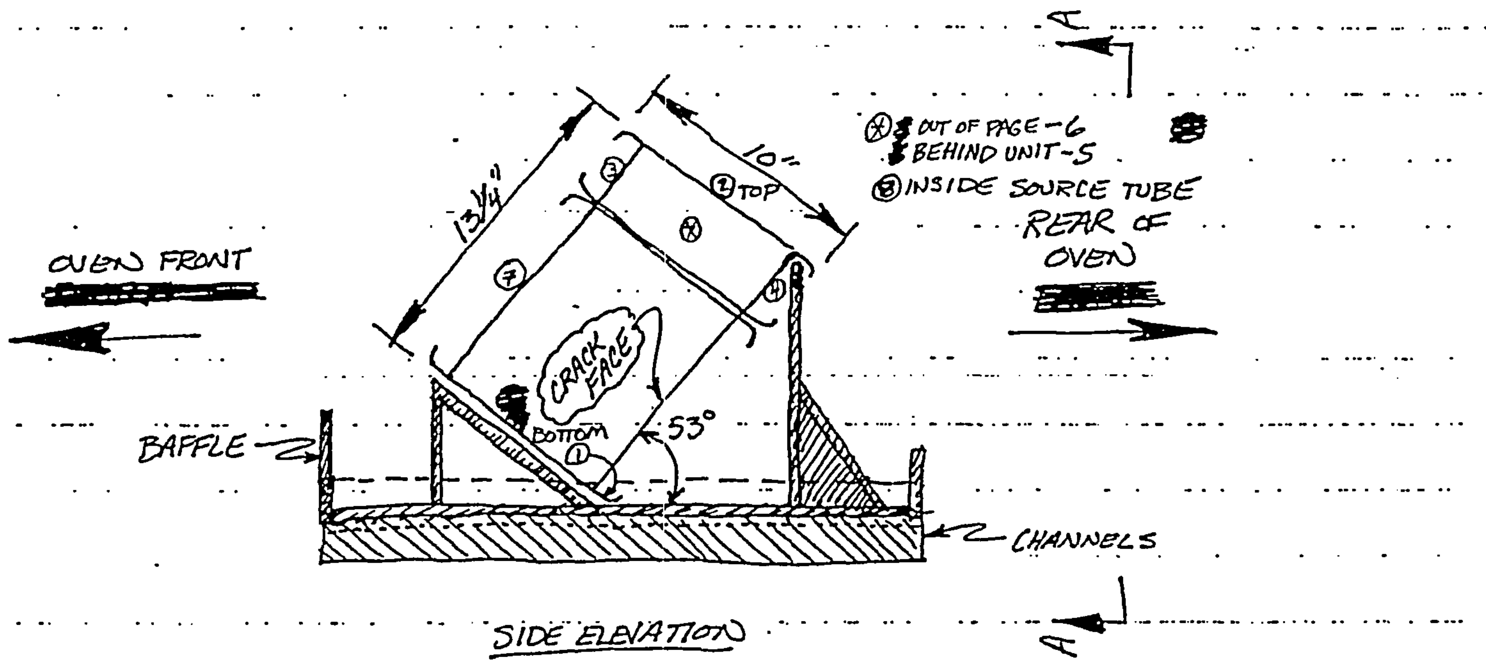
(54A1)

19MAR99

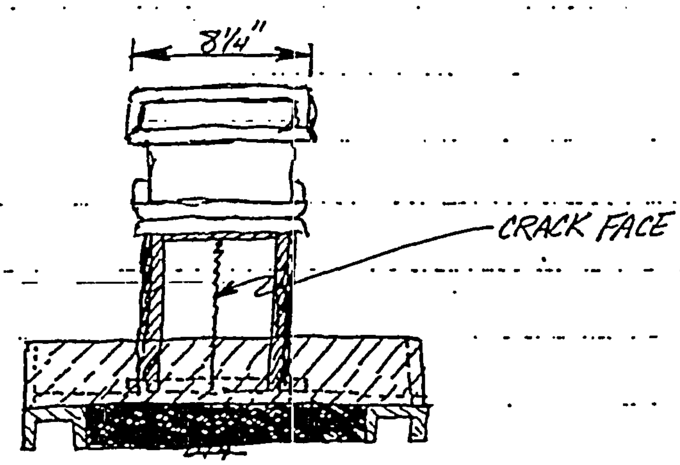
650L TP80(B) SN 182
THERMAL TEST ORIENTATION

(SUPPORT FIXTURE SHOWN CROSS-HATCHED)

◯ TC NUMBER



SIDE ELEVATION



VIEW A-A
(FACING FRONT OF OVEN)

23MAR99 @ MSC, OAK RIDGE, TN

INSPECTION & SET-UP FOR RADIATION PROFILE

1. SOURCE TUBE & SHELL TEMP'S AMBIENT (~16 °C)
2. [PHOTO 1] CRACKED PIECE OF INNER SHELL
3. [PHOTO 2] CRACKED PIECE OF INNER SHELL REMOVED
4. [PHOTO 3] " " " " ", OUTSIDE UNIT
5. VACUUMED DU. OXIDE VIA CRACK OPENING.
6. [PHOTO 4] MELTED LEAD AT BASE OF UNIT
7. ~~???~~ TUBES & ~~SHELL~~ SHIELD SEEM ~~FAIRLY~~ FIXED, i.e., CAN'T MOVE. (24MAR99)
8. CRACKED OFF REMAINING RIVETS FOR SS OVERWRAP.
9. DRILLED HOLE IN LOWER HALF OF SHELL OPPOSITE CRACK FACE — [PHOTOS 5 & 6]
10. VACUUMED D.U. OXIDE VIA HOLE; BASE AREA OF D.U. SHIELD LOOKED GOOD, COPPER SHIM AT BASE VISIBLE UNDER EDGE OF BASE, NO SIGN OF ANY REMAINING LEAD FROM THIS (THE UPPER) SIDE.
11. FOAMED w/ 20# VULTAFOAM FROM NEW HOLE; FOAM SURROUNDS SHIELD UP ABOUT 2/3 — i.e., TOPS OF DU "EARS" & SOURCE TUBES ARE STILL ACCESSIBLE.
12. DRILLED 3 ACCESS HOLES IN TOP SECTION OF UNIT SIDES, 90° APART, TO GET ACCESS TO DUMMY SOURCE WIRE IN "B" LOCK (FURTHER FROM CRACK).
13. REMOVED LID - [PHOTO 7] - "A" LOCK CYLINDER MELTED ("B" LOCK CYLINDER HAD BROKEN OUT DURING 9 M DROP.)

[CON'T]

23 MAR 99 - CON'T

(14) PHOTO 8: VIEW THROUGH CRACK: FOAM BELOW, RIVNUT ABOVE IN FOREGROUND, TOP OF "A" SOURCE TUBE (GREY) VISIBLE BELOW BOTTOM OF TOP PLATE, THERMOCOUPLE WIRE (SAME GREY COLOR AS TUBE) IS VISIBLE IN GAP BETWEEN TOP OF TUBE & BOTTOM OF TOP PLATE.

(15) DUMMY SOURCE WIRE MARKED W/ "WHITE OUT" @ TOP OF TUBE (VIA NEW HOLES)

(16) LOCK UNSCREWED, BUT SLIDE LEFT IN PLACE TO HOLD WIRE POSITION TEMPORARILY - PHOTO 9

(17) PHOTOS 10 & 11 SLIDE REMOVED ("B" SIDE), SOURCE WIRE STICKING UP.

(18) PHOTO 12: DUMMY SOURCE WIRE REMOVED; BRIGHT WHITE MARK ON 2ND BEND BELOW BALL IS TOP OF SOURCE TUBE POSITION; LIGHT GREY MARK BETWEEN BALL & WHITE MARK IS LIKELY ORIGINAL TOP OF TUBE MARK - GREY/DISCOLORATION IS DUE TO RUBBING OR SCUFFING.

(19) REMOVED "A" LOCK ASSEMBLY (WHICH HAD CONTAINED A TC WIRE & IS CLOSEST TO CRACK).

(20) PHOTOS 13 & 14: SOURCE TUBES VISIBLE BELOW TOP PLATE - SEE SKETCH FOR DIMENSIONS (A)

0.436"

Δ = 6.992 - 6.556 =

"A" OLD LOCK .768 NEW LOCK .780 Δ ≈ .010"

FOR 24 MAR 99: PHOTO 15

7.002 - .010 = 6.992" (↑ NEW LOCK Δ)

1. → CHECK "A" SOURCE TUBE DEPTH W/ NYLON & NEW LOCK
3. → ENLARGE HOLES IN TOP PLATE → PHOTO 16 → PHOTOS 17 & 18
4. → PRACTICE SOURCE TRANSFER W/ DUMMY SOURCE
5. → PERFORM PROFILE → SEE PROFILE SHEET — 6.947 - 6.430 = 0.517" (B)
2. → RE-CHECK "B" SOURCE TUBE DEPTH W/ NYLON ~~- USE Δ = 0.517" (WHICH IS SLIGHTLY HIGHER THAN NUMBER BACKED OUT FROM MARK MADE AT TOP OF SOURCE TUBE BY ~28 mils)~~ SEE NEXT SHEET FOR DETERMINATION OF SOURCE PULLOUT DISTANCE.

24 MAR 99 CSS

REF. DISTANCES:

	A	B
HT. ABOVE TOP PLATE TO TOP OF SOURCE	0.954"	0.925"
WITHDRAWAL HEIGHT	0.436"	~~0.517"~~ (24MAR99 CAA) ← BASED ON NYLON PROBE; 0.480" ← SEE BELOW
HT. ABOVE TOP PLATE FOR PROFILE	1.390"	~~1.442"~~ (24MAR99 CAA); 1.405"

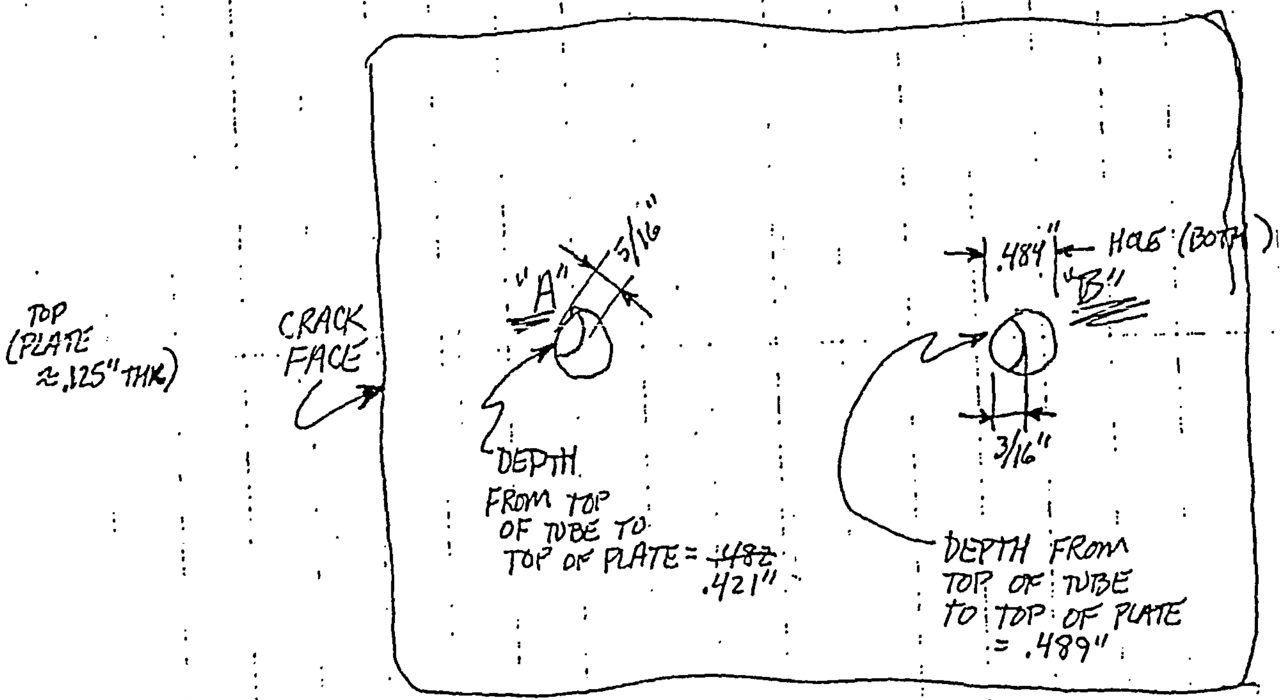
CROSS-CHECK ON "B" SIDE (NO LOCKS ON TOP PLATE):

