SAFETY ANALYSIS REPORT

AMERSHAM CORPORATION

MODEL 660

TYPE B (U) PACKAGE

USA/9033/B(U)

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SECTION 1

GENERAL INFORMATION

1.1 Introduction

The Amersham Model 660 is designed for use as a radiographic exposure device and transport package for Type B quantities of radioactive material in special form. The Model 660 conforms to the criteria for Type B(U) packaging in accordance with 10 CFR 71 and IAEA Safety Series No. 6, 1973 Revised Edition (as amended).

1.2 Package Description

1.2.1 Packaging

The Model 660 is 324 mm (12.75 in) long, 133 mm (5.25 in) wide and 245 mm (9.65 in) high. The package incorporates an aluminum handle for movement of the exposure device. The total mass of the package is 24 kg (53 lbs).

The radioactive material is sealed in a source capsule which conforms to the requirements for special form radioactive material. This source capsule is installed into a source holder assembly.

The source holder assembly is housed in an "S" shaped titanium or zircalloy source tube. The source tube has an outside diameter of 11.86 mm (0.467 in) and an inside diameter of 9.78 mm (0.385 in). The source tube is surrounded by uranium metal as shielding material. The uranium shielding is cast in place around the source tube. The mass of the uranium shield is (16.8 kg) 37 lbs.

The uranium shield is encased in a steel housing. The housing is made up of a shell and two end plates. The shell is fabricated from 16 gauge (0.063 in thick) stainless steel. The end plates are bolted together by means of 4 tapped rods that extend through the shell and by flat head screws.

The void space in the housing is filled with a rigid polyurethane foam. The outer packaging is designed to avoid the collection and retention of water. The package has a smooth finish to provide for easy decontamination.

Attached to the rear plate is the control connector and lock assembly. This assembly incorporates an automatic locking feature that locks the source assembly in the exposure device when the source is returned to the stored position.

In addition the source cannot be exposed unless a secure connection of the source assembly to the drive cable has been made. The control unit cannot be disconnected unless the source assembly is in the fully stored position in the shield.

Attached to the front plate of the exposure device is the storage plug connector. This connector provides a means of fastening the source storage plug to the exposure device. The storage plug and the connector are drilled for the attachment of a seal wire which provides a means of installing a tamper proof seal to insure that the source has not been inadvertently or intentionally moved from its proper storage position during shipment. The storage plug prevents dirt from entering the exposure device whenever the device is not in use.

The radioactive material is sealed inside a stainless steel capsule. This capsule acts as a containment vessel for the radioactive material.

1.2.2 <u>Operational Features</u>

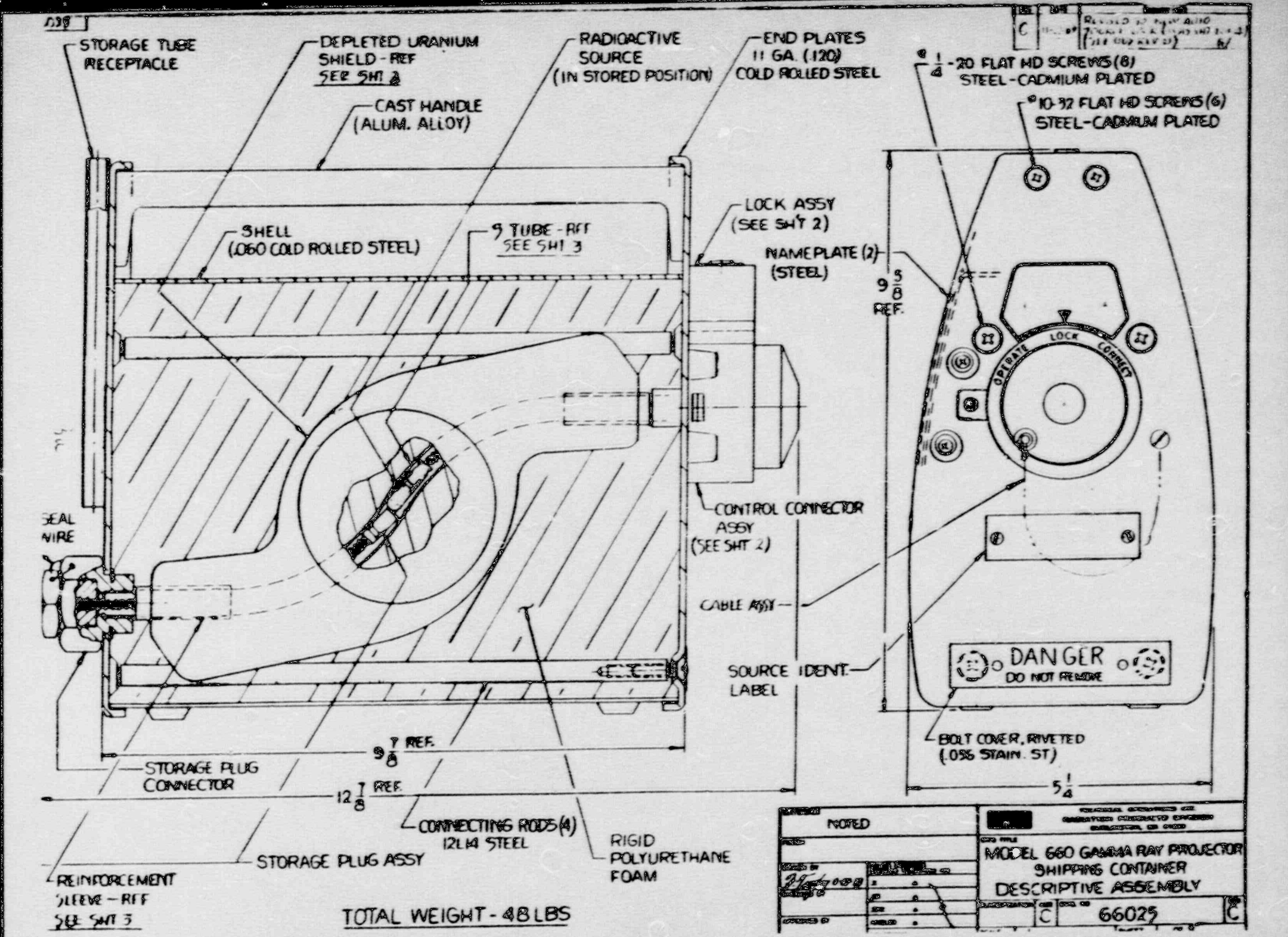
The source assembly is secured in the proper shielded storage position by the locking assembly. The source assembly is locked in position by the automatic locking slide and a key lock that prevents rotation of a selector ring which must be in the operate position in order for the locking slide to be unlocked. A protective cap is installed to prevent damage to the exposed end of the source assembly (the connector) when the control unit is not connected to the exposure device. The storage plug is used to provide another means of securing the source assembly in the proper storage position.

1.2.3 <u>Contents of the Package</u>

The Model 660 is designed for the transport of Iridium-192 in quantities up to 140 curies in the Amersham source assembly A424-9.

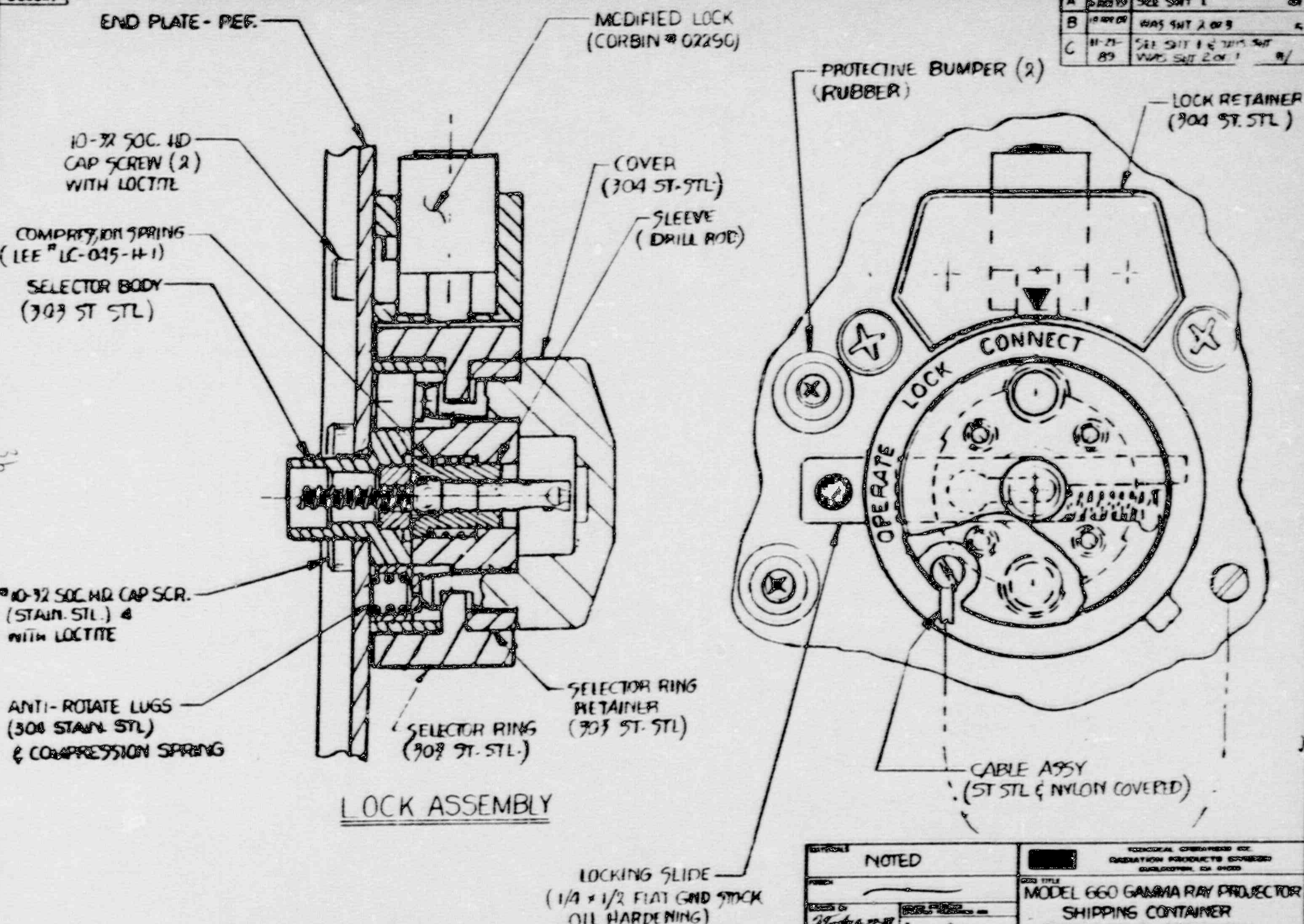
1.3 APPENDIX

Drawings: 66025 sheets 1-3


STORAGE TUBE RECEPTACLE
DEPLETED URANIUM SHIELD - REF SEE SHT 2
RADIOACTIVE 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 SHT 2)
SHELL (.060 COLD ROLLED STEEL)
S 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
BOLT COVER, RIVETED (.036 STAIN. ST)
9 7/8 REF.
STORAGE PLUG CONNECTOR
12 7/8 REF.
5 1/4
CONNECTING RODS (4) 12L14 STEEL
RIGID POLYURETHANE FOAM
STORAGE PLUG ASSY
REINFORCEMENT SLEEVE - REF SEE SHT 3
TOTAL WEIGHT - 48 LBS
NOTED
MODEL 660 GAMMA RAY PROJECTOR
SHIPPING CONTAINER
DESCRIPTIVE ASSEMBLY
C
66025
C

C66023

REV	DATE	DESCRIPTION	
A	[illegible]	922 SHT 1	
B	[illegible]	WAS SHT 2 OF 3	
C	11-21-89	SEE SHT 1 & THIS SHT WAS SHT 2 OF 1	



