Tech Ops

Radiation Products Division
40 North Avenue
Burlington, Massachusetts 01803
Telephone (617) 272-2000

PACKAGE DESCRIPTION

TECHNICAL OPERATIONS

MODEL 680

USA/9035/B

Prepared by

DAVID MARZILLI

8001070178

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1. General Information

The Tech/Ops Models 680 and 680E are designed for use as gamma ray projectors and shipping containers for Type B quantities of radioactive material in special form. The Model 680 differs from the Model 680E only by the addition of an electric circuit, which provides compatibility with Tech/Ops Model 657 Automatic Exposure Device. Throughout this evaluation, the Models 680 and 680E are considered interchangeable, except where specifically designated.

The Model 680 conforms to the criteria for Type B packaging in accordance with 10CFR71 and satisfies the criteria for Type B(U) packaging in accordance with IAEA Safety Series No. 6, 1973. The source to be used in conjunction with the Model 680 is Tech/Ops sealed source assembly Model No. A424-14. The Model 680 will contain a maximum of 110 curies of cobalt-60 as special form.

1.2 Package Description

1.2.1 Packaging

The Model 680 is 11.8 inches (300mm) high, 21 inches (533mm) long, and 14.75 inches (376mm) wide in overall dimension. The gross weight of the package is 405 pounds (184kg). The radioactive source assembly is stored in a zircalloy or titanium "S" tube in the geometric center of the package. The "S" tube is cast inside a depleted uranium shield assembly. The weight of the uranium shield is 285 pounds (130kg). The shield is provided with a paint finish.

The shield is enclosed in a shell fabricated of $\frac{1}{4}$ inch (6.35mm) thick hot rolled steel. The shield is fixed in position within the shell by the retaining bar assemblies. The void space between the shield and the shell is filled with a castable rigid polyurethane foam. Steel-uranium interfaces are separated with 0.010 inch (0.254mm) thick copper separators.

Attached to the sides of the container are 0.75 inch (19.1mm) thick hot rolled steel side frames used for lifting the package.

Mounted at each end of the "S" tube are positioning devices. The source assembly is locked in position by means of the control cable connector and additionally secured by means of a shipping plug. A protective shipping plate ($\frac{1}{4}$ inch thick steel) is mounted over the control cable connector assembly.

Tamperproof seals are provided during shipment of these sources. Assembly joints which are not leak-tight provide passageways for the escape of any gas generated from decomposition of the potting foam in the event the projector is involved in a fire accident. The outer packaging is designed to avoid the collection and retention of water. The package is painted and finished to provide for easy decontamination. The radioactive material is sealed inside a source capsule, which is the containment vessel of the package.

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The Model 680 has been previously approved for use as a Type B package under USNRC Certificate of Compliance No. 9035, Rev. 2 (enclosed in Section 1.3).

1.2.2 Operational Features

The source assembly is secured in the proper position by the control cable connector and lock assembly. This assembly requires a key for operation, and thus provides positive closure. A $\frac{1}{4}$ inch (6.35mm) thick steel shipping plate is used to protect the assembly during shipment. Additionally, the source assembly is secured by means of a shipping plug inserted in the opposite end of the "S" tube. This plug is seal wired and provided with a tamperproof seal.

1.2.3 Contents of Packaging

The Model 680 is designed for a capacity of up to 110 curies of cobalt-60 as Tech/Ops Source Asdembly A424-14. The source assembly is in special form as prescribed in 10CFR71 and IAEA Safety Series No. 6, 1973.

1.3 APPENDIX

- USNRC Certificate of Compliance No. 9035, Rev. 2
- Descriptive Assembly Drawing, Model 680

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Form NRC 618
(12-73)
10 CFR 71

U.S. NUCLEAR REGULATORY COMMISSION
CERTIFICATE OF COMPLIANCE
For Radioactive Materials Packages

1.(a) Certificate Number	1.(b) Revision No.	1.(c) Package Identification No.	1.(d) Pages No.	1.(e) Total No.
9035	2	USA/9035/B( )	1	2

2. PREAMBLE

2.(a) This certificate is issued to satisfy Sections 173.393a, 173.394, 173.395, and 173.396 of the Department of Transportation Haz Materials Regulations (49 CFR 170-189 and 14 CFR 103) and Sections 146-19-10a and 146-19-100 of the Department of Transportation Dangerous Cargoes Regulations (46 CFR 146-149), as amended.

2.(b) The packaging and contents described in item 5 below, meets the safety standards set forth in Subpart C of Title 10, Code of Federal Regulations, Part 71, "Packaging of Radioactive Materials for Transport and Transportation of Radioactive Material Un Certain Conditions."

2.(c) This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department Transportation or other applicable regulatory agencies, including the government of any country through or into which the pack will be transported.

3. This certificate is issued on the basis of a safety analysis report of the package design or application—

3.(a) Prepared by (Name and address):

Technical Operation, Inc.
Northwest Industrial Park
Burlington, Massachusetts 01803

3.(b) Title and identification of report or application:

Technical Operations, Inc. application dated January 13, 1975, as supplemented.

3.(c) Docket No. 71-9035

4. CONDITIONS
This certificate is conditional upon the fulfilling of the requirements of Subpart D of 10 CFR 71, as applicable, and the conditions spec in item 5 below.

5. Description of Packaging and Authorized Contents, Model Number, Fissile Class, Other Conditions, and References:

(a) Packaging

(1) Model Nos.: 680 and 680E

POOR ORIGINAL

(2) Description

A steel encased, uranium shielded Gamma Ray Projector. Primary components consists of an outer steel shell, internal bracing, polyurethane potting material, depleted uranium shield, and a zircalloy "S" tube. The contents are securely positioned in the zircalloy "S" tube by a source cable locking device and shipping plug. Tamper-proof seals are provided on the packaging and a 1/4-inch thick steel shipping plate is bolted over the source locking mechanism for additional protection during transport. The total weight of the package is approximately 405 pounds.

(3) Drawings

The packaging is constructed in accordance with the following Technical Operations, Inc. Drawing Nos.:

D68001, Sheet 1, 2	A52401-3
D68001-3	B65502
B68001-4, 10, 12	B65503
A68001-9, 11, 13, 14, 15	B655E01
D68002C68002-1	B65501-6
D68003	A74101-2
D68003-1	B74101-8
C68003-2	A84102-3

Bill of Mat'ls 68001 (Sheets 1-4)

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5. (b) Contents

(1) Type and form of material

Cobalt-60 as sealed sources which meet the requirements of special form as defined in §71.4(o) of 10 CFR Part 71.

(2) Maximum quantity of material per package

110 curies

6. The source shall be secured in the shielded position of the packaging by the shipping plug, source assembly, and locking device. The shipping plug, source assembly used must be fabricated of materials capable of resisting a 1475°F fire environment for one-half hour and maintaining their positioning function. The ball stop of the source assembly must engage the locking device. The flexible cable of the source assembly and shipping plug must be of sufficient length and diameter to provide positive positioning of the source in the shielded position.

7. The nameplates shall be fabricated of materials capable of resisting the fire test of 10 CFR Part 71 and maintaining their legibility.

8. The package authorized by this certificate is hereby approved for use under the general license provisions of Paragraph 71.12(b) of 10 CFR Part 71.

9. Expiration date: February 28, 1980.

REFERENCES

Technical Operation, Inc. application dated January 13, 1975.

Supplement dated: June 17, 1975.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

Charles E. MacDonald

Charles E. MacDonald, Chief
Transportation Branch
Division of Fuel Cycle and
Material Safety

Date: APR 13 1977

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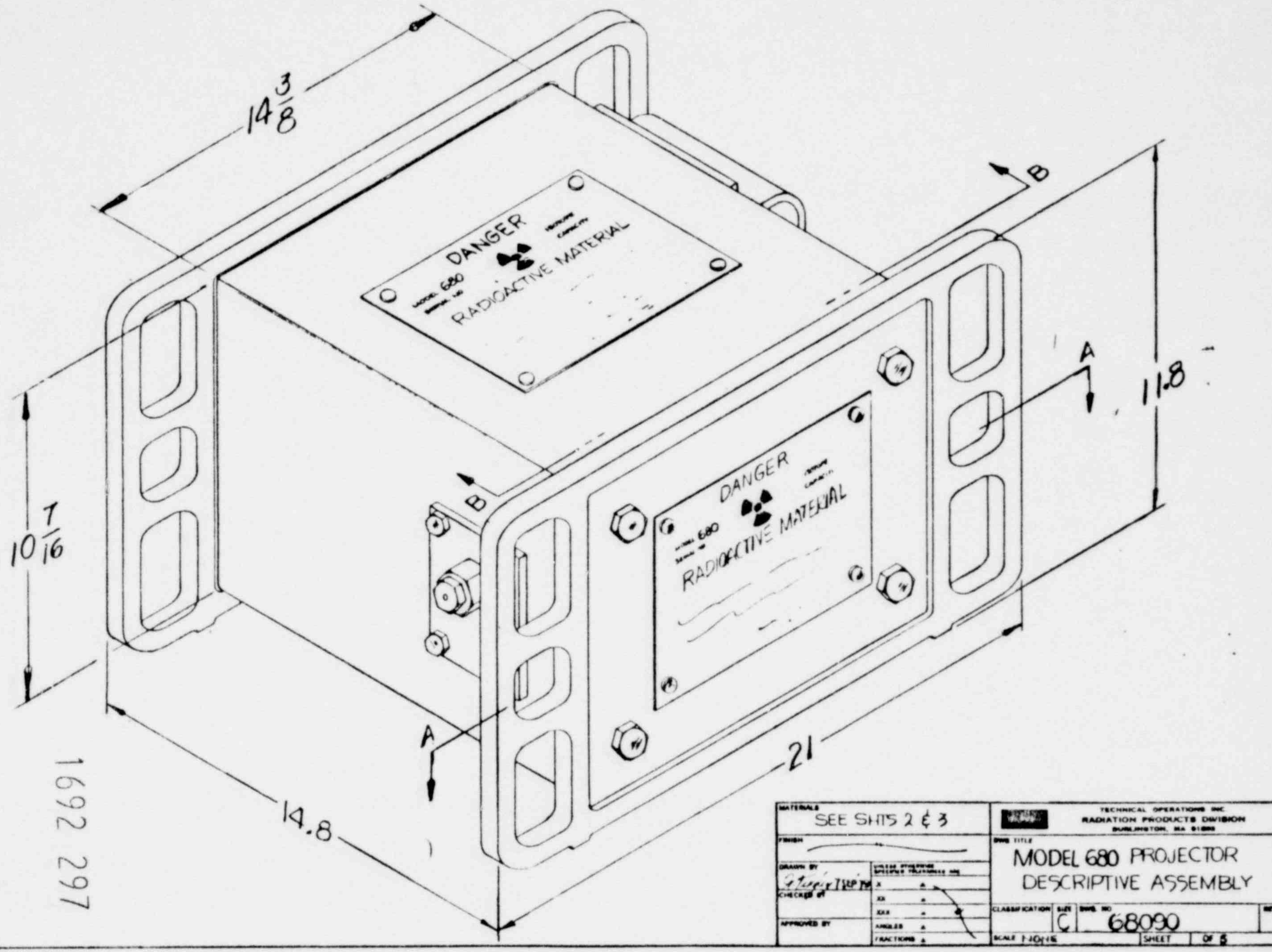
C68090



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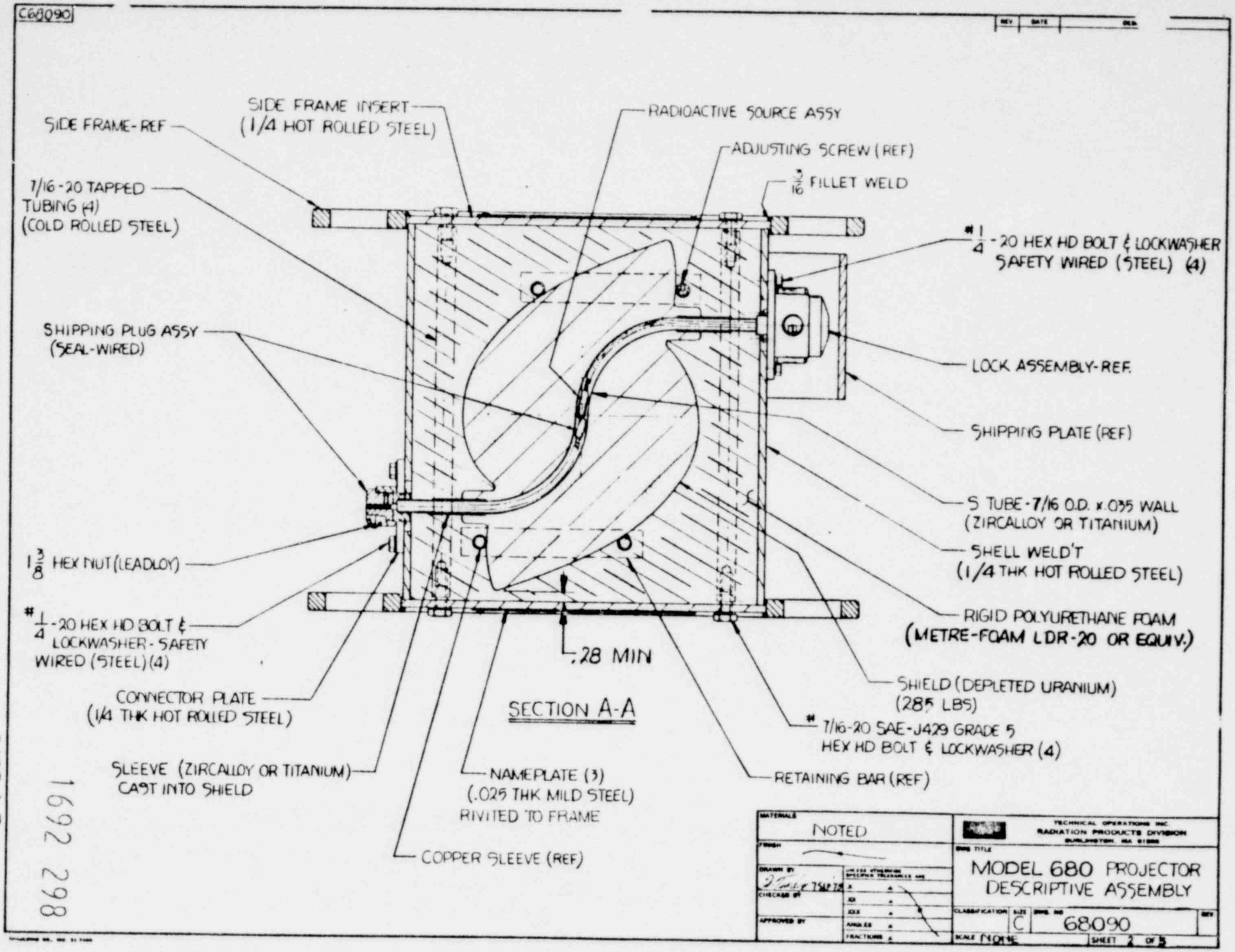

