Technical Assessment of the TITAN Gamma Radiography Exposure Device

with Respect to the Requirements of 10 CFR Part 34, ANSI N432-1980 and 10 CFR Part 71

TR 9303 N990

October 1993

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TECHNICAL REPORT

TR 9303 N990

Technical Assessment of the TITAN Gamma Radiography Exposure Device with Respect to the Requirements of 10 CFR Part 34, ANSI N432-1980 and 10 CFR Part 71.

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PART 1. INTRODUCTION AND ASSESSMENT WITH RESPECT TO 10 CFR PART 34 [1]

1.0 INTRODUCTION

This submission assesses the Titan with respect to the performance requirements for gamma radiography exposure devices. It is divided into four parts. Part 1 assesses the unit with respect to 10 CFR Part 34 [1], Part 2 with regard to ANSI N432-1980 [2] and Part 3 assesses the unit with respect to 10 CFR Part 71.[3] Part 4 provides a complete list of references used in the first three parts, and also includes copies of selected references.

With the exception of the common references, each part of this submission includes all materials necessary for regulatory review. Copies of documents such as IS/OM 0090 N990, "Titan Gamma Ray Projector User's Manual" are found in each part to facilitate review.

For the first two parts, compliance is demonstrated by a paragraph by paragraph comparison with the regulations. Section headings and numbers correspond with the headings and numbers of the applicable standards. For Part 3, the assessment is done according to the format guidelines of reference [4].

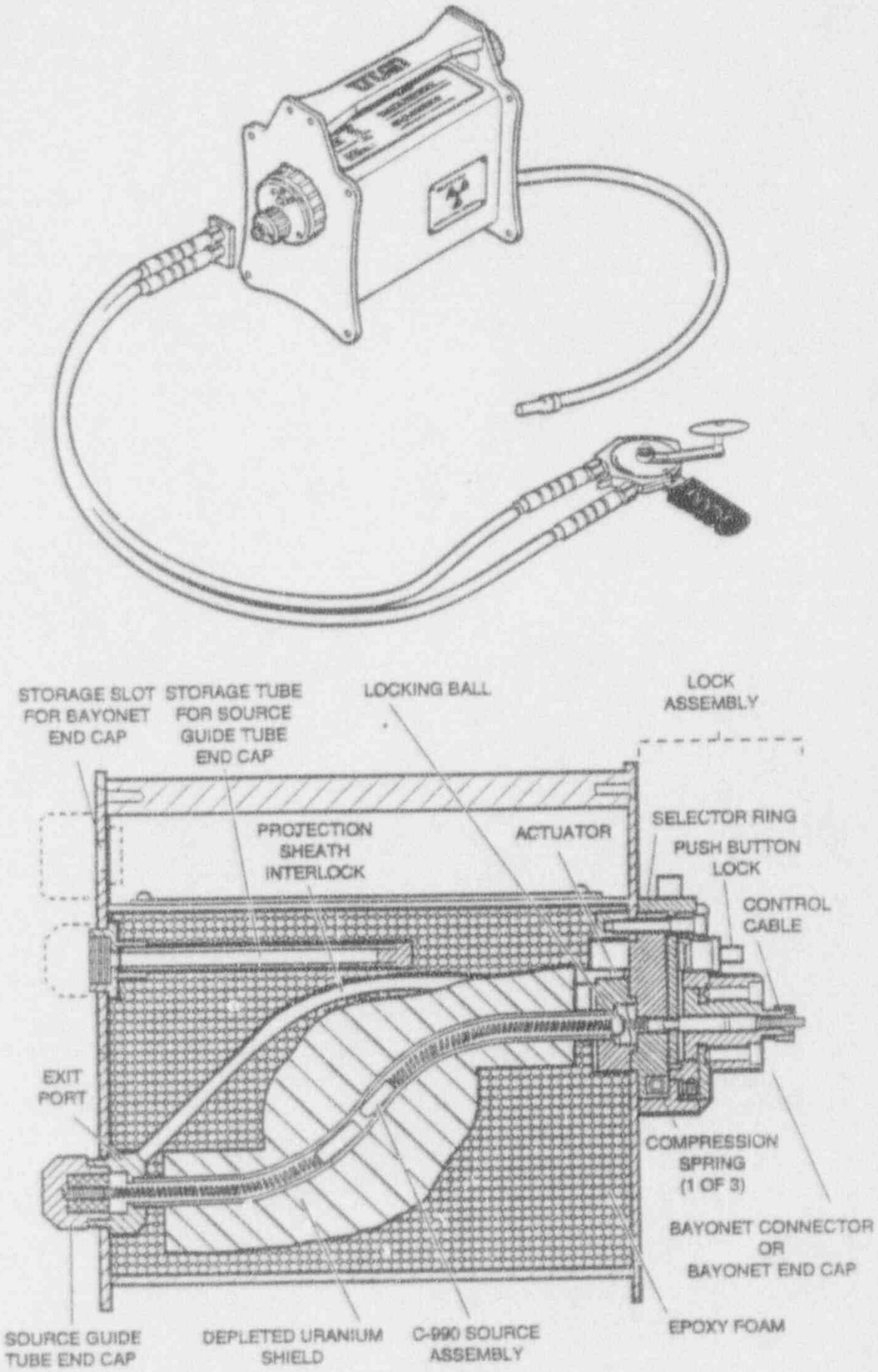

Figure 1. The Titan Gamma Radiography Exposure Device

34.20 Performance Requirements for Radiography Equipment

34.20(a) Compliance with ANSI N432-1980 is considered in part 2 of this submission.

34.20(b)(1) The identification label shown in engineering drawing A17720 accompanies each C-990 source assembly. This label includes the chemical symbol and mass number of the radionuclide (Ir-192), the activity and date on which it was measured, the model number (C-990) and serial number of the sealed source, and the manufacturer's identity.

The Titan User's Manual (IS/OM 0090 N990, Appendix 3) requires the user to attach this label to the front plate of the Titan after the source has been loaded. It is also the user's responsibility to add his name, address and telephone number to the unit. There is ample free space on the Titan to enable the user to meet both of these requirements.

34.20(b)(2) The Titan is intended to be used as a Type B transport package. Part 3 of this submission assesses the unit with respect to the requirements of 10 CFR Part 71.

34.20(b)(3) The Titan User's Manual does not allow for any modifications to the unit, or associated equipment. It is the user's responsibility to operate the Titan radiography system in accordance with the User's Manual and any local and national regulations.

34.20(c)(1) The coupling between the source assembly and the control cable consists of a ball in socket joint with the male attached to the control cable. It is shown in Figure 2. A secure connection is made by depressing the locking pin and inserting the male into the female. The compression spring ensures a secure connection once the locking pin is released.

Parts list

1. Control cable
2. D898 Male connector
3. D899 Female connector
4. Locking pin
5. Locking collar
6. Compression spring
7. Spring pin
8. Connector cap
9. Crimp
10. Crimped and threaded locking ball
11. Pig tail cable
12. Crimp
13. Cap capsule
14. Active material: ^{192}Ir
15. Base capsule

Notes

1. Conforms to IAEA Special Form requirements (AECB Certificate No. CDN/0001/S)
2. Manufactured to Nordion Specification IS/TS 0010 C000
3. Used with the Titan Gamma Radiography Exposure Device
4. The female connector has the following information engraved:
   DANGER
   RADIOACTIVE
   NII
   IR192 C990
   SERIAL NO. (as specified)

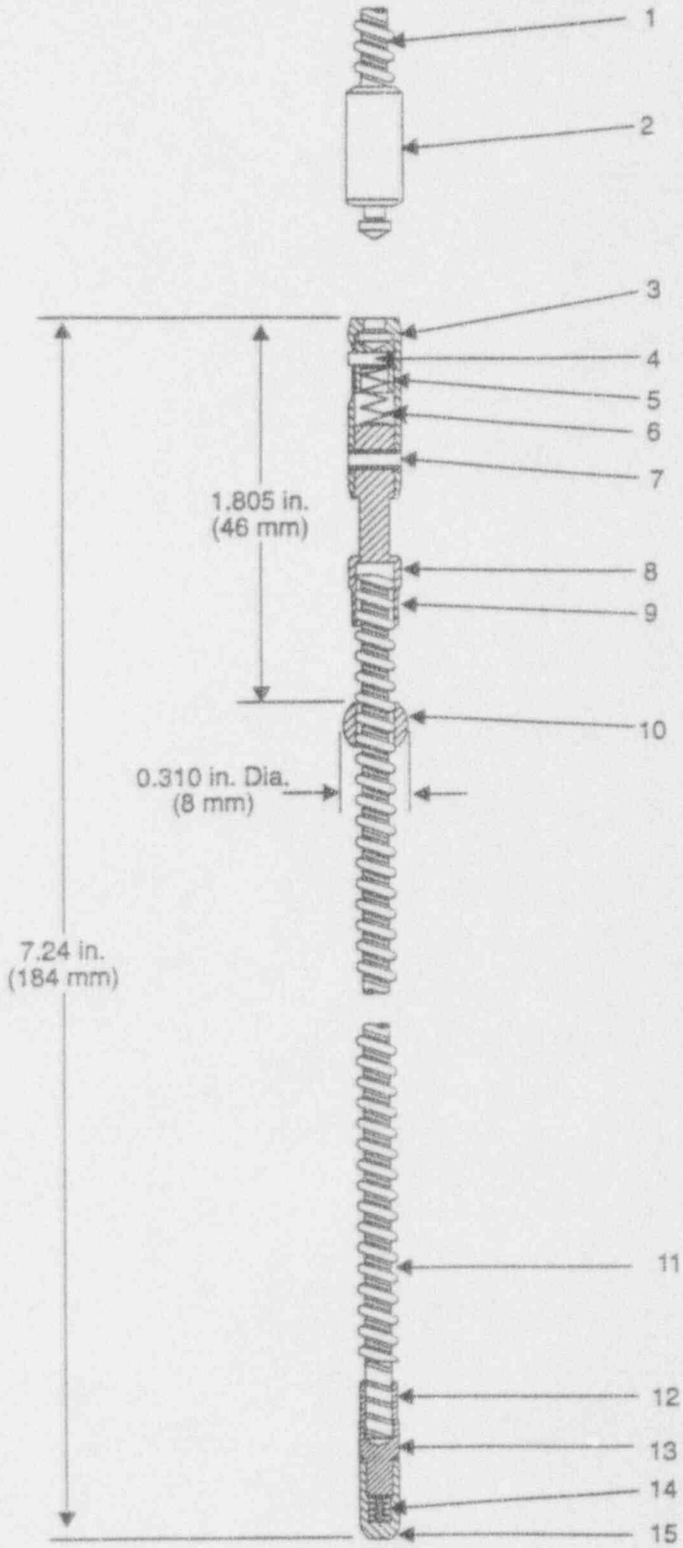

Figure 2. The C-990 Source Assembly

Nordion experience has shown this connection to be reliable and safe. It is used in various Nordion sealed source assemblies including the C-337, C-340 and C-343.

This connection remains secure under normal and reasonably foreseeable accident conditions. This has been demonstrated by the successful completion of full scale tensile tests and a 20,000 cycle endurance test. The tests are described in the test plan, which is found in Appendix 4. The results are documented in reference [5].

The tests for foreseeable accident conditions included 100 cycles without the terminal section of the projection sheath installed. For each cycle, the dummy C-990 source assembly was projected about 1 meter past the end of an open intermediate section of guide tube. The 100 cycles were completed without the dummy source disconnecting from the control cable. This demonstrates that the connection meets the requirements of this paragraph.

34.20(c)(2) The source assembly is secured by the selector ring within the Lock Assembly. Turning the selector ring to the OPERATE position releases the source assembly and allows it to move to the working position.

Rotation of the selector ring is done against the action of three compression springs. The springs are biased toward the LOCK position. Once the outer ring is turned into OPERATE, an actuator pin enters a receptacle and prevents the selector ring from returning to the LOCK position. This pin is connected to an actuator located between the lock assembly and the shield.

Upon its return to the storage position, the C-990 locking ball enters the actuator causing the actuator pin to be released from its receptacle. This allows the selector ring to snap back to the LOCK position. In this manner, the primary lock automatically secures the source assembly when it is cranked back into the fully shielded position.

The only way to release the source assembly is to deliberately turn the outer ring into the OPERATE position.

A more detailed description of this safety feature can be found in Appendix 2.

34.20(c)(3) The Titan includes caps for the lock assembly and exit port. They are shown in Figure 1.

Both caps are designed to protect the source assembly from foreign matter and accidental impact. The Titan User's Manual requires these caps to be installed whenever the unit is not in use. (See Appendix 3.)

34.20(c)(4) The C-990 has th words "DANGER RADIOACTIVE" engraved on its end connector. This is shown on engineering drawing K122213-600.

34.20(c)(5) Prototype source guide tubes and drive controls have been successfully kink and crush tested as described in Appendix 4. The results can be found in reference [5]. No significant damage was observed.

34.20(c)(6) The Titan is equipped with an interlock which prevents the selector ring from moving into the OPERATE position unless the projection sheath has been installed. The operation of this interlock is described in Appendix 2.

34.20(c)(7) An exposure head is crimped onto the terminating section of the projection sheath. It is the user's responsibility to ensure that the terminating section is installed during operation.

34.20(c)(8) Tensile tests on the guide tube exposure head connection are described in Appendix 4. The results of these tests are given in reference [5]. No significant damage was observed.

34.20(c)(9) This paragraph of the regulations applies to source changers and does not apply to the Titan.

34.20(d)(e) It is submitted that the Titan is in full compliance with the requirements of 10 CFR Part 34.

34.21(a) The Titan is designed for the maximum radiation fields listed below:

i) 200 mrem/h on contact with the surface of the unit;

ii) 50 mrem/h 50 mm from the surface of the unit

iii) 2 mrem/h 1 m from the surface of the unit.

The critical requirement is ii). Satisfying this requirement means that the other two are satisfied as well. The two prototypes were found to have radiation fields in excess of this limit. It is clear that about 1 to 2 mm of additional shielding is required over the surface of the unit. The net weight increase will be approximately 0.7 kg. (1.5 lb)

Nordion concedes that additional proof is required before full compliance with ANSI N432-1980 is demonstrated. New shields will be manufactured and surveyed as per the procedures described in Appendix 4.

The effect of the increase in unit weight has been considered in all of the tests for normal and accident conditions of handling and transport. In general, drop heights were increased by 5 % to account for the increased potential energy of the production units.

34.21(b) It is submitted that the Titan will meet the requirements of this paragraph as described in 34.21(a) above. Proof will be in the form of a supplemental test report.

34.22(a) The Titan Lock Assembly prevents unauthorized or accidental removal of the sealed source from the storage position. Its operation is described in Appendix 2.

It is the user's responsibility to ensure that the Titan is kept locked when it is not in the direct surveillance of a Radiographer or Radiographer's assistant. (See Appendix 3.)

The sealed source assembly is automatically secured every time the source returns to its shielded position. This feature is discussed in paragraph 34.20(c)(2) above, and in Appendix 2.

34.22(b) The Titan is neither a sealed source storage container nor a source changer. Therefore, the requirements of this paragraph do not apply.

34.23 through and 34.27 The requirements of these paragraphs apply to licensees only. They do not apply to the Titan and are not considered in this submission.

34.28 The Inspection and Maintenance requirements for the Titan are described in the User's Manual. (See Appendix 3.) It is the user's responsibility to carry out these procedures and to maintain records of these inspections.

34.29 through and 34.51 The requirements of these paragraphs apply to licensees only. They do not apply to the Titan and are not considered in this submission.

APPENDIX 1. Selected Engineering Drawings

The following engineering drawings are referenced in Part 1 of this submission. Current issues are included for reference.

K122213-600 rev. D
A17720 rev. E

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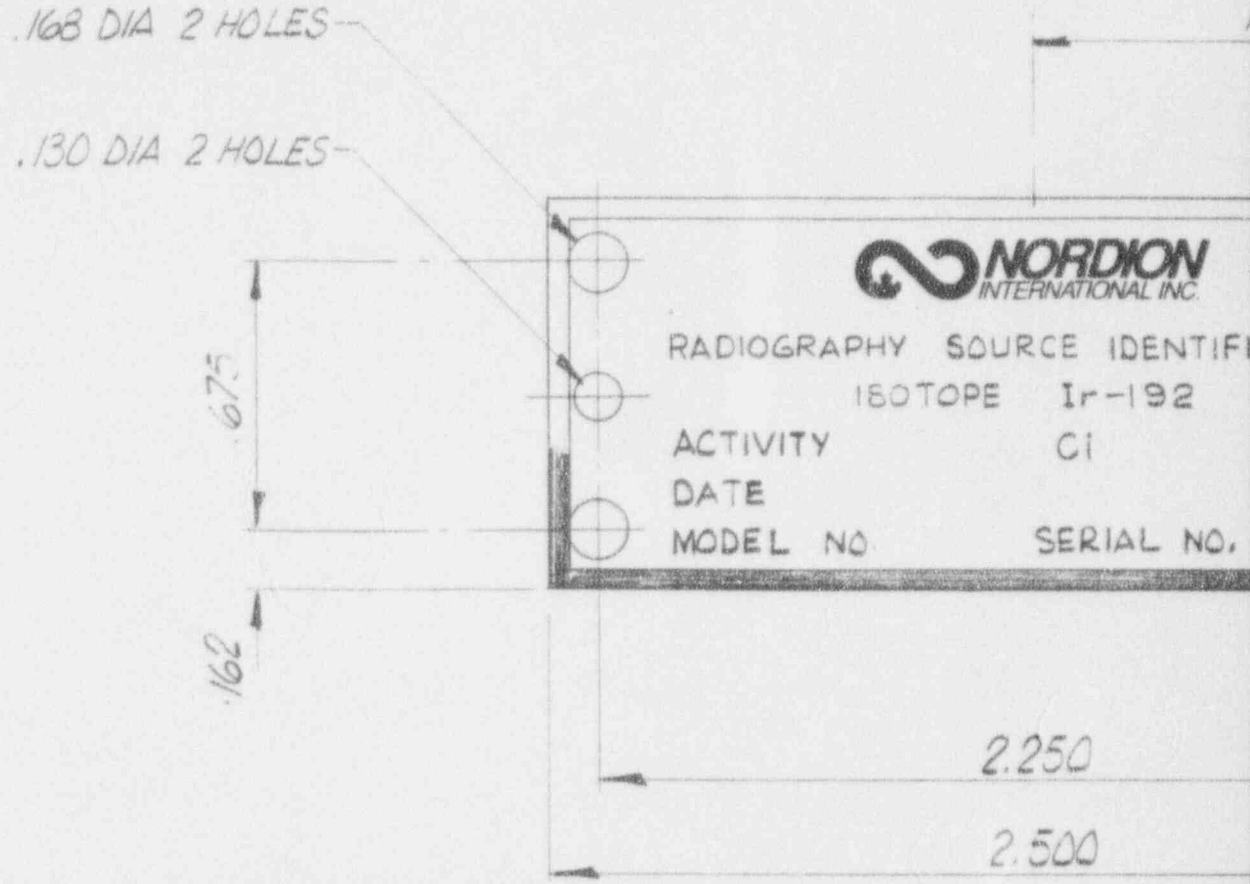

NOTE :-

1. BORDER, LETTERING & LOGO TO BE BLACK
2. LOGO TO BE CENTRED AS SHOWN
3. ALL LETTERING TO BE 8 PT HELVETICA
4. SPACE BETWEEN LINES .04
5. REMOVE BURRS & SHARP EDGES

ITEM NO	DRAWING NO.	PART N

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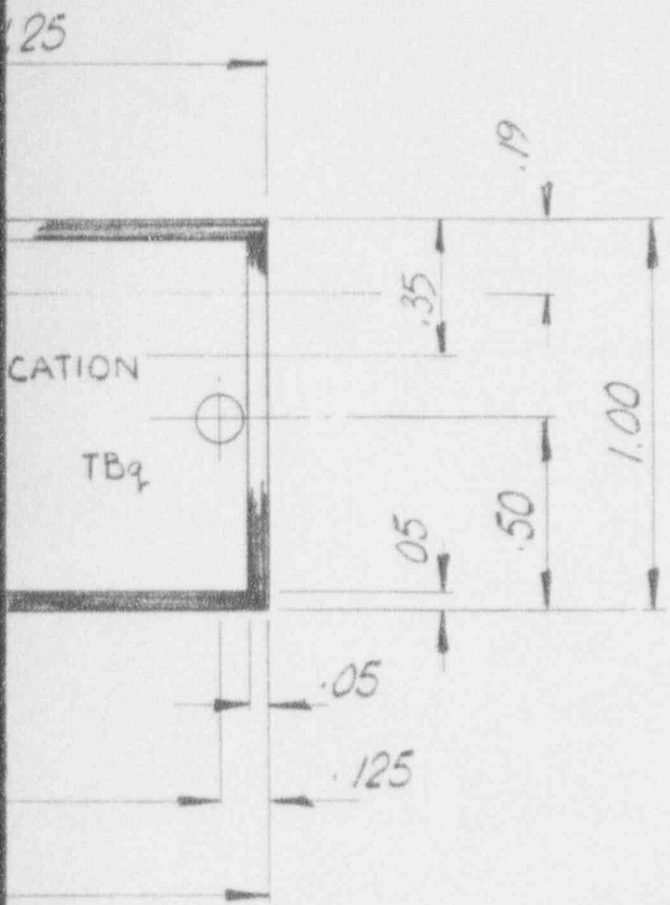
E	DCR # 2533



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PARTS LIST

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	92JUL28	GS	NK

DRAWN: MM — DATE: JULY 83 — CHECKED:

TJS				TJS
MECH. ENG.	ELECT. ENG.	CIVIL ENG.	PHYSICS	ENG. APPR'L

MATERIAL: BRASS SHEET .032 THK ASTM B36-260 — FINISH:

CODE NO.

NORDION INTERNATIONAL INC.
KANATA ONTARIO CANADA

TITLE: RADIOGRAPHY SOURCE TAG

K122213 — USED ON

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES

TOLERANCES:

FRACTIONS	DECIMALS	ANGLES
± —	XX ± .010 XXX ± .005	± —

SIZE	DWG. NO.	ISSUE
B	A 17720	E

SCALE: 2:1 — SHEET 1 OF 1

APPENDIX 2. OPERATION OF THE TITAN

A2.1 Overview

The Titan is shown schematically in Figure A2.1. It consists of a titanium shell, a lock assembly, an S tube cast within a depleted uranium (DU) shield, a C-990 sealed source assembly, and an exit port. Entries into the lock assembly and the exit port are sealed using end caps.

The lock assembly is shown in Figure A2.2 and consists of three main parts, the inner plate subassembly, the selector ring and the outer plate subassembly. The bayonet end cap is installed when the projector is not in use. The bayonet connector is used to attach the drive controls to the lock assembly.

At the start of an exposure cycle, the C-990 is secured in the S-tube, the selector ring is in the LOCK position, the bayonet and source guide tube end caps are installed, and the push button lock is engaged. This is termed transportation mode and in this configuration all requirements for the transport of radioactive materials are satisfied.

In transportation mode, it is impossible to remove the bayonet end cap. It is also impossible to turn the selector ring into the OPERATE position.

To perform an exposure, the radiographer unlocks the push button lock. This allows the bayonet end cap to be removed from the lock assembly and allows access to the C-990 end connector. (See Figure A2.3) The control cable is then connected to the C-990, and the bayonet connector is attached to the lock assembly. At this point, the remote control cable and the source assembly are fully connected. However, it is still not possible to move the selector ring into the OPERATE position. This action is prevented by an interlock with the projection sheath.

The source guide tube end cap is then removed and the projection sheath is attached. This releases the interlock and allows the selector ring to be turned counterclockwise into the OPERATE position. The motion is resisted by springs that bias the selector ring toward its LOCK position. Once the selector ring has been rotated into the OPERATE position, an actuator pin prevents the spring from returning the selector ring to the LOCK position.

In OPERATE, the sealed source is free to exit from the primary lock and the shield. The radiographer then uses the drive controls to project the source to the exposure site.

Once the exposure has been completed, the C-990 is retracted into the shield. As it approaches its secure position, its locking ball engages the actuator. This causes the actuator pin to disengage from the selector ring causing the ring to spring back into the LOCK position. This automatically secures the source assembly in the depleted uranium shield.

If additional exposures are planned, the selector ring is turned back into the OPERATE position and the cycle repeats. Otherwise, the drive controls and projection sheath are removed from the unit and replaced with the appropriate end caps, the push button lock is engaged and the wire seal is installed. This returns the unit to transportation mode.

A2.2 Design Principles for the Lock Assembly

This section describes the operation of the lock assembly in detail. The various lock components are shown in Figure A2.2.

A2.2.1 Design Principles for the Lock Assembly

The functions of the lock assembly are:

(a) To secure the source assembly in all positions except OPERATE.
(b) To prevent entry into the OPERATE position unless the control cable has been properly connected to the source assembly.
(c) To prevent entry into the OPERATE position unless the drive control has been installed.
(d) To prevent entry into the OPERATE position unless the projection sheath has been securely installed.
(e) To prevent the removal of the drive control while the selector ring is in the OPERATE position.
(f) To automatically lock the source assembly once it has returned from its working position.

Each of these functions is described below.

<u>Securing the Source Assembly</u>

The C-990 sealed source assembly is shown in Figure A2.3. It includes a two part end connector. The minor diameter of Item 8, the connector cap, is the smallest diameter along the entire length of the source assembly.

The C-990 is secured by the selector ring, which is shown in section in Figure A2.4. The smallest width in slot C aligns with the connector cap in all positions except OPERATE, and thus retains the source assembly. When the outer ring is in the OPERATE position, the source end connector is aligned with the hole at the end of slot C, and the C-990 is free to travel out into the working position.

Slot C is sized so that rotation of the selector ring from the OPERATE position to the LOCK position is only possible if the slot is aligned with the minor diameter of the connector cap. It is not wide enough to pass over the teleflex cable or any other part of the source assembly.

Preventing Operation if the Control is Improperly Installed

A secure connection between a male connector and the female C-990 connector is shown in Figure A2.5. If the male connector has not been securely connected to the female, the overall length of the connector assembly exceeds the length of a secure connection.

In order to turn the selector ring into the OPERATE position, the bayonet connector must be fully inserted into the lock assembly. An improper connection results in interference between the unconnected assembly and the bayonet connector, thus preventing the full insertion of the connector into the lock assembly. This makes it impossible to turn the bayonet connector and prevents operation if the control cable has not been securely connected to the source assembly.

Preventing Operation without the Drive Control

The lock is shown in section in Figure A2.6. (This section is different from the one shown in Figure A2.4.) It is prevented from moving into the OPERATE position by two interlocks. One of these interlocks is with the bayonet connector.

Movement into the OPERATE position can only be achieved if the cam follower pin is pushed into slot D. This only happens if the bayonet connector is inserted and rotated 90 degrees. Interference between the cam follower and the connector causes the follower to move radially outward against the action of a spring.

Only the bayonet connector can engage the cam follower. The bayonet end cap is similar to the bayonet connector. However, its smaller major diameter does not engage the cam follower. Thus, the cam follower is not pushed into slot D and the selector ring cannot be rotated into OPERATE.

Preventing Operation if the Projection Sheath is not Installed

The lock assembly includes an interlock with the projection sheath. The interlock is shown in Figures A2.1, A2.6 and A2.7. Rotation into the OPERATE position is prevented by the engagement of the interlock pin in slot B1. (See Figure A2.6.) The head of the pin is located in the outer plate subassembly and its tail extends through the selector ring and inner plate subassembly. The tail meets with a cable. (See Figure A2.7.) The other end of the cable is connected to a pin that projects into the exit port.

Installing the projection sheath depresses the pin which ultimately causes the interlock pin to disengage from slot B1. This allows the selector ring to be rotated into the OPERATE position.

The source guide tube end cap does not engage the pin in the exit port. This makes it impossible to reach the OPERATE position while the source guide tube end cap is installed.

Retention of the Drive Controls while in OPERATE

Figures A2.2 and A2.6 also shows a locking bar. Its function is to prevent the removal of the bayonet connector once the unit is in OPERATE mode.

The locking bar is related to slot E in the selector ring. (See Figure A2.6.) It is constrained to vertical motion by a slot in the outer plate. Rotation of the selector ring causes the locking bar to move upward. As soon as it leaves the lower position, the locking bar prevents the rotation of the bayonet connector. This prevents the removal of the drive controls from the lock assembly once the selector ring has been rotated into OPERATE.

Returning to the LOCK Position once the Source Assembly Returns

Rotation of the selector ring into OPERATE is resisted by springs. (See Figure A2.2.) The springs bias the ring toward LOCK.

Once the selector ring has been rotated into the OPERATE position, the actuator pin enters slot B2, and prevents the selector ring from returning to LOCK. (See Figure A2.6.) The head of this pin is within the outer plate and its tail extends through the selector ring and inner plate assembly to the actuator.

The tail of the pin can be engaged by a spring loaded actuator. (See Figure A2.2.) The actuator is biased toward the shield and the control cable moves freely through the actuator.

The C-990 source assembly includes a locking ball. Upon the return of the source to its shielded position, the locking ball engages the actuator. This causes the actuator to push the actuator pin out of slot B2. (See Figure A2.6.) This allows the springs to snap the selector ring into the LOCK position and secures the C-990.

A2.2.2 Design Principles for the Push Button Lock

The push button lock is an off-the-shelf component. It may be locked without the key. Its functions are:

a) To secure the bayonet end cap or the bayonet connector
b) While engaged, to prevent rotation of the selector ring into OPERATE
c) To enable the selector ring to be secured in its LOCK position at all times.

<u>Securing the Bayonet End Cap or the Bayonet Connector</u>

Engaging the push button lock causes a pin to enter through a lock pin and into the selector ring. (See Figure A2.6) The only time this can happen is when the locking pin is in its lower position. When the push button lock pin is installed through the locking pin, the locking plate cannot move.

The bayonet connector and the bayonet end cap have recesses that accept the locking pin. (See Figure A2.6.) If the locking pin is within the recess, neither connectors can be turned. Thus, with the push button lock engaged it is impossible to remove either the end cap or the bayonet connector.

Preventing Rotation into OPERATE while LOCKED

In addition to the interlock between the bayonet connector and the cam follower there is also an interlock between the push button lock and the selector ring. In its locked position, the push button lock pin engages a hole in the selector ring and prevents it from turning into the OPERATE position. (See Figure A2.6)

Enabling the Selector Ring to be Secured in the LOCK Position

In the event that both the bayonet end cap and bayonet connector are lost, it is still possible to secure the selector ring in the LOCK position. In this case, the lock pin is in its lower position and its hole is aligned with the push button lock. It is also aligned with the selector ring. This enables the push button lock to engage both the lock pin and the selector ring. This prevents the rotation of the selector ring into the OPERATE position.

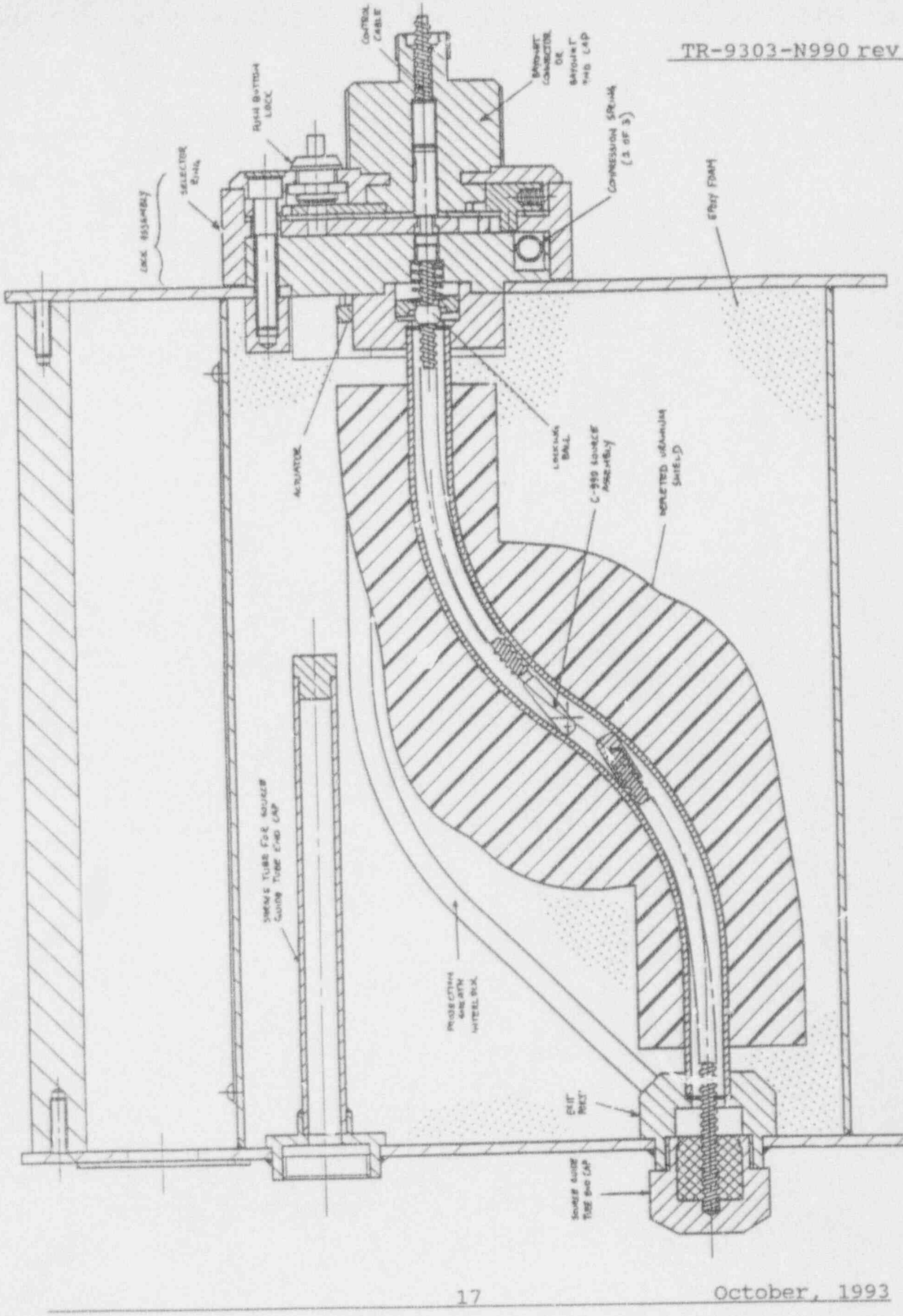


Figure A2.1. The Titan Gamma Radiography Exposure Device

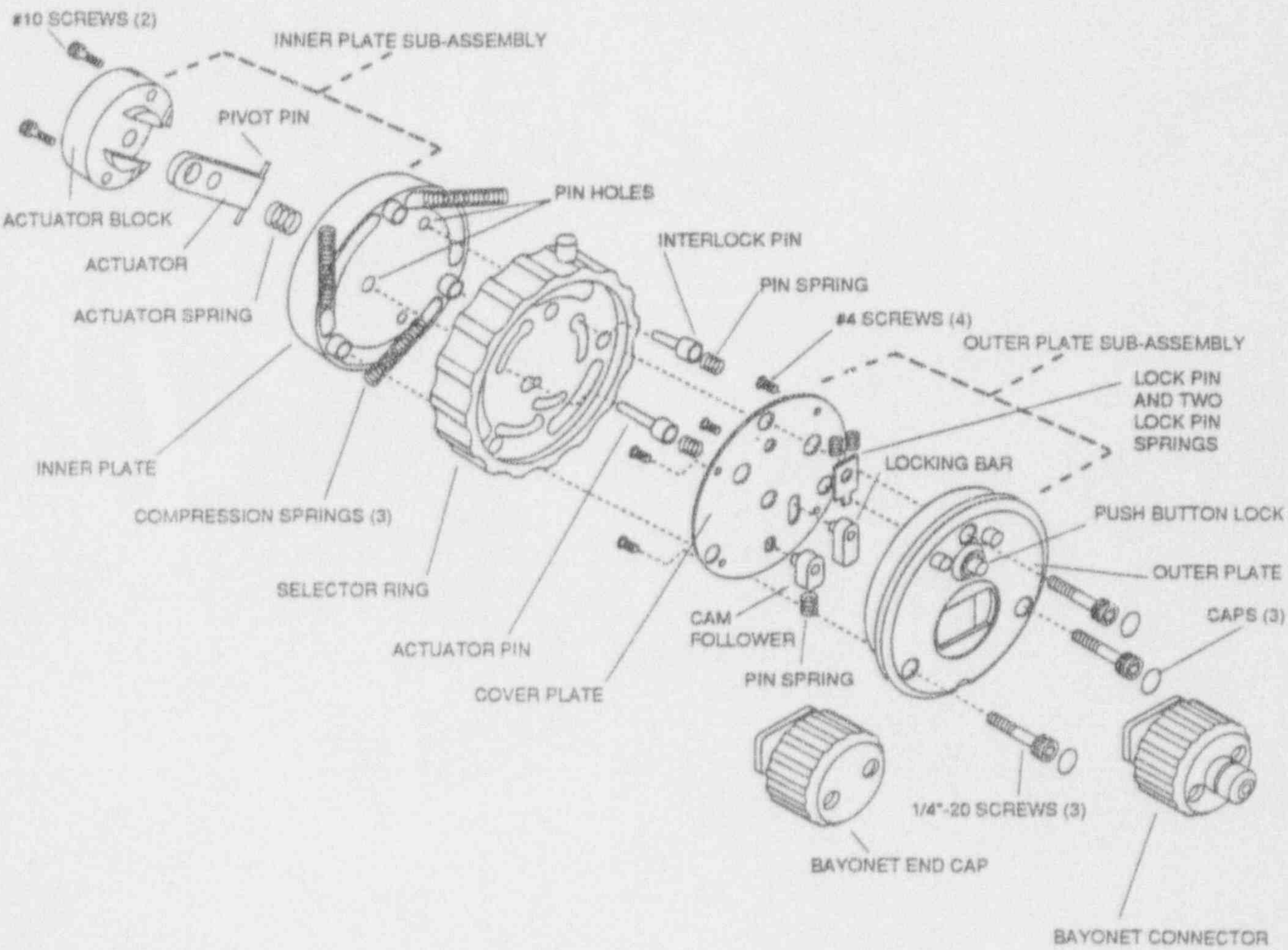
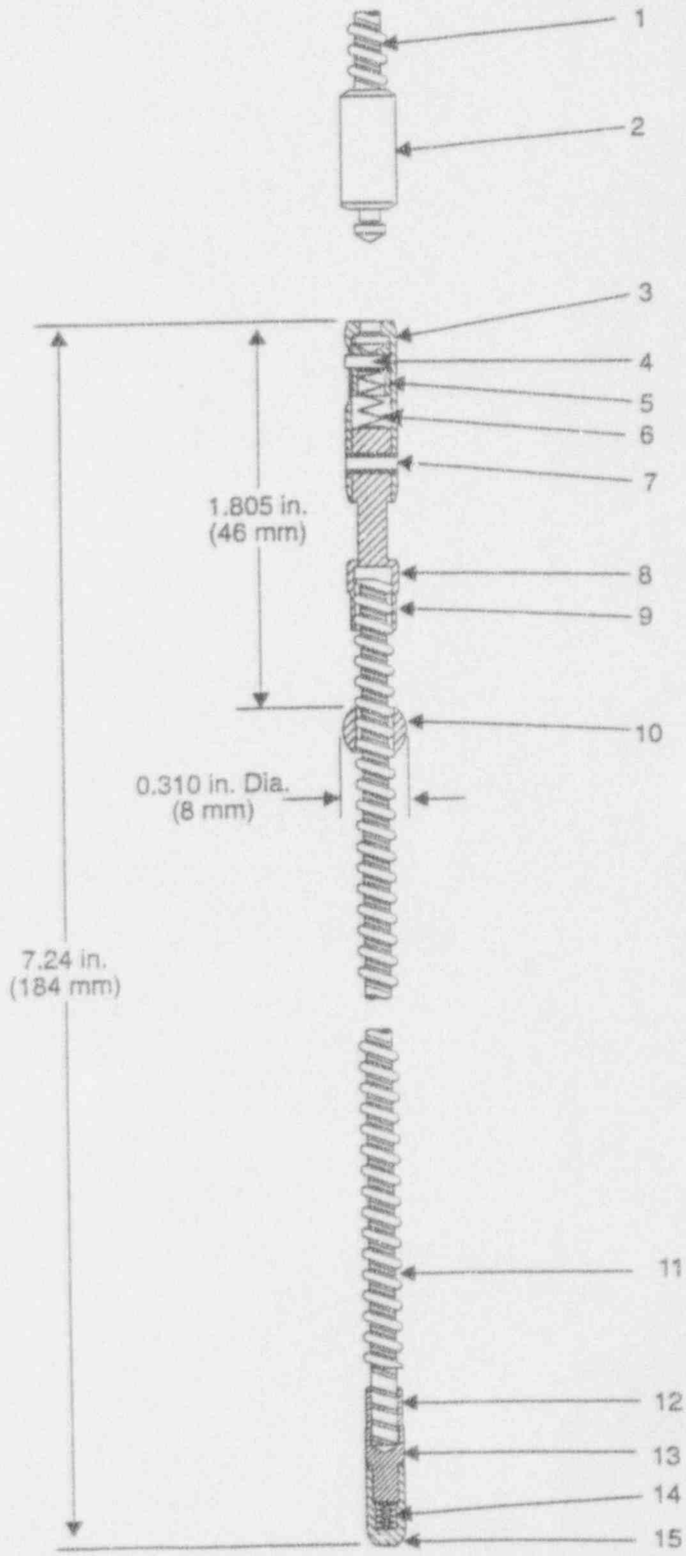


Figure A2.2 Exploded View of the Lock Assembly

Parts list

1. Control cable
2. D898 Male connector
3. D899 Female connector
4. Locking pin
5. Locking collar
6. Compression spring
7. Spring pin
8. Connector cap
9. Crimp
10. Crimped and threaded locking ball
11. Pig tail cable
12. Crimp
13. Cap capsule
14. Active material: ^{192}Ir
15. Base capsule



Notes

1. Conforms to IAEA Special Form requirements (AECB Certificate No. CDN/0001/S)
2. Manufactured to Nordion Specification IS/TS 0010 C000
3. Used with the Titan Gamma Radiography Exposure Device
4. The female connector has the following information engraved:

   DANGER
   RADIOACTIVE
   NII
   IR-192 C990
   SERIAL NO. (as specified)

Figure A2.3 The C-990 Sealed Source

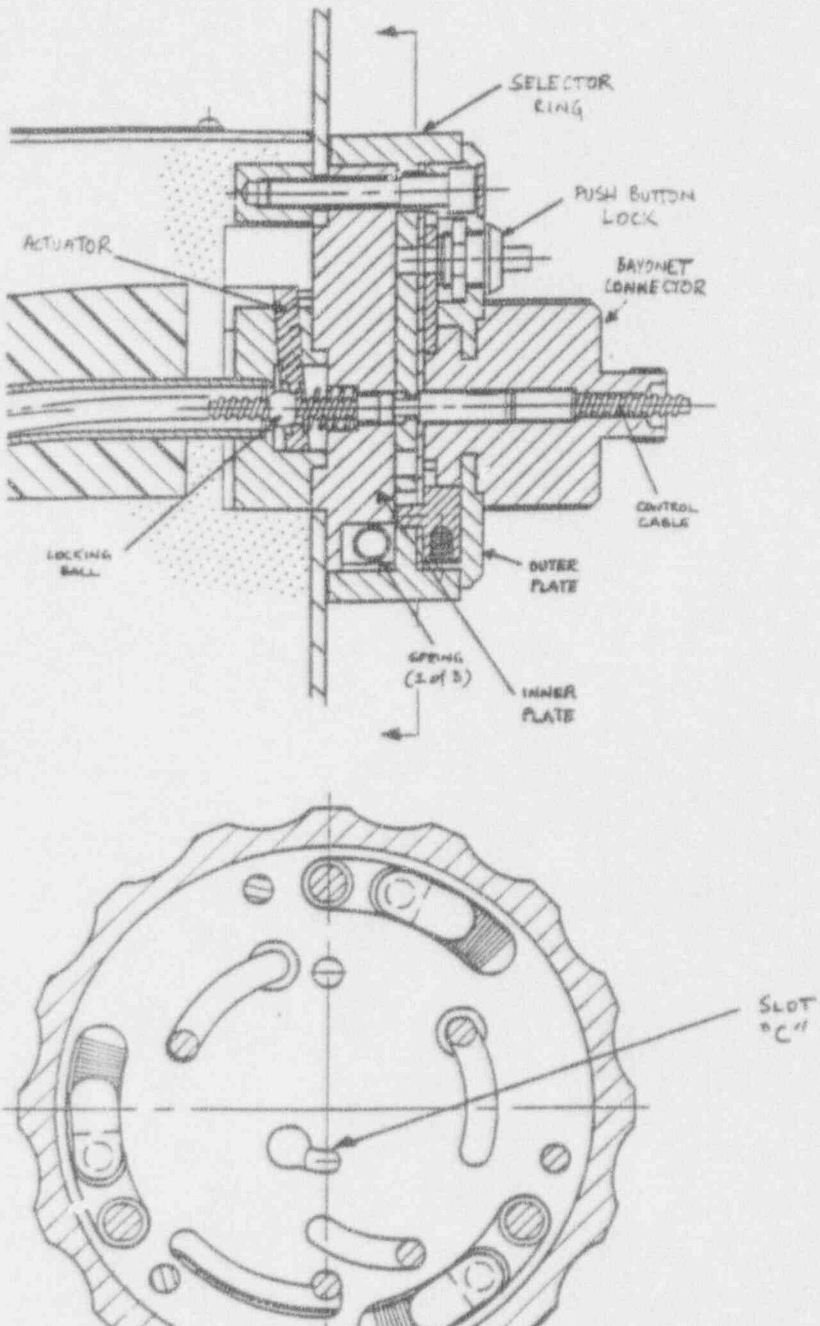
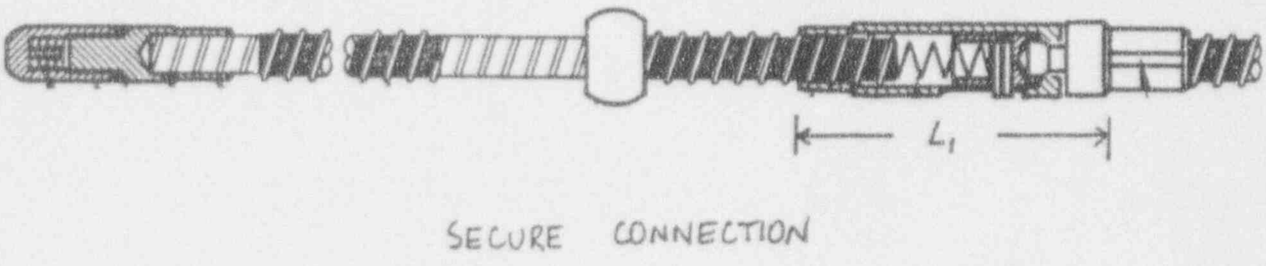


Figure A2.4 Section Through the Lock Assembly



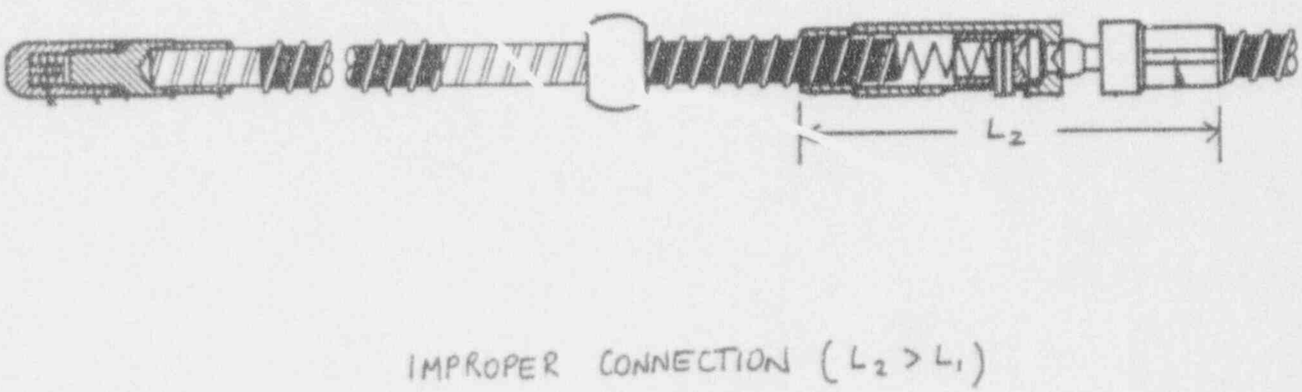


Figure A2.5 Connecting the Control Cable to the C-990

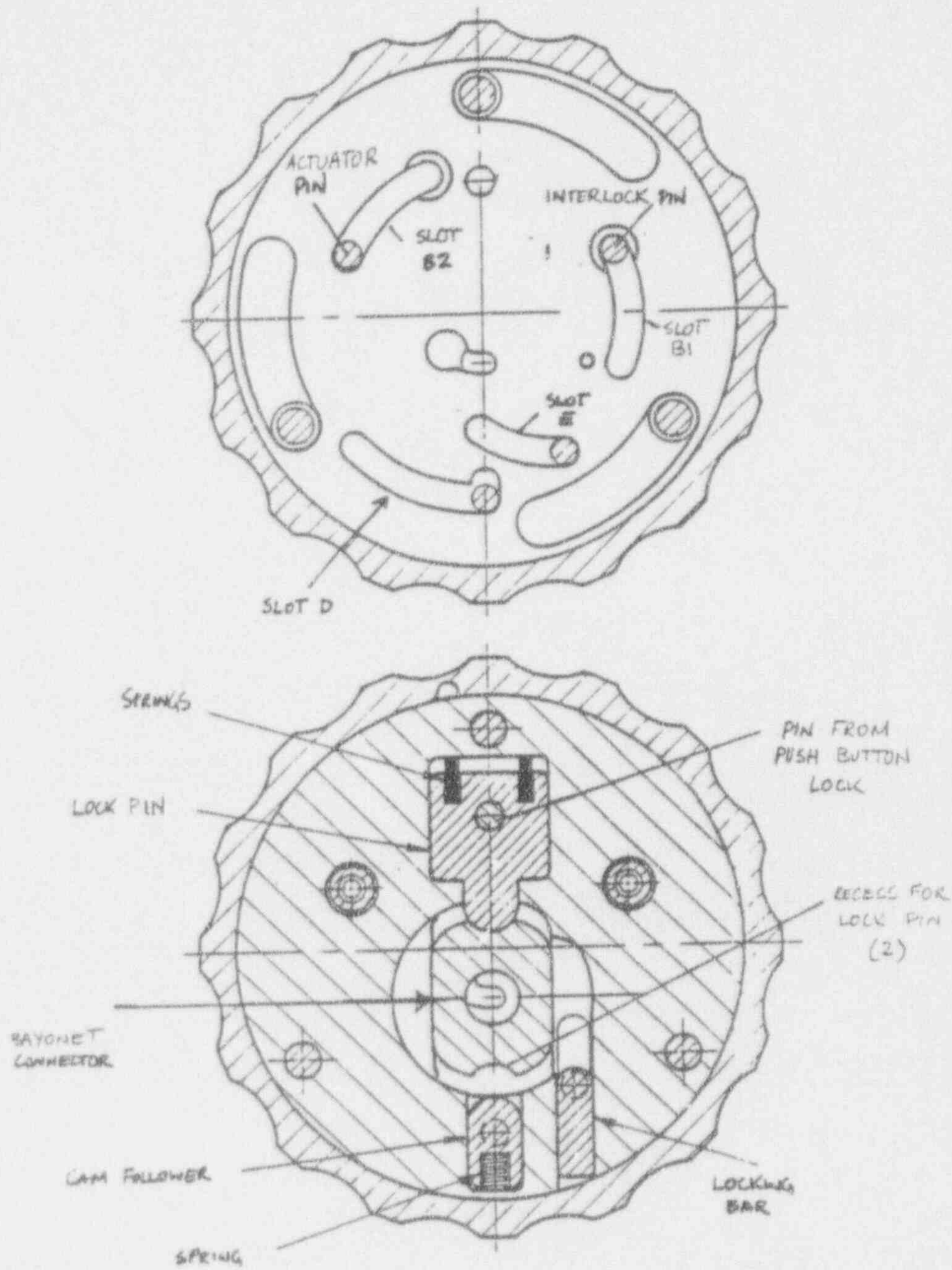


Figure A2.6 Lock Assembly Details

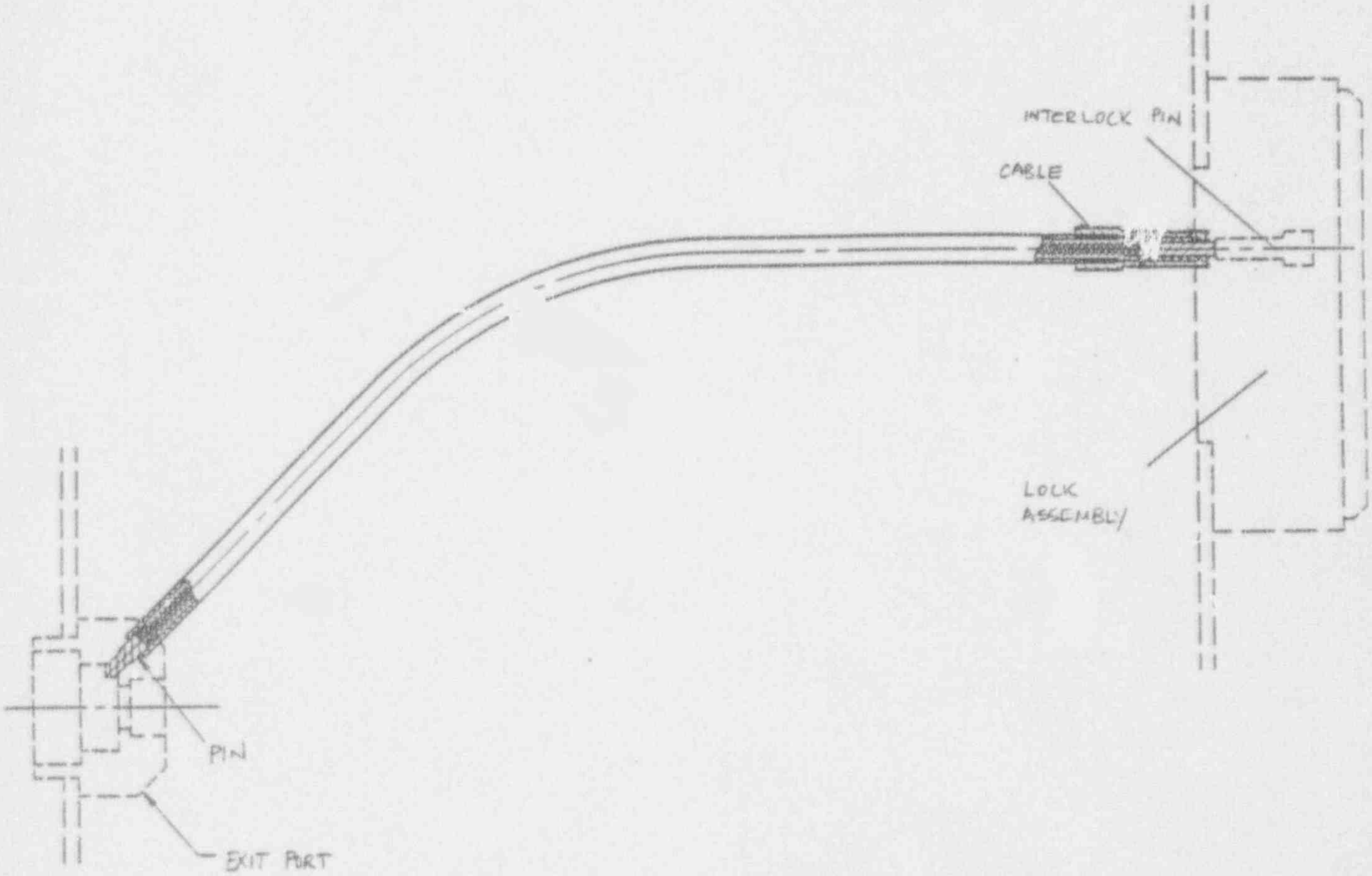
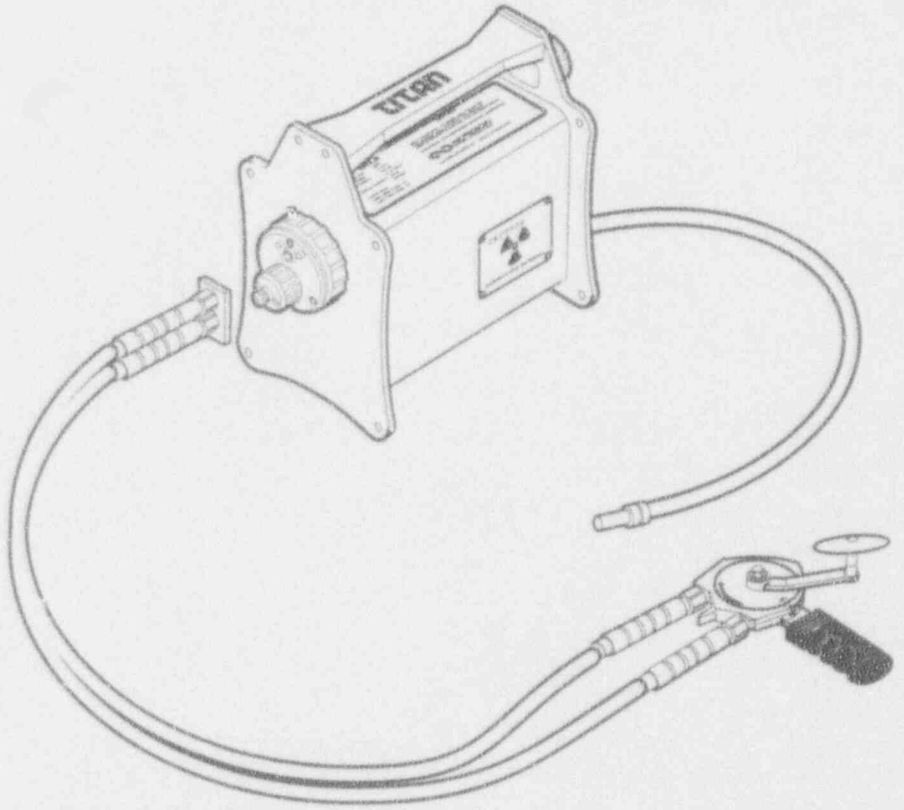


Figure A2.7 Projection Sheath Interlock

APPENDIX 3 IS/OM 0090 N990 rev B

TITAN™

Gamma Ray Projector User's Manual



TITAN™

User's Manual

IS/OM 0090 N990 (Rev B)
October 1993

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Chapter One

Introduction

1-1 GENERAL

The Nordion **TITAN** is a Gamma Ray Projector built to handle the most demanding industrial radiography applications. Designed to fit pipes more securely, the **TITAN** is rugged, reliable, easy to handle and can stand up to the toughest working conditions. The Nordion C-990 is the Source Assembly used for **TITAN** radiographic exposures.

1-2 REGULATORY REQUIREMENTS

The operation of this radiographic product is subject to regulations. Please check with your national and local authorities.

1-2-1 Packaging

This product meets USNRC, USDOT, AECB and IAEA regulations for Type B(U) packages. No overpack is required.

1-2-2 Source Assembly (C-990)

Nordion C-990 source capsules meet IAEA requirements for Special Form radioactive material (AECB Certificate No. CDN/0001/S). Replacement sources are normally shipped to a licensed user in a Source Changer.

1-2-3 Source Changer

Source Changers must conform to IAEA Type B(U) requirements. See Chapter Six —*Source Changer*.

1-3 OPERATOR'S RESPONSIBILITIES

The **TITAN** and its peripheral equipment have been designed in accordance with various international standards and regulations. Full compliance with these standards requires operator cooperation.