1. → MATCH MARK ON DUMMY SOURCE USED IN THERMAL & DROP TESTS WITH NEW DUMMY SOURCE.
2. → INSERT NEW DUMMY SOURCE WIRE IN TO THE POINT WHERE MARK MATCHES TOP OF TUBE.
3. → MEASURE DIST. BETWEEN TOP OF PLATE & TOP OF SOURCE. → 1.385"
4. → PUSH NEW DUMMY SOURCE ALL THE WAY TO BOTTOM OF TUBE AND MEASURE DIST. BETWEEN TOP OF PLATE & TOP OF SOURCE. → − 0.905"
5. → SUBTRACT TO GET SOURCE PULLOUT. → 0.480"

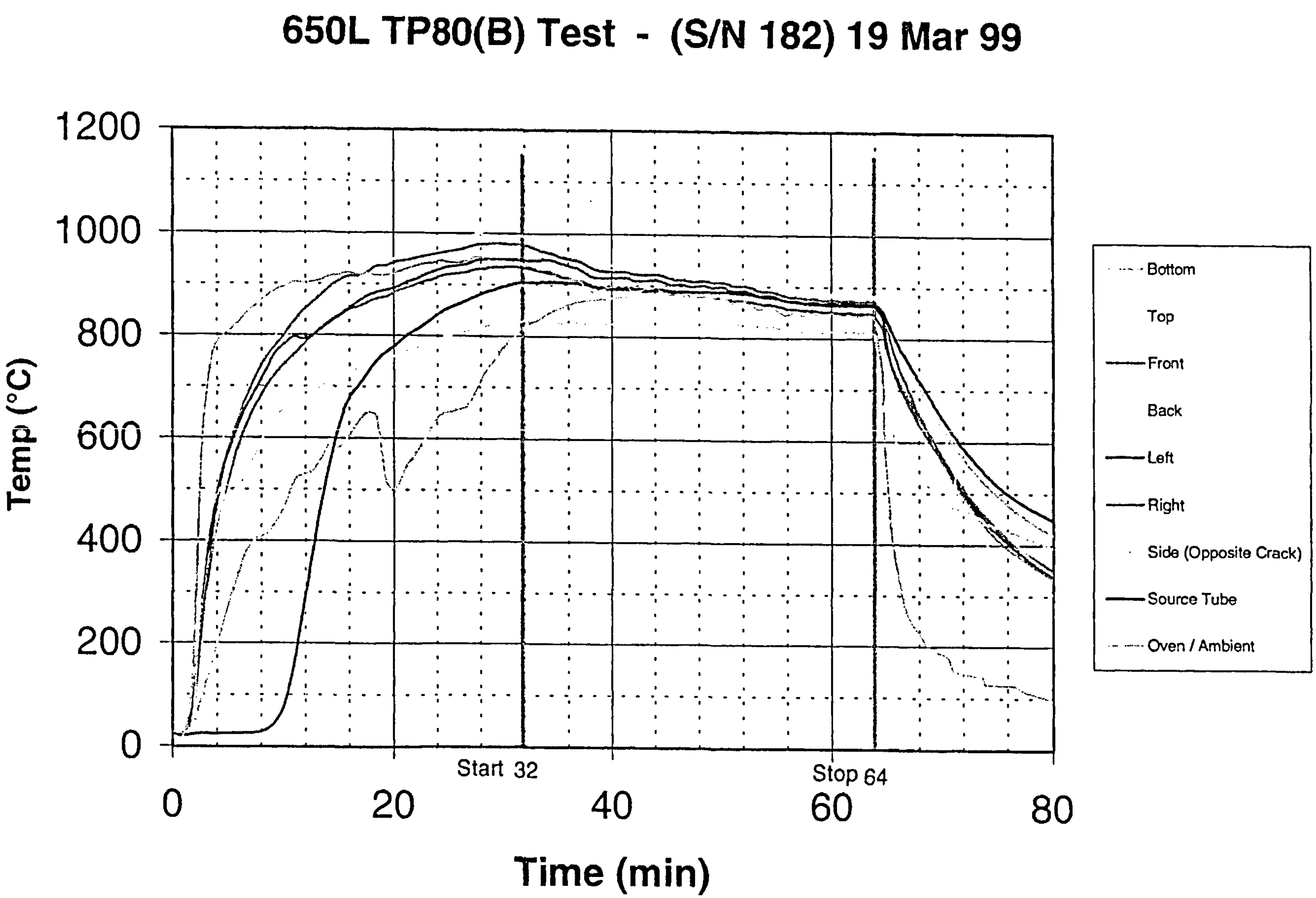
0.480" ← USE THIS NUMBER WHICH IS A DIRECT MEASUREMENT USING A DUMMY SOURCE WIRE.

23MAR99 TP80(B) SN 182 AFTER THERMAL TEST

- LOCK ASSEMBLIES REMOVED
- SOURCE TUBE POSITION (TUBES BELOW TOP PLATE)

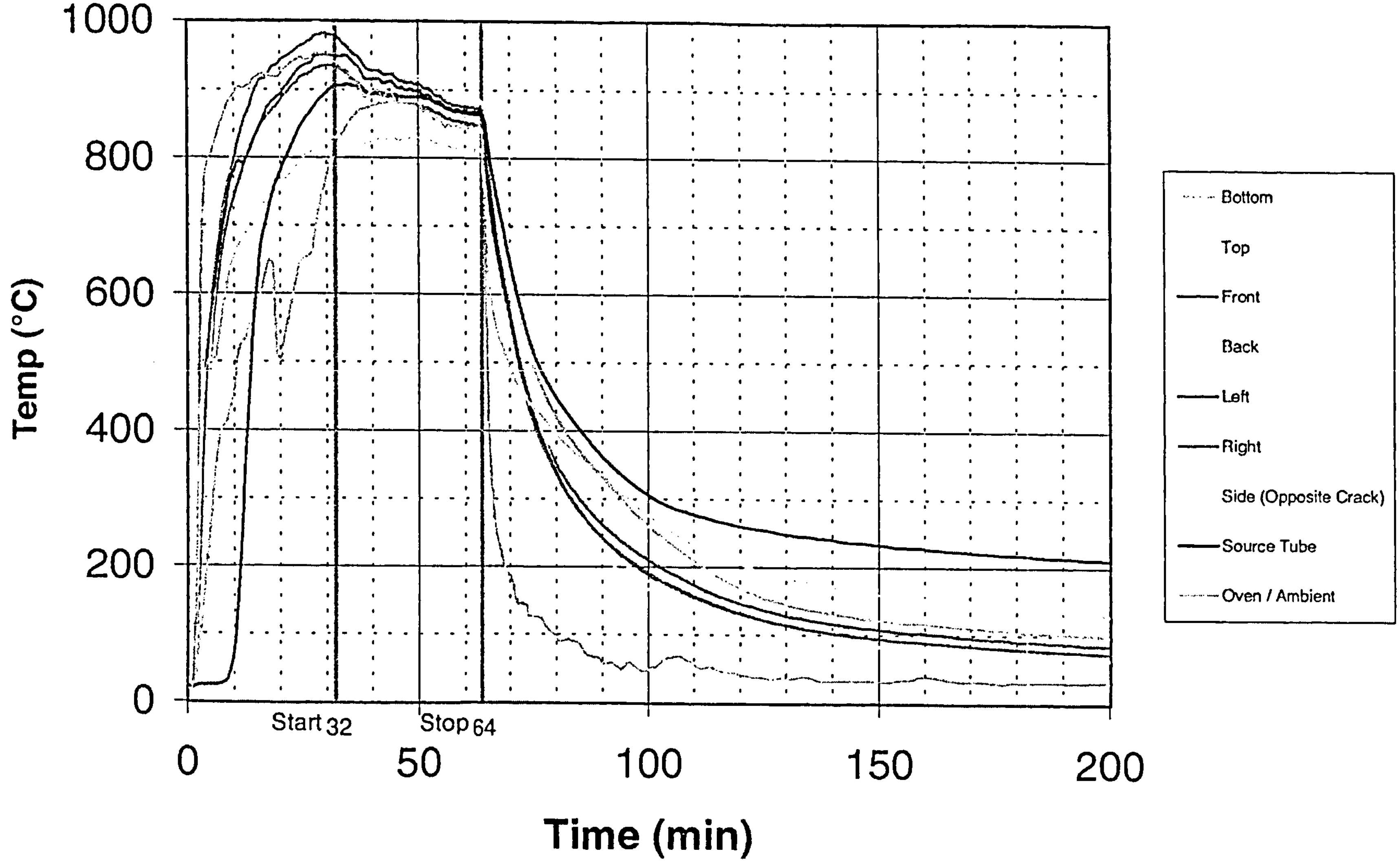


(54 A1, 54 A2 THRU 54 D)
24 MAR 99



650L TP80(B) Test - (S/N 182) 19 Mar 99
1200
1000
800
600
400
200
0
Temp (°C)
0
20
40
60
80
Start 32
Stop 64
Time (min)
Bottom
Top
Front
Back
Left
Right
Side (Opposite Crack)
Source Tube
Oven / Ambient

650L TP80(B) Test - (S/N 182) 19 Mar 99



SENTINEL TP 80(B) After Thermal Test

SHIELDING PROFILE AND INSPECTION FORM

odel: 650L Serial Number: 182 Radionuclide: Ir-192 Max.Capacity: 240 Ci

Shield Data

hield Heat#:	Mass of Shield: Lbs.	Lot #:

Initial Profile

ource Model: Source SN: Activity: Ci

urvey Inst.: SN: Date Cal.: Date Due:

Surface	Observed Intensity mR/hr	Surface Correction Factor	NA	Adjusted Intensity mR/hr
op			Capacity Correction Factor:	
ight				
ront				
eft				
ear				
ottom				

r: Date: NCR #:

Final Profile total = 213.3

ource Model: 424-9 Source SN: C9313/C9312 Activity: 107.3/106 Ci Mass of Device: 83.6 Lbs.

urvey Inst.: Bicron Tech 50 SN: B-816-S Date Cal.: 8 Sep 98 Date Due: 8 Sep 99

Observed Intensity mR/hr					Adjusted Intensity mR/hr	
Surface	At Surface	Surface Corr. Factor	At One Meter		At Surface	At One Meter
op			25	Capacity Correction Factor: 1.125		28
ight	NA		5			5.6
ront			5			5.6
eft			7			7.9
ear			7			7.9
ottom			1			1.1

nspector: Cathleen Roughan Date: 3-24-99 NCR #: NA

QI6-1/1

mments:

source SN C9313 - 109.3 Ci on 3-22-99 - 107.3 on 3-24-99 cmr
C9312 108 Ci on 3-22-99 - 106 on 3-24-99