C68090
SIDE FRAME-REF
SIDE FRAME INSERT (1/4 HOT ROLLED STEEL)
RADIOACTIVE SOURCE ASSY
ADJUSTING SCREW (REF)
3/16 FILLET WELD
7/16-20 TAPPED TUBING (4) (COLD ROLLED STEEL)
1/4-20 HEX HD BOLT & LOCKWASHER SAFETY WIRED (STEEL) (4)
SHIPPING PLUG ASSY (SEAL-WIRED)
LOCK ASSEMBLY-REF.
SHIPPING PLATE (REF)
S TUBE-7/16 O.D. x .035 WALL (ZIRCALLOY OR TITANIUM)
SHELL WELD'T (1/4 THK HOT ROLLED STEEL)
1 3/8 HEX NUT (LEADLOY)
1/4-20 HEX HD BOLT & LOCKWASHER-SAFETY WIRED (STEEL) (4)
RIGID POLYURETHANE FOAM (METRE-FOAM LDR-20 OR EQUIV.)
.28 MIN
CONNECTOR PLATE (1/4 THK HOT ROLLED STEEL)
SECTION A-A
SHIELD (DEPLETED URANIUM) (285 LBS)
7/16-20 SAE-J429 GRADE 5 HEX HD BOLT & LOCKWASHER (4)
SLEEVE (ZIRCALLOY OR TITANIUM) CAST INTO SHIELD
NAMEPLATE (3) (.025 THK MILD STEEL) RIVITED TO FRAME
RETAINING BAR (REF)
COPPER SLEEVE (REF)
MATERIALS NOTED
TECHNICAL OPERATIONS INC. RADIATION PRODUCTS DIVISION BURLINGTON, MA
MODEL 680 PROJECTOR DESCRIPTIVE ASSEMBLY
C
68090
SCALE NONE
SHEET 2 OF 5

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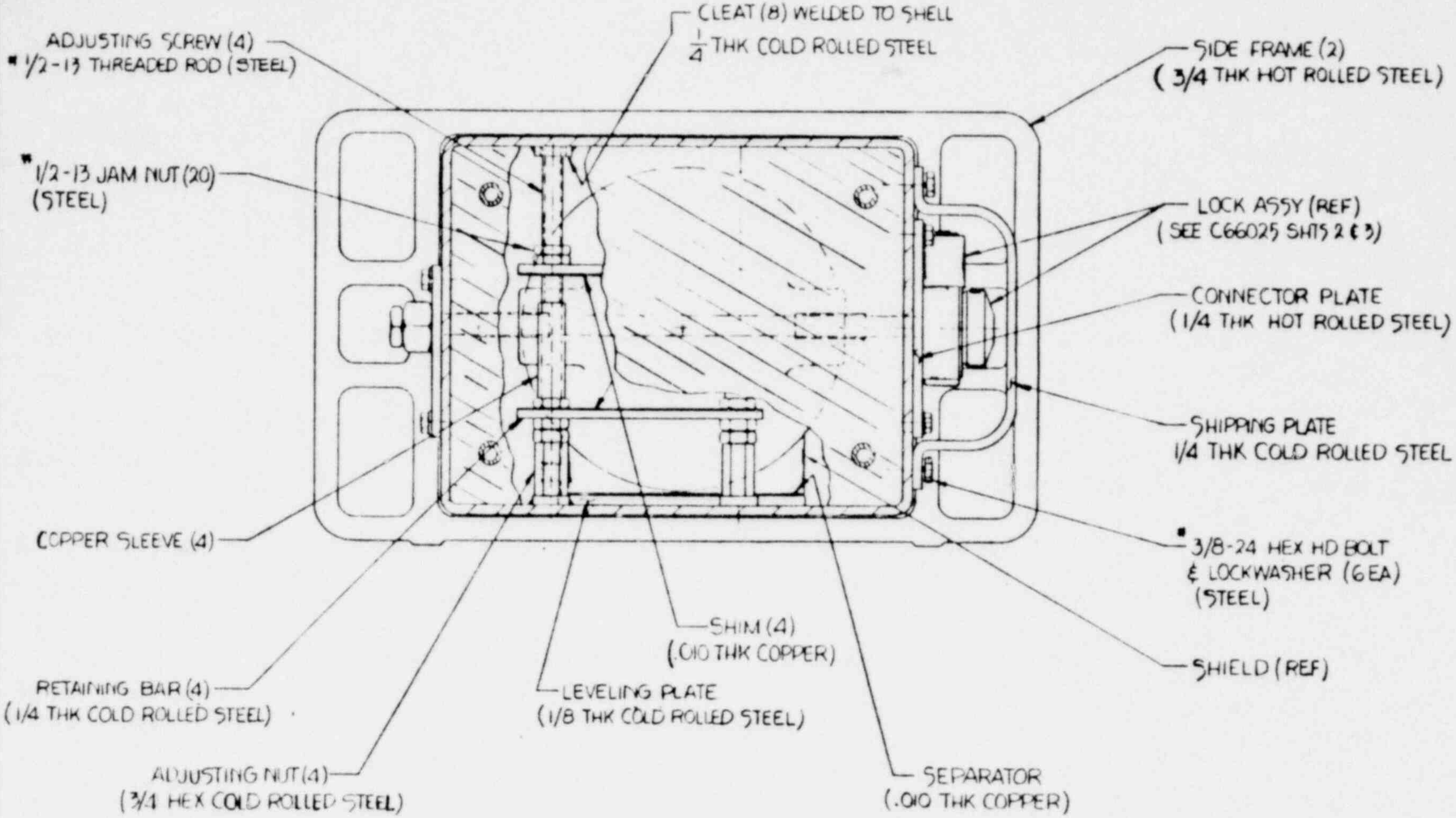
C68090



SECTION B-B

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PAGE 1-8

MATERIALS: NOTED	TECHNICAL OPERATIONS INC RADIATION PRODUCTS DIVISION BURLINGTON MA 01803
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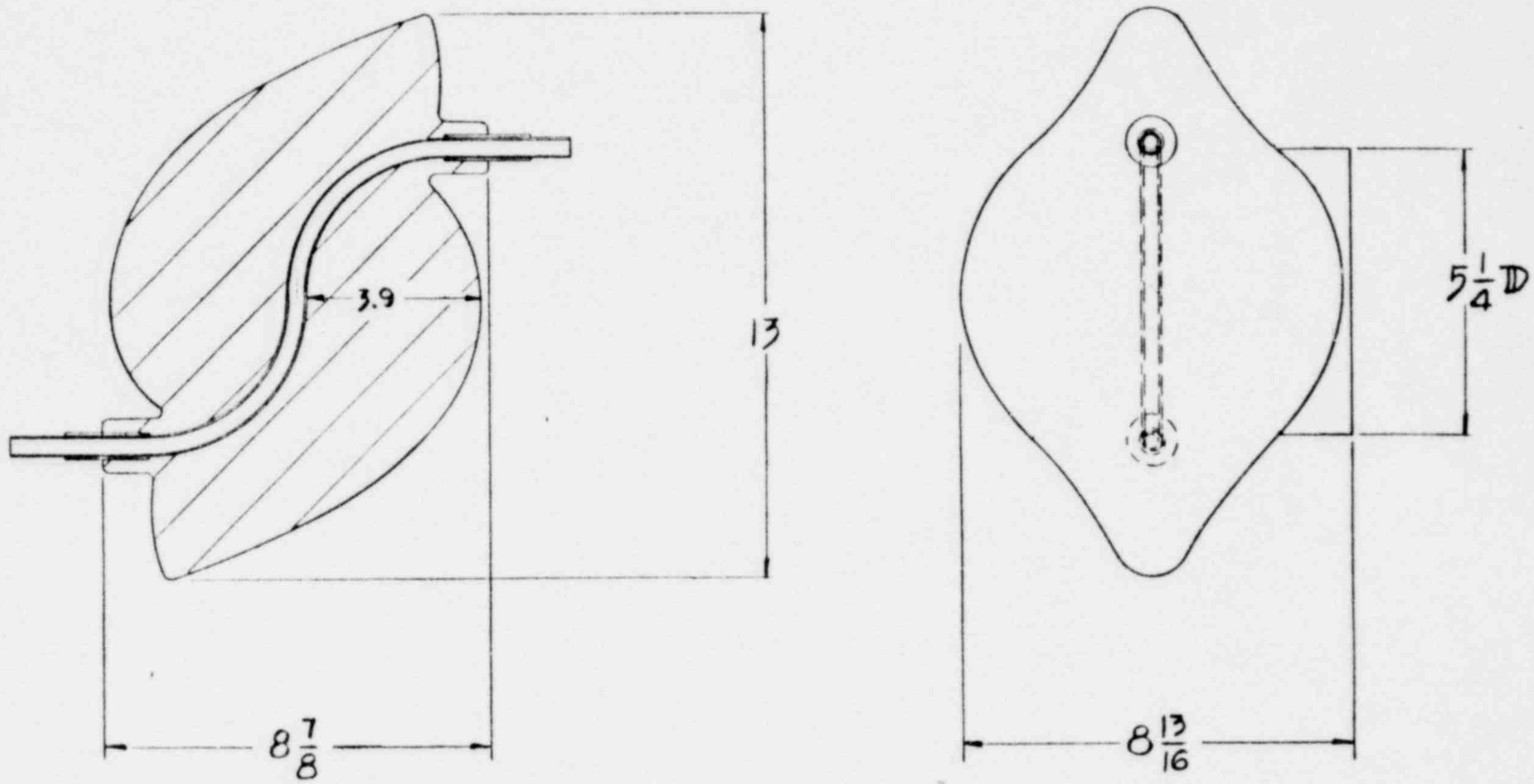
DRAWN BY: 7 JUN 79	UNLESS OTHERWISE SPECIFIED TOLERANCES ARE: X ±, XX ±, XXX ±, ANGLES ±, FRACTIONS ±
CHECKED BY	CLASSIFICATION / SIZE: C / DWG NO: 68090 / REV
APPROVED BY	SCALE: NONE / SHEET 3 OF 5

C68090



SHIELD DATA

285 LBS

MATERIALS: NOTED	TECHNICAL OPERATIONS INC. RADIATION PRODUCTS DIVISION BURLINGTON, MA 01803
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DRAWN BY: 7 NOV 79	CLASSIFICATION / SIZE: C / DWG NO: 68090 / REV
CHECKED BY	SCALE: NONE / SHEET 4 OF 5
APPROVED BY	

1692 300

TECHNICAL OPERATIONS INC.
RADIATION PRODUCTS DIVISION
BURLINGTON, MA 01803

DWG TITLE: MODEL 680 PROJECTOR DESCRIPTIVE ASSEMBLY

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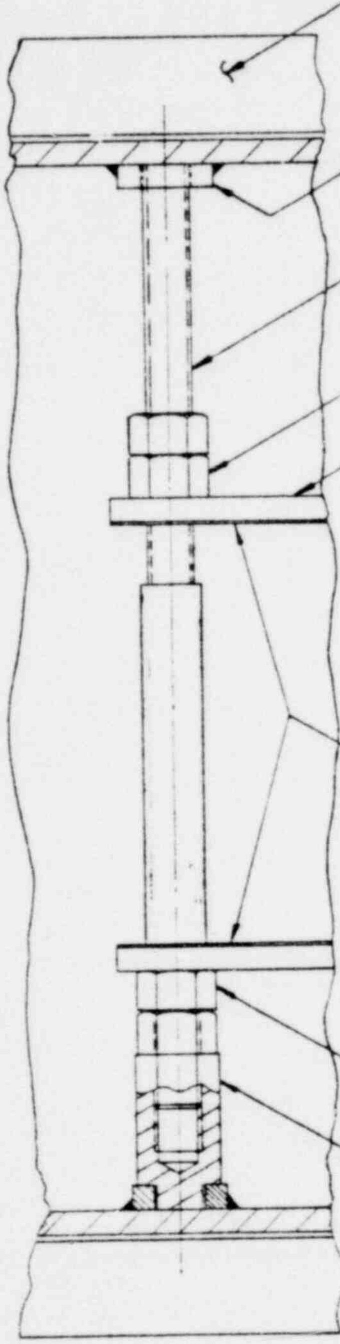

VIEW D

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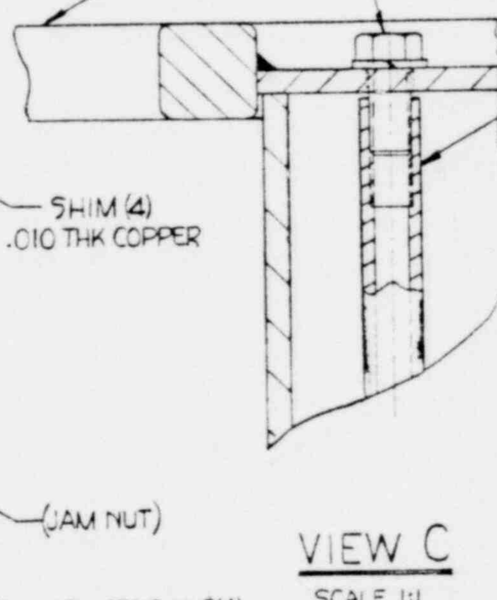