Operator's responsibilities include:

a) Obtaining and obeying local and national regulations. The TITAN must be operated by trained and licensed personnel. Records of training must be maintained by the user.

b) Using safe practices and operating the unit in accordance with this manual. You must read and fully understand this manual before operating the TITAN.

c) Inspecting and maintaining the unit according to this manual. Modifications to the unit or its peripheral equipment are not permitted. See Chapter Five - *Maintenance.*

d) Maintaining inspection and maintenance records.

e) Attaching an owner's label and a current source identification label. Source serial numbers and TITAN serial numbers should be tracked.

f) Locking and safely storing the unit when it is not in use.

g) Safely securing the unit in transport away from the public and photographic materials. Transportation of the unit must be in accordance with this manual and local/national regulations. See Chapter Four- *Transportation and Storage.*

h) Keeping emergency procedures and shipping papers in accessible and readily visible areas in the transport vehicle.

i) Reporting incidents and accidents to the local competent authority.

Chapter Two

Description

2-1 GENERAL

Described as the "light heavyweight", the Nordion TITAN has an optimized shield design within a lightweight titanium case. The TITAN projector is curved to fit pipes more securely and its broad base provides greater stability. See Figure 2-1—*Main Components of the Nordion TITAN.*

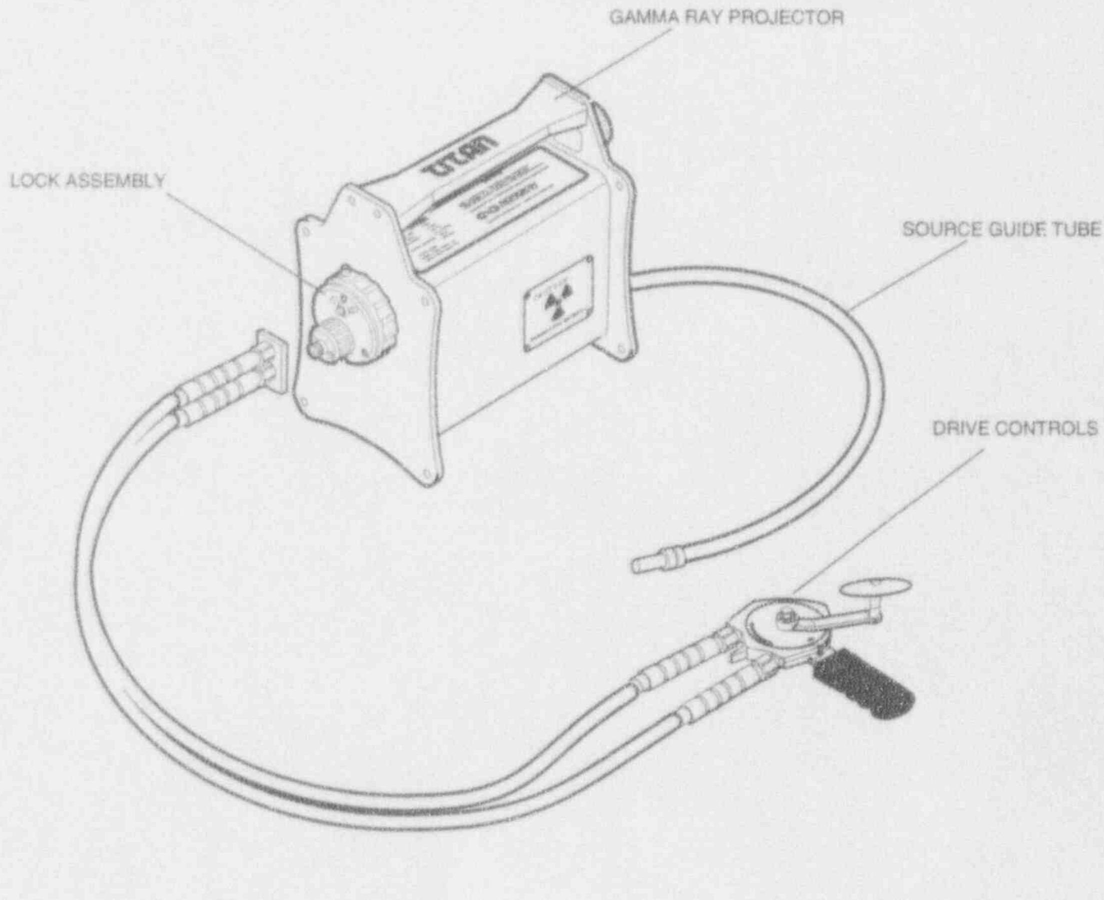

Figure 2-1
Main Components of the Nordion TITAN

2-2 SPECIFICATIONS

Isotope:	—	Ir-192
Half-Life:	—	73.8 days
Capacity:	—	120 Ci (4.44 TBq)
Shielding:	—	30 lbs. (13.5 kg) depleted uranium metal
Projector:	—	All titanium Length: 12.0 in. (305 mm) Width: 6.75 in. (171 mm) Height: 10.13 in. (257 mm) Weight: 44.0 lbs. (20 kg) including shielding
Pistol Grip Control:	—	Weight: 3.85 lbs. (1.75 kg)
Source Guide Tube:	—	Length: 7.0 to 21.0 ft. (2.1 m to 6.4 m) Weight: 1.4 lbs. to 4.4 lbs. (0.65 kg to 2.0 kg)
Drive Controls	—	Length: 25 ft. (7.6 m) Weight: 14 lbs. (6.4 kg) including Teleflex Cable (manufactured by Teleflex Inc.), Cable Sheath, and Bayonet Connector
Operating Specifications:	—	Standard Cable Sheath length on Drive Controls is 25 ft. (7.6 m) Standard source can travel up to 21 ft. (6.4 m)

2-3 PERIPHERAL COMPONENTS

2-3-1 Drive Controls

The Drive Controls include a steel Teleflex Cable which is projected by a Pistol Grip Control. A male connector on the Teleflex Cable attaches to the female connector on the Source Assembly and moves within a flexible teflon lined Cable Sheath covered in yellow PVC.

A radiographic source within the TITAN is connected to the Teleflex Cable and a Cable Sheath is fitted to the Lock Assembly. When turned in a counter clockwise direction, the Pistol Grip Control transfers the source out of the projector and through the Cable Sheath to the exposure position. A clockwise rotation retracts the source back into the projector. The TITAN recognizes the return of the Source Assembly, and automatically secures the source in the stored (shielded) position.

2-3-2 Source Guide Tube

The Source Guide Tube includes a protective yellow PVC cover. It consists of up to three 7 ft. (2.1 m) lengths. Two lengths of the Intermediate Section connected together with a Terminating Section provide a total length of 21 ft. (6.4 m).

The Terminating Section has a Source Stop and must always be used to positively locate the source. The Source Stop avoids accidental ejection and also prevents debris from jamming the source in an exposed position. See Figure 2-1—*Main Components of the Nordion TITAN.*

2-3-3 Source Assembly (C-990)

The **TITAN** is designed to operate with a Nordion C-990 source. Iridium 192 is sealed within the source capsule and crimped to a short length of Teleflex Cable. The opposite end of the Source Assembly has a connector for positive attachment to the Drive Controls. See Figure 2-2—*Source Assembly (C-990).*

The Source Assembly meets IAEA requirements for Special Form radioactive material (AECB Certificate CDN/0001/S).

Figure 2-2
Source Assembly (C-990)

2-4 DEFINITIONS

This section defines components and terms that appear in this guide. The component names or terms, **shown in bold**, are followed by alternate names within **[square brackets]**. All Component Names are capitalized throughout the main body of the text. See Figure 2-1 —*Main Components of the Nordion TITAN* and Figure 3-1 —*TITAN Cross-section.*

Actuator Pin:—A mechanical component inside the Selector Ring that holds the Selector Ring in the 'OPERATE' position.

Bayonet End Cap: —Plugs the Entry Port when the Drive Controls are not connected to the Gamma Ray Projector.

Cable Sheath: —A flexible stainless steel casing with a protective bright yellow PVC cover that is used in the Source Guide Tube and in the Drive Controls.

Collimator: [beam limiter] —A device used to limit the size, shape, and direction of the primary radiation beam. It is attached to the Source Stop.

Drive Controls: [controls, drive cable, control cable] —A manual device attached to the Gamma Ray Projector that enables the Source Assembly to be exposed or retracted. It consists of the following:

a) **Teleflex Cable** - 50 ft. (15.2 m) long and housed within the Cable Sheath.

b) **Cable Sheath** - two 25 ft. (7.6 m) lengths.

c) **Bayonet Connector** - affixed to the Cable Sheath, it is attached to the the Projector using a push and twist motion.

d) **Pistol Grip Control** - a manual remote control device attached to the opposite end of the Cable Sheath used to project and retract the Source Assembly to perform an exposure.

Entry Port: —Where the Drive Controls are connected to the Gamma Ray Projector.

Exit Port: —Where the Source Guide Tube is connected to the Gamma Ray Projector and where the source is projected from the exposure device.

Gamma Radiography System: —All components necessary to make radiographic exposures, including the Gamma Ray Projector, Source Assembly, Drive Controls, and other components associated with positioning the source such as the Source Guide Tube, Source Stop, and Collimators.

Gamma Ray Projector: [exposure device, gamma ray exposure device (GRED), projector] —A shielded device that permits the controlled projection of a sealed source for the purposes of radiography.

Interlock:—The Interlock is a mechanical connection between the Exit Port and the Selector Ring. This feature of the **TITAN** requires connecting the Source Guide Tube to the projector before the Selector Ring can be turned to the 'OPERATE' position. See Figure 3-1—*TITAN Cross-section*.

Lock Assembly:—An assembly consisting of the Selector Ring, an inner plate assembly and an outer plate assembly. See Figure 5-1—*Exploded View of Lock Assembly*. The Lock Assembly secures the Source Assembly when in the "store" position.

Locking Pin:—A small pin on the side of the Source End Connector that is used to push down the Source Assembly's spring loaded locking collar to permit connection of the female Source Assembly Connector to the male Teleflex Cable connector.

Push Button Lock: [lock] —A lock that, when engaged, prevents the rotation of the Selector Ring.

Radiation Safety Officer:—The person selected to be responsible for radiation safety in an organization. Also called by other names such as "Radiation Protection Officer" and "Radiation Safety Manager."

Selector Ring: —Two-positions: 'LOCK' and 'OPERATE'. While in the 'LOCK' position, the source is secured in the shielded position within the projector. When in the 'OPERATE' position the source may be projected from the shield.

Source Assembly: [pigtail, source] —A component that includes a small capsule containing iridium 192, and a connector that attaches to the drive cable. The connector and capsule are crimped onto a short length of cable.

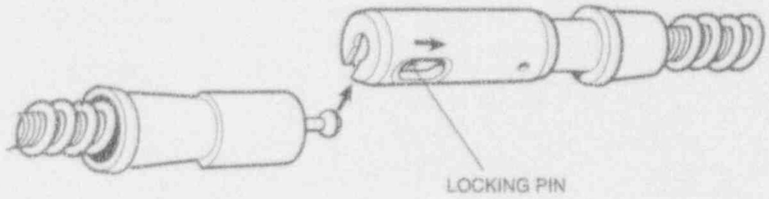

Figure 2-3
Source End Connector

Source Changer: —Used to transport new sources to the customers and return old sources to Nordion.

Source End Connector:—The female connector at the end of the Source Assembly that mates with the male connector on the Teleflex Cable (See Locking Pin). Refer to Figure 2-3—*Source End Connector*.

Source Guide Tube: [projection sheath] —A flexible tube for guiding the sealed source from the Gamma Ray Projector to the Source Stop. It may be up to 21 feet long consisting of the following sections:

a) **Terminating Section:** (7 ft. long) - section to which the Source Stop is attached.
b) **Intermediate Section:** (7 ft. long) - used between the TITAN and the terminating section.

Source Guide Tube End Cap: —Plugs the Exit Port when the Source Guide Tube is not connected to the Gamma Ray Projector.

Source Stop: [end stop, exposure head] —Locates the sealed source at the desired focal position. It is attached permanently to the Terminating Section of the Source Guide Tube.

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Chapter Three

Operation

3-1 GENERAL

The portability and light weight of the TITAN makes operation easy. Nordion's Gamma Ray Projector is shielded and self-contained. This unit uses a C-990 source for the radiographic inspection of steel and light alloy sections.

The TITAN 's titanium case contains a radiation shield of depleted uranium. Through computer analysis all excess weight has been removed to form a fully optimized radiation shield.

3-1-1 Component Overview

The TITAN , as shown in Figure 3-1—*TITAN Cross-section,* consists of the following:

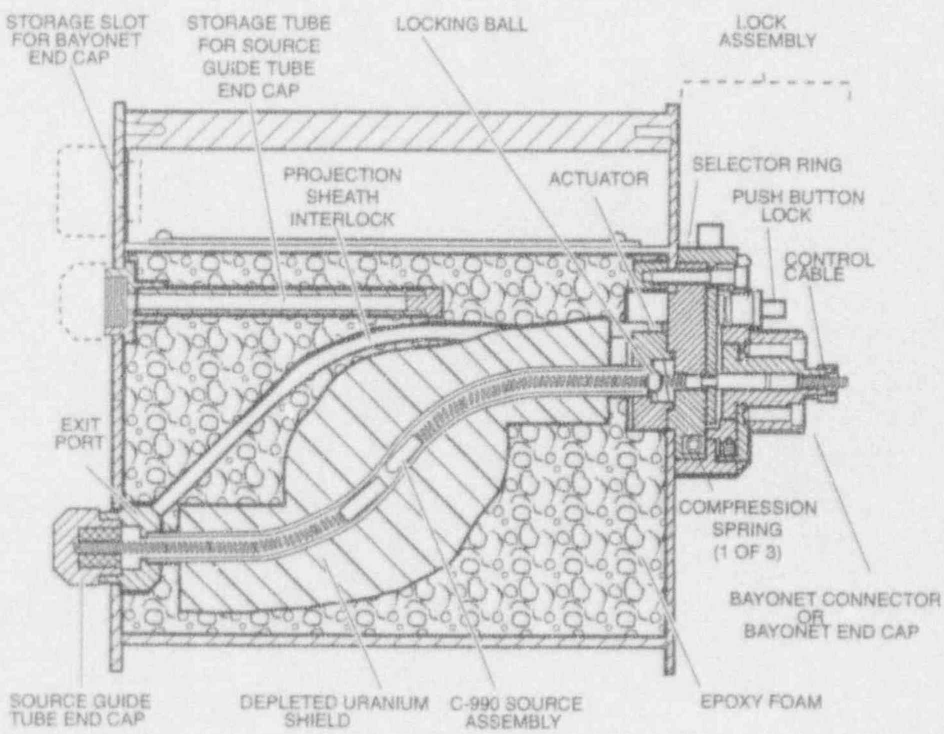

Figure 3-1
TITAN Cross-section

- an S-tube, cast within a depleted uranium shield,
- a Lock Assembly, including the Selector Ring
- a Push Button Lock
- a C-990 sealed Source Assembly,
- a port for the attachment of a Source Guide Tube,
- a port for the attachment of a Drive Control.

Entry & Exit Ports—The Entry Port and Exit Port at either end of the S-tube are sealed using end caps. A Bayonet Connector attaches the Drive Controls at the Entry Port and a threaded connector fastens the Source Guide Tube at the Exit Port.

End Caps—Each Port has a mating End Cap that is stored on the case when the unit is in use.

3-2 OPERATING PRINCIPLES

3-2-1 Overview

At the start of an exposure cycle, the C-990 is secured in the centre of the S-tube, the Selector Ring is in the 'LOCK' position, the Bayonet and Source Guide Tube End Caps are installed, and the Push Button Lock is pushed in with its key removed. This is termed "Transportation Mode" and in this configuration all requirements for the transport of radioactive materials are satisfied.

In Transportation Mode, it is impossible to remove the Bayonet End Cap. It is also impossible to turn the Selector Ring into the 'OPERATE' position.

To perform an exposure, the radiographer unlocks the Push Button Lock. This allows the Bayonet End Cap to be removed from the Selector Ring and allows access to the C-990 Source End Connector. The Teleflex Cable is then connected to the C-990 Source Assembly, and the Drive Controls are attached to the Lock Assembly. At this point, the Teleflex Cable and the Source Assembly are fully connected. However, the Interlock prevents the Selector Ring from moving into the 'OPERATE' position. The Source Guide Tube End Cap is then removed. Attaching the Source Guide Tube releases the Interlock and allows the Selector Ring to be turned counterclockwise into the 'OPERATE' position. The motion is resisted by springs that bias the Selector Ring toward its 'LOCK' position. Once the Selector Ring has been rotated into the 'OPERATE' position, an Actuator Pin prevents the spring from returning the Selector Ring to 'LOCK.

In the 'OPERATE' position, the Source Assembly is free to exit from the shield. The radiographer then uses the Drive Controls to project the source to the exposure site.

Once the exposure has been completed, the C-990 Source Assembly is retracted into the shield. As it approaches the 'LOCK' position, its locking ball engages an actuator. The Actuator Pin becomes disengaged and allows the Selector Ring to spring back into the 'LOCK' position. This action automatically secures the Source Assembly in the depleted uranium shield.

If additional exposures are planned, the Selector Ring is turned back to the 'OPERATE' position and the cycle repeats. Otherwise, the Drive Controls and Source Guide Tube are removed from the unit, the appropriate End Caps are fastened to the Entry and Exit Ports, and the Push Button Lock is pressed in. This returns the unit to Transportation Mode.

The safety features built into the **TITAN** require that to expose the source, you must:

- unlock the Push Button Lock
- securely connect the Teleflex Cable to the Source End Connector
- attach the Source Guide Tube(s),
- attach the Drive Controls,
- turn the Selector Ring to the 'OPERATE' position.

3-3 SITE SAFETY PRECAUTIONS

Only perform radiography in a restricted area where boundaries are clearly defined. Place appropriate radiation warning signs and physically secure the area against unauthorized entry. The radioactive source emits high levels of radiation and therefore it is a good practice to operate the system from as great a distance as possible.

Operation Distance Calculation —To calculate the minimum distance for operation, use the inverse square law: that is, double the distance results in quarter the level of radiation.

3-3-1 Personnel Precautions

> **WARNING:** All personnel shall wear a Thermal Luminescent Dosimeter (TLD) and shall carry a radiation survey meter capable of measuring dose rates of 0.02 mSv/h (2 mrem/h) to 100 mSv/h (10 rem/h) .

In some countries, including Canada and the United States, regulations require a direct reading dosimeter to be worn in addition to the TLD. Some countries also recommend an audible "beeper" pocket alarm. Check with your local authorities.

> CAUTION: Food and drink should not be permitted in the vicinity during the operation of the projector.

3-4 OPERATING PROCEDURES

3-4-1 Inspection

A daily inspection and the required maintenance procedures must be completed prior to using the **TITAN** . Refer to Chapter Five.

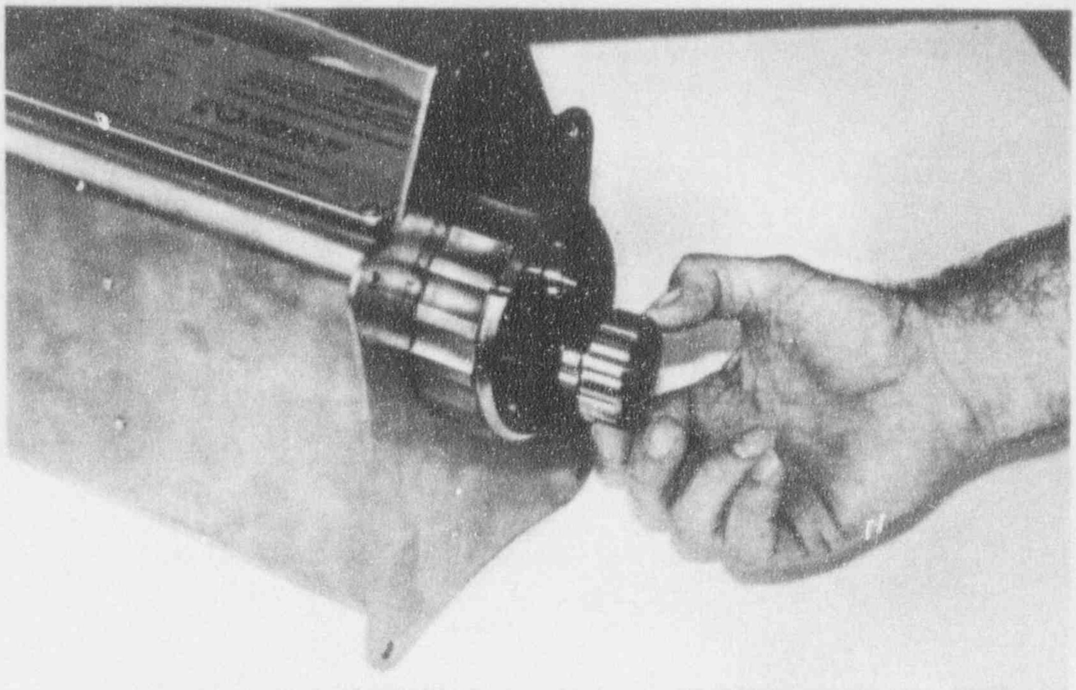

Figure 3-2

Removing the Bayonet End Cap

> **WARNING**: Proper operating procedures and regular inspection and maintenance will ensure that the TITAN operates safely.

3-4-2 Source Guide Tube Layout

1. Secure the Source Stop of the Terminating Section at the radiographic focal position. Use of a collimator is recommended.
2. Determine the position of the TITAN and lay out the Source Guide Tube as straight as possible. Avoid bend radii less than about half a meter (20 inches) to prevent restricting the source movements. Do not connect the Source Guide Tube to the TITAN at this stage.

> CAUTION: Ensure that the Source Guide Tube does not contact any surface at a temperature greater than 60°C (140°F).

> CAUTION: Position the projector and peripherals in a manner that minimizes the risk of accidental damage caused by crushing or by falling objects (vehicles or closing doors).

> **WARNING:** Ensure that the "available length" of the Teleflex Cable on the Drive Controls is greater than the total length of the Source Guide Tube. If the Teleflex Cable is shorter than the Source Guide Tube, the source cannot be projected all the way to the Source Stop and correctly placed for exposure.

3-4-3 Connecting The Drive Controls

3. Unlock the Push Button Lock with the key.
4. Turn the Bayonet End Cap counterclockwise to remove it. See Figure 3-2—*Removing the Bayonet End Cap.*
5. Secure the Bayonet End Cap in its storage position on the front of the TITAN just below the handle.
6. Crank the Pistol Grip Control and expose the male portion of the Teleflex Cable (the ball-end of the cable).
7. Locate the TITAN 's Source End Connector and press back the spring-loaded Locking Pin with a thumb nail. See Figure 3-3—*Engaging the Source End Connector.*
8. Engage the male and female portions of the swivel coupling. Ensure that the spring loaded Locking Pin returns to its original position and the connection is secure.
9. Insert the Bayonet Connector and rotate it clockwise 90 degrees. The Drive Controls are now coupled to the projector. It should engage freely. If any force is required, then a correct connection has not been made. See Figure 3-4—*Connecting the Bayonet Connector.*

> **WARNING:** Difficulty in attaching the Bayonet Connector, may indicate that a proper source connection has not been made or that the Selector Ring requires maintenance. Investigate and take appropriate action before proceeding further.

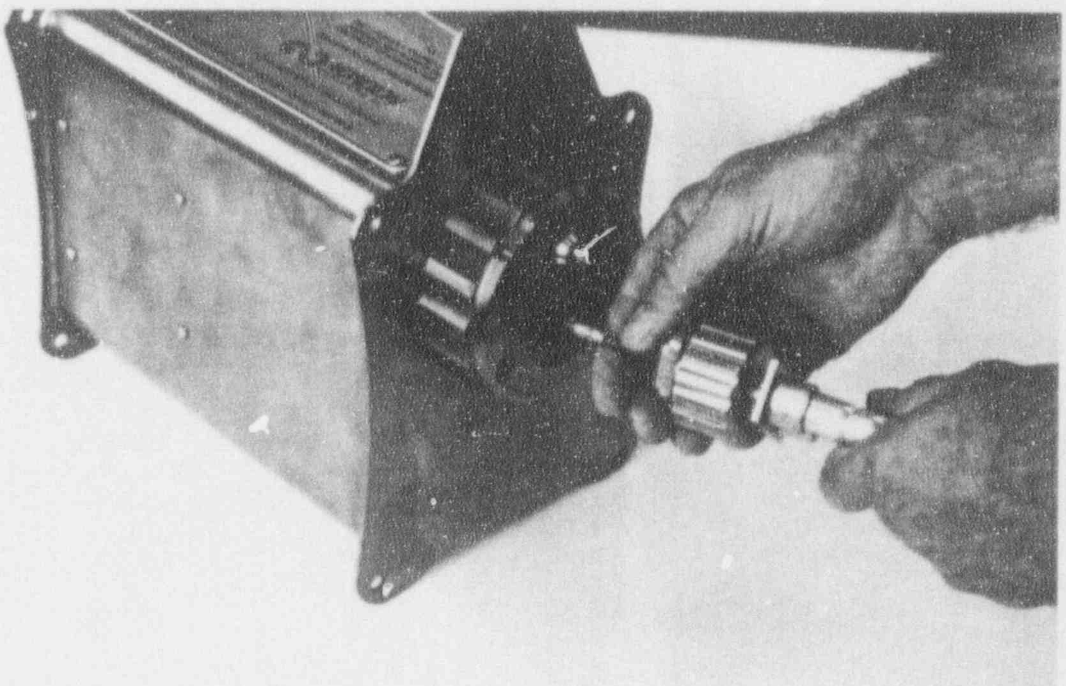

Figure 3-3

Engaging the Source End Connector

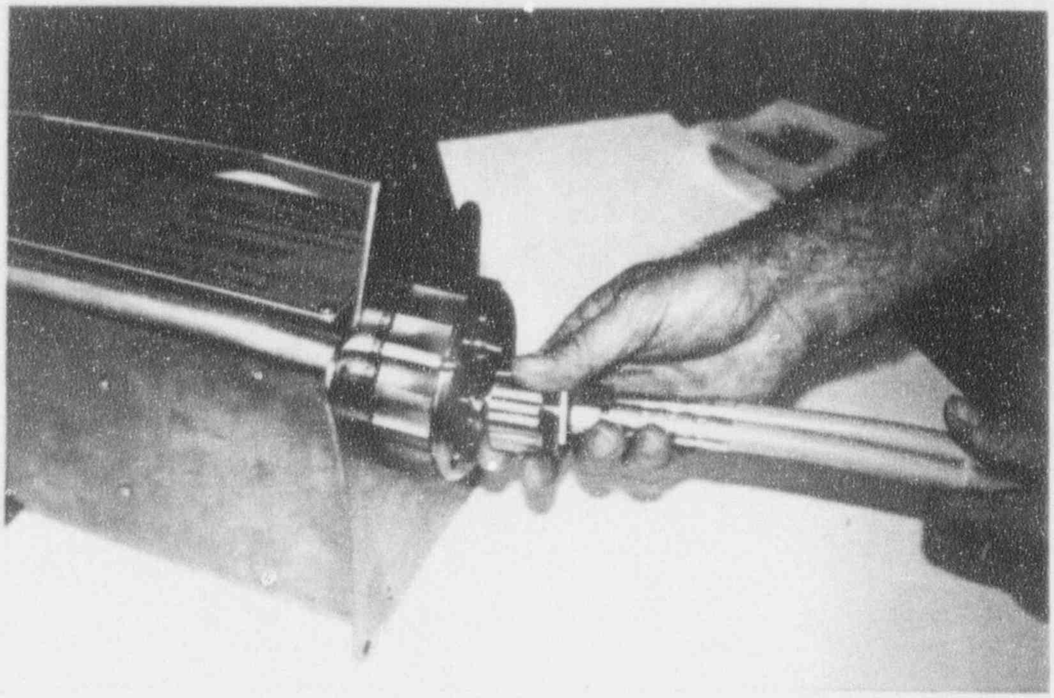

Figure 3-4

Connecting the Bayonet Connector

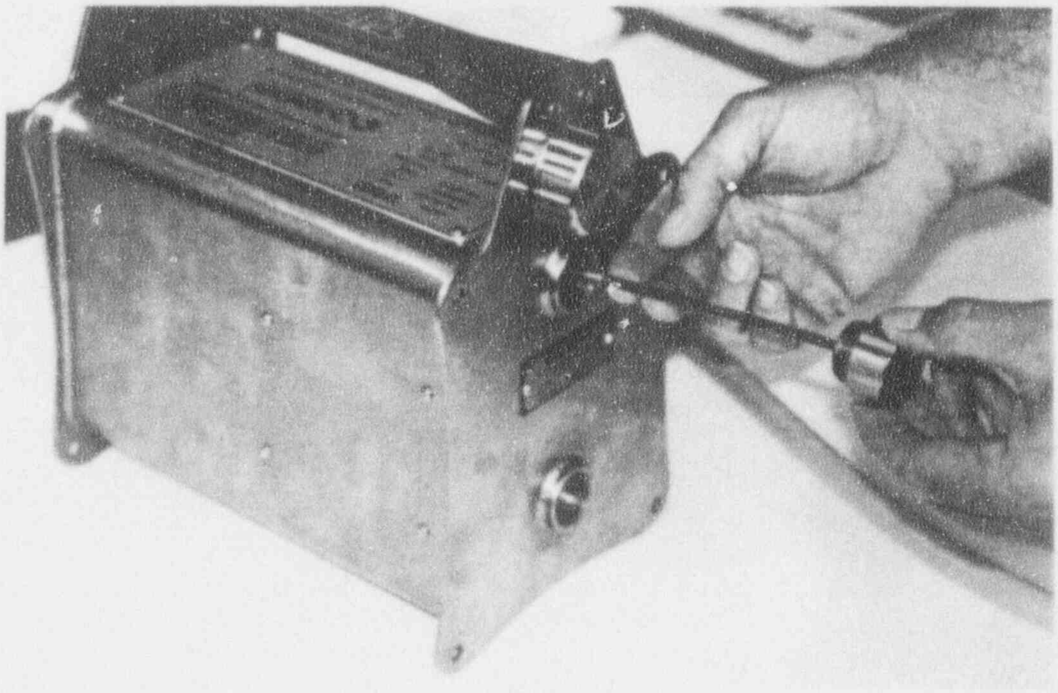

Figure 3-5

Store End Caps on the TITAN

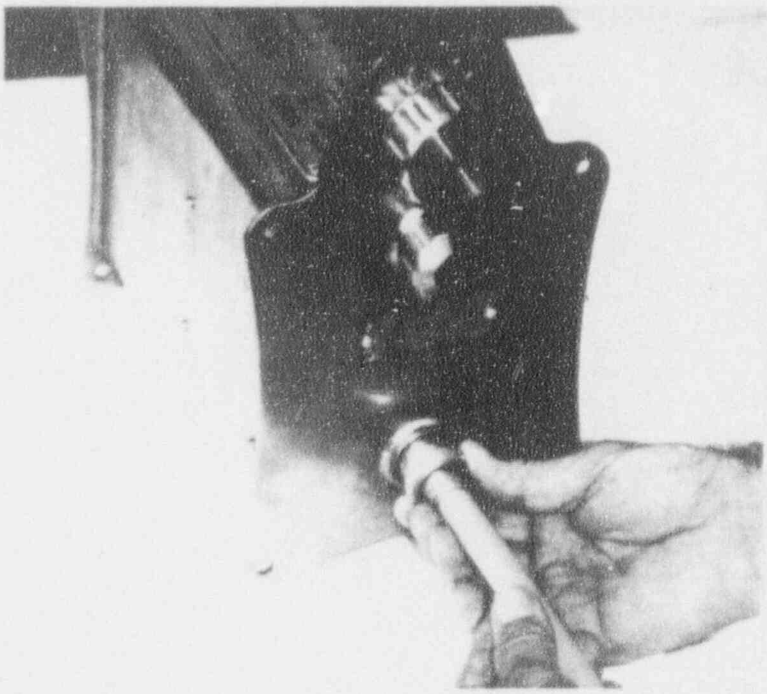

Figure 3-6

Connecting Source Guide Tube

10. Keep the Selector Ring in the 'LOCK' position until you are ready to start the exposure.

3-4-4 Performing a Radiographic Exposure

11. Unfasten the Source Guide Tube End Cap from the projector and install it in the storage receptacle. See Figure 3-5—*Store End Caps on the TITAN.*

> **WARNING:** Once the Source Guide Tube End Cap is removed, higher radiation fields will come out the Exit Port. DO NOT come into the path of the radiation beam emitted from the open Exit Port.

12. Connect the Source Guide Tube securely. See Figure 3-6—*Connecting Source Guide Tube.*
13. Check the surface of the projector with the area radiation survey meter. This is a precaution only to ensure that the meter responds to radiation. Record the radiation levels for later verification that the source is in the shielded position after exposure.
14. Verify that the Intermediate and Terminating Sections are correctly connected.
15. Ensure that no unauthorized personnel are inside the Restricted Area or Exposure Room. Make sure that warning signs are posted.
16. Rotate the Selector Ring counterclockwise to the 'OPERATE' position. When the indicator points to 'LOCK', the Source Assembly is secured in the shielded position. When the Indicator points to 'OPERATE', the Source Assembly is free to travel.

> NOTE: *Excessive tension in the Teleflex Cable (for example, the Pistol Grip Control is snagged) may prevent the Selector Ring from remaining in the 'OPERATE' position.*

17. Position yourself at the Drive Controls and verify that all personnel have left the restricted area.
18. Rapidly rotate the Pistol Grip Control in the 'EXPOSE' direction (counterclockwise) to transfer the source out of the TITAN and into the radiographic focal position. There will be some resistance when the source reaches its stop. DO NOT USE EXCESSIVE FORCE.
19. Set the brake to 'ON', at the Pistol Grip Control, to prevent any movement of the source during exposure.

3-4-5 Exposure

The measured exposure time starts from the moment the source reaches the stop.

Survey meter readings observed during the projection operation will significantly increase from background to a high level as the source leaves the TITAN. Readings will fall as the source moves into the collimator (if used) and remain steady throughout the exposure. Actual survey meter readings will depend on the source activity, distance, collimators, shielding and backscatter (building materials, especially steel, will generate significant amounts of scatter).

20. Observe the readings during the sequence of changes. Use the survey meter to check the boundary dose rate, but spend as little time as possible in the restricted area to minimize personal exposure.
21. At the end of the exposure time, set the brake to 'OFF' and rapidly turn the crank on the Pistol Grip Control in the 'RETRACT' (clockwise) direction until the crank comes to a stop. Check that the Selector Ring has returned to the 'LOCK' position by turning the hand crank counterclockwise. If the Source Assembly cannot be moved, the Selector Ring should be in the 'LOCK' position.
22. Set the brake to 'ON'.

> **WARNING:** Always check radiation fields as you approach the TITAN. This is the primary means of checking that the source is safely stored.

23. Survey the unit. Radiation fields should be the same as they were at the start of the exposure. Pay special attention to the fields at the Exit Port.

> **WARNING:** If the source is still exposed, attempt to store it properly by cranking it a short distance out into the Source Guide Tube and retracting it. If it cannot be stored after a few attempts, treat the situation as an **EMERGENCY**. See 7-2—*Emergency Procedures.*

3-4-6 Preparing for Storage or Transport

The following procedure shall be completed every time the TITAN is to be moved.

24. Unfasten the Source Guide Tube and replace it with the Source Guide Tube End Cap.
25. Replace the plastic caps or fasten both open ends of the Source Guide Tube together to form a closed loop.
26. Remove the Bayonet Connector.
27. Disengage the Source Assembly from the Teleflex Cable.
28. Replace the Bayonet End Cap in the Entry Port.
29. Press in the Push Button Lock.

> **WARNING:** The TITAN should always be locked when not under direct surveillance of a licensed radiographer or assistant.

30. Check the entire surface of the TITAN with a survey meter. When loaded with 120 Ci of Ir-192 in a C-990, the radiation field should not exceed 200 mrem/h on contact with the unit, 50 mrem/h 50 mm (2 inches) from the surface and 2 mrem/h one metre (39.4 inches) from the surface.

> **WARNING**: If the radiation fields exceed the above limits, treat the situation as an **EMERGENCY**. Do not proceed further unless the cause of the high field has been determined and corrected.

31. If the TITAN is to be stored or transported, install a wire seal between the Source Guide Tube End Cap and one of the four holes provided on the front of the unit.

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Chapter Four

Transportation and Storage

4-1 REGULATIONS

Canada—In Canada, the governing regulations are the Transportation of Dangerous Goods (TDG) Regulations and the Transport Packaging of Radioactive Materials Regulations, SOR/83-740, including all amendments.

United States—In the United States, the transport of Radiography Projectors and Source Changers is governed by 10 CFR Part 71, and 49 CFR Parts 171 through 179.

International—IAEA Safety Series No. 6, 1985 Edition (As Amended 1990), guides the transportation of radioactive materials internationally.

4-2 RECEIVING GAMMA PROJECTORS AND SOURCE CHANGERS

When shipping a radioactive package, the consignee must make arrangements for receiving prior to shipment. Upon notification of arrival, the package shall be promptly picked up at the carrier's terminal.

1. Upon receipt of the **TITAN**, measure the radiation fields at the surface of the package and at 1 meter. These should not exceed 2 mSv/h (200 mrem/h) at the surface and 20 μ Sv/h (2 mrem/h) at 1 meter.

   WARNING: If the package has been damaged and the fields exceed these limits, treat the situation as an **EMERGENCY**. Isolate and secure the package in a restricted area. Contact the appropriate authorities and your Radiation Safety Officer. See 7-2—*Emergency Procedures*.

2. Inspect the **TITAN** for damage. Check the condition of the wire seal.

   WARNING: If the package has been tampered with or damaged, contact your Radiation Safety Officer for further instructions. Do not proceed further unless authorized to do so.

3. Record the radiation levels in the receiving report. Enter the isotope (iridium 192), activity, **source model number and serial number**.

4-3 STORAGE/TRANSPORT

When preparing the TITAN for storage or transport, ensure that:

- the Selector Ring is in the 'LOCK' position;
- the Bayonet End Cap is installed and the Push Button Lock is engaged;
- the Source Guide Tube End Cap is installed.

> CAUTION: the End Caps on the TITAN Gamma Ray Projector provide additional radiation shielding. Always install the End Caps when the projector is not in use.

- the plastic dust caps on the Drive Controls and Source Guide Tube fittings are installed.

> NOTE: *The ends of Intermediate Sections of the Source Guide Tube can be threaded together rather than using the dust caps.*

- When not in use for extended periods, store the TITAN Gamma Ray Projector in a dry, clean and secure area. Lock and secure the storage area to prevent unauthorized entry.
- The door to the storage area must have a warning label with the trefoil symbol indicating the presence of radioactive material. The radiation levels at the outside wall of the radioactive materials storage area must be within the limits permitted for the general public.

4-4 SHIPPING

Prior to transport, ensure that the unit has been properly prepared for transport. Refer to section 3-4-6 for additional instructions.

> WARNING: Never ship a unit that has been tampered with or damaged.

The TITAN Gamma Ray Projector is licensed as a Type B(U) transport package and needs no overpack. The level of removable contamination must not exceed 4 Bq (0.0001 μ Ci) per cm^2, averaged over an area of 300 cm^2.

Two completed category labels must be added to opposite sides of the TITAN. The radioactive isotope (^{192}Ir), the activity in bequerels (Bq) or curies (Ci) and the transport index (TI) must be recorded on the label. To determine the transport index, the maximum radiation level in mrem/h is measured at a distance of 1 meter. For example, a package with a maximum field of 17 μ Sv/h (1.7 mrem/h) at 1 meter would have a TI of 1.7.

Guidance on the completion of the category labels can be found in Table 4-1.

Do not cover or remove any of the permanently affixed plates on the device, as this would violate shipping regulations by obscuring important information.

Refer to Figure 4-1—*Radioactive Material Category Labels.*

> WARNING: DO NOT ship the package if the dose rates exceed 2 mSv/h (200 mrem/h) at its surface or 20 μ Sv/h (2 mrem/h) at 1 metre from any surface. If radiation fields exceed these limits, treat the situation as an EMERGENCY. Do not proceed further until the cause of the high radiation field has been determined and corrected.

Table 4-1
Package Label Requirements

Label	Radiation Level at External Surface of Package	Transport Index (T.I.)[1]
RADIOACTIVE I (WHITE)	Not more than 0.005 *mSv / h* (≤ 0.5 *mrem / h*)	0
RADIOACTIVE II (YELLOW)	More than 0.005 *mSv / h* (0.5 *mrem / h*) But not more than 0.5 *mSv / h* (50 *mrem / h*)	More than 0 But not more than 1
RADIOACTIVE III (YELLOW)	More than 0.5 *mSv / h* (50 *mrem / h*) But not more than 2 *mSv / h* (200 *mrem / h*)	More than 1 But not more than 10

[1] T.I. - Radiation level in microsieverts per hour at 1 metre from the external surface of the package divided by 10. (This is equivalent to the radiation level in mrem/h at 1 metre from the external surface of the package.)

Figure 4-1

Radioactive Material Category Labels

The TITAN shall be securely stowed in the transport vehicle and shall not be carried in passenger compartments. Acceptable means of securing the unit include passing straps between the handle and the main body and fastening the straps to dedicated fittings. Use of a securely mounted box or drum is preferred.

A radiation survey must be completed prior to transport.

The TITAN may only be shipped if:

1) Radiation dose rates to occupants are less than 20 µ Sv/h (2 mrem/h)
2) Radiation levels from the external surface of the vehicle are less than 2 mSv/h (200 mrem/h)
3) Radiation levels at 2 metres from any point on the external surface of the vehicle are less than 0.1 mSv/h (10 mrem/h).
4) The sum of transport indexes from all packages on the vehicle is less than 50 if the shipment is not under Exclusive Use. (The sum of the transport indexes must be less than 100 for Exclusive Use shipments.)

> **WARNING:** Transport Regulations do not allow persons other than the driver and assistants to be in vehicles containing packages bearing Category II - Yellow or Category III - Yellow labels.

4-4-1 Preparing Shipping Documents

Prepare the shipping documents and include them with each shipment. The shipping papers must include:

a) The information "RADIOACTIVE MATERIAL, SPECIAL FORM, N.O.S., UN2974".
b) The United Nations Class Number "7".
c) The name and symbol of the radionuclide, "^{192}Ir".
d) The maximum activity of the ^{192}Ir during transport expressed in units of Terabecquerels (TBq) or curies (Ci).
e) The category of the package (i.e. I-white, II-yellow, III-yellow).
f) The Transport Index (TI).
g) USNRC Certificate of Compliance No. USA/XXXX/B(U) and Canadian AECB Approval Certificate No. CDN/1038/B(U)-85 and Special Form Certificate of Approval No. CDN/0001/S.
h) The Shipper's declaration:

   "I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked and labelled, and are in all respects in proper condition for transport by (air, sea, road, and rail) according to the applicable international and national governmental standards."

In the United States use the following declaration:

"This is to certify that the above named materials are properly classified, described, packaged, marked and labelled and are in proper condition for transportation according to the applicable regulations of THE DEPARTMENT OF TRANSPORTATION."

i) The shipper must sign and date the declaration. The declaration and signature must appear on the same page that contains the particulars of consignment listed above.

> **WARNING:** It is the consignor's responsibility to ensure that the TITAN is prepared for shipment in accordance with all pertinent regulations and this manual. It is the carrier's responsibility to placard the transport vehicle in accordance with these same regulations.

4-4-2 Handling

The TITAN is a portable device designed to be carried by one person. When moving the Gamma Ray Projector, remove the Drive Controls and Source Guide Tube, and replace the end caps.

Care must be exercised at all times to minimize radiation exposure. For example, no person should sit on the projector or loiter nearby. Personal dosimeters should be worn at all times. Only trained personnel should handle the equipment.

4-4-3 Placards

Canada

Canadian regulations require placards to be applied to all four sides of the vehicle whenever radioactive materials are shipped. For radioactive Category I or II shipments, non-retroreflective 250 mm × 250 mm placards must be used. For radioactive Category III shipments, the placards must be retroreflective. We recommend that you carry spare placards in case one is lost during transport.

> **WARNING:** Regardless of which placard is used, it must be removed upon entry to the USA and, if necessary, replaced with appropriate placards conforming to USA regulations (see below).

United States

In the United States, vehicles are only placarded when radioactive Category III Shipments are made. The placards are non-retroreflective, and contain the word "RADIOACTIVE." They must be attached to all four sides of the transport vehicle.

Rest of the World

Refer to IAEA Safety Series No. 6, 1985 Edition (As Amended 1990) and applicable national or local standards for placarding requirements for other countries.

4-4-4 Shipping an Empty TITAN

In order to safely transport the TITAN as an empty package, the spent source must be stored within a Source Changer and replaced with a dummy source assembly. In addition, each step of section 3-4-6 and the following must be completed:

1) Check the external surfaces of the TITAN for contamination. The level of removeable contamination must not exceed 4 Bq (0.0001 μ Ci) per cm^2, averaged over an area of 300 cm^2.

2) Perform a radiation survey around the unit.

3) *If the maximum radioactive field on contact is less than 5 μ Sv/h (0.5 mrem/h) and there is no measurable field 1 metre from the package then* label the package with the proper shipping name (Radioactive Material, articles [illegible]anufactured [illegible]om depleted uranium, UN 2909) and with the words:

   "Exempt from specification, packaging, shipping paper and certification, marking and labeling and exempt from the requirements of Parts 171-178 per 49 CFR 173.421-1 and 49 CFR 173.424."

   Include a notice containing the name of the consignee with the shipping documents. The notice should include 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."

4) *If the maximum radiation field on contact exceeds 5 μ Sv/h (0.5 mrem/h) , attach the appropriate radioactive category label (see* [illegible] *4-1).* Label the package with the proper shipping name (Radioactive M[illegible]l, LSA, n.o.s, UN 2912) and complete the shipping papers in accordar[illegible]th section 4-4-1.

Chapter Five

Maintenance

5-1 MAINTENANCE REQUIREMENTS

The TITAN is designed to operate with little maintenance. However, periodic inspections are required to ensure that the equipment is in proper operating condition. These inspections range from simple daily examination to more detailed inspections and procedures to be completed at every source change An annual maintenance procedure must also be completed once per year, or more frequently if the unit has been used under severe operating conditions. A recommended maintenance schedule is provided in Table 5.1.

All inspections should be recorded in a dedicated log book. Any component that fails an inspection shall be repaired or replaced before the unit is returned to service.

> **WARNING:** Inspect all equipment prior to use. Failure to remove damaged equipment from service may result in serious injury or death.

Maintenance shall be completed by trained and qualified personnel. All replacement components shall conform to Nordion Specifications. We recommend maintenance by an authorized service depot. Contact Nordion International Customer Service for the depot nearest you.

5-2 DAILY INSPECTION

The following items must be checked daily to ensure safe operation.

5-2-1 Gamma Ray Projector

a) Check that the unit, the Drive Controls and the Source Guide Tube have completed a quarterly inspection within the last three months and an annual inspection within the past year. If the unit is due for one of these inspections, complete the daily inspection procedure and refer to the appropriate section below.

b) Perform a routine radiation survey around the TITAN projector. The survey should be completed with the Source Guide Tube End Cap and Bayonet End Cap installed. When loaded with 120 Ci of iridium 192 in a C-990, the radiation field on contact with the surface shall not exceed 200 mrem/h on contact, 50 mrem/h 50 mm (2 inches) from the surface, and 2 mrem/h one metre (39.4 inches) from the surface.

> **WARNING**: If radiation fields exceed the above limits, treat the situation as an **EMERGENCY**. Do not proceed further until the cause of the high field has been determined and corrected.

c) Wipe test the external surface of the TITAN. The method used shall be capable of detecting any contamination in excess of 4 Bq/cm^2 (0.0001 µ Ci/cm^2).

> **WARNING:** Any projector contaminated in excess of 4 Bq/cm^2 (0.0001 µ Ci/cm^2) shall be quarantined and the cause of the contamination determined. Contact your Radiation Safety Officer for additional instructions. Do not proceed further unless authorized to do so.

d) Visually examine the external surface of the unit. Verify that all warning and identification labels are legible and securely attached and that there is no damage to the titanium shell.

e) Verify that the Bayonet End Cap cannot be removed from the unit while the Push Button Lock is in its locked position.

f) Check the operation of the Push Button Lock. It should lock and unlock freely.

g) Check that the handle is secure.

h) Check the threads on the end cap storage tube for damage. Clean if necessary.

> NOTE: *The following steps should be completed during your first exposure cycle. Refer to Chapter Three for Operating Procedures.*

i) Remove and examine the Source Guide Tube End Cap. Check the condition of the threads and ensure that the lead insert and teleflex plug are secure within it.

j) Check the operation of the Bayonet Connector. It should freely engage with the Lock Assembly.

k) Check the operation of the Selector Ring. Ensure that it turns freely into the 'OPERATE' position and that it returns to the 'LOCK' position at the end of the first exposure. Difficulty in turning the Selector Ring into the 'OPERATE' position indicates that some obstruction is present. Refer to 5-4 Annual Maintenance.

5-2-2 Drive Controls

a) Examine the Cable Sheaths for cuts, dents and broken or loose fittings. Damage to the stainless steel tube requires the Cable Sheaths be removed from service. Damage to the yellow PVC casing may be repaired using water resistant vinyl tape.

b) Verify that the plastic end caps on the Control Cable and Source Guide Tube are present and in good condition. Replace as necessary.

c) Nordion recommends daily examination of the male connector on the Teleflex Cable using a GO-NO GO gauge. Refer to Nordion Inspection Procedure IS/OP 0046 C000. (See Appendix B.)

d) Check the Pistol Grip Control for damage or loose components. Check the operation of the brake. With the brake in the 'OFF' position, ensure the crank rotates smoothly.

5-2-3 Source Guide Tube

a) Examine the Intermediate and Terminating Sections for cuts, dents and broken or loose fittings. Remove the Source Guide Tubes from service if the stainless steel tubes are damaged. Damage to the yellow PVC casing may be repaired using water resistant vinyl tape.

b) Verify that the plastic end caps are present and in good condition. Replace as necessary.

c) Examine each section of the Source Guide Tube for obstructions. Check the condition of the threads. Clean or repair as necessary.

5-3 QUARTERLY INSPECTION

A quarterly inspection shall be completed at every source change, or once every three months, whichever comes first. It includes a daily inspection plus the following procedures.

> **WARNING:** The following procedures shall only be completed with the C-990 Source Assembly safely stored within a Source Changer. Source transfers should only be completed by trained and licensed personnel.

5-3-1 Source Transfer Procedure

Refer to Chapter Six and your Source Changer's User's Instructions for procedures to safely transfer and store an active Source Assembly. Use a survey meter to check that the Source Assembly has been safely stored.

Once the active Source Assembly is safely stored in the Source Changer, disconnect it from the Teleflex Cable and replace it with a dummy source assembly. (Dummy Source Assemblies can be obtained from Nordion.)

5-3-2 Gamma Ray Projector

a) Retract the dummy source assembly into the **TITAN**. Ve... 'hat the Selector Ring returns to the 'LOCK' position.

b) Disconnect the source transfer hose from the **TITAN**. Test the function of the Interlock. It should NOT be possible to rotate the Selector Ring into the 'OPERATE' position.

c) Install the terminating section of the Source Guide Tube.

d) Remove the Bayonet Connector and disconnect the dummy Source Assembly from the Teleflex Cable. Reinstall the Bayonet End Cap and verify that the Selector Ring CANNOT be turned into the 'OPERATE' position.

e) Remove the Bayonet End Cap. Without connecting the dummy Source Assembly to the Teleflex Cable, try to install the Bayonet Connector. Verify that interference between the unconnected Source Assembly and the male connector prevents the Bayonet Connector from being installed.

> **WARNING:** Do not force the Bayonet Connector into the Lock Assembly as this may damage the male connector.

f) Connect the dummy Source Assembly to the Teleflex Cable and install the Bayonet Connector. Turn the Selector Ring into the 'OPERATE' position. Verify that the Bayonet Connector CANNOT be removed from the Lock Assembly.

g) Perform ten test exposures using the dummy Source Assembly. Verify that the Selector Ring snaps cleanly back into the 'LOCK' position at the end of each exposure cycle.

h) Remove Source Guide Tube and perform a swipe test on the S-tube using a pipe cleaner. The test method used should be able to detect any contamination in excess of 4 Bq/cm^2 (0.0001 μ Ci/cm^2).

> **WARNING:** Any projector contaminated in excess of 4 Bq/cm^2 (0.0001 μ Ci/cm^2) shall be quarantined and the cause of the contamination determined. Contact your Radiation Safety Officer for additional instructions. Do not proceed any further unless authorized to do so.

5-3-3 Source Assembly

Return to the Source Changer and inspect the exposed end of the Source Assembly for wear or other damage. Use a GO-NO GO gauge in accordance with Nordion Procedure IS/OP 0046 C000 (See Appendix B). This test shall be completed on the Source Assembly that will be installed in the **TITAN**.

> **WARNING:** Any Source Assembly failing this test shall not be used. Use of a damaged Source Assembly could result in serious injury or death.

5-3-4 Drive Controls and Source Guide Tube

a) Return the dummy Source Assembly to the TITAN projector and remove the Bayonet Connector.

b) Disconnect the Teleflex Cable from the Source Assembly. Clean and examine the male connector using a GO-NO GO gauge. Refer to Nordion Procedure IS/OP 0046 C000 (Appendix B).

5-4 ANNUAL MAINTENANCE

Annual maintenance shall only be completed by trained personnel and requires the purchase of a TITAN Maintenance Kit. The contents of the kit include an approved lubricant, a thread sealant, nine replacement springs, two spring pins and three replacement cover caps.

> **WARNING:** The following procedure shall only be completed with the C-990 Source Assembly safely stored within a Source Changer. Source transfers shall only be completed by trained and licensed personnel.

5-4-1 Source Transfer Procedure

Refer to Chapter Six and your Source Changer's User's Instructions for procedures to safely transfer and store an active Source Assembly. Check that the source has been properly stored using a survey meter.

Once the active Source Assembly is safely stored in the Source Changer, disconnect it from the Teleflex Cable and replace it with a dummy Source Assembly.

5-4-2 Gamma Ray Projector

Annual inspection consists of the complete breakdown, cleaning and lubrication of the Lock Assembly. It also includes the replacement of several springs within the Lock Assembly.

An exploded view of the Lock Assembly is provided in Figure 5-1. The Lock Assembly has three main components, the Selector Ring, the Outer Plate Subassembly and the Inner Plate Subassembly.

The Outer Plate Subassembly consists of several pins and springs all retained by a Cover Plate. It also includes the Push Button Lock. The Cover Plate is attached using four 0.112(#4)-40 UNC flat head screws.

The Inner Plate Subassembly includes the Actuator Block, the Actuator and the Actuator Spring. These are secured to the Inner Plate by two 0.190(#10)-32 UNF cap screws. There are also three compression springs loosely held within slots in the Inner Plate.

The Selector Ring includes an Actuator Pin and an Interlock Pin. The Actuator Pin is longer than the Interlock Pin and both pins include springs that fit into the Outer Plate

Subassembly. The underside of the Selector Ring includes three nubs that compress springs when the Selector Ring is rotated into the 'OPERATE' position.

> CAUTION: Wear safety glasses during this procedure. Handle all springs with caution as they may fly out of the lock assembly.

a) Use the parts list provided with your maintenance kit to check that you have all the components required to complete the annual maintenance procedure.

b) Retract the dummy Source Assembly into the projector. Verify that the Selector Ring has returned to the 'LOCK' position.

c) Drill out the three screw caps from the Outer Plate of the Lock Assembly. Removing these caps allows access to the three 0.25-20 UNC socket head cap screws that hold the lock assembly to the TITAN.

d) Remove the three socket head cap screws. Remove the complete Lock Assembly. Disassemble it slowly, taking care not to lose any pins or springs.

> NOTE: *It is easier to remove the complete Lock Assembly from the* TITAN *prior to disassembling the Lock Assembly.*

e) Check for cracks or other such damage to the epoxy foam.

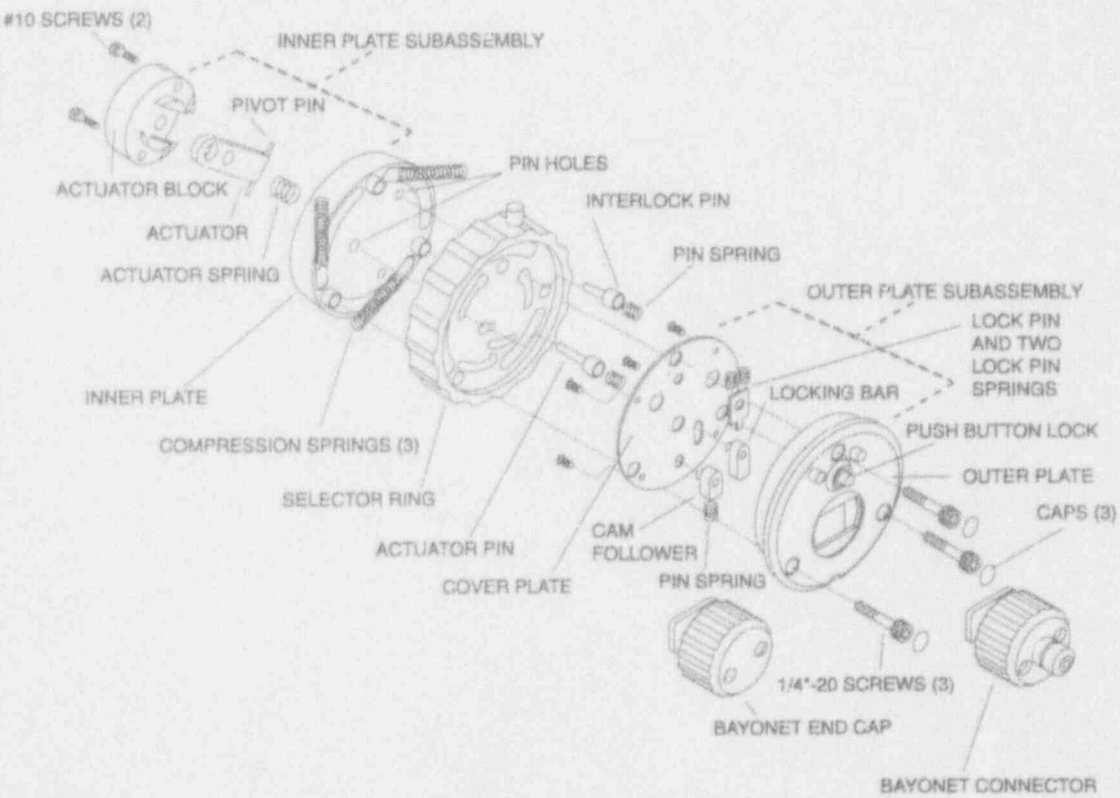

Figure 5-1
Exploded View of Lock Assembly

Inner Plate Subassembly

f) Remove the two screws from the Actuator Block and disassemble it. Clean the Actuator and the Actuator Block. Discard the old Actuator Spring. Check for excessive wear in the Actuator using the dummy Source Assembly. It should be IMPOSSIBLE to pass the locking ball through the Actuator.

g) Clean the Inner Plate.

h) Lubricate the Pivot Pin with Felpro C5A and place the Actuator in the Actuator Block. Ensure that the Spring Counterbore faces the Inner Plate. Install the new Actuator Spring in the Inner Plate. Place the Actuator Block in the register on the Inner Plate, taking care to align the counterbore with the spring. Use the thread sealant provided in the maintenance kit to install the two #10 Cap Screws.

Selector Ring

i) Clean the Selector Ring, the Actuator Pin and Interlock Pin. Check the fit of the pins in their respective slots. They should move freely within the slots and should smoothly engage in their holes. Check for wear around the base of the head of the pins.

j) Check for burrs and sharp edges on the Selector Ring and, if necessary, file them off.

k) Check the condition of the three nubs on the underside of the Selector Ring. Ensure that they are secure within the Selector Ring.

Outer Plate Subassembly

l) Check the operation of the Push Button Lock and replace it if necessary.

m) Remove the four cover plate screws and the cover plate. Use caution as the Cover Plate retains three loaded compression springs.

n) Remove and clean the Locking Bar, Lock Pin and Cam Follower. Clean the Cover Plate and the Outer Plate. Ensure that the slots for the Locking Bar, Lock Pin and and Cam Follower are thoroughly cleaned.

o) Replace the Lock Pin Springs and Cam Follower Spring with the new ones provided in the maintenance kit. Lightly lubricate the pins with Felpro C5A and reinstall them in the Outer Plate. Using the thread sealant provided in the maintenance kit, install the cover plate using the four #4 screws. Ensure that the screws are flush with the surface of the cover plate.