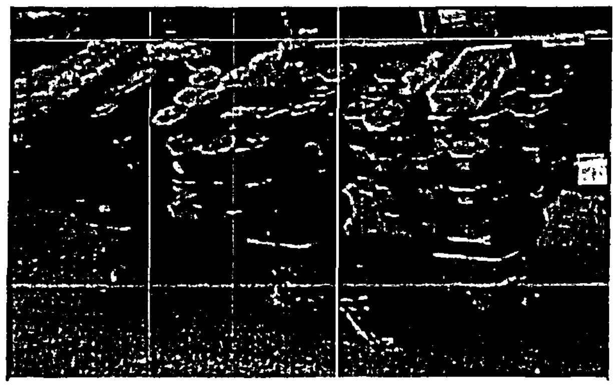
Amersham QSA

Total Activity 3-24-99 = 213.3

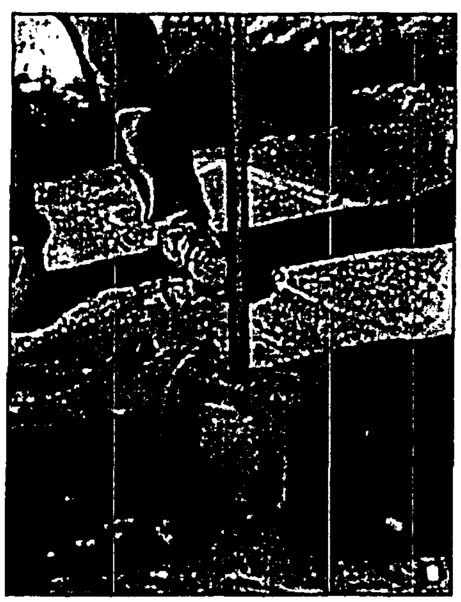
APPENDIX D

TEST PHOTOGRAPHS

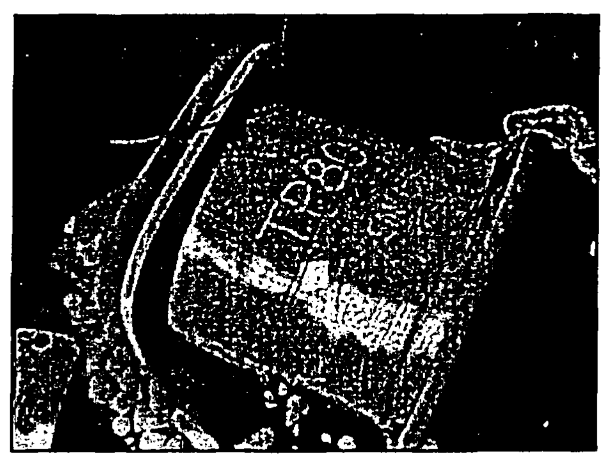
Test Plan 80 Photographs



Compression Test

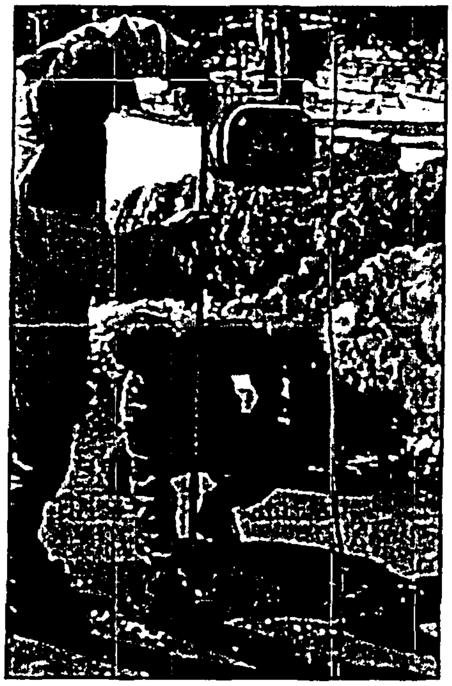


Typical Penetration Test Setup

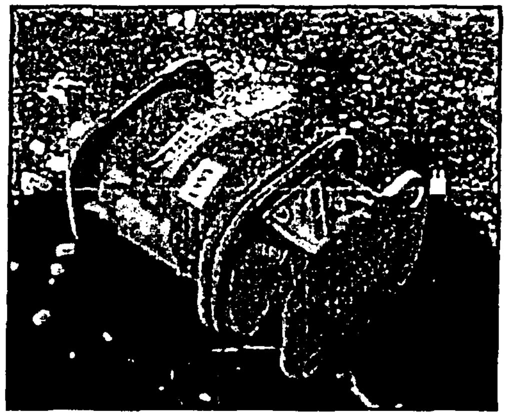


Typical Penetration Impact

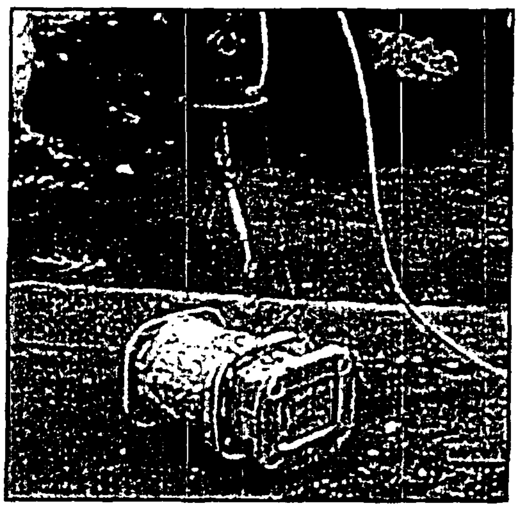
Test Plan 80 Photographs



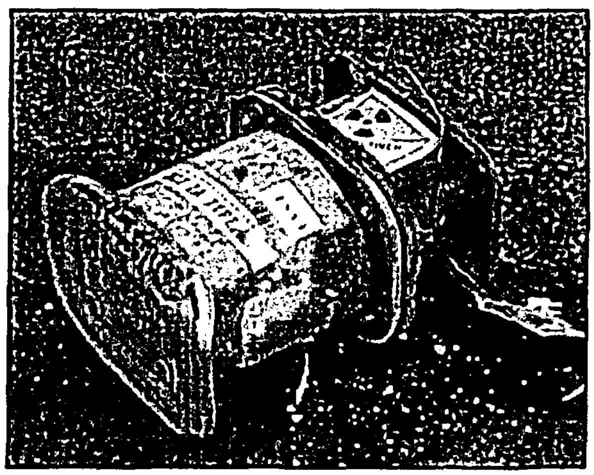
TP80(A) 4 Foot Drop Setup



TP80(A) 4 Foot Drop Results

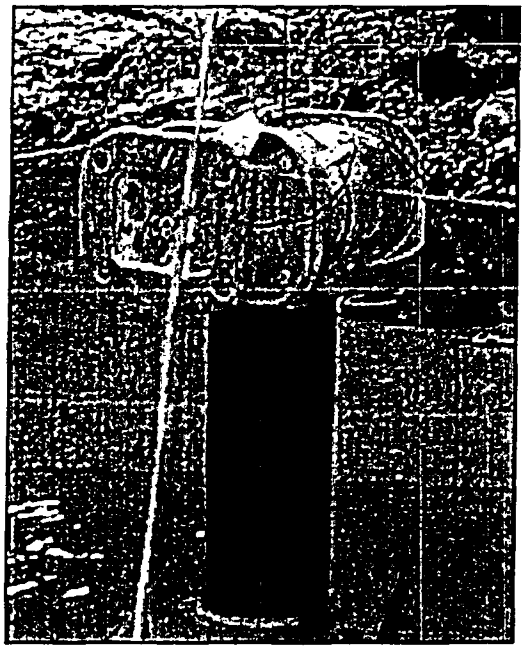


TP80(A) 30 Foot Drop Setup

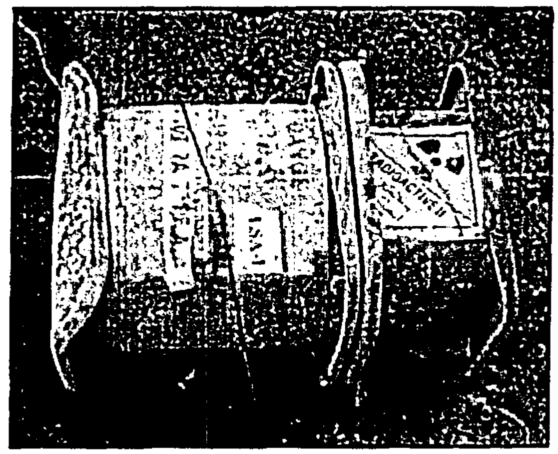


TP80(A) 30 Foot Drop Results

Test Plan 80 Photographs



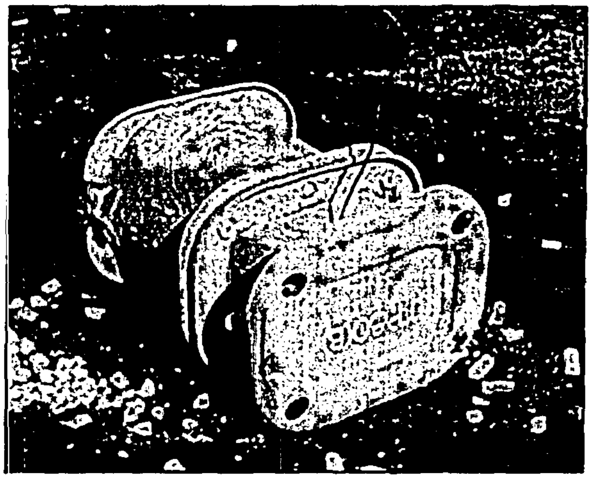
TP80(A) Puncture Test Setup



TP80(A) Puncture Test Results

Test Plan 80 Photographs

TP80(B) 4 Foot Drop Setup

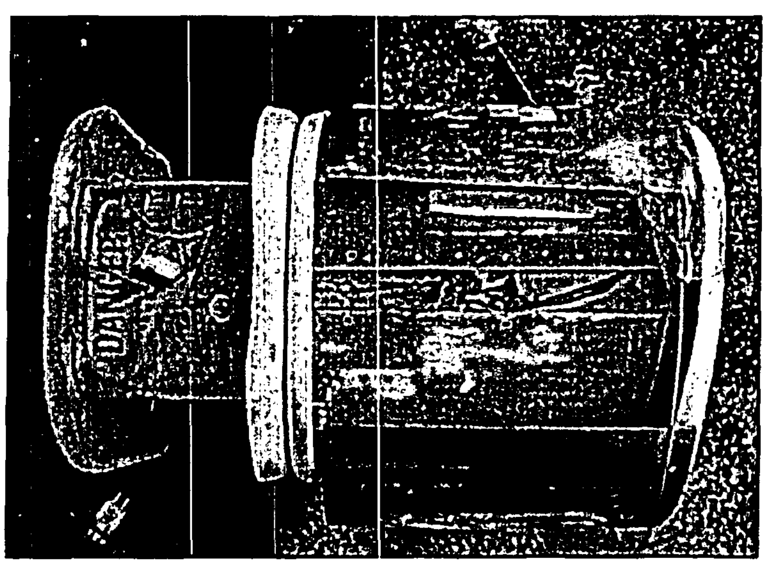


TP80(B) 4 Foot Drop Test Results

Test Plan 80 Photographs

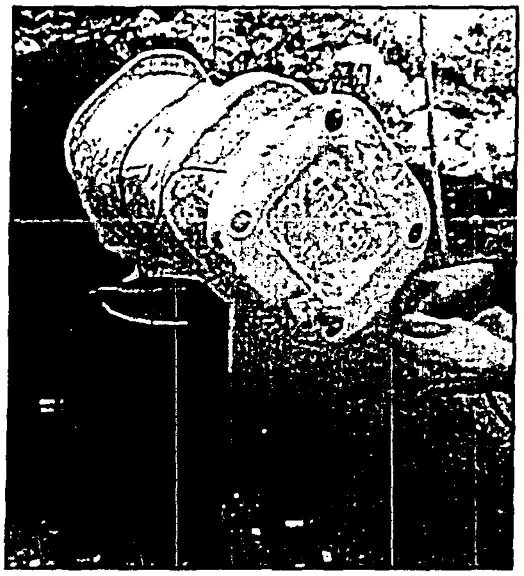
TP80(B) 30 Foot Drop Setup

TP80(B) 30 Foot Drop Results



TP80(B) 30 Foot Drop Results

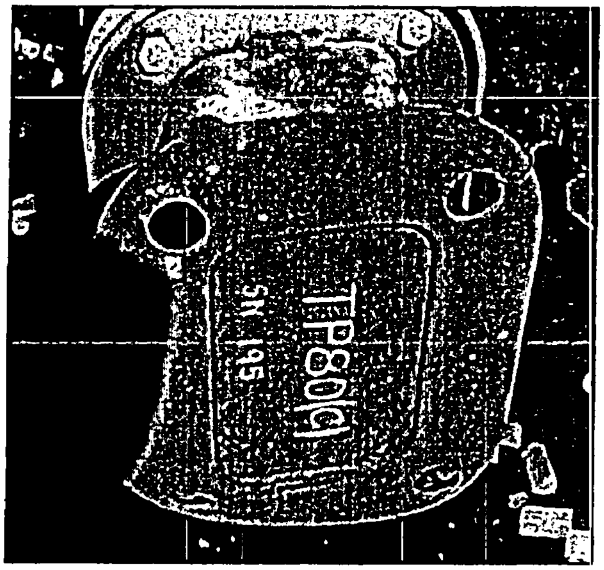
Test Plan 80 Photographs



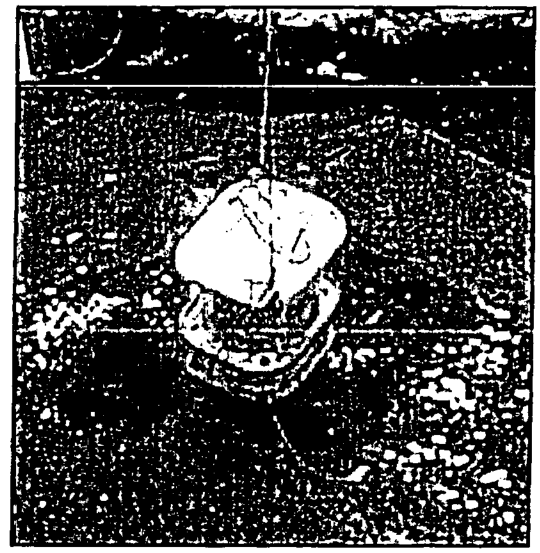
TP80(B) Puncture Test Setup

TP80(B) Puncture Test Results

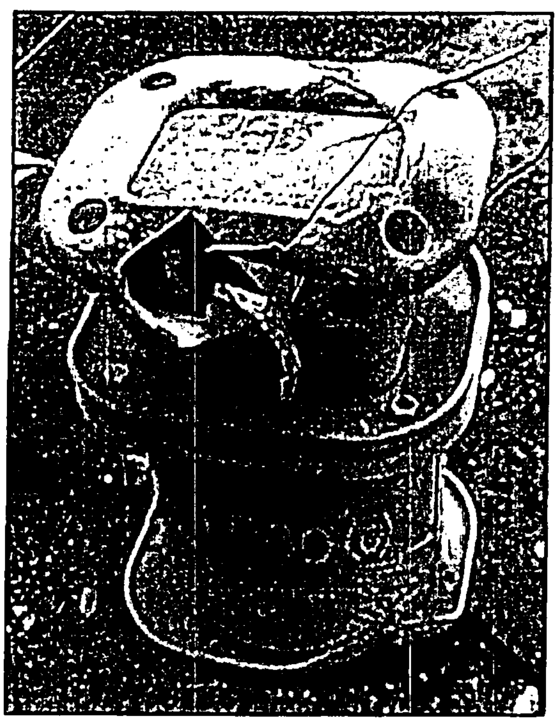
Test Plan 80 Photographs



TP80(C) 4 Foot Drop Test Results



TP80(C) 30 Foot Drop Setup

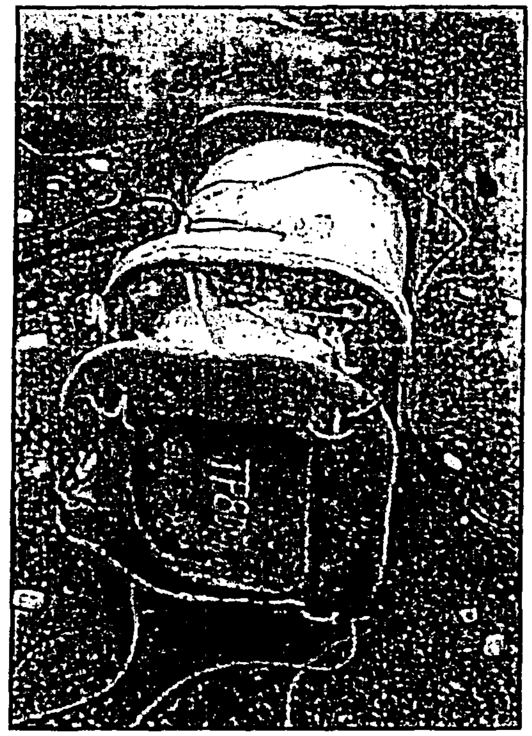


TP80(C) 30 Foot Drop Results

TP80(C) 30 Foot Drop Results

Test Plan 80 Photographs

TP80(C) Puncture Drop 1 Setup

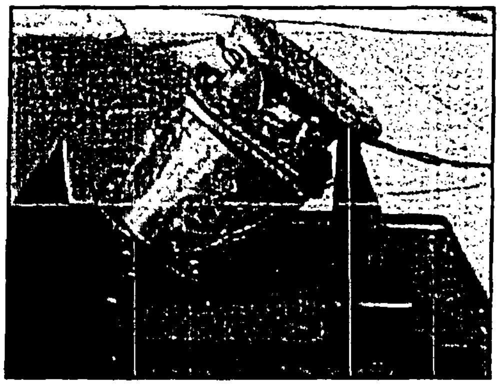


TP80(C) Puncture Drop 1 Results

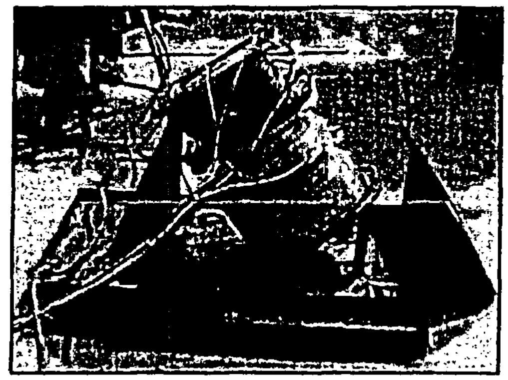
TP80(C) Puncture Drop 2 Setup

TP80(C) Puncture Drop 2 Results
Showing Closeup of Rivnut

Test Plan 80 Photographs



TP80(B) Thermal Test Setup



TP80(B) Thermal Test Setup

TP80(B) Thermal Test
After Removal From Oven

TP80(B) Thermal Test After
Removal From Oven

Test Plan 80 Photographs

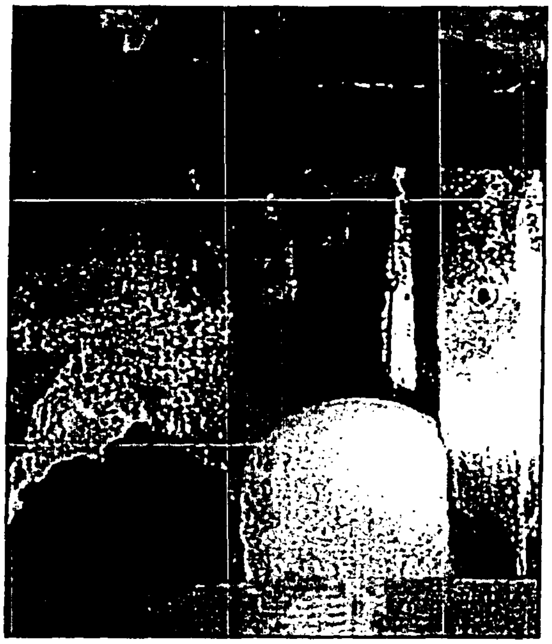
TP80(B) Thermal Test After Removal From Oven

TP80(B) Detail of Cracked Shell