VIEW C

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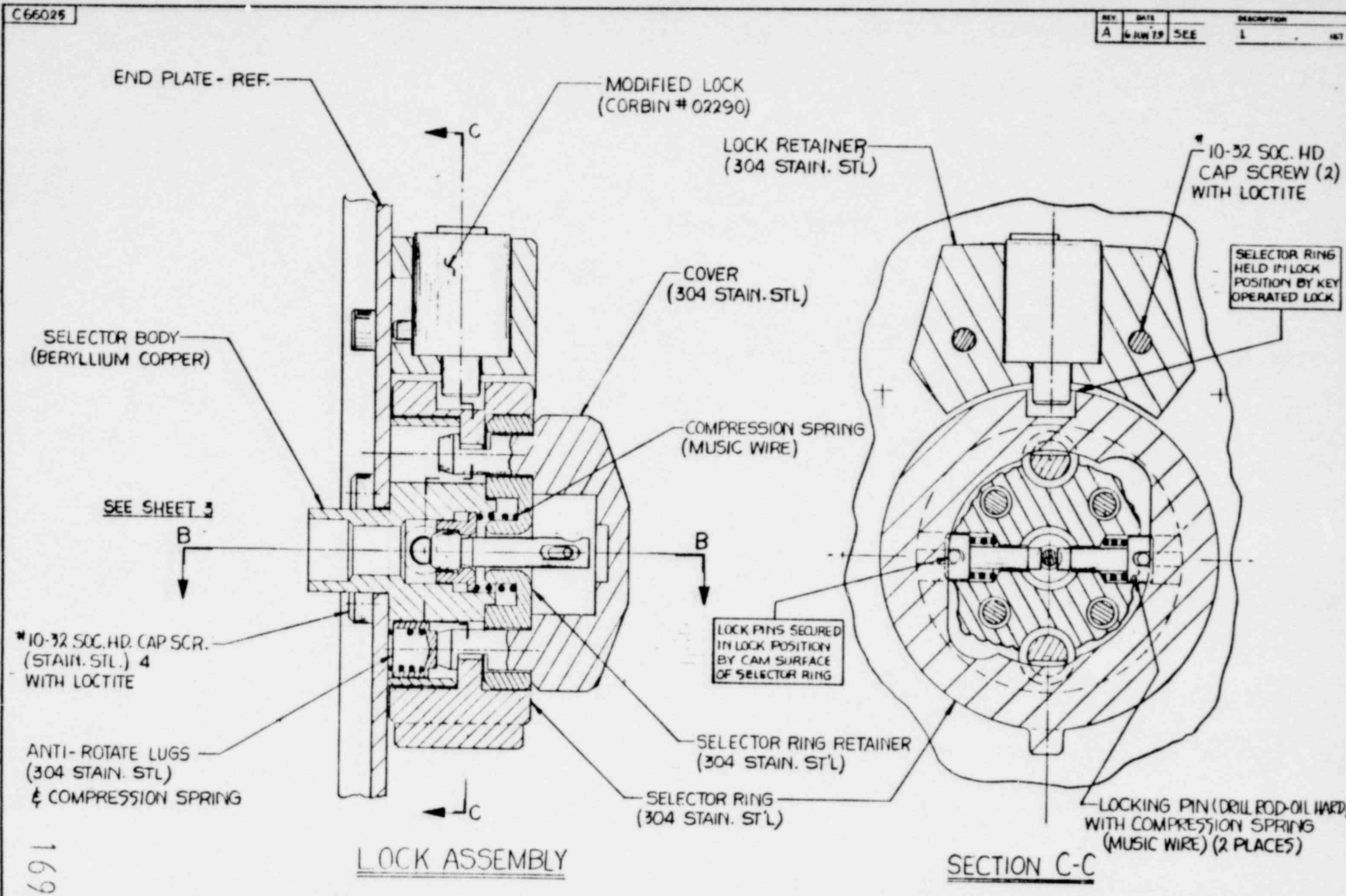
1692 301

C 68090



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SIZE	C
DWG. NO.	66025
REV	A
SCALE	2:1
SHEET	2 OF 3

PAGE 1-11

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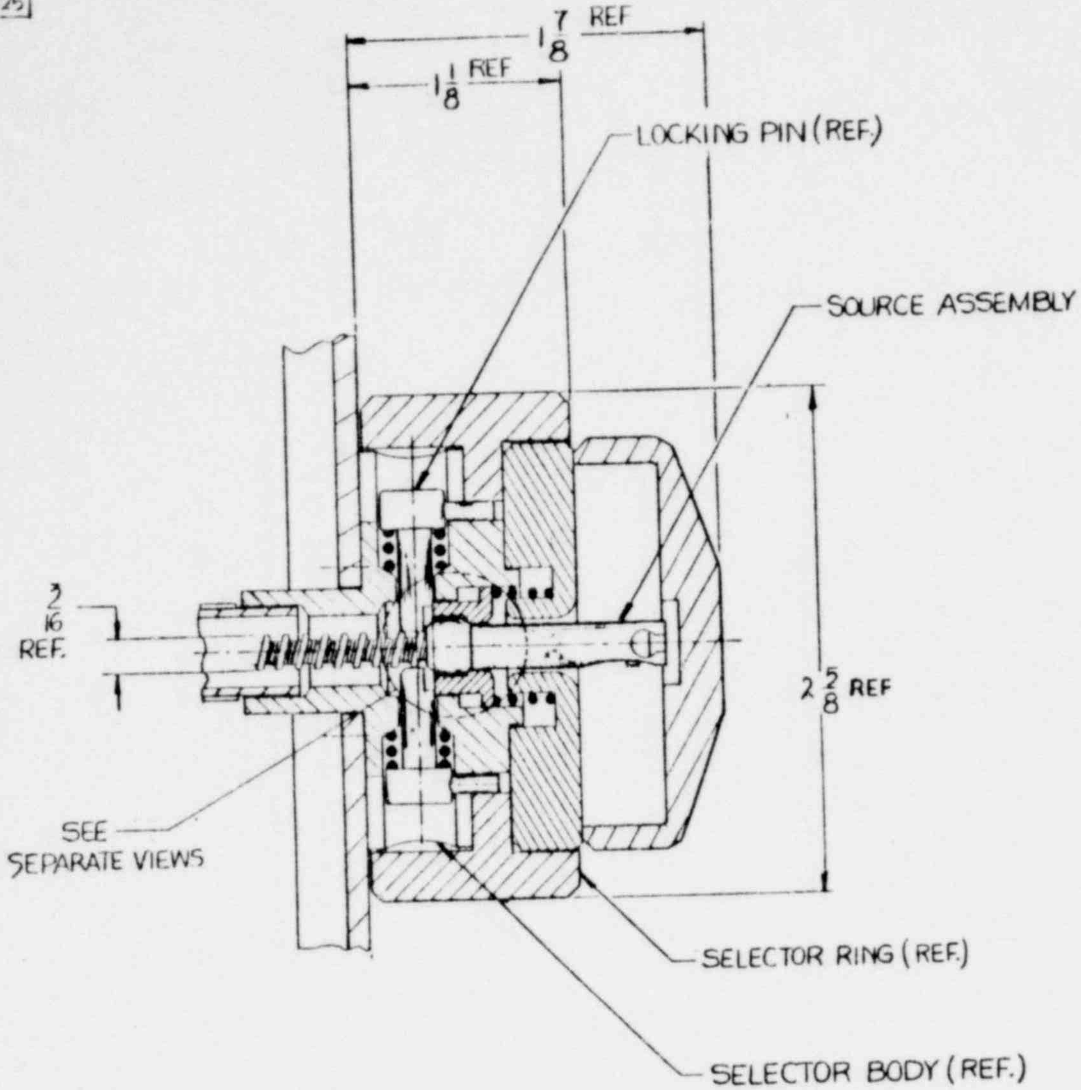
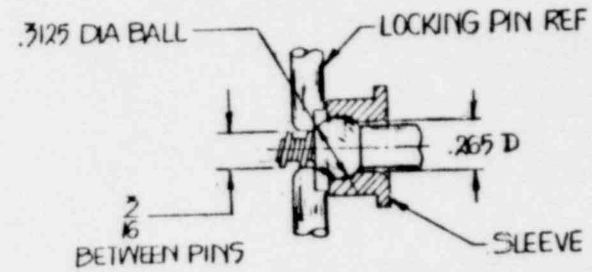
C66025

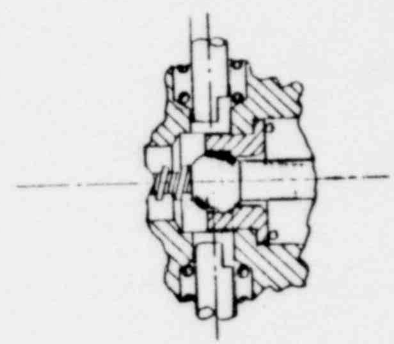
REV	DATE		OPTION
A	6 JUN 79	SEE SHT 1	



SECTION B-B



LOCKED POSITION



UNLOCKED POSITION

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DRAWN BY / CHECKED BY	CLASSIFICATION · SIZE C · DWG NO 66025 · REV A
APPROVED BY	SCALE 2:1 · SHEET 3 OF 3

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2. Structural Evaluation

2.1 Structural Design

2.1.1 Discussion

Structurally the Model 680 consists of five components: a source capsule, shield assembly, outer shell, side frames and lock assembly. The source capsule is the primary containment vessel. It meets the requirements for special form radioactive material as outlined in 10CFR71 (see Section 2.8). The shield is 285 pounds (130kg) of depleted uranium. The shield assembly fulfills two functions: It provides shielding for the radioactive material and, together with the positioning mechanisms, insures proper positioning of the source. The shield assembly is supported with retaining bars which are forced together by means of hex nuts threaded on adjusting screws. The adjusting screws and retaining bars are secured with jam nuts. The entire shield assembly is potted in a castable rigid polyurethane foam and encased in a $\frac{1}{4}$ inch (6.35mm) thick hot rolled steel shell. Steel-uranium interfaces are separated with copper. Attached to the shell are side frames made of 0.75 inch (19.1mm) thick steel which are bolted together with 7/16 - 20 UNF hex head bolts. These are designed as lifting devices and impact limiters. The key operated lock assembly and control cable connector secure the source in the shielded position. A $\frac{1}{4}$ inch (6.35mm) thick steel shipping plate is installed to protect the lock from damage. Positive proof of source position is evidenced by the use of a seal wired shipping plug.

2.1.2 Design Criteria

The Model 680 is designed to comply with the requirements of 10CFR71 and IAEA Safety Series No. 6, 1973. The device is simple in design, such that there are no design criteria which cannot be evaluated by straight-forward application of the appropriate section of 10CFR71 or IAEA Safety Series No. 6, 1973.

2.2 Weights and Centers of Gravity

The Model 680 projector weighs 405 pounds (184kg). The shield assembly contains 285 pounds (130kg) of depleted uranium. The center of gravity is located approximately at the geometric center of the package.

2.3 Mechanical Properties of Materials

The Model 680 Gamma Ray Projector shell is made of hot rolled steel. This material has a yield strength of 40,000 pounds per square inch (276MN/m^2). (Reference: Machinery's Handbook, 20th Edition, 1976, p. 452).

2.4 General Standards for All Packages

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2.4.1 Chemical and Galvanic Reactions

The materials used in the construction of the Model 680 Gamma Ray Projector are uranium metal, steel, beryllium copper, bronze, copper, and zircalloy or titanium. There will be no significant chemical or galvanic action between any of these components.

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

In support of this conclusion, the following test results are presented. A thermal test of a sample of bare depleted uranium metal was performed by Nuclear Metals, Inc. The test indicated that the uranium sample oxidized such that the radial dimension was reduced by 1/32 inch. A subsequent test was performed in which a sample of bare, depleted uranium metal was placed on a steel plate and subjected to the thermal test conditions. The test showed no alloying or melting characteristics in the sample, and the degree of oxidation was the same as evidenced in the first test. A copy of the test report appears in Section 2.10.

Although the likelihood of the formation of an iron-uranium eutectic alloy is remote, copper separators are used at steel-uranium interfaces.

2.4.2 Positive Closure

The Model 680 source cannot be exposed without opening a key-operated lock. Access to the lock requires the removal of the shipping plate. Additionally, there is a shipping plug which is seal wired and provided with a tamperproof seal.

2.4.3 Lifting Devices

The Model 680 is designed to be lifted by the side frames. Each is secured by four 7/16 - 20 UNF SAE-J429 Grade 5 hex head bolts. These bolts are installed with 7/16 lock washers. The yield strength of these 7/16 - 20 UNF bolts is 10,900 pounds (48.6kN). As there is a thread engagement of 3/4 inch between the bolt and the tapped rod, the yield strength is less than the stripping strength (approximately 21,000 pounds) and thus is the limiting factor. A torque of 30 foot-pounds (41N-m) is applied to these bolts. This corresponds to a tension of approximately 4080 pounds (18.2kN). The total tensile loading on each bolt is 4380 pounds (19.5kN), due to the bolt torque and three times the weight of the package. The total torsional loading is 6110 pounds (27.2kN). Both loads are less than the yield strength of the bolts.

The weld joining the side frame to the side frame insert on the Model 680 is a 3/16 inch fillet weld. The American Welding Society "Code for Arc and Gas Welding in Building Construction" permits the stress on a fillet weld to be 13,600psi (89.6MN/m^2). As the shear stress on the throat of the fillet weld is the limiting factor, the allowable stress on a 3/16 inch fillet weld (throat dimension, 0.133 inch, 3.38mm) is calculated to be 1,800 pounds per linear inch (320N/mm). As the perimeter of the side frame insert is 50 inches (1.27m), the allowable load is 90,000 pounds (401kN). Hence, the allowable load on the side frame insert weld is greater than the yield strength of the bolt.

2.4.4 Tiedown Devices

The tiedown devices on the Model 680 are the side frames. As indicated in 2.4.3 above, these frames can safely support the package.

2.5 Standards for Type B and Large Quantity Packages

2.5.1 Load Resistance

Considering the package as a simple beam supported on both ends with a uniform load of 5 times the package weight evenly distributed along its length, the maximum stress can be computed from:

$$S = \frac{Fl}{8Z}$$

where: F: total load (2025 pounds)
l: length of beam (21 inches)
Z: section modulus of beam (79.0 in^3)

(Reference: Machinery's Handbook, 20th ed., 1976, p. 442)

Thus, the maximum stress generated in the beam is 67.3 pounds per square inch (464kN/m^2), which is far below the yield strength of the material, 40,000psi (276MN/m^2).