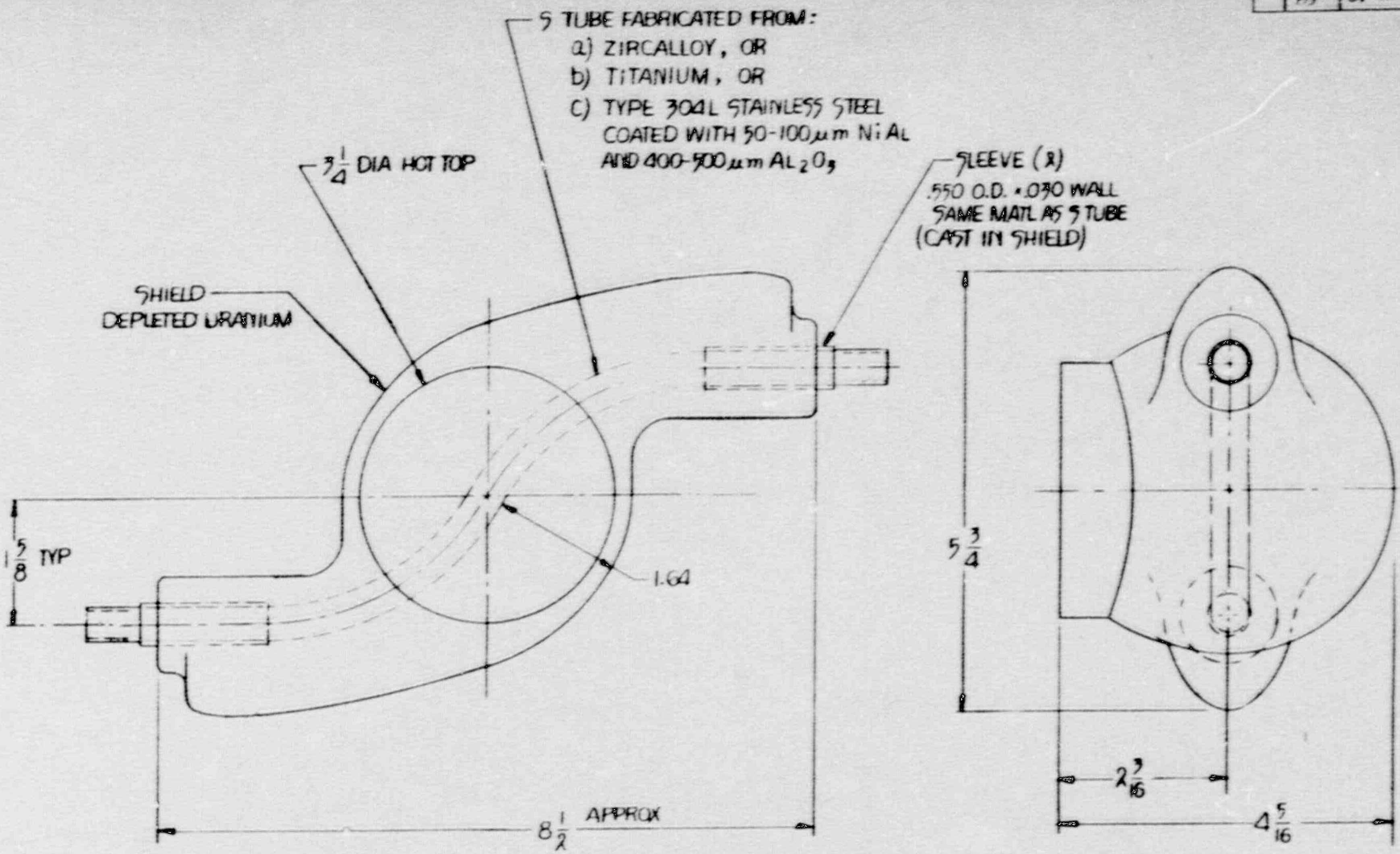
NOTED

MODEL 660 GAMMA RAY PROJECTOR
SHIPPING CONTAINER
DESCRIPTIVE ASSEMBLY

SIZE C — DWG. NO. 66025 — REV C

SCALE 2:1 — SHEET 2 OF 2

C	11-22-89	WAS SHT 4 OF 4 & REV OF THIS SHT WAS —



SHIELD DATA

35 LBS

MATERIALS	
AS NOTED	

MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY

RADIATION PRODUCTS DIVISION

SIZE C — DWG NO 66025 — REV C

SCALE 1:1 — SHEET 3 OF 3

SECTION 2

STRUCTURAL EVALUATION

2.1 Structural Design

2.1.1 Discussion

The Model 660 is comprised of five structural components: a source capsule, source holder assembly, shield assembly, outer housing assembly and locking assembly. The source capsule is the primary containment vessel. It satisfies the criteria for special form radioactive material. The shield assembly provides shielding for the radioactive material and, together with the source holder assembly and locking assembly, assures proper positioning of the radioactive source.

The outer housing is fabricated from 1.5 mm (0.060 in) thick stainless steel. The housing provides the structural integrity of the package.

The lockbox assembly secures the source holder assembly in the shielded position at the center of the source tube and assures positive closure.

2.1.2 Design Criteria

The Model 660 is designed to comply with the requirements for Type B(U) packaging as prescribed by 10 CFR 71 and IAEA Safety Series No. 6 1973 Revised Edition (as amended). All design criteria are evaluated by a straightforward application of the appropriate section of 10 CFR 71 or IAEA Safety Series No. 6.

2.2 Weights and Centers of Gravity

The total mass of the Model 660 is 24 kg (53 lbs). The shield assembly consists of 15 kg(34 lbs) of depleted uranium. The center of gravity is located approximately in the center of the device.

2.3 Mechanical properties of Materials

The outer housing of the Model 660 is fabricated from stainless steel. This material has a yield strength of 207 MPa (30,000 psi).

Drawings for the source capsules used in conjunction with the Model 660 are enclosed in Section 2.10. These source capsules are fabricated from titanium or stainless steel.

2.4 General Standards for All Packages

2.4.1 Chemical and Galvanic Reactions

The materials used in the construction of the Model 660 are uranium metal, stainless steel, titanium, and vultafoam. There will be no significant chemical or galvanic action between any of these components.

The possibility of the formation of an eutectic alloy of iron and uranium at temperatures below the melting temperatures of the individual metals has been considered. The iron uranium eutectic alloy temperature is approximately 725°C (1337°F). However, vacuum conditions and extreme cleanliness of the surfaces are necessary to produce this alloy at this low temperature. Due to the conditions in which the shield is mounted in the Model 660, sufficient contact for this effect would not exist.

In support of this conclusion, the following test results are presented. On 28 November 1973, a thermal test of a sample of bare depleted uranium metal was performed by Nuclear metals, Inc., Concord, MA. The sample was placed in a ceramic crucible and inserted in a furnace preheated to 800°C (1475°F) and remained there for thirty minutes. The sample was then removed and allowed to cool. The test indicated that the uranium sample oxidized such that the radial dimension was reduced by 0.18 mm (0.007 in).

On 25 January 1974, a subsequent test was performed by Nuclear Metals, Inc. In this test, a sample of bare depleted uranium metal was placed on a steel plate and subjected to the thermal test conditions. The test revealed no melting or alloying characteristics in the sample and the degree of oxidation was the same as experienced in the earlier test.

2.4.2 Positive Closure

The control connector and lock assembly consists of a hardened steel locking slide, a selector ring with three operating positions (connect, lock, and operate), and a casting which houses a key type lock.

The control connector and lock assembly provide for system safety in the following ways:

1. The source cannot be moved from the exposure device until a secure connection has been made between the source assembly and the control cable.

2. The locking slide cannot unlock the source until all of the following conditions are met.

   a) key lock is unlocked,
   b) the drive cable has been connected to the source assembly,
   c) the control unit has been connected to the exposure device,
   d) the selector ring has been rotated to the operate position,
   e) the locking slide is manually moved to the unlocked position.

   Note: When the locking slide is in the locked position a green colored indicator is visible. When in the unlocked position a red colored indicator can be seen.

3. The locking slide automatically locks the source assembly when the stop ball on the source assembly releases a spring loaded sleeve that keeps the locking slide open during exposure of the source. The source assembly cannot be exposed again until the locking slide is manually reset to the open position.

During transport a protective cap is inserted into the control connector, the selector ring is rotated to the lock position and the key lock is depressed into a recess in the selector ring. A storage plug is also threaded into the front of the exposure device and positioned against the source capsule on the source assembly preventing movement until the storage plug is removed. During transport the storage plug is seal wired to prevent unauthorized removal of the source assembly.

Positive closure of the package during transport is maintained with these features.

2.4.3 <u>Lifting Devices</u>

The Model 660 is designed to be lifted by its handle. Failure of this lifting system could be accomplished by shearing two Number 10 by 32 flat head screws securing one side of the handle. The yield strength of the material is assumed to be 40,000 pounds per square inch. The cross sectional area of each screw is 0.018 in. Therefore, a load of 1440 lbs must be applied to generate stress equal to the yield strength of the material.

This is equal to thirty times the weight of the package. Therefore the handle is capable of suporting three times the weight of the package without generating any stress in excess of the yield strength of the material.

2.4.4 <u>Tiedown Devices</u>

The handle of the Model 660 can also be used as a tie down device. The above analysis also demonstrates that the handle will also withstand the loading requirements of 10 CFR 71.45 (b)(3) without generating stress in excess of the yield strength.

If the tiedown technique were to fail under excessive load, the ability of the package to maintain its structural integrity and shielding efficiency would not be impaired. Therefore, the package tiedown design satisfies the criteria of 10 CFR 71.45 (b)(3).

2.5 Standards for Type B Packages

2.5.1 Load Resistance

A Model 660 was subjected to a compressive load of 300 pounds which is five times the weight of the package. This is greater than 1.85 lb/in^2 times the vertically projected area of the package.

This load was distributed uniformally over the top surface of the Model 660 for 24 hours. As a result of this test there was no loss of structural integrity or shielding efficiency. There was no visible or detectable damage as a result of this test. Therefore the Model 660 will withstand the normal conditions of transport compression condition.

2.5.2 External Pressure

The Model 660 is open to the atmosphere, thus there will be no differential pressure acting on it. The collapsing pressure of the source capsule is calculated assuming that the capsule is a thin wall tube with a wall thickness equal to the minimum depth of weld penetration which is 0.5mm (0.020 inch). The collapsing pressure is calculated from:

$$P = 597.6\ t/d - 9.556$$

where P: Collapsing pressure in MPa
t: Wall Thickness (0.5mm or 0.02 inch)
d: Outside Diameter (6.4mm or 0.250 inch)

(Ref: Machinery's Handbook, 22nd Edition, p. 330)

From this relationship, the collapsing pressure of the source capsule is calculated to be 37.1 MPa (5548 psi). Therefore, the source capsule could withstand an external pressure of 0.17 MPa (25psi).

2.6.0 Normal Conditions of Transport

2.6.1 Heat

The thermal evaluation of the Model 660 is presented in Section 3. From this evaluation, it is concluded that the Model 660 will maintain its structural integrity and shielding effectiveness under the normal transport heat condition.

2.6.2 Cold

The metals used in the manufacture of the Model 660 can all withstand a temperature of -40°C (-40°F). The outer package housing and the primary containment are all fabricated from stainless steel.

Vultafoam used in the Model 660 has an operating temperature range down to -43°C. From this data, it is concluded that the Model 660 will maintain its structural integrity and shielding effectiveness under the normal transport cold condition.

2.6.3 Reduced Pressure

The Model 660 is open to the atmosphere. Thus there will be no differential pressure acting on it.

A demonstration of the ability of the source capsules to withstand an external pressure of 0.5 atmosphere is presented in Section 3.5.4.

On the basis of this data, it is concluded that the Model 660 will maintain its structural integrity and shielding effectiveness under the normal transport pressure condition.

2.6.4 Vibration

The Model 660 has been in use for more than twenty years. In this period, there has been no evidence of vibration-induced failure.

On the basis of this history, it is concluded that the Model 660 will maintain its structural integrity and shielding effectiveness under the normal transport vibration condition.

2.6.5 Water Spray

The water spray test was not actually performed on the Model 660. The materials used in the construction of the Model 660 are highly water resistant. Therefore, it is concluded that the Model 660 will maintain its structural integrity and shielding effectiveness under the normal transport water spray condition.