> NOTE: *If the screws protrude from the Cover Plate, they may interfere with the smooth rotation of the Selector Ring.*

p) Lightly lubricate the Inner Plate including the three compression spring slots and the internal surfaces of the Selector Ring. Install new compression springs in the slots of the Inner Plate as shown in Figure 5-1. Leave the free ends of the springs extended from the slots.

> NOTE: *The Selector Ring Parts are precision machined components. Too much grease will cause interference. Use only a very thin film of lubricant.*

q) Align the Pin Slots in the Selector Ring with the Pin Holes in the Inner Plate. Rotate the Selector Ring so that the three nubs engage the exposed compression springs on the Inner Plate. Lower the Selector Ring onto the Inner Plate until the Compression Springs and the Selector Ring snap into position. Verify that the Pin Slots are aligned with the Pin Holes. The Selector Ring should now be in the 'LOCK' position.

r) Rotate the Selector Ring toward the 'OPERATE' position and install the dummy Source Assembly.

s) Lightly lubricate and install the Actuator Pin and the Interlock Pin. The Actuator Pin is longer than the Interlock Pin and goes in the Pin Hole aligned with the end of the Actuator. It should not engage its hole at the end of its slot when the Selector Ring is in the 'LOCK' position. The Interlock Pin should engage in its hole.

t) Install new pin springs in the heads of the Actuator Pin and Interlock Pin.

u) Lightly lubricate the outer diameter and flange of the Outer Plate subassembly and mount it on the Selector Ring. Ensure that the Pin Springs are aligned with the holes in the Outer Plate. If necessary, depress the Locking Bar until the Outer Plate snaps into position.

v) Using a thread sealant, reinstall the Lock Assembly using the three 1/4 - 20 socket head cap screws. Torque each screw evenly to 80-90 in-lbs.

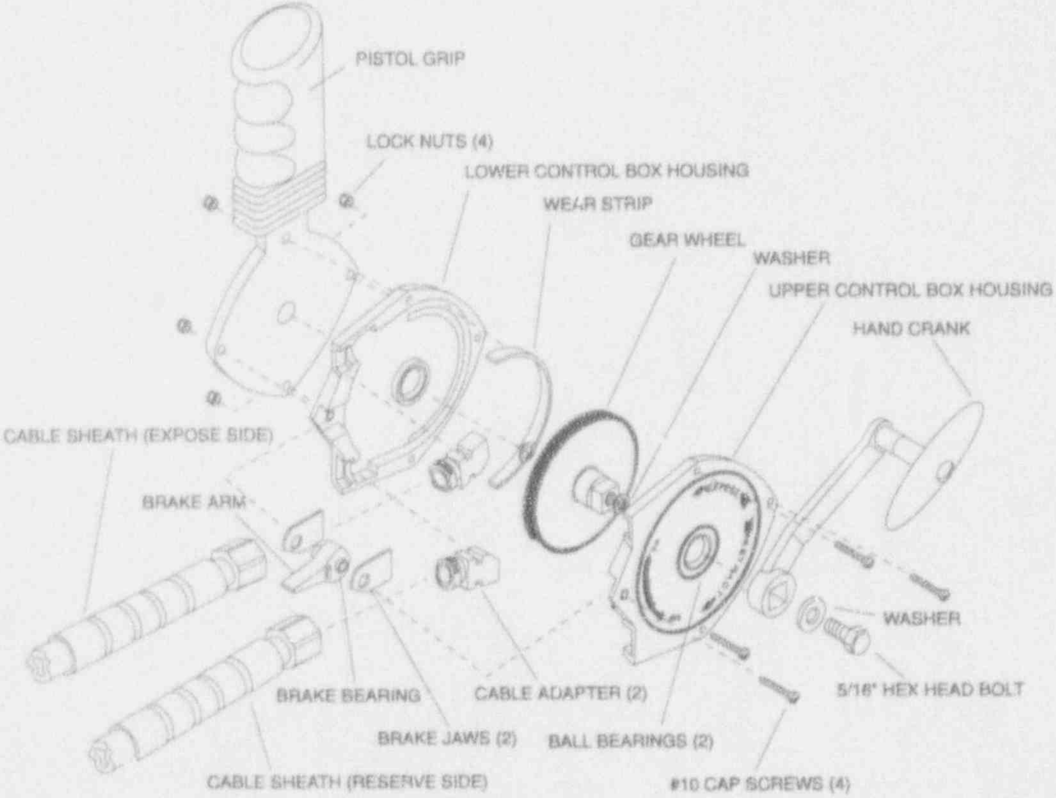

Figure 5-2
Exploded View of Pistol Grip Control

w) Perform a quarterly inspection to verify the function of the reassembled unit and all safety features. Once the quarterly inspection has been successfully completed, install the three Screw Cover Caps using the sealant provided in the maintenance kit.

5-4-3 Drive Controls

Annual inspection of the Drive Controls consists of the complete breakdown, cleaning and lubrication of the Pistol Grip Assembly, the Control Cable Sheaths and the Teleflex Cable.

An exploded view of the Pistol Grip Control is provided in Figure 5-2. Its main components are the Pistol Grip, the Hand Crank, the Control Box Housing, the Gear Wheel, the Brake and the Wear Strip.

a) In a clean area, straighten out the Control Cable Sheath. Pull out and coil the Teleflex Cable until you feel some resistance. This indicates that the Stop Spring has engaged the gear wheel. Do not use excessive force as this may damage the stop spring or the gear wheel.

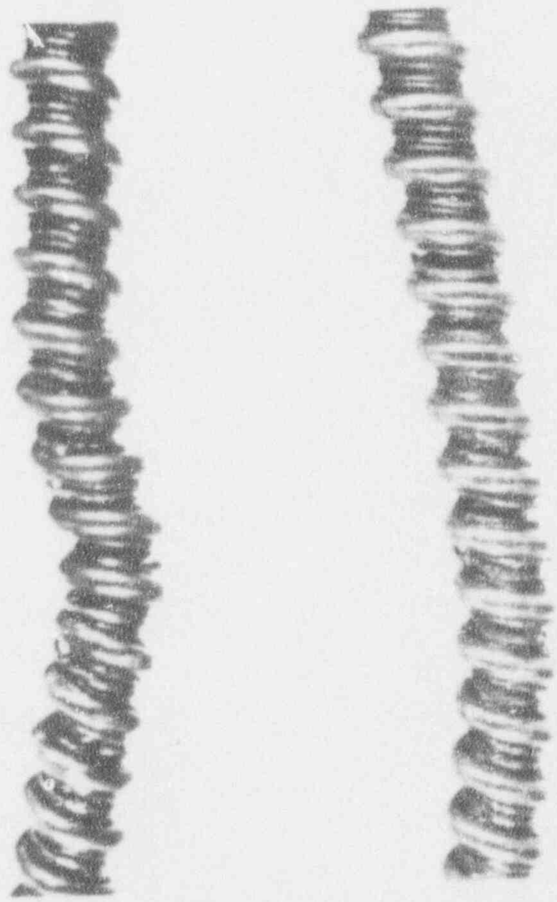

Figure 5-3
Examples of Teleflex Cable Defects

> NOTE: *The Teleflex Cable coil diameter should not be less than 30 cm (12 inches).*

b) Disconnect the Reserve Tube from the Pistol Grip Assembly and remove the Stop Spring. This allows the rest of the Teleflex Cable to be removed from the Pistol Grip Assembly.

c) Examine the Teleflex Cable for kinks and frays. Examples of Teleflex Cable Defects are shown in Figure 5-3. If no damage is observed, clean the drive cables using a brush and a degreaser.

> **WARNING:** Use of damaged Drive Controls increases the risk of a stuck source.

d) Clean the male connector and check that the crimped connection between the male connector and the Teleflex Cable is secure. Examine the male connector using a GO-NO GO gauge. Refer to Nordion Procedure IS/OP 0046 C000 (See Appendix B).

e) Remove the Bayonet Connector from the Control Cable Sheath and check that it swivels freely. Remove the spring pins, clean and lubricate the moving parts with Felpro C5A. Reassemble using the new spring pins provided in the maintenance kit.

f) Label the Cable Sheaths and remove them from the Pistol Grip. (Labels are necessary to replace the Cable Sheaths in the same orientation.)

g) Flush both Cable Sheaths with a solvent degreaser. Blow compressed air through the sheaths until they are dry.

> CAUTION: Perform this operation under well ventilated conditions and in accordance with the degreaser manufacturer's safety procedures.

h) Soak a cloth with solvent degreaser and wipe the external surfaces of the Cable Sheaths while checking for cuts, dents or other such damage. Verify that the Cable Sheaths flex smoothly and easily without crunching. Damage to the stainless steel tube requires that the Cable Sheaths be removed from service. Damage to the outer PVC casing may be repaired using water resistant vinyl tape.

i) Check the area around the Cable Sheath Connectors for damage. Ensure that the Connectors are securely fastened to the Control Cable Sheath.

j) Verify that the Cable Sheaths are 25 ft. (7.6 m) long.

5-4-4 Pistol Grip Control

> CAUTION: Wear safety glasses while performing this procedure. The Pistol Grip Control contains a Wear Strip that may fly out once the Control Box Housing is opened.

a) Remove the 5⁄16 hex head bolt and the washer from the Hand Crank. This allows the Hand Crank to be removed form the Control Box Housing.

b) Remove the four #10 round head cap screws from the Control Box Housing.

c) While holding the Cable Adapters, **SLOWLY** remove the upper Control Box Housing.

d) Remove and clean the Wear Strip.

e) Remove and degrease the Gear Wheel. Check for bent or broken teeth.

> **WARNING:** Damaged Gear Wheels increase the risk of a stuck source. Replace damaged components prior to use.

f) Remove and clean the Cable Adapters.

h) Remove and clean the brake arm, brake jaws and brake bearing.

i) Clean both halves of the Control Box Housing. Check that the ball bearings turn freely.

j) Install one Cable Adapter in the lower Control Box Housing.

k) CAREFULLY place one end of the Wear Strip against the installed Cable Adapter, and fit the Wear Strip in the track provided in the Control Box Housing.

l) Install the other Cable Adapter.

m) Install Gear Wheel Washers on each side of Gear Wheel Shaft, and install the Gear Wheel in the Control Housing. Take care not to contact the Wear Strip as this may cause it to fly out of the track.

n) Replace the brake jaws, brake arm and brake bearing as shown in Figure 5-2.

o) Install the upper Control Box Housing and check that the Gear Wheel spins freely.

p) Reinstall the four #10 cap screws and lock nuts through the pistol grip and Control Box Housing.

q) Replace the Hand Crank and washer using the 5⁄16 hex head bolt.

r) Install the Cable Sheath on the Cable Adapter that fits on the 'EXPOSE' side of the Pistol Grip Assembly. It should be replaced in the same orientation it was in at the start of this procedure. Do not install the Reserve Tube.

s) Replace the Bayonet Connector.

t) Lightly oil the Teleflex Cable, place it into the Cable Sheath and feed it into the Control Box Housing. Turn the crank to expose a short length of the Teleflex Cable on the 'RETRACT' side and reinstall the Stop Spring.

u) Reinstall the Reserve Tube.

v) Replace cable ties as necessary.

5-4-5 Source Guide Tubes

a) Soak a cloth with solvent degreaser and wipe the external surfaces of the Source Guide Tubes while checking for cuts, dents or other such damage. Verify that the Intermediate and Terminating Sections flex smoothly and easily without crunching. Damage to the stainless steel tube requires that the Cable Sheaths be removed from service. Damage to the outer PVC casing may be repaired using water resistant vinyl tape.

b) Check the area around the fittings for damage. Ensure that the fittings are securely fastened to the Intermediate and Terminating Sections. Verify that the threads on the fittings are undamaged.

c) Soak a swab in solvent degreaser and run it through the Source Guide Tube until it emerges clean. Ensure that no foreign material remains in the tubes.

d) Drop a dummy Source Assembly through the Source Guide Tube. It should pass freely through the length of the Source Guide Tube and into the Source Stop.

e) Verify that the Intermediate and Terminating Sections are 7 feet (2.1 metre) long.

TABLE 5-1

TITAN Recommended Maintenance Schedule				
Step	LEGEND: X = Required R = Recommended - = Not Required	Daily	Quarterly (Source Change)	Annual
Gamma Ray Projector				
1	Check due date for quarterly and annual inspection	X	-	-
2	Complete radiation survey	X	X	X
3	Check external surfaces for contamination	X	X	X
4	Check labels and general appearance	X	X	X
5	Check function of Push Button Lock	X	X	X
6	Check that handle is secure	X	X	X
7	Check End Cap Storage Tube	X	X	X
8	Check Condition of Source Guide Tube End Cap	X	X	X
9	Check engagement of Bayonet Connector	X	X	X
10	Check for smooth operation of Selector Ring	X	X	X
11	Verify function of Interlock	-	X	X
12	Verify that Selector Ring cannot be turned into OPERATE with End Cap installed	-	X	X
13	Verify that Selector Ring cannot be turned into OPERATE if Source is misconnected	-	X	X
14	Verify that Bayonet Connector cannot be removed with the Selector Ring in the OPERATE position	-	X	X
15	Perform ten test exposures with dummy Source Assembly	-	X	X
16	Check the S-tube for contamination	-	X	X
17	Check contents of maintenance kit	-	-	X
18	Breakdown, clean, replace springs and reassemble Lock Assembly	-	-	X
Source Guide Tube				
1	Check external surface for damage	X	X	X
2	Check fittings	X	X	X
3	Check condition of plastic end caps	X	X	X
4	Check for obstructions	X	X	X
5	Pass dummy Source Assembly	R	X	X

TITAN Recommended Maintenance Schedule				
Step	LEGEND: X = Required R = Recommended - = Not Required	Daily	Quarterly *(Source Change)*	Annual
6	Verify length	R	R	X
Drive Controls				
1	Check external surface for damage	X	X	X
2	Check condition of plastic end caps	X	X	X
3	Check Pistol Grip Control for damage or loose parts	X	X	X
4	Check swivel on Bayonet Connector	R	X	X
5	Clean, inspect and oil Teleflex Cable	-	R	X
6	Remove and clean Cable Sheaths	-	-	X
7	Check Cable Sheath Connectors	R	R	X
8	Verify Length	-	X	X
9	Breakdown, clean and reassemble Pistol Grip Control	-	-	X
10	Check Gear Wheel for damage	-	-	X

Source Assembly Maintenance Summary		
Item	Frequency	Maintenance
1.	Weekly	CLEAN male and female connectors. LUBRICATE female connector.
2.	Weekly	CHECK functioning of source locking collar
3.	Monthly	INSPECT source and drive cable connectors using the test gauge
4.	As required	VERIFY length of teleflex drive cable
5.	As required	CLEAN radiography equipment
6.	As required	RECORD all maintenance and repairs in the log book

Chapter Six

Source Changer

6-1 GENERAL

This section describes the storage and shipping of radioactive Source Assemblies and is applicable to all gamma radiography sources contained in a Source Changer. Source Changers are used to transport new and depleted sources to and from Nordion and the customer.

WARNING: The C-990 may only be shipped in a licensed Source Changer. Ensure that your changer is licensed for the C-990. If in doubt, contact Nordion International Inc.

6-2 CHANGING A SOURCE

6-2-1 Regulations

Canada—In Canada, the governing regulations are the Transportation of Dangerous Goods (TDG) Regulations and the Transport Packaging of Radioactive Materials Regulations, SOR/83-740, including all amendments.

United States—In the United States, the transport of Radiography Projectors and Source Changers is governed by 10 CFR Part 71, and 49 CFR Parts 171 through 179.

International—IAEA Safety Series No. 6, 1985 Edition (As Amended 1990), guides the transportation of radioactive materials internationally.

6-2-2 Prerequisite for Changing a Source

The user must be trained and qualified to carry out a source change. The operator must carry a TLD, direct reading dosimeter, and alarm. The operator must also use a calibrated area radiation survey meter that is capable of measuring from 0.02 mSv/h (2 mrem/h) to 100 mSv/h (10 rem/h).

6-2-3 Receiving Source Changers

When shipping a radioactive package, the consignee must make arrangements for receiving prior to shipment. Upon notification of arrival, the package shall be promptly picked up at the carrier's terminal.

a) Upon receipt of the Source Changer, measure the radiation fields at the surface of the package and at 1 meter. These should not exceed 2 mSv/h (200 mrem/h) at the surface and 100 μ Sv/h (10 mrem/h) at 1 meter.

> **WARNING:** If the package has been damaged and the radiation fields exceed these limits, treat the situation as an **EMERGENCY**. Isolate and secure the package in a restricted area. Contact the appropriate authorities and your Radiation Safety Officer. See 7-2—*Emergency Procedures.*

b) Inspect the Source Changer for damage. Check the condition of the wire seal.

> **WARNING:** If the package has been tampered with or damaged, contact your Radiation Safety Officer for further instructions. Do not proceed further unless authorized to do so.

c) Record the radiation levels in the receiving report. Enter the isotope (iridium 192), activity, **source model number and serial number**. In addition, **record the model number and serial number** of the Source Changer.

d) Read the User's Instructions that accompany the Source Changer.

6-2-4 Source Changer

Many different models of Source Changers may be used for changing a source. Please refer to the User's Guide that comes with the Source Changer.

6-2-5 Shipping

Refer to your Source Changer's User's Instructions for directions on preparing your Source Changer for transport.

> **WARNING:** Never ship a Source Changer that has been tampered with or damaged. Ensure that your Source Changer is licensed to carry the C-990.

Chapter Seven

Safety

7-1 GENERAL

As an operator, you are required to operate the TITAN in accordance with this manual and local/national regulations. The operating instructions and information presented here are intended only for the use of licensed personnel. Read and fully understand this manual before beginning operations. You are advised to:

- operate the equipment according to the instructions contained herein,
- observe all CAUTIONS and WARNINGS,
- ensure proper maintenance of the equipment,
- ensure that **only** properly instructed personnel are permitted to operate the TITAN .

As an operator of the TITAN , you are required to have the qualifications specified jointly by your Local Regulatory body and Principal Owner Licensee.

7-1-1 Safety Features

The TITAN incorporates an important new safety feature for Gamma Ray Projectors. That is, you cannot release the source from the Gamma Ray Projector unless you have secured both the Source Guide Tube and the Drive Controls. This feature significantly reduces the possibility of an accidental source disconnect through operator error.

7-2 EMERGENCY PROCEDURES

7-2-1 Operating Emergencies

> **WARNING:** DO NOT handle an unshielded source. Sources emit high levels of radiation . Close contact may cause severe injury or death.

In the event of an emergency, STAY CALM and consider the proper course of action. The following steps should be completed before any remedial action is taken:

a) **Immediately move away from the exposed source.**

Increasing the distance between yourself and the radiation source decreases your radiation dose. DO NOT PANIC if you cannot immediately shield the source.

b) **Establish a restricted area.**

Using a survey meter, check the restricted area boundaries and adjust them if necessary. Ensure that no one enters the restricted area. Do not leave the restricted area unattended.

c) **Get Assistance**

Remain in the area until help arrives and someone is able to provide assistance. Arrange to have your Radiation Safety Officer (RSO) contacted.

d) **Wait for Qualified Personnel to Arrive**

Well planned remedial action usually makes it possible to retrieve a source with little operator exposure. Source retrieval should only be performed by specially trained personnel. DO NOT ATTEMPT ANYTHING THAT YOU HAVE NOT BEEN TRAINED TO DO. If necessary, contact Nordion International Inc., at **1-800-267-6211**.

7-2-2 Transport Emergencies

The following emergency procedure does not apply to vehicle malfunctions where it can be readily determined that the radioactive material and the TITAN have not been disturbed.

In the event of a transportation emergency, **do not leave the vehicle unattended**. Arrange for a passing motorist to contact police.

When obtaining assistance in the case of an emergency, the information contained in shipping papers and emergency procedures should enable responsible persons to prepare a timely and effective response. Ensure that this information is kept in a readily accessible and visible area in the transport vehicle.

Transport regulations require carriers, organizations or persons transporting a radioactive material package that is involved in an accident to notify the appropriate authority that an accident has occurred in the area under their jurisdiction. Appendix C contains a list of appropriate agencies.

Accidents

In the event of an accident, the following steps should be taken;

a) Render first aid, if necessary.

b) Perform a radiation survey. Set up a restricted area if the source becomes exposed.

c) Notify the police. DO NOT LEAVE THE PACKAGE UNATTENDED. Arrange for a passing motorist to get help. Indicate if an ambulance is required.

d) Notify your Radiation Safety Officer. DO NOT leave the area without ensuring that the police will keep unauthorized personnel outside the restricted area.

e) Arrange for your Radiation Safety Officer to contact the appropriate regulatory agencies (See Appendix C.)

f) Delay clean up until properly trained personnel arrive.

Fire

In the event of a fire, the following steps should be taken;

a) Render first aid, if necessary.

b) Small fires can be extinguished with dry chemical (CO_2) extinguishers and large fires with foam or water from UPWIND, and at a maximum distance. Fumes should be assumed to be toxic. Large fires should be left to trained firemen.

c) Perform a radiation survey. Set up a restricted area if the source becomes exposed.

d) Notify the police. DO NOT LEAVE THE PACKAGE UNATTENDED. Arrange for a passing motorist to get help. Indicate if an ambulance is required.

e) Notify your Radiation Safety Officer. DO NOT leave the area without ensuring that the police will keep unauthorized personnel outside the restricted area.

f) Arrange for your Radiation Safety Office to contact the appropriate regulatory agencies. (See Appendix C.)

g) Delay clean up until properly trained personnel arrive.

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Chapter Eight

Warranty

8-1 TITAN WARRANTY

Nordion International Inc. makes the following warranties with respect to its products:

I. Sealed Sources: —Sealed sources shall conform to current Nordion specifications and shall be free from any material defect in workmanship or materials at the time of delivery.

II. Equipment: Nordion International Inc.—Gamma Ray Projectors and peripheral equipment will be free from any material defect in workmanship or materials for a period of one (1) year from the date of shipment of product to customer.

III. Parts: —Replacement parts supplied by Nordion shall be free from any material defect in workmanship or materials for a period of thirty (30) days from the date of shipment of product to customer.

Nordion's only obligation with respect to the warranties herein shall be to repair, or at its sole discretion, to replace defective products or parts thereof.

Customer shall return product to a Nordion authorized repair centre for repair or replacement, freight prepaid. Customer shall be responsible for preparing the product for shipment in accordance with local laws and regulations.

Under no circumstances should the customer return product to Nordion International Inc. without obtaining a product return authorization (P.R.A.) number from Nordion.

All warranty obligations of Nordion International Inc. shall cease and have no effect if the products are subjected to accident, abuse, misuse, alteration or neglect.

The warranties contained herein are expressly in lieu of and exclude all other express or implied warranties including, but not limited to, warranties of merchantibility and fitness for a particular purpose, use or application.

8-2 TITAN - INSPECTION AND RETURN OF PRODUCTS

All shipments shall be inspected on receipt by the buyer unless otherwise instructed by Nordion International Inc. Any defects shall be promptly communicated to the shipper and Nordion International Inc. in writing within ten (10) days of receipt of the product. No product shall be returned without a Nordion product return authorization (P.R.A.) number. Products returned shall be at the buyer's sole risk and expense. The buyer shall pay a re-stocking charge in respect of such products.

8-3 LIMITATION OF LIABILITY

Nordion's liability to the buyer for damages, howsoever caused, shall not exceed payment actually received by Nordion International Inc. for the product furnished, or to be furnished, as the case may be, and in no event shall Nordion International Inc. be liable for indirect, contingent, special or consequential damages (including loss of profit).

8-4 INDEMNITY

Customer shall indemnify Nordion for, and save Nordion harmless from, all losses, costs or damages suffered or incurred in respect of damage or destruction of property, personal injury or death which may be caused by or arise from, either wholly or in part, the use of products or customer's negligence, acts or omissions.

Appendix A

Troubleshooting

SYMPTOM	PROBLEM	SOLUTION
Cannot turn Selector Ring to 'OPERATE'.	Key is locked.	UNLOCK key.
	Bayonet Connector is not connected properly.	CHECK first to ensure that Source Assembly is properly connected. CONNECT Bayonet Connector. See 3-4-3 Operation Procedures "Connecting the Drive Controls."
	Source Guide Tube is not connected.	CONNECT Source Guide Tube. See 3-4 Operation Procedures.
Selector Ring does not easily turn to the 'OPERATE' position.	Teleflex Cable is pushing against inner plate in Lock Assembly.	RELIEVE compression by turning Pistol Grip Control crank clockwise.
	Lock is contaminated with foreign material.	CLEAN projector. See Chapter Five Maintenance
Selector Ring snaps back to the 'LOCK' position when turned to 'OPERATE'.	Teleflex Cable has disengaged the Stop Pin from the Selector Ring.	RELIEVE tension by turning Pistol Grip Control Crank counterclockwise.
Selector Ring does not snap back automatically to 'LOCK' when the source is retracted.	Source is not fully retracted.	RETRACT source fully.
	Source Assembly or Teleflex Cable is damaged.	REPLACE damaged Source Assembly or Teleflex cable. Always use a survey meter when approaching the projector. See 7-[illegible] Emergency Procedures.
	Lock Assembly is contaminated with foreign material.	CLEAN projector. See Chapter Five Maintenance.

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

SYMPTOM	PROBLEM	SOLUTION
Cannot connect Teleflex Cable to Source Assembly.	Source Assembly Lock Pin has seized.	LUBRICATE Source Assembly Lock Pin. See Chapter Five Maintenance.
	Source Assembly Connector or Teleflex Cable Connector is damaged.	REPLACE Source Assembly and/or Teleflex Cable.
Cannot connect Bayonet Connector to the Gamma Ray Projector.	Teleflex Cable has not been connected first to the Source Assembly.	CONNECT Teleflex Cable to Source End Connector.
Cannot disconnect Bayonet Connector.	Source is not fully shielded.	RETURN source to fully shielded position by turning Pistol Grip Control Crank.
	Selector Ring has not fully retracted to the 'LOCK' position.	ROTATE the Selector Ring completely clockwise. Always use a survey meter when approaching the projector.
	Push Button Lock is locked.	UNLOCK Push Button Lock with key.
Pistol Grip Control is difficult to turn.	Brake is engaged on Pistol Grip Control.	UNLOCK Brake.
	Pistol Grip Control is contaminated with foreign material.	CLEAN Pistol Grip Control and replace any damaged parts. See Chapter Five Maintenance.
	Teleflex Cable is kinked, frayed or otherwise damaged.	REPLACE Teleflex Cable. See Chapter Five Maintenance.
	Cable Sheath or Source Guide Tube is kinked, crushed or otherwise damaged.	ADJUST Cable Sheath or Source Guide Tube. See Chapter Five Maintenance.

Appendix B

IS/DS 0046 C000

NORDION INTERNATIONAL INC.
447 March Road, P.O. Box 13500, Kanata, Ontario, Canada, K2K 1X8
Tel: (613) 592-2790, Telex: (053) 4162, Telefax (613) 592-6937

OPERATING PROCEDURE

IS/OP 0046 C000

Maintenance Instructions for Cable-Type Radiography Sources

DATE	REV.	COMMENTS/AFFECTED PAGE	PREPARED BY	REVIEWED BY	APPROVED BY
90 JUL	0	Original Issue	A.W. Gunter	W.H. Pettipas	G. A. Burbidge
				P.L. Larabie	
93 AUG	A	DC 90614	M. Krzaniak	B. Menna	G. A. Burbidge
93 SEP	B	DC 90627	B. Menna	M. Krzaniak/	G. A. Burbidge
			B Menna	P. Larabie	GAB
				M Krzaniak	
				PL	

NOTE:
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1 SCOPE

This document describes the maintenance procedures for Nordion cable-type radiography sources. The test gauge (Figures 3 and 4) is used to test the operation of D898 and D899 connectors for the cable-type radiography sources listed in Table 1.

Table 1

Source Type	Female Connector	Male Connector
C-337	D898F	D898
C-340	D899	D898
C-343	D899	D898
C-359	D899	D898
C-361	D899	D898
C-990	D899	D898

2 GENERAL INSTRUCTIONS FOR CONNECTORS AND SOURCES

It is recommended that you perform the following steps as a matter of habit. If your radiography equipment is in high use, it is advisable to perform these steps more frequently than indicated.

Table 2 summarizes these detailed procedures.

WARNING

Always check that the source is secured in its shielded position in the Gamma Ray Projector or Source Changer before performing any maintenance action.

(1) Clean both male and female connectors weekly, using any high grade commercial organic solvent.

(2) Lubricate the female connector weekly, using a light oil such as WD-40.

(3) Check weekly that the spring loaded locking collar is functioning properly (see Figure 1). Ensure that it returns to the fully closed position after it has been released.

Table 2
Maintenance Summary

Item	Frequency	Maintenance
1.	Weekly	**CLEAN** male and female connectors. **LUBRICATE** female connector.
2.	Weekly	**CHECK** functioning of source locking collar
3.	Monthly	**INSPECT** source and drive cable connectors using the test gauge
4.	As required	**VERIFY** length of teleflex drive cable
5.	As required	**CLEAN** radiography equipment
6.	As required	**RECORD** all maintenance and repairs in the log book

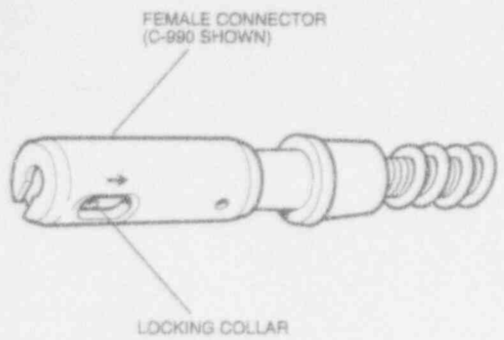


Figure 1

Operation of locking collar

4) Inspect the source end connector and drive cable male connector monthly according to the procedures of Section 3. Remove the source or drive cable from service if it has been damaged or fails any of the tests described in Section 3.

WARNING

> **Never use your Nordion source with anything other than a Nordion male connector on the end of your drive cable. It is dangerous to use other manufacturers' male connectors with Nordion sources.**

5) Verify that the length of the remote control drive cable is correct (see Figure 2). Disconnect the reserve side of the remote control sheath from the end plug. For a 25 foot remote control, when the drive cable is fully retracted, the end of the teleflex cable should be 8 inches short of the end of the reserve sheath. Remember to install the stop-spring when adjusting or replacing the drive cable. This procedure is particularly important for users of the Nordion TITAN Gamma Ray Projector or other projectors that automatically secure the source. The cable length must be checked once on existing equipment and then only when the drive cable is replaced.

6) Keep your drive controls and source guide tubes clean and dry. Always clean your accessories inside and out after working in a harsh environment.

7) Always store your radiography equipment in a clean, dry and secure storage area.

8) Follow the maintenance procedures and user's instructions in your gamma projector's operating manual. Record all maintenance in the equipment log book.

9) Call Nordion Customer Service if you have questions or problems with any of these procedures. 1-800-267-6211.

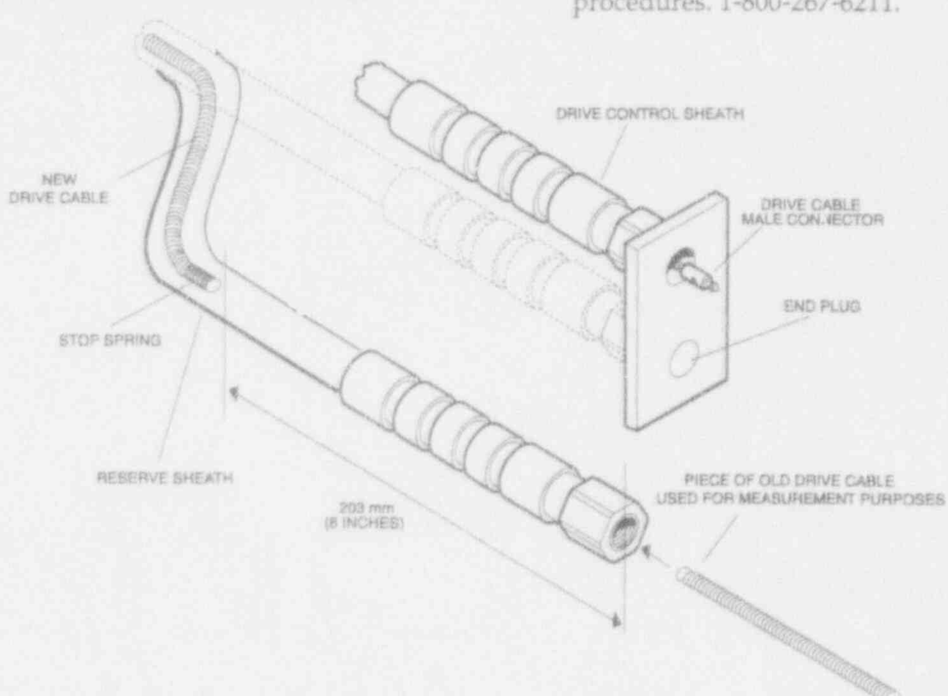


Figure 2: Measure Drive Cable

3 TEST GAUGE INSTRUCTIONS

CAUTION

Do not attempt to force the connectors through any of the holes or slots of the test gauge. This may damage the connector and cause unnecessary wear to the test gauge.

Check the source connector and the drive cable connector monthly using the test gauge. The connectors must pass all of the following tests. If a connector fails one or more of these tests, it must be removed from service immediately.

3-1 Male Connector (See Figure 3)

NOTE

Use the D898 side of the test gauge to perform all of the tests on the male D898 connectors.

(1) Place the male connector perpendicular to the plane of the test gauge.

(2) Check that the ball DOES NOT pass through hole "A". Should the ball pass through hole "A", this would indicate excessive wear on the ball.

(3) Pla~· the male connector perpendicular to the plane of the test gauge.

(4) Check that the neck DOES NOT pass through slot "B". Should the neck pass through slot "B", this would indicate excessive wear on the neck.

(5) Place the male connector parallel to the plane of the test gauge.

(6) Check that the connector DOES NOT go through opening "C". Should the connector pass through opening "C", this would indicate that the neck had been stretched, due to excessive pul'. force.

3-2 Female Connector (See Figure 4)

NOTE

Use the D899 side of the test gauge to test all female connectors listed in Table 1.

(1) Place the female connector perpendicular to the plane of the test gauge.

(2) Check that the connector DOES pass through hole "D". Should the connector not pass through hole "D", this would indicate stretch of the connector due to excessive pull force.

NOTE

On the C-990 source assembly there is a roll pin pressed through the source just above the notch in the connector. It is not necessary for this pin to pass through hole "D" on the gauge.

(3) Place the female connector parallel to the plane of the test gauge.

(4) Check that the connector DOES NOT fit on pin "E". Should the connector fit on pin "E", this would indicate excessive wear of the female connector.

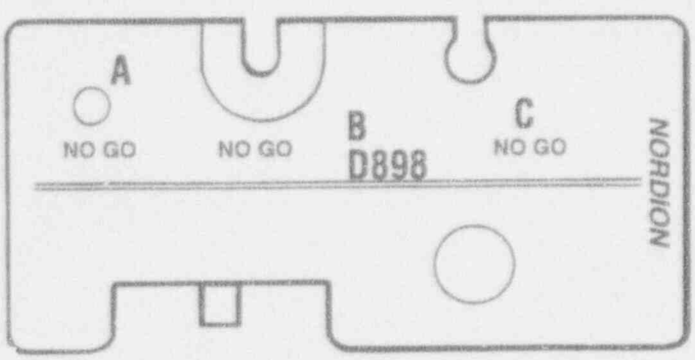


Figure 3

Gauge Orientation for Male Connectors

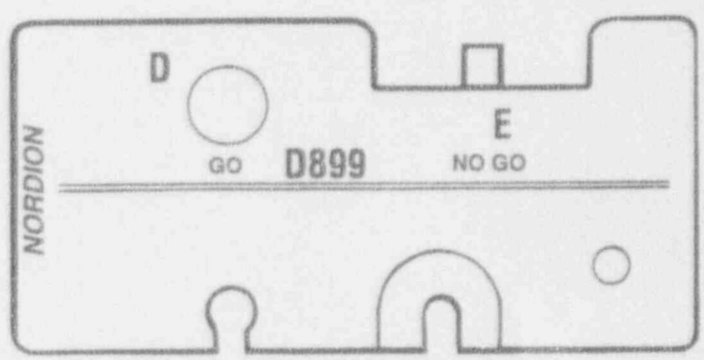


Figure 4

Gauge Orientation for Female Connectors

REFERENCES

1. Nordion Engineering Drawing, A16843, *D898, D899 Connector Test Gauge.*

2. Nordion Engineering Drawing, A17714, *Connector Body Female (D899).*

3. Nordion Engineering Drawing, A16828, *Connector Body Female (D898F).*

4. Nordion Engineering Drawing, A16832, *D898 Male Connector, Cable End.*

Appendix C

Regulatory Agencies

C-1 CANADA

AREA	REPRESENTATIVE	PLACE	TELEPHONE	
National	Atomic Energy Control Board Transport Canada Environment Canada	Ottawa Ottawa Hull	613 613 819	995-0479 996-6666 997-3742
Newfoundland	Dept. of Employment & Labour Relations	St. John's	709	729-2644
Prince Edward Island	P.E.I. Dept. of Health & Social Services	Charlottetown	902	368-4996
Nova Scotia	N.S. Dept. of Health	Halifax	902	424-4077
New Brunswick	N.B. Dept. of Health - Lab N.B. Dept. of Health St. John Regional Hospital	Fredericton Fredericton St. John	506 506 506	453-2067 453-2933 648-6852
Quebec	Atomic Energy Control Board	Laval	514	667-6360
Ontario	Ontario Ministry of Labour Atomic Energy Control Board	Toronto Mississauga	416 416	235-5922 821-7760
Manitoba	Department of Environment, Work Place Safety and Health	Winnipeg	204 204 204	945-7008 945-7039 944-4888
Saskatchewan	Department of Labour University of Saskatchewan	Regina Saskatoon	306 306 306	787-4538 933-7775 966-4675
Alberta	Compliance Information Centre Atomic Energy Control Board Alberta Labour	Edmonton Calgary Edmonton	403 403 403	422-9600 292-5181 427-2691
British Columbia	B.C. Ministry of Health Environmental Health Protection Services Radiation Protection Services	Vancouver Vancouver Vancouver	604 604 604	660-6633 660-6633 660-6633
Northwest Territories	N.W.T. Pollution Control Division N.W.T. Occupational Health & Safety Division	Yellowknife Yellowknife	403 403	873-7654 873-7468

C-2 UNITED STATES

AGREEMENT STATES

A state that has an agreement with the Nuclear Regulatory Commission allowing the state to regulate certain activities using radioactive materials, for example, gamma radiography using iridium-192 or cobalt-60 sources.

Alabama 205-261-5313
Bureau of Radiological Health
Environmental Health Administration
Room 314, State Office Building
Montgomery, Alabama 36130

Arizona 602-255-4845
Arizona Radiation Regulatory Agency
4814 South 40th Street
Phoenix, Arizona 85040

Arkansas 501-661-2301
Division of Radiation Control and Emergency Management
Arkansas Department of Health
4815 West Markham Street
Little Rock, Arkansas 72205-3867

California 916-445-4931
916-322-2073
Radiologic Health Branch
Department of Health
714 P Street, Room 498
Sacramento, California 95814

Colorado 303-331-8480
Radiation Control Division
Office of Health Protection
Department of Public Health
4210 East 11th Avenue
Denver, Colorado 80220

Florida 904-487-1004
Office of Radiation Control
Department of Health and Rehabilitative Services
1317 Winewood Boulevard
Tallahassee, Florida 32399-0700

Georgia 404-894-5795
Radiological Health Section
Department of Human Resources
Room 600 - 878 Peachtree Street
Atlanta, Georgia 30309

Idaho 208-334-5879
Compliance Section
Idaho Department of Health and Welfare
Statehouse, Boise, Idaho 83720

Illinois 217-785-9868
Department of Nuclear Safety
1035 Outer Park Drive
Springfield, Illinois 62704

Iowa 515-281-3478
Bureau of Radiological Health
Iowa Department of Health
Lucas State Office Building
Des Moines, Iowa 50319

Kansas 913-296-1542
Bureau of Air Quality and Radiation Control
Department of Health and Environment
Forbes Field, Building 321
Topeka, Kansas 66620

Kentucky 502-564-3700
Radiation Control Branch
Department of Health Services
Cabinet for Human Resources
275 East Main Street
Frankfort, Kentucky 40621

Louisiana 504-925-4518
Nuclear Energy Division
Office of Air Quality and Nuclear Energy
P.O. Box 14690
Baton Rouge, Louisiana 70898

Maryland 301-631-3300
Center for Radiological Health
Department of the Environment
2500 Broening Highway
Baltimore, Maryland 21224

Mississippi 601-354-6657/6670
Division of Radiological Health
State Board of Health
3150 Lawson Street
P.O. Box 1700
Jackson, Mississippi 39215-1700

Nebraska 402-471-2168
Division of Radiological Health
State Department of Health
301 Centennial Mall South
P.O. Box 95007
Lincoln, Nebraska 68509

Nevada 702-687-5394
Radiological Health Section
Health Division
Department of Human Resources
505 East King Street, Room 202
Carson City, Nevada 89710

New Hampshire 603-271-4588
Radiological Health Program
Bureau of Environmental Health
Division of Health Services
Health and Welfare Building,
Hazen Drive, Concord,
New Hampshire 03301

New Mexico 505-827-2959
Community Services Bureau
Environmental Improvement Division
Department of Health and Environment
1190 St. Francis Drive
Santa Fe, New Mexico 87503

New York 518-473-0048
Division of Policy Analysis and Planning
2 Rockefeller Plaza
Albany, New York 12223

North Carolina 919-741-4283
Department of Environment, Health and Natural Resources Division of Radiation Protection
P.O. Box 27687 Raleigh,
North Carolina 27603-7687

North Dakota 701-224-2348
Division of Environmental Engineering
Radiological Health Program
State Department of Health
1200 Missouri Avenue
Bismarck, North Dakota 58502-5520

Oregon 503-229-5797
Radiation Control Section
Department of Human Resources
1400 South West Fifth Avenue
Portland, Oregon 97201

Rhode Island 401-277-2438
Radioactive Materials and X-Ray Programs
Rhode Island Department of Health
Cannon Building, Davis Street
Providence, Rhode Island 02908

South Carolina 803-734-4700
Bureau of Radiological Health
South Carolina Department of Health and Environmental Control
J. Marion Sims Building
2600 Bull Street, Columbia,
South Carolina 29201

Tennessee 615-741-7812
Division of Radiological Health
TERRA Building, 150 9th Avenue, N.
Nashville, Tennessee 37219-5404

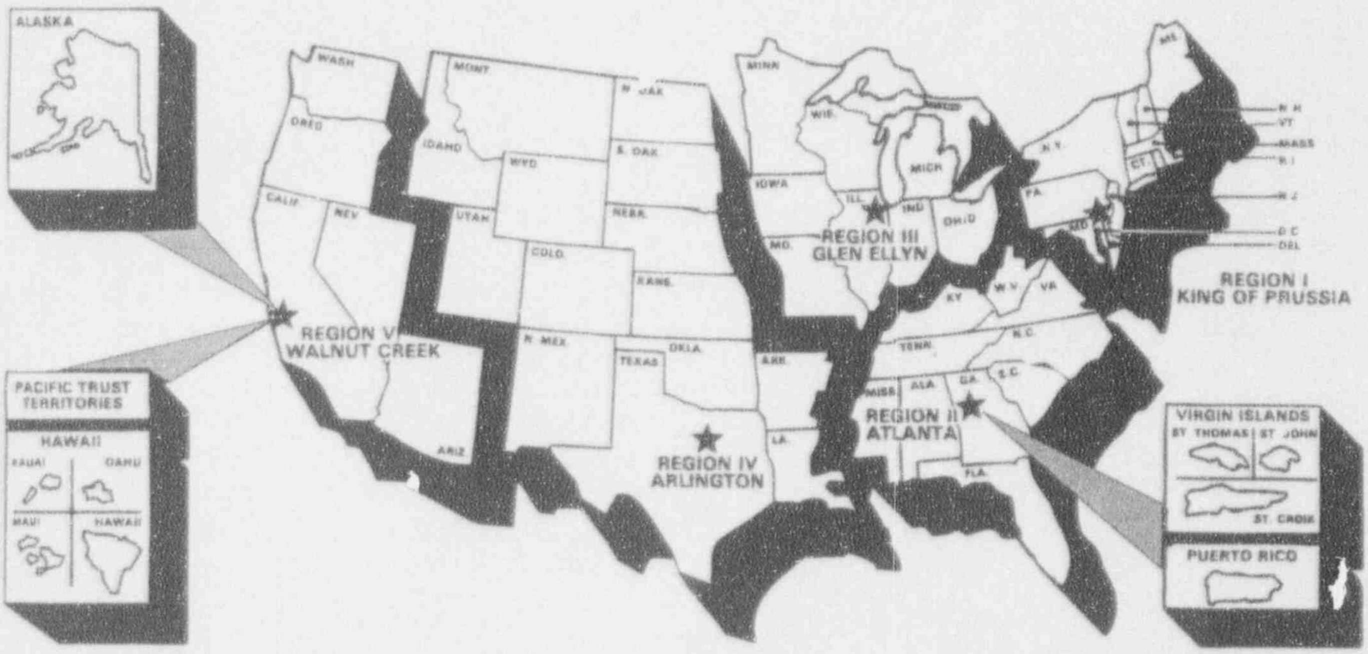
Texas 512-835-7000
Bureau of Radiation Control
Texas Department of Health
1100 W. 49th Street
Austin, Texas 78756

Utah 801-538-6734
Bureau of Radiation Control
State Department of Health
288 North 1460 West
P.O. Box 16690
Salt Lake City, Utah 84116-0690

Washington 206-586-8949
Office of Radiation Protection
Department of Social Health Services
Mail Stop LE-13
Olympia, Washington 98504

Updated lists of state addresses and telephone numbers are available upon request from:

Office of Governmental and Public Affairs USNRC
Washington D.C. 20555
(301) 492-0326



United States Nuclear Regulatory Commission Regional Offices

Region	Address	Telephone
I	631 Park Avenue, King of Prussia, Pennsylvania 19406	215-337-5000
II	101 Marietta Street, NW, Atlanta, Georgia 30323	404-331-4503
III	799 Roosevelt Road, Glen Ellyn, Illinois 60137	312-795-5500
IV	611 Ryan Plaza Drive, Arlington, Texas 76011	817-860-8100
V	1450 Maria lane, Walnut Creek, California 94596	415-943-3700

APPENDIX 4. IS/DS 0055 N990 rev B

NORDION INTERNATIONAL INC.

447 March Road, P.O. Box 13500, Kanata, Ontario, Canada, K2K 1X8
Tel: (613) 592-2790, Telex: (053) 4162, Telefax (613) 592-6937

DESIGN SPECIFICATION

Test Plan for the Titan Gamma Radiography Exposure Device

IS/DS C055 N990 (REV B)

CURRENT DATE: 93 MAY

DATE	ISSUE	COMMENTS/AFFECTEDPAGE	PREPARED BY	REVIEWED BY	APPROVED BY
92 Feb	0	Original Issue	B. Menna	M. Krzaniak/	G. Defalco
				G. Burbidge	
93 Jan	A	General Revisions	B. Menna	R. Goddard/	G. Defalco
				M. Krzaniak/	
				G. Burbidge	
93 May	B	DC 90571	B. Menna	M. Krzaniak	G. Burbidge
			B Menna	M Krzaniak	GAB

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IS0055B1

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3 PROJECT REQUIREMENTS 3

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1 INTRODUCTION

This document describes the detailed test plan for the Nordion Titan Gamma Radiography Exposure Device (GRED). The tests are required to demonstrate that the Titan meets the regulations for the design of gamma radiation exposure devices and the regulations for the safe transport of radioactive material (references 1, 3, 4, 6, 7). A description of the tests and detailed test procedures are included.

2 CLASSIFICATION

The Titan GRED is classified under ANSI N432(1980) as a Class P, Type 1, Type R exposure device. The testing described herein demonstrates that the device meets the requirements of this specification for a device of this type. Additional testing will be performed in order to support the design and to demonstrate that the Titan meets the transportation requirements for Type B(U) transport packaging (reference 6, 7).

3 PROJECT REQUIREMENTS

The guidelines for design, inspection and testing within ANSI N432(1980) and ISO 9000(1987) will be followed throughout the project. Some requirements of the revised ANSI standard, ANSI N43.9(1991) have been adopted.

4 TEST REQUIREMENTS

Reference documents 1, 3, 4, 6 and 7 outline in detail the test requirements for gamma radiography equipment and transport packagings. Table 1 summarizes these test requirements. Details of the requirements are listed in section 7 of this test plan. Figure 1 illustrates the sequence and flow of these tests.

The C990 source assembly has been demonstrated to meet Special Form requirements and has been classified as C43515 according to ANSI N543(1977) (see Appendix B).

5 DEFINITIONS

Many documents govern the testing to be performed on the Titan. They use many terms which are sometimes interchangeable or which may have subtle differences in meaning. For the purposes of this Test Plan, the following definitions shall apply.

Exposure Device

A shielded device employing a sealed source designed to allow the controlled use of gamma radiation for the purpose of making a radiographic exposure.

GRED

Gamma Radiography Exposure Device. This term typically refers only to the exposure device, and not to the entire apparatus.

Locked Position

Condition of the exposure device when it is locked (with a key) in addition to being in the secured position.

Projection Sheath

A flexible tube for guiding the control cable and the attached source assembly from the exposure device to the working position. Also known as a source guide tube.

Quality Assurance Representative

A representative designated by Nordion's Quality Assurance Department whose responsibility is to verify that the testing has been conducted in accordance with the quality assurance requirements and that the test results are thoroughly recorded and are accurate.

Remote Control Device

A device enabling the sealed source to be moved to an exposing position by operation at a distance away from the exposure device. The remote control device includes the crank mechanism, control cable and sheath. The remote control sheath consists of a reserve side and a projection side (see Figure 12 for illustration).

Secured Position

Condition of the exposure device when the source assembly is fully shielded and restricted from movement.

Source Assembly

A complete assembly including a sealed source, a short length (150 mm) of cable, a locking ball and an end connector. The source assembly used in the Titan is called the "C990" (ref. drawing K12223-600 Rev. B).

Table 1 - Governing Specifications and Their Tests

Device Under Test	Test	Standard or Specification						
		Nordion IS/DS 0055	ANSI N432 (1980)	ANSI N43.9 (1991)	IAEA Safety Series No. 6	10CFR 34 (Radiography) see note 1	10CFR 71 (Transport) see note 2	ISO CD 3999
Entire Apparatus	Projection Under Stress	✗		✗				✗
	Endurance	20,000	20,000	50,000				50,000
Exposure Device	Radiation Shielding	✗	✗	✗	✗	✗	✗	✗
	Vibration	see note 3		✗			✗	✗
	Horizontal Shock	✗	✗	✗				✗
	Vertical Shock	✗	✗	✗				✗
	Handle Wrench	✗		✗				✗
	Lock Breaking							✗
	Water Spray	see note 3			✗		✗	
	Immersion	see note 3			✗		✗	
	Penetration	✗			✗		✗	
	Puncture Resistance	✗	✗	✗	✗		✗	✗
	Accidental Drop	✗	✗	✗	✗		✗	✗
	Fire	✗		✗	✗		✗	✗
	Corrosion	see note 3						✗
	Free drop Test	see note 3			✗			
	Stacking Text	see note 3			✗			
Remote Control Device	Kinking	✗	✗	✗				✗
	Crushing	✗	✗	✗				✗
	Tensile	✗	✗	✗				✗
Projection Sheath	Kinking	✗		✗		✗		✗
	Crushing	✗		✗		✗		✗
	Tensile	✗		✗		✗		✗
	Tightness							✗
Source Assembly	Tensile	✗	✗	✗				✗

Notes:
1) 10CFR 34 requires all of the tests from ANSI N432 (1980) in addition to those indicated.
2) 10CFR71 includes the following tests that will not be performed: Heat, cold, reduced external pressure, increased external pressure and compression.
3) Test will not be performed, but device is qualified by discussion.

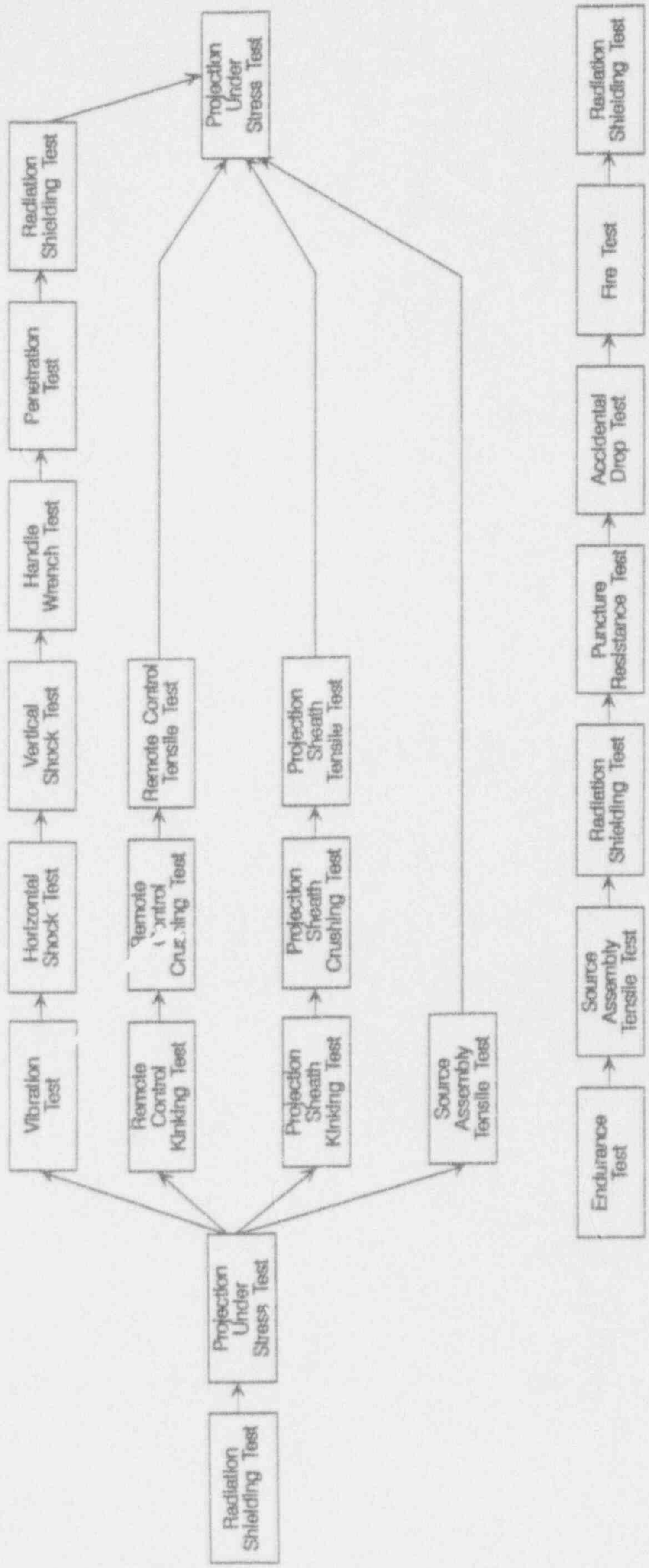

Figure 1
Test Flow Chart

6 QUALITY ASSURANCE REQUIREMENTS

The Nordion Titan project is managed in accordance with Nordion Specification IS/QP-0052-N990 and ISO 9000(1987). Testing will be performed in accordance with IS/QP-0052-N990.

6-1 Independent Testing

Where testing is performed by an organization independent of Nordion International, the testing and results will be documented by this independent organization. Where testing is performed by Nordion International, it will be thoroughly documented by the test engineer using sketches, photographs, video tapes and the Data Sheets in Appendix A. All test results will be validated by the project engineer. The testing will be witnessed by a Quality Control Representative where appropriate.

Representatives from the Canadian Atomic Energy Control Board will be invited to witness all testing.

6-2 Sub-Contractor's Quality Assurance

Sub-contractors must have a quality assurance system in accordance with ISO 9003 or CSA Z299.3. Quality system requirements include a quality policy, a quality system organization, quality records, a calibration system and personnel training. Sub-contractors will be evaluated on systems, procedures, and ability, prior to the start of testing.

6-3 Calibration

Equipment used for measuring test results shall be calibrated at the time of the test. The equipment calibration due date shall be recorded on the data sheets.

Calibration shall be performed by a qualified laboratory.

7 PROTOTYPE TESTING

7-1 Tests On The Entire Apparatus

7-1-1 Projection Under Stress Test

7-1-1-1 Purpose

The purpose of this test is to measure whether the torque required to drive and retract the source through a complete exposure cycle changes during a lifetime of normal use. This test is not a requirement of ANSI N432(1980). It is performed to verify the design and is based on the Projection Under Stress Test from ANSI N43.9(1991).

7-1-1-2 Equipment

The entire GRED apparatus shall be tested. Before the final test it will have been subjected to a variety of tests (see Figure 1). A torque meter Snap On model TBS2FUA will be employed.

7-1-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-1-1-4 Approach

The testing will be performed in two stages. Initial torque readings will be made on the new GRED equipment. Then, after a series of tests on the individual components, the measurements will be repeated.

The final torque measurements will be performed on equipment that has been subjected to the following tests:

- exposure device : horizontal shock, vertical shock, handle wrench and penetration
- remote control device : kinking, crushing, tensile
- projection sheaths : kinking, crushing, tensile
- source assembly: tensile

The test setup is shown in Figure 2. The bending radii for the remote control and projection sheath will be 500 mm.

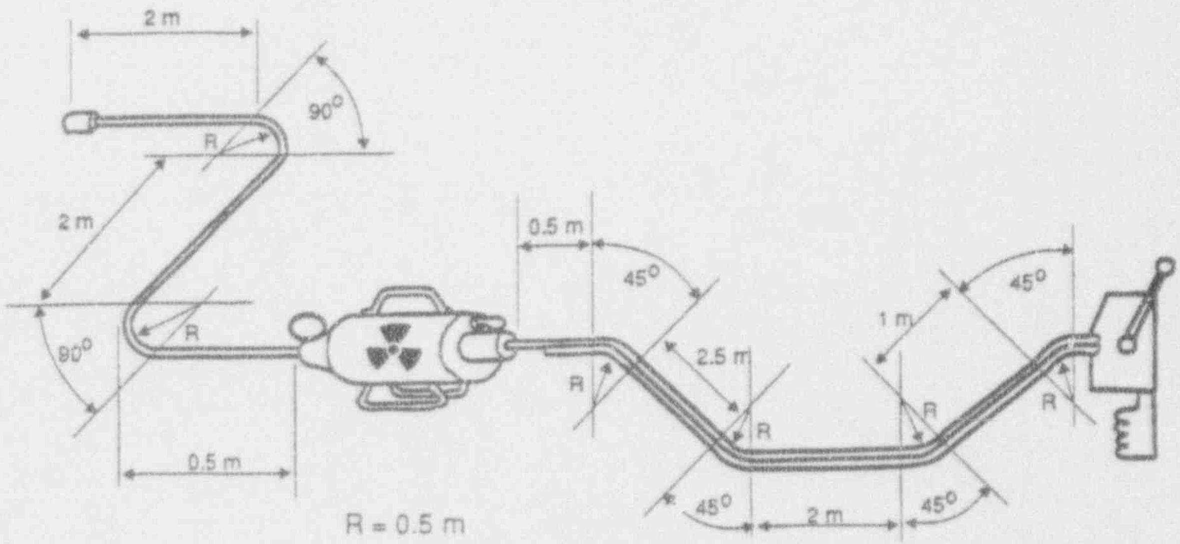

Figure 2
GRED Apparatus Endurance Test Configuration

Ten exposure cycles will be performed during which the maximum driving/retracting torque will be recorded.

7-1-1-5 Procedure

1) Set up the GRED equipment in the configuration shown in Figure 2. The bending radii at corners shall be 500 mm for the remote control and projection sheath. Connect the torque meter to the remote control crank mechanism.

2) Drive the source assembly to its fully extended position and then retract it fully. Care must be exercised in order not to measure the sharp rise in torque when the source reaches the end of its travel at each extreme.

3) Measure the driving torque and record the maximum value measured during the cycle.