2.5.2 External Pressure

The Model 680 is open to the atmosphere; thus, there will be no differential pressure acting on it. The collapsing pressure of the source capsules can be found:

$$P = 86{,}670 \frac{t}{D} - 1386$$

where: P: collapsing pressure in pounds per square inch
t: wall thickness in inches (0.020 inch)
D: outside diameter in inches (0.25 inch)

(Reference: Machinery's Handbook, 20th ed., 1976, p.448)

The collapsing pressure of the capsules is calculated to be 5550 pounds per square inch ($38,3 MN/m^2$). Therefore, the capsule can withstand an external pressure of 25psig.

2.6 Normal Conditions of Transport

2.6.1 Heat

The thermal evaluation is performed in Chapter 3 of this application. From this evaluation, it can be concluded that the Model 680 can withstand the normal heat transport conditions.

2.6.2 Cold

The metals used in the manufacture of the Model 680 can all withstand temperatures of -40°F (-40°C). The lower operating limit of the polyurethane foam is -100°F (-73°C). Thus, it is concluded that the Model 680 will withstand the normal transport cold conditions.

2.6.3 Pressure

The Model 680 is open to the atmosphere; thus, there will be no differential pressure acting on it. In Section 3.5.4, the source capsules are demonstrated to be able to withstand an external pressure reduction of 0.5 atmospheres ($50.7 kN/m^2$).

2.6.4 Vibration

The Model 680 has been in use nine years. During that time there has never been a vibrational failure reported. Thus, we contend the Model 680 will not undergo a vibrational failure in transport.

2.6.5 Water Spray Test

The water spray test was not actually performed on the Model 680. We contend that the materials used in construction of the Model 680 are all highly water resistant and that exposure to water will not reduce the shielding or affect the structural integrity of the package.

2.6.6 Free Drop

The drop analysis performed in Hypothetical Accident Conditions (see Section 2.7.1) is sufficient to satisfy the requirements outlined for the normal transport free drop condition in 10CFR71 and IAEA Safety Series No. 6, 1973. On this basis, we conclude that the Model 680 can withstand the free drop without impairment of the shielding or package integrity.

2.6.7 Corner Drop

Not applicable.

2.6.8 Penetration

A penetration test of the Model 680 was not actually performed. However, the similar Model 684 was subjected to the penetration test with no resultant loss of shielding or package integrity (a copy of the test report is enclosed in Section 2.10). The following analysis demonstrates that the maximum damage exhibited by the Model 680 due to the penetration test is less than that of the Model 684.

The maximum stress observed in a flat rectangular plate supported on all edges due to concentrated central loading is:

$$S = \frac{0.62F}{t^2}\left[\ln\left(\frac{L}{2r_o}\right) + 0.577\right]$$

where: F : total load
t : thickness of plate (inches)
L : length of longest side (inches)
r_o: 0.325t (inches)

(Reference: Machinery's Handbook, 20th ed., 1976, p. 444)

The appropriate dimensions for the Model 680 and Model 684 are:

	Model 680	Model 684
t	0.25 inch (6.35mm)	0.1875 in. (4.76mm)
L	21 inch (533mm)	17 in. (432mm)
r_o	0.0182 in. (2.06mm)	0.0609 in. (1.55mm)

The calculated stress for the Model 680 is 54.0F; for the Model 684 it is 97.3F. In both cases the load F (40 inch drop of a 13 pound hemispherical billet) and the material of construction (hot rolled steel) are the same. The maximum stress, and thus the maximum damage, to the flat plate occurs in the Model 684. The shipping plate which protects the lock mechanism is the same in the two models. As the Model 684 successfully withstood the penetration condition, we conclude that the Model 680 can undergo the penetration test with no loss of structural integrity or shielding. (A copy of the test report for the Model 684 is enclosed in Section 2.10).

2.6.9 Compression

The gross weight of the Model 680 is 405 pounds (184kg). The maximum cross-sectional area of the package is 310 square inches ($0.20m^2$). Thus two pounds per square inch times the cross-sectional area (620 pounds, 282kg) is less than five times the package weight (2025 pounds, 290kg). For this analysis, the load will be taken to be 2025 pounds.

The maximum stress generated in a flat rectangular steel plate with all edges fixed and a load distributed uniformly over the surface of the plate can be computed from:

$$S = \frac{0.5F}{t^2\left[\frac{1}{w} + 0.623\frac{1}{w}\right]^5}$$

where: S: maximum stress
F: total load (2025 pounds)
t: thickness of plate (0.25 inches)
w: width of plate (14.8 inches)
l: length of plate (21 inches)

(Reference: Machinery's Handbook, 20th ed., 1976, p. 444, Eq. 13)

From this relationship, the maximum stress generated in the plate is 3240 pounds per square inch (22.3MN/m^2). This figure is greatly below the yield strength of the material, 40,000 pounds per square inch (276MN/m^2). Thus, it can be concluded that compression will not adversely affect the package.

2.7 Hypothetical Accident Conditions

2.7.1 Free Drop

The Model 680 was not actually submitted to the 30 foot drop test. However, the Model 655 was submitted to the drop test (the test report appears in Section 2.10). The Model 680 has approximately the same weight and is constructed from the same materials as the Model 655:

	Model 655	Model 680
Length	19-3/4 inches (502 mm)	21 inches (533 mm)
Width	11 inches (279 mm)	14-3/4 inches (375 mm)
Height	10-1/4 inches (260 mm)	11-13/16 inches (300 mm)
Weight of Shield	280 lbs.	285 lbs.
Gross Weight of Container	385 lbs.	405 lbs.
Side Frame Material	3/4 inch thick (19.1 mm) ductile iron	3/4 inch thick (19.1 mm) hot rolled steel
Shell Material	¼ inch thick (6.35 mm) steel	¼ inch thick (6.35 mm) hot rolled steel

Based on the satisfactory performance of the Model 655, we conclude that the Model 680 will undergo no loss of shielding or structural integrity as a result of the 30 foot free drop test.

2.7.2 Puncture

The Model 680 was not submitted to the puncture test of 10CFR71. However, the similar Model 676 was submitted to the puncture test.

There was no resultant damage to the container nor reduction in shielding. (A copy of the test report appears in Section 2.10). The shipping plate used in the Model 680 is the same as that used in the Model 676. The Model 676 puncture test report (included in Section 2.10) shows that the shipping plate withstood the puncture test. On this basis, we conclude that the Model 680 can successfully withstand the puncture condition of 10CFR71.

2.7.3 Thermal

The thermal analysis is presented in Section 3.5. There it is shown that the melting point of the materials, except the potting compound, used in the construction of Model 680 are all greater than 1475°F (800°C). Also indicated is the previous acceptability of this design (NRC Certificate of Compliance No. 9035 Rev. 2) using this evaluation.

Thus, it is concluded that the Model 680 satisfactorily meets the requirements for the hypothetical accident-thermal evaluation as set forth in 10CFR71.

2.7.4 Water Immersion

Not applicable

2.7.5 Summary of Damage

The tests designed to induce mechanical stress (drop, puncture) caused minor deformation, but no reduction in the safety features of the package. The thermal test resulted in no reduction of the safety of the package. It can be concluded that the hypothetical accident conditions have no adverse effect on the shielding effectiveness and structural integrity of the package.

2.8 Special Form

The Model 680 Gamma Ray Projector is designed for use with Tech/Ops Source Assembly A424-14. This source assembly has been previously certified as special form radioactive material. (IAEA Certificate of Competent Authority No. USA/0165/S, see Section 2.10). We contend that this certificate is sufficient evidence that the requirements for special form radioactive materials, as established in IAEA Safety Series No. 6, 1973 are satisfied.

2.9 Fuel Rods

Not applicable

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2.10 APPENDIX

- Nuclear Metals, Inc., Test Report: Iron Uranium Alloying
- Test Report: Penetration Test, Model 684
- Test Report: Drop and Puncture Tests, Model 655
- Test Report: Puncture Test, Model 676
- Descriptive Assembly Drawings, Source Assembly
- IAEA Certificate of Competent Authority No. USA/0165/S

1692 311

REVISION O
NOV 2 0 1979

NUCLEAR METALS, INC.

2229 MAIN STREET
CONCORD, MASSACHUSETTS 01742
TELEPHONE 617 369-5410

28 January 1974

Technical Operations, Inc.
Radiation Products Division
South Avenue
Burlington, Massachusetts 01803

Attention: Mr. J. Lima

Gentlemen:

In response to a request by Joe Lima of Tech Ops, a simulated fire test was performed on samples of bare depleted uranium in contact with mild steel, the object being to determine what, if any, alloying or melting would occur under these conditions.

TEST DATA:

A 3/4-inch diameter x 5/8-inch long bare depleted uranium specimen was set on a 1-inch diameter x 1/8-inch thick mild steel plate, placed in a thin wall ceramic crucible. A mild steel cover plate was used on top of the crucible to act as a partial air seal. The crucible was loaded in a preheated 1450°F resistance heated furnace, held for 35 minutes, then removed and allowed to air cool under a ventilated hood.

RESULTS:

No reaction was evidenced between the two metals. Both separated readily and showed no alloying or melting characteristics.

Oxidation of the uranium was about the same degree as that reported to Joe Lima on an earlier experiment.

The test was performed by NMI on 25 January 1974.

Very truly yours,

John G. Powers

John G. Powers
Project Engineer

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TEST REPORT

RADIATION PRODUCTS DIVISION

BY: John J. Munro III

DATE: 5 September 1979

SUBJECT: Model 684 Penetration Test

On 5 September 1979, a penetration test was performed on a Technical Operations Model 684 Shipping Container in accordance with 10CFR71 Appendix A.8 and IAEA Safety Series No. 6, 1973, paragraphs 714a and 714b.

The hemispherical end of a vertical steel cylinder 1.25 inch in diameter weighing 14 pounds was dropped from the height of 40 inches onto the geometric center of the bottom surface of the Model 684. There was no deformation and no damage which would affect the shielding or structural integrity of the package.

A second test was conducted using the same cylinder. It was dropped from the height of 40 inches onto the shipping plate. There was no deformation and no damage which would affect the shielding or structural integrity of the package.

Documentry photographs are enclosed.

Performed by

John J. Munro III

Witnessed by

Angelo Kiklis

REVISION O

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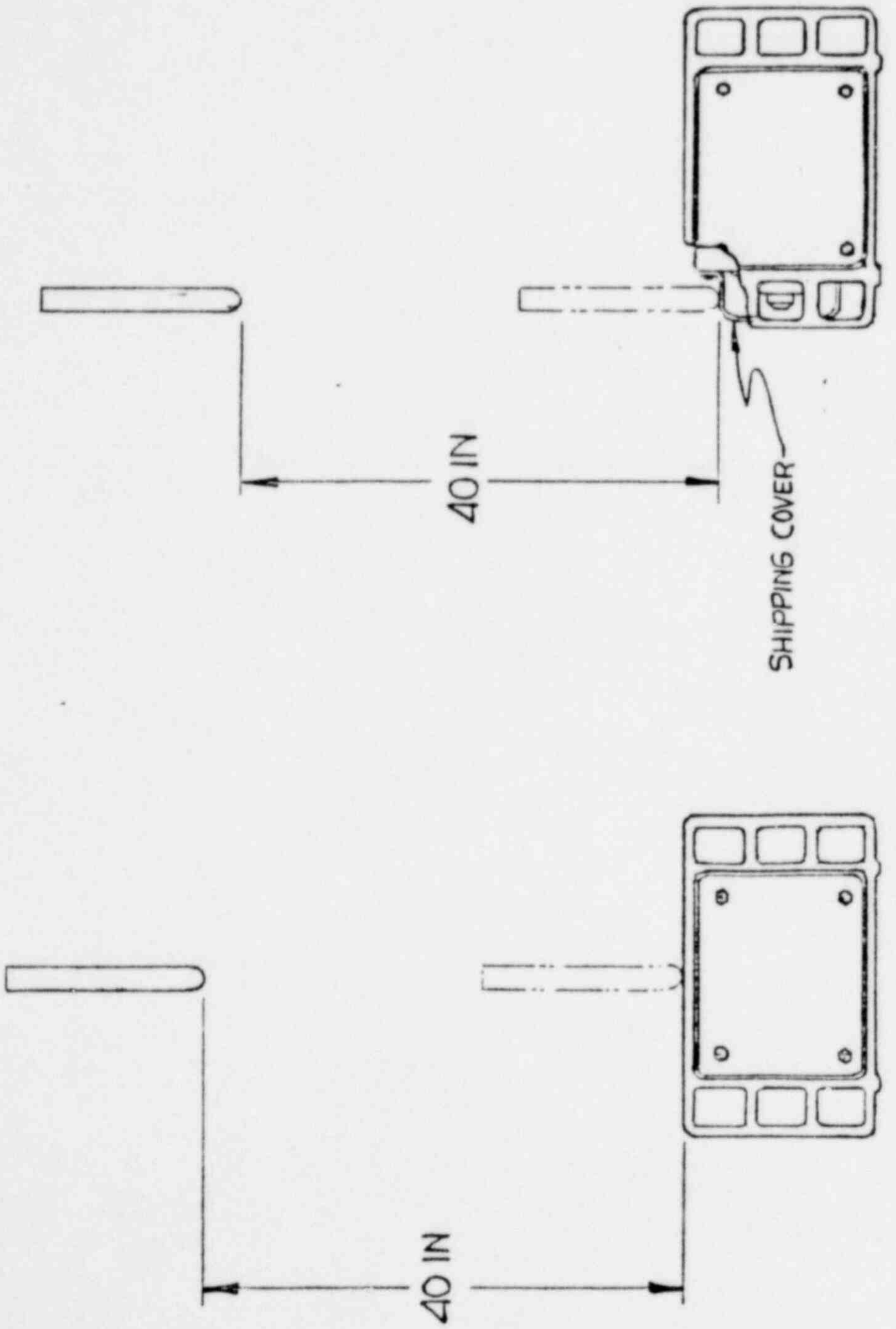
1692 313