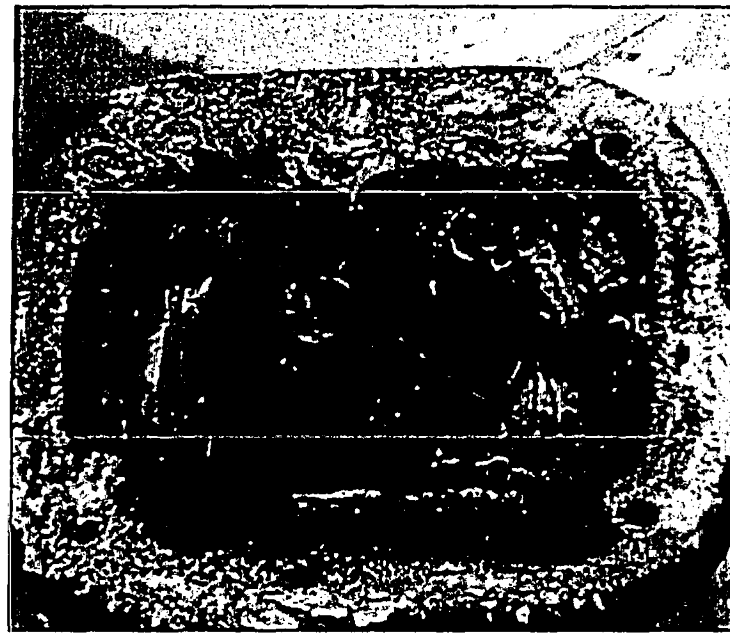
TP80(B) Detail of Uranium Oxide Residue

TP80(B) Detail of Uranium Oxide Residue

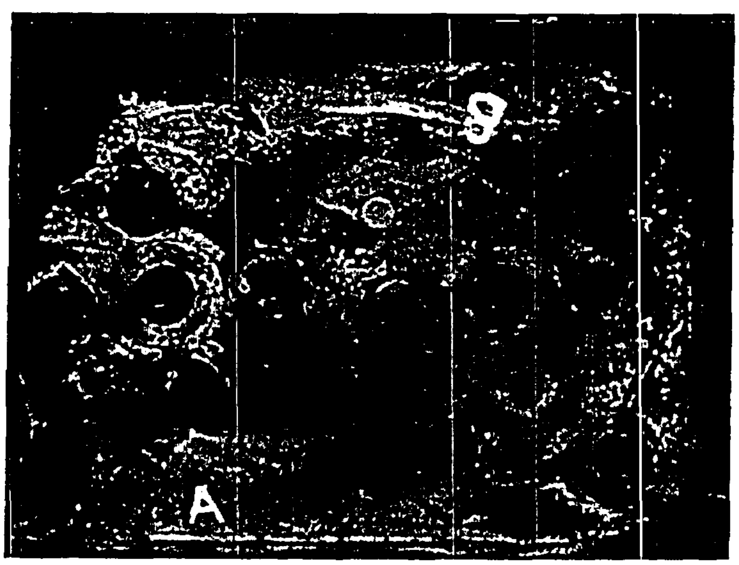
Test Plan 80 Photographs



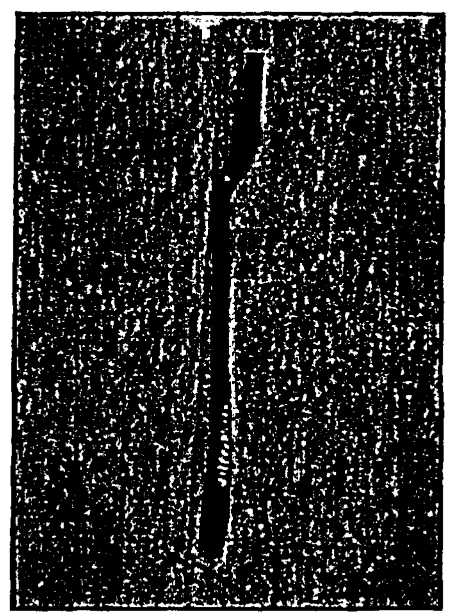
TP80(B) Thermal Test After Removal From Oven--Detail of Crack After Foaming to Stabilize Shield



TP80(B) Thermal Test After Removal From Oven—Lid Removed



TP80(B) Thermal Test After Removal From Oven--Detail of Source Tube Displacement After Removal of Lock Assemblies



TP80(B) Thermal Test After Removal From Oven--Dummy Source Wire--White Mark Shows Top of Source Tube Position

Section 3 - THERMAL EVALUATION

3.1 Description of Thermal Design

(Reference:
- *USNRC, 10 CFR 71.33(a)(5)(v) and 71.33(b)(7)*
- *IAEA TS-R-1, paragraphs 651(b) and 655)*

The Model 880 Series transport packages are completely passive thermal devices having no mechanical cooling system or relief valves. The exterior surface finish of the package is light silvery stainless steel having an absorptivity of about 0.44, or a reflectivity of 0.56. Cooling of the package is through free convection and radiation. There are no specific cooling or insulating design features. Pressure relief of the container weldment is only necessary during the thermal test and is provided by the holes in both the rear and front end plates which will vent to atmosphere.

The maximum activity for this package is 150 Ci of Ir-192. Accounting for source absorption, this equals a maximum content activity of 345 Ci of Ir-192. The corresponding decay heat generation rate for the content activity is approximately 3 Watts (See Table 1.2d).

3.1.1 Design Features

The Model 880 Series transport packages are described in Section 1. The thin walls of the steel weldment exhibit almost no thermal gradient. During a fire test, the exterior steel weldment will very quickly heat to a uniform temperature, eliminating stresses induced by thermal differentials within the material. Further, the steel weldment will move and flex easily, thus relieving any thermal expansion stress without rupture.