2.6.6 Free Drop

A prototype Model 660 weighing 26 kg (58 lbs), was subjected to the hypothetical accident free fall condition. This is described in Section 2.7.1. On the basis of this test, it is concluded that the Model 660 will maintain its structural integrity and shielding effectiveness under the normal transport free drop condition.

2.6.7 Corner Drop

Not applicable.

2.6.8 Penetration

A prototype Model 66Ø was subjected to a penetration test. The package was impacted by the penetration bar on the locking assembly. As a result of this impact, there was no loss of structural integrity nor reduction of shielding efficiency. A report of this test is presented in Section 2.1Ø.

On the basis of this test it is concluded that the Model 66Ø will maintain its structural integrity and shielding effectiveness under the normal transport penetration condition.

2.6.9 Compression

A compression test was performed on the Model 66Ø; results are listed in Section 2.5.1.

2.7 Hypothetical Accident Conditions

2.7.1 Free Drop

The Model 66Ø was subjected to the conditions of the free drop test. The target used in this free drop test is described in the test report in Section 2.1Ø.

During the test, the package fell from a height of 1Ø m (3Ø ft) onto the target. The lock assembly was impacted as a result of this drop.

As a result of this test, there was no loss of structural integrity nor reduction in shielding efficiency. A report of this test is presented in Section 2.1Ø. On the basis of these tests, it is concluded that the Model 66Ø will maintain its structural integrity and shielding effectiveness under the hypothetical free drop accident condition.

2.7.2 Puncture

At the conclusion of the free drop test, a Model 66Ø was subjected to the puncture condition. The target for the puncture test was a steel billet 152 mm (6 in) in diameter and 2Ø3 mm (8 in) high mounted on the target used in the free drop test.

During this test, the packages dropped from the height of one meter (40 in) onto the billet, and impacted the lock assembly.
As a result of this test, there was no loss of structural integrity nor reduction in shielding efficeincy. A report of this test is presented in Section 2.10. On the basis of these tests, it is concluded that the Model 660 will maintain its structural integrity and shielding effectiveness under the hypothetical puncture accident condition.

2.7.3 Thermal

The thermal analysis is presented in Section 3.5. It is shown that the melting temperatures of the materials used in the construction of the Model 660 except for the Vultafoam are all in excess of (1475°F) 800°C.

To demonstrate that the radioactive source assemblies will remain in a shielded position following the hypothetical accident condition, the following analysis is presented. At the conclusion of the thermal test it is assumed that the Vultafoam has completely escaped from the package. The shield assembly is prohibited from movement by the front housing, rear plate and the 4 tapped rods passing from front to back to secure the shield in place.

A Model 660 was insolved in a fire in 1974 and did not suffer any loss of shielding effectiveness. A copy of this report is presented in Section 2.10.

Thus it is concluded that the Model 660 satisfactorily meet the requirements of the hypothetical thermal accident conditions of 10 CFR 71.

2.7.4 Water Immersion

Not applicable.

2.7.5 Summary of Damage

The tests designed to induce mechanical stress (free drop, puncture) caused minor deformation but no reduction in structural integrity nor impairment of any safety features. The thermal test would have no adverse affect on the package.

As a result of these tests, there was no loss of structural integrity nor release of any contents.

Prior to the performance of these tests and subsequent to the conduct of these tests, measurements of the radiation intensity in the vicinity of the package were made. The results of these measurements demonstrate that there was no reduction in shielding efficiency as a result of these tests.

2.8 Special Form

The Model 66Ø is designed to transport Amersham source capsules. These source capsules have been certified as special form radioactive material. These certificates are presented in Section 2.1Ø.

2.9 Fuel Rods

Not applicable.

2.10 Appendix

IAEA Certificate of Competent Authority USA/0335/S

Test Reports:

1) Free Drop Test
2) Puncture Test
3) 660 Involved in Fire

US Department of Transportation
Research and Special Programs Administration

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

CORRECTED COPY

IAEA CERTIFICATE OF COMPETENT AUTHORITY
SPECIAL FORM RADIOACTIVE MATERIALS
CERTIFICATE NUMBER USA/0335/S, REVISION 1

This certifies that the source described has been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in IAEA Regulations[1] and USA regulations[2] for the transport of radioactive materials.

1. Source Description - The source described by this certificate is identified as Amersham Model 875 source capsule assembly which is a single welded encapsulation constructed of Type 304 or 304L stainless steel, and measures approximately 24 mm (0.95") in length by 6.4 mm (0.25") in diameter. Contents may be further contained in stainless steel or titanium inner secondary encapsulations with springs and spacers.

2. Radioactive Contents - This source consists of not more than 8.88 TBq (240 Ci) Iridium 192 as solid metal, 8.14 TBq (220 Ci) Cobalt 60 as solid metal, 7.4 TBq (200 Ci) Ytterbium 169 as Yb_2O_3, 1.11 TBq (30 Ci) Cesium 137 as $CsCl_2$ in a secondary stainless steel encapsulation, or 1.85 TBq (50 Ci) Thulium 170 as Tm_2O_3.

3. Expiration Date - This certificate expires July 15, 1994.

This certificate is issued in accordance with paragraph 803 of the IAEA Regulations and Section 173.476 of Title 49 of the Code of Federal Regulations, and in response to the June 14, 1989 petition by Amersham Corporation, Burlington, MA, and in consideration of the associated information therein, and other information filed with this office.

Certified by:

Michael E. Wangler (signature) JUL - 5 1989

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

(DATE)

Revision 1 - Issued to change the source identification from Tech Ops to Amersham and to extend the expiration date.

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

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

TEST REPORT

BY: CATHLEEN ROUGHAN CMR
DAVE DUNCANSON

DATE: 13 OCTOBER 1989

SUBJECT: Model 660 Free Drop Test

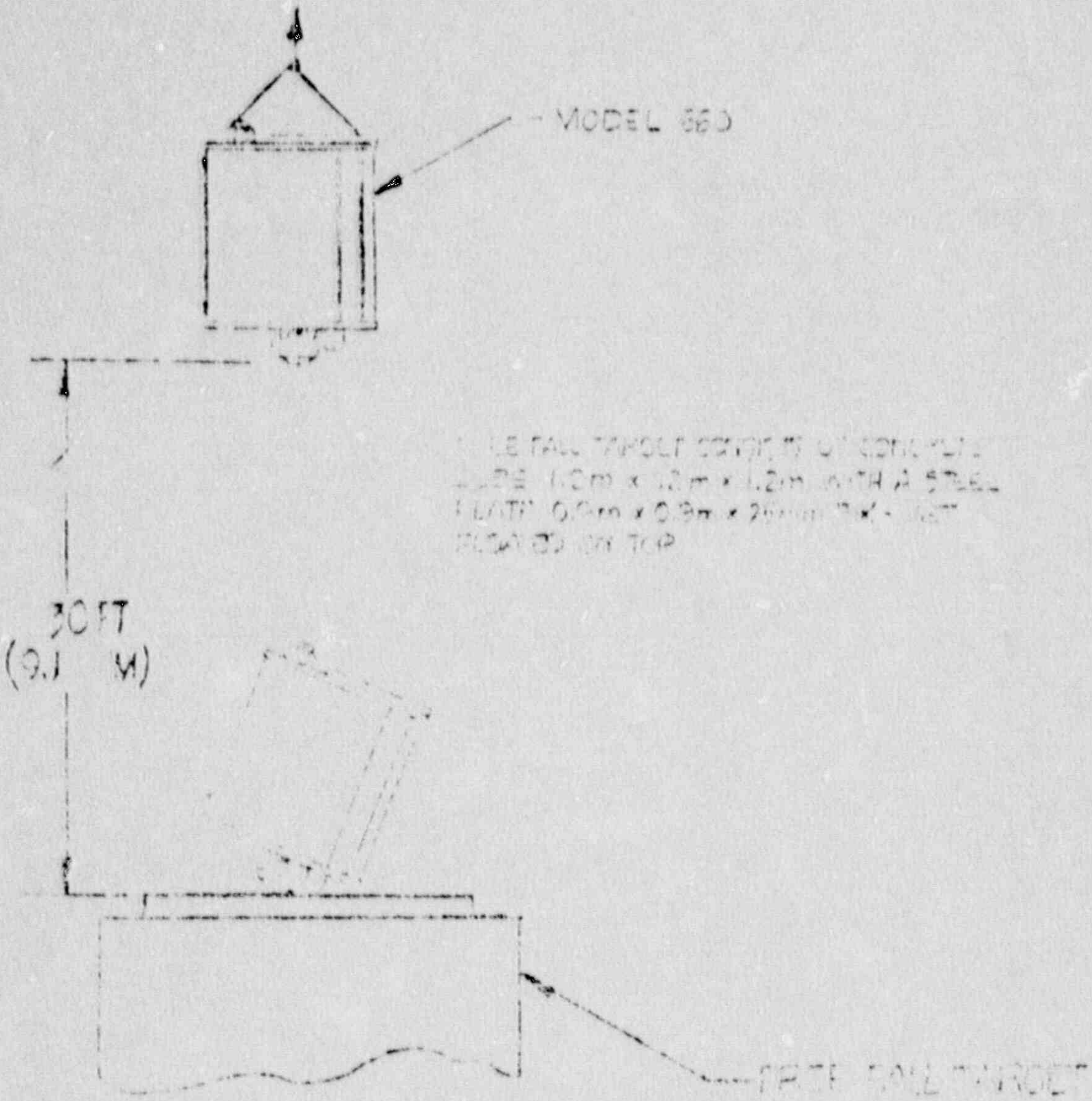
On 29 September 1989, a prototype Model 660 package modified with the automatic securing was subjected to a free drop test in accordance with the requirements of 10 CFR 71.73(c) (1) and IAEA Safety Series No. 6, paragraph 719(a). This test was performed at Valley Tree Service, Groveland, MA.

The Model 660 package was dropped from a height of 9.1 meters (30 feet) onto a target. The target consisted of a concrete cube, each side measuring 1.2m (48 inches) upon which had been wet floated a steel plate 0.9m (36 inches) wide, 0.9m (36 inches) long and 25mm (one inch) thick. This target conforms to the guidance for an essentially unyielding surface as prescribed in paragraph 7.01 of IAEA Safety Series No. 37.

During the drop, the package impacted the target on the shipping cap over the locking assembly.

As a result of this test, there was no impairment of any design or safety features of the package. There was no structural damage to the locking assembly or package closure. There was no release of the package contents.

A shielding efficiency test performed subsequent to the completion of the Model 660 test program demonstrated that the free drop tests did not reduce the shielding efficiency of the package.