TEST 1

PENETRATION TEST

MODEL 684

1692 314

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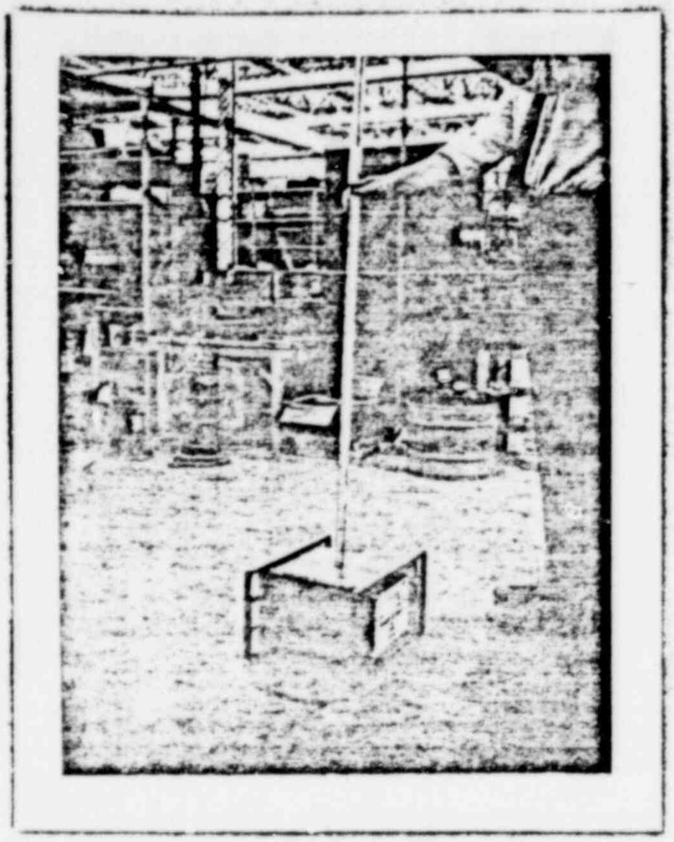

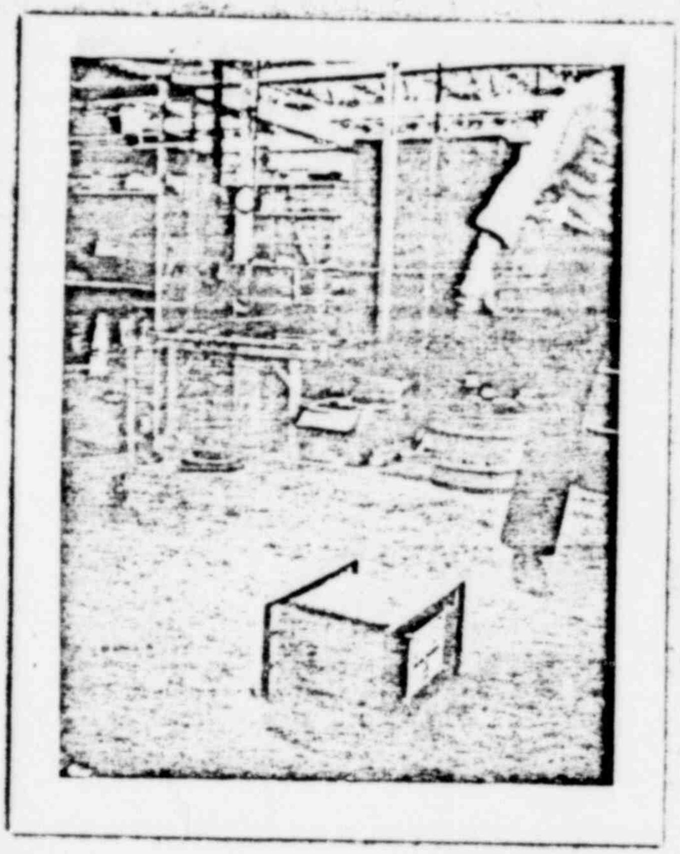

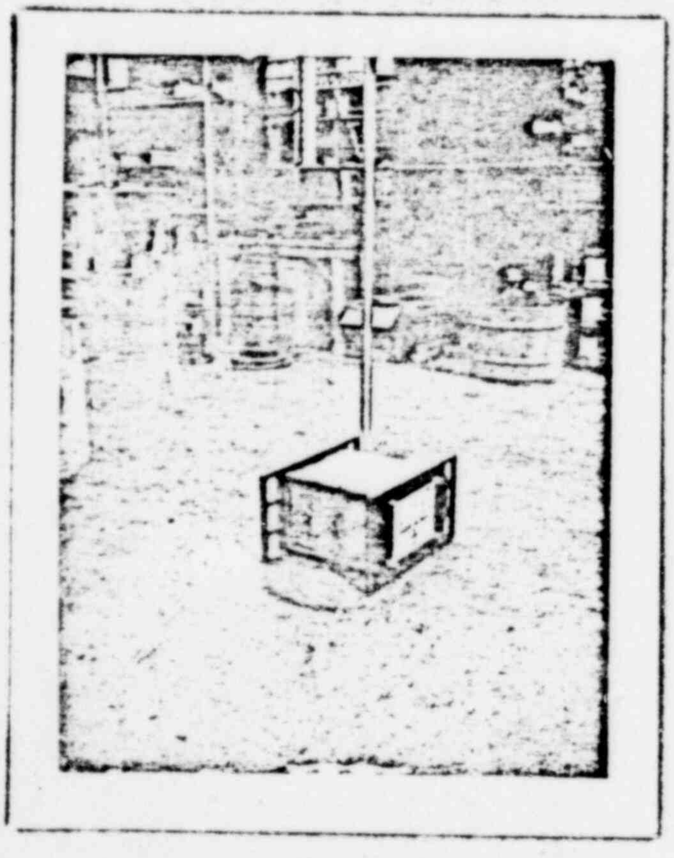

POOR ORIGINAL

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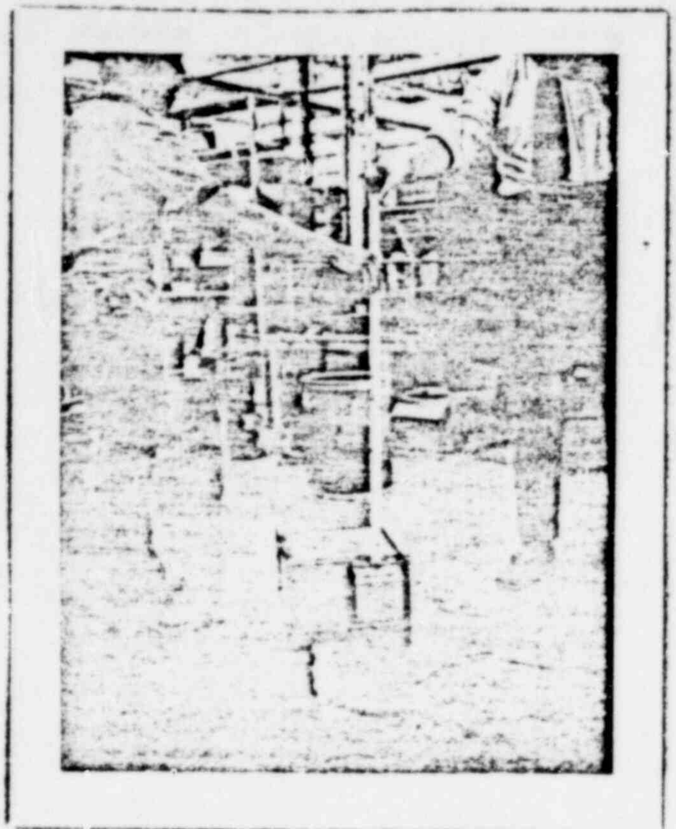
REVISION 0

NOV. 2 0 1979



POOR ORIGINAL

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REVISION 0

NOV. 20 1979

FROM LEFT, MODELS 670, 655 AND 672 GAMMA RAY PROJECTORS
AFTER CONCLUSION OF 30 FOOT DROP TEST AND PUNCTURE TEST

TEST REPORT

DESCRIPTION: DATE 9 December 1974

Puncture Test of Model 676 Container Connector

A Model 676 Gamma Ray Projector with Shipping Plate installed was dropped from a height of 40 inches onto a six inch diameter, eight inch high steel Billet as shown in Figure 1 a. The Container impacted on the Shipping Plate as shown in Figure 1 b.

CONCLUSION:

No damage to the container, shipping plate or control cable connector resulted. There was no reduction of shielding effectiveness nor loss of Radioactive Material.

BY Don Brasseur WITNESSED BY John J. Munro 111

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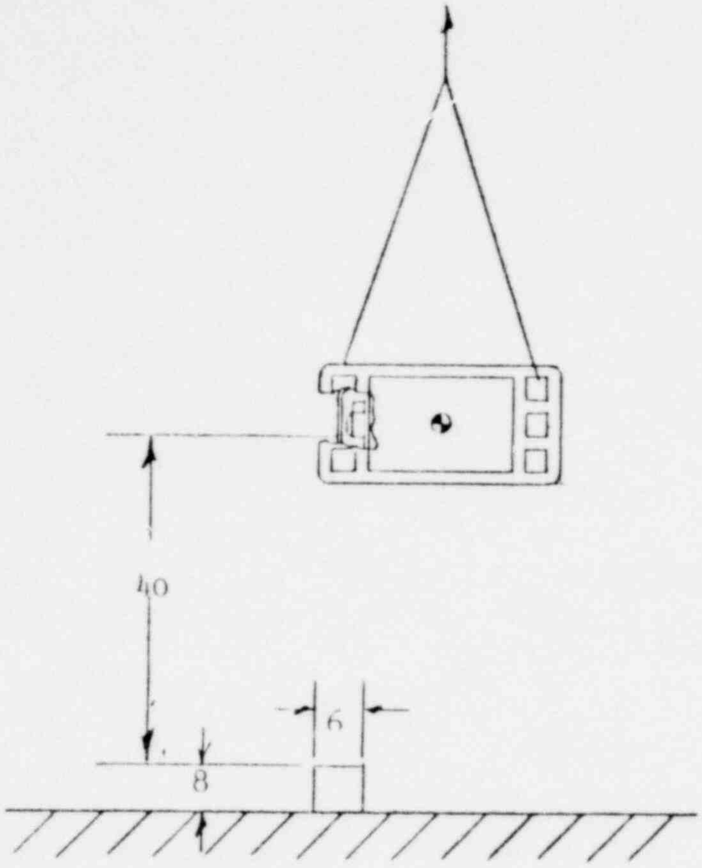
1692 318

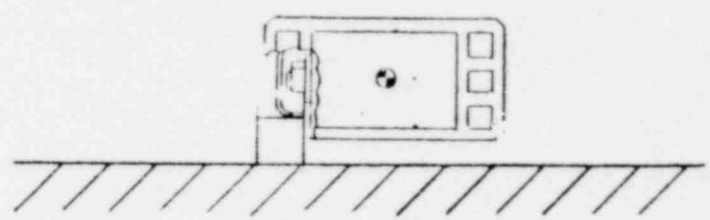
PUNCTURE TEST

CONTROL CABLE CONNECTOR ASSEMBLY

Model 676 Gamma Ray Projector (weight 545 pounds) dropped from a height of 40 inches onto a steel cylinder (6in dia x 8 in high)



1a



1 b

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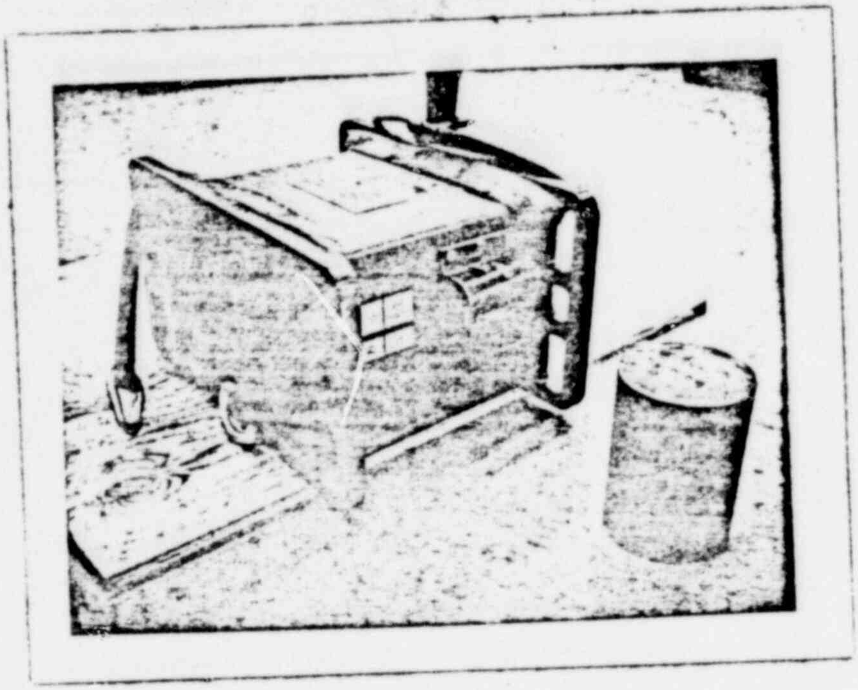
POOR ORIGINAL



Model 676 at Conclusion of Puncture Test

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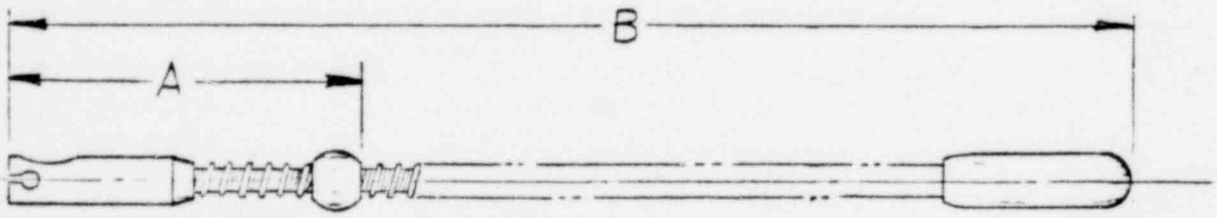
A60060