The containers use depleted uranium shielding. The depleted uranium is fully enclosed in the welded steel structure and endplates which are attached by screws. This construction prevents oxidation by severely limiting oxygen from reaching the depleted uranium shield.

3.1.2 Content's Decay Heat

From Table 1.2d, a maximum of 3 Watts of decay energy is available to be absorbed by the package.

3.1.3 Summary Tables of Temperatures

Table 3.1a: Summary Table of Temperatures

Surface Temperature Condition	Model 880 Series Packages	Comments
Insolation (38°C in full sun)	65.4°C (149.6°F)	Section 3.4.1.1
Decay Heating (38°C in shade)	47°C (116°F)	Section 3.4.1.2
Fire Test During	800°C (1,472°F)	
Post-Fire (Maximum Temperature)	800°C (1,472°F)	

3.1.4 Summary Tables of Maximum Pressures

All Model 880 Series containers are vented to atmosphere. As such, no pressure will build up in the units under either Normal or Hypothetical Accident conditions.

Table 3.1b: Summary Table of Maximum Pressures

Package Configuration	Void Volume IN^3	Normal Conditions 88°C (190°F) Pressure Developed	Fire Conditions 800°C (1,472°F) Pressure Developed	Comments
880 Delta	0	0 psig	0 psig	
880 Sigma	0	0 psig	0 psig	
880 Elite	0	0 psig	0 psig	

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

Table 3.2a lists the relevant thermal properties of the important materials in the transport package. The sources referred to in the last column are listed below the table.

Table 3.2a: Thermal Properties of Principal Transport Package Materials

Material	Density (lb/in^3)	Melting/Combustion Temperature	Thermal Expansion	Source
Depleted Uranium	0.68	1,130°C (2,066°F)	8μin/in°F	Reference #1, p. 6-11 and Reference #2
Brass	0.3	900 – 1,025°C (1,652 – 1,877°F)	18.7 - 21.2μm/m°K	Reference #3
Steel (nominal)	0.28	1,510°C (2,750°F)	6.3μin/in°F	Reference #1, p. 6-7 and 6-11
Stainless Steel-Type 304	0.29	1,427°C (2,600°F)	9.9μin/in°F	Reference #1, p. 6-11
Tungsten	0.70	3,370°C (6,098°F)	2.4μin/in°F	Reference #1, p. 6-51
Titanium	0.16	1,500 – 1,700°C (2,732 – 3,092°F)	11μm/m°K	Reference #4

Resource references:

1. Eugene A. Avallone and Theodore Baumeister III, *Mark's Standard Handbook for Mechanical Engineers, Tenth Edition,* New York: McGraw-Hill, 1996.

2. Lowenstein, Paul. *Industrial Uses of Depleted Uranium.* American Society for Metals. Metals Handbook, Volume 3, Ninth Edition.

3. Metals Handbook. American Society for Metals, 8th Edition.

4. ASM Material Properties Handbook Titanium Alloys, ed. Rodney Boyer, Gerhard Welsch, E.W. Collings, 1994

3.2.2 Component Specifications

All components are specified and described on the drawings included in the Section 1.4.

3.3 General Considerations

3.3.1 Evaluation by Analysis

Evaluations by analysis are described in the section they apply to in this Safety Analysis Report or when applicable in the Test Plans contained in Section 2.12.

3.3.2 Evaluation by Test

Evaluations by direct testing are documented in the Test Plans contained in Section 2.12.

3.3.3 Margins of Safety

Margins of safety are discussed in each section as appropriate. All testing and analysis resulted in no loss of source containment or securement in the transport packages. Though this demonstrates package compliance, it is difficult to quantify the margin related to these results. All physical testing used multiple specimens, with demonstrated results well within the regulatory requirements. Based on the results of the physical testing and the related analyses, we estimate the margin of safety for the Model 880 Series packages as high.

3.4 Thermal Evaluation for Normal Conditions of Transport

3.4.1 Heat and Cold

3.4.1.1 Insolation and Decay Heat
(Reference:
- *USNRC, 10 CFR 71.71(c)(1)*
- *IAEA TS-R-1, paragraphs 651)*

This analysis determines the maximum surface temperature produced by solar heating of the Model 880 Series transport package loaded at maximum activity in accordance with 10 CFR 71.71(c)(1) and IAEA TS-R-1. This will be compared to the Normal Transport test conditions temperature range to determine which is the most onerous for thermal stress considerations.

The model consists of taking a steady state heat balance over the surface of the transport package. The following design analysis calculates the steady state surface temperature of a cylindrical package subjected to insolation and self-heat. The analysis is based on recognized heat transfer theory and specifically, that the total heat input due to the self-heat of the radioactive contents and the insolation energy absorbed must balance the heat loss due to convection and emitted radiation from the package surface.

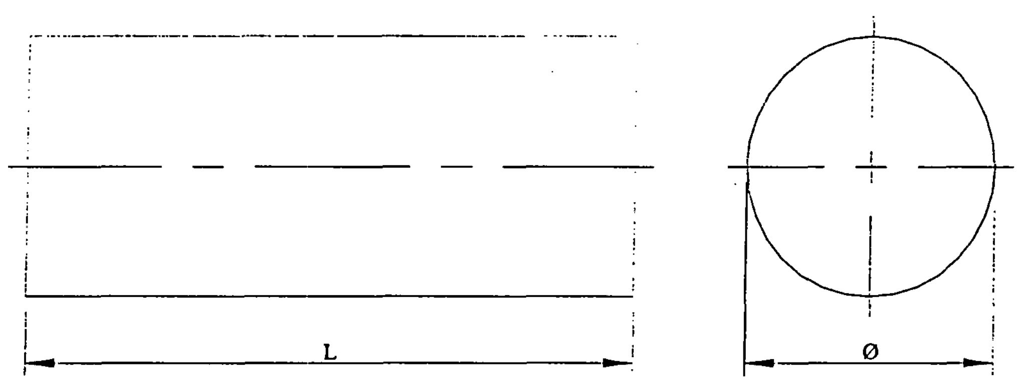


Figure 3.4a: Model of Cylindrical Package for Heat Analysis

The package is evaluated in the orientation shown in Figure 3.4a, which also defines the overall package dimensions. In order to assure conservatism, the following assumptions are made:

a. Basic Input Parameters:

Max Content Activity, A = 345 Ci of Ir-192
(150 Ci x 2.3 for self absorption)
The surface finish of the package is light silvery grade 304 stainless steel
Length of Package, L = 0.33 m
Diameter of Package, $\phi = 0.127$ m
Stefan-Boltzmann constant, $\sigma = 5.669 \times 10^{-8}$ W/m^{2}K^4
By Kirchhoff's Law Emissivity, ε = Absorptivity, α= 0.44

(Ref: Heat Transmission, 3rd Edition - McAdams)
Ambient Temperature, $T_A = 311$ K
Area of cylinder ends, $A_{CE} = 0.025$ m^2
Total Area of curved surfaces, $A_{CS} = 0.132$ m^2
Decay Heat Input $Q_{DT} = 3$ W

The transport package is assumed to undergo free radiative heat transfer from the top and sides.

b. The transport package is assumed to undergo free convective heat transfer from the top, sides and bottom.

c. To maximize the temperature of the stainless steel cylinder surface temperature, the inside transport package faces are considered perfectly insulated so there is no conduction into the transport package. In use, the inside transport package will act as a heat sink during daylight hours and a heat source during the night, but this will be ignored for this calculation.

d. The transport package is approximated as a right cylinder with dimensions, 5 inches (0.13 m) in diameter and 13 inches (0.33m) long (approximation of the solid length of the cylinder).

e. The surfaces of the transport package are assumed to be solid. The faces are considered to be sufficiently thin so that no temperature gradients exist in the faces.

f. The worst case decay heat load (3 Watts) is added to the solar heat input load.

The following heat calculations are based on the steady-state equilibrium relationship between the heat gained by the package and the heat lost.

Heat Input, Q_{IN} = Heat Output, Q_{OUT} in the steady-state.
Q_{IN} = Solar Heat Input + Decay Heat
Q_{OUT} = Heat loss by Radiation and Convection
Q_{IE} = Heat input due to insolation falling on ends
Q_{IC} = Heat input due to insolation on curved surfaces,

Solar Heat Input = $\alpha(Q_{IE} + Q_{IC})$, where α is the absorptivity

The solar heat input is the combined solar heating of the top horizontal surface and the vertical side surface. The insolation data, provided in 10 CFR 71.71(c)(1), is found in Table 3.4.1a.

Table 3.4a: Insolation Data

Surface	Insolation for a 12 hour period (g-cal/cm^2 or W/m^2)
Horizontal base	None
Other horizontal flat surfaces	800

Non-horizontal flat surfaces	200
Curved surfaces	400

Practically all solid materials used in engineering are opaque to thermal radiation (even glass is only transparent to a fairly narrow range of wavelengths), and thermal radiation is in fact either reflected or absorbed within a very shallow depth of matter. Thus for solids it is possible to neglect transmissivity and write:

$$\text{reflectivity}, \rho + \text{absorptivity}, \alpha = 1$$

i.e., the sum of the radiation reflected and absorbed by the material is equal to the total incident energy. Since the reflected energy does not contribute to the heat energy contained within the system, or package, it is not necessary to consider it in the analysis. However, the absorptivity of the material is the fraction of the total incident energy entering the system, which in this case is the heat input due to insolation.

Heat input due to insolation falling on ends, $Q_{IE} = 200\ W/m^2 \times A_{CE} = 5.1\ W$
Heat input due to insolation on curved surfaces, $Q_{IC} = 400\ W/m^2 \times A_{CS} = 52.7\ W$

In the case of a cylindrical package standing on the ground, the top surface can radiate freely to the surroundings assumed to be effectively at ambient temperature. For the vertical surface, the upper 90° of azimuth can radiate freely to the surrounding air in the same way as the top surfaces. However, some radiation emitted in the lower 90° will be intercepted by the ground and vice versa. Owing to the complex nature of radiation interchange, and allowing for this asymmetrical characteristic, a geometrical factor g is assumed in the following analysis.

For curved surfaces, $g_c = 0.5$
For vertical surfaces, $g_s = 0.5$

Radiation heat transfer from curved surfaces,

$$Q_{RC} = g_c \sigma \varepsilon A_{CS}\{T_W^4 - T_A^4\} = 1.54\times10^{-9}\{T_W^4 - T_A^4\}$$

Radiation heat transfer from end surface,

$$Q_{RE} = g_s \sigma \varepsilon A_{CE}\{T_W^4 - T_A^4\} = 3.12\times10^{-10}\{T_W^4 - T_A^4\}$$

Heat transfer by convection is complex as it represents a dynamic process involving fluid flow. Newton introduced a quantity known as the "heat transfer coefficient" represented by the symbol, h. From Newton's Law of cooling due to heat loss by convection:

$$Q_C = hA[T_W - T_A]$$

Consider the curved surface of the cylinder:

Cylindrical Surface Convection, $Q_{CC} = H_C A_{CS}[T_W - T_A]$

Where the free convection coefficient, $H_C = 1.32\{(1/\phi)^{1/4}(T_W-T_A)^{1/4}\}$ (Ref 1)

Therefore, $Q_{CC} = 0.27(T_W-T_A)^{5/4}$

Considering the vertical surfaces of the cylinder:

Vertical End Surface Convection, $Q_{CE} = H_S A_{CE}\{T_W-T_A\}$

Where the free convection coefficient, $H_S = 1.42\{(1/\phi)^{1/4}(T_W-T_A)^{1/4}\}$ (Ref. 1)

Therefore, $Q_{CE} = 0.06\,(T_W-T_A)^{1.25}$

Total Heat Input, $Q_{IN} = \alpha(Q_{IE} + Q_{IC}) + Q_{DT} = 28$ W

Total Heat Output, $Q_{OUT} = (Q_{RC} + Q_{RE}) + (Q_{CC} + Q_{CE})$

$$28\text{W} = 1.86\times10^{-9}\{T_W^4 - (311)^4\} + 3.34\times10^{-1}(T_W - (311))^{1.25}$$

Iteration of this relationship yields a maximum wall temperature (T_W) of 65.4°C (149.6°F). This temperature would constitute the most onerous Normal Transport thermal condition. Based on the package materials of construction, this temperature will not be sufficient to adversely affect the package containment or shielding integrity. As such the package complies with the requirements of this section.