MODEL 660
FREE FALL TEST

TEST REPORT

BY: CATHLEEN M. ROUGHAN MR
DAVE DUNCANSON

DATE: 13 OCTOBER 1989

SUBJECT: Model 660 Puncture Test

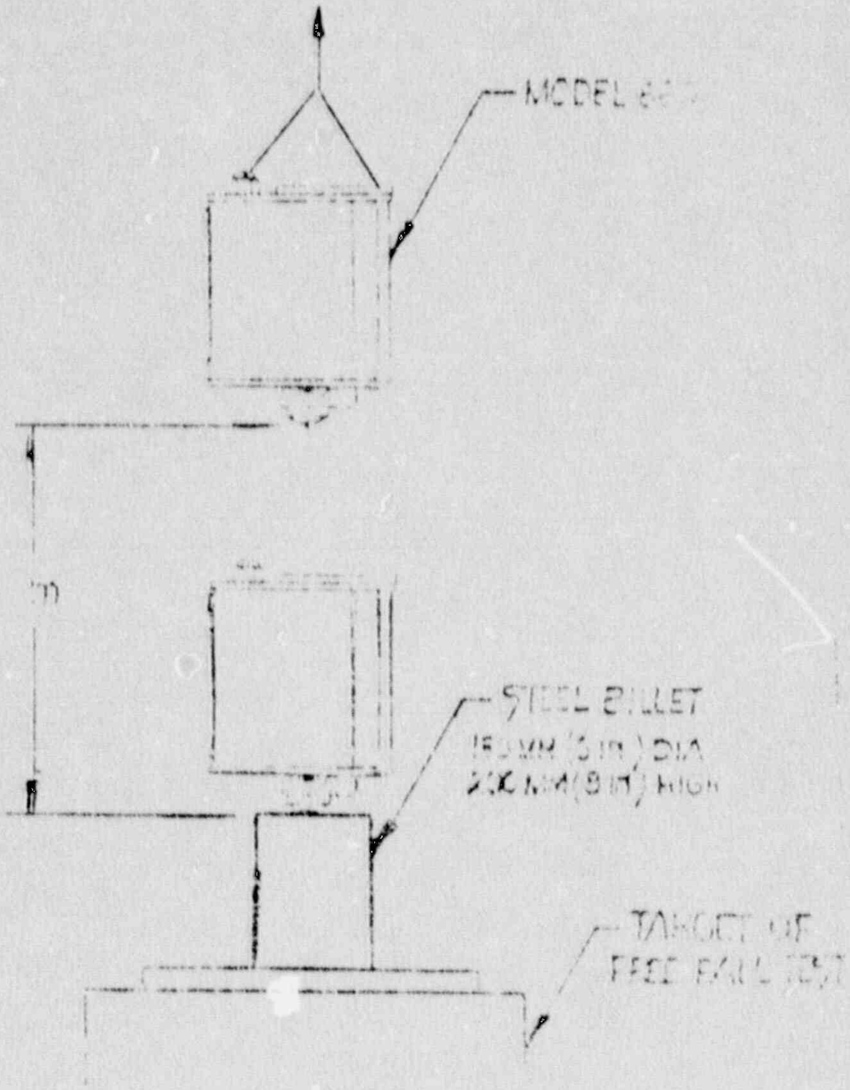
On 29 September 1989, a prototype Model 660 modified with the automatic securing mechanism was subjected to a puncture test in accordance with the requirements of 10 CFR 71.73(c) (2) and IAEA Safety Series No. 6, paragraph 719(b). This test was performed at Valley Tree Service, Groveland, MA.

Immediately following the free drop test, the prototype Model 660 package was dropped from a height of one meter onto a target. The target consisted of a right circular cylindrical steel billet 152mm (6 inches) in diameter and 203mm (8 inches) high mounted onto the target used in the free drop tests.

During the drop, the package impacted the target squarely on the shipping cap of the locking assembly. There was no observable additional deformation as a result of this drop.

As a result of these tests, there was no impairment of any design or safety features of the package. There was no structural damage to the locking assembly or package closure. There was no release of the package contents.

A shielding efficiency test performed subsequent to completion of the Model 660 test program demonstrated that these puncture test did not reduce the shielding efficiency of the package.



MODEL 660
PUNCTURE TEST

Visit Report

NRPB/VR 7/440

Subject: Dismantling of damaged source container

Address visited: Technical Operations Limited,
Princesway,
Team Valley Industrial Estate,
Gateshead,
Co. Durham.

Date of visit: May 15th, 1974

Date of report: May 17th, 1974

Previous relevant report: NRPB/VR 7/422

Introduction

This visit followed the damage of a remote exposure container Type 709 in a van fire.

General conclusions

The shielding afforded by the container had been maintained and the source had not been damaged.

Measurements

Several dose rate measurements were made close to the outside surface of the container before any attempt was made to dismantle it, and the maximum dose rate measured was 5 mrem/h. Several wipes were made of the control cable connecting mechanism and inside the guide tube during the dismantling procedure. The activity was less than 0.1 nanocuries on each of these wipes.

Description

Mr. Gilligan of Technical Operations Limited proceeded to transfer the 10.6 curie iridium-192 source to a transport container suitable for return to the suppliers. No difficulty was experienced in connecting the control cable but because of congealed grease in the guide tube several attempts were necessary before transfer was achieved. This operation was conducted remotely with the source container in a compound.

Con'd..........

[illegible] ately 3 mm of the depleted uranium. Further investigation indicated no discernible damage to the uranium shielding.

The control cable connecting mechanism was dismantled and it was clear that two springs in the lock had perished in the fire. However, the mechanism had failed safe and the container could not be opened without the appropriate key and connection of the control cable.

The handle of the container had partially melted and distorted but was still substantially intact. It is understood that the handle is made from Tenzalloy which is apparently an aluminium - copper (or brass) alloy with a melting point of 1220° F.

J. K. Overend

SECTION 3

THERMAL EVALUATION

3.1 Thermal Properties of Package

The Model 660 is a completely passive thermal device and has no mechanical cooling system nor relief valves. All cooling of the package is through free convection and radiation. The maximum heat source is 140 curies of Iridium-192. The corresponding decay heat generation rate is approximately 1.2 watts.

3.2 Summary of Thermal Properties of Materials

The materials used in the construction of the Model 660 includes:

Depleted Uranium	Melting Point 1133°C
Steel	Melting Point 1345°C
Titanium	Melting Point 1800°C

The Vultafoam in this device has an operating temperature range of -43°C to 104°C (-45°F to 220°F).

3.3 Technical Specifications of Components

Not applicable.

3.4 Normal Conditions of Transport

3.4.1 Thermal Model

The heat source in the Amersham Model 660 is a maximum of 140 curies of Iridium-192. Iridium-192 decays with a total energy liberation of 1.45 MeV per disintegration or 8.6 milliwatts per curie. Assuming all the decay energy is transformed into heat, the heat generation rate for the 140 curies of Iridium-192 would be approximately 1.20 watt.

To demonstrate compliance with the requirements of 10 CFR 71.43(g) and paragraph 130 of IAEA Safety Series No. 6, a separate analysis is presented in Section 3.6. The thermal model employed is described in that analysis.

To demonstrate compliance with the requirements of paragraph 240 of IAEA Safety Series No. 6 for Type B(U) packaging, a separate analysis is presented in Section 3.6. The thermal model employed is described in that analysis.

3.4.2 Maximum Temperatures

The maximum temperatures encountered under normal conditions of transport will have no adverse effect on the structural integrity or shielding efficiency of the package. As presented in Section 3.6, the maximum temperature in the shade would not exceed 42°C (108°F) and the maximum temperature when insulated would not exceed 68°C (154°F).

3.4.3 Minimum Temperatures

The minimum normal operating temperature of the Model 660 is -40°C (-40°F). This temperature will have no adverse effect on the structural integrity of shielding efficiency of the package.

3.4.4 Maximum Internal Pressures

Normal operating conditions will generate negligible internal pressures. Any pressure generated is significantly below that which would be generated during the hypothetical thermal accident condition, which is shown to result in no reduction in structural integrity or shielding efficiency.

3.4.5 Maximum Thermal Stress

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

3.4.6 Evaluation of Package Performance under Normal Conditions of Transport.

The normal transport thermal condition will have no adverse effect on the structural integrity or shielding efficiency of the package. The applicable conditions of IAEA Safety Series No. 6 for Type B(U) packages are shown to be satisfied by the Model 660.

3.5.0 Hypothetical Thermal Accident Evaluation

3.5.1 Thermal Model

3.5.2 Package Conditions and Environment

The prototype Model 660 package which was subjected to the free drop test and puncture test, suffered minor structural deformation during these mechanical tests, but suffered no reduction in structural integrity or shielding efficiency.

3.5.3 Package Temperatures

As indicted in Section 3.2 the entire package is assumed to reach a temperature of 800°C. Examination of the melting temperatures of the materials used in construction of the Amersham Model 660, indicates there will be no damage to the package as a result of this temperature.

The possibility of the formation of a iron-uranium eutectic alloy was addressed in Section 2.4.1 where it was concluded that the formation of the alloy was not a likely possibility. There was no indication of any melting or alloy formation as a result of this thermal test.

3.5.4 Maximum Internal Pressures

In Section 3.6.3, an analysis of the source capsule, which serves as the primary containment, under the thermal test conditions is presented. This analysis demonstrates that the maximum internal gas pressure at 800°C would be 373 kPa (54 psi).

The critical location for failure is the source capsule weld. The analysis shoes that an internal pressure of 373 kPa (54 psi) would generate a maximum stress of 1.96 MPa (284 psi). At 870°C (1600°F), the yield strength of stainless steel is 69 MPa (10,000 psi).

Therefore, if the source capsule were to reach a temperature of 800°C, the maximum stress in the capsule would be only 3 percent of the yield strength of the material.

3.5.5 Maximum Thermal Stress

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

3.5.6 Evaluation of Package Performance

The Model 660 will undergo no loss of structural integrity or shielding when subjected to the thermal accident condition. The pressures and temperatures have been demonstrated to be within acceptable limits.

3.6.0 Appendix

3.6.1 Model 660 Type B(U) Thermal Analysis: 10 CFR 71.43 (g) and paragraph 230 of IAEA Safety Series No. 6.

3.6.2 Model 660 Type B(U) Thermal Analysis: Paragraph 240 of IAEA Safety Series No. 6.

3.6.3 Iridium-192 Source Capsule Thermal Analysis

3.6.1 <u>Model 66Ø Type B(U) Thermal Analysis 1Ø CFR 71.43 (g) and Paragraph 231 of IAEA Safety Series No. 6</u>

This analysis demonstrates that the maximum surface temperature of the Model 66Ø will not exceed 5Ø°C with the package in the shade and an ambient temperature of 38°C.

To assure conservatism, the following assumptions are used:

(a) The entire decay heat 1.2 watts is deposited in the exterior surfaces of the package.

(b) The interior of the package is perfectly insulated and heat transfer occurs only from the exterior surface to the environment.

(c) Because each face of the package eclipses a different solid angle, it is assumed that twenty-five percent of the total heat is deposited in the smallest face.

(d) The only heat transfer mechanism is free convection.

Using these assumptions, the maximum wall temperature is found from

$$q = hA(T_W - T_a)$$

where q = heat deposited per unit time in the face of interest (Ø.3Ø watts)

h = Free convection heat transfer coefficient for air

$$= 1.42 \left(\frac{\Delta T}{d}\right)^{1/4} \text{ watt}/^2 \ ^\circ C$$

A = Area of the face of interest (Ø.Ø32 m^2)

Tw = Maximum temperature of the surface of the package

Ta = Ambient Temperature (38°C)

d = Height of face of interest (m) = Ø.244 m

From this relationship, the maximum temperature of the surface is 42°C. This satisfies the requirement of 1Ø CFR 71.43 (g) and paragraph 23Ø of IAEA Safety Serial No. 6

3.6.2 Model 660 Type B(U) Thermal Analysis, paragraph 240 of IAEA Safety Series No. 6

This analysis demonstrates that the maximum surface temperature of the Model 660 will not exceed 82°C when the package is in an ambient temperature of 38°C and is insulated in accordance with 10 CFR 71.71 (c) (1) and Table III of IAEA Safety Series No. 6.

The calculational model consists of taking a steady state heat balance over the surface of the package. In order to assure conservatism, the following assumptions are used.

(a) The package is insulated at the rate of 775 W/m^2 (800 cal/cm^2-12 hr) on the top surface, 194 W/m^2 (200 cal/cm^2-12 hr) on the side surfaces and on insolation on the bottom surface.

(b) The decay heat load is added to the solar heat load.

(c) The package has an unpainted stainless steel surface. The solar absorptivity is assumed to be 0.9. The solar emissivity is assumed to 0.8.

(d) The package is assumed to undergo the convection from the sides and top, and undergo radiation from the sides, top and bottom. The inside faces are considered perfectly insulated so there is no conduction into the package. The faces are considered to be sufficiently thin so that no temperature gradients exist in the faces.

(e) The package is approximated as a rectangular solid of 13.3 cm (5.25 in) wide, 24.4 cm (9.62 in) high and 25.1 cm (9.87 in) long transported on its side. The total surface area of the top and bottom is 0.062 m^2. The total surface area of the sides is 0.189 m^2.