REV.	DATE	DESCRIPTION

MODEL	CAPACITY (CURIES)	CAPSULE STYLE	DIM A (INCHES)	DIM B (INCHES)
A424-2	22	60011, 60001	N.A.	9 11/16
A424-3	22	60011, 60001	N.A.	11 13/16
A424-4	55	60011, 60000	N.A	20
A424-5	6	60011, 60001	N.A.	7 7/16
A424-7	165	60012, 60002	N.A.	17 1/4
A424-8	110	60011, 60000	N.A.	11 15/16
A424-10	6	60011, 60004	1.225	7 3/4
A424-11	55	60011, 60004	1.225	9 9/16
A424-12	110	60011, 60004	1.225	10 7/8
A424-13	330	60012, 60002	1.225	10 15/16
A424-14	110	60011, 60004	1.225	10 5/8
A424-15	11	60011, 60004	1.225	8 15/16
A424-16	55	60011, 60000	2.373	13 1/2
A424-17	55	60011, 60000	2.373	13 1/2
A424-18	33	60011, 60000	1.225	10 1/4
A424-19	0.11	60001, 60004	1.225	7 3/16
A453-1	110	60011, 60000	N.A.	11 15/16
A453-2	165	60012, 60002	N.A.	17 1/4
A453-5	550	60012, 60002	N.A.	17 1/4
A453-6	1100	60013, 60003	N.A.	17 1/4
A453-7	110	60011, 60000	N.A	11 15/16
A453-8	55	60011, 60000	N.A.	11 15/16
A453-9	55	60011, 60000	2.373	13 1/2
A453-10	55	60011, 60000	2.373	13 1/2



MATERIALS

FINISH

DRAWN BY V. Tindall 21 JUN '79

CHECKED BY

APPROVED BY

UNLESS OTHERWISE SPECIFIED TOLERANCES ARE
.X ±
.XX ±
.XXX ±
ANGLES ±
FRACTIONS ±

TECHNICAL OPERATIONS INC.
RADIATION PRODUCTS DIVISION
BURLINGTON, MA 01803

DWG TITLE

^{60}COBALT SOURCE REFERENCE

CLASSIFICATION	SIZE	DWG. NO.	REV.
	A	60060	

SCALE —

SHEET 1 OF 3

SPAULDING CO., INC. 21-60169

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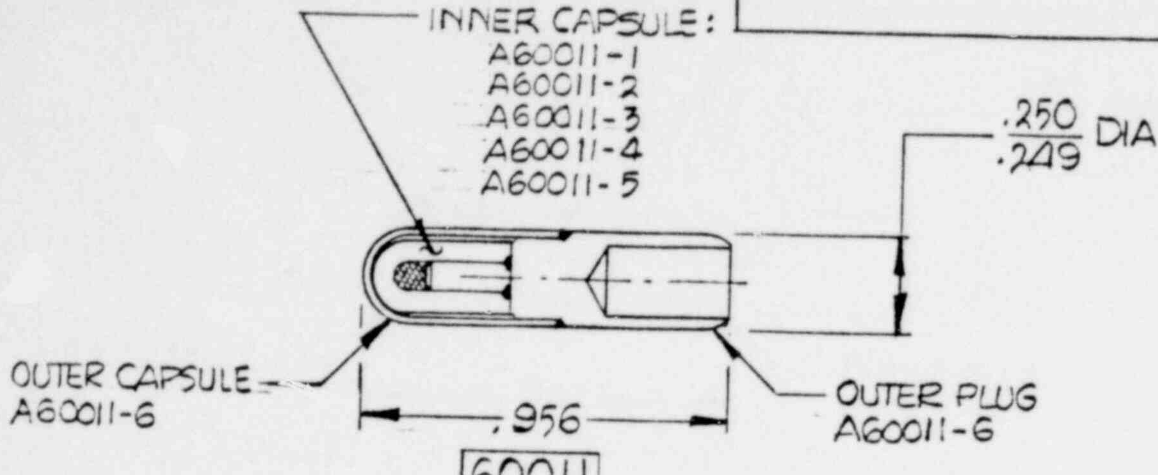
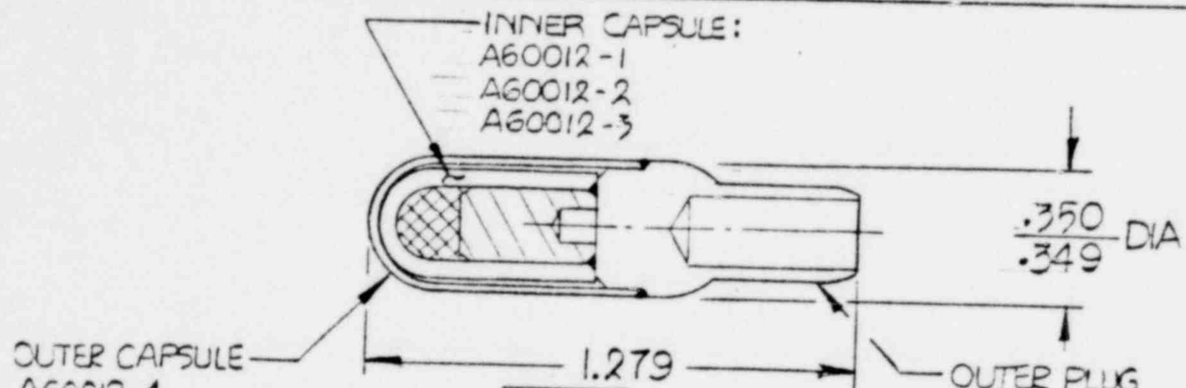
A60060

REV.	DATE	DESCRIPTION



60011



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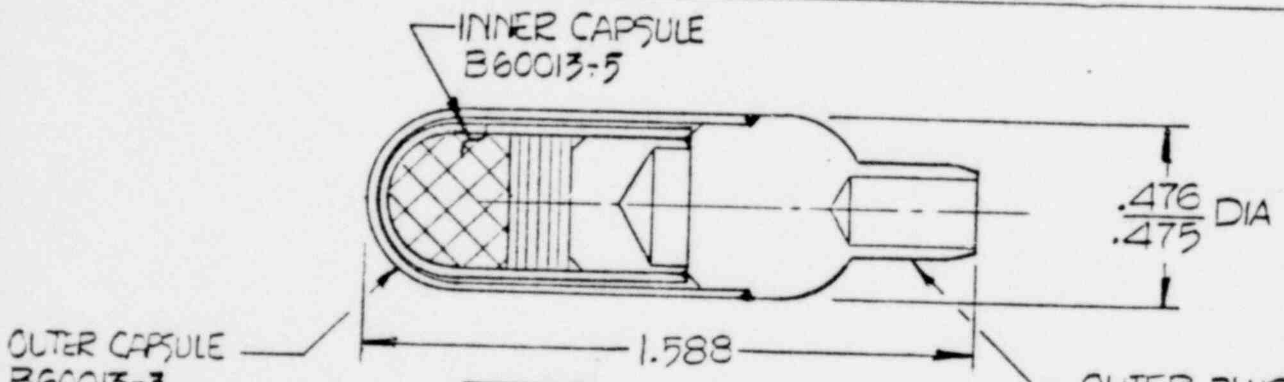


60013

MATERIALS

FINISH

DRAWN BY 5 Jul 79

CKED BY

APPROVED BY

UNLESS OTHERWISE SPECIFIED TOLERANCES ARE	
.X	±
.XX	±
.XXX	±
ANGLES	±
FRACTIONS	±

TECHNICAL OPERATIONS INC.
RADIATION PRODUCTS DIVISION
BURLINGTON, MA 01803

DWG TITLE

COBALT ^{60} SOURCE REFERENCE (DOUBLE ENCAPSULATION)

CLASSIFICATION	SIZE	DWG. NO.	REV.
	A	60060	

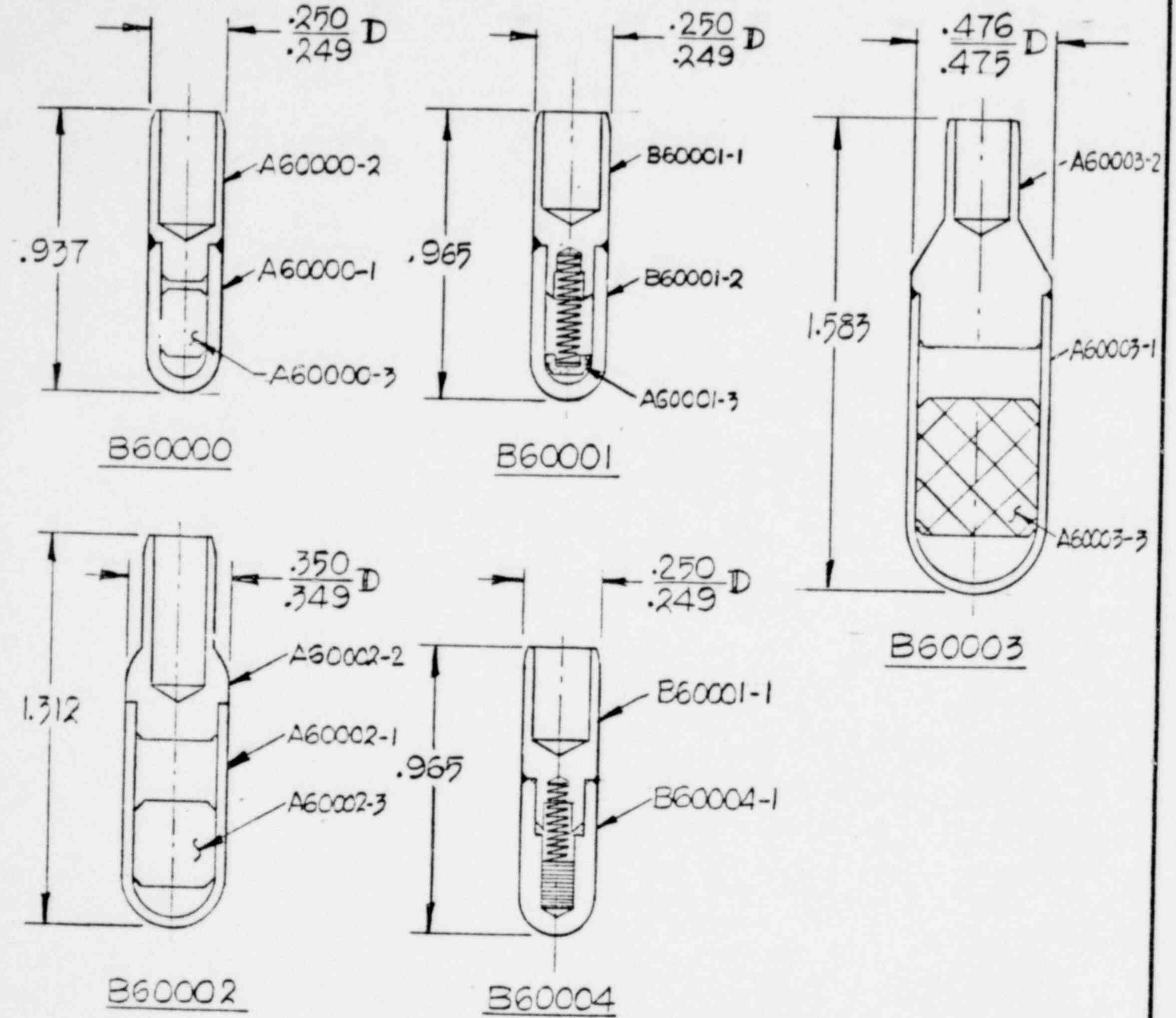
SCALE 2:1 | SHEET 2 OF 3

SPAULDING CO., INC. 21-60169

1692 322

A60060

REV.	DATE	DESCRIPTION



MATERIALS	TECHNICAL OPERATIONS INC. RADIATION PRODUCTS DIVISION BURLINGTON, MA 01803			
FINISH	DWG TITLE COBALT 60 SOURCE REFERENCE (SINGLE ENCAPSULATION)			
DRAWN BY [signature]	UNLESS OTHERWISE SPECIFIED TOLERANCES ARE .X ± .XX ± .XXX ±			
CHECKED BY				
APPROVED BY	ANGLES ± FRACTIONS ±	CLASSIFICATION	SIZE A	DWG. NO. 60060 REV.
		SCALE 2:1	SHEET 3 OF 3	

SPAULDING CO., INC. 21-60169

1692 323

DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
WASHINGTON, D.C. 20590

REFER TO:

IAEA CERTIFICATE OF COMPETENT AUTHORITY

Special Form Radioactive Material Encapsulation

Certificate Number USA/0165/S
(Revision 0)

This certifies that the encapsulated sources, as described, when loaded with the authorized radioactive contents, have been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in IAEA[1] and USA[2] Regulations for the transport of radioactive materials.

I. Source Description and Radioactive Contents - The sources described by this certificate consist of the following Technical Operations, Inc., models which are welded capsules constructed of either 304 or 304L stainless steel to the listed capsule designs (see Appendix A) and which contain not more than the listed quantities of Cobalt-60 in metallic form:

Model	Capsule Style	Activity (Curies)
A424-2	60011, 60001	22
A424-3	60011, 60001	22
A424-4	60011, 60000	55
A424-5	60011, 60001	6
A424-7	60012, 60002	165
A424-8	60011, 60000	110
A424-10	60011, 60004	6
A424-11	60011, 60004	55
A424-12	60011, 60004	110
A424-13	60012, 60002	330
A424-14	60011, 60004	110
A424-15	60011, 60004	11
A424-16	60011, 60000	55
A424-17	60011, 60000	55
A424-18	60011, 60000	33
A424-19	60001, 60004	0.11
A453-1	60011, 60000	110
A453-2	60012, 60002	165
A453-5	60012, 60002	550
A453-6	60013, 60003	1100
A453-7	60011, 60000	110
A453-8	60011, 60000	55
A453-9	60011, 60000	55
A453-10	60011, 60000	55

II. This certificate, unless renewed, expires on September 30, 1982.

This certificate is issued in accordance with paragraph 803 of the IAEA Regulations and in response to the July 26, 1979, petition by Technical Operations, Inc., Burlington, Massachusetts, and in consideration of the associated information therein.

Certified by:

R R Rawl September 17, 1979
(Date)

R. R. Rawl
Designated U.S. Competent Authority for the
International Transportation of Radioactive Materials
Office of Hazardous Materials Regulation
Materials Transportation Bureau
U.S. Department of Transportation

[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, Part 170-178, USA.

3. Thermal Evaluation

3.1 Discussion

The Model 680 Gamma Ray Projector is a completely passive thermal device and has no mechanical cooling systems or relief valves. All cooling of the package is through free convection and radiation. The only heat source is the maximum 110Ci Cobalt-60 Source. The corresponding decay heat is 2 watts (see Section 3.4.1).