4) Repeat the process 10 times and record the data on the Projection Under Stress Test Data Sheet provided in Appendix A. Be certain to fill out all of the information requested on the data sheet. The test engineer must sign the data sheet and a quality control representative must witness the test setup and at least one cycle of the testing. The test results must be validated by the project engineer.

5) Steps 1 to 5 are to be repeated once the equipment has been subjected to the tests for conditions of normal use listed in paragraph 7.1.1.4.

7-1-1-6 Data and Results

The test data shall be recorded on the form provided in Appendix A. All of the required information must be completed. An increase in drive torque of 25% or more shall constitute a failure.

7-1-2 Endurance Test

7-1-2-1 Purpose

The purpose of this test is to repeatedly operate the apparatus in order to determine its resistance to fatigue, and to measure any wear on the equipment components. After 20,000 cycles, an exercise will be performed in order to demonstrate that the source assembly will not disconnect when projected out of an open projection sheath.

7-1-2-2 Equipment

The automated endurance test equipment illustrated in Figure 3 will be used to perform the cycling. Impressions of the source tube will be made using Dow Corning Mold Making Compound DC HSII.

7-1-2-3 Location

With the exception of the thermal cycling this test shall be performed at Nordion International Inc., Kanata, Ontario.

7-1-2-4 Approach

The equipment will be subjected to continuous cycling for 20,000 cycles.

At the completion of 20,000 cycles, 50 cycles will be performed with the end of the projection sheath open. During these exposures, the source assembly will extend at least 1 meter out of the projection sheath. This additional test is not a requirement of ANSI N432(1980). Rather it is a requirement of ANSI N43.9(1991) that has been adopted to prove that the source assembly will not accidentally disconnect or snag outside the projection sheath.

At the conclusion of the test, 100 cycles will be performed with the exposure device at -40^{o}C, and an additional 100 cycles will be performed at +55^{o}C. These cycles are not a requirement of ANSI N432(1980) and will be performed after the completion of the 50,000 cycles. The entire remote control and projection sheath need not be exposed to the temperature extremes and these peripherals may be shorter than those used for the Endurance Test at ambient temperature.

After having been subjected to the endurance test, the source assembly will undergo the Tensile Test of paragraph 7.5.1.

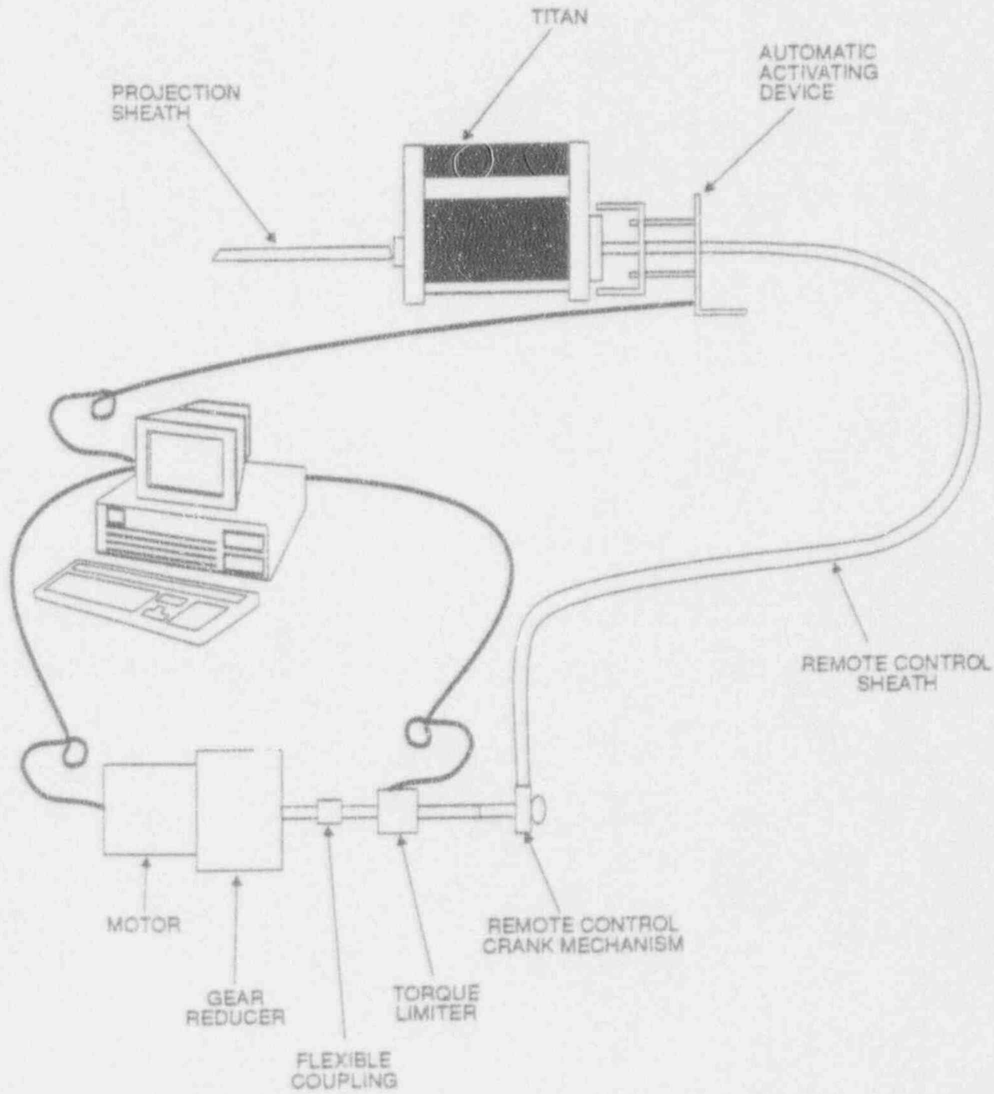

Figure 3
Endurance Test Setup

The test setup is shown in Figures 2 and 3. The automatic test apparatus shall meet the following requirements:

Minimum speeds : rotating 180 RPM
linear 0.75 m/s

The torque that the apparatus exerts at each extreme shall be determined by measuring the force experienced by the drive cable during manual operation. The test apparatus will then be adjusted accordingly.

7-1-2-5 Procedure

1) Measure the length of the dummy source assembly. Record the measurements and the source assembly serial number on the C990 Source Assembly Tensile Test Data Sheet, as this length will be required for comparison at the completion of testing. Record the tolerance associated with the length measurement and the calibration date of the instrument.

2) Check the integrity of the source tube by taking an internal impression using Dow Corning Mold Making Compound DC HSII.

3) Connect the equipment under test as shown in Figures 2 and 3.

4) Start the automated test equipment and verify that the counters are working properly. Check that the source assembly is travelling from the secured position, to the fully extended position and back. Record the date, time and cycle number on the Endurance Test Log Sheet in Appendix A. Be certain to initial every entry on the Log Sheet.

5) Regularly check the test apparatus for proper function or any incidents. An incident includes test startup or shutdown, failures or any other test anomalies.

6) Record any incidents on an Endurance Test Log Sheet provided in Appendix A. The date and time of each incident must be recorded and initialled. If the incident results in the shutdown of the test apparatus, it must be witnessed by a Quality Assurance Representative before the apparatus may be restarted. Disposition must be given by the project engineer.

7) Once 20,000 cycles have been completed, the end of the projection sheath shall be opened to allow the source assembly to pass through. 50 cycles shall be performed during which the source assembly shall extend at least 1 m from the projection sheath.

8) At the completion of the testing, the apparatus shall be moved to an environmental test chamber where the equipment shall be subjected to 100 cycles at temperature of -40°C. The remote control device and projection sheath do not need to be entirely exposed to the temperature extreme, and these peripherals may be shorter than those used for the Endurance Test at ambient temperature.

9) Repeat step 8 with the temperature stabilized at +55°C.

10) Remove the dummy source assembly. Tag and identify it, as a Tensile Test will be performed on it as per paragraph 7.5.1.

11) Check the integrity of the source tube by taking an internal impression using Dow Corning Mold Making Compound DC HSII.

7-1-2-6 Data and Results

Any start up, shut down or maintenance action shall be recorded on the Endurance Test Log Sheet. Photographs of any failures or maintenance actions are required. Failure criterium shall be failure of the apparatus to remain completely operational after 20,000 cycles. Additionally, the integrity of the sealed source and the encasement of the depleted uranium shielding must not be breached through wear after 20,000 cycles. An impression of the inside of the source tube will be made before and after the test.

7-2 Tests On The Exposure Device

7-2-1 Radiation Shielding Test

7-2-1-1 Purpose

The purpose of this test is to determine the exposure rate from the device to assure that the

dose rates in the vicinity of the device are within the limits specified.

7-2-1-2 Equipment

The Radiation Shielding Test will be performed on new exposure devices prior to the commencement of any mechanical testing, after the Penetration Test, after the Endurance Test, and if possible, after the tests for accident conditions. The measurements will be made on exposure devices with the end caps installed.

The Victoreen Model 440 and Model 660 survey meters will be used for measurements. Substitute survey meters may be used provided that the meter used to measure the exposure rate at 50 mm from the surface does not average over an area greater than 10 cm^2 and has a sensitive volume with no linear dimension greater than 5 cm. The meter used to measure the exposure rate at 1 m from the surface must average over an area no greater than 100 cm^2 and its sensitive volume must have no linear dimension greater than 20 cm.

7-2-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-1-4 Approach

A detailed survey will be performed on the two prototypes when they are new. Measurements will be made at every node on the grid system shown in Figure 4. In locations where the fields are relatively high, the hot spots will be located and identified in relation to the grid system. Radiation field measurements made after the exposure device has been subjected to testing will not be as thorough. They will be limited to areas of the device which have been affected or damaged by the testing.

A sample source is to be used for the measurement and the exposure rate is to be extrapolated to the maximum rating of 4.44 TBq (120 Ci) for the device. The extrapolation is not to exceed a factor of 10, but the source should approach an activity of 4.44 TBq (120 Ci) as safely and as practically as possible.

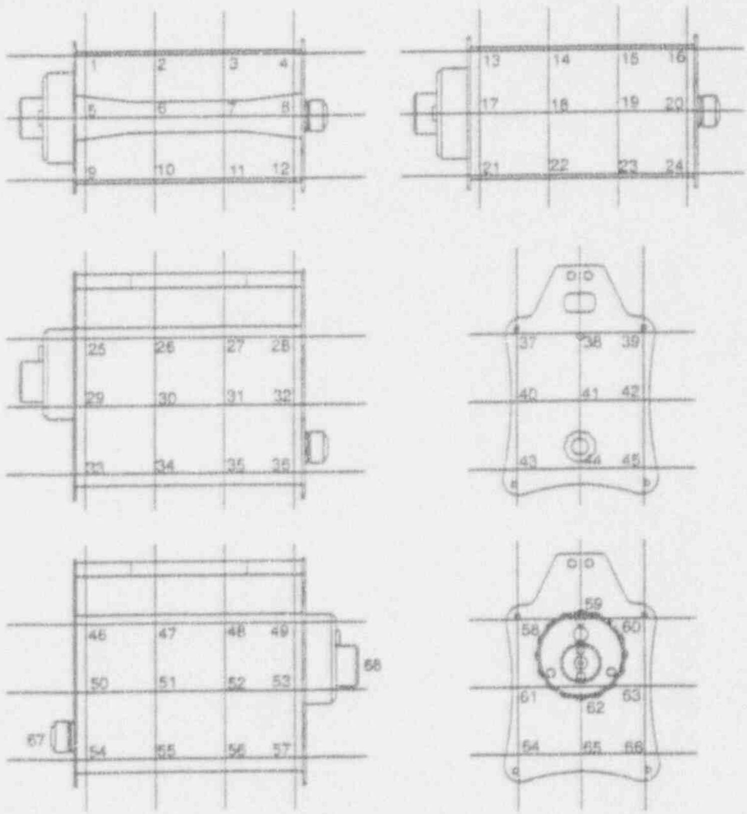

Figure 4
Radiation Survey Grid System

The maximum specified dose rates are as follows:

- 2 mSv/hr (200 mrem/h) on surface
- 0.5 mSv/hr (50 mrem/h) at 50 mm from the surface
- 0.02 mSv/hr (2 mrem/h) at 1 m from the surface

The activity of the source will be determined based on 0.55R/h-Ci at 1m for Ir-192.

If it is not possible to load a source assembly into the device after the tests for accident conditions, then a radiation shielding analysis will be performed to determine the exposure rate at this time.

7-2-1-5 Procedure

1) Measure the fields from the sample source and record the field output at 1m on the Radiation Shielding Test Data Sheet.

2) Observing the required safety procedures, install the sample source in the exposure device.

3) Using the Victoreen Model 471 Survey Meter, measure the fields 50 mm from the surface of the exposure device at each of the nodes identified on the 3 inch grid system in Figure 4. Allow the meter reading to stabilize for 5 seconds at each node before recording the measurement. Record each measurement on the Radiation Survey Data Sheet, and record the maximum reading on the Radiation Shielding Test Data Sheet.

4) Measure the fields at 1 m from each of the 6 faces of the exposure device. Record the measurements on the Radiation Survey Data Sheet, and record the maximum reading on the Radiation Shielding Test Data Sheet.

5) After the initial Radiation Shielding Survey on the exposure device, it is only necessary to make readings at locations on the device that are likely to have been affected by the testing.

6) Record all of the data on the Data Sheets, including the date, activity of the test source, serial number of the exposure device, and calibration data for the test equipment. Complete all of the calculations on the Radiation Shielding Test Data Sheet.

7-2-1-6 Data and Results

The measured field for the source and the activity calculation shall be shown on the Radiation Shielding Test Data Sheet. The extrapolation calculation shall also be recorded on the data sheet.

Fields in excess of the following constitute a failure:

- 2 mSv/hr (200 mrem/h) on surface
- 0.5 mSv/hr (50 mrem/h) at 50 mm from the surface
- 0.02 mSv/hr (2 mrem/h) at 1 m from the surface

7-2-2 Vibration Test

7-2-2-1 Purpose

The purpose of this test is to determine the resistance to the exposure device to the vibration that it may encounter during normal service. This test is not a requirement of ANSI N432(1980).

7-2-2-2 Discussion

The vibration test is intended to reveal any environmental effects that may occur during normal service. Examples of such effects include loosening of fasteners, component fatigue, chafing between parts and cracking or rupturing of structural members. The Titan is a welded structure, and any threaded fasteners are fixed with thread sealant. Additionally, the enclosure is injected with an epoxy foam which fills all internal voids. The Titan is therefore not susceptible to the environmental effects caused by vibration and there is no need to perform the vibration test.

7-2-3 Horizontal Shock Test

7-2-3-1 Purpose

The purpose of the Horizontal Shock Test is to test the resistance of the device to the shocks that may be encountered during normal service.

7-2-3-2 Equipment

The equipment used for the Horizontal Shock Test is shown in Figure 5. The exposure device shall have been subjected to the Projection Under Stress Test of paragraph 7-1-1 prior to the Horizontal Shock Test.

7-2-3-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-3-4 Approach

The Horizontal Shock Test consists of pendulum swings of the device into a rigidly mounted cylindrical steel bar. The exposure device will be suspended such that it just touches the target when at rest. The release position will be a point where the center of gravity of the device is 100 mm above its rest position. The steel bar will have a diameter of 50 mm and a length of 300 mm. It will be mounted to a rigid object with a mass of at least 225 kg. 20 impacts will be performed on each of the following areas:

- side of the exposure device
- side of the lock
- face of the lock
- bottom of the exposure device
- side of projection sheath connector
- face of projection sheath connector

7-2-3-5 Procedure

1) Connect the device under test to the suspension chain. Adjust the height and orientation so that the device will strike the pin in the desired location.
2) Measure the height to the bottom of the exposure device.
3) Swing the exposure device back until the height to the bottom of the device has increased by 100 mm.
4) Release the exposure device and allow it to swing into the target.

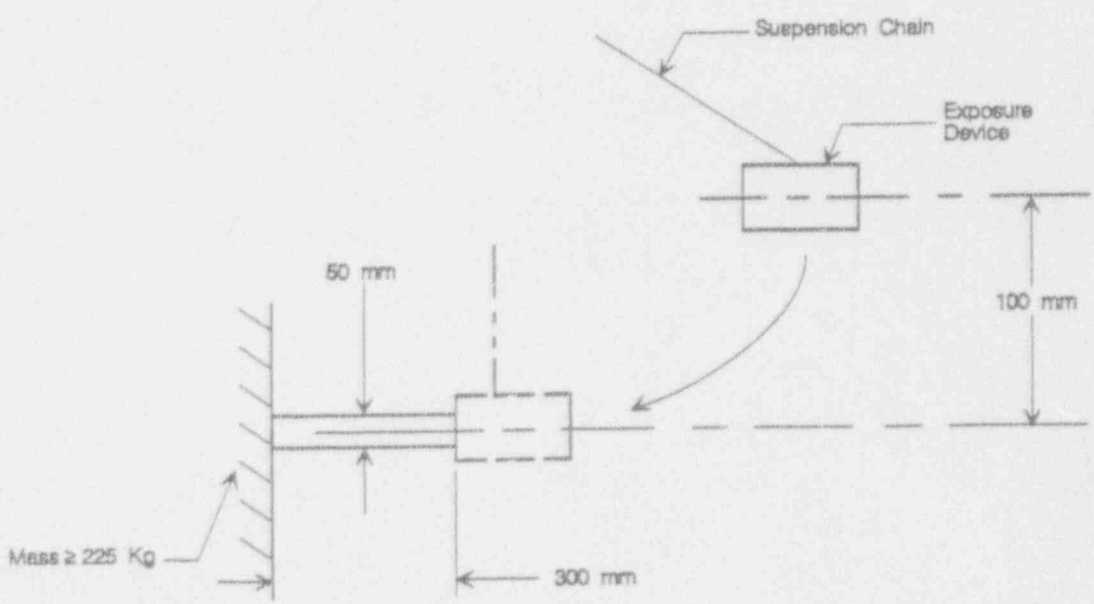

Figure 5
Horizontal Shock Test

5) Record any observations on the Horizontal Shock Test Data Sheet in Appendix A. Video tapes and photographs are required.

6) Repeat steps 3 to 6 until the device has been subjected to 20 impacts in the same area.

7) Repeat step 1 to 6 until each of the areas listed in paragraph 7.2.3.4 has been tested.

8) Connect the remote control and the projection sheath to the exposure device and perform 10 exposure cycles. This step may be performed at the completion of the Penetration Test of paragraph 7.2.10 at the discretion of the test engineer.

7-2-3-6 Data and Results

The date of the testing and the observations after each impact shall be recorded on the Horizontal Shock Test Data Sheet. Video tapes and photographs of each impact area shall be taken as a minimum. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles or failure of the Radiation Shielding Test.

7-2-4 Vertical Shock Test

7-2-4-1 Purpose

The purpose of the Vertical Shock Test is to test the resistance of the device to the shocks that may be encountered during normal service.

7-2-4-2 Equipment

The test equipment is shown in Figure 6. The exposure device shall have been subjected to the Horizontal Shock Test of paragraph 7.2.3.

7-2-4-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-4-4 Approach

The vertical shock consists of a drop from a height of 150 mm in the normal carrying position. The impact surface will consist of a rigid body with a mass greater than 225 kg covered by 25 mm of plywood. 100 shocks will be performed.

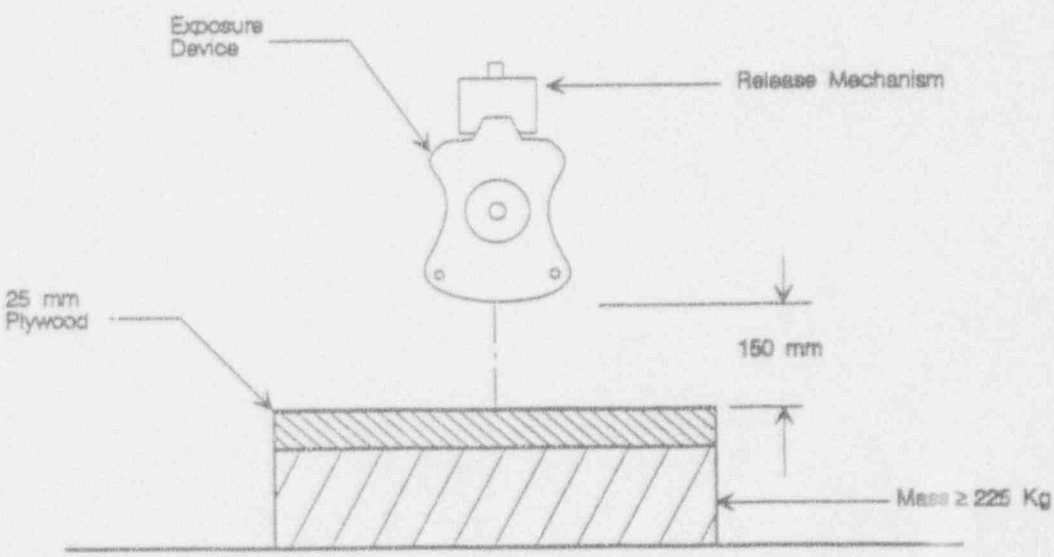

Figure 6
Vertical Shock Test

7-2-4-5 Procedure

1) Attach the exposure device to the release mechanism and verify that the height to the bottom of the exposure device is 150 mm.

2) Release the exposure device and allow it to fall onto the target.

3) Record any observations. Video tapes and photographs are required.

4) Repeat steps 1 to 3 until 100 shocks have been performed.

5) Connect the remote control and the projection sheath to the exposure device and perform 10 exposure cycles. This step may be performed at the completion of the Penetration Test of paragraph 7.2.10 at the discretion of the test engineer.

7-2-4-6 Data and Results

The date of the testing and the observations after each impact shall be recorded. Video tapes and photographs shall be taken. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles or failure of the Radiation Shielding Test.

7-2-5 Handle Wrench Test

7-2-5-1 Purpose

The purpose of this test is to demonstrate that the carrying handle is able to withstand the wrenching force applied to it when the device is dropped while tethered to a security chain. This test is not a requirement of ANSI N432(1980). It is a requirement of ANSI N43.9(1991) and has been adopted because it is considered to be an important verification of the design.

7-2-5-2 Equipment

The test equipment is shown in Figure 7. The exposure device shall have been subjected to the Vertical Shock Test of paragraph 7-2-4.

7-2-5-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-5-4 Approach

The device will be dropped 1 m while attached to a chain. The upper end of the chain will be attached to a rigid mounting point.

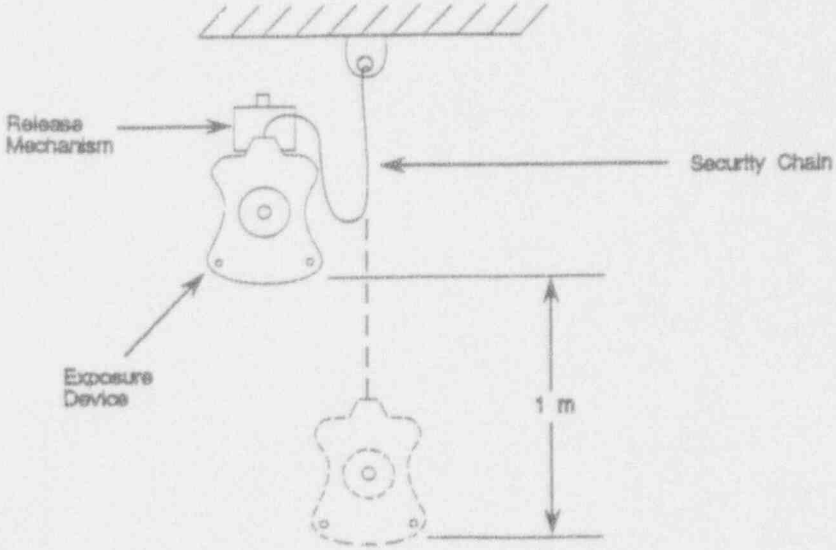

Figure 7
Handle Wrench Test

7-2-5-5 Procedure

1) Fasten the safety chain to the handle of the exposure device.

2) Suspend the exposure device so that it will drop 1 m when released. Make certain that the exposure device will not reach the ground or strike any obstructions when it is released.

3) Release the exposure device and allow it to drop freely.

4) Record any observations. Photographs and video tapes are required to support the observations.

5) Connect the remote control and projection sheath to the exposure device and perform 10 exposure cycles. This step may be performed at the completion of the Penetration Test of paragraph 7.2.10 at the discretion of the test engineer.

7-2-5-6 Data and Results

Observations shall be recorded. Photographs and video tapes will be taken. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles, loss of use of the handle or failure of the Radiation Shielding Test.

7-2-6 Water Spray Test

7-2-6-1 Purpose

The purpose of the Water Spray Test is to subject the device under test to a simulated rainfall of 50 mm per hour for at least one hour. This test would reveal any problems with packagings vulnerable to water saturation.

7-2-6-2 Discussion

The Water Spray Test is particularly intended for packagings where distance shielding may rely on non-metallic materials which are softened by water or materials bonded by water soluble glue. Since the structure of the exposure device is made entirely of metal, it is not vulnerable to such conditions. There is therefore no need to perform this test.

7-2-7 Immersion Test

7-2-7-1 Purpose

The purpose of this test is to verify that the exposure device will not suffer any damage when subjected to immersion in 15 m of water.

7-2-7-2 Discussion

The primary purpose of the Immersion Test is to demonstrate that a package can maintain its structural integrity when subjected to an external pressure. The Titan does not incorporate seals to prevent the influx of water, nor are any of its components sensitive to water. The source assembly has been demonstrated to meet Special Form requirements (Appendix B). Therefore, the Titan would not suffer any damage if immersed in water and there is no need to perform the Immersion Test.

7-2-8 Free Drop Test

7-2-8-1 Purpose

The free drop test is intended to simulate the type of shock that a package would experience if it were to fall off the platform of a vehicle or if it were dropped during handling.

7-2-8-2 Discussion

Since the Titan GRED will be subjected to a 9 m drop test, the requirements for the free drop test are exceeded and there is therefore no need to perform this test.

7-2-9 Stacking Test

7-2-9-1 Purpose

The stacking test is designed to simulate the loads pressing on a package over a prolonged period of time and is intended to ensure that the effectiveness of the shielding and containment systems will not be impaired

7-2-9-2 Discussion

Because of the shape of the Titan GRED, stacking of the device is improbable and nearly impossible. There is therefore no need to perform this test.

7-2-10 Penetration Test

7-2-10-1 Purpose

The purpose of this test is to demonstrate that the exposure device can withstand the impact that the device may receive during normal conditions of transport. The test simulates the exposure device being struck by a slender object such as a length of metal tubing or the handlebar of a falling bicycle. The test is a transport requirement (reference 6).

7-2-10-2 Equipment

The equipment required consists of a 32 mm bar and a guide tube to direct its fall. The bar shall have a hemispherical end and a mass of 6 kg. The exposure device shall have been subjected to the Handle Wrench Test of paragraph 7-2-5.

7-2-10-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-10-4 Approach

The bar will be dropped vertically so as to strike the exposure device at the following sensitive areas:

- bottom of exposure device
- side of exposure device
- front of lock
- side of lock

The height of the drop shall be 1 m measured from the lower end of the bar to the intended point of impact.

7-2-10-5 Procedure

1) Position the exposure device so that the target impact area is facing up.

2) Using the guide tube, adjust the relative position of the bar and the exposure device so that the bar will fall vertically and strike the target impact area when released.

3) Adjust the height between the bottom of the bar and the target impact area to 1m.

4) Release the bar.

5) Record any observations on the Penetration Test Data Sheet in Appendix A. Video tapes, sketches and photographs are required to support the observations.

6) Repeat steps 1 to 5 for all of the areas of the device listed in paragraph 7.2.10.4.

7) Connect the remote control and projection sheath to the exposure device and perform 10 exposure cycles.

7-2-10-6 Data and Results

Observations shall be recorded on the Penetration Test Data Sheet. Sketches, photographs and video tapes shall be taken. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles or failure of the Radiation Shielding Test.

7-2-11 Puncture Resistance Test

7-2-11-1 Purpose

The purpose of the Puncture Resistance Test is to simulate accident conditions and to demonstrate that the source is not accidentally exposed as a result.

7-2-11-2 Equipment

The equipment used for this test includes a 9 m drop tower, an unyielding surface and a mild steel pin with a diameter of 150 mm and a length of 200 mm. The exposure device shall have been subjected to the endurance test of paragraph 7-1-2.

7-2-11-3 Location

The Accidental Drop Test will be performed at AECL Research, Chalk River Laboratories, Chalk River, Ontario.

7-2-11-4 Approach

The test will consist of a 1 m drop onto the end of a cylindrical target such as to cause the maximum damage to the device under test. The target will be rigidly mounted perpendicularly to an unyielding surface. The surface consists of a 100 mm thick steel slab on a cubic block of

concrete measuring 3 m on each side. The concrete sits on bedrock.

7-2-11-5 Procedure

1) Suspend the exposure device in the upright orientation so that when released the lock will strike the pin. Hoist it so that the height measured between the upper surface of the pin and the bottom of the lock is 1 m.

2) Start the high-speed camera and release the exposure device.

3) Record the results, including observations, sketches and photographs of the damaged areas.

7-2-11-6 Data and Results

The Puncture Resistance Test shall be documented with high-speed video, photographs and sketches. The exposure device need not be operational after the test, however the radiation fields are not permitted to exceed 10 mSv/h (1 rem/h) at 1 m.

-12 Accidental Drop Test

7-2-12-1 Purpose

The purpose of the Accidental Drop Test is to simulate an accidental impact and to demonstrate that the source will not be accidentally exposed as a result of such an impact.

7-2-12-2 Equipment

The equipment used for this test includes a 9 m drop tower and an unyielding surface. The exposure device shall have been subjected to a Puncture Resistance Test of paragraph 7-2-11.

7-2-12-3 Location

The Accidental Drop Test will be performed at AECL Research, Chalk River Laboratories, Chalk River, Ontario.

7-2-12-4 Approach

A total of three 9 meter drop tests will be completed using two prototype units. One prototype will be subjected to a 9 m upright drop followed by a 9 m oblique drop in the orientation shown in Figure 8. The second prototype will be subjected to a 9 m drop directly onto the lock. See reference 5 for further discussion on the drop orientations.

7-2-12-5 Procedure

1) Suspend the exposure device in the upright orientation and hoist it so that the height measured between the upper surface of the target and the lowest point on the exposure device is 9 m.

2) Start the high-speed camera and release the exposure device.

3) Record the results, including observations, sketches and photographs of the damaged areas.

4) Repeat steps 1 to 3 with the exposure device oriented for a corner drop as shown in Figure 8. Ensure that the centre of gravity of the exposure device is aligned vertically over the lower corner.

5) Repeat steps 1 to 3 with the exposure device oriented so that the primary impact will be on the lock.

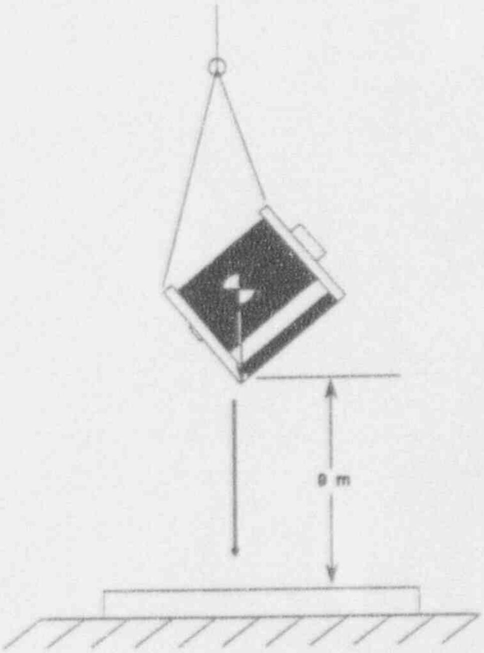

Figure 8
9 m Corner Drop Test

7-2-12-6 Data and Results

The Accidental Drop Test shall be documented with high-speed video, photographs and sketches. The exposure device need not be operational after the test, however the radiation fields are not permitted to exceed 10 mSv/h (1 rem/h) at 1 m.

7-2-13 Fire Test

7-2-13-1 Purpose

The purpose of the Fire Test is to measure the resistance of the test specimen to an accidental fire condition.

7-2-13-2 Discusion

The fire test is intended to demonstrate that the radioactive material's shielding and containment are not vulnerable to an accidental fire with a temperature of 800 °C and duration of 30 minutes.

The C990 source assembly has been demonstrated to meet special form requirements and can therefore withstand such a fire. The shielding material is depleted uranium which has a melting point of 1200 °C and will therefore survive a fire. The outer structure of the TITAN is made of titanium which has a melting point of 1670 °C and can also withstand a fire.

The only material susceptible to a fire is the epoxy foam which fills the void between the outer structure and the depleted uranium shield. The shield is structurally supported by means other than the epoxy foam and shielding provided by foam is insignificant. There is therefore no need to perform the fire test.

7-3 Tests On The Remote Control Device

7-3-1 Kinking Test

7-3-1-1 Purpose

The purpose of this test is to verify that the remote control cable and sheath can withstand the stress due to kinking that may occur during normal use.

7-3-1-2 Equipment

The remote control device will have been subjected to the Projection Under Stress Test of paragraph 7-1-1.

The test apparatus used is shown in Figure 9. The remote control sheath will be pulled manually, and the speed will be measured using an Ametek digital tachometer with a linear measurement adaptor.

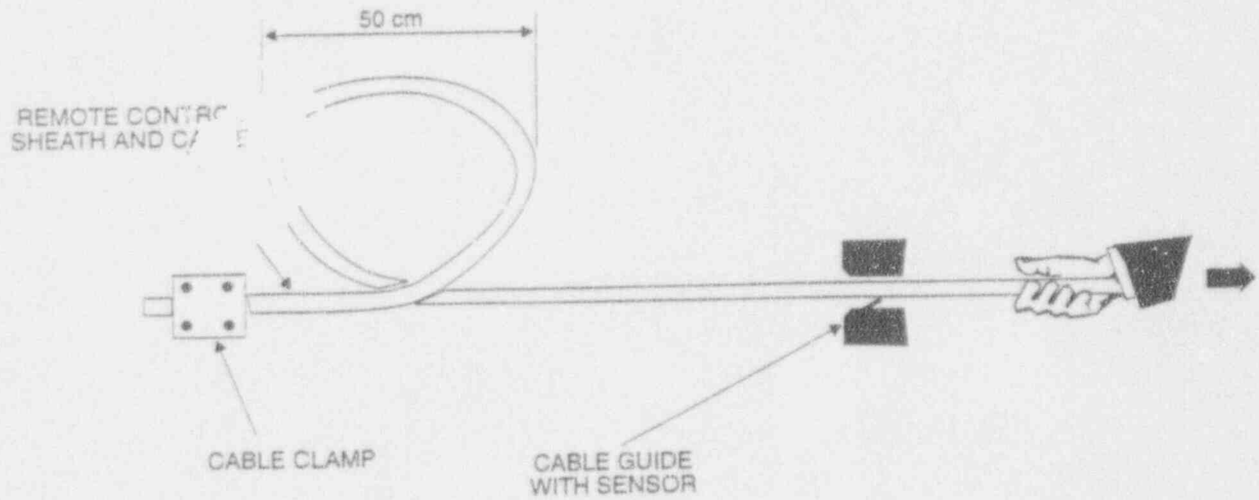

Figure 9
Remote Control Kinking Test Setup

7-3-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-3-1-4 Approach

The cable will be laid out on a flat surface with a 500 mm diameter loop and one end secured. The free end of the cable will be pulled at a rate of 2.0 m/s ± 10% until the loop has disappeared. The test will be repeated 10 times with loop in different locations.

7-3-1-5 Procedure

1) Arrange the control cable and sheath on the test apparatus with a loop 500 mm in diameter as shown in Figure 9.

2) Secure one end of the sheath using the clamp provided.

3) Pull the free end of the sheath at a speed of 2 m/s until the loop has disappeared.

4) Verify that the speed was between 1.8 m/s and 2.2 m/s. Record any observations on the Remote Control Kinking Test Data Sheet in Appendix A. Mark the sheath to indicate the location where the test was performed.

5) Repeat steps 1 to 4 with the loop at different locations on the sheath until 10 satisfactory tests have been performed.

7-3-1-6 Data and Results

All observations shall be recorded on the data sheet provided. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-3-2 Crushing Test

7-3-2-1 Purpose

The purpose of this test is to demonstrate that the remote control cable can withstand the stress of the heel of a 100 kg person impacting at a horizontal and vertical speed of 0.8 m/s.

7-3-2-2 Equipment

The test apparatus is shown in Figure 10. The remote control device shall have been subjected to the Kinking Test of paragraph 7-3-1.

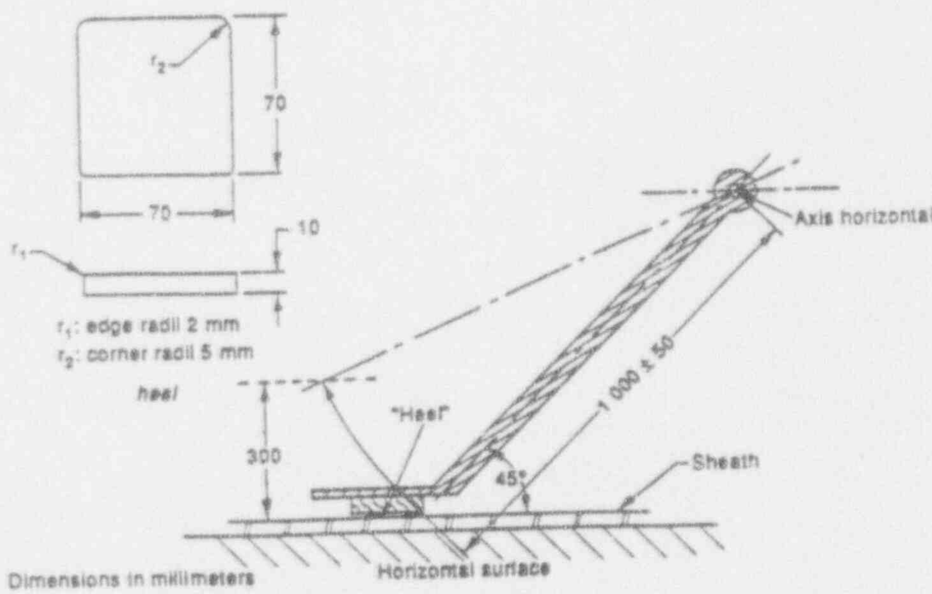

Figure 10
Crushing Test Setup

7-3-2-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-3-2-4 Approach

The apparatus to be used for the test is shown in Figure 10. The mass of the heel and crank shall be 15 kg. The test surface shall have a mass greater than 225 kg. The heel will be dropped from a height of 300 mm. The test will be repeated 10 times at different locations along the cable.

7-3-2-5 Procedure

1) Arrange the equipment as shown in Figure 10. The sheath shall contain the control cable. Fix the sheath using guides.

2) Raise the arm and verify that the height between the sheath and the heel in 300 mm.

3) Release the arm and allow the heel to swing freely down onto the sheath.

4) Record any observations on the Crushing Test Data Sheet in Appendix A. Mark the sheath to indicate the location where the test was performed.

5) Repeat steps 1 to 4 at 10 different points along the sheath. For five of the tests the projection side and reserve side of the sheath shall be superposed vertically. For the other five tests they shall be side by side. Note whether the control cable is in the projection sheath or reserve sheath or both.

7-3-2-6 Data and Results

The observations will be recorded on the data sheet provided. Each trial will be video taped and the test setup will be photographed. The failure criterium wi.` be failure of the final Projection Under Stress Test.

7-3-3 Tensile Test

7-3-3-1 Purpose

The purpose is to demonstrate that the control cable and sheath can withstand the tensile forces that may be encountered during use.

7-3-3-2 Equipment

The remote control device shall have been subjected to the Crushing Test of paragraph 7-3-2. The test apparatus is shown in Figures 11 and 12.

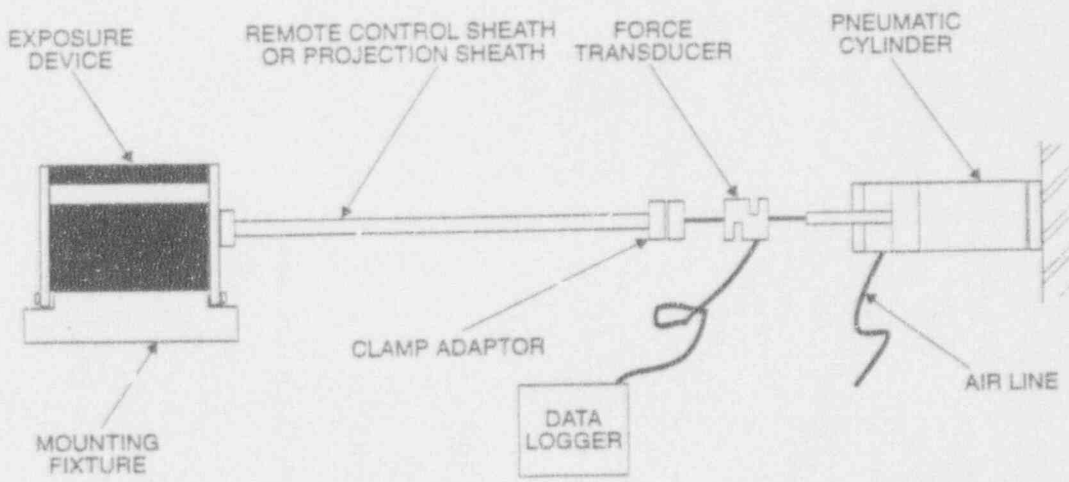

Figure 11

Remote Control Sheath & Projection Sheath Tensile Tests

7-3-3-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-3-3-4 Approach

This test consists of two parts; first the remote control sheath will be tested and then the control cable and crank mechanism will be tested.

In the first part of the test, the remote control sheath will be tested. A tensile force of 500 N (112 lb) will be applied for 30 seconds. The test will be repeated 10 times.

In the second part of the test, the crank mechanism will be secured and the crank arm will be immobilized. A source assembly will be connected to the control cable and a force of 1000 N (225 lb) will be applied to the free end of the source for 10 seconds. The test will be repeated 10 times.

7-3-3-5 Procedure

1) Secure the exposure device as shown in Figure 11.
2) Connect the remote control sheath to the exposure device.
3) Connect the tensioning apparatus to the crank mechanism using the clamp adaptor.
4) Apply a load of 500 N (112 lb) for 30 s.
5) Record any observations and include the plot of the force profile from the data logger with the results.
6) Repeat steps 4 and 5 until 10 tests have been performed.
7) Secure the remote control as shown in Figure 11. Immobilize the crank handle.
8) Connect a source assembly to the control cable.
9) Apply a force of 1000 N (225 lb) for 10 s to the lock ball on the source assembly.
10) Record any observations and include a plot of the force profile from the data logger with the results.
11) Repeat steps 9 and 10 until 10 tests have been performed.

7-3-3-6 Data and Results

The observations will be recorded and plots of the measured force profile will be provided. Each test will be video taped and the test setup will be photographed. The failure criteria will be failure of the final Projection Under Stress Test or failure of the source assembly (see paragraph 7.5.1.6).

7-4 Tests On The Projection Sheath

7-4-1 Kinking Test

7-4-1-1 Purpose

The purpose of this test is to verify that the projection sheath can withstand the stresses due to kinking that may occur during normal use.

7-4-1-2 Equipment

The projection sheath shall have been subjected to the initial projection Under Stress Test of paragraph 7-1-1. The test apparatus is shown in Figure 12.

7-4-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-4-1-4 Approach

One end of the projection sheath will be secured. A flat closed loop will be formed, with the fixed end under the loop. A hoop will secure the ends where they cross so that the loop cannot come undone, yet will still allow the sheath to slide. A force will be applied to the free end of the projection sheath at a tangent to the loop. The force will be applied such that it reaches 200 N (45 lb) in 5 seconds. The force will then be held for 10 seconds. The test will be repeated 10 times at the same place in the projection sheath.

7-4-1-5 Procedure

1) Arrange the projection sheath on the test apparatus with a loop 500 mm in diameter as shown in Figure 12. The fixed end of the sheath must be on the under side of the loop.

2) Close the clamping hoop over both ends of the sheath where they cross in the loop so that the sheath can still slide, yet the loop cannot become undone.

3) Secure the exposure device using the mounting fixture and attach the projection sheath to the exposure device. Attach the other end of the projection sheath to the tensile test apparatus.

4) Apply a force to the sheath so that the force reaches 200 N (45 lb) in 5 s. Maintain the force for 10 s.

5) Record any observations including the final diameter of the loop in the Projection Sheath Kinking Test Data Sheet in Appendix A. Attach the force measurement plot to the data sheet. Mark the sheath to indicate the location where the test was performed.

6) Repeat steps 1 to 5 with the loop always at the same location on the sheath until 10 tests have been performed.

7-4-1-6 Data and Results

All observations shall be recorded on the data sheet provided. The force measurement will be recorded automatically and a printout for each trial will be included with the results. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-4-2 Crushing Test

7-4-2-1 Purpose

The purpose of this test is to demonstrate that the projection sheath can withstand the stress of the heel of a 100 kg person impacting at a horizontal and vertical speed of 0.8 m/s.

7-4-2-2 Equipment

The projection sheath shall have been subjected to the Kinking Test of paragraph 7-4-1. The test apparatus is shown in Figure 10.

7-4-2-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

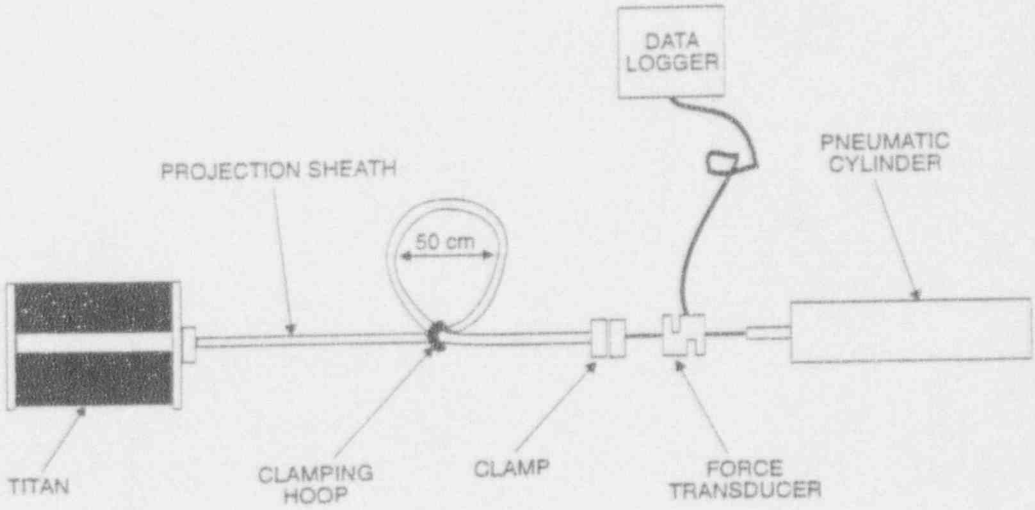

Figure 12
Projection Sheath Kinking Test

7-4-2-4 Approach

The apparatus to be used for the test is shown in Figure 10. The mass of the heel and crank shall be 15 kg. The heel will be dropped from a height of 300 mm. The test will be repeated 10 times at different locations along the sheath.

7-4-2-5 Procedure

1) Arrange the equipment as shown in Figure 10.
2) Raise the arm and verify that the height between the sheath and the heel is 300 mm.
3) Release the arm and allow the heel to swing freely down onto the sheath.
4) Record any observations on the Crushing Test Data Sheet in Appendix A. Mark the sheath to indicate where the test was performed.
5) Repeat steps 1 to 4 at 10 different points along the sheath, one of which shall include a connection.

7-4-2-6 Data and Results

The observations will be recorded on the data sheet provided. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-4-3 Tensile Test

7-4-3-1 Purpose

The purpose of this test is to demonstrate that the projection sheath can withstand the tensile forces that may be encountered during use.

7-4-3-2 Equipment

The projection sheath shall have been subjected to the Crushing Test of paragraph 7-4-2. The test apparatus is shown in Figure 11.

7-4-3-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-4-3-4 Approach

The projection sheath will be connected to the exposure device and the exposure device will be fixed so that it cannot move during the test. A tensile force of 500 N (112 lb) will be applied to the sheath for 30 seconds. The test will be repeated 10 times.

7-4-3-5 Procedure

1) Secure the exposure device as shown in Figure 11.
2) Connect the projection sheath to the exposure device.
3) Connect the tensioning apparatus to the opposite end of the projection sheath using the clamp adaptor.
4) Apply a load of 500 N (112 lb) for 30 s.
5) Record any observations. Plot the force profile from the data logger and include it with the results.
6) Repeat steps 4 and 5 until 10 tests have been performed.

7-4-3-6 Data and Results

The observations will be recorded and each test will be video taped. The measured force profile will be plotted and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-5 Tests On The Source Assembly

7-5-1 Tensile Test

7-5-1-1 Purpose

The purpose of this test is to demonstrate that the source assembly can withstand the tensile forces that may be encountered during use.

7-5-1-2 Equipment

The source assembly shall have been subjected to the Projection Under Stress Test of paragraph 7-1-1.

7-5-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-5-1-4 Approach

A control cable will be attached to the source assembly and the opposite end of the source assembly will be fixed. A tensile force will be gradually applied to the control cable so as to attain a load of 1000 N (225 lb) after 10 seconds. The force will be maintained for 30 seconds. The test will be repeated 10 times.

The largest diameter of the locking ball will be fixed and the testing will be repeated.

7-5-1-5 Procedure

1) Measure the length of the source assembly. This must be done using a calibrated instrument. Record the measurement and the calibration date of the measuring device. Take a magnified photo of the source assembly and connector.

2) Attach a control cable connector to the source assembly.

3) Secure the opposite end of the source assembly (i.e., the capsule) using the source clamp provided.

4) Apply a tensile force gradually to the cable connector so as to reach 1000 N (225 lb) after 10 s.

5) Maintain this force for 30 s.

6) Record any observations on the Source Assembly Tensile Test Data Sheet in Appendix A. Plot the force profile from the data logger and attach the plot to the data sheet. After the testing, take a magnified photo of the source assembly connector.

7) Repeat steps 4 to 6 until 10 tests have been performed.

8) Repeat steps 3 to 7 with the locking ball secured.

7-5-1-6 Data and Results

The observations will be recorded on the data sheet provided. Each test will be video taped and the test setup will be photographed. The source assembly shall not show an elongation of more than 1% of its length.

8 REFERENCES

1) ANSI N432 "Radiological Safety for the Design and Construction of Apparatus for Gamma Radiography", August 1980

2) ANSI N43.9 "Gamma Radiography - - Specifications for Design and Testing of Apparatus", October 1991.

3) Title 10, Code of Federal Regulations, Nuclear Regulatory Commission, Part 34 - Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations.

4) Title 10, Code of Federal Regulations, Nuclear Regulatory Commission, Part 71 - Packaging and Transportation of Radioactive Material.

5) TR-9240-N990, Safety Analysis Report for the Titan Radiography Device, Nordion International Inc.

6) Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990), IAEA Safety Series No. 6, IAEA, Vienna, 1990.

7) Transport Packaging of Radioactive Materials Regulations, Atomic Energy Control Act, SOR/91-304, 9 May 1991.

8) IS/QP 0052 N990, Quality Plan for the Nordion Titan Gamma Radiography Exposure Device.

APPENDIX A

Test Data Sheets

Projection Under Stress Test Data Sheet

Date ________________________ Torque Meter Model ________________________

Calibration Date ________________________ Torque Meter Serial Number ________________________

Trial Number	Maximum Torque Reading (N·m)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Has the equipment under test been subjected to the tests for conditions of normal use? Y ☐ N ☐

Test By ________________________ Witness ________________________

Project Engineer ________________________

C990 Source Assembly Tensile Test Data Sheet

Source Assembly Serial No. ____________________

A. **Initial Measurement**

Micrometer Model No. ________________

Serial No. ____________________

Calibration Due Date ______________________________

Initial Length ____________________

Test Engineer or Technician _________________________ Date _________________________

B. **Additional Testing**

Was any additional testing performed on source assembly (e.g., endurance testing)? Y ☐ N ☐

If yes, indicate details of test (e.g., endurance test, date, first cycle no., last cycle no.)

____

____

____

C. **Tensile Test**

Force Transducer Model No. _____________

Serial No. ____________________

Calibration Due Date ______________________________

Test Force ____________________ N

Test Duration ________________ s
(Attach a plot of the force measure⁻ .ent)

Test Engineer or Technician _________________________ Date _________________________

D. **Final Length Measurement**

Micrometer Model No. ________________

Serial No. ____________________

Calibration Due Date ______________________________

Final Length ____________________

Test Engineer or Technician _________________________ Date _________________________

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials

Radiation Shielding Test Data Sheet

Serial Number ______________________ Date ______________________

The device has been subjected to the following tests: ______________________

____

____

____

C990 Serial No. ______________________

Activity of test source at 1 m = 0 ______________________ R/h

divided by 0.55 R/h-Ci = ______________________ (curie content)

divided by 120Ci = ______________________ (extrapolation constant)

Maximum measured dose rates:

at 5 cm = ______________________ (a)

at 1 m = ______________________ (b)

Calculated dose rates

(a) divided by extrapolation constant = ______________________ at 5 cm

(b) divided by extrapolation constant = ______________________ at 1 m

Victoreen Model 471 Survey Meter

Serial Number ______________________ Calibration Due Date ______________________

Surveyor ______________________ QA Witness ______________________

Test Engineer __________ ______________________ Project Engineer ______________________

Horizontal Shock Test Data Sheet

Titan Serial Number ______________________ Date ______________________

Orientation

Trial Number	Observations
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

Test Engineer ______________________ QA Witness ______________________

Project Engineer ______________________

Penetration Test Data Sheet

Impact Area	Observations
bottom of the exposure device	
side of the exposure device	
front of lock	
side of lock	

Date ____________________ Test Engineer ____________________

QA Witness ____________________ Project Engineer ____________________

Nordion Titan Radiation Survey Data Sheet

Titan Serial Number ______________________ Victoreen 471 Serial Number ______________________

Date ______________________ Calibration [illegible] Date ______________________

Radiation Survey Readings in mrem/h											
Position Readings at 5 cm from surface	1	2	3	4	5	6	7	8	9	10	11
	12	13	14	15	16	17	18	19	20	21	22
	23	24	25	26	27	28	29	30	31	32	33
	34	35	36	37	38	39	40	41	42	43	44
	45	46	47	48	49	50	51	52	53	54	55
	56	57	58	59	60	61	62	63	64	65	66
	67	68									
Readings at 1 m	Top		Bottom		Right		Left		Front		Back

Note:

The meter on the surface is actually measuring the value approximately 5 cm from the surface (1 mrem/h = 10 usv/h)

Source Activity ______________________

Surveyor ______________________ Test Engineer ______________________

QA Witness ______________________ Project Engineer ______________________

Crushing Test Data Sheet

Device under test ______________________

Trial Number	Location of Impact	Observations
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Date ______________________ Test Engineer ______________________

QA Witness ______________________ Project Engineer ______________________

Remote Control Kinking Test Data Sheet

Date ______________________________

Trial Number	Minimum Speed (ft/s)	Average Speed (ft/s)	Maximum Speed (ft/s)	Observations
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Test Engineer ______________________________ Witness ______________________________

Project Engineer ______________________________

Projection Sheath Kinking Test Data Sheet

Trial Number	Observations (attach the force measurement plot)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Force Transducer Model No. ______________________ Serial No. ______________________

Calibration Due Date ______________________

Date ______________________ Test Engineer ______________________

QA Witness ______________________ Project Engineer ______________________

APPENDIX B

Special Form Radioactive Material Test Summary

Certificate, Sealed Source Classification
Designation and Performance (ANSI N542-1977)

SPECIAL FORM RADIOACTIVE MATERIAL TEST SUMMARY

The capsule model specified herein has been evaluated in accord with the International Atomic Energy Agency (I.A.E.A.) Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1985 Edition, Section VI, paragraphs 604-613 and 618.

TEST SUMMARY NO: 25

DATE: 1992 July 20

CAPSULE MODEL: C-990

CONTENTS: Iridium-192

DRWG NO: K122213-600

CAPSULE MATERIAL: 316L Stainless Steel

OVERALL DIAMETER: 0.187 inches

ENCAPSULATION: Single

OVERALL LENGTH: 0.775 inches

SPECIAL FORM REQUIREMENTS (1)

TEST	PASS	FAIL	METHOD	REMARKS
IMPACT (607)(618)	X		Comparison	Comments below
PERCUSSION (608)	X		Comparison	Comments below
BENDING (609)			Not required	
HEAT (610)	X		Comparison	Comments below
LEACHING (612)(613)	X		Comparison	Comments below

(1) See special form requirements on reverse side

COMMENTS:
The C-343 has been tested and has passed all Special Form tests, and has been certified to meet the requirements for Special Form via Certificate CDN/0001/S. Since the containment system for the C-990 is identical to the C-343, the C-990 also meets the requirements for Special Form.

This summary verifies that the described capsule model meets the requirements of Special Form in accord with the I.A.E.A. Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1985 Edition, Section VI, paragraphs 604-613 and 618.

Tested by M. Krzaniak, P.Eng. [signature]
Title Development Officer
Date 92/07/21

Authorized G.A. Burbidge [signature]
Title Manager, Package Engineering
Date 92/07/30

NORDION INTERNATIONAL INC.

CERTIFICATE

SEALED SOURCE
CLASSIFICATION DESIGNATION AND PERFORMANCE

Sealed sources are classified in accord with standards established by
THE AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) and
THE INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

CERTIFICATE NO: 76
DATE: 92 August 20
CAPSULE MODEL: C-990
CONTENTS: Iridium-192
DRWG. NO: K122213-600
CAPSULE MATERIAL: 316L Stainless Steel
OVERALL DIAMETER: 0.187 inches
ENCAPSULATION: Single
OVERALL LENGTH: 0.775 inches

ANSI CLASSIFICATION AND PERFORMANCE STANDARD (1) — **ANSI 77** C43515

CLASSIFIED PERFORMANCE STANDARD (2)

TEST	CLASS	METHOD	REMARKS
TEMPERATURE	4	Comparison	Pass (See Comments)
EXTERNAL PRESSURE	3	Comparison	Pass (See Comments)
IMPACT	5	Comparison	Pass (See Comments)
VIBRATION	1	No Test Reqd.	
PUNCTURE	5	Comparison	Pass (See Comments)

(1) See definition on reverse side
(2) See Table 1. Performance Standards on reverse side
(3) American National Standard N542-1977 is a revision of ANSI N5.10-1968

COMMENTS: The C-343 sealed source has been tested and found to meet the performance requirements of ANSI N542-1977 classification C43515. Since the containment system for the C-990 as identical to the C-343, the C-990 meets the same performance requirements.

It is hereby certified that the described sealed source meets the specified standard as prescribed in (3) American National Standard N542-1977 "Sealed Radioactive Sources, Classification". This standard complies with the classification and performance requirements of ISO 2919-1980(E).

Tested by M. Krzaniak, P.Eng.
Title Development Officer
Date [signature] 92/08/25

Authorized G.A. Burbidge
Title Manager Package Engineering
Date [signature] 92/08/25

NORDION INTERNATIONAL INC.

REFERENCES

[1] DEFINITION - CLASSIFICATION DESIGNATION:

The classification of a sealed source shall be designated by the code ANSI followed by two digits to indicate the year of approval of the American National Standard used to determine the classification followed by a letter and five digits.

The letter shall be either a C or an E. The letter C designates that the contained activity does not exceed the maximum levels established by ANSI. The letter E designates that the contained activity exceeds the maximum levels established by ANSI.

The first digit shall be the class number which describes the performance standards for temperature.

The second digit shall be the class number which describes the performance standards for external pressure.

The third digit shall be the class number which describes the performance standards for impact.

The fourth digit shall be the class number which describes the performance standards for vibration.

The fifth digit shall be the class number which describes the performance standards for puncture.