The maximum surface temperature is computed from a steady state heat balance relationship.

$$q_{in} = q_{out}$$

The heat load applied to the package is

$$q_{in} = q_s\alpha + q_d$$

Where σ = solar absorptivity (0.9)

q_s = solar heat load (91.4 watts)

q_d = decay heat load (1.20 watts)

The heat dissipation is expressed as

$$q_{out} = q_c + q_r$$

Where q_c = convective heat transfer

= ((hA)top + (hA) sides) (Tw - Ta)

where h = convective heat transfer coefficient

A = area of the surface of interest

T_w = Temperatures of the surface

T_a = Ambient Temperature (38°C)

q_r = Radiative heat transfer

$= \sigma \epsilon A (T_w{}^4 - T_a{}^4)$

Where σ = Stefan Boltzmann Constant (5.669 x 10-8 $W/m^2{}^\circ K^4$)

ϵ = Emissivity (0.8)

Iteration of this relationship yields a maximum wall temperature of 68°C which satisfies the requirements of paragraph 240 of the IAEA Safety Series No. 6.

3.6.3 Amersham Model 660 Type B(U) Source Capsule Thermal Analysis Paragraph 238 of IAEA Safety Series No. 6 1973.

This analysis demonstrates that the pressure inside the source capsule used in conjunction with the Model 660, when subjected to the hypothetical thermal accident condition, does not exceed the pressure with corresponds to the minimum yield strength at the thermal test temperature.

The source capsule is fabricated from stainless steel, either Type 304 or 304L. The outside diameter of the capsule is 6.35 mm (0.250 in). The source capsule is seal welded. The minimum weld penetration is 0.5 mm (0.02 in). Under conditions of internal pressure, the critical location for failure is this weld.

The internal volume of the source capsule contains only iridium metal (as a solid) and air. It is assumed at the time of loading the entrapped air is at standard temperature and pressure (20°C and 100 kPa). This is a conservative assumption because, during the welding process, the internal air is heated, causing some of the air mass to escape before the capsule is sealed. When the welded capsule returns to ambient temperature, the internal pressure would be somewhat reduced.

Under the conditions of paragraph 238 of IAEA Safety Series No. 6, it is assumed that the capsule could reach a temperature of 800°C (1475°F). Using the ideal gas law and requiring the air to occupy a constant volume, the internal gas pressure could reach 373 kPa (54 psi).

The capsule is assumed to be a thin walled cylindrical pressure vessel with the wall thickness equal to the depth of weld penetration.

The maximum longitudinal stress is calculated from:

$$\sigma A = PA_p$$

where σ = Longitudinal Stress
A = Stress Area
P = Pressure
A_p = Pressure Area

From this relationship, the maximum longitudinal stress is calculated to be 900 kPa (129 psi).

The hoop stress is calculated from:

$$2\ \sigma_h\ lt = P_l t$$

where σ_h = Hoop Stress
l = Length of the Cylinder
t = Thickness of the Cylinder (0.5 mm or 0.02 in)

From this relationship, the hoop stress is calculated to be 1.96 MPa (284 psi).

At a temperature of 870°C (1600°F), the yield strength of type 304 stainless steel is 69 MPa (10,000 psi). Therefore, under the conditions of paragraphs 238 of IAEA Safety Series No. 6, the stress generated is less than 3 percent of the yield strength of the material.

SECTION 4

CONTAINMENT

4.1.0 Containment Boundary

4.1.1 Containment Vessel

The containment system for the Model 660 is the radioactive source capsule as described in Section 1.2.3 of this application. This source capsule is certified as special form radioactive material in IAEA Certificate of Competent Authority Number USA/0335/S.

4.1.2 Containment Penetrations

There are no penetrations of the containment.

4.1.3 Seals and Welds

The containment in seal welded by tungsten insert gas welding process which is described in Amersham Standard Source Encapsulation Procedure presented in Section 7.5.1. The minimum weld penetration is 0.5 mm (0.02 in).

4.1.4 Closure

Not applicable.

4.2.0 Requirements for Normal Conditions of Transport

4.2.1 Release of Radioactive Material

The source capsules used in conjunction with the Model 660 have satisfied the requirements for the special form radioactive material as prescribed in 10 CFR 71.77 and IAEA Safety Series No. 6. There will be no release of radioactive material under the normal conditions of transport.

4.2.2 Pressurization of the Containment Vessel

Pressurization of the source capsules under the conditions of the hypothetical thermal accident was demonstrated to generate stresses well below the yield strength of the capsule material as described in Section 3.6.3. Therefore, the containment will withstand the pressure variations of normal transport.

4.2.3 Coolant Contamination

Not applicable.

4.2.4 Coolant Loss

Not applicable.

4.3 Containment Requirements for the Hypothetical Accident Condition

4.3.1 Fission Gas Products

Not applicable.

4.3.2 Release of Contents

The hypothetical accident conditions of 10 CFR 71.73 will result in no loss of package containment. This conclusion is based on information information presented in Sections 2.71, 2.7.2, 2.7.3, 2.7.4, and 3.5.

SECTION 5

SHIELDING EVALUATION

5.1 Discussion and Results

The principle shielding of the Model 660 is the uranium shield assembly. The mass of the uranium shield is 16.8 kg (37 lbs).

A radiation profile of Model 660, Serial Number 4537, was made using an AN/PDR-27(R) survey meter, Serial Number I-130. The Model 660 contained 107 Curies of Iridium-192 as Amersham Source Assembly A424-9, Serial Number 8534. The results of these measurements are presented below. The maximum radiation intensity measured at the surface of the container was 127 milliroentgens per hour, and the maximum intensity measured at 1 meter was 1.0 milliroentgens per hour. Extrapolating these measurements to the maximum container capacity of 140 curies demonstrates that the radiation levels are below the regulatory limits.

5.2 Source Specification

5.2.1 Gamma Source

The gamma source is Iridium-192 in a sealed capsule as special form radioactive material in quantities up to 140 curies.

5.2.2 Neutron Source

Not applicable.

5.3 Model Specification

Not applicable.

5.4 Shielding Evaluation

A shielding efficiency test of a Model 660 containing 107 curies of Iridium-192 was performed. The results of this test, which are presented in Section 2.10, demonstrated that the dose rates surrounding this package are within the regulatory limits.

Table 5.1

Summary of Radiation Profile Results
of a Model 660 With 107 Curies of Ir-192
(mR/hr)

Location	At Surface	At One Meter from Surface
Top	89	0.7
Right	86	0.5
Front	74	0.9
Left	127	1.0
Rear	99	1.0
Bottom	65	0.4

Table 5.2

Summary of Maximum Dose Rates
Extrapolated to 140 Curies of Iridium-192
(mR/hr)

Location	Surface	One Meter
Top	116	0.9
Right	110	0.6
Front	97	1.2
Left	166	1.3
Rear	129	1.3
Bottom	85	0.5

SECTION 6

CRITICALITY EVALUATION

Not applicable.

SECTION 7

OPERATING PROCEDURES

7.1 Procedure for Loading the Package

The procedure for fabricating the special form source capsule is presented in Section 7.5.1. The procedure for loading the source assemblies into the package is also included in Section 7.5.1.

7.2 Procedure for Using the Exposure Device

The procedure for performing industrial radiography with the Model 660 exposure device is included in Section 7.5.2.

7.3 Procedure for Unloading the Package

The procedure for unloading the package is presented in Section 7.5.2.

7.4 Preparation of a Package for Transport

The procedure for preparation of a package for transport is included in the Model 660 Instruction Manual presented in Section 7.5.2.

7.5 Appendix

7.5.1 Procedure for Encapsulation of Sealed Sources

7.5.2 Model 660 Exposure Device Operation Manual

ENCAPSULATION OF SEALED SOURCES

A. Personnel Requirements

Only an individual qualified as a Radiological Technician shall perform the operations associated with the encapsulation of sealed sources. A second Radiological Technician must be available in the building when these operations are being performed.

B. General Requirements

1. In the Burlington, Ma, facility, a loading cell shall be used for the encapsulation of sealed sources and repackaging of sealed sources. The maximum amount and form of radioactive material which may be handled in the loading cell is specified below:

Radioisotope	Form	Maximum Activity
Iridium-192	Solid Metallic	2000 curies
Cobalt-60	Solid Metallic or sealed sources	1 curie
Cesium-137	Sealed Sources only	100 curies
Ytterbium-169	Sealed Sources only	100 curies
Tantalum-182	Sealed Metallic or Solid Carbide	100 curies
Gadolinium-153	Solid Oxide	300 curies

Limits for any other radioisotopes or forms shall be specified by the Radiation Protection and General Safety Committee.

2. The loading and general purpose hot cells are designed to be operated at less than atmospheric pressure. The exhaust blower should not be turned off during the operation or at any time that radioactive material is in the cell.

3. Unencapsulated radioactive material shall not be stored in these cells when the cell is unattended. Material may only be stored inside these cells in welded capsules or screw top capsules. When radioactive material is stored in these cells, a radioactive material tag identifying the types, quantities, locations and storage dates of all such material shall be attached to the manipulator or to the cell body adjacent to the window.

4. When any "through the wall" tool is removed, the opening shall be closed with the plug provided. All tools shall be decontaminated whenever they are removed from the cell.

5. Each individual performing this operation must wear a film badge and pocket dosimeter at waist level and a second film badge and pocket dosimeter in the vicinity of the head. All operations must be monitored with a calibrated and operational radiation survey meter.

C. <u>Preparatory Procedure</u>

1. Record the names and initial pocket dosimeter readings for the personnel performing the loading operation on the Loading Log Sheet.

2. Check the cell lights for proper operation. Check the cell manipulators both visually and operationally. Assure that all cell ports are plugged.

3. Assure that the exhaust system is operational. Record the manometer reading on the Loading Log Sheet. If the manometer reading is less than 0.5 inch or greater than 2.0 inches of water, the filter must be changed.

4. Assure that the air sampling system is operational and that sample filters are in place.

5. Perform the pre-operational contamination survey as indicated on the Loading Log Sheet. Record the results on the Loading Log Sheet.

6. Perform the encapsulation procedure omitting the insertion of any activity. Examine this phantom capsule weld. If this weld is acceptable, preparation of active capsules may proceed. If the weld is not acceptable, the condition responsible for this unacceptable weld must be corrected and an acceptable phantom capsule weld produced prior to proceeding. This step must also be performed each time the welding electrode is changed.

D. <u>Encapsulation Procedure</u>

1. Prior to use, assemble and visually inspect the two capsule components to assure the weld zone does not exhibit any misalignment and/or separation. Defective capsules shall be rejected.

2. Degrease capsule components in the Ultrasonic Bath, using isopropyl alcohol as degreasing agent, for a period of 30 minutes. Dry the capsule components at 100 C for a minimum of 20 minutes.

3. Insert capsule components into hot cell with the posting bar.

4. Place capsule bottom in weld positioning device. Withdraw the posting bar.

5. Move the drawer bar of the source transfer container into the loading cell. Open the screw top capsule.

6. Withdraw the proper amount of activity from the screw top capsule and place it in the capsule bottom. A brass rivet must be used with wafers to prevent contamination of weld zone.

7. Assure that all unused radioactive material is removed from the loading cell by installing it in the screw top capsule and withdrawing the drawer bar of the source transfer container from the cell.

8. Remove the rivet (if applicable).

9. Assemble the capsule components.

10. Weld in accordance with the written welding procedure for the capsule being welded.

11. Visually inspect the weld. An acceptable weld must be continuous without cratering, cracks or evidence of blow out. If the weld is defective, the capsule must be cleaned and re-welded to acceptable conditions or disposed of as radioactive waste.

12. Check the capsule in the height gauge to be sure that the weld is at the center of the capsule.

13. Wipe the exterior of the capsule with a flannel patch wetted with EDTA solution or equivalent.

14. Count the patch with the scaler counting system. The patch must show no more than 0.005 microcurie of contamination. If the patch shows more than 0.005 microcurie, the capsule must be cleaned and re-wiped. If the re-wipe patch still shows more than 0.005 of contamination, steps 10 through 14 must be repeated.

15. Vacuum bubble test the capsule. Place the welded capsule in a glass vial containing isopropyl alcohol. Apply a vacuum of 15 inch Hg(Gauge) while alertly watching the capsule for the emergence of bubbles. Any visual detection of bubbles will indicate a leaking source. If the source is determined to be leaking, place the source in a dry vacuum vial and boil off the residual alcohol. Re-weld the capsule; repeat steps 10 through 15.