3.2 Summary of Thermal Properties of Materials

The melting points of the metals used in the construction of the Model 680 are:

Depleted Uranium Metal	2070°F (1133°C)
Carbon Steel	2453°F (1345°C)
Copper	1940°F (1060°C)
Bronze	1840°F (1005°C)

(Reference: Machinery's Handbook, 20th ed., 1976)

Titanium	3300°F (1820°C)
Beryllium Copper	1600°F (870°C)
Zircalloy	3350°F (1845°C)

(Reference: Metals Handbook, 1961)

The rigid polyurethane foam has a minimum operating range of -100°F to 200°F (-73°C to 93°C). It will decompose at the fire test temperature of 1475°F (800°C). Decomposition will result in gaseous byproducts which will burn in air.

3.3 Technical Specifications of Components

Not applicable.

3.4 Normal Conditions of Transport

3.4.1 Thermal Model

The heat source in the Model 680 results from a maximum 110Ci of Cobalt-60. Cobalt-60 decays by beta emission, Q_{beta} = 2.819MeV (Reference: Radiological Health Handbook, p. 389). Thus:

$$2.819\text{MeV} \times 3.7 \times 10^{10} \frac{\text{disint}}{\text{s-Ci}} \times \frac{1.6 \times 10^{-13}}{\text{MeV}} \times 110\text{Ci} = 1.8 \text{ watts}$$

The decay heat source is taken to be 2 watts.

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To qualify as a Type B(U) package the requirements of IAEA Safety Series No. 6, 1973, paragraphs 231 and 232 must be satisfied. The calculational model used to demonstrate compliance with these regulations is described in detail in Section 3.6, along with the results of the analysis. Essentially, it is assumed that one-fourth of the entire decay heat load is deposited uniformly in each of six sides. The smallest of the sides is assumed to reach the maximum surface temperature. Heat transfer from the side is restricted only to convective heat transfer from the upper face of the plate.

To meet the additional requirements of paragraph 240 of the IAEA regulations, a separate analysis was performed. To do this, a heat balance was set up over the surface of the package, using the insolation data in Table III of the IAEA regulations. The decay heat source was considered negligible. The outer shell was assumed to be insulated from the interior of the package. Heat transfer from the package was taken to occur by radiation, and over specific surface areas by free convection. A detailed description of the model is given in the analysis, in Section 3.6.

3.4.2 Maximum Temperatures

An examination of the melting points of the materials used in construction of the Model 680 show that the maximum temperatures encountered under normal conditions of transport engender no loss of shielding of the package. The specific Type B(U) analyses (Section 3.6) show the package temperature to be below 40°C (104°F) in the shade and below 73°C (163°F) when insolated.

3.4.3 Minimum Temperatures

The minimum normal operating temperature of the Model 680 is -40°C (-40°F). This temperature will have no adverse effect on the package.

3.4.4 Maximum Internal Pressure

Normal operating conditions generate negligible internal pressures. Any pressure generated is significantly below that of the hypothetical accident pressure, which is shown to result in no loss of shielding or containment.

3.4.5 Maximum Thermal Stresses

The maximum temperatures that occur during normal transport are low enough to insure that thermal gradients will cause no significant thermal stresses.

3.4.6 Evaluation of Package Performance for Normal Conditions of Transport

The thermal conditions of normal transport are obviously insignificant from a functional point of view for the Model 680. Also, the applicable conditions of IAEA Regulations for Type B(U) packages have been shown to be satisfied by the Model 680.

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3.5 Hypothetical Accident Thermal Evaluation

3.5.1 Thermal Model

The Model 680, including the source assembly, is assumed to reach the fire test temperature of 800°C (1475°F). At this temperature the polyurethane potting compound will have decomposed and the resulting gases will have escaped the package through the assembly joints which are not leak tight.

3.5.2 Package Conditions and Environment

The Model 680 is considered to have undergone no significant damage during the free drop and puncture tests; thus, the package in this analysis is assumed to be free from functional damage.

3.5.3 Package Temperatures

As indicated in 3.5.1, the package reaches a maximum temperature of 800°C (1475°F) throughout. An examination of the melting points of the materials used in the construction of the Model 680 (except the potting compound, as noted) indicates that there will be no damage to the package as a result of this temperature. The possibility of the formation of the iron-uranium eutectic alloy was addressed in Section 2.4.1, where it was concluded that the formation of the alloy was unlikely.

3.5.4 Maximum Internal Pressures

The Model 680 packaging is open to the atmosphere, insuring that there will be no pressure buildup within the package. In Section 3.6 there is an analysis of the source capsules under the fire test conditions. It is shown that the maximum internal gas pressure at this temperature is 54.7psi ($0.377 MN/m^2$).

The critical location for failure of the capsule is the weld. An internal pressure of 54.7psi ($0.377 MN/m^2$) will generate a maximum stress of 287psi ($1.98 MN/m^2$) in the weld. At a temperature of 870°C (1600°F) the yield strength of Type 304 or 304L stainless steel is 10,000 psi ($69.0 MN/m^2$).

Thus, at 800°C (1475°F), the maximum stress in the capsule would be only 3% of the yield strength at that point.

3.5.5 Maximum Thermal Stresses

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

3.5.6 Evaluation of Package Performance

The Model 680 will undergo no loss of structural integrity or shielding when subjected to the conditions of the hypothetical thermal accident. The pressures and temperatures generated have been demonstrated to be within acceptable limits.

3.6 APPENDIX

- Model 680 Thermal Analysis: IAEA Safety Series No. 6, 1973, paragraphs 231, 232
- Model 680 Thermal Analysis: IAEA Safety Series No. 6, 1973, paragraph 240
- Thermal Analysis, 0.25 inch O.D. Capsules

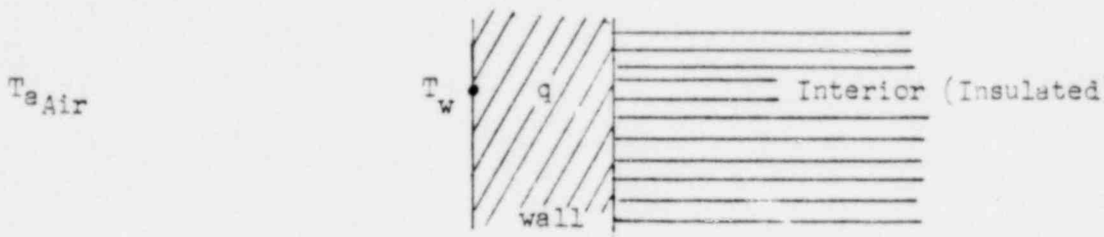
Model 680 - Thermal Analysis

Type B(U), Paragraphs 231, 232, IAEA Safety Series No. 6, 1973

This analysis is performed to demonstrate that the Model 680 Gamma Ray Projector meets the specific Type B(U) thermal requirements of paragraphs 231 and 232 of IAEA Safety Series No. 6, 1973, i.e., that the maximum surface temperature does not exceed 50°C in the shade, assuming 38°C ambient temperature.

To assure conservatism, it is assumed that: (1) the entire decay heat (2 watts) is deposited in the exterior faces of the Model 680, (2) the interior of the Model 680 is perfectly insulated, providing heat transfer from the wall only to the atmosphere. The rectangular shape of the container means that each face eclipses a different amount of the solid angle through which the radiation (and thus decay heat) is distributed. To (conservatively) simplify, it is assumed that each of the six exterior faces receives $\frac{1}{6}$ of the total source (0.5 watts) uniformly distributed over the face.

Considering the smallest face as undergoing one-dimensional convective heat transfer:



$$T_w = \frac{q}{hA} + T_a \quad \text{where:}$$

T_w: temperature at the wall outer surface

q: (decay) heat source (0.5 watts)

A: Surface area of the smallest face ($0.11 m^2$)

h: free convective heat transfer coefficient for air

5 watts/meter^2 - °C (Reference: Heat Transfer, J. P. Holman, 4 th Edition, p. 13)

Thus, the maximum temperature at the wall T_w is 40°C (104°F) under normal conditions of transport. This satisfies the requirements of the aforementioned regulations.

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Model 680 - Thermal Analysis

Type B(U), Paragraph 240, IAEA Safety Series No. 6, 1973

This analysis is performed to demonstrate that the Model 680 Gamma Ray Projector meets the specific Type B(U) thermal requirements of paragraph 240, IAEA Safety Series No. 6, 1973. This paragraph requires that the maximum surface temperature of a Type B(U) package not exceed 82°C (180°F) under normal conditions of transport, given insolation as outlined in Table III of the regulations and an ambient temperature of 38°C (100°F).

The calculational model used consists of taking a steady state heat balance over the surface of the package. To facilitate calculations, certain simplifying assumptions are made. These are outlined below:

Insolation

800 cal/cm^2-12hr (775W/m^2) for the top surface, 200 cal/cm^2-12hr (194W/m^2) for the side and side frames, none for the base as outlined in Table III of IAEA Safety Series No. 6.

The package is finished with russett enamel. The solar absorptivity of this enamel is 0.81 (Reference: Thermal Radiation Properties Survey, G.G. Gubareff et. al., 2nd ed., 1960, p. 260). A conservative figure of 0.90 was used as the package absorptivity.

Decay Heat Load

The decay heat load (maximum 2 watts) is negligible.

Package Orientation

The package rests on the side frames, i.e., in the normal transport orientation.

Heat Transfer Mechanisms

The Model 680 is assumed to undergo free convection and to radiate to the environment. The inside faces are considered to be insulated, so there is no conduction into the package. Further, the sides are taken to be thin enough so there are no temperature gradients present.

Radiation: The package is assumed to radiate from the outer shell only i.e. a cube 10.6 inches (268mm) x 14.5 inches (368mm) x 13.8 inches (349mm).
This assumption provides for conservatism by not considering any radiative heat loss through the side frames.

Convection, top: The upper surface of the outer shell is taken to undergo free convection. To provide conservatism, the upper surfaces of the side frames are considered not to undergo convection. The heat transfer coefficient of a horizontal flat plate is given by:

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$$h_t = 1.32 \left(\frac{\Delta T}{L}\right)^{0.25}$$

(Reference: <u>Heat Transfer</u>, J. P. Holman, 4th ed., 1976, p. 253)

where L is the average of the lengths of the sides 0.359m.

Thus:

$$h_t = 1.71 \ (\Delta T)^{0.25}$$

<u>Convection</u>, sides: The vertical components of the outer shell are considered to exhibit free convective heat transfer. For conservatism, the side frames are taken to be insulated. Effectively, the vertical convective heat transfer area is that of a vertical plate 0.268m high x 2(0.349m + 0.368m) long, convecting on one side only.

The heat transfer coefficient for a vertical flat plate is:

$$h_s = 1.42 \left(\frac{\Delta T}{L}\right)^{0.25}$$

(Reference: <u>Heat Transfer</u>, J. P. Holman, 4th ed., 1976, p. 253)

where L is the height of the plate, 0.268m.

Thus:

$$h_s = 1.97 \ (\Delta T)^{0.25}$$

Taking a heat balance over the package surface:

heat in = heat out (rad. + con. top + con. sides)

$$q_{in} = q_{rad} + q_{ct} + q_{cs}$$

$$= 0.90 \left(775 \frac{W}{m^2} \times A_t + 194 \frac{W}{m^2} \times A_s\right)$$

$$= 0.90 \ (775 \times 0.128 + 194 \times 0.544) = 205 \text{ watts}$$

$$q_{rad} = \epsilon \sigma A_r (T_w^4 - T_a^4)$$

$$= (0.8) \left(5.669 \times 10^{-8} \frac{W}{m^2 - k^4}\right) (0.64m^2) \left[T_w^4 - (311^\circ k)^4\right]$$

$$q_{ct} = h_t A_t (\Delta T) \text{ where } \Delta T = T_w - T_a$$

$$= \left[1.71 \times (\Delta T)^{0.25}\right] (0.128m^2) (\Delta T)$$

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$$q_{cs} = h_s A_s' (\Delta T)$$
$$= \left[1.97\ (\Delta T)^{0.25}\right] (0.38 m^2)\ (\Delta T)$$

Iteration yields a wall temperature T_w of 70°C (158°F). Thus, the Model 680 satisfies the requirements of paragraph 240, IAEA Safety Series No. 6, 1973.

0.25 Inch O.D. Source Capsules - Thermal Analysis

Hypothetical Fire Conditions

This analysis is intended to demonstrate that Tech/Ops source capsules which are of 0.25 inch (6.35mm) diameter, seal welded to a minimum penetration of 0.020 inch (0.51mm), made of Type 304 or 304L stainless steel, and licensed as special form containers under IAEA Safety Series No. 6, 1973, also meet the requirements of paragraph 238, IAEA Safety Series No. 6, 1973, i.e., containment under specified thermal test conditions.

The actual containment vessel for the radioactive material is the welded source capsule. These capsules are all 0.25 inches (6.35mm) in diameter and less than 1 inch (25.4mm) in length.

The internal volume of the source capsules contains only iridium-192 or cobalt-60 metal (as a solid) and air. It is assumed at the time of loading that the entrapped air in the capsule is at standard temperature and pressure (20°C, 0.101 Meganewtons per square meter). We contend that 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 is somewhat reduced.

As described in Tech/Ops standard source encapsulation procedure, the minimum weld penetration is 0.020 inch (0.51mm). Under conditions of internal pressure, the critical location for failure is this weld. Since the capsule has an outside diameter of 0.25 inch (6.35mm), this weld has a cross-sectional area of 0.014 square inches (9.30mm^2).

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

$$P_2 = \frac{P_1 T_2}{T_1}$$

P_1 = initial pressure($0.101 MN/m^2$)

T_1 = initial temperature ($293^\circ k$)

T_2 = final temperature ($1093^\circ k$)

The internal gas pressure could reach $0.377 MN/m^2$. It is assumed that the capsule can be treated as a thin-walled, cylindrical pressure vessel.

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The maximum longitudinal tensile stress can be calculated by writing a longitudinal force balance through the weld:

stress x $area_s$ - pressure x $area_p$ = 0

$$S_1 \pi \frac{(D_o^2 - D_i^2)}{4} - P \pi \frac{D_i^2}{4} = 0$$

where S_1 = longitudinal stress

D_o = outer diameter (6.35cm)

D_i = inner diameter (5.35cm)

P = pressure ($0.377 MN/m^2$).