[2] TABLE 1 - PERFORMANCE STANDARDS:

TEST	CLASS						
	1	2	3	4	5	6	X
Temperature	No Test	-40°C (20 min) +80°C (1h)	-40°C (20 min) +180°C (1h)	-40°C (20 min) +400°C (1h) and thermal shock 400°C to 20°C	-40°C (20 min) +600°C (1h) and thermal shock 600°C to 20°C	-40°C (20 min) +800°C (1h) and thermal shock 800°C to 20°C	Special Test
External Pressure	No Test	25 kN/m² abs. (3.6 lbf/in²) to atmosphere	25 kN/m² abs. to 2 MN/m² (290 lbf/in²) abs.	25 kN/m² abs. to 7 MN/m² (1015 lbf/in²) abs.	25 kN/m² abs. to 70 MN/m² (10 153 lbf/in²) abs.	25 kN/m² abs. to 170 MN/m² (24 656 lbf/in²) abs.	Special Test
Impact	No Test	50 g (1.8 oz) from 1 m (3.28 ft) and free drop ten times to a steel surface from 1.5 m (4.92 ft)	200 g (7 oz) from 1 m	2 kg (4.4 lb) from 1 m	5 kg (11 lb) from 1 m	20 kg (44 lb) from 1 m	Special Test
Vibration	No Test	30 min 25 to 500 Hz at 5 g peak amp.	30 min 25 to 50 Hz at 5 g peak amp. and 50 to 90 Hz at 0.635 mm amp. peak to peak and 90 to 500 Hz at 10 g	90 min 25 to 80 Hz at 1.5 mm amp. peak to peak and 80 to 2000 Hz at 20g	Not Used	Not Used	Special Test
Puncture	No Test	1 g (15.4 gr) from 1 m (3.28 ft)	10 g (154 gr) from 1 m	50 g (1.76 oz) from 1 m	300 g (10.6 oz) from 1 m	1 kg (2.2 lb) from 1 m	Special Test

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REFERENCES

(1) DEFINITION - CLASSIFICATION DESIGNATION:

The classification of a sealed source shall be designated by the code ANSI followed by two digits to indicate the year of approval of the American National Standard used to determine the classification followed by a letter and five digits.

The letter shall be either a C or an E. The letter C designates that the contained activity does not exceed the maximum levels established by ANSI. The letter E designates that the contained activity exceeds the maximum levels established by ANSI.

The first digit shall be the class number which describes the performance standards for temperature.

The second digit shall be the class number which describes the performance standards for external pressure.

The third digit shall be the class number which describes the performance standards for impact.

The fourth digit shall be the class number which describes the performance standards for vibration.

The fifth digit shall be the class number which describes the performance standards for puncture.

(2) TABLE 1 - PERFORMANCE STANDARDS:

TEST	CLASS						
	1	2	3	4	5	6	X
Temperature	No Test	-40°C (20 min) +80°C (1h)	-40°C (20 min) +180°C (1h)	-40°C (20 min) +400°C (1h) and thermal shock 400°C to 20°C	-40°C (20 min) +600°C (1h) and thermal shock 600°C to 20°C	-40°C (20 min) +800°C (1h) and thermal shock 800°C to 20°C	Special Test
External Pressure	No Test	25 kN/m^2 abs. (3.6 lbf/in^2) to atmosphere	25 kN/m^2 abs. to 2 MN/m^2 (290 lbf/in^2) abs.	25 kN/m^2 abs. to 7 MN/m^2 (1015 lbf/in^2) abs.	25 kN/m^2 abs. to 70 MN/m^2 (10 153 lbf/in^2) abs.	25 kN/m^2 abs. to 170 MN/m^2 (24 656 lbf/in^2) abs.	Special Test
Impact	No Test	50 g (1.8 oz) from 1 m (3.28 ft) and free drop ten times to a steel surface from 1.5 m (4.92 ft)	200 g (7 oz) from 1 m	2 kg (4.4 lb) from 1 m	5 kg (11 lb) from 1 m	20 kg (44 lb) from 1 m	Special Test
Vibration	No Test	30 min 25 to 500 Hz at 5 g peak amp.	30 min 25 to 50 Hz at 5 g peak amp. and 50 to 90 Hz at 0.635 mm amp. peak to peak and 90 to 500 Hz at 10 g	90 min 25 to 80 Hz at 1.5 mm amp. peak to peak and 80 to 2000 Hz at 20g	Not Used	Not Used	Special Test
Puncture	No Test	1 g (15.4 gr) from 1 m (3.28 ft)	10 g (154 gr) from 1 m	50 g (1.76 oz) from 1 m	300 g (10.6 oz) from 1 m	1 kg (2.2 lb) from 1 m	Special Test

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PART 2. ASSESSMENT WITH RESPECT TO ANSI N432-1980 [2]

1.0 SCOPE

It is recognized that ANSI N432-1980 applies to the Titan.

2.0 DEFINITIONS

The terms defined in this section are used throughout this submission.

3.0 CLASSIFICATION

3.1 The Titan is a Class P exposure device. It is designed to be carried by one person.

3.2 The Titan allows the sealed source to move out into a working position. As such, it is a Type 1 exposure device.

3.3 The Titan uses a remote control cable. As such, it is a Type R exposure device.

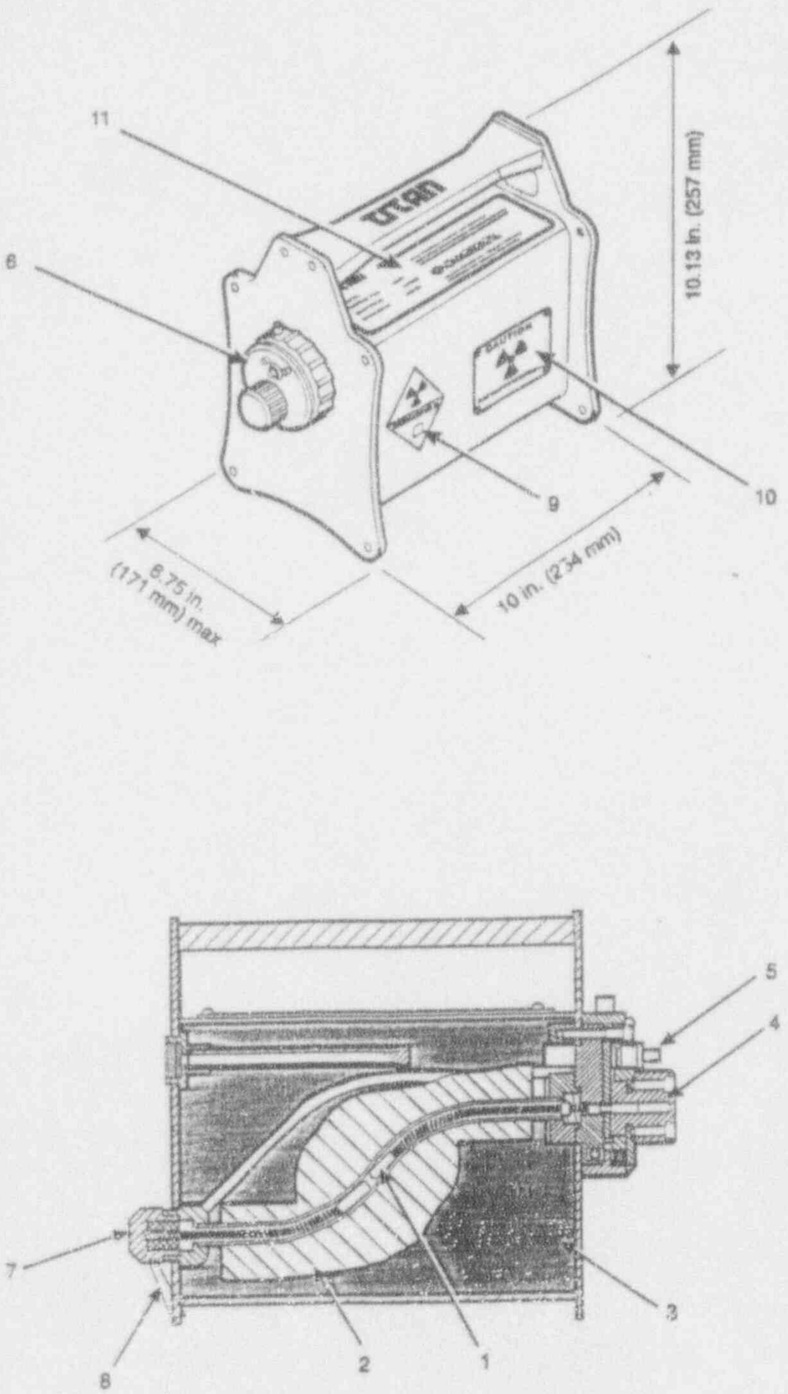
4.0 MARKING AND IDENTIFICATION

4.1 The Titan includes yellow plates embossed with the trefoil symbol and the words "CAUTION RADIOACTIVE MATERIAL". Two plates are located on opposite sides of the unit and are shown in engineering drawing F125401-013. The trefoil is magenta and greater than 25 mm in diameter. The words "RADIOACTIVE MATERIAL" are magenta and approximately 5 mm high.

It is submitted that this label clearly indicates the radiation hazard and that it satisfies the intent of this paragraph of the regulations.

4.2 The Titan is labelled with the manufacturer's name, model number, serial number, capacity and radionuclide. This identification label includes the weight of the depleted uranium shield and the mass of the unit without accessories. The label is shown in engineering drawing K122213-107 and in Figure 1.

Engineering drawing A17720 shows the Nordion plate that bears the chemical symbol and mass number of the radionuclide (Ir-192), its activity and the date on which the activity was measured, the model and serial number of the source assembly (C-990 No. XXXX), and the manufacturer of the sealed source (Nordion). Provisions are made to attach this label to the front of the Titan. (See engineering drawing K122213-501.)



Parts List

1. C-990 Sealed Source
2. Depleted Uranium Shield
3. Epoxy Foam
4. Bayonet End Cap
5. Push Button Lock (Shown in Unlocked Position)
6. Lock Assembly
7. Source Guide Tube End Cap
8. Wire Seal
9. Radioactive Category Label (2)
10. Radioactive Material Caution Plate (2)
11. Identification Plate

Notes

1. Meets Type B(U) Requirements
   AECB Certificate No: CDN/1038/B(U)-85
2. Gross Weight : 20kg (44lb)
3. Authorized Contents : 120 Ci (4.44 TBq) Ir-192
4. C-990 Meets IAEA Requirements for Special Form Radioactive Material (AECB Certificate No: CDN/0001/S)
5. Operated, maintained and prepared for shipment in accordance with Nordion Specification IS/OM 0090 N990.

Figure 1. The Titan Gamma Radiography Exposure Device

5.0 DESIGN AND CONSTRUCTION OF EXPOSURE DEVICES

5.1 General Requirements

5.1.1 a) The body of the Titan incorporates stainless steel and titanium components. Both materials offer excellent corrosion resistance under the conditions expected during use.

The robustness of controls and moving parts has been demonstrated through endurance testing as described in Appendix 4 and reference [5].

b) The entry of foreign matter into the unit is minimized by requiring the drive controls and the projection sheath to be securely mounted to the unit before an exposure can be completed. During transport, these openings are capped. (See the Titan User's Manual in Appendix 3.)

c) The external surfaces of the Titan are smooth and can be easily cleaned.

Cleaning of the S-tube is easily done by storing the source assembly in a source changer or other such location and passing cleaning materials through the unit. (See the TITAN User's Manual in Appendix 3.)

Cleaning the lock assembly requires the disassembly of the unit by authorized personnel. Plugs covering critical fasteners must be removed from the unit before such work can be undertaken. Instructions for performing this work are found in the Titan User's Manual.

d) The Titan has been designed for the conditions likely to be encountered during use. It is constructed from materials that do not break down in the -40° to 55° C temperature range.

Appendix 4 describes the tests completed at these two temperature extremes. 100 cycles were completed at -40° and 55° C. There were no significant findings.[5]

e) There are no materials that can be damaged by gamma radiation in close proximity to the C-990 sealed source.

f) The Titan is small and lightweight and can be easily strapped to working surfaces.

g) Fasteners are secured using semi-permanent adhesive material. This assures their ongoing effectiveness.
The performance of these fasteners during the tests for normal and accident conditions is described in reference [5]. They were found to pass a 20,000 cycle endurance test, as well as various drop tests for the normal and accident conditions of use.

5.1.1.1 Depleted uranium alloy U-0.75Ti is used as a shielding material. This alloy was chosen because of its excellent corrosion resistance and high density.

The casting is painted and further encased within an epoxy foam. No part of the shield is directly exposed to the environment.

The epoxy foam is further encased within a titanium shell. It is submitted that each of these barriers provide redundant protection to the DU casting and that they also adequately prevent the release of any corrosion products to the environment.

Regular inspection and maintenance according to the Titan User's Manual ensures that these barriers remain intact.

5.1.2 Locks

The design functions of the TITAN lock assembly are described in Appendix 2. There is no requirement for a separate padlock.

5.1.2.1 Dismantling the Lock Assembly requires caps to be removed from the outer plate. (See Appendix 3.) This makes it difficult for unauthorized personnel to remove the lock.

5.1.2.2 The lock assembly retains the C-990 in all positions except OPERATE. Its selector ring is equipped with a slot that uniquely accepts the C-990 end connector. It is impossible to move the source assembly as long as the Titan is in the locked position.

This safety feature is described in greater detail in Appendix 2.

The design of the Titan does not allow for the movement of the shield. It is a Type 1 exposure device.

5.1.2.3 The operation of the unit is described in Appendix 2. It is only possible to move into OPERATE mode if the push button lock has been unlocked using an external key. This operation cannot be completed using an easily available substitute for the key.

5.1.2.4 The selector ring includes a slot that uniquely accepts the C-990 end connector. This makes it impossible to move from the OPERATE into the LOCK position unless the C-990 is in its fully shielded position. Furthermore, motion from the OPERATE to the LOCK position requires the C-990 locking ball to trigger an actuator between the lock and the shield. This also requires the C-990 to be in its fully shielded position.

This safety feature is discussed in greater detail in Appendix 2.

5.1.2.5 The diameter of the C-990 locking ball is greater than the hole diameters of the actuator and the lock assembly. This makes it impossible for the C-990 to pass through the back of the Titan.

5.1.3 Connections

The remote control cable is attached using a bayonet connection. This connection is described in detail in Appendix 2 and provides a secure attachment point for the cable.

The projection sheath is securely attached using a threaded connection.

The two connections cannot be interchanged.

5.1.4 Tests

The Titan was tested in accordance with the test plan found in Appendix 4. As the Titan is a Type P device, all of the tests of Table 5.1 (ANSI N432-1980) were applied. The results are found in reference [5].

5.2 Additional Requirements for Class P Exposure Devices

The Titan is equipped with a handle that permits the carrying of the unit by hand. The handle is securely mounted to the unit using screws. The Titan can be safely hoisted using the handle.

Tests completed on the handle assembly include the wrench test described in Appendix 4 and the results are found in reference [5].

Calculations demonstrating the ability of the handle to withstand a 3 g snatch load are given in Appendix 5.

5.3 Additional Requirements for Class M Exposure Devices

The Titan is not a Class M device. Therefore, this paragraph does not apply.

6. Design and Construction of Controls

6.1 General Requirements

6.1.1 It is impossible to remove the drive control from the unit unless the source assembly is in the secure position. Rotation of the selector ring to the OPERATE position is only possible with the bayonet connector installed. As the selector ring rotates, a locking bar engages the bayonet connector, thus preventing the removal of the drive control, while the unit is in the OPERATE mode.

This safety feature is described in Appendix 2.

6.1.2 The markings on the remote control are shown in engineering drawing QRM064 and clearly indicate the direction of control movement to expose or retract the source.

6.1.3 The drive cable includes a stop to prevent disengagement from the drive.

6.1.4 To perform an exposure, the remote control must be connected to the Titan using the bayonet connector. If a secure connection is not made between the control cable and the source assembly, interference between the male connector on the teleflex cable and the bayonet connector prevents the bayonet connector from being installed in the lock assembly. This safety feature is described in Appendix 2.

6.1.5 The Titan controls do not operate with liquid, gas or vacuum. Therefore, this paragraph does not apply.

6.1.6 Full scale testing was used to qualify the remote controls. A description of the tests performed is provided in Appendix 4. The results of the tests are documented in reference [5]. The remote controls successfully completed the kinking, crushing, tensile and endurance tests specified in this paragraph of the regulations.

6.2 Additional Requirement for Local Controls

The Titan does not employ local controls. Therefore, this requirement does not apply.

7. Design and Construction of Source Assemblies

7.1 Appendix 6 shows that the C-990 sealed source meets the requirements of ANSI N542. Comparison with the C-343 sealed source is used to classify the C-990 as type ANSI77 C43515.

7.2 Full scale testing was used to demonstrate that the source capsule, locking ball and end connector connections withstand a tensile load greater than 890 N. The results are documented in reference [5].

7.3 The results of tensile and endurance tests on prototype C-990 assemblies are described in reference [5].

8. Tests

All of the tests required by the ANSI N432-1980 have been completed. The tests are described in Appendix 4. Test results are documented in reference [5]. They are also summarized in Table 1.

8.1 Shielding Efficiency Test

The results of the shielding efficiency tests can be found in reference [5] and Appendix 7. The critical requirement is the 50 mrem/hr radiation level 50 mm from the surface of the unit. The two prototypes were found to have radiation fields in excess of this limit. It is clear that about 1 to 2 mm of additional shielding is required over the surface of the unit. The net weight increase will be approximately 0.7 kg. (1.5 lb)

Nordion concedes that additional proof is required before full compliance with ANSI N432-1980 is demonstrated. New shields will be manufactured and surveyed as per the procedures described in Appendices 4 and 7. In the interim period, it is submitted that adding the amounts of depleted uranium specified in Figures 7 and 8 of Appendix 7 will enable the Titan to meet the shielding requirements of ANSI N432-1980.

The effect of the increase in unit weight has been considered in all of the tests for normal and accident conditions of handling and transport. In general, drop heights were increased by 5 % to account for the increased potential energy of the production units.

8.2 Horizontal Shock Test

The Titan was subjected to several horizontal shock tests in different orientations. In each case the unit was dropped from a height of 105 mm. This 5 % increase in drop height was used to offset the increase in unit weight expected from the shielding modification described in section 8.1.

Table 1. Summary of Tests [5]

Specimen	Test	Notes	Result
Entire Apparatus	Projection Under Stress Test	Initial test: peak torque = 24 in-lb	Pass
		Final test: peak torque = 28 in-lb	Pass
	Endurance Test	20,000 cycles. 11 problems related to Remote Control.	Pass
Exposure Device	Radiation Shielding Test	Initial test: more shielding needed.	Fail
		Final test (Post drop test)	Pass
	Horizontal Shock	6 orientations. Push-button lock deforms	Fail
		Retest with bumpers. Outer Plate deforms.	Fail
		Retest with new Cover Plate.	Pass
	Vertical Shock	100 impacts. No significant damage.	Pass
	Handle Wrench	1.1 m drop snatch. No significant damage.	Pass
	Penetration Test	4 impacts. No significant damage.	Pass
	Puncture Resistance	2 prototypes tested. No significant damage.	Pass
	Accidental Drop	2 prototypes, 3 orientations tested. No excessive increase in fields. No loss of containment.	Pass
Remote Control	Kinking	10 trials performed without incident.	Pass
	Crushing	10 trials performed without incident.	Pass
	Tensile	10 trials on sheath without incident.	Pass
		12 trials on cable. 1 failure of Source Assembly at 133%.	Pass
Projection Sheath	Kinking	10 trials performed without incident.	Pass
	Crushing	10 trials performed without incident.	Pass
	Tensile	19 trials performed in total 4 tests to failure: a) crimp failed at 113% b) crimp failed at 175% c) crimp failed at 165% d) crimp failed at 182%	Pass
Source Assembly	Tensile	20 trials performed on each of two source assemblies without incident.	Pass

Twenty shocks each were applied to the front of the lock assembly, the front source guide tube end cap, the side of the source guide tube end cap, the side of the titanium shell and the bottom of the shell at the weld. There were no significant findings for the latter four orientations. However, after the initial 20 shocks on the lock assembly, the push button lock was damaged and inoperable.

A design modification incorporating two bumpers on either side of the lock was implemented and tested. The push button lock survived, but burrs and internal deformation made the lock assembly inoperable. Further design modifications to the internal components resolved this problem. Twenty final impacts were completed on the front and side of the lock assembly. The lock assembly was fully operational at the conclusion of the test.

The design modifications and test results are described in detail in reference [5]. All changes were implemented under Nordion Drawing Change Request (DCR) number 2767.

8.3 Vertical Shock Test

A Titan prototype was subjected to 100 vertical drop tests in accordance with the requirements of paragraph 8.3.2 of the regulations. The drop height was increased to 160 mm to offset the 5 % weight increase expected as a result of the shield modifications discussed in section 8.1. The test procedure is described in Appendix 4 and the results are discussed in reference [5]. There was no significant damage.

8.4 Accidental Drop Test

Two Titan prototypes were subjected to a total of three one meter pin drops and three 9 meter drop tests. These are termed drops 1 through 6 respectively and the orientations are summarized in Table 2 and reference [5]. Three pin drops were required as the lock assembly had only slight contact with the pin during the first drop. Thus drop 1 was repeated in the same orientation.

Table 2. Drop Test Orientations

Drop Number	Drop Height	Orientation
1	1.05 meter onto pin	Aligned with lock assembly. Titan serial 002.
2	1.05 meter onto pin	Aligned with lock assembly. Repeat of Drop 1 using Titan serial 002.
3	1.05 meter onto pin	Aligned with lock assembly. Titan serial 003.
4	9.45 meter	Upright using serial 002.
5	9.45 meter	Top front corner, using serial 002.
6	9.45 meter	Onto lock assembly using serial 003

NOTE: The units were dropped from a 5 % greater height to offset the increase in weight required to pass the shielding test. However, the following analysis still refers to these drops as 1 m and 9 m drops even though the drop heights were 1.05 and 9.45 m respectively.

In each pin drop the unit was oriented such that the primary impact would be on the lock assembly. This was judged to be the most damaging orientation because of the following:

1) It directly affects the shielding system. Damage to the lock assembly has the potential to release the C-990 source assembly.

2) The light weight of the unit implies little damage to the external titanium shell. This can be justified by considering the following:

a) There was relatively little damage resulting from drop 1.(See reference [5].) Damage was limited to some bending of the front plate of the unit.
b) There was relatively little deformation to the shell as a result of the much more severe 9 meter corner and end drops.
c) There was very little damage to the shell as a result of the horizontal shock test and the penetration test. The larger diameter of the pin used for the pin drop spreads the load over a larger area than the pins used in the horizontal shock and penetration tests. Therefore, less damage to the shell is expected from the pin drop.

The pin drop was completed prior to the 9 meter drop as this sequence of tests is more damaging. Damage to the lock assembly resulting from the pin drop could weaken the unit for the more severe 9 m drop, increasing the risk of loss of the lock assembly.

The three drop orientations for the 9 m drops were judged to bound all drop orientations while providing objective evidence of the ability of the package to survive full scale drop tests. The orientations were chosen on the basis of the fact that they would cause the maximum shield shift and the most damage to the lock assembly. The goals were to demonstrate that the worst case shift of the shield would continue to satisfy the requirements of the regulations and to show that the lock assembly will retain the C-990 under direct loading.

The orientations were chosen on the following bases:

1) The upright drop imparts relatively high inertial loads to the unit and tends to force the shield through the base of the unit.
2) The top front corner drop provides the least surface area and hence results in the greatest deformation.
3) The combination of the upright and corner drops on a single unit bounds the damage expected from any single drop. While this is difficult to justify analytically, it is reasonable to assume that two drops in two different orientations are worse than any one single drop onto any part of the titanium shell. The damage to the epoxy foam during the first drop lessens the support offered to the depleted uranium during the second. As such, it will experience a greater shift as a result of the

combined drops. This can be partially justified by comparing the results of drops 4 and 5 to drop 6. The shield shifted approximately 5 mm as a result of the combined drops, whereas there was negligible shift as a result of drop 6. (See reference [5].

4) The only time appreciable stresses are imparted to the lock is during a direct impact. Therefore, the worst damage to the lock assembly results from a drop directly onto it.

5) The only time significant stresses are imparted to the C-990 is during a direct impact onto the lock. The light weight of the C-990 combined with the flexibility of the teleflex cable make it impossible to damage the source containment system. The only way to damage the source assembly is to damage the portion in contact with the lock. Since the lock only sees appreciable stresses during a direct impact, the only time the C-990 can be damaged is during a drop onto the lock.

The results of the drop tests are described in reference [5]. Radiation surveys completed after the drop showed a maximum radiation field of 1500 mrem/hr on contact with the lock after extrapolation to a 120 Ci source. (See reference [5].) Using the inverse square law, the field 1 m from the lock is estimated to be 19 mrem/hr, which is substantially less than the 1000 mrem/h allowed by the Regulations.

The only significant damage observed was the shift of the radiation shield in serial number 002. It was found that, after all drops had been completed, the shield shifted about 5 mm (0.2 in) during the drops. This is significant as any movement outside of the lock assembly decreases the support offered to the shield in the subsequent fire test. Since the drop test, the design has been modified to allow for greater engagement of the S-tube within the exit port and the actuator block. (The engagement has been increased from 6.4 mm (0.25 in) to 9.5 mm (0.375 in).) This provides an additional safety margin to the design. It is submitted that the revised design will shift less than 5 mm for the following reasons.

1) Serial 002 was subjected to two 1.05 m drops and two 9.45 m drops. The observed 5 mm shift was at least partially due to the cumulative damage resulting from the two 9.45 m drops. A single drop will result in less than 5 mm shift.

This can be partially justified by considering the results of the radiation surveys. Unit 003 had negligible shield shift as its radiation fields were lower than those of unit 002. (See reference [5].)

2) The increase in engaged length provides additional support against lateral motion.

This change has been implemented under Nordion Drawing Change Request (DCR) number 2767. It improves the safety of the package relative to the tests completed on prototype units.

8.5 Kinking Test

The drive controls were subjected to the kinking test according to the test procedure found in Appendix 4. The results are found in reference [5]. There was no significant damage.

8.6 Crushing Test

The drive controls were subjected to the crushing test according to the procedure found in Appendix 4. The results are found in reference [5]. Damage was limited to dents where the heel contacted the cable. However, the torque required to drive the source out to the working position and back was unchanged and within reasonable limits.[5]

It should be noted that the source guide tubes were also subjected to this test with similar results.

8.7 Tensile Test for Controls

The drive controls were subjected to tensile tests as described in Appendix 4. The test results are summarized in reference [5]. There was no significant damage.

8.8 Tensile Test for Source Assemblies

Prototype source assemblies were subjected to the tensile test described in Appendix 4. The results are found in reference [5]. There was no significant damage.

8.9 Endurance Test

A 20,000 cycle endurance test was completed on Titan serial 002. There were no failures in the projector but there were a few incidents with the peripheral equipment attributed to the harsh test conditions. A substantial discussion on the test procedure and its results can be found in reference [5].

APPENDIX 1. Selected Engineering Drawings

The following engineering drawings are referenced in Part 2 of this submission. Current issues are included for reference.

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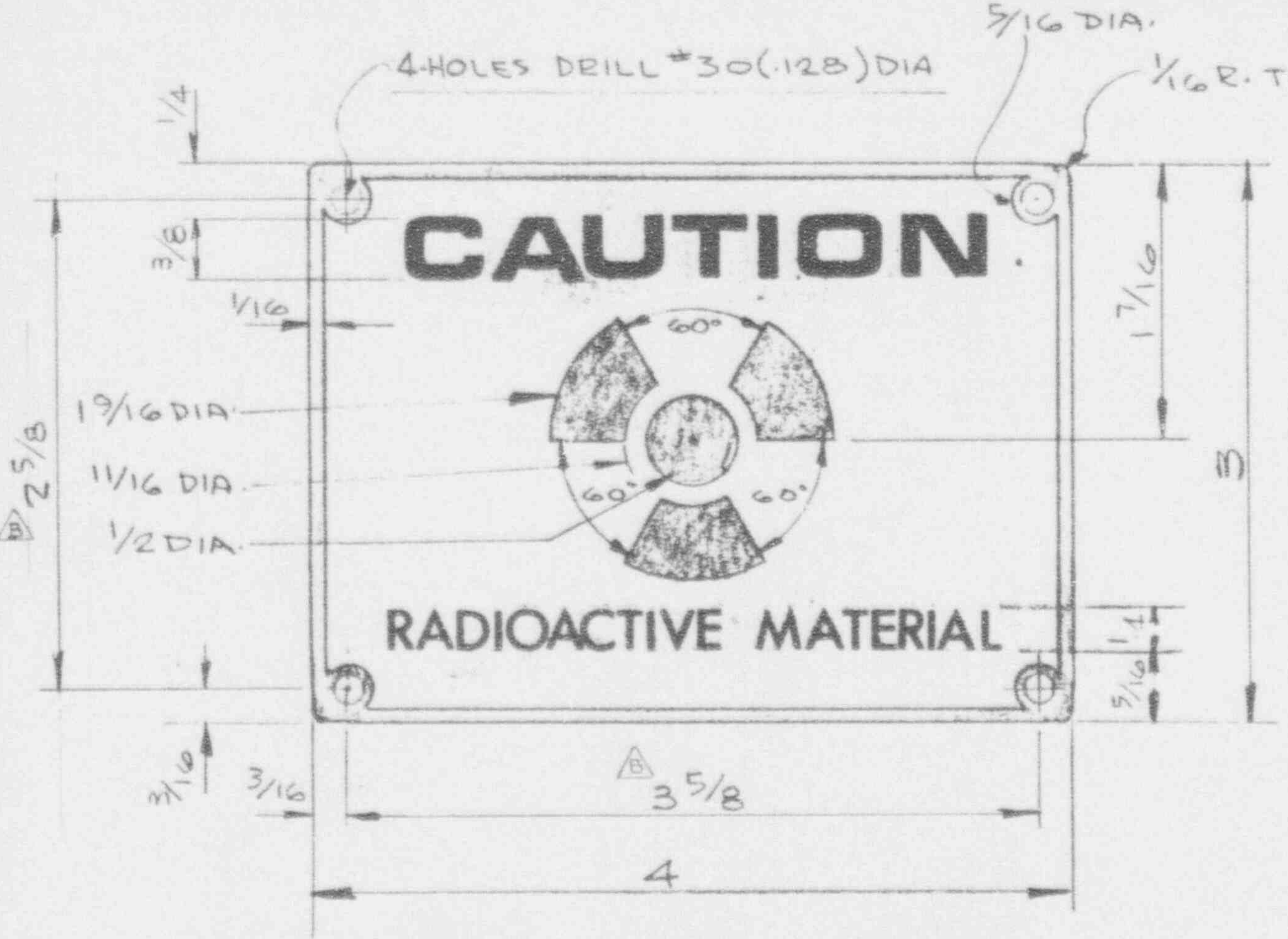
K122213-107 rev. A
K122213-501 rev. 1
K122213-600 rev. D
A17720 rev. E
QRM064 rev. 0



NOTES

1.- EMBOSSED STAINLESS ST'L NAME PLATE 4×3×.020 LETTERING & SYMBOL ENAMELLED MAGENTA & EMBOSSED, BORDER ENAMELLED MAGENTA. ALL ON YELLOW ENAMEL BACKGROUND

2.- NORDION STORES CODE No. 6A001388

ISSUE	DESCRIPTION	DATE	BY	APP
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A	ORIG. ISSUE TICK - 3117	—	—	—

NORDION INTERNATIONAL INC.

REQUIRED FOR: F125401.001

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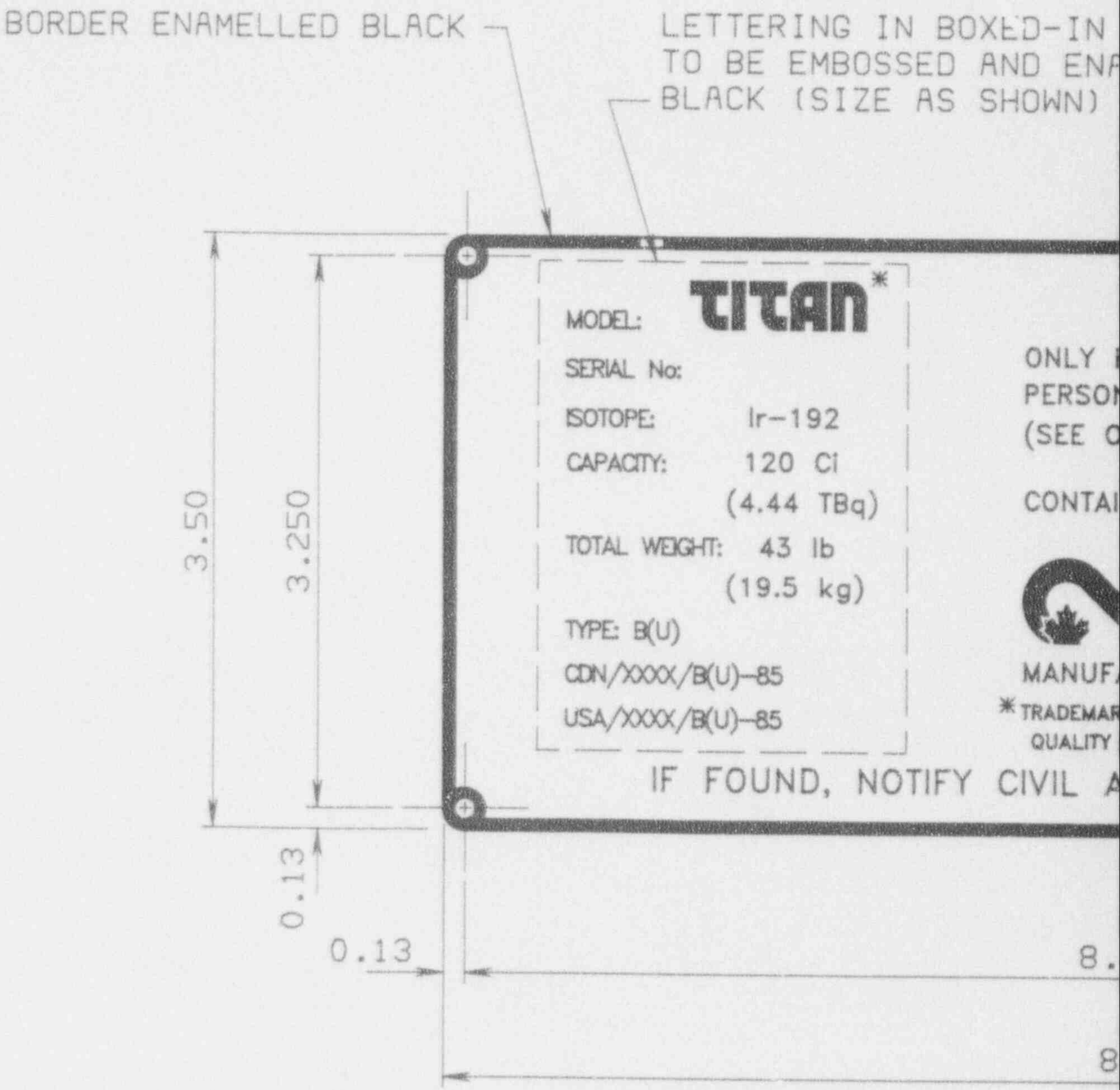
DATE: DEC-12-75
DRAFTING APP'L
MECH ENG | ELECT ENG | CIVIL ENG | PHYSICS | ENG APPR'L

MAT'L & SPEC: STAINLESS ST'L TYPE 304 .020
FINISH: —
CODE NO

SCALE: 1/1
TOLERANCES: ± 1/64 FRACTION | ± — DECIMAL | ± 1° ANGULAR

TITLE: RADIOACTIVITY CAUTION PLATE

DRAWING NUMBER: F 1 2 5 4 0 1 0 1 3 — ISSUE: B



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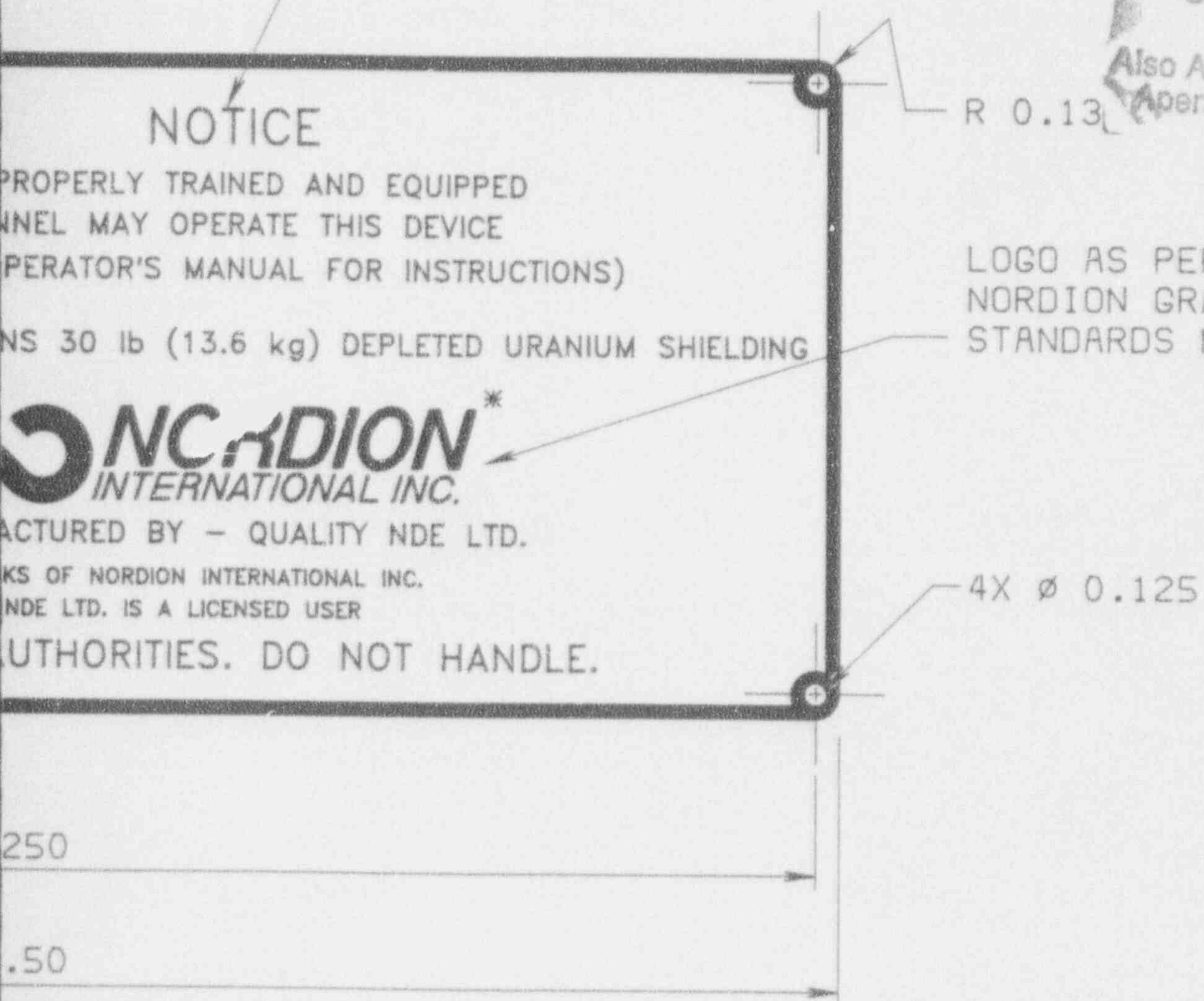

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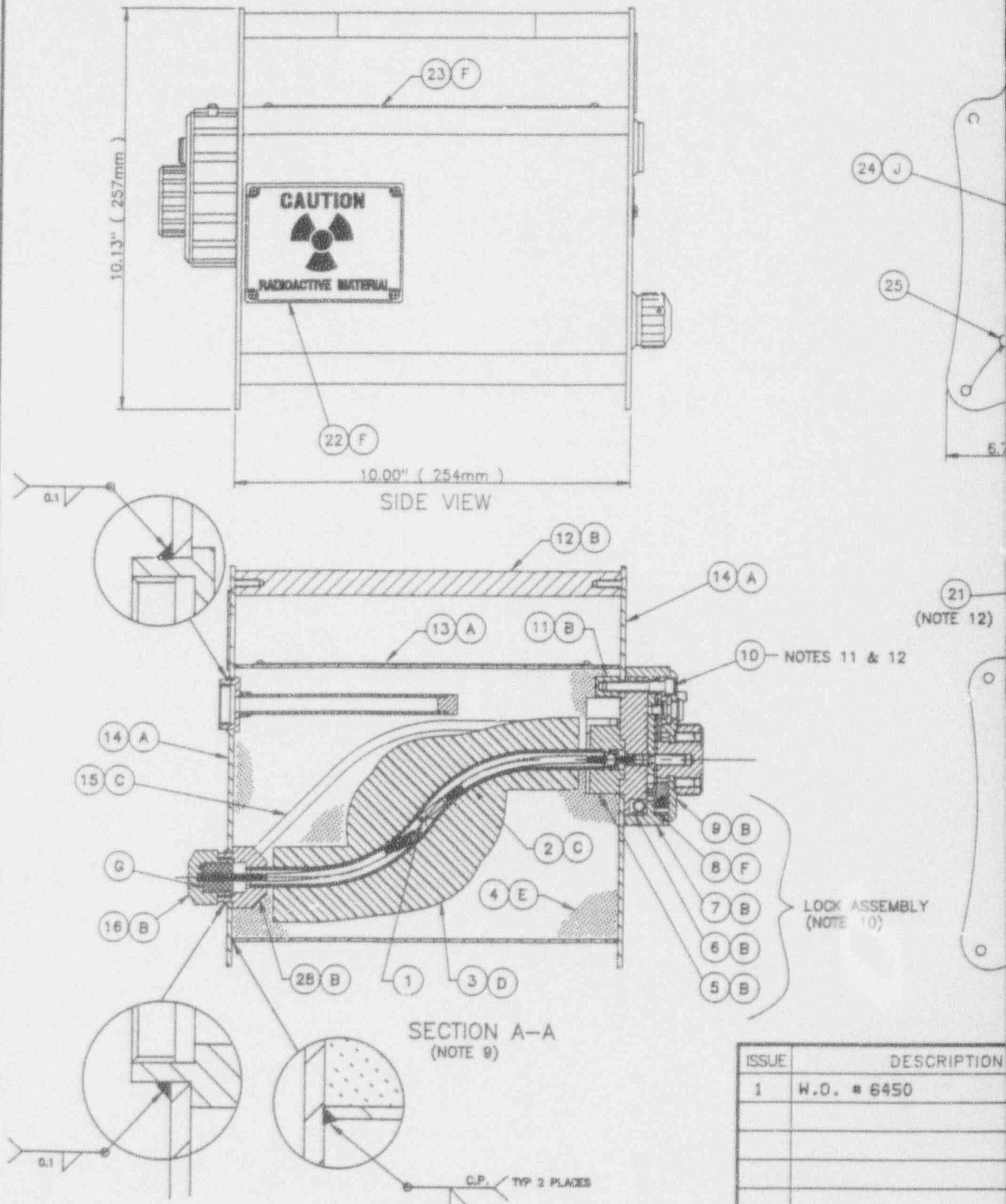

ISSUE	DESCRIPTION
1	W.O. # 6450

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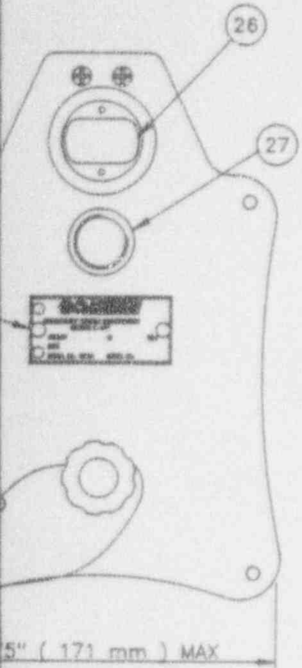
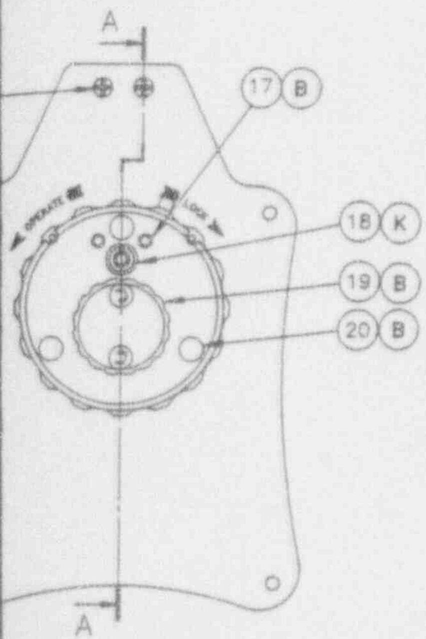


FRONT VIEW



BACK VIEW

NOTES :

1. GROSS WEIGHT – 44 lbs (20 Kg)
2. CAPACITY – 120 Ci (4.44 TBq) Ir-192
3. AECB PACKAGE DESIGN APPROVAL CERTIFICATE CDN/1038/8(U)-85
4. USNRC/USDOT CERTIFICATE USA/????/B(U)
5. C-990 SOURCE ASSEMBLY MEETS REQUIREMENTS FOR SPECIAL FORM RADIOACTIVE MATERIAL (AECB CERTIFICATE No CDN/0001/S
6. MANUFACTURE IN ACCORDANCE WITH NORDION SPECIFICATION IS/TS 0054 N990
7. OPERATED, MAINTAINED AND PREPARED FOR SHIPMENT IN ACCORDANCE WITH NORDION SPECIFICATION IS/OM 0090 N990
8. WELDING IN ACCORDANCE WITH ASME BPV CODE SECTION IX
9. ITEM (15) NOT SHOWN IN TRUE SECTION
10. LOCK ASSEMBLY INCLUDES SCREWS, SPRINGS AND STAINLESS STEEL PINS (NOT SHOWN)
11. TORQUED TO 80–90 in lbs
12. INCLUDES SEALANT

MATERIALS :

A. TITANIUM PLATE GRADE 2 (ASTM B-265)
B. TITANIUM BAR GRADE 2 (ASTM B-348)
C. TITANIUM TUBE GRADE 2 (ASTM B-338)
D. DEPLETED URANIUM (0.75% Ti – 18.6 g/cc DENSIT ,
E. RIGID EPOXY FOAM(0.2 – 0.25 g/cc DENSITY)
F. STAINLESS STEEL PLATE (ASTM A-240)
G. COMMON LEAD (ASTM B-29)
H. STAINLESS STEEL (ASTM A-320 GRADE B8 CLASS 2)
J. BRASS SHEET (ASTM B-36)
K. CAMLOC # PTCL 66-1R1N1AA

PARTS LIST :

1) C-990 SEALED SOURCE ASSEMBLY
2) S – TUBE
3) DEPLETED URANIUM SHIELD
4) EPOXY FOAM
5) ACTUATOR BLOCK
6) INNER PLATE
7) SELECTOR RING
8) COVER PLATE
9) OUTER PLATE
10) 0.25 – 20 UNC X 1.25 LONG SOCKET HEAD SCREW
11) THREADED BOSS
12) HANDLE
13) SHELL
14) END PLATES (2)
15) PROJECTION SHEATH INTERLOCK ASSEMBLY
16) SOURCE GUIDE TUBE END CAP ASSEMBLY
17) BUMPERS (2)
18) PUSH BUTTON LOCK
19) BAYONET END CAP
20) SCREW COVER
21) 0.190(#10)-32 UNC SCREWS
22) RADIATION CAUTION PLATES (2)
23) IDENTIFICATION PLATE
24) SOURCE IDENTIFICATION PLATE
25) WIRE SEAL
26) STORAGE RECEPTACLE FOR ITEM 19
27) STORAGE RECEPTACLE FOR ITEM 16
28) EXIT PORT

	DATE	BY	APPR

DRAWN: G. SHAW — DATE: 93oct13 — DRAFT. APPR'L: [illegible]

MK

MECH. ENG. | ELECT. ENG. | CIVIL ENG. | PHYSICS | ENG. APPR'L

MATERIAL

FINISH

NORDION INTERNATIONAL INC.
KANATA ONTARIO CANADA

TITLE: TITAN G.R.E.D. INFO. DRAWING

DION INTERNATIONAL ... ERATION ON THE ... NO EXPLOITATION ... EXCEPT WITH THE ... INTERNATIONAL INC.

USED ON

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES.
TOLERANCES: DECIMALS .XX ± .XXX ± ANGLES ±

THIRD ANGLE PROJECTION

SIZE: B — DWG. NO. K122213-501 — ISSUE 1

SCALE — SHEET 1 OF 1

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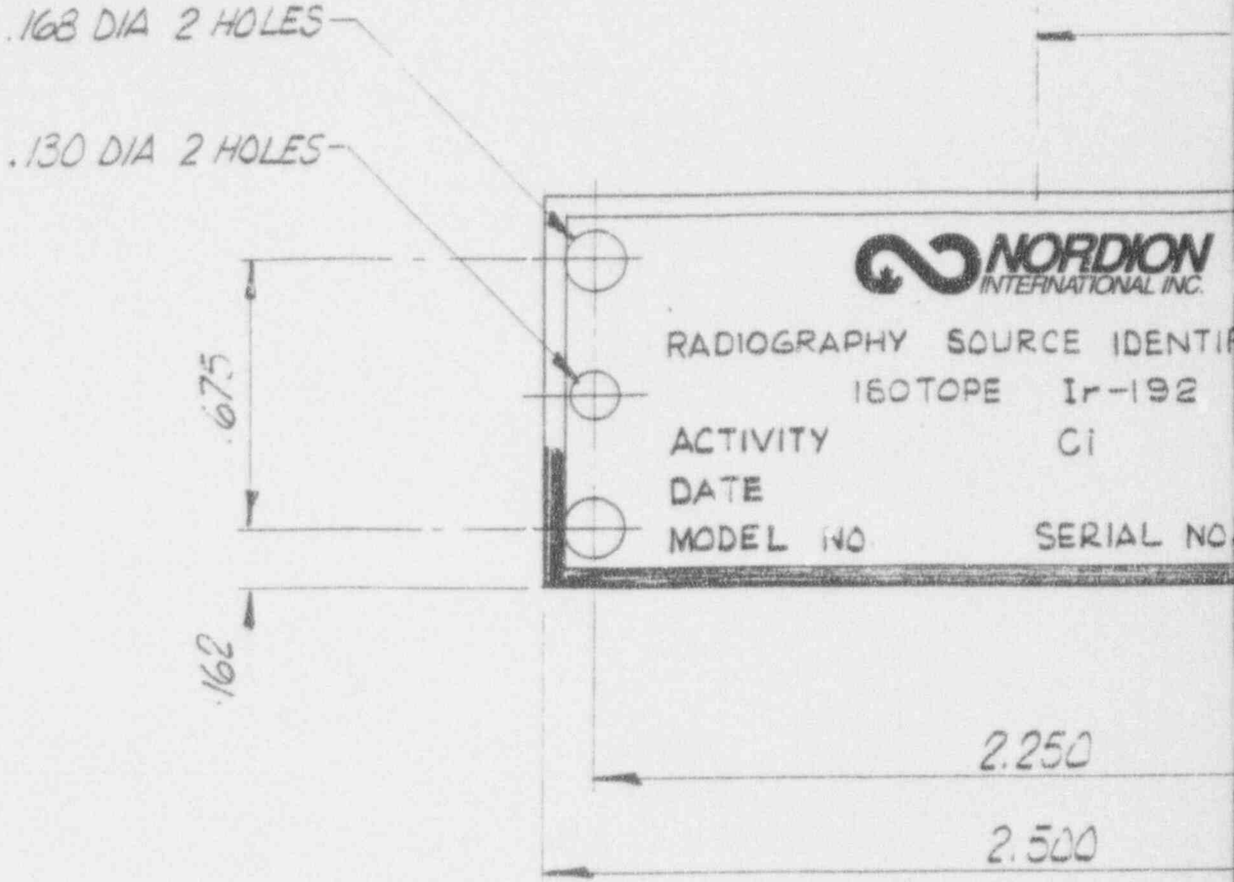

NOTE :-

1. BORDER, LETTERING & LOGO TO BE BLACK
2. LOGO TO BE CENTRED AS SHOWN
3. ALL LETTERING TO BE 8 PT HELVETICA
4. SPACE BETWEEN LINES .04
5. REMOVE BURRS & SHARP EDGES

ITEM NO	DRAWING NO.	PART

ISSUE	DESCRIPTION
	ORIGINAL ISSUE
D	REDESIGNED & NAME CHANG (W.O.
E	DCR # 2533

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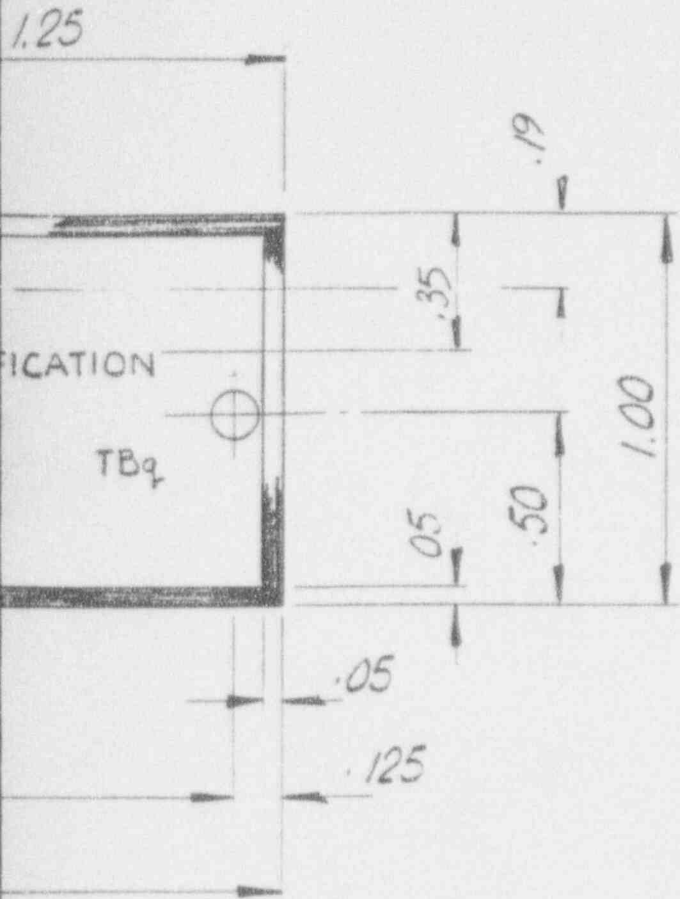

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NO.	ASSY	QTY	DWG SIZE	DESCRIPTION

PARTS LIST

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...ED (...149)	11JAN89	JRB	[illegible]
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DRAWN: MM — DATE: JULY 83 — CHECKED

TJS				TJS
MECH ENG	ELECT ENG	CIVIL EN...	PHYSICS	ENG APPR'L

MATERIAL: BRASS SHEET .032 THK ASTM B36-260

FINISH

CODE NO

NORDION INTERNATIONAL INC.
KANATA ONTARIO CANADA

TITLE: RADIOGRAPHY SOURCE TAG

...NAL INCOR... ...NDERSTAND... ...ATION CON... ...ONSENT OF

E K122213...

USED ON

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES

FRACTIONS	TOLERANCES: DECIMALS	ANGLES
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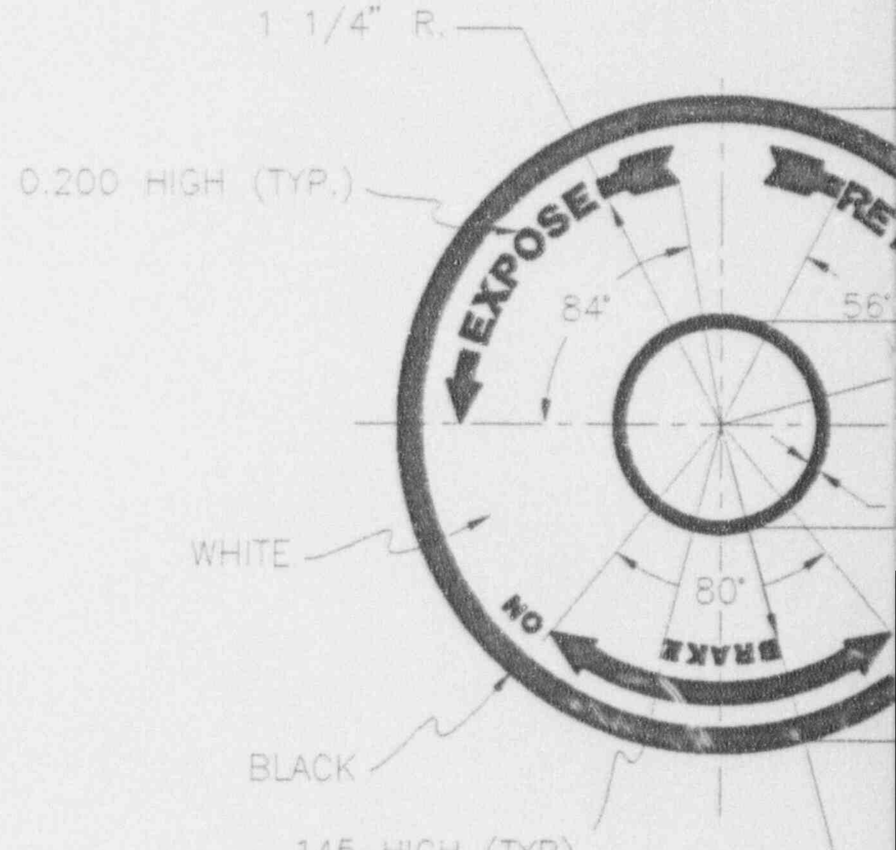
SCALE 2:1 — SHEET 1 OF 1



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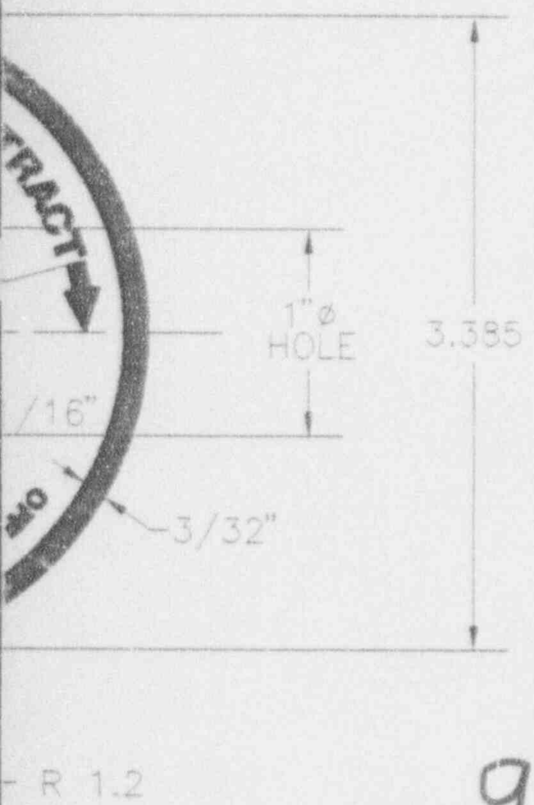

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BREAK ALL SHARP EDGES.

SIGNATURES		DA	MO	YR
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CHECKED	[signature]	10	05	93
ISSUED				
MFG				
QC				

MATERIAL: SCOTCH 3M 467MP HI PERF. ADHESIVE

FINISH:

TOLERANCES		
FRACTIONS	DECIMALS	ANGLES
± 1/64	.XX ± .01 .XXX ± .005	± .5

FOR: QME692

Quality NDE LTD.

TITLE: EXPOSE RETRACT LABEL

REV NO	DRAWING NO
0	QRM064

SCALE / ECHELLE:

SHEET NO. 1 OF 1

APPENDIX 2. OPERATION OF THE TITAN

A2.1 Overview

The Titan is shown schematically in Figure A2.1. It consists of a titanium shell, a lock assembly, an S tube cast within a depleted uranium (DU) shield, a C-990 sealed source assembly, and an exit port. Entries into the lock assembly and the exit port are sealed using end caps.

The lock assembly is shown in Figure A2.2 and consists of three main parts, the inner plate subassembly, the selector ring and the outer plate subassembly. The bayonet end cap is installed when the projector is not in use. The bayonet connector is used to attach the drive controls to the lock assembly.

At the start of an exposure cycle, the C-990 is secured in the S-tube, the selector ring is in the LOCK position, the bayonet and source guide tube end caps are installed, and the push button lock is engaged. This is termed transportation mode and in this configuration all requirements for the transport of radioactive materials are satisfied.

In transportation mode, it is impossible to remove the bayonet end cap. It is also impossible to turn the selector ring into the OPERATE position.