16. Transfer the welded source capsule to the sealed source section of the loading cell.

17. For wire mounted source capsules, transfer the capsule to the swaging fixture. Insert the wire and connector assembly and swage. Hydraulic pressure should not be less than 1250 nor more than 1500 pounds.

    For source holder mounted source capsules, transfer the capsule to the appropriate source holder loading fixture. Insert the source capsule into the source holder. Screw the source holder together and install the roll pin (if applicable). Check to assure that the pin does not protrude on either side.

18. Apply the tensile test to assembly between the capsule and connector (where applicable) by applying proof load of 100 lbs. Extension under the load shall not exceed 0.05 inch. If the extension exceeds 0.05 inch, the source must be disposed of as radioactive waste.

19. Assure that the cell tunnel door is closed. Position the source in the exit port of the loading cell. Use the remote control to insert the source into the ion chamber and position the source for maximum response. Record the meter reading. Compute the activity in curies and fill out a temporary source tag.

20. Again using remote control, eject the source from cell into source changer or transport container through the tube gauze wipe test fixture. Monitor the radiation level as the cell tunnel shielded door is opened. Remove the tube gauze and count with scaler counting system. This assay must show no more than 0.005 microcurie. If contamination is in excess of this level, the source is leaking and shall be rejected.

21. Secure the source in the source changer or transport container and remove the container from the source loading area.

22. At the end of the day's operations, perform the post-operational contamination survey as indicated on the Loading Log Sheet. Record the results on the Loading Log Sheet.

23. Record the final pocket dosimeter readings for the personnel performing the loading operation on the Loading Log Sheet.

24. Record the daily air sample results on the Loading Log Sheet.

IRIDIUM LOADING LOG

Sheet 1 of 2

Burlington, MA Facility Week of:

	Operator	Dosimeter Init.	Dosimeter Final	Exposure	Loading Time	Curies Loaded	Cell Reading	Air Sample	Remarks
MON									
TUE									
WED									
THU									
FRI									
SAT									

27e

CONTAMINATION SURVEY RECORD

Burlington, MA Facility

Week of:

		Right Shelf	Left Shelf	Vacuum Test Bottle	Transfer Pig Slide	Floor Under Transfer Pig	Lead Bar Along Rear of Cell	Ring for Transfer Pig - Cell Rear	Workbench	Floor Cell Left	Shield Tunnel Floor	Vacuum Needle Filter Holder	Transfer Bar Shelf - Left Side	Transfer Bar	Masslin Dry Mop (E120/HP210)	Calibration Factors Well Counter: cpm = 0.001µCi E110/HP210°: cpm = 0.001µCi REMARKS
MON																
TUE																
WED																
THU																
FRI																
SAT																

MODEL 660
EXPOSURE DEVICE
OPERATION MANUAL

NOTICE

This device is used as a radiographic exposure device and Type B(U) transport package for Amersham Corporation radioactive sources listed in this manual. The user should become thoroughly familiar with the instruction manual before attempting operation of the equipment.

In order to use this equipment to perform industrial radiography within the United States, the user must be specifically licensed to do so. Application for a license should be filed on Form NRC 313 with the appropriate U.S. Nuclear Regulatory Commission Regional Office listed in Appendix D of 10 CFR 20 or with the appropriate agreement state office.

Prior to initial use of a radiographic exposure device as a transport package, the user in the United States must register his name, license number and package identification number with:

Director
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory commission
Washington, DC 20555

The user must have in his possession a copy of USNRC Certificate of Compliance No. 9033 issued for this package.

Prior to the first export shipment of this exposure device from the United States, the user must also register his identity with:

Office of Hazardous Materials Regulation
Materials Transportation Bureau
U.S. Department of Transportation
Washington, DC 20590

The user must have in his possession a copy of International Atomic Energy Agency Certificate of Competent Authority Number USA/9033/B(U) issued for this radiographic exposure device.

Users of this equipment outside the United States must comply with the regulatory, licensing and transportation rules and regulations as they apply in their respective countries.

General

The Model 660 series portable gamma radiography system are used primarily for industrial radiography. The systems operate in similar manner and differ only in the specific control unit supplied.

The basic radiography system consists of the Model 660 radiographic exposure device, the source drive assembly and the source guide tube. The exposure device serves as the storage and transport package for the radioactive source.

Safety Systems

The systems are designed to provide maximum operator safety. There is a positive mechanical control of the source, and the odometer provides a visual indication of the source's position. In addition, the source connector is designed to be fail-safe so that:

1. The system cannot be operated (source exposed) unless a secure connection of the source assembly to the drive cable is made; and

2. The control unit cannot be disconnected unless the radioactive source assembly is properly stored in the shield.

Radiation Safety Considerations

Pursuant to USNRC and agreement state regulations, all personnel present during radiographic and source changing operations are required to wear a direct reading pocket dosimeter and either a film badge or a thermoluminescent dosimeter (TLD). The pocket dosimeter must be recharged at the start of each shift. The operator should frequently check the pocket dosimeter reading throughout the shift. Dosimeter readings must be recorded at the end of each shift. Records of the initial and final readings of the pocket dosimeter must be kept for inspection by the USNRC.

In the event that a person's pocket dosimeter is found to be off scale, that person must stop all work with radiation immediately. His film badge (or TLD) must be sent in immediately for processing, and he must not reenter a restricted area until it has been determined that he received less than the maximum allowed occupational exposure as defined in 10 CFR 20.101.

Personnel performing source changing and radiographic operations must also have a calibrated and operable radiation survey meter capable of measuring from 2 mR/hr to at least 1000 mR/hr to determine radiation levels when performing these operations.

Areas in which source changing or radiography is performed must be identified. If a permanent radiographic installation is used, it must have the appropriate personnel access control devices as defined in 10 CFR 20.203. Otherwise, certain areas must be established as follows:

> Access to the Restricted Area must be controlled. A Restricted Area is defined in 10 CFR 20.105 as the area where an individual could receive an exposure in excess of two milliroentgens in any one hour, or 100

milliroentgens in seven consecutive days or 500 milliroentgens in one year. The Restricted Area should also be posted with signs reading "Caution (or Danger) - Radiation Area." Signs reading "Caution (or Danger) - high Radiation Area" should be posted around the perimeter where an individual could receive an exposure in excess of 100 milliroentgens in any one hour.

The radiographer or radiographer's assistant must guard against unauthorized entrance into these areas at all times. No personnel should be allowed into the restricted area without a direct reading pocket dosimeter and either a film badge or TLD.

Receipt of Radioactive Material

The consignee of a package of radioactive material must make arrangements to receive the package when it is delivered. If the package is to be picked up at the carrier's terminal, 10 CFR 20.205 requires that this be done expeditiously upon notification of its arrival.

Upon receipt, survey the exposure device with a survey meter as soon as possible, preferably at the time of pickup and no more than three hours after it was received during normal working hours. Radiation levels should not exceed 200 milliroentgens per hour at the surface of the exposure device, nor 10 miliroentgens per hour at a distance of three feet from the surface. Actual radiation levels should be recorded on the receiving report. If the radiation levels exceed these limits, the container should be secured in a Restricted Area, and the apprupriate personnel notified.

All components should be inspected for physical damage.

The radioisotope, activity, model number, and serial number of the source and the package model number and serial number should be recorded.

Operation

1. Survey the entire circumference of the exposure device to assure the source is properly stored and to obtain a reference reading of the radiographic exposure device. Assure that the device is locked.

2. Position and secure the source stop of the master source guide tube at the radiographic focal position using the tripod stand and swivel clamps.

3. Determine where the exposure device will be positioned and connect the extended source guide tubes as required, laying them as straight as possible and with no bend radius less than twenty inches. (Smaller bend radii will restrict the movement of the control cable).

NOTE: Never operate the system with more than three guide tube sections (including the master).

4. Remove the storage plug from the exposure device and connect the source guide tube(s) to the exposure device.

5. Determine where the control unit will be positioned (as far away from the radiographic focal position as possible and preferably behind a radiation shield) and lay out the control housing with no bend radii less than 36 inches.

6. Connect the control unit to the exposure device according to the illustrated sequence in Figures 1 through 5.

7. Before operation check all connections and bend radii, and check the position of the source stop, which represents the radiographic focal position of the source.

8. Check the operation of the survey meter by reading the radiation level at the surface of the exposure device. It should read no more than 200 mR/hr for a 140 curie Iridium-192 source.

9. Unlock the exposure device lock and rotate the selector ring to the OPERATE position. Move the lock slide to the right, so that the red indicator shows. The source is now free to move.

10. Return to the control unit. Adjust the odometer reset knob to obtain a 000 reading on the odometer.

11. Recheck to be sure that no unauthorized personnel are inside the Restricted Area.

12. Rapidly rotate the crank in the EXPOSE (counterclockwise) direction to move the source to the radiographic focal position. The survey meter should read about full scale (1000 mR/hr) for a 100 curie Iridium 192 source when the source first leaves the exposure device, drop gradually as the source is driven to the radiographic focal position, and remain steady during the exposure. The survey meter readings will be substantially reduced if the meter is operated behind a radiation shield or if a collimator is used.

13. When the source reaches the source stop, the hand crank will stop turning. Never exert more than 5 ft.-lbs. of torque on the hand crank, as this may cause damage to the control unit or drive cable. The odometer reading will indicate the total distance the source has traveled (approximately 7 ft. for one source guide tube section, 14 ft. for two source guide tube sections, and 21 ft. for three sections). Set the brake to ON to prevent movement of the source during the exposure.

14. Figure the specimen exposure time from the moment the source reaches the source stop.

15. During the exposure, spent as little time as possible in the Restricted Area to minimize personnel exposure.

16. To return the source to the exposure device after the desired exposure time has elapsed, turn the brake to OFF and rapidly turn the crank in the RETRACT (clockwise) direction until the crank will no longer move. The odometer should read ØØØ. During this process, the survey meter should indicate a continually increasing radiation level up to approximately 1ØØØ mR/hr for a 1ØØ curie Iridium-192 source, then drop to background level when the source is shielded in the exposure device.

17. Approach the exposure device with the survey meter and survey the exposure device on all sides. The meter should indicate the same radiation level as observed in step 8 of **Operation**.

18. The lock slide will automatically secure the source in the shielded position. The slide will show the green indicator when the source is properly stored.

19. Survey the entire source guide tube with the survey meter. If the meter shows a sharp increase, the source could still be exposed or incompletely shielded.

2Ø. If the source is still exposed, attempt to store it properly by cranking the source a short distance toward the source stop and retracting it, repeating if necessary.

21. If the source becomes jammed in an exposed position, do not try to retrieve the source. Treat the situation as an emergency: notify the supervisor and Amersham for help if necessary.

22. When the source is properly stored in the exposure device rotate the selector ring from the OPERATE position to the LOCK position and secure it with the exposure device lock.

    NOTE: If the selector ring cannot be rotated to the LOCK position, the source has not been fully retracted. Check the control unit odometer reading. It should be 000. Turn the hand crank to the full clockwise (RETRACT) direction.

23. Unlock the exposure device, and rotate the selector ring from LOCK to connect. The control unit connector will partially disengage.

24. Refer to Figures 1 through 5 to disengage the control unit from the exposure device.

25. Replace the storage cover in the control unit connector and rotate the selector ring to the LOCK position. Remove the key and engage the lock to secure the exposure device. Survey the entire circumference of the exposure device with the survey meter to ensure the source is properly secured.

26. Unscrew the source guide tube sections and remove the master guide tube from the tripod stand. Place the plastic caps on the tubes and on the Model 661 connector to eliminate dust and dirt from entering the tubes.

27. Insert the storage plug into the guide tube connector and tighten.

28. Disassemble the tripod stand and store the system where it will not be subjected to any undue stress or abuse.

<u>Source Changes</u>

Source changes may be performed using Amersham Model 650 source changer, which also serves as a shipping container. The specific instructions for the appropriate source changer should be followed to perform a source exchange. The source exchange must be done in a Restricted Area as previously described. The same personnel monitoring requirements and safety precautions previously described for performing radiography must also be followed in performing source exchanges.