References:

1. Engineering Thermodynamics, Work & Heat Transfer - 4th Edition., Rogers & Mayhew.

2. Heat Transmission, 3rd Edition - M^{c}Adams.

3.4.1.2 <u>Still Air (shaded) Decay Heating</u>
(Reference:
- *USNRC, 10 CFR 71.43(g)*
- *IAEA TS-R-1, paragraphs 617)*

This analysis calculates the maximum surface temperature of the Model 880 Series Transport package in the shade (i.e., no insolation effects), assuming an ambient temperature of 38°C (100°F), per 10 CFR 71.43(g).

The same assumptions from Section 3.4.1.1 are used. The following heat calculations are based on the steady-state equilibrium relationship between the heat gained by the package and the heat lost.

Heat Input, Q_{IN} = Heat Output, Q_{OUT} and Q_{IN} = Decay Heat = 3 Watts

Q_{OUT} = Heat loss by Convection

Heat transfer by convection is complex as it represents a dynamic process involving fluid flow. Newton introduced a quantity known as the "heat transfer coefficient" represented by the symbol, h. From Newton's Law of cooling due to heat loss by convection:

$$Q_C = hA[T_W - T_A]\ (W)$$

Considering the curved surface of the cylinder:

Cylindrical Surface Convection, $Q_{CC} = H_C A_{CS}[T_W - T_A]$

Where the free convection coefficient, $H_C = 1.32\{(1/\phi)^{1/4}(T_W - T_A)^{1/4}\}$ (Ref. 1 Section 3.4.1.2)

Therefore, $Q_{CC} = 0.27\ (T_W - T_A)^{1.25}$

Considering the vertical surfaces of the cylinder:

Vertical End Surface Convection, $Q_{CE} = H_S A_{CE}\{T_W - T_A\}$

Where the free convection coefficient, $H_S = 1.42\{(1/\phi)^{1/4}(T_W - T_A)^{1/4}\}$ (Ref. 1 Section 3.4.1.2)

Therefore, $Q_{CE} = 0.06\times(T_W - T_A)^{1.25}$

Total Heat Input, $Q_{IN} = Q_{DT} = 3$ W

Total Heat Output, $Q_{OUT} = (Q_{CC} + Q_{CE}) = 3.34\times10^{-1}(T_W - T_A)^{1.25}$

Since Heat Input, Q_{IN} = Heat Output, Q_{OUT}, in the steady state.

$$3\ W = 3.34\times10^{-1}(T_W - T_A)^{1.25}$$

Solving for T_W, $T_W = T_A + [3/(3.34\times10^{-1})]^{0.8} = 320$ K

Therefore, a maximum wall temperature (T_W) of 47°C (116°F), which is less than the maximum 50°C (122°F) allowed by 10 CFR 71.43(g).

3.4.1.3 Cold Effected Materials

An ambient air temperature of –40 F in still air and shade has no effect on the safety of the package. The safety materials: stainless steel, titanium, tungsten and depleted uranium retain their mechanical properties at this temperature. Thus, it is concluded that the Model 880 transport package will withstand the normal transport cold condition.

3.4.2 Maximum Normal Operating Pressure

All 880 Series components are vented to the atmosphere. As such, pressure will not build up in the packages during Normal Transport conditions. Containers will exhibit a pressure differential of 0 psi as they are vented to the atmosphere with no means for creating a pressure differential. No other contributing gas sources are present.

3.4.3 Maximum Thermal Stresses

The temperature and pressure variations described in Sections 3.4.1 and 3.4.2 will not adversely affect the transport package during normal transport since the melting temperatures of all safety critical components are well above these temperatures and the package will experience no pressures sufficient to cause package failure. It its therefore concluded that the Model 880 Series transport packages will maintain their structural integrity and shielding effectiveness under the normal transport thermal stress conditions.

3.5 Thermal Evaluation Under Hypothetical Accident Conditions

3.5.1 Initial Conditions

The thermal test was not performed. Rather, an assessment was performed to demonstrate that the thermal test would not create sufficient additional damage to the package that would cause it to fail final profile criteria.

Consideration of the principle materials of manufacture and their melting points indicates that they would not fail and shielding integrity would not be significantly degraded. (See Table 6: Thermal Properties of Principle Package Materials.)

Damage to the outer containment, increasing the potential for oxygen ingress to the shield, by a build up of pressure within the assembly through the pyrolization of the foam, or expansion of a trapped volume of air is not possible. The projector is vented to atmosphere through both the front and rear end plates. These vents will relieve any internal generation or expansion of gases created by the elevated temperatures.

Damage incurred during the drop testing (4 foot, 30 foot and puncture) was minimal, consisting of insignificant deformation of the shell, lock mounting block and dust cover, slight bowing of the end plates and loss of one rear plate bolt. None of the damage significantly increased, or created new, pathways for the ingress of oxygen. Oxygen ingress has been shown empirically to be the primary contributing factor in the oxidation of depleted uranium shields during thermal testing (see Section 2.7.4.1.2).

3.5.2 Fire Test Condition Assessment

Without the possibility of gross oxidation, and subsequent destruction of the shield, thermal failure is then predicated on mechanical degradation of the packages' support structure. The Model 880 is predominately of welded stainless steel construction. A similar type of construction was analyzed for the Model 865 (Certificate of Compliance number 9165). A copy of this thermal analysis is contained in Appendix E as additional supporting information. It showed that the thermal gradients that occur during temperature ramp-up (especially within the first 3 minutes) do not create undue stresses on the structure of the device (~4-5% strain).

In addition, the effect of structural yielding under self-weight at temperature caused by the degradation of mechanical properties of the materials of construction was insignificant. Areas examined were:

a. Tear-out of the shield support pin from the support bracket with the device in a vertical position (see Section 2.7.4.1.3.a).
b. Cracking of the depleted uranium (DU) around the titanium support pin due to differential expansion (see Section 2.7.4.1.3.b).
c. De-attachment of the rear lock assembly due to failure of the three- (3) remaining security screws (see Section 2.7.4.1.3.c).

Based on the previous empirical data and analyses, we conclude that oxidation of the shield will not occur, the structural integrity of the package will remain intact and the containment of the source will not be affected. As such, the Model 880 would pass the thermal test without exceeding the final profile criteria.

3.5.3 Maximum Temperatures and Pressure

All 880 Series components are vented to the atmosphere. The packages are vented to atmosphere through both the front and rear end plates. These vents will relieve any internal generation or expansion of gases created by the elevated temperatures. As such, pressure will not build up in the packages during Hypothetical Accident Transport conditions. Containers will exhibit a pressure differential of 0 psi as they are vented to the atmosphere with no means for creating a pressure differential. No other contributing gas sources are present.

3.5.4 Accident Conditions for Fissile Material Packages for Air Transport

Not Applicable. This package is not used for transport of Type B quantities of fissile material.

3.6 Appendix

Not Applicable.

Section 4 – CONTAINMENT

4.1 Description of the Containment System

(Reference:

- *USNRC, 10 CFR 71.33(a)(4)*
- *IAEA TS-R-1, paragraph 501(a), 501(b), 639 through 643 and 645)*

4.1.1 Containment Boundary

The containment system consists of the Model 880 Series transport packages and the radioactive source capsule(s). The source capsule(s) shall be qualified as Special Form radioactive material under 49 CFR 173 and IAEA TS-R-1.

4.1.2 Special Requirements for Plutonium

Not applicable. This package is not used for transport of Type B quantities of Plutonium.

4.2 General Considerations

4.2.1 Type A Fissile Packages

Not applicable. This package is not used for transport of Type A quantities of fissile material.

4.2.2 Type B Packages

(Reference:

- *USNRC, 10 CFR 71.51*
- *IAEA TS-R-1, paragraphs 646 & 656)*

As demonstrated in the Test Plan Reports and supported by assessments when applicable (Section 2.12), performance of the normal conditions of transport testing caused no loss or dispersal of radioactive contents, no significant increase in surface radiation levels and no substantial reduction in the effectiveness of the package. The Model 880 Series packages therefore meets the requirements of this section.

4.3 Containment Under Normal Conditions of Transport (Type B Packages)

(Reference:

- *USNRC, 10 CFR 71.51(a)(1)*
- *IAEA TS-R-1, paragraphs 656(a))*

As demonstrated in the Test Plan Reports and supported by assessments when applicable (Section 2.12), performance of the normal conditions of transport testing caused no breach of the source capsules contained in the package. Since the source capsules are the primary containment of the radioactive contents and no release from the source capsules occurred, the Model 880 Series packages meet the requirements of this section.

4.4 Containment Under Hypothetical Accident Conditions (Type B Packages)

(Reference:

- *USNRC, 10 CFR 71.51(a)(2)*
- *IAEA TS-R-1, paragraphs 656(b))*

As demonstrated in the Test Plan Reports and supported by assessments when applicable (Section 2.12), performance of the hypothetical accident conditions of transport testing, the radiation level at one meter from the surface of the package did not exceed 1 R/hr. The Model 880 Series packages therefore meet the requirements of this section.

4.5 Leakage Rate Tests for Type B Packages

(Reference:

- *USNRC, 10 CFR 71.51*
- *IAEA TS-R-1, paragraphs 656(a))*

The primary containment for the radioactive material in the Model 880 Series transport packages are the radioactive source capsules. All source capsules authorized for Type B transport in the Model 880 Series packages are certified as special form radioactive material under 10 CFR Part 71, 49 CFR Part 173 and IAEA TS-R-1. After manufacture and again once every six months thereafter prior to transport, the source capsule is leak tested in accordance with ISO9978:1992(E) (or more recent editions) to ensure that containment of the source does not allow release of more than 0.005 µCi of radioactive material. These fabrication and periodic tests ensure that contamination release from the package does not exceed the regulatory limits.

Reference : ISO9978:1992(E) – Radiation Protection – Sealed Radioactive Sources – Leakage Test Methods.

4.6 Appendix

Not Applicable.

Section 5 - SHIELDING EVALUATION

5.1 Description of Shielding Design

(Reference:
- *USNRC, 10 CFR 71.31*
- *IAEA TS-R-1, paragraph 701 and 702)*

5.1.1 Design Features

The principal shielding in the Model 880 transport package is the depleted uranium shield assembly. The shielding is cast as one piece and is essentially enclosed by stainless steel. Dimensional information for the individual shield containers is contained in the shield drawings included in Section 1.4.

5.1.2 Summary Table of Maximum Radiation Levels

Table 5.1a includes radiation profile data obtained from the 880 Delta package that was tested to the Normal and Hypothetical Accident Conditions of Transport under Test Plan 108 (see Section 2.12). Note that radiation survey results from this package were obtained after the package had also been subjected to the Hypothetical Accident Condition testing.

Table 5.1a: Model 880 Delta sn TP108C
Summary Table of External Radiation Levels Extrapolated to Capacity of 150 Ci Ir-192 (Non-Exclusive Use) After Normal and Hypothetical Accident Transport Condition Testing Under Test Plan 108 Report

Normal Conditions of Transport	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	1.20 (120)	1.65 (165)	1.80 (180)	0.007 (0.7)	0.008 (0.8)	0.006 (0.6)
Neutron	NA	NA	NA	NA	NA	NA
Total	1.20 (120)	1.65 (165)	1.80 (180)	0.007 (0.7)	0.008 (0.8)	0.006 (0.6)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)[1]	0.1 (10)[1]	0.1 (10)[1]

[1]Transport Index may not exceed 10. The Transport Index is equivalent to the 1 meter reading in mRem per hour (i.e., 5 mRem per hour at 1 meter = a Transport Index of 5.0).
[2]The maximum Transport Index based on the mrem per hour readings at one meter from the surface of this package was 0.8. All packages accepted and released for shipment under this Model designation will have a Transport Index less than or equal to 10.

NOTE: Survey results in Test Plan 108 Report both before and after hypothetical accident conditions were obtained from the Model 880 Delta without the optional jacket. This produced dose rates which would be higher than the Model 880 Delta if it had the optional jacket attached. Values after hypothetical accident conditions are measured 1 meter from the surface of the Model 880 Delta.