To perform an exposure, the radiographer unlocks the push button lock. This allows the bayonet end cap to be removed from the lock assembly and allows access to the C-990 end connector. (See Figure A2.3) The control cable is then connected to the C-990, and the bayonet connector is attached to the lock assembly. At this point, the remote control cable and the source assembly are fully connected. However, it is still not possible to move the selector ring into the OPERATE position. This action is prevented by an interlock with the projection sheath.

The source guide tube end cap is then removed and the projection sheath is attached. This releases the interlock and allows the selector ring to be turned counterclockwise into the OPERATE position. The motion is resisted by springs that bias the selector ring toward its LOCK position. Once the selector ring has been rotated into the OPERATE position, an actuator pin prevents the spring from returning the selector ring to the LOCK position.

In OPERATE, the sealed source is free to exit from the primary lock and the shield. The radiographer then uses the drive controls to project the source to the exposure site.

Once the exposure has been completed, the C-990 is retracted into the shield. As it approaches its secure position, its locking ball engages the actuator. This causes the actuator pin to disengage from the selector ring causing the ring to spring back into the LOCK position. This automatically secures the source assembly in the depleted uranium shield.

If additional exposures are planned, the selector ring is turned back into the OPERATE position and the cycle repeats. Otherwise, the drive controls and projection sheath are removed from the unit and replaced with the appropriate end caps, the push button lock is engaged and the wire seal is installed. This returns the unit to transportation mode.

A2.2 Design Principles for the Lock Assembly

This section describes the operation of the lock assembly in detail. The various lock components are shown in Figure A2.2.

A2.2.1 Design Principles for the Lock Assembly

The functions of the lock assembly are:

(a) To secure the source assembly in all positions except OPERATE.
(b) To prevent entry into the OPERATE position unless the control cable has been properly connected to the source assembly.
(c) To prevent entry into the OPERATE position unless the drive control has been installed.
(d) To prevent entry into the OPERATE position unless the projection sheath has been securely installed.
(e) To prevent the removal of the drive control while the selector ring is in the OPERATE position.
(f) To automatically lock the source assembly once it has returned from its working position.

Each of these functions is described below.

Securing the Source Assembly

The C-990 sealed source assembly is shown in Figure A2.3. It includes a two part end connector. The minor diameter of Item 8, the connector cap, is the smallest diameter along the entire length of the source assembly.

The C-990 is secured by the selector ring, which is shown in section in Figure A2.4. The smallest width in slot C aligns with the connector cap in all positions except OPERATE, and thus retains the source assembly. When the outer ring is in the OPERATE position, the source end connector is aligned with the hole at the end of slot C, and the C-990 is free to travel out into the working position.

Slot C is sized so that rotation of the selector ring from the OPERATE position to the LOCK position is only possible if the slot is aligned with the minor diameter of the connector cap. It is not wide enough to pass over the teleflex cable or any other part of the source assembly.

Preventing Operation if the Control is Improperly Installed

A secure connection between a male connector and the female C-990 connector is shown in Figure A2.5. If the male connector has not been securely connected to the female, the overall length of the connector assembly exceeds the length of a secure connection.

In order to turn the selector ring into the OPERATE position, the bayonet connector must be fully inserted into the lock assembly. An improper connection results in interference between the unconnected assembly and the bayonet connector, thus preventing the full insertion of the connector into the lock assembly. This makes it impossible to turn the bayonet connector and prevents operation if the control cable has not been securely connected to the source assembly.

Preventing Operation without the Drive Control

The lock is shown in section in Figure A2.6. (This section is different from the one shown in Figure A2.4.) It is prevented from moving into the OPERATE position by two interlocks. One of these interlocks is with the bayonet connector.

Movement into the OPERATE position can only be achieved if the cam follower pin is pushed into slot D. This only happens if the bayonet connector is inserted and rotated 90 degrees. Interference between the cam follower and the connector causes the follower to move radially outward against the action of a spring.

Only the bayonet connector can engage the cam follower. The bayonet end cap is similar to the bayonet connector. However, its smaller major diameter does not engage the cam follower. Thus, the cam follower is not pushed into slot D and the selector ring cannot be rotated into OPERATE.

Preventing Operation if the Projection Sheath is not Installed

The lock assembly includes an interlock with the projection sheath. The interlock is shown in Figures A2.1, A2.6 and A2.7. Rotation into the OPERATE position is prevented by the engagement of the interlock pin in slot B1. (See Figure A2.6.) The head of the pin is located in the outer plate subassembly and its tail extends through the selector ring and inner plate subassembly. The tail meets with a cable. (See Figure A2.7.) The other end of the cable is connected to a pin that projects into the exit port.

Installing the projection sheath depresses the pin which ultimately causes the interlock pin to disengage from slot B1. This allows the selector ring to be rotated into the OPERATE position.

The source guide tube end cap does not engage the pin in the exit port. This makes it impossible to reach the OPERATE position while the source guide tube end cap is installed.

Retention of the Drive Controls while in OPERATE

Figures A2.2 and A2.6 also shows a locking bar. Its function is to prevent the removal of the bayonet connector once the unit is in OPERATE mode.

The locking bar is related to slot E in the selector ring. (See Figure A2.6.) It is constrained to vertical motion by a slot in the outer plate. Rotation of the selector ring causes the locking bar to move upward. As soon as it leaves the lower position, the locking bar prevents the rotation of the bayonet connector. This prevents the removal of the drive controls from the lock assembly once the selector ring has been rotated into OPERATE.

Returning to the LOCK Position once the Source Assembly Returns

Rotation of the selector ring into OPERATE is resisted by springs. (See Figure A2.2.) The springs bias the ring toward LOCK.

Once the selector ring has been rotated into the OPERATE position, the actuator pin enters slot B2, and prevents the selector ring from returning to LOCK. (See Figure A2.6.) The head of this pin is within the outer plate and its tail extends through the selector ring and inner plate assembly to the actuator.

The tail of the pin can be engaged by a spring loaded actuator. (See Figure A2.2.) The actuator is biased toward the shield and the control cable moves freely through the actuator.

The C-990 source assembly includes a locking ball. Upon the return of the source to its shielded position, the locking ball engages the actuator. This causes the actuator to push the actuator pin out of slot B2. (See Figure A2.6.) This allows the springs to snap the selector ring into the LOCK position and secures the C-990.

A2.2.2 Design Principles for the Push Button Lock

The push button lock is an off-the-shelf component. It may be locked without the key. Its functions are:

a) To secure the bayonet end cap or the bayonet connector
b) While engaged, to prevent rotation of the selector ring into OPERATE
c) To enable the selector ring to be secured in its LOCK position at all times.

<u>Securing the Bayonet End Cap or the Bayonet Connector</u>

Engaging the push button lock causes a pin to enter through a lock pin and into the selector ring. (See Figure A2.6) The only time this can happen is when the locking pin is in its lower position. When the push button lock pin is installed through the locking pin, the locking plate cannot move.

The bayonet connector and the bayonet end cap have recesses that accept the locking pin. (See Figure A2.6.) If the locking pin is within the recess, neither connectors can be turned. Thus, with the push button lock engaged it is impossible to remove either the end cap or the bayonet connector.

Preventing Rotation into OPERATE while LOCKED

In addition to the interlock between the bayonet connector and the cam follower there is also an interlock between the push button lock and the selector ring. In its locked position, the push button lock pin engages a hole in the selector ring and prevents it from turning into the OPERATE position. (See Figure A2.6)

Enabling the Selector Ring to be Secured in the LOCK Position

In the event that both the bayonet end cap and bayonet connector are lost, it is still possible to secure the selector ring in the LOCK position. In this case, the lock pin is in its lower position and its hole is aligned with the push button lock. It is also aligned with the selector ring. This enables the push button lock to engage both the lock pin and the selector ring. This prevents the rotation of the selector ring into the OPERATE position.

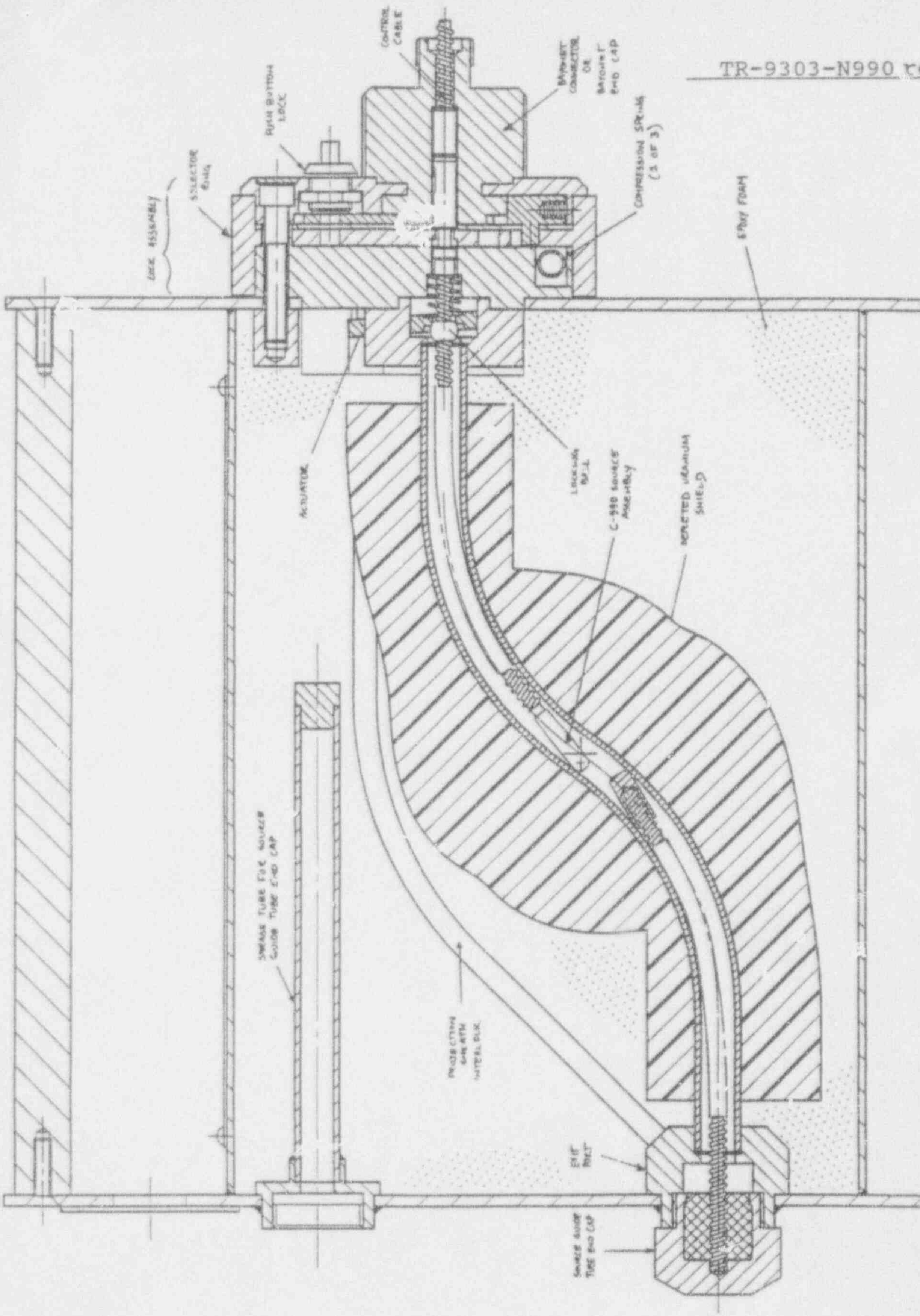


Figure A2.1. The Titan Gamma Radiography Exposure Device

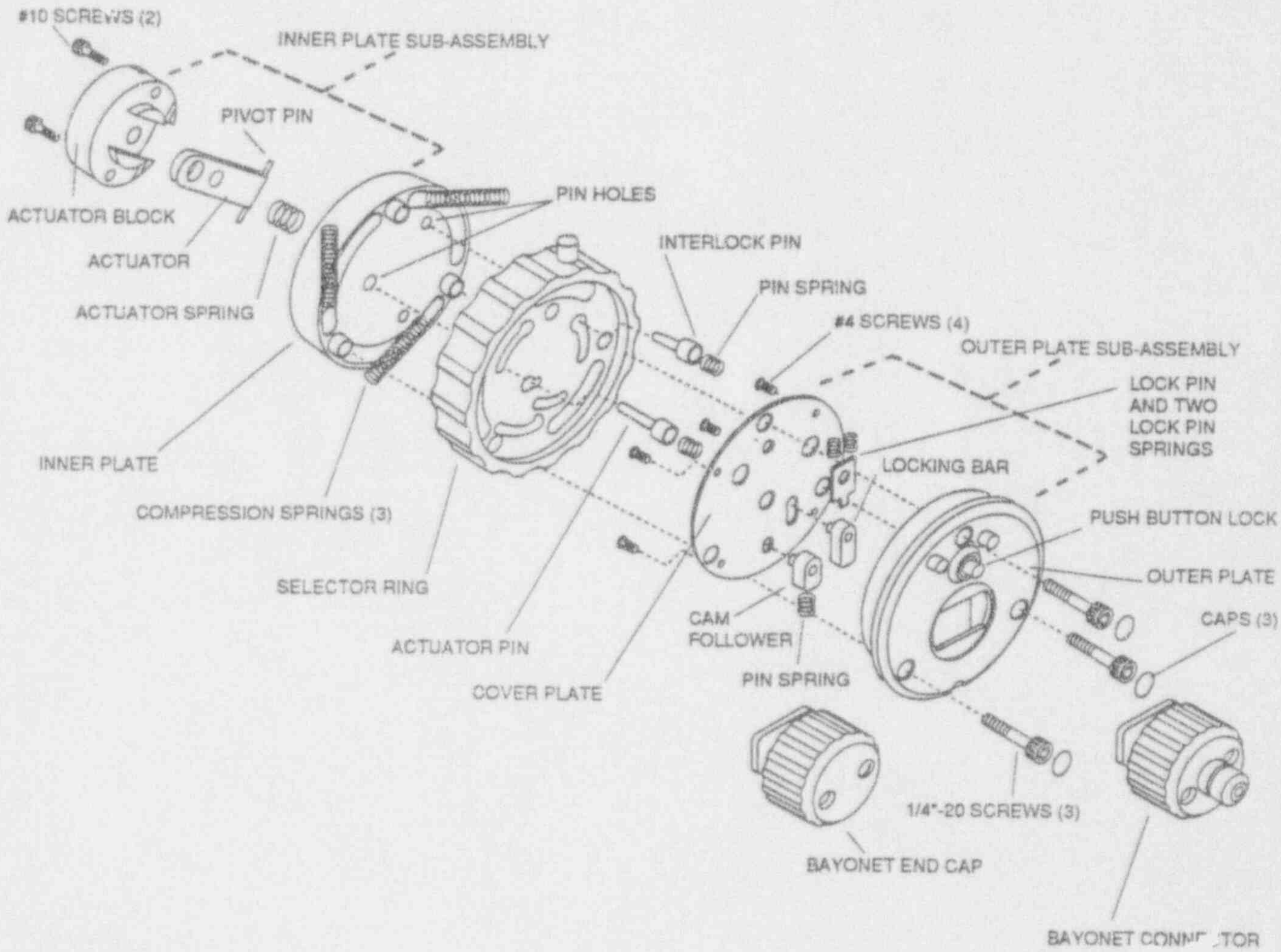
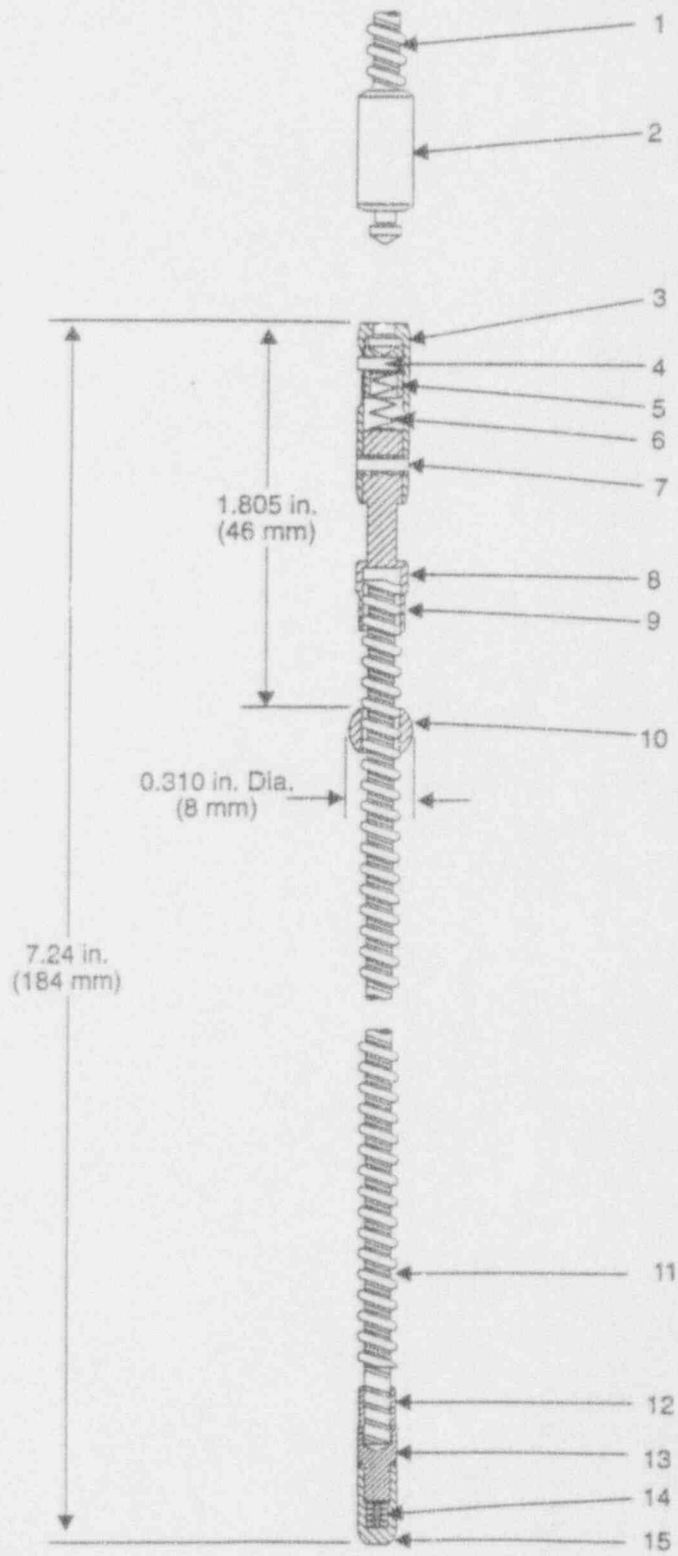


Figure A2.2 Exploded View of the Lock Assembly

Parts list

1. Control cable
2. D898 Male connector
3. D899 Female connector
4. Locking pin
5. Locking collar
6. Compression spring
7. Spring pin
8. Connector cap
9. Crimp
10. Crimped and threaded locking ball
11. Pig tail cable
12. Crimp
13. Cap capsule
14. Active material: ^{192}Ir
15. Base capsule



Notes

1. Conforms to IAEA Special Form requirements (AECB Certificate No. CDN/0001/S)
2. Manufactured to Nordion Specification IS/TS 0010 C000
3. Used with the Titan Gamma Radiography Exposure Device
4. The female connector has the following information engraved:

DANGER
RADIOACTIVE
NII
IR192 C990
SERIAL NO. (as specified)

Figure A2.3 The C-990 Sealed Source

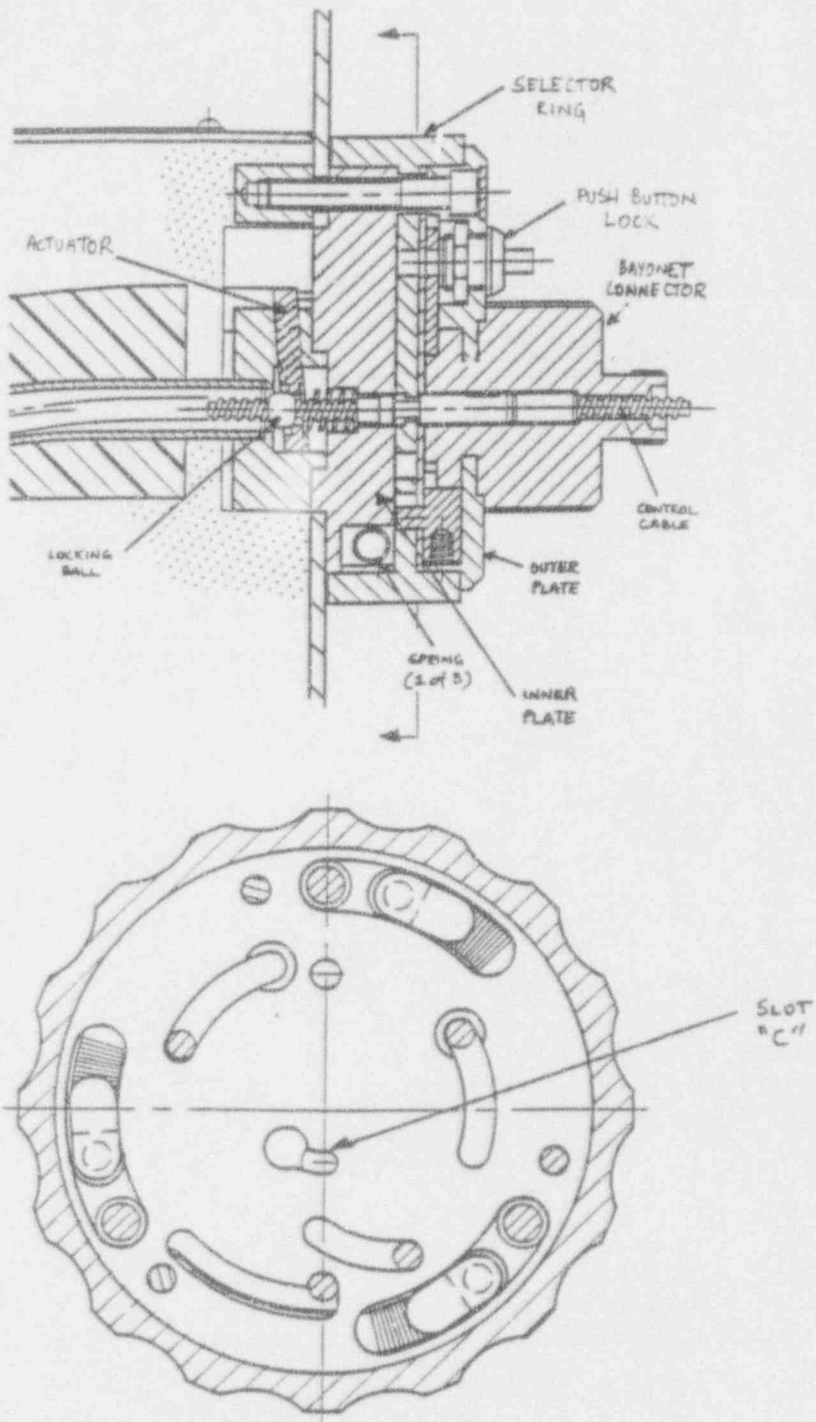


Figure A2.4 Section Through the Lock Assembly

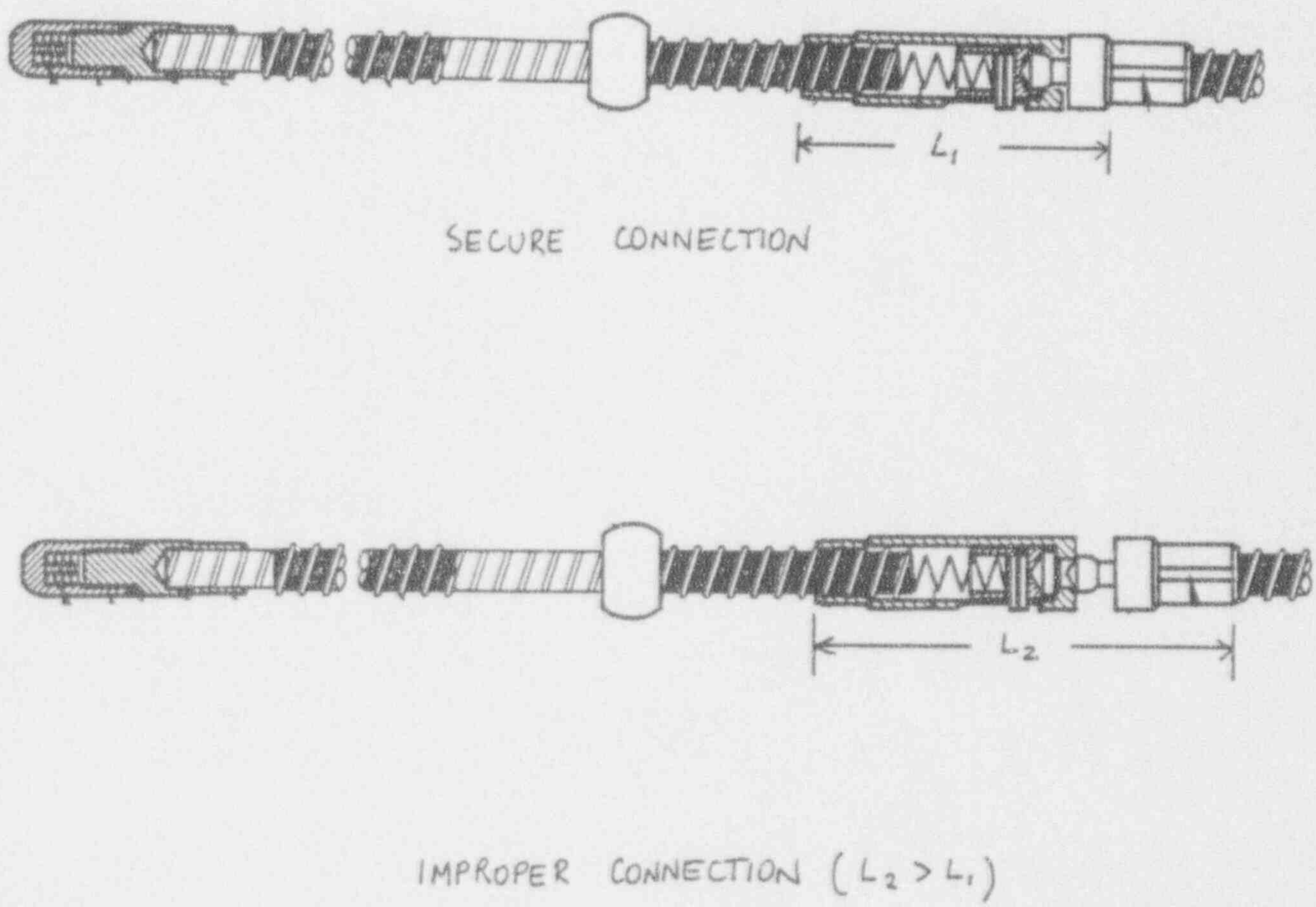


Figure A2.5 Connecting the Control Cable to the C-990

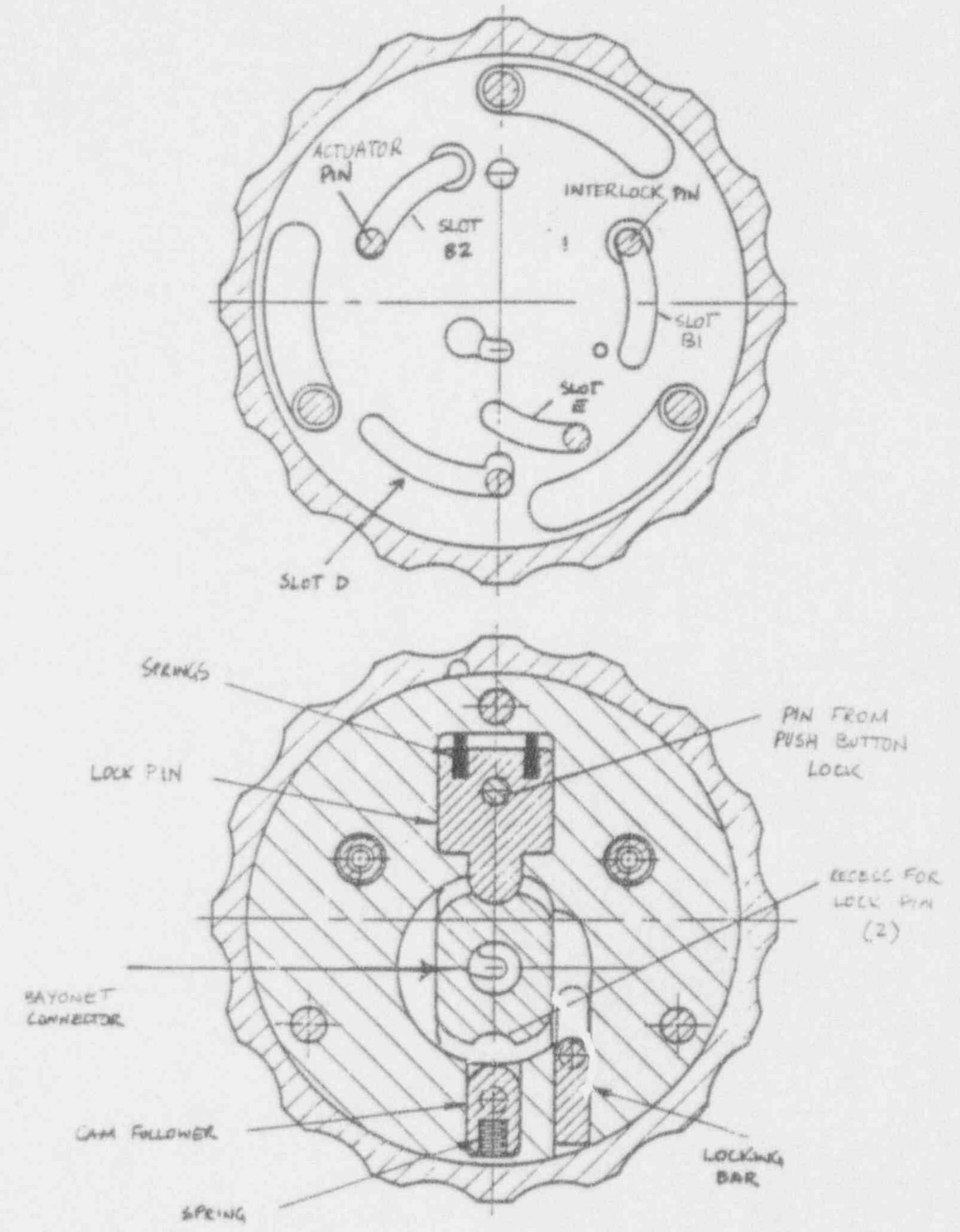


Figure A2.6 Lock Assembly Details

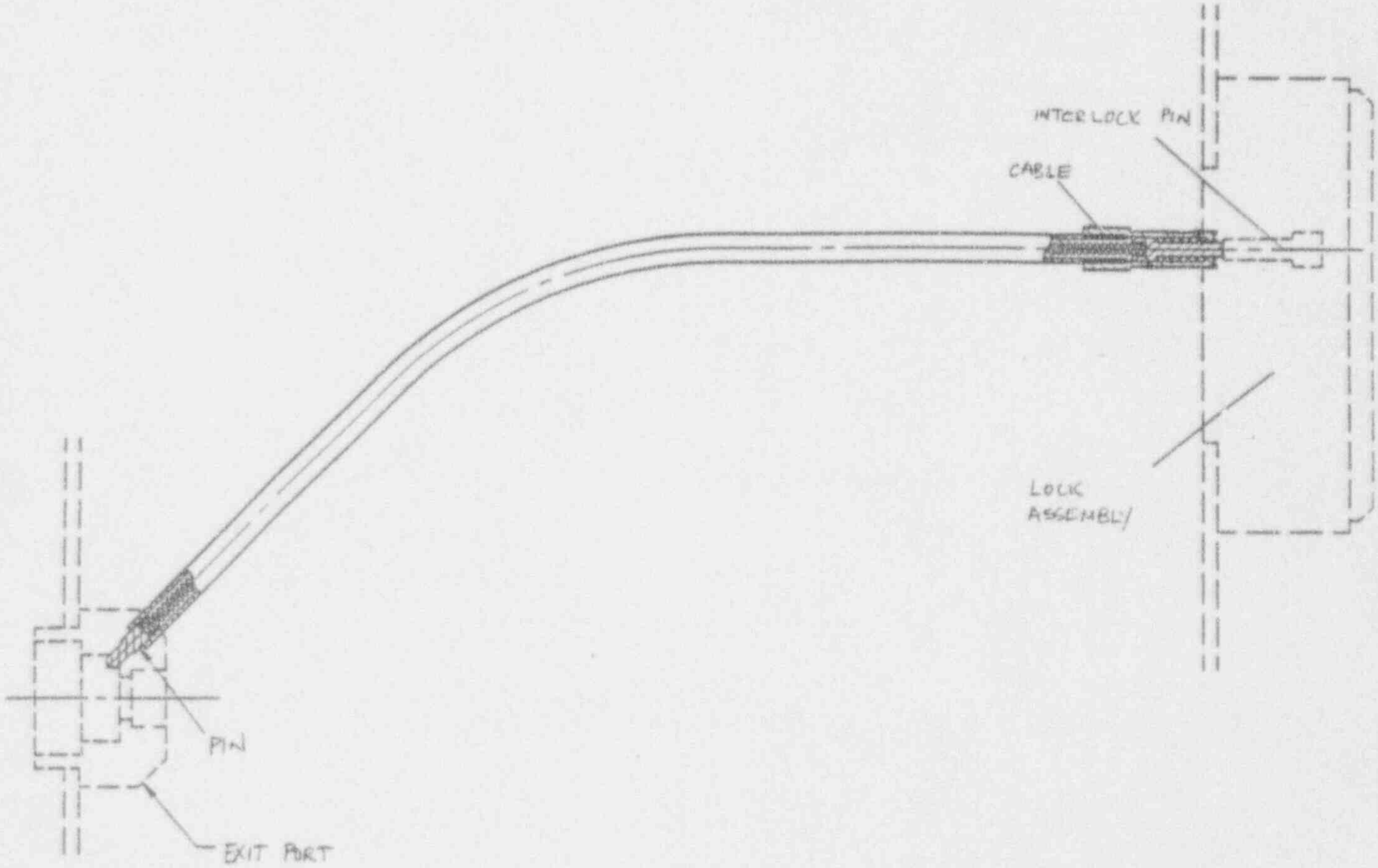
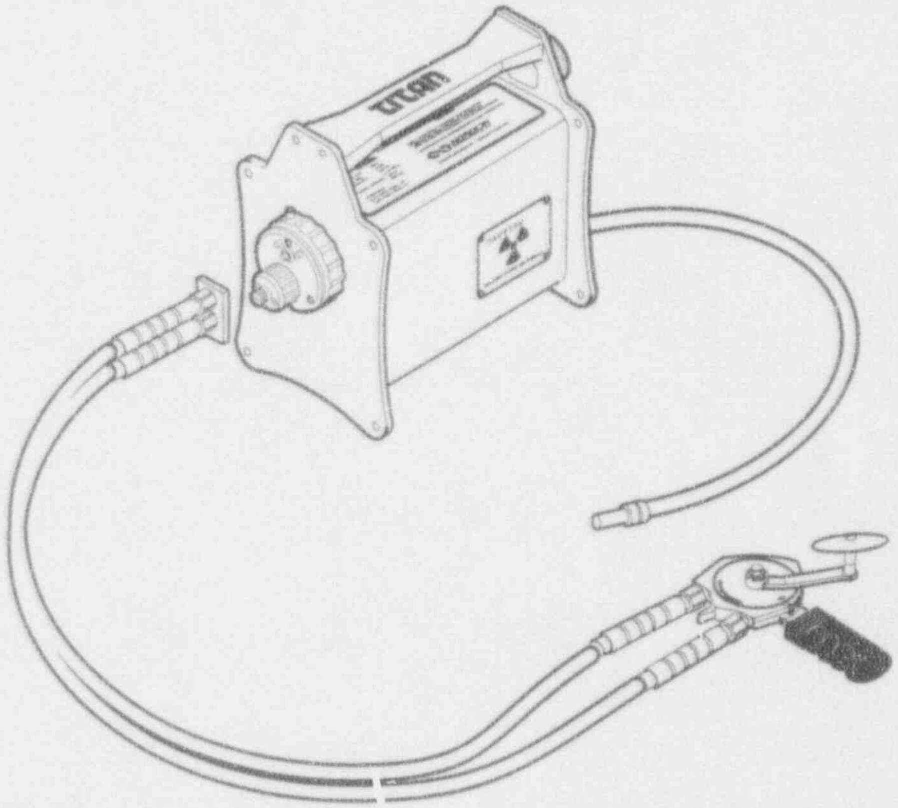


Figure A2.7 Projection Sheath Interlock

APPENDIX 3 IS/OM 0090 N990 rev B

TITAN™

Gamma Ray Projector User's Manual



TITAN™

User's Manual

IS/OM 0090 N990 (Rev B)
October 1993

Nordion Customer Service
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NORDION INTERNATIONAL INC.
447 March Road, P.O. Box 13500
Kanata, Ontario, Canada, K2K 1X8
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Chapter One

Introduction

1-1 GENERAL

The Nordion **TITAN** is a Gamma Ray Projector built to handle the most demanding industrial radiography applications. Designed to fit pipes more securely, the **TITAN** is rugged, reliable, easy to handle and can stand up to the toughest working conditions. The Nordion C-990 is the Source Assembly used for **TITAN** radiographic exposures.

1-2 REGULATORY REQUIREMENTS

The operation of this radiographic product is subject to regulations. Please check with your national and local authorities.

1-2-1 Packaging

This product meets USNRC, USDOT, AECB and IAEA regulations for Type B(U) packages. No overpack is required.

1-2-2 Source Assembly (C-990)

Nordion C-990 source capsules meet IAEA requirements for Special Form radioactive material (AECB Certificate No. CDN/0001/S). Replacement sources are normally shipped to a licensed user in a Source Changer.

1-2-3 Source Changer

Source Changers must conform to IAEA Type B(U) requirements. See Chapter Six —*Source Changer*.

1-3 OPERATOR'S RESPONSIBILITIES

The **TITAN** and its peripheral equipment have been designed in accordance with various international standards and regulations. Full compliance with these standards requires operator cooperation.

Operator's responsibilities include:

a) Obtaining and obeying local and national regulations. The **TITAN** must be operated by trained and licensed personnel. Records of training must be maintained by the user.

b) Using safe practices and operating the unit in accordance with this manual. You must read and fully understand this manual before operating the **TITAN**.

c) Inspecting and maintaining the unit according to this manual. Modifications to the unit or its peripheral equipment are not permitted. See Chapter Five - *Maintenance.*

d) Maintaining inspection and maintenance records.

e) Attaching an owner's label and a current source identification label. Source serial numbers and **TITAN** serial numbers should be tracked.

f) Locking and safely storing the unit when it is not in use.

g) Safely securing the unit in transport away from the public and photographic materials. Transportation of the unit must be in accordance with this manual and local/national regulations. See Chapter Four- *Transportation and Storage.*

h) Keeping emergency procedures and shipping papers in accessible and readily visible areas in the transport vehicle.

i) Reporting incidents and accidents to the local competent authority.

Chapter Two

Description

2-1 GENERAL

Described as the "light heavyweight", the Nordion TITAN has an optimized shield design within a lightweight titanium case. The TITAN projector is curved to fit pipes more securely and its broad base provides greater stability. See Figure 2-1—*Main Components of the Nordion TITAN.*

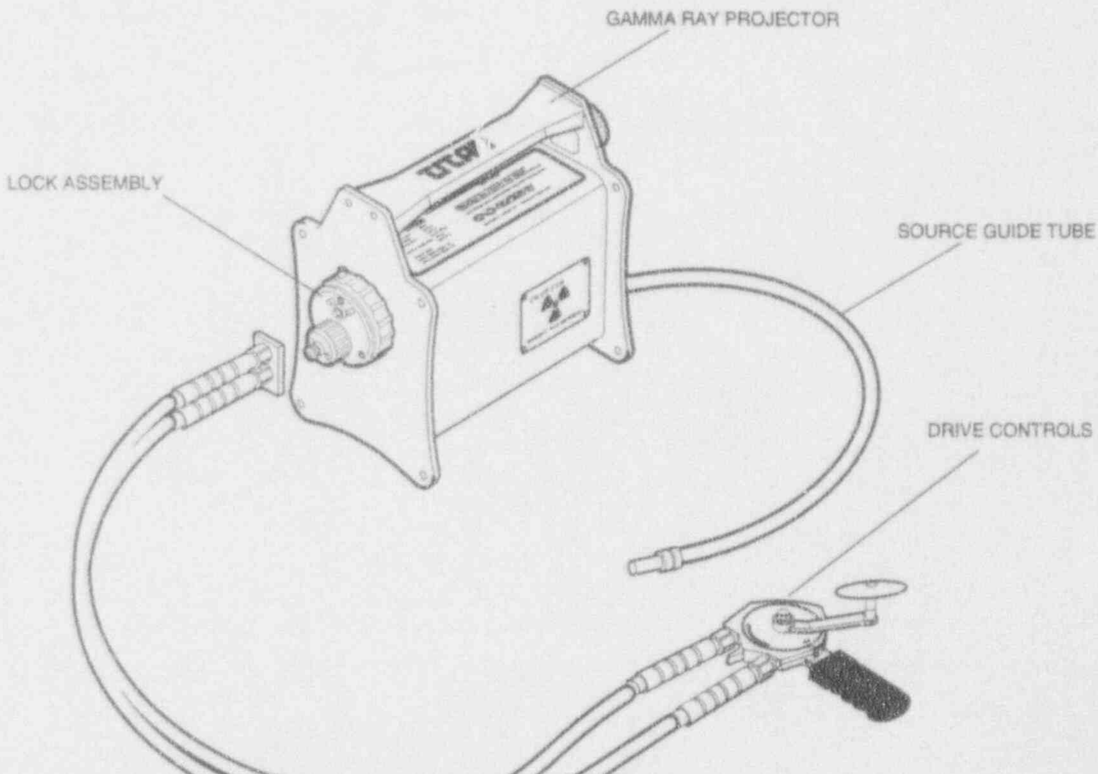

Figure 2-1
Main Components of the Nordion TITAN

2-2 SPECIFICATIONS

Isotope:	—	Ir-192
Half-Life:	—	73.8 days
Capacity:	—	120 Ci (4.44 TBq)
Shielding:	—	30 lbs. (13.5 kg) depleted uranium metal
Projector:	—	All titanium Length: 12.0 in. (305 mm) Width: 6.75 in. (171 mm) Height: 10.13 in. (257 mm) Weight: 44.0 lbs. (20 kg) including shielding
Pistol Grip Control:	—	Weight: 3.85 lbs. (1.75 kg)
Source Guide Tube:	—	Length: 7.0 to 21.0 ft. (2.1 m to 6.4 m) Weight: 1.4 lbs. to 4.4 lbs. (0.65 kg to 2.0 kg)
Drive Controls	—	Length: 25 ft. (7.6 m) Weight: 14 lbs. (6.4 kg) including Teleflex Cable (manufactured by Teleflex Inc.), Cable Sheath, and Bayonet Connector
Operating Specifications:	—	Standard Cable Sheath length on Drive Controls is 25 ft. (7.6 m) Standard source can travel up to 21 ft. (6.4 m)

2-3 PERIPHERAL COMPONENTS

2-3-1 Drive Controls

The Drive Controls include a steel Teleflex Cable which is projected by a Pistol Grip Control. A male connector on the Teleflex Cable attaches to the female connector on the Source Assembly and moves within a flexible teflon lined Cable Sheath covered in yellow PVC.

A radiographic source within the TITAN is connected to the Teleflex Cable and a Cable Sheath is fitted to the Lock Assembly. When turned in a counter clockwise direction, the Pistol Grip Control transfers the source out of the projector and through the Cable Sheath to the exposure position. A clockwise rotation retracts the source back into the projector. The TITAN recognizes the return of the Source Assembly, and automatically secures the source in the stored (shielded) position.

2-3-2 Source Guide Tube

The Source Guide Tube includes a protective yellow PVC cover. It consists of up to three 7 ft. (2.1 m) lengths. Two lengths of the Intermediate Section connected together with a Terminating Section provide a total length of 21 ft. (6.4 m).

The Terminating Section has a Source Stop and must always be used to positively locate the source. The Source Stop avoids accidental ejection and also prevents debris from jamming the source in an exposed position. See Figure 2-1—*Main Components of the Nordion TITAN.*

2-3-3 Source Assembly (C-990)

The **TITAN** is designed to operate with a Nordion C-990 source. Iridium 192 is sealed within the source capsule and crimped to a short length of Teleflex Cable. The opposite end of the Source Assembly has a connector for positive attachment to the Drive Controls. See Figure 2-2—*Source Assembly (C-990).*

The Source Assembly meets IAEA requirements for Special Form radioactive material (AECB Certificate CDN/0001/S).

Figure 2-2
Source Assembly (C-990)

2-4 DEFINITIONS

This section defines components and terms that appear in this guide. The component names or terms, **shown in bold**, are followed by alternate names within **[square brackets]**. All Component Names are capitalized throughout the main body of the text. See Figure 2-1 —*Main Components of the Nordion TITAN* and Figure 3-1 —*TITAN Cross-section.*

Actuator Pin:—A mechanical component inside the Selector Ring that holds the Selector Ring in the 'OPERATE' position.

Bayonet End Cap: —Plugs the Entry Port when the Drive Controls are not connected to the Gamma Ray Projector.

Cable Sheath: —A flexible stainless steel casing with a protective bright yellow PVC cover that is used in the Source Guide Tube and in the Drive Controls.

Collimator: [beam limiter] —A device used to limit the size, shape, and direction of the primary radiation beam. It is attached to the Source Stop.

Drive Controls: [controls, drive cable, control cable] —A manual device attached to the Gamma Ray Projector that enables the Source Assembly to be exposed or retracted. It consists of the following:

a) **Teleflex Cable** - 50 ft. (15.2 m) long and housed within the Cable Sheath.

b) **Cable Sheath** - two 25 ft. (7.6 m) lengths.

c) **Bayonet Connector** - affixed to the Cable Sheath, it is attached to the the Projector using a push and twist motion.

d) **Pistol Grip Control** - a manual remote control device attached to the opposite end of the Cable Sheath used to project and retract the Source Assembly to perform an exposure.

Entry Port: —Where the Drive Controls are connected to the Gamma Ray Projector.

Exit Port: —Where the Source Guide Tube is connected to the Gamma Ray Projector and where the source is projected from the exposure device.

Gamma Radiography System: —All components necessary to make radiographic exposures, including the Gamma Ray Projector, Source Assembly, Drive Controls, and other components associated with positioning the source such as the Source Guide Tube, Source Stop, and Collimators.

Gamma Ray Projector: [exposure device, gamma ray exposure device (GRED), projector] —A shielded device that permits the controlled projection of a sealed source for the purposes of radiography.

Interlock:—The Interlock is a mechanical connection between the Exit Port and the Selector Ring. This feature of the **TITAN** requires connecting the Source Guide Tube to the projector before the Selector Ring can be turned to the 'OPERATE' position. See Figure 3-1—*TITAN Cross-section*.

Lock Assembly:—An assembly consisting of the Selector Ring, an inner plate assembly and an outer plate assembly. See Figure 5-1—*Exploded View of Lock Assembly*. The Lock Assembly secures the Source Assembly when in the "store" position.

Locking Pin:—A small pin on the side of the Source End Connector that is used to push down the Source Assembly's spring loaded locking collar to permit connection of the female Source Assembly Connector to the male Teleflex Cable connector.

Push Button Lock: [lock] —A lock that, when engaged, prevents the rotation of the Selector Ring.

Radiation Safety Officer:—The person selected to be responsible for radiation safety in an organization. Also called by other names such as "Radiation Protection Officer" and "Radiation Safety Manager."

Selector Ring: —Two-positions: 'LOCK' and 'OPERATE'. While in the 'LOCK' position, the source is secured in the shielded position within the projector. When in the 'OPERATE' position the source may be projected from the shield.

Source Assembly: [pigtail, source] —A component that includes a small capsule containing iridium 192, and a connector that attaches to the drive cable. The connector and capsule are crimped onto a short length of cable.

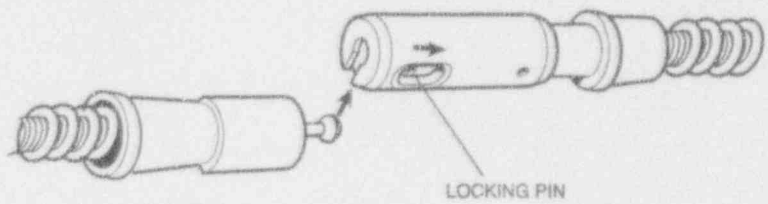

Figure 2-3
Source End Connector

Source Changer: —Used to transport new sources to the customers and return old sources to Nordion.

Source End Connector:—The female connector at the end of the Source Assembly that mates with the male connector on the Teleflex Cable (See Locking Pin). Refer to Figure 2-3—*Source End Connector*.

Source Guide Tube: [projection sheath] —A flexible tube for guiding the sealed source from the Gamma Ray Projector to the Source Stop. It may be up to 21 feet long consisting of the following sections:

a) **Terminating Section:** (7 ft. long) - section to which the Source Stop is attached.

b) **Intermediate Section:** (7 ft. long) - used between the TITAN and the terminating section.

Source Guide Tube End Cap: —Plugs the Exit Port when the Source Guide Tube is not connected to the Gamma Ray Projector.

Source Stop: [end stop, exposure head] —Locates the sealed source at the desired focal position. It is attached permanently to the Terminating Section of the Source Guide Tube.

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Chapter Three

Operation

3-1 GENERAL

The portability and light weight of the TITAN makes operation easy. Nordion's Gamma Ray Projector is shielded and self-contained. This unit uses a C-990 source for the radiographic inspection of steel and light alloy sections.

The TITAN 's titanium case contains a radiation shield of depleted uranium. Through computer analysis all excess weight has been removed to form a fully optimized radiation shield.

3-1-1 Component Overview

The TITAN , as shown in Figure 3-1—*TITAN Cross-section*, consists of the following:

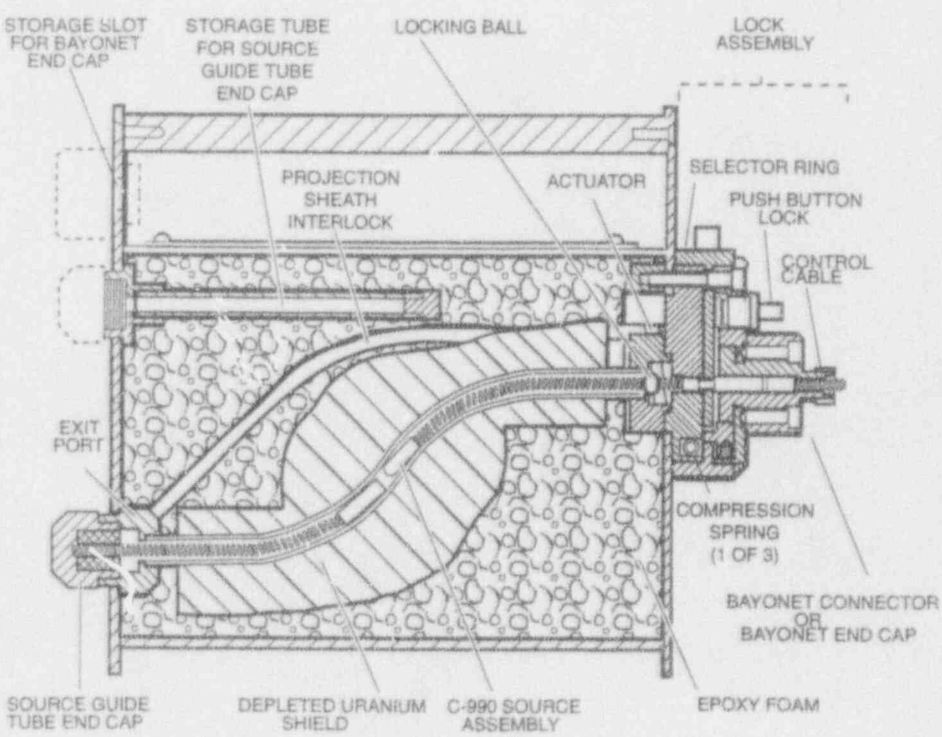

Figure 3-1
TITAN Cross-section

- an S-tube, cast within a depleted uranium shield,
- a Lock Assembly, including the Selector Ring
- a Push Button Lock
- a C-990 sealed Source Assembly,
- a port for the attachment of a Source Guide Tube,
- a port for the attachment of a Drive Control.

Entry & Exit Ports—The Entry Port and Exit Port at either end of the S-tube are sealed using end caps. A Bayonet Connector attaches the Drive Controls at the Entry Port and a threaded connector fastens the Source Guide Tube at the Exit Port.

End Caps—Each Port has a mating End Cap that is stored on the case when the unit is in use.

3-2 OPERATING PRINCIPLES

3-2-1 Overview

At the start of an exposure cycle, the C-990 is secured in the centre of the S-tube, the Selector Ring is in the 'LOCK' position, the Bayonet and Source Guide Tube End Caps are installed, and the Push Button Lock is pushed in with its key removed. This is termed "Transportation Mode" and in this configuration all requirements for the transport of radioactive materials are satisfied.

In Transportation Mode, it is impossible to remove the Bayonet End Cap. It is also impossible to turn the Selector Ring into the 'OPERATE' position.

To perform an exposure, the radiographer unlocks the Push Button Lock. This allows the Bayonet End Cap to be removed from the Selector Ring and allows access to the C-990 Source End Connector. The Teleflex Cable is then connected to the C-990 Source Assembly, and the Drive Controls are attached to the Lock Assembly. At this point, the Teleflex Cable and the Source Assembly are fully connected. However, the Interlock prevents the Selector Ring from moving into the 'OPERATE' position. The Source Guide Tube End Cap is then removed. Attaching the Source Guide Tube releases the Interlock and allows the Selector Ring to be turned counterclockwise into the 'OPERATE' position. The motion is resisted by springs that bias the Selector Ring toward its 'LOCK' position. Once the Selector Ring has been rotated into the 'OPERATE' position, an Actuator Pin prevents the spring from returning the Selector Ring to 'LOCK.

In the 'OPERATE' position, the Source Assembly is free to exit from the shield. The radiographer then uses the Drive Controls to project the source to the exposure site.

Once the exposure has been completed, the C-990 Source Assembly is retracted into the shield. As it approaches the 'LOCK' position, its locking ball engages an actuator. The Actuator Pin becomes disengaged and allows the Selector Ring to spring back into the 'LOCK' position. This action automatically secures the Source Assembly in the depleted uranium shield.

If additional exposures are planned, the Selector Ring is turned back to the 'OPERATE' position and the cycle repeats. Otherwise, the Drive Controls and Source Guide Tube are removed from the unit, the appropriate End Caps are fastened to the Entry and Exit Ports, and the Push Button Lock is pressed in. This returns the unit to Transportation Mode.

The safety features built into the TITAN require that to expose the source, you must:

- unlock the Push Button Lock
- securely connect the Teleflex Cable to the Source End Connector
- attach the Source Guide Tube(s),
- attach the Drive Controls,
- turn the Selector Ring to the 'OPERATE' position.

3-3 SITE SAFETY PRECAUTIONS

Only perform radiography in a restricted area where boundaries are clearly defined. Place appropriate radiation warning signs and physically secure the area against unauthorized entry. The radioactive source emits high levels of radiation and therefore it is a good practice to operate the system from as great a distance as possible.

Operation Distance Calculation —To calculate the minimum distance for operation, use the inverse square law: that is, double the distance results in quarter the level of radiation.

3-3-1 Personnel Precautions

> **WARNING:** All personnel shall wear a Thermal Luminescent Dosimeter (TLD) and shall carry a radiation survey meter capable of measuring dose rates of 0.02 mSv/h (2 mrem/h) to 100 mSv/h (10 rem/h) .

In some countries, including Canada and the United States, regulations require a direct reading dosimeter to be worn in addition to the TLD. Some countries also recommend an audible "beeper" pocket alarm. Check with your local authorities.

> CAUTION: Food and drink should not be permitted in the vicinity during the operation of the projector.

3-4 OPERATING PROCEDURES

3-4-1 Inspection

A daily inspection and the required maintenance procedures must be completed prior to using the TITAN . Refer to Chapter Five.

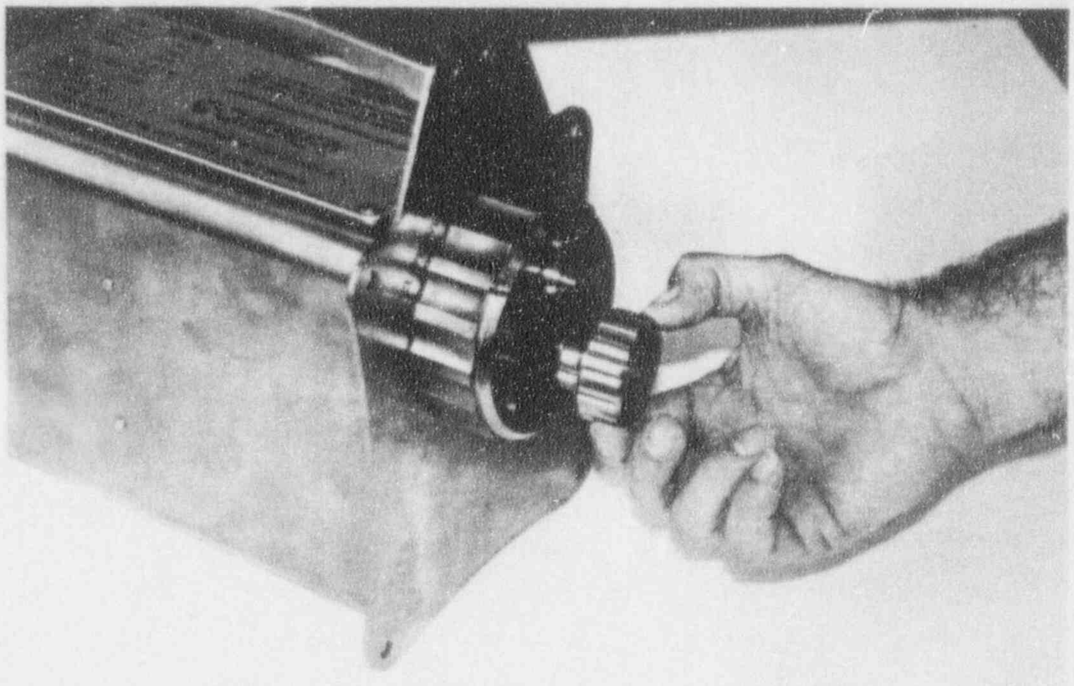

Figure 3-2

Removing the Bayonet End Cap

WARNING: Proper operating procedures and regular inspection and maintenance will ensure that the **TITAN** operates safely.

3-4-2 Source Guide Tube Layout

1. Secure the Source Stop of the Terminating Section at the radiographic focal position. Use of a collimator is recommended.
2. Determine the position of the **TITAN** and lay out the Source Guide Tube as straight as possible. Avoid bend radii less than about half a meter (20 inches) to prevent restricting the source movements. Do not connect the Source Guide Tube to the **TITAN** at this stage.

CAUTION: Ensure that the Source Guide Tube does not contact any surface at a temperature greater than 60°C (140°F).

CAUTION: Position the projector and peripherals in a manner that minimizes the risk of accidental damage caused by crushing or by falling objects (vehicles or closing doors).

WARNING: Ensure that the "available length" of the Teleflex Cable on the Drive Controls is greater than the total length of the Source Guide Tube. If the Teleflex Cable is shorter than the Source Guide Tube, the source cannot be projected all the way to the Source Stop and correctly placed for exposure.

3-4-3 Connecting The Drive Controls

3. Unlock the Push Button Lock with the key.

4. Turn the Bayonet End Cap counterclockwise to remove it. See Figure 3-2—*Removing the Bayonet End Cap.*

5. Secure the Bayonet End Cap in its storage position on the front of the TITAN just below the handle.

6. Crank the Pistol Grip Control and expose the male portion of the Teleflex Cable (the ball-end of the cable).

7. Locate the TITAN 's Source End Connector and press back the spring-loaded Locking Pin with a thumb nail. See Figure 3-3—*Engaging the Source End Connector.*

8. Engage the male and female portions of the swivel coupling. Ensure that the spring loaded Locking Pin returns to its original position and the connection is secure.