1. Survey the source changer to ensure the source is in the proper storage position.

2. Position the source changer and exposure device close together so that one section of source guide tube will connect them with no sharp turns or bends. The bend radius of the guide tube should never be less than twenty inches. Shorter bend radii can restrict source movement in the source guide tube.

3 Remove the storage plug from the exposure device, and attach the source guide tube. Remove the source changer cover and attach the other end of the tube to the empty chamber of the source changer.

4. Attach the control unit to the exposure device as in Step 6 of the operating procedure.

5. Crank the source rapidly from the exposure device to the source changer. During this process, the survey meter reading should increase (to approximately 1000 mR/hr for a 100 curie Iridium-192 source) as the source is first exposed, fall slightly as the source is being cranked out, then drop to background when the source is in the source changer.

6. Approach the source changer and source guide tube with the survey meter to ensure that the source is fully within the source changer.

7. Open the source guides and disconnect the drive cable from the source assembly by moving the lock pin down and sliding the drive cable connector out through the keyway.

8. Disconnect the source guide tube from the source changer. If a replacement source is to be installed in the exposure device, connect the source guide tube to the fitting above the chamber containing the new source and couple the drive cable to the new source. If the source is being removed to service the exposure device, connect the drive cable to the jumper that is clipped inside the storage cover of the exposure device.

9. Return to the controls and crank the new source (or jumper) into the exposure device. If a new source is being transferred, the survey meter reading should increase as the source leaves the source changer and approaches the exposure device, then drop to background level when the source is shielded in the exposure device. If a jumper is being transferred, the survey meter should indicate only background radiation levels.

10. Survey the exposure device to ensure that the process has been properly completed. Radiation levels should read no more than 200 mR/hr at the surface of the exposure device if a new 140 curie source has been transferred. If the jumper is in the exposure device, only background radiation should be detected by the survey meter. Rotate the selector ring to the LOCK position.

11. Survey the source guide tube and source changer to check that the source has been correctly transferred.

12. Secure the source(s) in the source changer in accordance with the appropriate source changer instruction manual.

13. Disconnect the control unit and source guide tube from the exposure device as in Step 23 of the Operating Procedure and disconnect the source guide tube from the source changer.

14. Remove the source identification plate from the exposure device and attach it with seal wire to the source holddown cap.

15. If the exposure device contains a source, affix the identification plate of the new source to the exposure device. If not, attach an EMPTY tag to the handle of the exposure device.

16. If the source changer is to be transported, survey it to determine the correct shipping label required as in Shipping Radioactive Material. (Radiation levels must not exceed 200 mR/hr at the surface nor 10 mR/hr at one meter from the surface.) Bolt the source changer cover in place and secure it with seal wire.

17. Return the source changer promptly to Amersham. Demurrage rental charges will be assessed for containers held beyond normal operating time.

<u>Shipment of Radioactive Source</u>

1. Ensure that the source is locked into place in its storage position. To check this, the lock should be in the down position, the key removed, and the selector ring should be immobile. Attach a tamper proof security seal with an identification mark to the storage plug.

2. If the shipping container is to be packaged in a crate or other outer packaging, the outer packaging must be strong enough to withstand the normal conditions of transport. These requirements are outlined in 10 CFR 71. The shipping container should be put in the outer package with sufficient blocking to prevent shifting during transportation.

3. Perform a radioactive contamination wipe test of the outer shipping package. This consists of rubbing filter paper or other absorbent material, using heavy finger pressure, over an area of 100 cm^2 (16 in^2) of the package surface. The activity on the filter paper should not exceed 0.001 uCi of removable contamination.

4. Survey the package with a survey meter at the surface and at a distance of one meter from the surface to determine the proper radioactive shipping labels to be applied to the package as required by 49 CFR 172.403. The radiation exposure limits for each shipping label are given in Figure 4.1. If radiation levels above 200 mR/hr at the surface or 10 mR/hr one meter from the surface are measured, the container must not be shipped.

5. Properly complete two shipping labels indicating the radioactive isotope, activity and the Transport Index. The Transport Index is used only on Yellow II and Yellow III labels and is defined as the maximum radiation level in milliroentgens per hour measured at a distance of one meter from the surface of the package. Put these two labels on opposite sides of the container after making sure any previous labels have been removed. The package should be marked with the proper shipping name (Radioactive Material, Special Form, n.o.s., UN 2974). If the exposure device is packaged inside an outer container, mark the outside package "INSIDE PACKAGE COMPLIES WITH PRESCRIBED SPECIFICATIONS - TYPE B USA/9033/B(U)."

6. Complete the appropriate shipping papers - These shipping papers must include:

   a. Proper shipping Name (Radioactive Material, Special Form, n.o.s.) and Identification Number (UN 2974).

   b. Name of Radionuclide (Iridium-192).

   c. Activity of the Source (in Curies).

   d. Category of Label Applied (i.e. Radioactive Yellow II).

   e. Transport Index.

   f. Package Identification Number (i.e. USA/9033/B(U) Type B(U)

   g. Shipper's Certification.

   "This is to certify that the above named materials are properly classified, described, packaged, marked and labeled and are in proper condition for transport according to the applicable regulations of the Department of Transportation."

Notes:

1. For air shipments, the following shipper's certification may be used:

   "I hereby certify that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked and labeled, and are in proper condition for carriage by air according to applicable national govermental regulations."

2. For air shipments to, from or through the United States, a "CARGO AIRCRAFT ONLY" label and the shipping papers must state:

   "THIS SHIPMENT IS WITHIN THE LIMITATIONS PRESCRIBED FOR CARGO ONLY AIRCRAFT."

6. Due to the depleted uranium used as shielding in the exposure device, a notice must also be enclosed in or on the package included with the packing list, or otherwise forwarded with the package. This notice must include the name of the consignor or consignee and the following statement:

   "This package conforms to the conditions and limitations specified in 49 CFR 173.424 for expected radioactive material, articles manufactured from depleted uranium, UN 2909.

7. For shipment of an empty exposure device, assure that there is no source in the container. If the radiation level is below 0.5 mR/hr at the surface, and there is no measurable radiation level at one meter from the container, no label is required. Mark the outside of the package with the proper shipping name (Radioactive material, articles manufactured from depleted uranium, UN 2909). Mark the outside of the package:

   "Exempt from specification packaging, shipping paper and certification, marking and labeling and exempt from the requirements of Part 175 per 49 CFR 173.421-1 and 49 CFR 173.424."

   Additionally, a notice must be enclosed in our on the package included with the packing list or otherwise forwarded with the package. This notice must include the name of the consignor or consignee and the statement:

   "This package conforms to the conditions and limitations specified in 49 CFR 173.424 for excepted radioactive materials, articles manufactured from depleted uranium, UN 2909."

8. Return the container to Amersham Corporation according to proper procedures for transporting radioactive material as established in 49 CFR 171-178.

NOTE: The U.S. 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.

Maintenance

Inspection and maintenance of the Model 660 exposure device and the control unit must be performed at intervals not to exceed three months, in accordance with 10 CFR 34.28.

Drive Cable, Control Housings and Source Guide Tubes

1. Disconnect the control unit from the exposure device.

2. Turn the hand crank of the control unit in the EXPOSE (counter clockwise) direction until the crank will no longer turn. Do not use force, as this may damage the drive wheel inside the control box. The emergent cable should be cranked into a bucket or other container to keep it clean.

3. Disconnect the control housing from the RETRACT side of the crank and remove the stop spring from the drive cable. The drive cable will now pass through the crank.

4. Turn the crank until the drive cable is totally disconnected.

5. Pull the drive cable out through the Model 661 control cable connector and coil it with a radius of no less than 4 inches.

6. Remove the Model 661 control cable connector and connector plug from the control housings, and disconnect the other control housing from the crank. Label the housings for proper reassemble.

7. Clean the drive cable with chlorothene and flush the control housings and source guide tubes.

8. Using compressed dry air (15 psi max.), thoroughly dry the drive cable, control housings and guide tubes. Any remaining solvent can cause permanent damage.

9. Check the source guide tubes for binding by holding them vertical and dropping a dummy source (or jumper) through them.

10. Wipe the guide tubes and control housings with a cloth soaked in chlorothene and flex them to check for internal damage. Damage is evidenced by a crunching feeling when the housing or tube is bent. While doing this, feel for dents. Cut, flattened or burnt control housings or guide tubes should be repaired or replaced.

11. The guide tubes or control housings may be covered with tape where only the outer plastic is cut through.

12. Using a Model 550 no-go guage, check the male connector of the drive cable. If the ball of the connector fits through the hole of the guage or the ball shank fits into the slot in the guage, the connector is worn and the cable must be replaced. Refer to Figure 7.1.

13. Lightly grease the cable using Mil-G-23827 B grease or equivalent. Other greases may form tars or corrosive compounds when exposed to radiation.''

Exposure Device

To service the exposure device, remove the source following the source changing procedures. (Before removing the source, check the female drive cable connector of the source with a Model 550 no-go guage, as in Figure 7.1; if the gauge width can fit into the female slot, the connector is worn and the source must be replaced.) After the source has been removed, service the exposure device by performing the following steps:

1. Remove the Danger Tag (secured with rivets) from the bottom of the rear plate.

2. Remove the rear plate by unscrewing the six phillips head screws securing it to the exposure device body.

3. Unlock the connector lock, and then remove the lock assembly and control unit connector assembly by unscrewing the six socket head screws securing them to the rear plate.

4. Disassemble the control unit connector assembly, referring to Figure 7.2 for component identification and for order of removal. There are several spring loaded parts in the connector assembly, so care should be taken that these parts are not lost.

5. To disassemble the lock assembly, refer to Figure 7.2 for component identification and for order of removal. Remove the lock (2) from the lock retainer (3) by unscrewing the screw (4) and turning the key about 90°.

6. Remove the front end plate from the exposure device, and remove the guide tube connector and retaining ring with Tru Arc pliers, referring to Figure 7.2. The handle may be left on the front plate.

7. Clean all parts in chlorothene and flush the source tube with solvent. Dry the parts and the source tube thoroughly using dry compressed air (20 psi maximum). Clean the S-Tube in the exposure device by running a cloth soaked with chlorothene through it several times. Dry the S-Tube by running a dry cloth through the tube.

8. Inspect all parts for damage or excessive wear, and replace if necessary. Use Figure 7.2 for component identification numbers.

9. Lightly grease all moving parts at their contact surfaces with MI-G-23827 B grease or equivalent.

10. Reassemble the front end plate, and secure it to the exposure device with the proper screws.

11. Reassemble the lock by placing the return springs and spring guides into the lock (2), depressing the internal plunger, inserting the lock (2) into the lock retainer (3), an securing the lock with the set screw (4).

12. Attach the lock assembly to the rear plate with two socket head screws.

13. To reassemble the control unit connector assembly, refer to Figure 7.2.

14. Refer to Figure 7.2 and place the compression spring (11) on the hub of the selector ring retainer. The spring should be firmly seated over the hub. Then place the sleeve (12) on top of the compression spring (11)

15. Place the selector body (6) on a flat surface so that it is resting on its 5/8" hub.

16. Insert the two short compression springs (8) and locking pins (7) into the holes on the edge of the selector body.

17. Place the selector ring (10) over the selector body (6) while restraining the locking pins (7). Ensure that the lettering (OPERATE-LOCK-CONNECT) on the selector ring is facing up and that the stop pin on the selector body is in the cam slot of the selector ring. This is shown in Figure 7.2.

18. Hold the selector ring (10) and selector body (6) together and place them over the assembly shown in Figure 7.2. The resulting assembly is shown in Figure 7.2. Align the resulting assembly such that the two large holes in the selector ring retainer (9) line up with the two large holes in the selector body (6). The internal locking cam will partially block these holes.

19. Insert the anti-rotation lugs (13) and long compression springs (14) into the two large holes in the selector body. Secure the resulting assembly onto the rear plate with four socket head screws. The word OPERATE should be facing outward, and should be in the 12 o'clock position.

20. Connect the jumper to the short length drive cable and insert the cable through the rear end plate and control unit connector assembly.