Tables 5.1b and 5.1c include radiation profile data used to demonstrate that the Model 880 Delta and 880 Elite package configurations will meet the external radiation level requirements for non-exclusive use transport when loaded to capacity for Se-75. By assessment, since the Model 880 Sigma shield has greater shielding than the Model 880 Elite shield, the Model 880 Sigma package configuration will also meet the external radiation level requirements for non-exclusive use when loaded to capacity for Se-75.

Table 5.1b: Model 880 Delta sn D2375 - Summary Table of External Radiation Levels Extrapolated to Capacity of 150 Ci Se-75 (Non-Exclusive Use)[1]

	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.13 (13)	0.13 (13)	0.13 (13)	0.01 (1.0)	0.01 (1.0)	0.01 (1.0)
Neutron	NA	NA	NA	NA	NA	NA
Total	0.13 (13)	0.13 (13)	0.13 (13)	0.01 (1.0)	0.01 (1.0)	0.01 (1.0)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)[1]	0.1 (10)	0.1 (10)

[1]Profile results obtained based on Model 424-25W sn 23904B Se-75 source assembly of 79.2 Ci. Values listed in the table are corrected for capacity and detector geometry. Physical measurements were obtained using Model E-600 and Model ND-500P survey meters.

Table 5.1c: Model 880 Elite sn E1060 - Summary Table of External Radiation Levels Extrapolated to Capacity of 150 Ci Se-75 (Non-Exclusive Use)[1]

	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.13 (13)	0.13 (13)	0.13 (13)	0.01 (1.0)	0.01 (1.0)	0.01 (1.0)
Neutron	NA	NA	NA	NA	NA	NA
Total	0.13 (13)	0.13 (13)	0.13 (13)	0.01 (1.0)	0.01 (1.0)	0.01 (1.0)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)[1]	0.1 (10)	0.1 (10)

[1]Profile results obtained based on Model 424-25W sn 23904B Se-75 source assembly of 79.2 Ci. Values listed in the table are corrected for capacity and detector geometry. Physical measurements were obtained using Model E-600 and Model ND-500P survey meters.

Tables 5.1d includes radiation profile data used to demonstrate that the Model 880 Elite package configuration will meet the external radiation level requirements for non-exclusive use transport when loaded to capacity for Ir-192.

Table 5.1d: Model 880 Elite sn E1060 - Summary Table of External Radiation Levels Extrapolated to Capacity of 50 Ci Ir-192 (Non-Exclusive Use)[1]

	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	1.35 (135)	1.64 (164)	1.43 (143)	0.008 (0.8)	0.017 (1.7)	0.009 (0.9)
Neutron	NA	NA	NA	NA	NA	NA
Total	1.35 (135)	1.64 (164)	1.43 (143)	0.008 (0.8)	0.017 (1.7)	0.009 (0.9)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)[1]	0.1 (10)	0.1 (10)

[1]Profile results obtained based on Model 424-9 sn 22029B Ir-192 source assembly of 43.3 Ci. Values listed in the table are corrected for capacity and detector geometry. Physical measurements were obtained using Model E-600 and Model ND-500P survey meters.

5.2 Source Specification

5.2.1 Gamma Source

(Reference:

- *USNRC, 10 CFR 71.33(b)(1) & (3))*
- *IAEA TS-R-1, Section IV & paragraph 807(a))*

The gamma sources allowed for transport in the Model 880 Series transport package specified in Sections 1.2.3 and 2.10.

5.2.2 Neutron Source

Not Applicable. The Model 880 Series transport packages are not used for the transportation of neutron emitting sources.

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

A shielding model was not used as the primary justification for these packages. Shielding justification was based on direct measurement.

5.3.2 Material Properties

Not Applicable. A shielding model was not used in the justification for these packages. Shielding justification was based on direct measurement.

5.4 Shielding Evaluation

5.4.1 Methods

Shielding justification was based on direct measurement and assessment. Radiation profiles have not been performed for the Model 880 Sigma, however, the shield design is identical to the Model 880 Delta. This design is capable of producing shields that can adequately shield 150 Ci of Ir-192 to within the regulatory dose limits. Due to variances in the shield manufacturing process, some shields are produced with a slightly lower shielding capacity. Shields which demonstrate a capacity of 130 Ci of Ir-192, based on device profiles prior to final acceptance and shipment, are distributed as Model 880 Sigma devices.

All packages are profiled prior to final acceptance and shipment. This profile takes into account the maximum capacity and detector geometry. Any package not meeting the required dose rates is rejected.

If the optional jacket is used, it will further reduce surface dose rates on some areas of the package. As such, the use of the jacket will have no detrimental impact on dose rates.

5.4.2 Input and Output Data

Radiation measurements included in this Section were adjusted to the maximum activity capacity for the package (e.g., activity correction factor) and the surface measurements were also adjusted to correct for off-set of the survey meter probe from the true surface of the package.

Activity correction factors (CF_A) were obtained by using the following relationship:

$$CF_A = \frac{Maximum Package Activity Capacity\ (A_C)}{Actual\ \mathrm{Pr}ofile Activity\ (A_P)}$$

$$For Example,\ if\ A_P = 135\ Ci\ and\ A_C = 150\,Ci,\ then$$

$$CF_A = \frac{150\,Ci}{135\,Ci} = 1.1$$

Therefore all original surface and 1 meter profile measurements would be multiplied by a factor of 1.2 for a package profiled using 834 Ci and a package capacity of 1,000 Ci.

Radiation measurements at the surface of the container were also adjusted to compensate for the off-set of the survey meter probe from the true surface of the package.

Surface correction factors (SCF) were obtained by using one of the following relationships:

$$SCF = \sqrt{\frac{d_2^2}{d_1^2}} \text{ where } d_1 \text{ and } d_2 \text{ are determined as shown in Figure 5.a.}$$

$$For Example, \text{ if } d_1 = 9 \text{ inches and } d_2 = 9.5 \text{ inches, then}$$

$$SCF = \sqrt{\frac{(9.5\, inches)^2}{(9\, inches)^2}} = 1.06$$

Subsequent evaluation of the SCF revealed that the use of the inverse square law introduces an error when the material of the shield contains a heavy element such as tungsten, uranium or lead. When heavy shields are involved there is a build up of Compton-scattered photons and X-rays which causes scattered radiation to emanate from everywhere within the shield and not just from the source in the center. Under these circumstances, the inverse square law relationship between dose rate and distance overestimates the actual dose rate on the surface of the device.

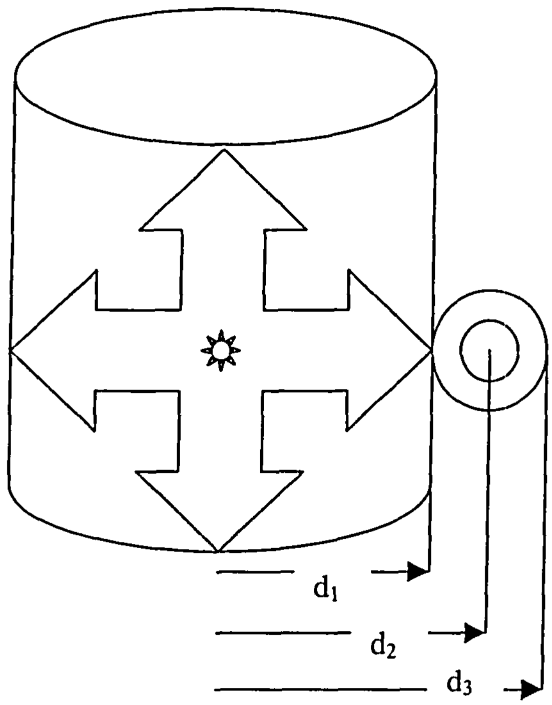
Experimental measurement using TLDs have demonstrated that the SCF for devices using heavy element shielding varies more accurately as follows:

$$SCF = \sqrt{\frac{d_3}{d_1}} \text{ where } d_1 \text{ and } d_3 \text{ are determined as shown in Figure 5.a.}$$

$$For Example, \text{ if } d_1 = 9 \text{ inches and } d_3 = 10 \text{ inches, then}$$

$$SCF = \sqrt{\frac{(10\, inches)}{(9\, inches)}} = 1.05$$

Therefore in the example shown, all original surface profile measurements located along the side of the device shown in Figure 23 would also be multiplied by a factor to account for surface correction of the detector to the device. Different SCF's would be calculated for the any dimension of the container where the minimum distance from the center of the activity to the center of the radiation probe is different.



d_1 =	distance from activity center to surface of container.
d_2 =	distance from activity center to surface of container plus radius of the survey meter probe.
d_3 =	distance from activity center to back of the probe.

FIGURE 5.a. SAMPLE SURFACE CORRECTION FACTOR DISTANCE CRITERIA

The radiation profile data showed no increase in radiation dose after testing beyond normal measurement variations. All test specimens met the regulatory requirements.

5.4.3 Flux-to-Dose-Rate Conversion

Not Applicable. Flux rates were not used to convert to dose rates in any shielding evaluations.

5.4.4 External Radiation Levels

Radiation surveys for all 880 Series configurations showed maximum surface and 1 meter radiation levels from the transport packages within regulatory limits. Radiation surveys of 880 Series transport packages after undergoing normal and accident condition transport testing were also well within the regulatory limits.

5.5 Appendix

Not Applicable.

Section 6 - CRITICALITY EVALUATION

All parts of this section are not applicable. The Model 880 Series transport packages are not used for shipment of Type B quantities of fissile material.

Section 7 – Package Operations

Operation of the Model 880 Series transport packages must be in accordance with the operating instructions supplied with the transport package, per 10 CFR 71.87 and 71.89.

(Reference:
- *USNRC, 10 CFR 71.87 and 71.89*
- *IAEA TS-R-1, paragraph 501(a), 502(e) and 503)*

7.1 Package Loading

7.1.1 Preparation for Loading

The Model 880 Series packages must be loaded and closed in accordance with the following (or equivalent) written procedures. Shipment of Type B quantities of radioactive material are authorized for sources specified in Section 7.1.1.1. Maintenance and inspection of the Model 880 Series packaging is in accordance with the requirements specified in Section 7.1.1.2.

7.1.1.1 Authorized Package Contents

(Reference:
- *USNRC, 10 CFR 71.87(a)*
- *IAEA TS-R-1, paragraph 502(f))*

Table 7.1a: Model 880 Series Package Information

Identification	Nuclide	Form	Maximum Capacity[2]	Maximum DU Weight	Maximum Weight Without Jacket	Maximum Weight With Jacket
880 Delta	Ir-192	Special Form Sources	150 Ci	34 lbs (15 kg)	46 lbs (21 kg)	52 lbs (24 kg)
	Se-75	Special Form Sources	150 Ci			
880 Sigma	Ir-192	Special Form Sources	130 Ci	34 lbs (15 kg)	46 lbs (21 kg)	52 lbs (24 kg)
	Se-75	Special Form Sources	150 Ci			
880 Elite	Ir-192	Special Form Sources	50 Ci	25 lbs (11 kg)	37 lbs (17 kg)	42 lbs (19 kg)
	Se-75	Special Form Sources	150 Ci			

[2] Maximum Capacity Activity for Ir-192 is defined as output Curies as required in ANSI N432 and 10 CFR 34.20 and in line with TS-R-1 and Rulemaking by the USNRC and the USDOT published in the Federal Register on 26 January 2004 .

7.1.1.2 Packaging Maintenance and Inspection Prior to Loading

7.1.1.2.a Ensure all markings are legible.

7.1.1.2.b Inspect the container for signs of significant degradation. Ensure all welds are intact, the container is free of heavy rust and cracks/damage to the steel housing which breaches the container.

7.1.1.2.c Ensure all bolts are present and secured. Assure the front port is properly secured. Ensure a seal wire is properly installed, if used.

7.1.1.2.d If the container fails any of the inspections in steps 7.1.1.2.a-c, remove the container from use until it can be brought into compliance with the Type B certificate.

7.1.2 Loading of Contents

NOTE: ***These loading operations apply to "dry" loading only. None of the shield configurations for the Model 880 Series packages are approved for wet loading.***

7.1.2.1 Prior to transportation, ensure the package and its contents meet the following requirements:

7.1.2.1.a The contents are authorized for use in the package.

7.1.2.1.b The package condition has been inspected in accordance with Section 7.1.1.2.