9. Insert the Bayonet Connector and rotate it clockwise 90 degrees. The Drive Controls are now coupled to the projector. It should engage freely. If any force is required, then a correct connection has not been made. See Figure 3-4—*Connecting the Bayonet Connector.*

> **WARNING:** Difficulty in attaching the Bayonet Connector, may indicate that a proper source connection has not been made or that the Selector Ring requires maintenance. Investigate and take appropriate action before proceeding further.

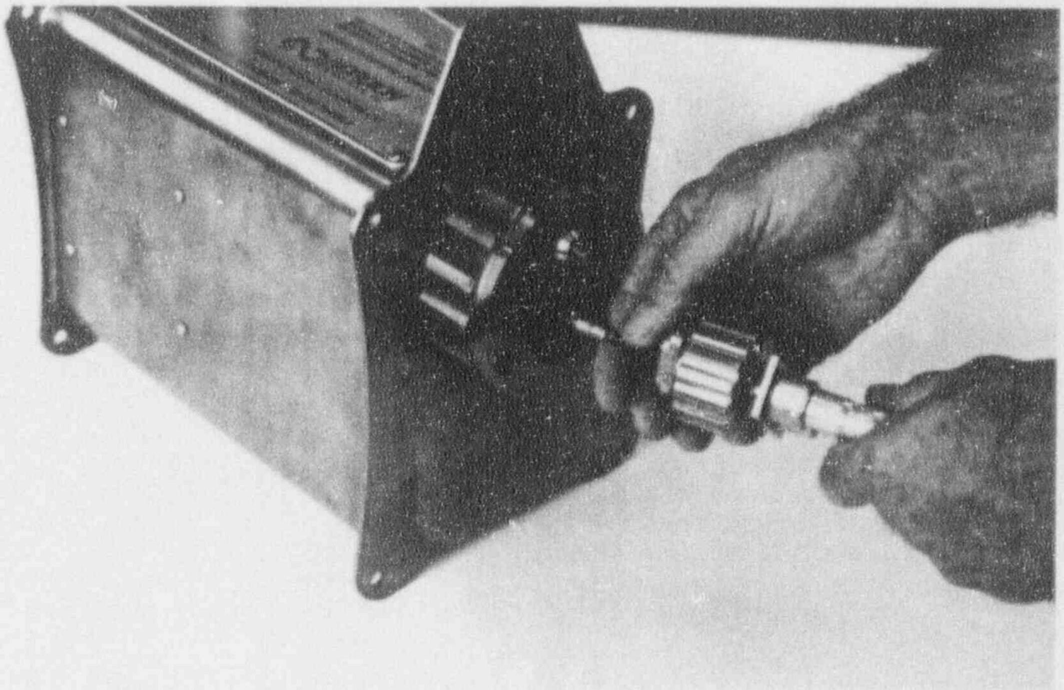

Figure 3-3

Engaging the Source End Connector

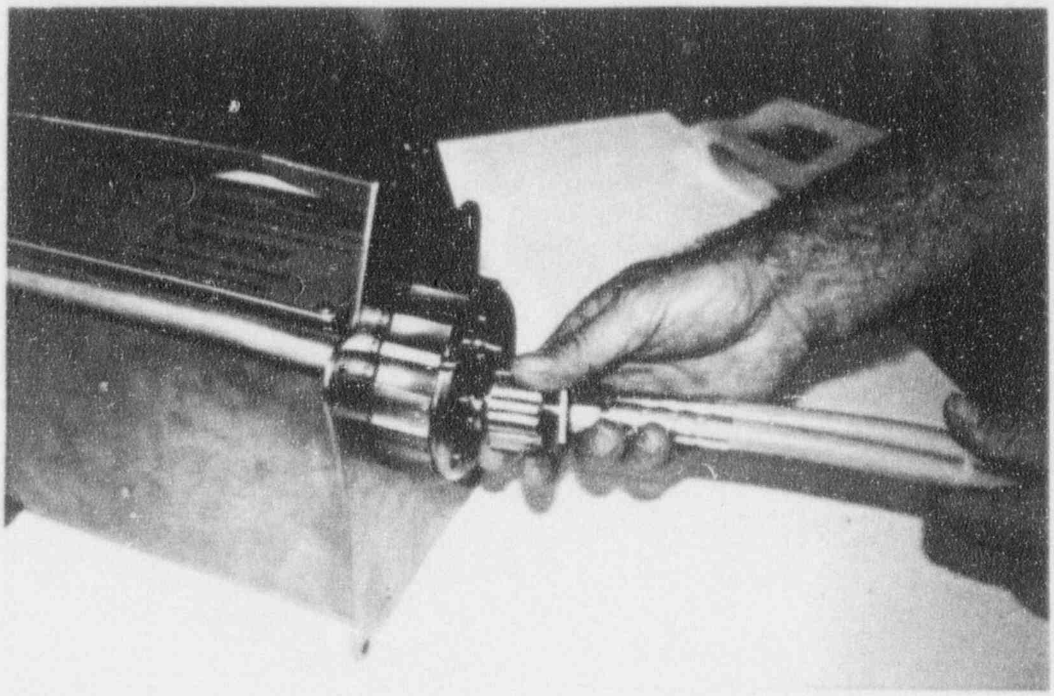

Figure 3-4

Connecting the Bayonet Connector

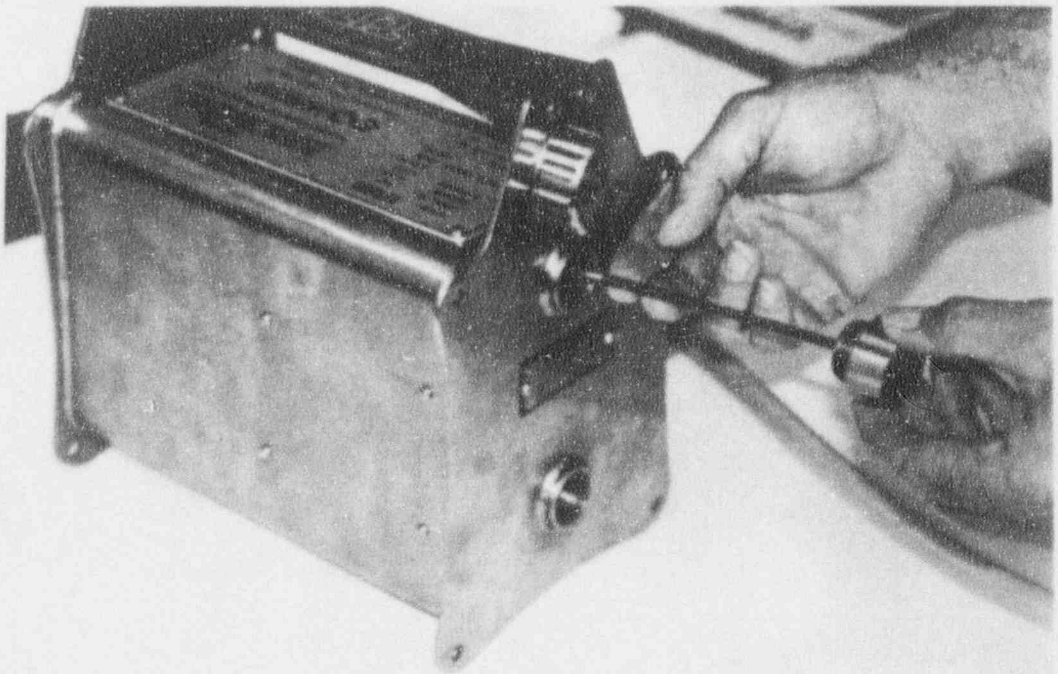

Figure 3-5

Store End Caps on the TITAN

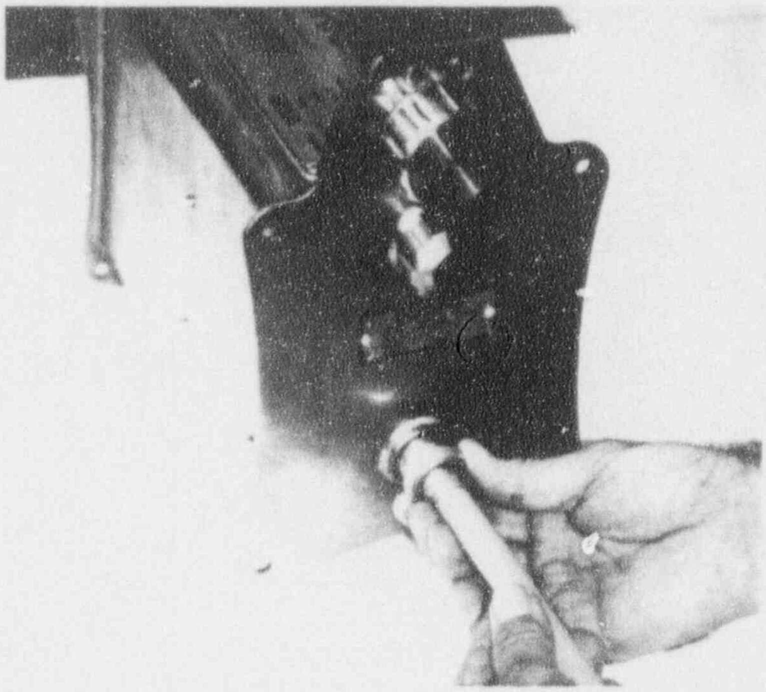

Figure 3-6

Connecting Source Guide Tube

10. Keep the Selector Ring in the 'LOCK' position until you are ready to start the exposure.

3-4-4 Performing a Radiographic Exposure

11. Unfasten the Source Guide Tube End Cap from the projector and install it in the storage receptacle. See Figure 3-5—*Store End Caps on the TITAN.*

> **WARNING:** Once the Source Guide Tube End Cap is removed, higher radiation fields will come out the Exit Port. DO NOT come into the path of the radiation beam emitted from the open Exit Port.

12. Connect the Source Guide Tube securely. See Figure 3-6—*Connecting Source Guide Tube.*
13. Check the surface of the projector with the area radiation survey meter. This is a precaution only to ensure that the meter responds to radiation. Record the radiation levels for later verification that the source is in the shielded position after exposure.
14. Verify that the Intermediate and Terminating Sections are correctly connected.
15. Ensure that no unauthorized personnel are inside the Restricted Area or Exposure Room. Make sure that warning signs are posted.
16. Rotate the Selector Ring counterclockwise to the 'OPERATE' position. When the indicator points to 'LOCK', the Source Assembly is secured in the shielded position. When the Indicator points to 'OPERATE', the Source Assembly is free to travel.

> NOTE: *Excessive tension in the Teleflex Cable (for example, the Pistol Grip Control is snagged) may prevent the Selector Ring from remaining in the 'OPERATE' position.*

17. Position yourself at the Drive Controls and verify that all personnel have left the restricted area.
18. Rapidly rotate the Pistol Grip Control in the 'EXPOSE' direction (counterclockwise) to transfer the source out of the **TITAN** and into the radiographic focal position. There will be some resistance when the source reaches its stop. DO NOT USE EXCESSIVE FORCE.
19. Set the brake to 'ON', at the Pistol Grip Control, to prevent any movement of the source during exposure.

3-4-5 Exposure

The measured exposure time starts from the moment the source reaches the stop.

Survey meter readings observed during the projection operation will significantly increase from background to a high level as the source leaves the **TITAN**. Readings will fall as the source moves into the collimator (if used) and remain steady throughout the exposure. Actual survey meter readings will depend on the source activity, distance, collimators, shielding and backscatter (building materials, especially steel, will generate significant amounts of scatter).

20. Observe the readings during the sequence of changes. Use the survey meter to check the boundary dose rate, but spend as little time as possible in the restricted area to minimize personal exposure.
21. At the end of the exposure time, set the brake to 'OFF' and rapidly turn the crank on the Pistol Grip Control in the 'RETRACT' (clockwise) direction until the crank comes to a stop. Check that the Selector Ring has returned to the 'LOCK' position by turning the hand crank counterclockwise. If the Source Assembly cannot be moved, the Selector Ring should be in the 'LOCK' position.
22. Set the brake to 'ON'.

> **WARNING**: Always check radiation fields as you approach the **TITAN**. This is the primary means of checking that the source is safely stored.

23. Survey the unit. Radiation fields should be the same as they were at the start of the exposure. Pay special attention to the fields at the Exit Port.

> **WARNING:** If the source is still exposed, attempt to store it properly by cranking it a short distance out into the Source Guide Tube and retracting it. If it cannot be stored after a few attempts, treat the situation as an **EMERGENCY**. See 7-2—*Emergency Procedures*.

3-4-6 Preparing for Storage or Transport

The following procedure shall be completed every time the TITAN is to be moved.

24. Unfasten the Source Guide Tube and replace it with the Source Guide Tube End Cap.
25. Replace the plastic caps or fasten both open ends of the Source Guide Tube together to form a closed loop.
26. Remove the Bayonet Connector.
27. Disengage the Source Assembly from the Teleflex Cable.
28. Replace the Bayonet End Cap in the Entry Port.
29. Press in the Push Button Lock.

> **WARNING:** The TITAN should always be locked when not under direct surveillance of a licensed radiographer or assistant.

30. Check the entire surface of the TITAN with a survey meter. When loaded with 120 Ci of Ir-192 in a C-990, the radiation field should not exceed 200 mrem/h on contact with the unit, 50 mrem/h 50 mm (2 inches) from the surface and 2 mrem/h one metre (39.4 inches) from the surface.

> **WARNING:** If the radiation fields exceed the above limits, treat the situation as an **EMERGENCY.** Do not proceed further unless the cause of the high field has been determined and corrected.

31. If the TITAN is to be stored or transported, install a wire seal between the Source Guide Tube End Cap and one of the four holes provided on the front of the unit.

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Chapter Four

Transportation and Storage

4-1 REGULATIONS

Canada—In Canada, the governing regulations are the Transportation of Dangerous Goods (TDG) Regulations and the Transport Packaging of Radioactive Materials Regulations, SOR/83-740, including all amendments.

United States—In the United States, the transport of Radiography Projectors and Source Changers is governed by 10 CFR Part 71, and 49 CFR Parts 171 through 179.

International—IAEA Safety Series No. 6, 1985 Edition (As Amended 1990), guides the transportation of radioactive materials internationally.

4-2 RECEIVING GAMMA PROJECTORS AND SOURCE CHANGERS

When shipping a radioactive package, the consignee must make arrangements for receiving prior to shipment. Upon notification of arrival, the package shall be promptly picked up at the carrier's terminal.

1. Upon receipt of the **TITAN**, measure the radiation fields at the surface of the package and at 1 meter. These should not exceed 2 mSv/h (200 mrem/h) at the surface and 20 μ Sv/h (2 mrem/h) at 1 meter.

   > **WARNING:** If the package has been damaged and the fields exceed these limits, treat the situation as an **EMERGENCY**. Isolate and secure the package in a restricted area. Contact the appropriate authorities and your Radiation Safety Officer. See 7-2—*Emergency Procedures*.

2. Inspect the **TITAN** for damage. Check the condition of the wire seal.

   > **WARNING:** If the package has been tampered with or damaged, contact your Radiation Safety Officer for further instructions. Do not proceed further unless authorized to do so.

3. Record the radiation levels in the receiving report. Enter the isotope (iridium 192), activity, **source model number and serial number**.

4-3 STORAGE/TRANSPORT

When preparing the TITAN for storage or transport, ensure that:

- the Selector Ring is in the 'LOCK' position;
- the Bayonet End Cap is installed and the Push Button Lock is engaged;
- the Source Guide Tube End Cap is installed.

> CAUTION: the End Caps on the TITAN Gamma Ray Projector provide additional radiation shielding. Always install the End Caps when the projector is not in use.

- the plastic dust caps on the Drive Controls and Source Guide Tube fittings are installed.

> NOTE: *The ends of Intermediate Sections of the Source Guide Tube can be threaded together rather than using the dust caps.*

- When not in use for extended periods, store the TITAN Gamma Ray Projector in a dry, clean and secure area. Lock and secure the storage area to prevent unauthorized entry.
- The door to the storage area must have a warning label with the trefoil symbol indicating the presence of radioactive material. The radiation levels at the outside wall of the radioactive materials storage area must be within the limits permitted for the general public.

4-4 SHIPPING

Prior to transport, ensure that the unit has been properly prepared for transport. Refer to section 3-4-6 for additional instructions.

> WARNING: Never ship a unit that has been tampered with or damaged.

The TITAN Gamma Ray Projector is licensed as a Type B(U) transport package and needs no overpack. The level of removable contamination must not exceed 4 Bq (0.0001 μ Ci) per cm^2, averaged over an area of 300 cm^2.

Two completed category labels must be added to opposite sides of the TITAN. The radioactive isotope (^{192}Ir), the activity in becquerels (Bq) or curies (Ci) and the transport index (TI) must be recorded on the label. To determine the transport index, the maximum radiation level in mrem/h is measured at a distance of 1 meter. For example, a package with a maximum field of 17 μ Sv/h (1.7 mrem/h) at 1 meter would have a TI of 1.7.

Guidance on the completion of the category labels can be found in Table 4-1.

Do not cover or remove any of the permanently affixed plates on the device, as this would violate shipping regulations by obscuring important information.

Refer to Figure 4-1—*Radioactive Material Category Labels.*

> WARNING: DO NOT ship the package if the dose rates exceed 2 mSv/h (200 mrem/h) at its surface or 20 μ Sv/h (2 mrem/h) at 1 metre from any surface. If radiation fields exceed these limits, treat the situation as an EMERGENCY. Do not proceed further until the cause of the high radiation field has been determined and corrected.

Table 4-1
Package Label Requirements

Label	Radiation Level at External Surface of Package	Transport Index (T.I.)[1]
RADIOACTIVE I (WHITE)	Not more than 0.005 *mSv / h* (≤ 0.5 *mrem / h*)	0
RADIOACTIVE II (YELLOW)	More than 0.005 *mSv / h* (0.5 *mrem / h*) But not more than 0.5 *mSv / h* (50 *mrem / h*)	More than 0 But not more than 1
RADIOACTIVE III (YELLOW)	More than 0.5 *mSv / h* (50 *mrem / h*) But not more than 2 *mSv / h* (200 *mrem / h*)	More than 1 But not more than 10

[1] T.I. - Radiation level in microsieverts per hour at 1 metre from the external surface of the package divided by 10. (This is equivalent to the radiation level in mrem/h at 1 metre from the external surface of the package.)

Figure 4-1

Radioactive Material Category Labels

The **TITAN** shall be securely stowed in the transport vehicle and shall not be carried in passenger compartments. Acceptable means of securing the unit include passing straps between the handle and the main body and fastening the straps to dedicated fittings. Use of a securely mounted box or drum is preferred.

A radiation survey must be completed prior to transport.

The **TITAN** may only be shipped if:

1) Radiation dose rates to occupants are less than 20 μ Sv/h (2 mrem/h)
2) Radiation levels from the external surface of the vehicle are less than 2 mSv/h (200 mrem/h)
3) Radiation levels at 2 metres from any point on the external surface of the vehicle are less than 0.1 mSv/h (10 mrem/h).
4) The sum of transport indexes from all packages on the vehicle is less than 50 if the shipment is not under Exclusive Use. (The sum of the transport indexes must be less than 100 for Exclusive Use shipments.)

> **WARNING:** Transport Regulations do not allow persons other than the driver and assistants to be in vehicles containing packages bearing Category II - Yellow or Category III - Yellow labels.

4-4-1 Preparing Shipping Documents

Prepare the shipping documents and include them with each shipment. The shipping papers must include:

a) The information "RADIOACTIVE MATERIAL, SPECIAL FORM, N.O.S., UN2974".
b) The United Nations Class Number "7".
c) The name and symbol of the radionuclide, "^{192}Ir".
d) The maximum activity of the ^{192}Ir during transport expressed in units of Terabecquerels (TBq) or curies (Ci).
e) The category of the package (i.e. I-white, II-yellow, III-yellow).
f) The Transport Index (TI).
g) USNRC Certificate of Compliance No. USA/XXXX/B(U) and Canadian AECB Approval Certificate No. CDN/1038/B(U)-85 and Special Form Certificate of Approval No. CDN/0001/S.
h) The Shipper's declaration:

   "I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked and labelled, and are in all respects in proper condition for transport by (air, sea, road, and rail) according to the applicable international and national governmental standards."

In the United States use the following declaration:

"This is to certify that the above named materials are properly classified, described, packaged, marked and labelled and are in proper condition for transportation according to the applicable regulations of THE DEPARTMENT OF TRANSPORTATION."

i) The shipper must sign and date the declaration. The declaration and signature must appear on the same page that contains the particulars of consignment listed above.

> **WARNING:** It is the consignor's responsibility to ensure that the **TITAN** is prepared for shipment in accordance with all pertinent regulations and this manual. It is the carrier's responsibility to placard the transport vehicle in accordance with these same regulations.

4-4-2 Handling

The **TITAN** is a portable device designed to be carried by one person. When moving the Gamma Ray Projector, remove the Drive Controls and Source Guide Tube, and replace the end caps.

Care must be exercised at all times to minimize radiation exposure. For example, no person should sit on the projector or loiter nearby. Personal dosimeters should be worn at all times. Only trained personnel should handle the equipment.

4-4-3 Placards

Canada

Canadian regulations require placards to be applied to all four sides of the vehicle whenever radioactive materials are shipped. For radioactive Category I or II shipments, non-retroreflective 250 mm × 250 mm placards must be used. For radioactive Category III shipments, the placards must be retroreflective. We recommend that you carry spare placards in case one is lost during transport.

> **WARNING:** Regardless of which placard is used, it must be removed upon entry to the USA and, if necessary, replaced with appropriate placards conforming to USA regulations (see below).

United States

In the United States, vehicles are only placarded when radioactive Category III Shipments are made. The placards are non-retroreflective, and contain the word "RADIOACTIVE." They must be attached to all four sides of the transport vehicle.

Rest of the World

Refer to IAEA Safety Series No. 6, 1985 Edition (As Amended 1990) and applicable national or local standards for placarding requirements for other countries.

4-4-4 Shipping an Empty TITAN

In order to safely transport the TITAN as an empty package, the spent source must be stored within a Source Changer and replaced with a dummy source assembly. In addition, each step of section 3-4-6 and the following must be completed:

1) Check the external surfaces of the TITAN for contamination. The level of removeable contamination must not exceed 4 Bq (0.0001 μ Ci) per cm^2, averaged over an area of 300 cm^2.

2) Perform a radiation survey around the unit.

3) *If the maximum radioactive field on contact is less than 5 μ Sv/h (0.5 mrem/h) and there is no measurable field 1 metre from the package then* label the package with the proper shipping name (Radioactive Material, articles manufactured from depleted uranium, UN 2909) and with the words:

   "Exempt from specification, packaging, shipping paper and certification, marking and labeling and exempt from the requirements of Parts 171-178 per 49 CFR 173.421-1 and 49 CFR 173.424."

   Include a notice containing the name of the consignee with the shipping documents. The notice should include 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."

4) *If the maximum radiation field on contact exceeds 5 μ Sv/h (0.5 mrem/h), attach the appropriate radioactive category label (see Table 4-1).* Label the package with the proper shipping name (Radioactive Material, LSA, n.o.s, UN 2912) and complete the shipping papers in accordance with section 4-4-1.

Chapter Five

Maintenance

5-1 MAINTENANCE REQUIREMENTS

The TITAN is designed to operate with little maintenance. However, periodic inspections are required to ensure that the equipment is in proper operating condition. These inspections range from simple daily examination to more detailed inspections and procedures to be completed at every source change. An annual maintenance procedure must also be completed once per year, or more frequently if the unit has been used under severe operating conditions. A recommended maintenance schedule is provided in Table 5.1.

All inspections should be recorded in a dedicated log book. Any component that fails an inspection shall be repaired or replaced before the unit is returned to service.

> **WARNING:** Inspect all equipment prior to use. Failure to remove damaged equipment from service may result in serious injury or death.

Maintenance shall be completed by trained and qualified personnel. All replacement components shall conform to Nordion Specifications. We recommend maintenance by an authorized service depot. Contact Nordion International Customer Service for the depot nearest you.

5-2 DAILY INSPECTION

The following items must be checked daily to ensure safe operation.

5-2-1 Gamma Ray Projector

a) Check that the unit, the Drive Controls and the Source Guide Tube have completed a quarterly inspection within the last three months and an annual inspection within the past year. If the unit is due for one of these inspections, complete the daily inspection procedure and refer to the appropriate section below.

b) Perform a routine radiation survey around the TITAN projector. The survey should be completed with the Source Guide Tube End Cap and Bayonet End Cap installed. When loaded with 120 Ci of iridium 192 in a C-990, the radiation field on contact with the surface shall not exceed 200 mrem/h on contact, 50 mrem/h 50 mm (2 inches) from the surface, and 2 mrem/h one metre (39.4 inches) from the surface.

> **WARNING**: If radiation fields exceed the above limits, treat the situation as an **EMERGENCY**. Do not proceed further until the cause of the high field has been determined and corrected.

c) Wipe test the external surface of the TITAN. The method used shall be capable of detecting any contamination in excess of 4 Bq/cm^2 (0.0001 μ Ci/cm^2)

> **WARNING:** Any projector contaminated in excess of 4 Bq/cm^2 (0.0001 μ Ci/cm^2) shall be quarantined and the cause of the contamination determined. Contact your Radiation Safety Officer for additional instructions. Do not proceed further unless authorized to do so.

d) Visually examine the external surface of the unit. Verify that all warning and identification labels are legible and securely attached and that there is no damage to the titanium shell.

e) Verify that the Bayonet End Cap cannot be removed from the unit while the Push Button Lock is in its locked position.

f) Check the operation of the Push Button Lock. It should lock and unlock freely.

g) Check that the handle is secure.

h) Check the threads on the end cap storage tube for damage. Clean if necessary.

> NOTE: *The following steps should be completed during your first exposure cycle. Refer to Chapter Three for Operating Procedures.*

i) Remove and examine the Source Guide Tube End Cap. Check the condition of the threads and ensure that the lead insert and teleflex plug are secure within it.

j) Check the operation of the Bayonet Connector. It should freely engage with the Lock Assembly.

k) Check the operation of the Selector Ring. Ensure that it turns freely into the 'OPERATE' position and that it returns to the 'LOCK' position at the end of the first exposure. Difficulty in turning the Selector Ring into the 'OPERATE' position indicates that some obstruction is present. Refer to 5-4 Annual Maintenance.

5-2-2 Drive Controls

a) Examine the Cable Sheaths for cuts, dents and broken or loose fittings. Damage to the stainless steel tube requires the Cable Sheaths be removed from service. Damage to the yellow PVC casing may be repaired using water resistant vinyl tape.

b) Verify that the plastic end caps on the Control Cable and Source Guide Tube are present and in good condition. Replace as necessary.

c) Nordion recommends daily examination of the male connector on the Teleflex Cable using a GO-NO GO gauge. Refer to Nordion Inspection Procedure IS/OP 0046 C000. (See Appendix B.)

d) Check the Pistol Grip Control for damage or loose components. Check the operation of the brake. With the brake in the 'OFF' position, ensure the crank rotates smoothly.

5-2-3 Source Guide Tube

a) Examine the Intermediate and Terminating Sections for cuts, dents and broken or loose fittings. Remove the Source Guide Tubes from service if the stainless steel tubes are damaged. Damage to the yellow PVC casing may be repaired using water resistant vinyl tape.

b) Verify that the plastic end caps are present and in good condition. Replace as necessary.

c) Examine each section of the Source Guide Tube for obstructions. Check the condition of the threads. Clean or repair as necessary.

5-3 QUARTERLY INSPECTION

A quarterly inspection shall be completed at every source change, or once every three months, whichever comes first. It includes a daily inspection plus the following procedures.

> **WARNING:** The following procedures shall only be completed with the C-990 Source Assembly safely stored within a Source Changer. Source transfers should only be completed by trained and licensed personnel.

5-3-1 Source Transfer Procedure

Refer to Chapter Six and your Source Changer's User's Instructions for procedures to safely transfer and store an active Source Assembly. Use a survey meter to check that the Source Assembly has been safely stored.

Once the active Source Assembly is safely stored in the Source Changer, disconnect it from the Teleflex Cable and replace it with a dummy source assembly. (Dummy Source Assemblies can be obtained from Nordion.)

5-3-2 Gamma Ray Projector

a) Retract the dummy source assembly into the TITAN. Verify that the Selector Ring returns to the 'LOCK' position.

b) Disconnect the source transfer hose from the TITAN. Test the function of the Interlock. It should NOT be possible to rotate the Selector Ring into the 'OPERATE' position.

c) Install the terminating section of the Source Guide Tube.

d) Remove the Bayonet Connector and disconnect the dummy Source Assembly from the Teleflex Cable. Reinstall the Bayonet End Cap and verify that the Selector Ring CANNOT be turned into the 'OPERATE' position.

e) Remove the Bayonet End Cap. Without connecting the dummy Source Assembly to the Teleflex Cable, try to install the Bayonet Connector. Verify that interference between the unconnected Source Assembly and the male connector prevents the Bayonet Connector from being installed.

> **WARNING:** Do not force the Bayonet Connector into the Lock Assembly as this may damage the male connector.

f) Connect the dummy Source Assembly to the Teleflex Cable and install the Bayonet Connector. Turn the Selector Ring into the 'OPERATE' position. Verify that the Bayonet Connector CANNOT be removed from the Lock Assembly.

g) Perform ten test exposures using the dummy Source Assembly. Verify that the Selector Ring snaps cleanly back into the 'LOCK' position at the end of each exposure cycle.

h) Remove Source Guide Tube and perform a swipe test on the S-tube using a pipe cleaner. The test method used should be able to detect any contamination in excess of 4 Bq/cm^2 (0.0001 $\mu Ci/cm^2$).

> **WARNING:** Any projector contaminated in excess of 4 Bq/cm^2 (0.0001 $\mu Ci/cm^2$) shall be quarantined and the cause of the contamination determined. Contact your Radiation Safety Officer for additional instructions. Do not proceed any further unless authorized to do so.

5-3-3 Source Assembly

Return to the Source Changer and inspect the exposed end of the Source Assembly for wear or other damage. Use a GO-NO GO gauge in accordance with Nordion Procedure IS/OP 0046 C000 (See Appendix B). This test shall be completed on the Source Assembly that will be installed in the TITAN.

> **WARNING:** Any Source Assembly failing this test shall not be used. Use of a damaged Source Assembly could result in serious injury or death.

5-3-4 Drive Controls and Source Guide Tube

a) Return the dummy Source Assembly to the TITAN projector and remove the Bayonet Connector.

b) Disconnect the Teleflex Cable from the Source Assembly. Clean and examine the male connector using a GO-NO GO gauge. Refer to Nordion Procedure IS/OP 0046 C000 (Appendix B).

5-4 ANNUAL MAINTENANCE

Annual maintenance shall only be completed by trained personnel and requires the purchase of a TITAN Maintenance Kit. The contents of the kit include an approved lubricant, a thread sealant, nine replacement springs, two spring pins and three replacement cover caps.

> **WARNING:** The following procedure shall only be completed with the C-990 Source Assembly safely stored within a Source Changer. Source transfers shall only be completed by trained and licensed personnel.

5-4-1 Source Transfer Procedure

Refer to Chapter Six and your Source Changer's User's Instructions for procedures to safely transfer and store an active Source Assembly. Check that the source has been properly stored using a survey meter.

Once the active Source Assembly is safely stored in the Source Changer, disconnect it from the Teleflex Cable and replace it with a dummy Source Assembly.

5-4-2 Gamma Ray Projector

Annual inspection consists of the complete breakdown, cleaning and lubrication of the Lock Assembly. It also includes the replacement of several springs within the Lock Assembly.

An exploded view of the Lock Assembly is provided in Figure 5-1. The Lock Assembly has three main components, the Selector Ring, the Outer Plate Subassembly and the Inner Plate Subassembly.

The Outer Plate Subassembly consists of several pins and springs all retained by a Cover Plate. It also includes the Push Button Lock. The Cover Plate is attached using four 0.112(#4)-40 UNC flat head screws.

The Inner Plate Subassembly includes the Actuator Block, the Actuator and the Actuator Spring. These are secured to the Inner Plate by two 0.190(#10)-32 UNF cap screws. There are also three compression springs loosely held within slots in the Inner Plate.

The Selector Ring includes an Actuator Pin and an Interlock Pin. The Actuator Pin is longer than the Interlock Pin and both pins include springs that fit into the Outer Plate

Subassembly. The underside of the Selector Ring includes three nubs that compress springs when the Selector Ring is rotated into the 'OPERATE' position.

> CAUTION: Wear safety glasses during this procedure. Handle all springs with caution as they may fly out of the lock assembly.

a) Use the parts list provided with your maintenance kit to check that you have all the components required to complete the annual maintenance procedure.

b) Retract the dummy Source Assembly into the projector. Verify that the Selector Ring has returned to the 'LOCK' position.

c) Drill out the three screw caps from the Outer Plate of the Lock Assembly. Removing these caps allows access to the three 0.25-20 UNC socket head cap screws that hold the lock assembly to the **TITAN**.

d) Remove the three socket head cap screws. Remove the complete Lock Assembly. Disassemble it slowly, taking care not to lose any pins or springs.

> NOTE: *It is easier to remove the complete Lock Assembly from the* **TITAN** *prior to disassembling the Lock Assembly.*

e) Check for cracks or other such damage to the epoxy foam.

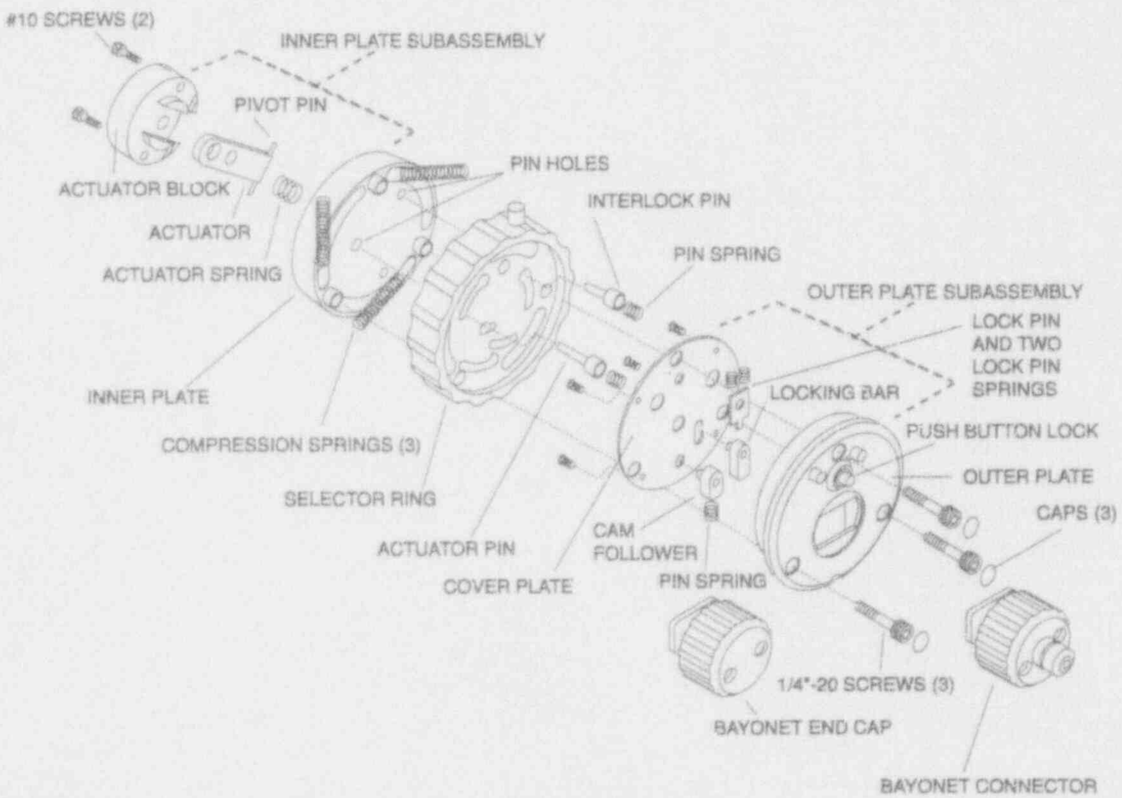

Figure 5-1
Exploded View of Lock Assembly

Inner Plate Subassembly

f) Remove the two screws from the Actuator Block and disassemble it. Clean the Actuator and the Actuator Block. Discard the old Actuator Spring. Check for excessive wear in the Actuator using the dummy Source Assembly. It should be IMPOSSIBLE to pass the locking ball through the Actuator.

g) Clean the Inner Plate.

h) Lubricate the Pivot Pin with Felpro C5A and place the Actuator in the Actuator Block. Ensure that the Spring Counterbore faces the Inner Plate. Install the new Actuator Spring in the Inner Plate. Place the Actuator Block in the register on the Inner Plate, taking care to align the counterbore with the spring. Use the thread sealant provided in the maintenance kit to install the two #10 Cap Screws.

Selector Ring

i) Clean the Selector Ring, the Actuator Pin and Interlock Pin. Check the fit of the pins in their respective slots. They should move freely within the slots and should smoothly engage in their holes. Check for wear around the base of the head of the pins.

j) Check for burrs and sharp edges on the Selector Ring and, if necessary, file them off.

k) Check the condition of the three nubs on the underside of the Selector Ring. Ensure that they are secure within the Selector Ring.

Outer Plate Subassembly

l) Check the operation of the Push Button Lock and replace it if necessary.

m) Remove the four cover plate screws and the cover plate. Use caution as the Cover Plate retains three loaded compression springs.

n) Remove and clean the Locking Bar, Lock Pin and Cam Follower. Clean the Cover Plate and the Outer Plate. Ensure that the slots for the Locking Bar, Lock Pin and and Cam Follower are thoroughly cleaned.

o) Replace the Lock Pin Springs and Cam Follower Spring with the new ones provided in the maintenance kit. Lightly lubricate the pins with Felpro C5A and reinstall them in the Outer Plate. Using the thread sealant provided in the maintenance kit, install the cover plate using the four #4 screws. Ensure that the screws are flush with the surface of the cover plate.

> NOTE: *If the screws protrude from the Cover Plate, they may interfere with the smooth rotation of the Selector Ring.*

p) Lightly lubricate the Inner Plate including the three compression spring slots and the internal surfaces of the Selector Ring. Install new compression springs in the slots of the Inner Plate as shown in Figure 5-1. Leave the free ends of the springs extended from the slots.

> NOTE: *The Selector Ring Parts are precision machined components. Too much grease will cause interference. Use only a very thin film of lubricant.*

q) Align the Pin Slots in the Selector Ring with the Pin Holes in the Inner Plate. Rotate the Selector Ring so that the three nubs engage the exposed compression springs on the Inner Plate. Lower the Selector Ring onto the Inner Plate until the Compression Springs and the Selector Ring snap into position. Verify that the Pin Slots are aligned with the Pin Holes. The Selector Ring should now be in the 'LOCK' position.

r) Rotate the Selector Ring toward the 'OPERATE' position and install the dummy Source Assembly.

s) Lightly lubricate and install the Actuator Pin and the Interlock Pin. The Actuator Pin is longer than the Interlock Pin and goes in the Pin Hole aligned with the end of the Actuator. It should not engage its hole at the end of its slot when the Selector Ring is in the 'LOCK' position. The Interlock Pin should engage in its hole.

t) Install new pin springs in the heads of the Actuator Pin and Interlock Pin.

u) Lightly lubricate the outer diameter and flange of the Outer Plate Subassembly and mount it on the Selector Ring. Ensure that the Pin Springs are aligned with the holes in the Outer Plate. If necessary, depress the Locking Bar until the Outer Plate snaps into position.

v) Using a thread sealant, reinstall the Lock Assembly using the three 1/4 - 20 socket head cap screws. Torque each screw evenly to 80-90 in- lbs.

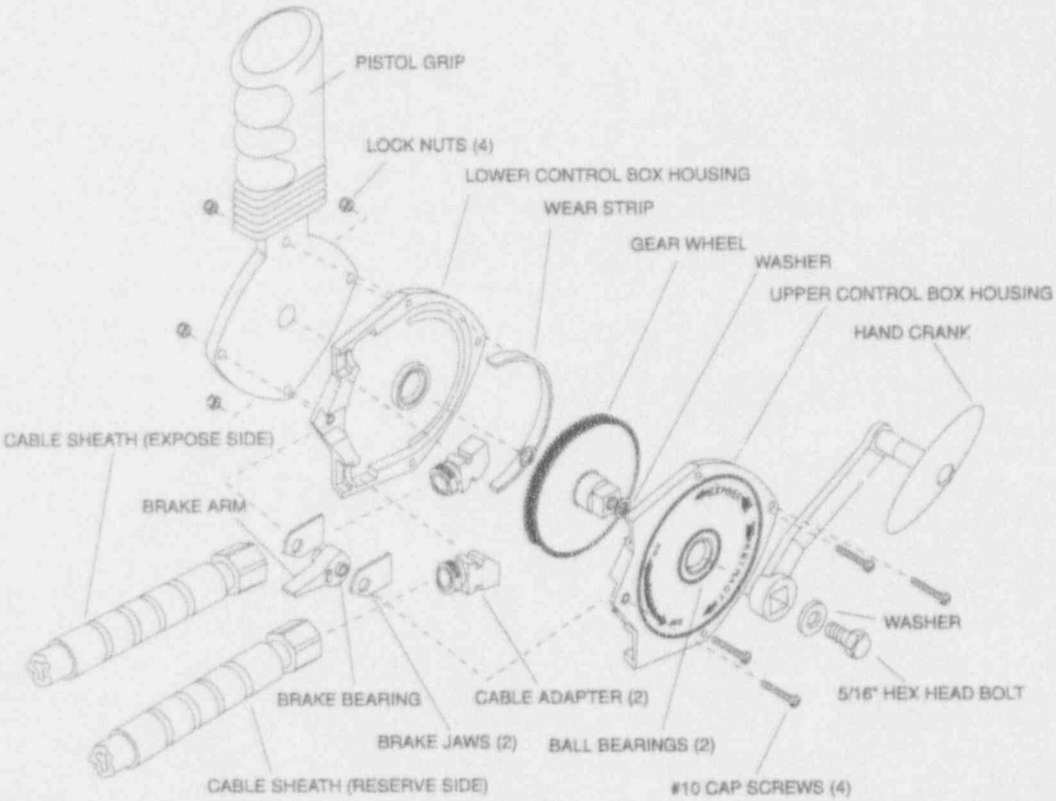

Figure 5-2
Exploded View of Pistol Grip Control

w) Perform a quarterly inspection to verify the function of the reassembled unit and all safety features. Once the quarterly inspection has been successfully completed, install the three Screw Cover Caps using the sealant provided in the maintenance kit.

5-4-3 Drive Controls

Annual inspection of the Drive Controls consists of the complete breakdown, cleaning and lubrication of the Pistol Grip Assembly, the Control Cable Sheaths and the Teleflex Cable.

An exploded view of the Pistol Grip Control is provided in Figure 5-2. Its main components are the Pistol Grip, the Hand Crank, the Control Box Housing, the Gear Wheel, the Brake and the Wear Strip.

a) In a clean area, straighten out the Control Cable Sheath. Pull out and coil the Teleflex Cable until you feel some resistance. This indicates that the Stop Spring has engaged the gear wheel. Do not use excessive force as this may damage the stop spring or the gear wheel.

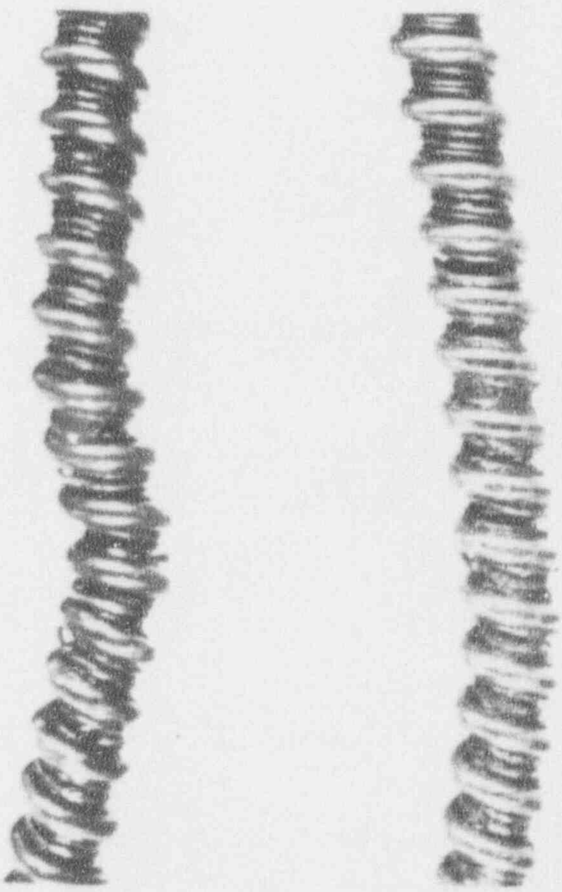

Figure 5-3
Examples of Teleflex Cable Defects

NOTE: *The Teleflex Cable coil diameter should not be less than 30 cm (12 inches).*

b) Disconnect the Reserve Tube from the Pistol Grip Assembly and remove the Stop Spring. This allows the rest of the Teleflex Cable to be removed from the Pistol Grip Assembly.

c) Examine the Teleflex Cable for kinks and frays. Examples of Teleflex Cable Defects are shown in Figure 5-3. If no damage is observed, clean the drive cables using a brush and a degreaser.

WARNING: Use of damaged Drive Controls increases the risk of a stuck source.

d) Clean the male connector and check that the crimped connection between the male connector and the Teleflex Cable is secure. Examine the male connector using a GO-NO GO gauge. Refer to Nordion Procedure IS/OP 0046 C000 (See Appendix B).

e) Remove the Bayonet Connector from the Control Cable Sheath and check that it swivels freely. Remove the spring pins, clean and lubricate the moving parts with Felpro C5A. Reassemble using the new spring pins provided in the maintenance kit.

f) Label the Cable Sheaths and remove them from the Pistol Grip. (Labels are necessary to replace the Cable Sheaths in the same orientation.)

g) Flush both Cable Sheaths with a solvent degreaser. Blow compressed air through the sheaths until they are dry.

CAUTION: Perform this operation under well ventilated conditions and in accordance with the degreaser manufacturer's safety procedures.

h) Soak a cloth with solvent degreaser and wipe the external surfaces of the Cable Sheaths while checking for cuts, dents or other such damage. Verify that the Cable Sheaths flex smoothly and easily without crunching. Damage to the stainless steel tube requires that the Cable Sheaths be removed from service. Damage to the outer PVC casing may be repaired using water resistant vinyl tape.

i) Check the area around the Cable Sheath Connectors for damage. Ensure that the Connectors are securely fastened to the Control Cable Sheath.

j) Verify that the Cable Sheaths are 25 ft. (7.6 m) long.

5-4-4 Pistol Grip Control

CAUTION: Wear safety glasses while performing this procedure. The Pistol Grip Control contains a Wear Strip that may fly out once the Control Box Housing is opened.

a) Remove the 5⁄16 hex head bolt and the washer from the Hand Crank. This allows the Hand Crank to be removed form the Control Box Housing.

b) Remove the four #10 round head cap screws from the Control Box Housing.

c) While holding the Cable Adapters, **SLOWLY** remove the upper Control Box Housing.

d) Remove and clean the Wear Strip.

e) Remove and degrease the Gear Wheel. Check for bent or broken teeth.

> **WARNING:** Damaged Gear Wheels increase the risk of a stuck source. Replace damaged components prior to use.

f) Remove and clean the Cable Adapters.

h) Remove and clean the brake arm, brake jaws and brake bearing.

i) Clean both halves of the Control Box Housing. Check that the ball bearings turn freely.

j) Install one Cable Adapter in the lower Control Box Housing.

k) CAREFULLY place one end of the Wear Strip against the installed Cable Adapter, and fit the Wear Strip in the track provided in the Control Box Housing.

l) Install the other Cable Adapter.

m) Install Gear Wheel Washers on each side of Gear Wheel Shaft, and install the Gear Wheel in the Control Housing. Take care not to contact the Wear Strip as this may cause it to fly out of the track.

n) Replace the brake jaws, brake arm and brake bearing as shown in Figure 5-2.

o) Install the upper Control Box Housing and check that the Gear Wheel spins freely.

p) Reinstall the four #10 cap screws and lock nuts through the pistol grip and Control Box Housing.

q) Replace the Hand Crank and washer using the 5⁄16 hex head bolt.

r) Install the Cable Sheath on the Cable Adapter that fits on the 'EXPOSE' side of the Pistol Grip Assembly. It should be replaced in the same orientation it was in at the start of this procedure. Do not install the Reserve Tube.

s) Replace the Bayonet Connector.

t) Lightly oil the Teleflex Cable, place it into the Cable Sheath and feed it into the Control Box Housing. Turn the crank to expose a short length of the Teleflex Cable on the 'RETRACT' side and reinstall the Stop Spring.

u) Reinstall the Reserve Tube.

v) Replace cable ties as necessary.

5-4-5 Source Guide Tubes

a) Soak a cloth with solvent degreaser and wipe the external surfaces of the Source Guide Tubes while checking for cuts, dents or other such damage. Verify that the Intermediate and Terminating Sections flex smoothly and easily without crunching. Damage to the stainless steel tube requires that the Cable Sheaths be removed from service. Damage to the outer PVC casing may be repaired using water resistant vinyl tape.

b) Check the area around the fittings for damage. Ensure that the fittings are securely fastened to the Intermediate and Terminating Sections. Verify that the threads on the fittings are undamaged.

c) Soak a swab in solvent degreaser and run it through the Source Guide Tube until it emerges clean. Ensure that no foreign material remains in the tubes.

d) Drop a dummy Source Assembly through the Source Guide Tube. It should pass freely through the length of the Source Guide Tube and into the Source Stop.

e) Verify that the Intermediate and Terminating Sections are 7 feet (2.1 metre) long.

TABLE 5-1

TITAN Recommended Maintenance Schedule				
Step	LEGEND: X = Required R = Recommended - = Not Required	Daily	Quarterly *(Source Change)*	Annual
Gamma Ray Projector				
1	Check due date for quarterly and annual inspection	X	-	-
2	Complete radiation survey	X	X	X
3	Check external surfaces for contamination	X	X	X
4	Check labels and general appearance	X	X	X
5	Check function of Push Button Lock	X	X	X
6	Check that handle is secure	X	X	X
7	Check End Cap Storage Tube	X	X	X
8	Check Condition of Source Guide Tube End Cap	X	X	X
9	Check engagement of Bayonet Connector	X	X	X
10	Check for smooth operation of Selector Ring	X	X	X
11	Verify function of Interlock	-	X	X
12	Verify that Selector Ring cannot be turned into OPERATE with End Cap installed	-	X	X
13	Verify that Selector Ring cannot be turned into OPERATE if Source is misconnected	-	X	X
14	Verify that Bayonet Connector cannot be removed with the Selector Ring in the OPERATE position	-	X	X
15	Perform ten test exposures with dummy Source Assembly	-	X	X
16	Check the S-tube for contamination	-	X	X
17	Check contents of maintenance kit	-	-	X
18	Breakdown, clean, replace springs and reassemble Lock Assembly	-	-	X
Source Guide Tube				
1	Check external surface for damage	X	X	X
2	Check fittings	X	X	X
3	Check condition of plastic end caps	X	X	X
4	Check for obstructions	X	X	X
5	Pass dummy Source Assembly	R	X	X

TITAN Recommended Maintenance Schedule				
Step	LEGEND: X = Required R = Recommended - = Not Required	Daily	Quarterly *(Source Change)*	Annual
6	Verify length	R	R	X
Drive Controls				
1	Check external surface for damage	X	X	X
2	Check condition of plastic end caps	X	X	X
3	Check Pistol Grip Control for damage or loose parts	X	X	X
4	Check swivel on Bayonet Connector	R	X	X
5	Clean, inspect and oil Teleflex Cable	-	R	X
6	Remove and clean Cable Sheaths	-	-	X
7	Check Cable Sheath Connectors	R	R	X
8	Verify Length	-	X	X
9	Breakdown, clean and reassemble Pistol Grip Control	-	-	X
10	Check Gear Wheel for damage	-	-	X

Source Assembly Maintenance Summary		
Item	Frequency	Maintenance
1.	Weekly	CLEAN male and female connectors. LUBRICATE female connector.
2.	Weekly	CHECK functioning of source locking collar
3.	Monthly	INSPECT source and drive cable connectors using the test gauge
4.	As required	VERIFY length of teleflex drive cable
5.	As required	CLEAN radiography equipment
6.	As required	RECORD all maintenance and repairs in the log book

Chapter Six

Source Changer

6-1 GENERAL

This section describes the storage and shipping of radioactive Source Assemblies and is applicable to all gamma radiography sources contained in a Source Changer. Source Changers are used to transport new and depleted sources to and from Nordion and the customer.

WARNING: The C-990 may only be shipped in a licensed Source Changer. Ensure that your changer is licensed for the C-990. If in doubt, contact Nordion International Inc.

6-2 CHANGING A SOURCE

6-2-1 Regulations

Canada—In Canada, the governing regulations are the Transportation of Dangerous Goods (TDG) Regulations and the Transport Packaging of Radioactive Materials Regulations, SOR/83-740, including all amendments.

United States—In the United States, the transport of Radiography Projectors and Source Changers is governed by 10 CFR Part 71, and 49 CFR Parts 171 through 179.

International—IAEA Safety Series No. 6, 1985 Edition (As Amended 1990), guides the transportation of radioactive materials internationally.

6-2-2 Prerequisite for Changing a Source

The user must be trained and qualified to carry out a source change. The operator must carry a TLD, direct reading dosimeter, and alarm. The operator must also use a calibrated area radiation survey meter that is capable of measuring from 0.02 mSv/h (2 mrem/h) to 100 mSv/h (10 rem/h).

6-2-3 Receiving Source Changers

When shipping a radioactive package, the consignee must make arrangements for receiving prior to shipment. Upon notification of arrival, the package shall be promptly picked up at the carrier's terminal.

a) Upon receipt of the Source Changer, measure the radiation fields at the surface of the package and at 1 meter. These should not exceed 2 mSv/h (200 mrem/h) at the surface and 100 µ Sv/h (10 mrem/h) at 1 meter.

> **WARNING:** If the package has been damaged and the radiation fields exceed these limits, treat the situation as an **EMERGENCY**. Isolate and secure the package in a restricted area. Contact the appropriate authorities and your Radiation Safety Officer. See 7-2—*Emergency Procedures.*

b) Inspect the Source Changer for damage. Check the condition of the wire seal.

> **WARNING:** If the package has been tampered with or damaged, contact your Radiation Safety Officer for further instructions. Do not proceed further unless authorized to do so.

c) Record the radiation levels in the receiving report. Enter the isotope (iridium 192), activity, **source model number and serial number**. In addition, **record the model number and serial number** of the Source Changer.

d) Read the User's Instructions that accompany the Source Changer.

6-2-4 Source Changer

Many different models of Source Changers may be used for changing a source. Please refer to the User's Guide that comes with the Source Changer.

6-2-5 Shipping

Refer to your Source Changer's User's Instructions for directions on preparing your Source Changer for transport.

> **WARNING:** Never ship a Source Changer that has been tampered with or damaged. Ensure that your Source Changer is licensed to carry the C-990.

Chapter Seven

Safety

7-1 GENERAL

As an operator, you are required to operate the TITAN in accordance with this manual and local/national regulations. The operating instructions and information presented here are intended only for the use of licensed personnel. Read and fully understand this manual before beginning operations. You are advised to:

- operate the equipment according to the instructions contained herein,
- observe all CAUTIONS and WARNINGS,
- ensure proper maintenance of the equipment,
- ensure that **only** properly instructed personnel are permitted to operate the TITAN .

As an operator of the TITAN , you are required to have the qualifications specified jointly by your Local Regulatory body and Principal Owner Licensee.

7-1-1 Safety Features

The TITAN incorporates an important new safety feature for Gamma Ray Projectors. That is, you cannot release the source from the Gamma Ray Projector unless you have secured both the Source Guide Tube and the Drive Controls. This feature significantly reduces the possibility of an accidental source disconnect through operator error.

7-2 EMERGENCY PROCEDURES

7-2-1 Operating Emergencies

> **WARNING:** DO NOT handle an unshielded source. Sources emit high levels of radiation . Close contact may cause severe injury or death.

In the event of an emergency, STAY CALM and consider the proper course of action. The following steps should be completed before any remedial action is taken:

a) **Immediately move away from the exposed source.**

Increasing the distance between yourself and the radiation source decreases your radiation dose. DO NOT PANIC if you cannot immediately shield the source.

b) **Establish a restricted area.**

Using a survey meter, check the restricted area boundaries and adjust them if necessary. Ensure that no one enters the restricted area. Do not leave the restricted area unattended.

c) **Get Assistance**

Remain in the area until help arrives and someone is able to provide assistance. Arrange to have your Radiation Safety Officer (RSO) contacted.

d) **Wait for Qualified Personnel to Arrive**

Well planned remedial action usually makes it possible to retrieve a source with little operator exposure. Source retrieval should only be performed by specially trained personnel. DO NOT ATTEMPT ANYTHING THAT YOU HAVE NOT BEEN TRAINED TO DO. If necessary, contact Nordion International Inc., at **1-800-267-6211**.

7-2-2 Transport Emergencies

The following emergency procedure does not apply to vehicle malfunctions where it can be readily determined that the radioactive material and the TITAN have not been disturbed.

In the event of a transportation emergency, **do not leave the vehicle unattended**. Arrange for a passing motorist to contact police.

When obtaining assistance in the case of an emergency, the information contained in shipping papers and emergency procedures should enable responsible persons to prepare a timely and effective response. Ensure that this information is kept in a readily accessible and visible area in the transport vehicle.

Transport regulations require carriers, organizations or persons transporting a radioactive material package that is involved in an accident to notify the appropriate authority that an accident has occurred in the area under their jurisdiction. Appendix C contains a list of appropriate agencies.

Accidents

In the event of an accident, the following steps should be taken;

a) Render first aid, if necessary.

b) Perform a radiation survey. Set up a restricted area if the source becomes exposed.

c) Notify the police. DO NOT LEAVE THE PACKAGE UNATTENDED. Arrange for a passing motorist to get help. Indicate if an ambulance is required.

d) Notify your Radiation Safety Officer. DO NOT leave the area without ensuring that the police will keep unauthorized personnel outside the restricted area.

e) Arrange for your Radiation Safety Officer to contact the appropriate regulatory agencies (See Appendix C.)

f) Delay clean up until properly trained personnel arrive.

Fire

In the event of a fire, the following steps should be taken;

a) Render first aid, if necessary.

b) Small fires can be extinguished with dry chemical (CO_2) extinguishers and large fires with foam or water from UPWIND, and at a maximum distance. Fumes should be assumed to be toxic. Large fires should be left to trained firemen.

c) Perform a radiation survey. Set up a restricted area if the source becomes exposed.

d) Notify the police. DO NOT LEAVE THE PACKAGE UNATTENDED. Arrange for a passing motorist to get help. Indicate if an ambulance is required.

e) Notify your Radiation Safety Officer. DO NOT leave the area without ensuring that the police will keep unauthorized personnel outside the restricted area.

f) Arrange for your Radiation Safety Office to contact the appropriate regulatory agencies. (See Appendix C.)

g) Delay clean up until properly trained personnel arrive.

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Chapter Eight

Warranty

8-1 TITAN WARRANTY

Nordion International Inc. makes the following warranties with respect to its products:

I. Sealed Sources: —Sealed sources shall conform to current Nordion specifications and shall be free from any material defect in workmanship or materials at the time of delivery.

II. Equipment: Nordion International Inc.—Gamma Ray Projectors and peripheral equipment will be free from any material defect in workmanship or materials for a period of one (1) year from the date of shipment of product to customer.

III. Parts: —Replacement parts supplied by Nordion shall be free from any material defect in workmanship or materials for a period of thirty (30) days from the date of shipment of product to customer.

Nordion's only obligation with respect to the warranties herein shall be to repair, or at its sole discretion, to replace defective products or parts thereof.

Customer shall return product to a Nordion authorized repair centre for repair or replacement, freight prepaid. Customer shall be responsible for preparing the product for shipment in accordance with local laws and regulations.