21. Insert a U-tool into the control unit connector assembly and check the operation by turning the selector ring from OPERATE to CONNECT several times. If the connector assembly does not operate properly, disassemble and inspect the parts for damage and proper alignment. Relubricate the parts and reassemble.

22. Secure the rear end plate to the exposure device and handle using the six attaching phillips head screws and replace the protective plate over the bottom two rear plate screws using pop rivets (0.125 in diameter x 0.295 in long).

23. Check the system for proper reassembly. Check all connections and fittings for tightness. Check for proper operation of the control unit and control unit connector assembly.

24. Reload the source in the exposure device by following Section VI, Source Changes.

25. Survey the exposure device on all sides to ensure that radiation levels do not exceed 200 mR/hr at the surface nor 10 mR/hr at one meter from the surface.

26. Check the exposure device for the proper labels.

Cable connection: Connect the drive cable to the source projector as shown in fig. 5.2.

(a) Unlock with the key and turn the selector ring from LOCK to CONNECT. The storage cover will disengage from the projector.

(b) Slide the control cable collar back and open the jaws to expose the male portion of the swivel coupling (ie. the ball-end on the drive cable).

Figure 5.2(i)

Figure 1

(c) Press back the spring-loaded locking pin with a thumb nail and engage the male and female portions of the swivel coupling.

Figure 5.2(ii)

(d) Release the locking pin and check that the connection is secure.
Close the jaws of the control cable connector over the swivel coupling.

Figure 2

(e) Slide the control cable collar over the connector jaws.

Figure 5.2(iii)

Note that the drive cable connector, when properly installed with the selector ring in the CONNECT position, displaces anti-rotation lugs which allows the selector ring to be rotated to the LOCK position and when required, through to the OPERATE position.

Figure 3

(f) Push and hold the control cable collar flush against the projector connector and rotate the selector ring from CONNECT to LOCK.

Do not rotate past LOCK.

The drive cable connector is now locked into the projector.

Figure 5.2(iv)

(g) Keep the projector in the LOCK position until ready to start the exposure.

Figure 4

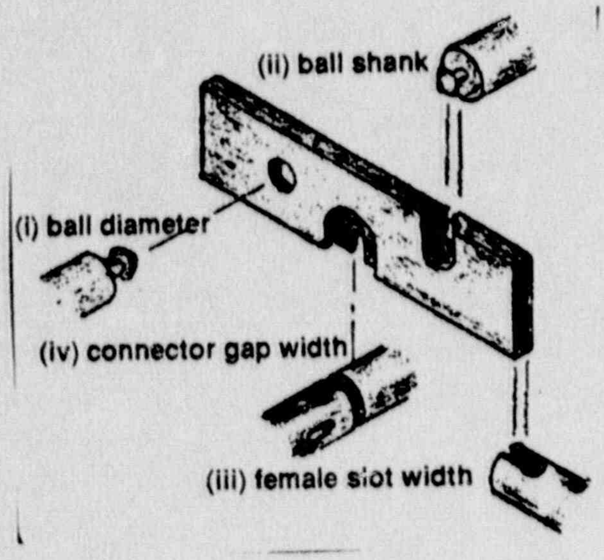
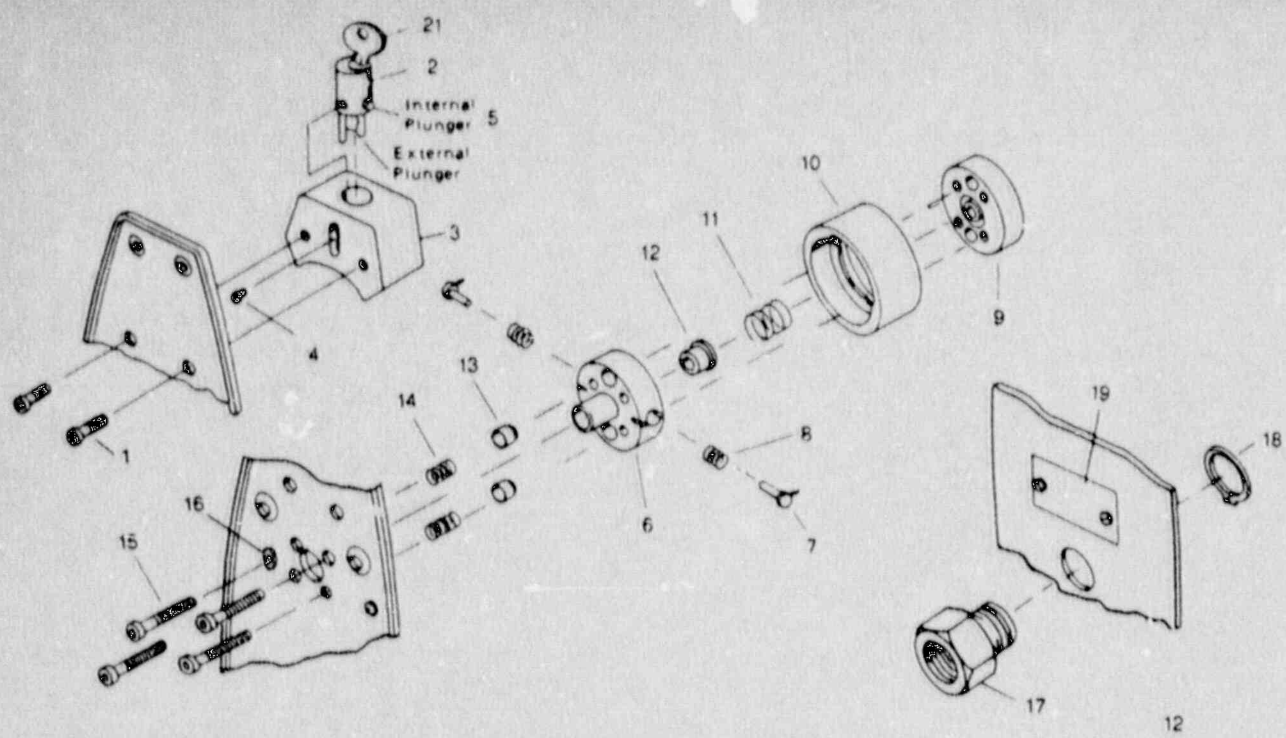
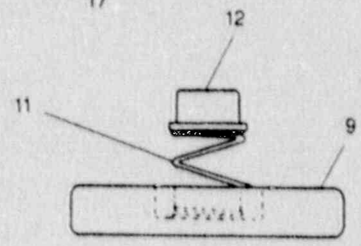

(ii) ball shank
(i) ball diameter
(iv) connector gap width
(iii) female slot width

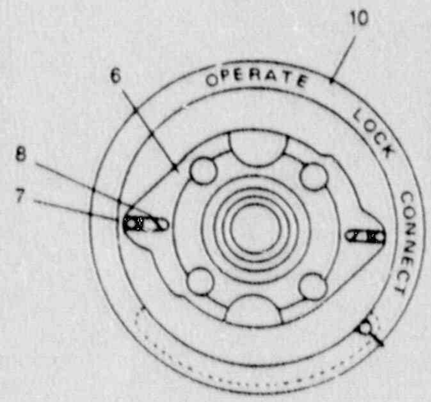
Figure 7.1



AMERTEST™ 660 GAMMA RAY PROJECTOR

Ref #	Cat Code	Part # U.S.A.	Qty	Description	660 Repair Kit Code Kit-002 Qty in Kit
1	TMN1		2	Socket Head screw 10-32x5/8 in.	4
2	TSN66011	66001-11	1	Lock	
3	TSN66012	66001-12	1	Lock Retainer	
4			1	Screw (supplied w/item 2)	1
5			1	Internal Plunger	
6	TSN66001	66001-1	1	Selector Body	
7	TSN66005	66001-5	2	Locking Pin	
8	TSN0321		2	Compression spring (LC-032E-1)	2
9	TSN66003	66001-3	1	Selector Ring Retainer	
10	TSN66008	66001-8	1	Selector Ring	
11	TSN0541		1	Compression Spring	1
12	TSN66004	66001-4	1	Sleeve	
13	TSN66006	66001-6	2	Anti-Rotation Lugs	
14	TSN0267		2	Compression Spring	2
15	TMN1		4	Socket Head Screws 10-32x1 1/4 in. (st. steel)	8
16	TMN1		4	Lock Washer, #10	4
17	TSN53311	53301-11	1	Guide Tube Connector Nut	
18	TMN1		1	Retaining Ring	
19	TSN002	LBL-010	1	Source Identification Plate	
20				1/4-20x3/4" PH Screws	8
21		66001-811		Key	2
22			4	4-40 3/16 BHMS (for lock)	4
23			1	6-32 x 5/8" (for	2
24				10-32x3/8" S.S. Allen Screw	4
*		66001-20	1	Jumper Connector	1
*				#30 Drill Bit	1
*			12	1/8" S.S. Pop Rivets	12
*			1	6 Links of Cover Chain	1
*			1	#4 Scott Drive Screws 5/6"	2
*		GRE-TUB		Grease	1
*		660-CL		Check List	1
*		MAN-006	1	660 Operations/Maint. Manual	





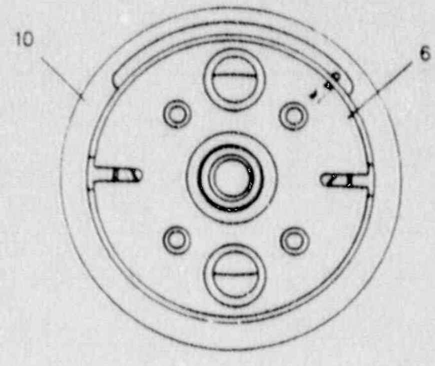


Figure 7.2

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SECTION 8

ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

8.1.1 Visual Inspection

The package is visually examined to assure that the appropriate fasteners are properly seal wired. The package is inspected to assure that the proper marking and labeling is present.

The seal weld of the radioactive source capsule is visually inspected for proper closure.

8.1.2 Structural and Pressure Tests

The swage coupling between the source capsule and cable is subjected to a static tensile test with a load of one hundred pounds.

8.1.3 Leak Tests

The radioactive source capsule, which serves as the primary containment, is wipe tested for leakage of radioactive contamination. The source capsule is subjected to a vacuum bubble leak test. These tests are described in Section 7.5.1. Failure of either of these tests will prevent use of this source assembly.

8.1.4 Component tests

The lock assembly of the package is tested to assure that the security of the source will be maintained. A simulated (dummy) source assemoly is installed in the radiographic exposure device and the lockbox locked. An attempt is made to pull the simulated source out through the lockbox. The shipping plugs are installed and checked to be sure they are attached securely to the device. Failure of either of these two tests will prevent use of the package until the cause of the failure is corrected and retested.

8.1.5 Tests for Shielding Integrity

With the package containing a source assembly, the radiation levels at the surface of the package and at one meter from the surface of the package are measured using a small detector survey instrument. These radiation levels, when extrapolated to the rated capacity of the package, must not exceed 200 milliroentgens per hour at the surface of the package nor 2mR/hr at one meter from the surface.

8.1.6 Thermal Acceptance Tests

Not applicable.

8.2 Maintenance Program

8.2.1 Structural and Pressure Tests

Not applicable.

8.2.2 Leak Tests

As described in section 8.1.3, the radioactive source assembly is leak tested at manufacture. Additionally, the source assembly is wipe tested for leakage of radioactive contamination every six months.

8.2.3 Subsystem Maintenance

The lockbox assembly is tested as described in section 8.1.4 prior to each use of the package. Additionally, the package is inspected for tightness of fasteners, proper seal wires, and general condition before each use.

8.2.4 Valves, Rupture Discs, and Gaskets

Not applicable.

8.2.5 Shielding

Prior to each use, a radiation survey of the package is made to assure that the radiation levels do not exceed 200 milliroentgens per hour at the surface nor 2 milliroentgens per hour at one meter from the surface.

8.2.6 Thermal

Not applicable.

8.2.7 Miscellaneous

Inspections and tests designed for secondary users of this package under the general license provisions of 10 CFR 71.12(b) are included in Section 7.4.