7.1.2.1.c Ensure that the source is secured into place in the storage position in accordance the operating instructions supplied with the transport package, per 10 CFR 71.89.

7.1.3 Preparation for Transport

(Reference:

- *10 CFR 71.87*
- *IAEA TS-R-1, applicable paragraphs of Section V)*

7.1.3.1 Ensure that all conditions of the certificate of compliance are met.

7.1.3.2 Perform a contamination wipe of the outside surface of the package and ensure removable contamination does not exceed 0.0001 μCi when averaged over a wipe area of 300 cm^2.

7.1.3.3 Survey all exterior surfaces of the package to assure that the radiation level does not exceed 200 mR/hr at the surface. Measure the radiation level at one meter from all exterior surfaces to assure that the radiation level is less than 10 mR/hr.

7.1.3.4 Ship the container according to the procedure for transporting radioactive material as established in 49 CFR 171-178.

NOTE: The US Department of Transportation, in 49 CFR 173.22(c), requires each shipper of Type B quantities of radioactive material to provide prior notification to the consignee of the dates of shipment and expected arrival.

7.2 Package Unloading

7.2.1 Receipt of Package from Carrier

7.2.1.1 The consignee of a transport package of radioactive material must make arrangements to receive the transport package when it is delivered. If the transport package is to be picked up at the carrier's terminal, 10 CFR 20.1906 requires that this be done expeditiously upon notification of its arrival.

7.2.1.2 Upon receipt of a transport package of radioactive material:
(Reference:
- *IAEA TS-R-1, paragraph 510 and 511)*

7.2.1.2.a Survey the transport package with a survey meter as soon as possible, preferably at the time of pick-up and no more than three hours after it was received during normal working hours. Radiation levels should not exceed 200 mR/hr at the surface of the transport package, nor 10 mR/hr at a distance of 1 meter from the surface.

7.2.1.2.b Record the actual radiation levels on the receiving report.

7.2.1.2.c If the radiation levels exceed these limits, secure the container in a Restricted Area and notify the appropriate personnel in accordance with 10 CFR 20 or applicable Agreement State regulations.

7.2.1.2.d Inspect the outer container for physical damage or leaking. If the package is damaged or leaking or it is suspected that the package may have leaked or been damaged, restrict access to the package. As soon as possible, contact the Radiation Safety Office to perform a full assessment of the package condition and take necessary follow-up actions.

7.2.1.2.e Record the radioisotope, activity, model number, and serial number of the source and the transport package model number and serial number.

7.2.2 Removal of Contents

7.2.2.1 Unload the package must be in accordance with the instructions supplied with the package per 10 CFR 71.89.

7.2.2.2 Unloading of the package must also be in accordance with applicable licensing provisions for the user's facility related to radioactive material handling.

7.3 Preparation of Empty Package for Transport

(Reference:
- *IAEA TS-R-1, paragraph 520)*

In the following instructions, an *empty* transport package refers to a Model 880 Series transport package without an active source contained within the shielded container. To ship an empty transport package:

7.3.1. Perform the following procedure to confirm that there are no unauthorized sources within the container:

7.3.1.1. Remove the authorized source assembly from the package be in accordance with the instructions supplied with the package per 10 CFR 71.89.

7.3.1.2. After removing the source and disconnecting the source assembly, attach the jumper (dummy connector without a serial number) to the male connector of the drive cable.

7.3.1.3. Retract the jumper into the package and disconnect the controls.

7.3.1.4. Insert the shipping cover, rotate the selector ring to the lock position, depress the plunger lock and remove the key.

7.3.1.5. Remove the source identification tag from the package and keep it with the source.

7.3.2 Assure that the levels of removable radioactive contamination on the outside surface of the transport package does not exceed 4 Bq/cm^2 (when averaged over 300 cm^2).

7.3.3 Assure that the levels of removable radioactive contamination on the inside surface of the shield container does not exceed 400 Bq/cm^2 (when averaged over 300 cm^2).

7.3.4 When it is confirmed that the Model 880 Series transport package is empty, prepare the transport package for shipment. Survey the assembled package to ensure the external surface radiation level does not exceed 5 μSv/h.

7.3.5 Ship the container according to the procedure for transporting radioactive material as established in 49 CFR 171-178.

7.4 Other Operations

7.4.1 Package Transportation By Consignor

(Reference:
- *IAEA TS-R-1, paragraph 508, 512 through 514)*

Persons transporting the Model 880 Series transport package in their own conveyances should comply with the following:

7.4.1.1 For a conveyance and equipment used regularly for radioactive material transport, check to determine the level of contamination that may be present on these items. This contamination check is suggested if the package shows signs of damage upon receipt or during transport, or if a leak test on the special form source transported in the package exceeds the allowable limit of 185 Bq.

7.4.1.2 If contamination above 4 Bq/cm^2 (when averaged over 300 cm^2) is detected on any part of a conveyance or equipment used regularly for radioactive material transport, or if a radiation level exceeding 5 μSv/h is detected on any conveyance or equipment surface, then remove the affected item from use until decontaminated or decayed to meets these limits.

7.4.2 Emergency Response

(Reference:

- *IAEA TS-R-1, paragraph 308 and 309)*

In the event of a transport emergency or accident involving this package, follow the guidance contained in "2000 Emergency Response Guidebook: A Guidebook for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident", or equivalent guidance documentation.

Reference: "2000 Emergency Response Guidebook: A Guidebook for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident"

7.5 Appendix

Not Applicable.

Section 8 - ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Test

8.1.1 Visual Inspections and Measurements

8.1.1.1 Visually inspect each transport package component to be shipped to assure the following:

8.1.1.1.a Remove the authorized source assembly from the package be in accordance with the instructions supplied with the package per 10 CFR 71.89

8.1.1.1.b The transport package was assembled properly to the applicable drawing.

8.1.1.1.c Evaluate each shield container for shielding integrity when used in the applicable Model 880 Series assembly to ensure the transport dose rate requirements are met when the container is loaded to capacity.

8.1.1.1.d All fasteners as required by the applicable drawings are properly installed and secured.

8.1.1.1.e The relevant labels are attached, contain the required information, and are marked in accordance with 10 CFR 20.1904, 10 CFR 40.13(c)(6)(i), 10 CFR 34, and 10 CFR 71 or equivalent Agreement State regulations.

8.1.1.2 Visual inspections and measurements will be performed in accordance with QSA Global Inc.'s USNRC approved Quality Assurance Program No. 0040.

8.1.2 Weld Examinations

Weld examinations will be performed in accordance with the applicable drawings requirements and in accordance with QSA Global Inc.'s USNRC approved Quality Assurance Program No. 0040.

8.1.3 Structural and Pressure Tests

(Reference:

- *10 CFR 71.85(a) and (b))*
- *IAEA TS-R-1, paragraph 501(a))*

Prior to first use as part of a 880 Series transport package, container structural conformance will be evaluated in accordance with the applicable drawings requirements and in accordance with QSA Global Inc.'s USNRC approved Quality Assurance Program No. 0040. The containment system is not designed to require increased or decreased operating pressures to maintain containment during transport, therefore pressure tests of package components prior to first use is not required.

8.1.4 Leakage Tests

The source capsules (primary containment) are wipe tested for leakage of radioactive contamination upon initial manufacture. The removable contamination must be less than 0.005 microcuries. The source capsules will also be subjected to leak tests under ISO9978:1992(E) (or more recent editions). The source capsules are not used if they fail any of these tests.

8.1.5 Component and Material Tests

Component and material compliance is achieved in accordance with the requirements in QSA Global Inc.'s USNRC approved Quality Assurance Program No. 0040.

8.1.6 Shielding Tests

The radiation levels at the surface of the transport package and at 1 meter from the surface are evaluated prior to first transport. These radiation levels, when extrapolated to the rated capacity of the transport package, must not exceed 200 mR/hr at the surface, nor 10 mR/hr at 1 meter from the surface of the transport package. Failure of this test will prevent use of the transport package as a Type B(U) package.

8.1.7 Thermal Tests

Not applicable. The source content of the Model 880 Series packages has minimal effect on the package surface temperature and therefore no additional testing is necessary to evaluate thermal properties of the packaging.

8.1.8 Miscellaneous Tests

Not applicable.

8.2 Maintenance Program

8.2.1 Structural and Pressure Tests

Not applicable. Material certification, or equivalent dedication process, is obtained for Safety Class A components used in the transport package prior to their initial use. Based on the construction of the design, no additional structural testing during the life of the package is necessary if the container shows no signs of defect when prepared for shipment in accordance with the requirements of Section 7 of the SAR. The 880 Series packaging system is not designed to require increased or decreased operating pressures to maintain containment during transport, therefore pressure tests of package components prior to individual shipment is not required.

8.2.2 Leakage Tests

As described in Section 8.1.4, "Leakage Tests," the radioactive source assembly is leak-tested at manufacture. In addition, the sources are leak tested in accordance with that Section at least once every six months thereafter if being transported to ensure that removable contamination is less than 0.005 microcuries. Also a contamination wipe is performed of the shield source tubes whenever the shield is returned to the manufacturer (typically the shield is shipped to a customer with new sources and may be returned directly to the manufacturer with decayed sources for disposition).

8.2.3 Component and Material Tests

The transport package is inspected for tightness of fasteners, proper seal wires, and general condition prior to each use as described in Section 7 of this SAR. No additional component or material testing is required prior to shipment.

8.2.4 Thermal Tests

Not applicable. The source content of the Model 880 Series packages has minimal effect on the package surface temperature and therefore no additional testing is necessary to evaluate thermal properties of the packaging prior to shipment.

8.2.5 Miscellaneous Tests

Inspections and tests designed for secondary users of this transport package under the general license provisions of 10 CFR 71.17(b) are provided in Section 7.

8.3 Appendix

Not applicable.

Section 9 – IAEA TS-R-1 1996 Edition (Revised) Requirements not Otherwise Addressed – Section VI

9.1 General Package Design Requirements

9.1.1 *(Reference: IAEA TS-R-1, paragraph 609)*

As far as practicable, the packaging shall be so designed and finished that the external surfaces are free from protruding features and can be easily decontaminated.

The exterior surface of the 880 Series packages is comprised of a stainless steel drum with an optional polyurethane jacket. The materials and fabrication of the package provides an external surface which is free from protruding features not necessary for use of the package and it can be easily decontaminated if necessary.

9.1.2 *(Reference: IAEA TS-R-1, paragraph 610)*

As far as practicable, the outer layer of the package shall be so designed as to prevent the collection and the retention of water.

The exterior surface of the 880 Series packages is comprised of a stainless cylinder and an optional polyurethane jacket. The materials and fabrication of the package are water resistant and prevent, as far as practicable, the collection and retention of water.

9.1.3 *(Reference: IAEA TS-R-1, paragraph 611)*

Any features added to the package at the time of transport which are not part of the package shall not reduce its safety.

There are no added features to the package other than transport labels, markings, etc. These items are standard in package shipment and will not reduce the package safety due to their presence.

9.1.4 *(Reference: IAEA TS-R-1, paragraph 614)*

All valves through which the radioactive contents could otherwise escape shall be protected against unauthorized operation.

Not applicable. This package does not incorporate the use of valves.

9.1.5 *(Reference: IAEA TS-R-1, paragraph 616)*

For radioactive material having other dangerous properties the package design shall take into account those properties; see paras 109 and 507.

Not applicable. The contents of this package do not have any other dangerous properties other than its radioactivity.

9.2 Requirements for Type A Packages (required by TS-R-1 paragraph 650)

9.2.1 *(Reference: IAEA TS-R-1, paragraph 644)*

All valves, other than pressure relief valves, shall be provided with an enclosure to retain any leakage from the valve.

Not applicable. This package does not incorporate the use of valves.

9.2.2 *(Reference: IAEA TS-R-1, paragraph 647)*

The design of a package intended for liquid radioactive material shall make provision for ullage to accommodate variations in the temperature of the contents, dynamic effects and filling dynamics.

Not applicable. This package is not used for the transport of liquids.

9.3 Requirements for Type B(U) Packages

9.3.1 *(Reference: IAEA TS-R-1, paragraph 659)*

A package shall not include a pressure relief system from the containment system which would allow the release of radioactive material to the environment under the conditions of the tests specified in paras 719-724 and 726-729.

Not applicable. This package does not incorporate a pressure relief system.

9.4 Appendix

Not Applicable.