Thus, the longitudinal stress is $0.922 MN/m^2$

The hoop stress can be found in a similar fashion. Taking a longitudinal cross-section and summing forces:

hoop stress x $area_s$ - pressure x $area_p$ = 0

$$2S_h Lt - pD_i L = 0$$

where S_h = hoop stress

L = length of cylinder

t = thickness of weld (0.51m m)

Thus, the hoop stress is $1.98 MN/m^2$

At a temperature of 1600°F (870°C) the yield strength of type 304 stainless steel is 10,000 psi ($69.0 MN/m^2$) Thus, the pressure induced stresses are less than 3% of the yield strength at 800°C.

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4. Containment

4.1 Containment Boundary

4.1.1 Containment Vessel

The containment system for the Model 680 Gamma Ray Projector is the Tech/Ops Model A424-14 Source Assembly. The source assembly is currently certified (IAEA Certificate of Competent Authority No. USA/0165/S) as special form containment for radioactive materials.

The actual containment vessel is the welded source capsule, either style 60004 or 60011. The capsule is made of Type 304 or 304L Stainless steel. It is seal welded with a minimum weld penetration of 0.020 in. (0.51mm). The capsule is a rounded cylinder 0.25 inches (6.35mm) in diameter and 0.97 inches (25mm) in length. Appropriate descriptive drawings are enclosed in Section 2.10.

4.1.2 Containment Penetrations

There are no penetrations of containment. The source capsule is seal welded to provide conformity to special form requirements.

4.1.3 Seals and Welds

The containment vessel is tungsten inert gas welded by General Electric at their plant in Vallecitos, California. This is done in accordance with Tech/Ops standard source encapsulation procedure (See Section 7.4). The minimum weld penetration is 0.020 inches (0.51mm). This has proved acceptable for licensing this vessel as special form.

4.1.4 Closure

Not Applicable

4.2 Requirements for Normal Conditions of Transport

4.2.1 Release of Radioactive Material

The source assembly used meets the requirements of special form radioactive material as delineated in IAEA Safety Series No. 6, 1973 and 10CFR71. Thus, there will be no release of radioactive materials under conditions of normal transport.

4.2.2 Pressurization of Containment Vessel

The source assemblies used all meet the requirements of special form radioactive material. Pressure buildup due to the conditions of the hypothetical thermal accident has been shown to create stresses well below the structural limits of the capsule (See Section 3.5). Thus, the containment vessel will withstand the pressure variations of normal transport.

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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 as outlined in 10CFR71, Appendix B, 1., 2., and 3. have been shown (Sections 2.7.1, 2.7.2 and 3.5 respectively) to result in no loss of package containment.

5. Shielding Evaluation

5.1 Discussion and Results

The Model 680 is shielded with 285 pounds (130kg) of depleted uranium. The uranium metal is cast around the zircalloy or titanium "S" tube which holds the source. The storage position for the source is at the inflection in the "S" tube.

A radiation profile of Model 680 S.N. 257 containing 108Ci of cobalt-60 (see Section 5.5) was made. An extrapolation for a 110Ci source yielded the results which are presented in Table 5.1. From this data, and from previous acceptability (NRC Certificate of Compliance No. 9035, Rev. 2) it is concluded that the Model 680 complies with the regulatory standards in 10CFR71 and IAEA Safety Series No. 6, 1973.

TABLE 5.1

SUMMARY OF MAXIMUM DOSE RATES
(mR/hr)

	Contact			At 1 Meter		
	Side	Top	Bottom	Side	Top	Bottom
Gamma	163	173	122	2.6	2.0	1.5
Neutron	Not applicable			Not applicable		
Total	163	173	122	2.6	2.0	1.5

Hypothetical accident conditions will result in essentially no change in the above readings.

5.2 Source Specification

5.2.1 Gamma Source

The gamma source used is encapsulated cobalt-60 in quantities of up to 110 curies.

5.2.2 Neutron Source

Not applicable

5.3 Model Specifications

Not applicable.

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5.2.2 Neutron Source

Not applicable.

5.3 Model Specifications

Not applicable.

5.4 Shielding Evaluation

The Model 680 shielding evaluation was performed on Model 680 Serial Number 257, containing 108Ci of cobalt-60. The radiation profile is included in Section 5.5. Extrapolation of this data to the capacity of 110 curies (Section 5.1) clearly indicates that the Model 680 conforms to regulatory radiation limits. As the hypothetical accident evaluation (Section 2.7) revealed no change in the shielding arrangement, it is concluded that shielding after the hypothetical accident is essentially unchanged. Therefore, the radiation profile indicates the package will be within acceptable limits.

5.5 APPENDIX

- Model 680: Radiation Profile

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RADIATION PROFILE

Model 680 Serial Number 257

Source Model Number A424-14

Serial Number 1803: 108 Curies ^{60}Cobalt

Location	At Contact	At 1 Meter
Top	170	2.0
Right Side	120	2.6
Bottom	120	1.5
Left Side	90	1.5
Front	150	2.0
Back	160	2.0

NOTES:

1. All intensities are expressed in units of milliroentgens per hour.
2. Intensities expressed are the maximum intensities on the particular surface.
3. Measurements were made with an AN/PDR - 27(J) Survey Meter.

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6. <u>Criticality Evaluation</u>

Not applicable

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7. Operating Procedures

7.1 Procedures for Loading the Package

Section 7.4 describes the procedure for fabricating the special form source encapsulation . Section 7.4 also contains the procedure for loading this source assembly into the package and preparing the package for transport.

7.2 Procedures for Unloading the Package

Section 7.4 contains the procedure for unloading the source assembly from the package.

7.3 Preparation of an Empty Package for Transport

Section 7.4 describes the procedure for preparing an empty package for transport.

7.4 APPENDIX

- Encapsulation of Sealed Sources
- Technical Operations Model 680: Procedures of Loading - Unloading the Package

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RADIATION SAFETY MANUAL
Part II In Plant Operations
Section 2

ENCAPSULATION OF SEALED SOURCES

A. Personnel Requirements

Only an individual qualified as a Senior Radiological Technician shall perform the operations associated with the encapsulation of ^{192}Iridium. There must be a second qualified Radiological Technician available in the building when these operations are being performed.

B. General Requirements

The ^{192}Iridium loading cell shall be used for the encapsulation of solid metallic ^{192}Iridium and the packaging of sealed sources such as ^{170}Thulium, ^{137}Cesium and ^{169}Ytterbium. Solid metallic ^{60}Cobalt not exceeding one curie may be handled in this cell also.

The maximum amount of ^{192}Iridium to be handled in this cell at any one time shall not exceed 1000 curies. The maximum amount of ^{137}Cs to be handled in this cell at any one time shall not exceed 100 curies.

This cell is designed to be operated at less than atmospheric pressure. The exhaust blower provided shall not be turned off except when the cell is in a decontaminated condition.

Sources shall not be stored in this cell overnight or when cell is unattended. Unencapsulated material shall be returned to the transfer containers and encapsulated sources transferred to approved source containers.

When any of the "through-the-wall" tools such as the welding fixture or transfer pigs are removed, the openings are to be closed with the plugs provided. These tools shall be decontaminated whenever they are removed from the hot cell.

C. Preparatory Procedure

1. Check welding fixture, capsule drawer and manipulator fingers from cell and survey for contamination. If contamination in excess of 0.001 μCi of removable contamination is found, these items must be decontaminated.

2. If the welding fixture or the electrodes have been changed, perform the encapsulation procedure omitting the insertion of any activity. Examine this dummy capsule by sectioning thru weld. Weld penetration must be not less than 0.020 inch.

If weld is sound and penetration is at least 0.020 inch, the preparation of active capsules may proceed. If not, the condition responsible for an unacceptable weld must be corrected and the preparatory procedure repeated.

3. Check pressure differential across first absolute filter, as measured by the manometer on the left side of the hot cell. This is about $\frac{1}{2}$ inch of water for a new filter. When this pressure differential rises to about 2 inches of water, the filter must be changed.

D. Encapsulation Procedure

1. Prior to use, assemble and visually inspect the two capsule components to determine if weld zone exhibits 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 10 minutes. Dry the capsule components at 100°C for a minimum of twenty minutes.

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

4. Place capsule in weld positioning device.

5. Move drawer of source transfer container into hot cell.

6. Place proper amount of activity in capsule . Disposable funnel must be used with pellets and a brass rivet with wafers to prevent contamination of weld zone.

7. Remove unused radioactive material from the hot cell by withdrawing the drawer of the source transfer container from the cell.

8. Remove funnel or rivet.

9. Assemble capsule components.

10. Weld adhering to the following conditions:

    a. Electrode spacing .021" to .024" centered on joint ±.002"; use jig for this purpose.

    b. Preflow argon, flush 10 seconds.

    c. Start 15 amps.

    d. Weld 15 amps.

    e. Slope 15 amps.

    f. Post flow 15 seconds

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 rewelded to acceptable conditions or disposed of as radioactive waste.

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

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

14. Count the patch with the scaler counting system. Patch must show no more than .005 μCi of contamination. If the patch shows more than .005 μCi, the capsule must be cleaned and rewiped. If the rewipe patch still shows more than 0.005 μCi of contamination, steps 8 through 11 must be repeated.

15. Vacuum bubble test the capsule. Place t he welded capsule in a glass vial containing isopropyl alcohol. Apply a vacuum of 15 in Hg (Gauge). 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. Reweld the capsule.

16. 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.

17. Apply the tensile test to assembly between the capsule and connector by applying proof load of 75 lbs. Extension under the load shall not exceed 0.1 inch. If the extension exceeds 0.1 inch, the source must be disposed of as radioactive waste.

18. Position the source in the exit port of hot cell. Withdraw all personnel to the control area. Use remote control to insert source in 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.

19. Using remote control, eject the source from cell into source changer through the tube gauze wipe test fixture. Monitor before reentering the hot cell area to be sure that the source is in the source changer. Remove the tube gauze and count with scaler counting system. This assay must show no more than 0.005 μCi. If contamination is in excess of this level, the source is leaking and shall be rejected.

20. Complete a Source Loading Log (Figure II.2.1) for the operation.

Technical Operations
Model 680

Procedures for Loading - Unloading the Package

Wear personnel monitoring devices during all source changing procedures. Monitor all operations with a calibrated, operable survey meter.

> Note: All the precautions used when making radiographic exposures must be followed.

1. Survey the projector to ensure that the source is in the proper position.

2. Locate the projector and source changer in a restricted area. Locate the devices so as to avoid sharp bends in the guide tube or control housing.

   The control cable housing bend radius should not be less than 36 inches (0.914m), and the guide tube bend radius should not be less than 20 inches (0.508m).

3. Set the source changer for operation.

4. Attach one end of a guide tube fitting to the fitting above the empty chamber in the source changer and the other end to the projector.

5. Attach the control cable to the projector:

   a. Unlock the projector with the key provided and turn the connector selector ring from the LOCK position to the CONNECT position. When the ring is in the CONNECT position, the storage cover will disengage from the projector.

   b. Slide the control cable collar back and open the jaws of the swivel connector, exposing the male portion of the connector. Engage the male and female portions of the swivel connector by depressing the spring loaded locking pin toward the projector with the thumbnail. Release the locking pin and test that the connection has been made.

   c. Close the jaws of the control cable connector over the swivel type connector.

   d. Slide the control cable collar over the connector jaws. Hold the control cable collar flush against the projector connector and rotate the selector ring from the CONNECT position to the OPERATE position.

6. Crank the source into source changer.

   a. Survey this operation with a survey meter to be sure the source has been transferred from projector to changer.

b. With a survey meter verify radiation level does not exceed 200 mR/hr at the surface of the changer.

7. Disconnect the control cable from the source assembly. Disconnect the guide tube from the source changer. Secure the source in the source changer.

8. IF THE PROJECTOR IS TO REMAIN EMPTY:

a. * Fully retract the control cable. Disengage the control cable from the projector and lock the projector.

b. Attach the identification plate of the source to the source changer.

c. Affix a green "empty" tag to projector.

d. Perform a wipe test of the projector to assure that the radiation observed is less than 0.001 microcuries per 100 square centimeters.

e. Survey the projector to assure that the radiation levels do not exceed 200mR/hr at the surface nor 10mR/hr at three feet from the surface.

f. Mark the projector: Radioactive - "LSA". Affix the proper shipping labels to the package.

g. Complete the proper shipping papers as specified in Tech/Ops Radiation Safety Manual II.6.3E(4), (5), (6).

9. IF THE PROJECTOR IS TO BE RELOADED: connect the source changer end of the guide tube to the fitting above the new source in the source changer.

10. Crank source to full retraction within the projector.

a. Survey this operation with a survey meter to be sure the source has been transferred into the projector.

b. With a survey meter verify radiation level does not exceed 200mr/hr at the surface of the projector.

11. Disconnect the control cable and lock the projector.

12. Disconnect the source guide tube from the projector and source changer.

13. Affix the identification plate of the new source to the projector and attach the identification plate of the old source to the source changer.

14. Prepare for shipment:

a. Again survey projector to insure that the radiation level does not exceed 200mr/hr at the surface of the projector.

b. Survey the radiation level at a distance of three feet from the surface of the projector. This radiation level should not exceed 10mr/hr. The highest radiation level measured at three feet from the container is used to determine the Transport Index in accordance with 49CFR173.389(h).

c. Affix the proper shipping labels.

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 seal wired properly and that the package is properly marked.

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 seventy-five pounds. Failure of this test will prevent the source assembly from being used.

8.1.3 Leak Tests

The radioactive source capsule (the primary containment) is wipe tested for leakage of radioactive contamination. The source capsule is subjected to a vacuum bubble leak test. The capsule is then subjected to a second wipe test for leakage of radioactive contamination. These tests are described in Section 7.4. Failure of any 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 security of the source will be maintained. Failure of this test will prevent use of the package until the lock assembly is corrected and retested.

8.1.5 Tests for Shielding Integrity

The radiation levels at the surface of the package and at three feet from the surface are measured using a small detector survey instrument (e.g., AN/PDR-27). These radiation levels, when extrapolated to the rated capacity of the package, must not exceed 200 milliroentgens per hour at the surface nor ten milliroentgens per hour at the surface nor ten milliroentgens per hour at three feet from the surface of the package. Failure of this test will prevent use of the package.

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 lock 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 prior to 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 ten milliroentgens per hour at three feet 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 10CFR71.12(b) are included in Section 7.4.

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