Under no circumstances should the customer return product to Nordion International Inc. without obtaining a product return authorization (P.R.A.) number from Nordion.

All warranty obligations of Nordion International Inc. shall cease and have no effect if the products are subjected to accident, abuse, misuse, alteration or neglect.

The warranties contained herein are expressly in lieu of and exclude all other express or implied warranties including, but not limited to, warranties of merchantibility and fitness for a particular purpose, use or application.

8-2 TITAN - INSPECTION AND RETURN OF PRODUCTS

All shipments shall be inspected on receipt by the buyer unless otherwise instructed by Nordion International Inc. Any defects shall be promptly communicated to the shipper and Nordion International Inc. in writing within ten (10) days of receipt of the product. No product shall be returned without a Nordion product return authorization (P.R.A.) number. Products returned shall be at the buyer's sole risk and expense. The buyer shall pay a re-stocking charge in respect of such products.

8-3 LIMITATION OF LIABILITY

ordion's liability to the buyer for damages, howsoever caused, shall not exceed payment actually received by Nordion International Inc. for the product furnished, or to be furnished, as the case may be, and in no event shall Nordion International Inc. be liable for indirect, contingent, special or consequential damages (including loss of profit).

8-4 INDEMNITY

Customer shall indemnify Nordion for, and save Nordion harmless from, all losses, costs or damages suffered or incurred in respect of damage or destruction of property, personal injury or death which may be caused by or arise from, either wholly or in part, the use of products or customer's negligence, acts or omissions.

Appendix A

Troubleshooting

SYMPTOM	PROBLEM	SOLUTION
Cannot turn Selector Ring to 'OPERATE'.	Key is locked.	UNLOCK key.
	Bayonet Connector is not connected properly.	CHECK first to ensure that Source Assembly is properly connected. CONNECT Bayonet Connector. See 3-4-3 Operation Procedures "Connecting the Drive Controls."
	Source Guide Tube is not connected.	CONNECT Source Guide Tube. See 3-4 Operation Procedures.
Selector Ring does not easily turn to the 'OPERATE' position.	Teleflex Cable is pushing against inner plate in Lock Assembly.	RELIEVE compression by turning Pistol Grip Control crank clockwise.
	Lock is contaminated with foreign material.	CLEAN projector. See Chapter Five Maintenance
Selector Ring snaps back to the 'LOCK' position when turned to 'OPERATE'.	Teleflex Cable has disengaged the Stop Pin from the Selector Ring.	RELIEVE tension by turning Pistol Grip Control Crank counterclockwise.
Selector Ring does not snap back automatically to 'LOCK' when the source is retracted.	Source is not fully retracted.	RETRACT source fully.
	Source Assembly or Teleflex Cable is damaged.	REPLACE damaged Source Assembly or Teleflex cable. Always use a survey meter when approaching the projector. See 7-2 Emergency Procedures.
	Lock Assembly is contaminated with foreign material.	CLEAN projector. See Chapter Five Maintenance.

SYMPTOM	PROBLEM	SOLUTION
Cannot connect Teleflex Cable to Source Assembly.	Source Assembly Lock Pin has seized.	LUBRICATE Source Assembly Lock Pin. See Chapter Five Maintenance.
	Source Assembly Connector or Teleflex Cable Connector is damaged.	REPLACE Source Assembly and/or Teleflex Cable.
Cannot connect Bayonet Connector to the Gamma Ray Projector.	Teleflex Cable has not been connected first to the Source Assembly.	CONNECT Teleflex Cable to Source End Connector.
Cannot disconnect Bayonet Connector.	Source is not fully shielded.	RETURN source to fully shielded position by turning Pistol Grip Control Crank.
	Selector Ring has not fully retracted to the 'LOCK' position.	ROTATE the Selector Ring completely clockwise. Always use a survey meter when approaching the projector.
	Push Button Lock is locked.	UNLOCK Push Button Lock with key.
Pistol Grip Control is difficult to turn.	Brake is engaged on Pistol Grip Control.	UNLOCK Brake.
	Pistol Grip Control is contaminated with foreign material.	CLEAN Pistol Grip Control and replace any damaged parts. See Chapter Five Maintenance.
	Teleflex Cable is kinked, frayed or otherwise damaged.	REPLACE Teleflex Cable. See Chapter Five Maintenance.
	Cable Sheath or Source Guide Tube is kinked, crushed or otherwise damaged.	ADJUST Cable Sheath or Source Guide Tube. See Chapter Five Maintenance.

Appendix B

IS/DS 0046 C000

NORDION INTERNATIONAL INC.

447 March Road, P.O. Box 13500, Kanata, Ontario, Canada, K2K 1X8
Tel: (613) 592-2790, Telex: (053) 4162, Telefax (613) 592-6937

OPERATING PROCEDURE

IS/OP 0046 C000

Maintenance Instructions for Cable-Type Radiography Sources

DATE	REV.	COMMENTS/AFFECTED PAGE	PREPARED BY	REVIEWED BY	APPROVED BY
90 JUL	0	Original Issue	A.W. Gunter	W.H. Pettipas	G. A. Burbidge
				P.L. Larabie	
93 AUG	A	DC 90614	M. Krzaniak	B. Menna	G. A. Burbidge
93 SEP	B	DC 90627	B. Menna	M. Krzaniak/	G. A. Burbidge
			B Menna	P. Larabie	GAB
				[signature]	
				[signature]	

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RECORDS AND REPORTS MANAGEMENT BRANCH

1 SCOPE

This document describes the maintenance procedures for Nordion cable-type radiography sources. The test gauge (Figures 3 and 4) is used to test the operation of D898 and D899 connectors for the cable-type radiography sources listed in Table 1.

Table 1

Source Type	Female Connector	Male Connector
C-337	D898F	D898
C-340	D899	D898
C-343	D899	D898
C-359	D899	D898
C-361	D899	D898
C-990	D899	D898

2 GENERAL INSTRUCTIONS FOR CONNECTORS AND SOURCES

It is recommended that you perform the following steps as a matter of habit. If your radiography equipment is in high use, it is advisable to perform these steps more frequently than indicated.

Table 2 summarizes these detailed procedures.

WARNING

Always check that the source is secured in its shielded position in the Gamma Ray Projector or Source Changer before performing any maintenance action.

(1) Clean both male and female connectors weekly, using any high grade commercial organic solvent.

(2) Lubricate the female connector weekly, using a light oil such as WD-40.

(3) Check weekly that the spring loaded locking collar is functioning properly (see Figure 1). Ensure that it returns to the fully closed position after it has been released.

Table 2
Maintenance Summary

Item	Frequency	Maintenance
1.	Weekly	**CLEAN** male and female connectors. **LUBRICATE** female connector.
2.	Weekly	**CHECK** functioning of source locking collar
3.	Monthly	**INSPECT** source and drive cable connectors using the test gauge
4.	As required	**VERIFY** length of teleflex drive cable
5.	As required	**CLEAN** radiography equipment
6.	As required	**RECORD** all maintenance and repairs in the log book

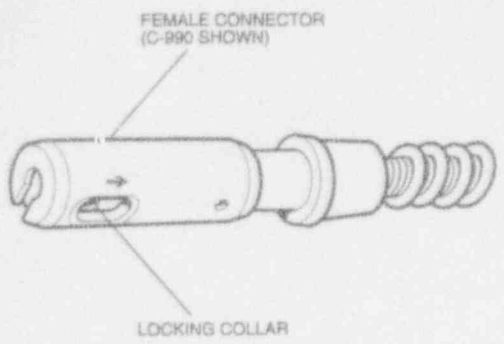


Figure 1

Operation of locking collar

4) Inspect the source end connector and drive cable male connector monthly according to the procedures of Section 3. Remove the source or drive cable from service if it has been damaged or fails any of the tests described in Section 3.

WARNING

> **Never use your Nordion source with anything other than a Nordion male connector on the end of your drive cable. It is dangerous to use other manufacturers' male connectors with Nordion sources.**

5) Verify that the length of the remote control drive cable is correct (see Figure 2). Disconnect the reserve side of the remote control sheath from the end plug. For a 25 foot remote control, when the drive cable is fully retracted, the end of the teleflex cable should be 8 inches short of the end of the reserve sheath. Remember to install the stop-spring when adjusting or replacing the drive cable. This procedure is particularly important for users of the Nordion TITAN Gamma Ray Projector or other projectors that automatically secure the source. The cable length must be checked once on existing equipment and then only when the drive cable is replaced.

6) Keep your drive controls and source guide tubes clean and dry. Always clean your accessories inside and out after working in a harsh environment.

7) Always store your radiography equipment in a clean, dry and secure storage area.

8) Follow the maintenance procedures and user's instructions in your gamma projector's operating manual. Record all maintenance in the equipment log book.

9) Call Nordion Customer Service if you have questions or problems with any of these procedures. 1-800-267-6211.

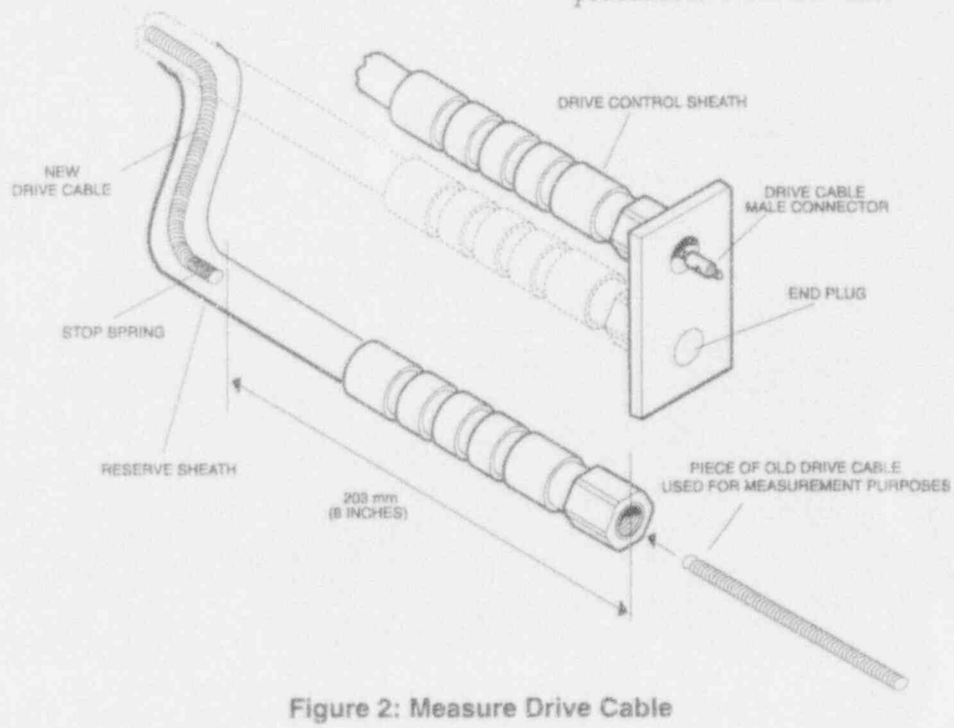


Figure 2: Measure Drive Cable

3 TEST GAUGE INSTRUCTIONS

CAUTION

Do not attempt to force the connectors through any of the holes or slots of the test gauge. This may damage the connector and cause unnecessary wear to the test gauge.

Check the source connector and the drive cable connector monthly using the test gauge. The connectors must pass all of the following tests. If a connector fails one or more of these tests, it must be removed from service immediately.

3-1 Male Connector (See Figure 3)

NOTE

Use the D898 side of the test gauge to perform all of the tests on the male D898 connectors.

(1) Place the male connector perpendicular to the plane of the test gauge.

(2) Check that the ball DOES NOT pass through hole "A". Should the ball pass through hole "A", this would indicate excessive wear on the ball.

(3) Place the male connector perpendicular to the plane of the test gauge.

(4) Check that the neck DOES NOT pass through slot "B". Should the neck pass through slot "B", this would indicate excessive wear on the neck.

(5) Place the male connector parallel to the plane of the test gauge.

(6) Check that the connector DOES NOT go through opening "C". Should the connector pass through opening "C", this would indicate that the neck had been stretched, due to excessive pull force.

3-2 Female Connector (See Figure 4)

NOTE

Use the D899 side of the test gauge to test all female connectors listed in Table 1.

(1) Place the female connector perpendicular to the plane of the test gauge.

(2) Check that the connector DOES pass through hole "D". Should the connector not pass through hole "D", this would indicate stretch of the connector due to excessive pull force.

NOTE

On the C-990 source assembly there is a roll pin pressed through the source just above the notch in the connector. It is not necessary for this pin to pass through hole "D" on the gauge.

(3) Place the female connector parallel to the plane of the test gauge.

(4) Check that the connector DOES NOT fit on pin "E". Should the connector fit on pin "E", this would indicate excessive wear of the female connector.

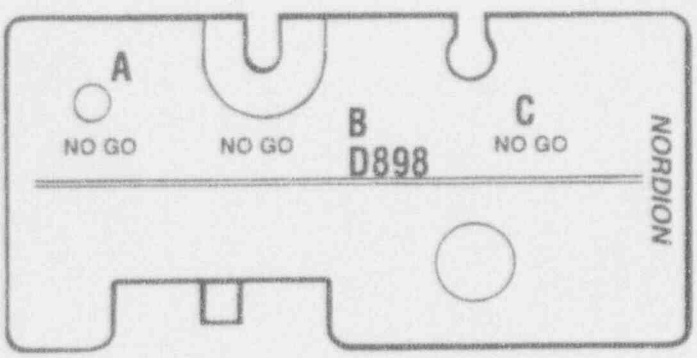


Figure 3

Gauge Orientation for Male Connectors

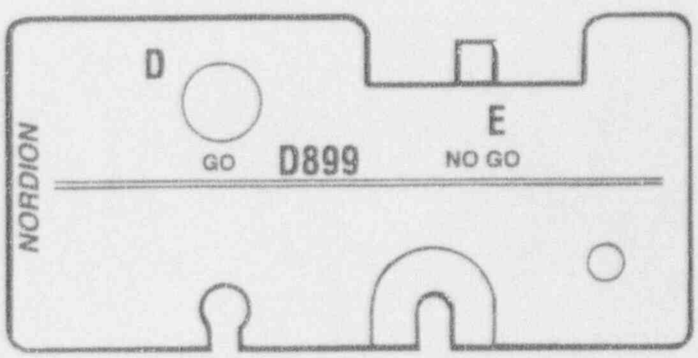


Figure 4

Gauge Orientation for Female Connectors

REFERENCES

1. Nordion Engineering Drawing, A16843, *D898, D899 Connector Test Gauge.*

2. Nordion Engineering Drawing, A17714, *Connector Body Female (D899).*

3. Nordion Engineering Drawing, A16828, *Connector Body Female (D898F).*

4. Nordion Engineering Drawing, A16832, *D898 Male Connector, Cable End.*

Appendix C

Regulatory Agencies

C-1 CANADA

AREA	REPRESENTATIVE	PLACE	TELEPHONE	
National	Atomic Energy Control Board Transport Canada Environment Canada	Ottawa Ottawa Hull	613 613 819	995-0479 996-6666 997-3742
Newfoundland	Dept. of Employment & Labour Relations	St. John's	709	729-2644
Prince Edward Island	P.E.I. Dept. of Health & Social Services	Charlottetown	902	368-4996
Nova Scotia	N.S. Dept. of Health	Halifax	902	424-4077
New Brunswick	N.B. Dept. of Health - Lab N.B. Dept. of Health St. John Regional Hospital	Fredericton Fredericton St. John	506 506 506	453-2067 453-2933 548-6852
Quebec	Atomic Energy Control Board	Laval	514	667-6360
Ontario	Ontario Ministry of Labour Atomic Energy Control Board	Toronto Mississauga	416 416	235-5922 821-7760
Manitoba	Department of Environment, Work Place Safety and Health	Winnipeg	204 204 204	945-7008 945-7039 944-4888
Saskatchewan	Department of Labour University of Saskatchewan	Regina Saskatoon	306 306 306	787-4538 933-7775 966-4675
Alberta	Compliance Information Centre Atomic Energy Control Board Alberta Labour	Edmonton Calgary Edmonton	403 403 403	422-9600 292-5181 427-2691
British Columbia	B.C. Ministry of Health Environmental Health Protection Services Radiation Protection Services	Vancouver Vancouver Vancouver	604 604 604	663-6635 660-6633 660-6633
Northwest Territories	N.W.T. Pollution Control Division N.W.T. Occupational Health & Safety Division	Yellowknife Yellowknife	403 403	873-7654 87[illegible]-7468

C-2 UNITED STATES

AGREEMENT STATES

A state that has an agreement with the Nuclear Regulatory Commission allowing the state to regulate certain activities using radioactive materials, for example, gamma radiography using iridium-192 or cobalt-60 sources.

Alabama 205-261-5313
Bureau of Radiological Health
Environmental Health Administration
Room 314, State Office Building
Montgomery, Alabama 36130

Arizona 602-255-4845
Arizona Radiation Regulatory Agency
4814 South 40th Street
Phoenix, Arizona 85040

Arkansas 501-661-2301
Division of Radiation Control and Emergency Management
Arkansas Department of Health
4815 West Markham Street
Little Rock, Arkansas 72205-3867

California 916-445-4931
916-322-2073
Radiologic Health Branch
Department of Health
714 P Street, Room 498
Sacramento, California 95814

Colorado 303-331-8480
Radiation Control Division
Office of Health Protection
Department of Public Health
4210 East 11th Avenue
Denver, Colorado 80220

Florida 904-487-1004
Office of Radiation Control
Department of Health and Rehabilitative Services
1317 Winewood Boulevard
Tallahassee, Florida 32399-0700

Georgia 404-894-5795
Radiological Health Section
Department of Human Resources
Room 600 - 878 Peachtree Street
Atlanta, Georgia 30309

Idaho 208-334-5879
Compliance Section
Idaho Department of Health and Welfare
Statehouse, Boise, Idaho 83720

Illinois 217-785-9868
Department of Nuclear Safety
1035 Outer Park Drive
Springfield, Illinois 62704

Iowa 515-281-3478
Bureau of Radiological Health
Iowa Department of Health
Lucas State Office Building
Des Moines, Iowa 50319

Kansas 913-296-1542
Bureau of Air Quality and Radiation Control
Department of Health and Environment
Forbes Field, Building 321
Topeka, Kansas 66620

Kentucky 502-564-3700
Radiation Control Branch
Department of Health Services
Cabinet for Human Resources
275 East Main Street
Frankfort, Kentucky 40621

Louisiana 504-925-4518
Nuclear Energy Division
Office of Air Quality and Nuclear Energy
P O. Box 14690
Baton Rouge, Louisiana 70898

Maryland 301-631-3300
Center for Radiological Health
Department of the Environment
2500 Broening Highway
Baltimore, Maryland 21224

Mississippi 601-354-6657/6670
Division of Radiological Health
State Board of Health
3150 Lawson Street
P.O. Box 1700
Jackson, Mississippi 39215-1700

Nebraska 402-471-2168
Division of Radiological Health
State Department of Health
301 Centennial Mall South
P.O. Box 95007
Lincoln, Nebraska 68509

Nevada 702-687-5394
Radiological Health Section
Health Division
Department of Human Resources
505 East King Street, Room 202
Carson City, Nevada 89710

New Hampshire 603-271-4588
Radiological Health Program
Bureau of Environmental Health
Division of Health Services
Health and Welfare Building,
Hazen Drive, Concord,
New Hampshire 03301

New Mexico 505-827-2959
Community Services Bureau
Environmental Improvement Division
Department of Health and Environment
1190 St. Francis Drive
Santa Fe, New Mexico 87503

New York 518-473-0048
Division of Policy Analysis and Planning
2 Rockefeller Plaza
Albany, New York 12223

North Carolina 919-741-4283
Department of Environment, Health and Natural Resources Division of Radiation Protection
P.O. Box 27687 Raleigh,
North Carolina 27603-7687

North Dakota 701-224-2348
Division of Environmental Engineering
Radiological Health Program
State Department of Health
1200 Missouri Avenue
Bismarck, North Dakota 58502-5520

Oregon 503-229-5797
Radiation Control Section
Department of Human Resources
1400 South West Fifth Avenue
Portland, Oregon 97201

Rhode Island 401-277-2438
Radioactive Materials and X-Ray Programs
Rhode Island Department of Health
Cannon Building, Davis Street
Providence, Rhode Island 02908

South Carolina 803-734-4700
Bureau of Radiological Health
South Carolina Department of Health and Environmental Control
J. Marion Sims Building
2600 Bull Street, Columbia,
South Carolina 29201

Tennessee 615-741-7812
Division of Radiological Health
TERRA Building, 150 9th Avenue, N.
Nashville, Tennessee 37219-5404

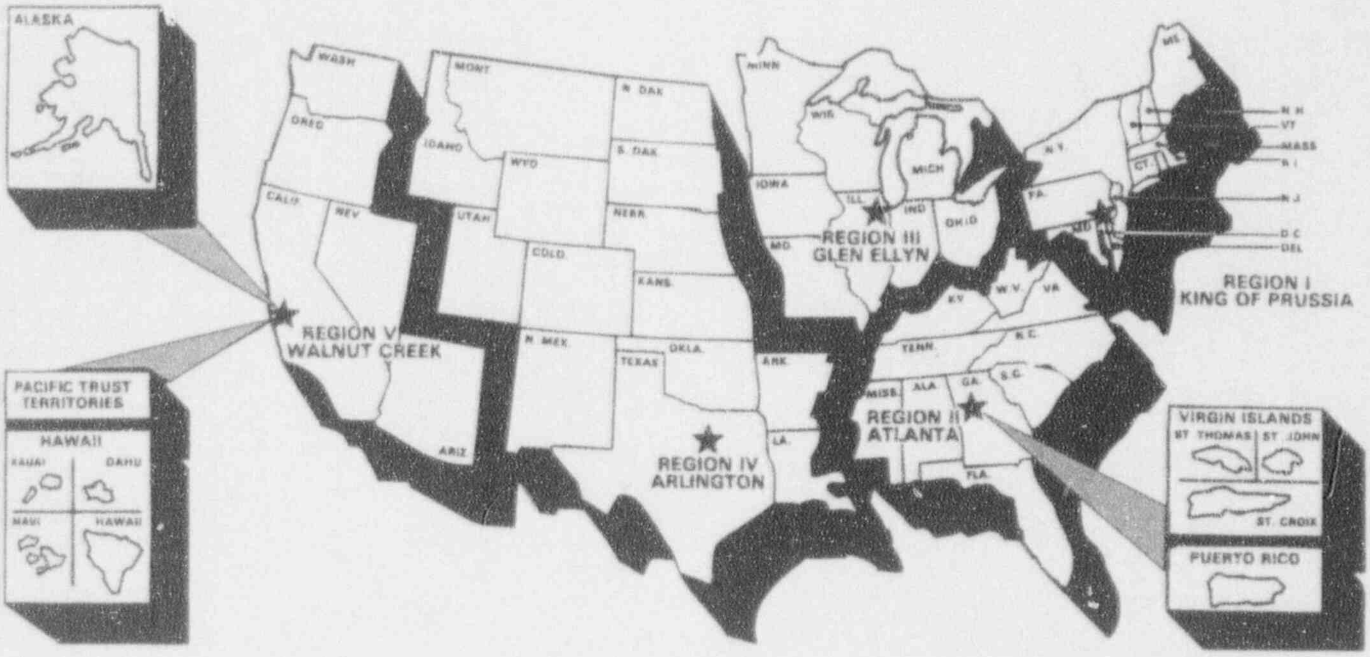
Texas 512-835-7000
Bureau of Radiation Control
Texas Department of Health
1100 W. 49th Street
Austin, Texas 78756

Utah 801-538-6734
Bureau of Radiation Control
State Department of Health
288 North 1460 West
P.O. Box 16690
Salt Lake City, Utah 84116-0690

Washington 206-586-8949
Office of Radiation Protection
Department of Social Health Services
Mail Stop LE-13
Olympia, Washington 98504

Updated lists of state addresses and telephone numbers are available upon request from:

Office of Governmental and Public Affairs USNRC
Washington D.C. 20555
(301) 492-0326



United States Nuclear Regulatory Commission Regional Offices

Region	Address	Telephone
I	631 Park Avenue, King of Prussia, Pennsylvania 19406	215-337-5000
II	101 Marietta Street, NW, Atlanta, Georgia 30323	404-331-4503
III	799 Roosevelt Road, Glen Ellyn, Illinois 60137	312-795-5500
IV	611 Ryan Plaza Drive, Arlington, Texas 76011	817-860-8100
V	1450 Maria lane, Walnut Creek, California 94596	415-943-3700

APPENDIX 4. IS/DS 0055 N990 rev B

NORDION INTERNATIONAL INC.
447 March Road, P.O. Box 13500, Kanata, Ontario, Canada, K2K 1X8
Tel: (613) 592-2790, Telex: (053) 4162, Telefax (613) 592-6937

DESIGN SPECIFICATION

Test Plan for the Titan Gamma Radiography Exposure Device

IS/DS 0055 N990 (REV B)

CURRENT DATE: 93 MAY

DATE	ISSUE	COMMENTS/AFFECTEDPAGE	PREPARED BY	REVIEWED BY	APPROVED BY
92 Feb	0	Original Issue	B. Menna	M. Krzaniak/	G. Defalco
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93 Jan	A	General Revisions	B. Menna	R. Goddard/	G. Defalco
				M. Krzaniak/	
				G. Burbidge	
93 May	B	DC 90571	B. Menna	M. Krzaniak	G. Burbidge
			[signature]	[signature]	[signature]

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Material Test Summary

1 INTRODUCTION

This document describes the detailed test plan for the Nordion Titan Gamma Radiography Exposure Device (GRED). The tests are required to demonstrate that the Titan meets the regulations for the design of gamma radiation exposure devices and the regulations for the safe transport of radioactive material (references 1, 3, 4, 6, 7). A description of the tests and detailed test procedures are included.

2 CLASSIFICATION

The Titan GRED is classified under ANSI N432(1980) as a Class P, Type 1, Type R exposure device. The testing described herein demonstrates that the device meets the requirements of this specification for a device of this type. Additional testing will be performed in order to support the design and to demonstrate that the Titan meets the transportation requirements for Type B(U) transport packaging (reference 6, 7).

3 PROJECT REQUIREMENTS

The guidelines for design, inspection and testing within ANSI N432(1980) and ISO 9000(1987) will be followed throughout the project. Some requirements of the revised ANSI standard, ANSI N43.9(1991) have been adopted.

4 TEST REQUIREMENTS

Reference documents 1, 3, 4, 6 and 7 outline in detail the test requirements for gamma radiography equipment and transport packagings. Table 1 summarizes these test requirements. Details of the requirements are listed in section 7 of this test plan. Figure 1 illustrates the sequence and flow of these tests.

The C990 source assembly has been demonstrated to meet Special Form requirements and has been classified as C43515 according to ANSI N543(1977) (see Appendix B).

5 DEFINITIONS

Many documents govern the testing to be performed on the Titan. They use many terms which are sometimes interchangeable or which may have subtle differences in meaning. For the purposes of this Test Plan, the following definitions shall apply.

Exposure Device

A shielded device employing a sealed source designed to allow the controlled use of gamma radiation for the purpose of making a radiographic exposure.

GRED

Gamma Radiography Exposure Device. This term typically refers only to the exposure device, and not to the entire apparatus.

Locked Position

Condition of the exposure device when it is locked (with a key) in addition to being in the secured position.

Projection Sheath

A flexible tube for guiding the control cable and the attached source assembly from the exposure device to the working position. Also known as a source guide tube.

Quality Assurance Representative

A representative designated by Nordion's Quality Assurance Department whose responsibility is to verify that the testing has been conducted in accordance with the quality assurance requirements and that the test results are thoroughly recorded and are accurate.

Remote Control Device

A device enabling the sealed source to be moved to an exposing position by operation at a distance away from the exposure device. The remote control device includes the crank mechanism, control cable and sheath. The remote control sheath consists of a reserve side and a projection side (see Figure 12 for illustration).

Secured Position

Condition of the exposure device when the source assembly is fully shielded and restricted from movement.

Source Assembly

A complete assembly including a sealed source, a short length (150 mm) of cable, a locking ball and an end connector. The source assembly used in the Titan is called the "C990" (ref. drawing K12223-600 Rev. B).

Table 1 - Governing Specifications and Their Tests

Device Under Test	Test	Standard or Specification						
		Nordion IS/DS 0055	ANSI N432 (1980)	ANSI N43.9 (1991)	IAEA Safety Series No. 6	10CFR 34 (Radiography) see note 1	10CFR 71 (Transport) see note 2	ISO CD 3999
Entire Apparatus	Projection Under Stress	✗		✗				✗
	Endurance	20,000	20,000	50,000				50,000
Exposure Device	Radiation Shielding	✗	✗	✗	✗	✗	✗	✗
	Vibration	see note 3		✗			✗	✗
	Horizontal Shock	✗	✗	✗				✗
	Vertical Shock	✗	✗	✗				✗
	Handle Wrench	✗		✗				✗
	Lock Breaking							✗
	Water Spray	see note 3			✗		✗	
	Immersion	see note 3			✗		✗	
	Penetration	✗			✗		✗	
	Puncture Resistance	✗	✗	✗	✗		✗	✗
	Accidental Drop	✗	✗	✗	✗		✗	✗
	Fire	✗		✗	✗		✗	✗
	Corrosion	see note 3						✗
	Free drop Test	see note 3			✗			
	Stacking Text	see note 3			✗			
Remote Control Device	Kinking	✗	✗	✗				✗
	Crushing	✗	✗	✗				✗
	Tensile	✗	✗	✗				✗
Projection Sheath	Kinking	✗		✗		✗		✗
	Crushing	✗		✗		✗		✗
	Tensile	✗		✗		✗		✗
	Tightness							✗
Source Assembly	Tensile	✗	✗	✗				✗

Notes:
1) 10CFR 34 requires all of the tests from ANSI N432 (1980) in addition to those indicated.
2) 10CFR71 includes the following tests that will not be performed: Heat, cold, reduced external pressure, increased external pressure and compression.
[illegible] Test will not be performed, but device is qualified by discussion.

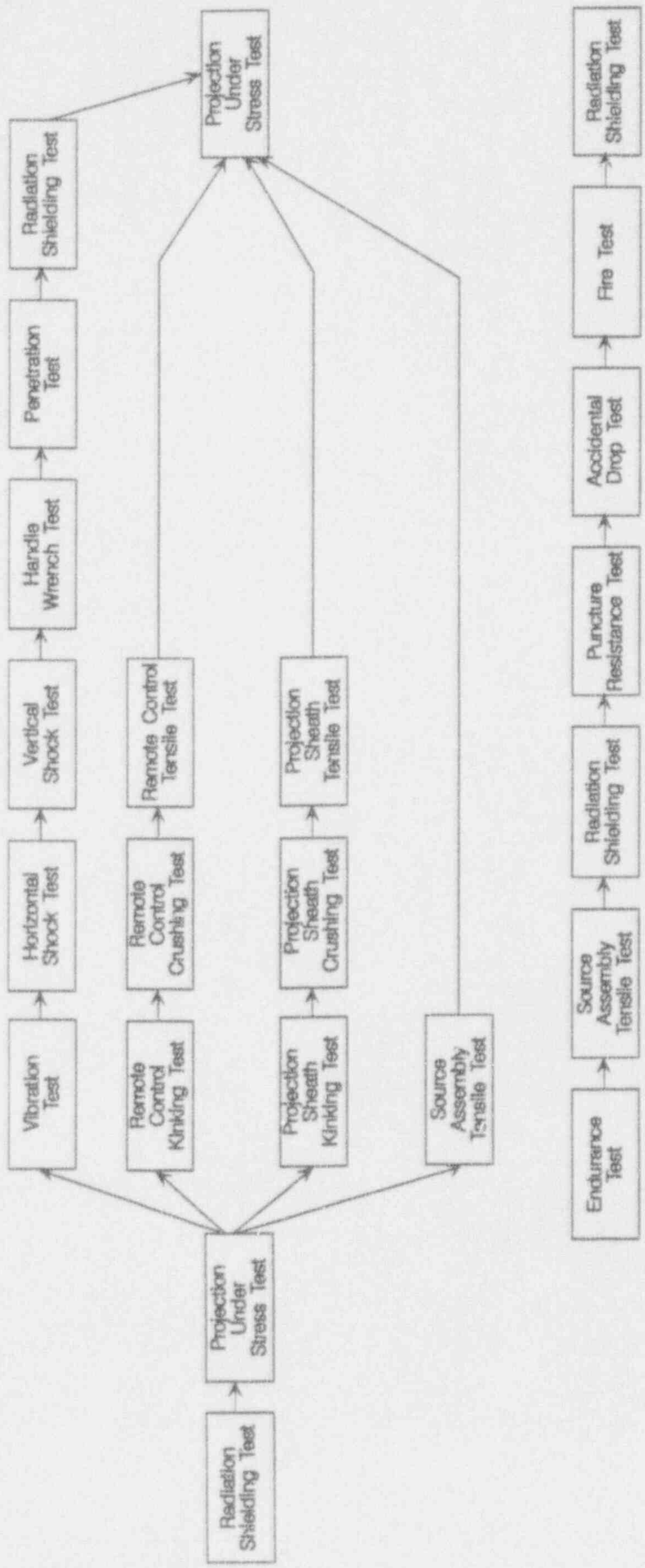

Figure 1
Test Flow Chart

6 QUALITY ASSURANCE REQUIREMENTS

The Nordion Titan project is managed in accordance with Nordion Specification IS/QP-0052-N990 and ISO 9000(1987). Testing will be performed in accordance with IS/QP-0052-N990.

6-1 Independent Testing

Where testing is performed by an organization independent of Nordion International, the testing and results will be documented by this independent organization. Where testing is performed by Nordion International, it will be thoroughly documented by the test engineer using sketches, photographs, video tapes and the Data Sheets in Appendix A. All test results will be validated by the project engineer. The testing will be witnessed by a Quality Control Representative where appropriate.

Representatives from the Canadian Atomic Energy Control Board will be invited to witness all testing.

6-2 Sub-Contractor's Quality Assurance

Sub-contractors must have a quality assurance system in accordance with ISO 9003 or CSA Z299.3. Quality system requirements include a quality policy, a quality system organization, quality records, a calibration system and personnel training. Sub-contractors will be evaluated on systems, procedures, and ability, prior to the start of testing.

6-3 Calibration

Equipment used for measuring test results shall be calibrated at the time of the test. The equipment calibration due date shall be recorded on the data sheets.

Calibration shall be performed by a qualified laboratory.

7 PROTOTYPE TESTING

7-1 Tests On The Entire Apparatus

7-1-1 Projection Under Stress Test

7-1-1-1 Purpose

The purpose of this test is to measure whether the torque required to drive and retract the source through a complete exposure cycle changes during a lifetime of normal use. This test is not a requirement of ANSI N432(1980). It is performed to verify the design and is based on the Projection Under Stress Test from ANSI N43.9(1991).

7-1-1-2 Equipment

The entire GRED apparatus shall be tested. Before the final test it will have been subjected to a variety of tests (see Figure 1). A torque meter Snap On model TBS2FUA will be employed.

7-1-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-1-1-4 Approach

The testing will be performed in two stages. Initial torque readings will be made on the new GRED equipment. Then, after a series of tests on the individual components, the measurements will be repeated.

The final torque measurements will be performed on equipment that has been subjected to the following tests:

- exposure device : horizontal shock, vertical shock, handle wrench and penetration
- remote control device : kinking, crushing, tensile
- projection sheaths : kinking, crushing, tensile
- source assembly: tensile

The test setup is shown in Figure 2. The bending radii for the remote control and projection sheath will be 500 mm.

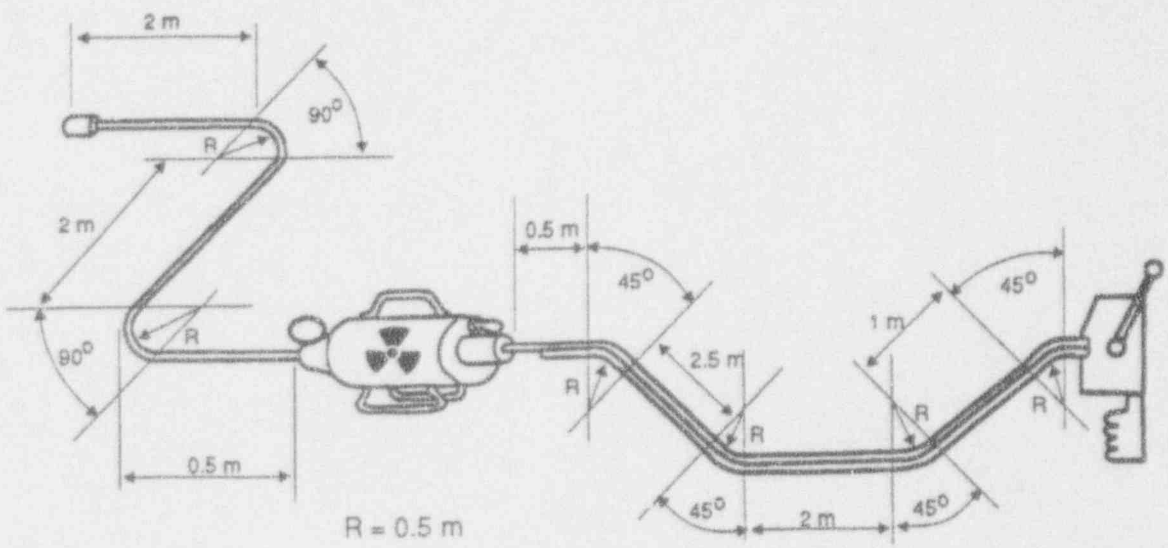

Figure 2
GRED Apparatus Endurance Test Configuration

Ten exposure cycles will be performed during which the maximum driving/retracting torque will be recorded.

7-1-1-5 Procedure

1) Set up the GRED equipment in the configuration shown in Figure 2. The bending radii at corners shall be 500 mm for the remote control and projection sheath. Connect the torque meter to the remote control crank mechanism.

2) Drive the source assembly to its fully extended position and then retract it fully. Care must be exercised in order not to measure the sharp rise in torque when the source reaches the end of its travel at each extreme.

3) Measure the driving torque and record the maximum value measured during the cycle.

4) Repeat the process 10 times and record the data on the Projection Under Stress Test Data Sheet provided in Appendix A. Be certain to fill out all of the information requested on the data sheet. The test engineer must sign the data sheet and a quality control representative must witness the test setup and at least one cycle of the testing. The test results must be validated by the project engineer.

5) Steps 1 to 5 are to be repeated once the equipment has been subjected to the tests for conditions of normal use listed in paragraph 7.1.1.4.

7-1-1-6 Data and Results

The test data shall be recorded on the form provided in Appendix A. All of the required information must be completed. An increase in drive torque of 25% or more shall constitute a failure.

7-1-2 Endurance Test

7-1-2-1 Purpose

The purpose of this test is to repeatedly operate the apparatus in order to determine its resistance to fatigue, and to measure any wear on the equipment components. After 20,000 cycles, an exercise will be performed in order to demonstrate that the source assembly will not disconnect when projected out of an open projection sheath.

7-1-2-2 Equipment

The automated endurance test equipment illustrated in Figure 3 will be used to perform the cycling. Impressions of the source tube will be made using Dow Corning Mold Making Compound DC HSII.

7-1-2-3 Location

With the exception of the thermal cycling this test shall be performed at Nordion International Inc., Kanata, Ontario.

7-1-2-4 Approach

The equipment will be subjected to continuous cycling for 20,000 cycles.

At the completion of 20,000 cycles, 50 cycles will be performed with the end of the projection sheath open. During these exposures, the source assembly will extend at least 1 meter out of the projection sheath. This additional test is not a requirement of ANSI N432(1980). Rather it is a requirement of ANSI N43.9(1991) that has been adopted to prove that the source assembly will not accidentally disconnect or snag outside the projection sheath.

At the conclusion of the test, 100 cycles will be performed with the exposure device at -40°C, and an additional 100 cycles will be performed at +55°C. These cycles are not a requirement of ANSI N432(1980) and will be performed after the completion of the 50,000 cycles. The entire remote control and projection sheath need not be exposed to the temperature extremes and these peripherals may be shorter than those used for the Endurance Test at ambient temperature.

After having been subjected to the endurance test, the source assembly will undergo the Tensile Test of paragraph 7.5.1.

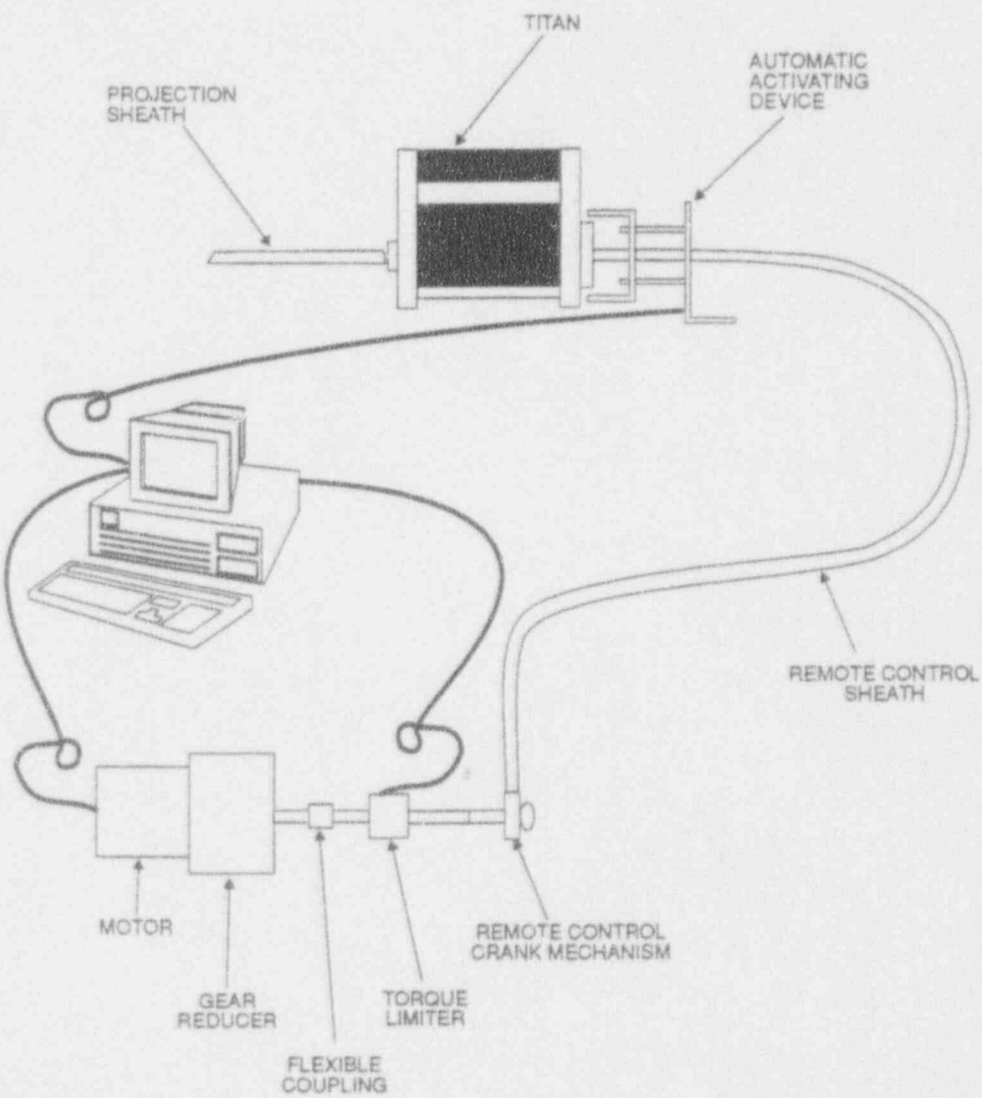

Figure 3
Endurance Test Setup

The test setup is shown in Figures 2 and 3. The automatic test apparatus shall meet the following requirements:

Minimum speeds : rotating 180 RPM
linear 0.75 m/s

The torque that the apparatus exerts at each extreme shall be determined by measuring the force experienced by the drive cable during manual operation. The test apparatus will then be adjusted accordingly.

7-1-2-5 Procedure

1) Measure the length of the dummy source assembly. Record the measurements and the source assembly serial number on the C990 Source Assembly Tensile Test Data Sheet, as this length will be required for comparison at the completion of testing. Record the tolerance associated with the length measurement and the calibration date of the instrument.

2) Check the integrity of the source tube by taking an internal impression using Dow Corning Mold Making Compound DC HSII.

3) Connect the equipment under test as shown in Figures 2 and 3.

4) Start the automated test equipment and verify that the counters are working properly. Check that the source assembly is travelling from the secured position, to the fully extended position and back. Record the date, time and cycle number on the Endurance Test Log Sheet in Appendix A. Be certain to initial every entry on the Log Sheet.

5) Regularly check the test apparatus for proper function or any incidents. An incident includes test startup or shutdown, failures or any other test anomalies.

6) Record any incidents on an Endurance Test Log Sheet provided in Appendix A. The date and time of each incident must be recorded and initialled. If the incident results in the shutdown of the test apparatus, it must be witnessed by a Quality Assurance Representative before the apparatus may be restarted. Disposition must be given by the project engineer.

7) Once 20,000 cycles have been completed, the end of the projection sheath shall be opened to allow the source assembly to pass through. 50 cycles shall be performed during which the source assembly shall extend at least 1 m from the projection sheath.

8) At the completion of the testing, the apparatus shall be moved to an environmental test chamber where the equipment shall be subjected to 100 cycles at temperature of -40°C. The remote control device and projection sheath do not need to be entirely exposed to the temperature extreme, and these peripherals may be shorter than those used for the Endurance Test at ambient temperature.

9) Repeat step 8 with the temperature stabilized at +55°C.

10) Remove the dummy source assembly. Tag and identify it, as a Tensile Test will be performed on it as per paragraph 7.5.1.

11) Check the integrity of the source tube by taking an internal impression using Dow Corning Mold Making Compound DC HSII.

7-1-2-6 Data and Results

Any start up, shut down or maintenance action shall be recorded on the Endurance Test Log Sheet. Photographs of any failures or maintenance actions are required. Failure criterium shall be failure of the apparatus to remain completely operational after 20,000 cycles. Additionally, the integrity of the sealed source and the encasement of the depleted uranium shielding must not be breached through wear after 20,000 cycles. An impression of the inside of the source tube will be made before and after the test.

7-2 Tests On The Exposure Device

7-2-1 Radiation Shielding Test

7-2-1-1 Purpose

The purpose of this test is to determine the exposure rate from the device to assure that the

dose rates in the vicinity of the device are within the limits specified.

7-2-1-2 Equipment

The Radiation Shielding Test will be performed on new exposure devices prior to the commencement of any mechanical testing, after the Penetration Test, after the Endurance Test, and if possible, after the tests for accident conditions. The measurements will be made on exposure devices with the end caps installed.

The Victoreen Model 440 and Model 660 survey meters will be used for measurements. Substitute survey meters may be used provided that the meter used to measure the exposure rate at 50 mm from the surface does not average over an area greater than 10 cm^2 and has a sensitive volume with no linear dimension greater than 5 cm. The meter used to measure the exposure rate at 1 m from the surface must average over an area no greater than 100 cm^2 and its sensitive volume must have no linear dimension greater than 20 cm.

7-2-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-1-4 Approach

A detailed survey will be performed on the two prototypes when they are new. Measurements will be made at every node on the grid system shown in Figure 4. In locations where the fields are relatively high, the hot spots will be located and identified in relation to the grid system. Radiation field measurements made after the exposure device has been subjected to testing will not be as thorough. They will be limited to areas of the device which have been affected or damaged by the testing.

A sample source is to be used for the measurement and the exposure rate is to be extrapolated to the maximum rating of 4.44 TBq (120 Ci) for the device. The extrapolation is not to exceed a factor of 10, but the source should approach an activity of 4.44 TBq (120 Ci) as safely and as practically as possible.

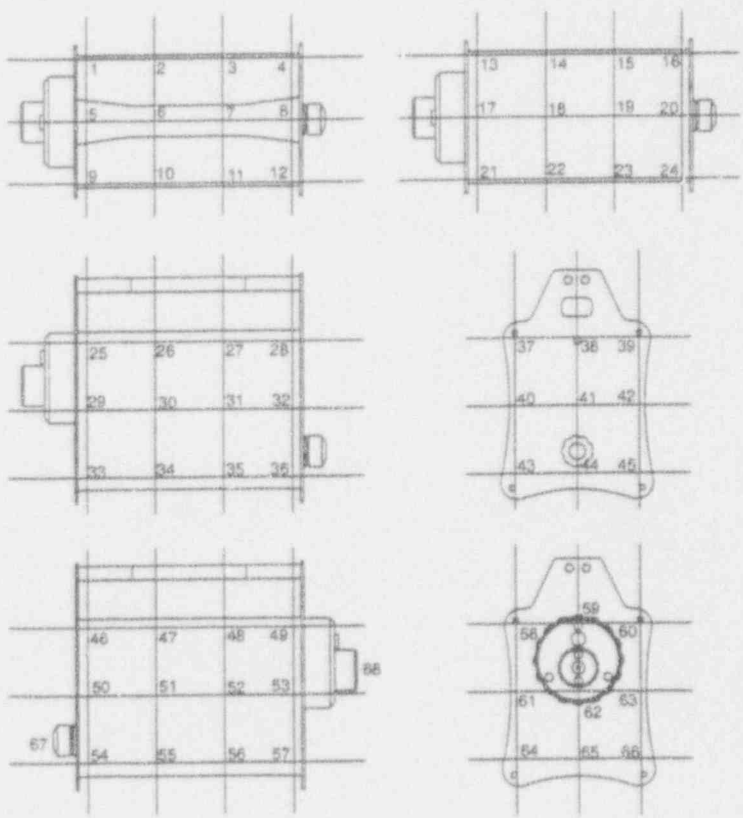

Figure 4
Radiation Survey Grid System

The maximum specified dose rates are as follows:

- 2 mSv/hr (200 mrem/h) on surface
- 0.5 mSv/hr (50 mrem/h) at 50 mm from the surface
- 0.02 mSv/hr (2 mrem/h) at 1 m from the surface

The activity of the source will be determined based on 0.55R/h-Ci at 1m for Ir-192.

If it is not possible to load a source assembly into the device after the tests for accident conditions, then a radiation shielding analysis will be performed to determine the exposure rate at this time.

7-2-1-5 Procedure

1) Measure the fields from the sample source and record the field output at 1m on the Radiation Shielding Test Data Sheet.

2) Observing the required safety procedures, install the sample source in the exposure device.

3) Using the Victoreen Model 471 Survey Meter, measure the fields 50 mm from the surface of the exposure device at each of the nodes identified on the 3 inch grid system in Figure 4. Allow the meter reading to stabilize for 5 seconds at each node before recording the measurement. Record each measurement on the Radiation Survey Data Sheet, and record the maximum reading on the Radiation Shielding Test Data Sheet.

4) Measure the fields at 1 m from each of the 6 faces of the exposure device. Record the measurements on the Radiation Survey Data Sheet, and record the maximum reading on the Radiation Shielding Test Data Sheet.

5) After the initial Radiation Shielding Survey on the exposure device, it is only necessary to make readings at locations on the device that are likely to have been affected by the testing.

6) Record all of the data on the Data Sheets, including the date, activity of the test source, serial number of the exposure device, and calibration data for the test equipment. Complete all of the calculations on the Radiation Shielding Test Data Sheet.

7-2-1-6 Data and Results

The measured field for the source and the activity calculation shall be shown on the Radiation Shielding Test Data Sheet. The extrapolation calculation shall also be recorded on the data sheet.

Fields in excess of the following constitute a failure:

- 2 mSv/hr (200 mrem/h) on surface
- 0.5 mSv/hr (50 mrem/h) at 50 mm from the surface
- 0.02 mSv/hr (2 mrem/h) at 1 m from the surface

7-2-2 Vibration Test

7-2-2-1 Purpose

The purpose of this test is to determine the resistance to the exposure device to the vibration that it may encounter during normal service. This test is not a requirement of ANSI N432(1980).

7-2-2-2 Discussion

The vibration test is intended to reveal any environmental effects that may occur during normal service. Examples of such effects include loosening of fasteners, component fatigue, chafing between parts and cracking or rupturing of structural members. The Titan is a welded structure, and any threaded fasteners are fixed with thread sealant. Additionally, the enclosure is injected with an epoxy foam which fills all internal voids. The Titan is therefore not susceptible to the environmental effects caused by vibration and there is no need to perform the vibration test.

7-2-3 Horizontal Shock Test

7-2-3-1 Purpose

The purpose of the Horizontal Shock Test is to test the resistance of the device to the shocks that may be encountered during normal service.

7-2-3-2 Equipment

The equipment used for the Horizontal Shock Test is shown in Figure 5. The exposure device shall have been subjected to the Projection Under Stress Test of paragraph 7-1-1 prior to the Horizontal Shock Test.

7-2-3-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-3-4 Approach

The Horizontal Shock Test consists of pendulum swings of the device into a rigidly mounted cylindrical steel bar. The exposure device will be suspended such that it just touches the target when at rest. The release position will be a point where the center of gravity of the device is 100 mm above its rest position. The steel bar will have a diameter of 50 mm and a length of 300 mm. It will be mounted to a rigid object with a mass of at least 225 kg. 20 impacts will be performed on each of the following areas:

- side of the exposure device
- side of the lock
- face of the lock
- bottom of the exposure device
- side of projection sheath connector
- face of projection sheath connector

7-2-3-5 Procedure

1) Connect the device under test to the suspension chain. Adjust the height and orientation so that the device will strike the pin in the desired location.

2) Measure the height to the bottom of the exposure device.

3) Swing the exposure device back until the height to the bottom of the device has increased by 100 mm.

4) Release the exposure device and allow it to swing into the target.

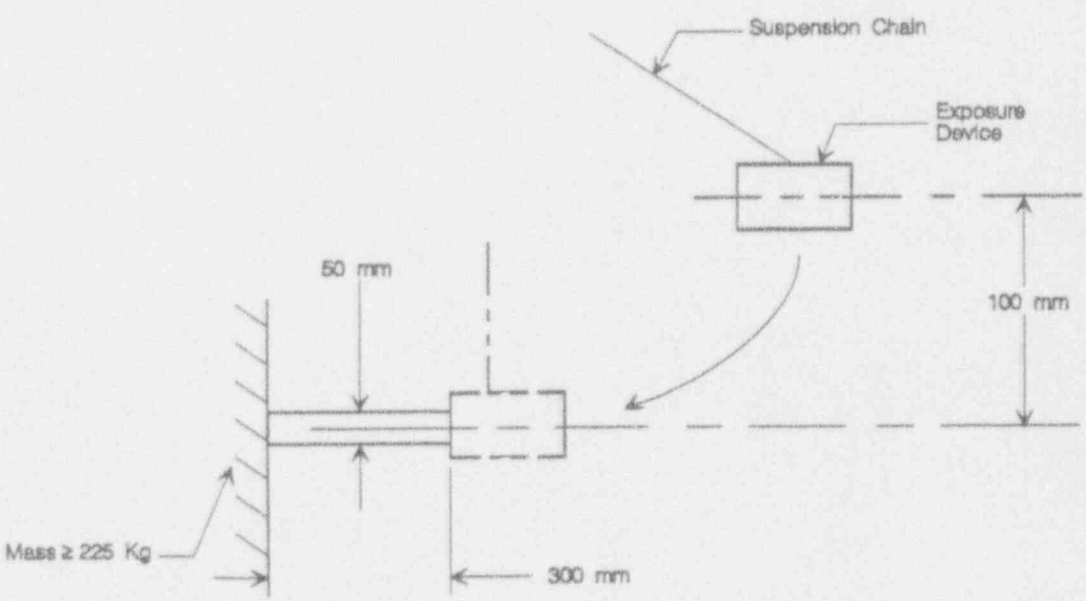

Figure 5
Horizontal Shock Test

5) Record any observations on the Horizontal Shock Test Data Sheet in Appendix A. Video tapes and photographs are required.

6) Repeat steps 3 to 6 until the device has been subjected to 20 impacts in the same area.

7) Repeat step 1 to 6 until each of the areas listed in paragraph 7.2.3.4 has been tested.

8) Connect the remote control and the projection sheath to the exposure device and perform 10 exposure cycles. This step may be performed at the completion of the Penetration Test of paragraph 7.2.10 at the discretion of the test engineer.

7-2-3-6 Data and Results

The date of the testing and the observations after each impact shall be recorded on the Horizontal Shock Test Data Sheet. Video tapes and photographs of each impact area shall be taken as a minimum. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles or failure of the Radiation Shielding Test.

7-2-4 Vertical Shock Test

7-2-4-1 Purpose

The purpose of the Vertical Shock Test is to test the resistance of the device to the shocks that may be encountered during normal service.

7-2-4-2 Equipment

The test equipment is shown in Figure 6. The exposure device shall have been subjected to the Horizontal Shock Test of paragraph 7.2.3.

7-2-4-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-4-4 Approach

The vertical shock consists of a drop from a height of 150 mm in the normal carrying position. The impact surface will consist of a rigid body with a mass greater than 225 kg covered by 25 mm of plywood. 100 shocks will be performed.

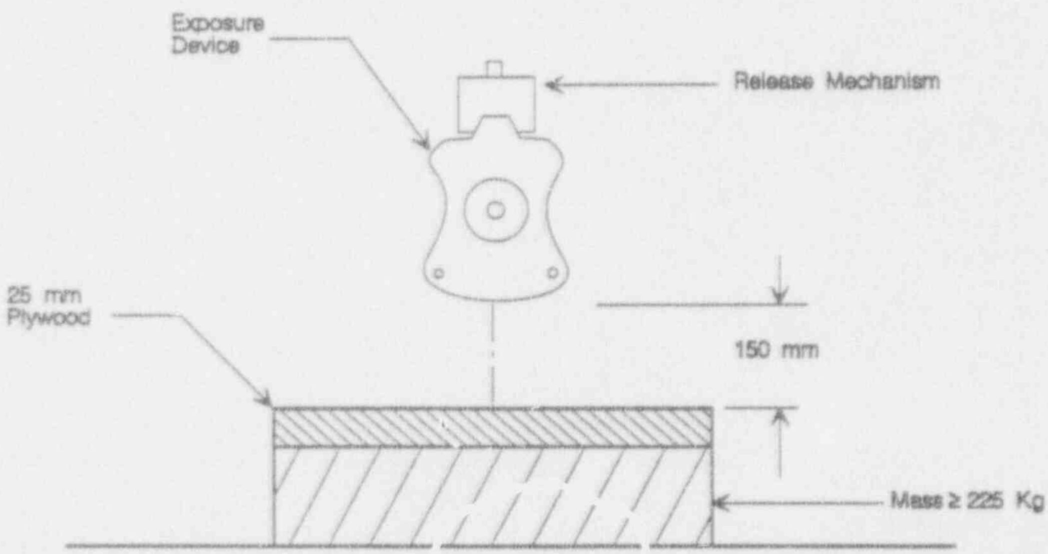

Figure 6
Vertical Shock Test

7-2-4-5 Procedure

1) Attach the exposure device to the release mechanism and verify that the height to the bottom of the exposure device is 150 mm.

2) Release the exposure device and allow it to fall onto the target.

3) Record any observations. Video tapes and photographs are required.

4) Repeat steps 1 to 3 until 100 shocks have been performed.

5) Connect the remote control and the projection sheath to the exposure device and perform 10 exposure cycles. This step may be performed at the completion of the Penetration Test of paragraph 7.2.10 at the discretion of the test engineer.

7-2-4-6 Data and Results

The date of the testing and the observations after each impact shall be recorded. Video tapes and photographs shall be taken. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles or failure of the Radiation Shielding Test.

7-2-5 Handle Wrench Test

7-2-5-1 Purpose

The purpose of this test is to demonstrate that the carrying handle is able to withstand the wrenching force applied to it when the device is dropped while tethered to a security chain. This test is not a requirement of ANSI N432(1980). It is a requirement of ANSI N43.9(1991) and has been adopted because it is considered to be an important verification of the design.

7-2-5-2 Equipment

The test equipment is shown in Figure 7. The exposure device shall have been subjected to the Vertical Shock Test of paragraph 7-2-4.

7-2-5-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-5-4 Approach

The device will be dropped 1 m while attached to a chain. The upper end of the chain will be attached to a rigid mounting point.

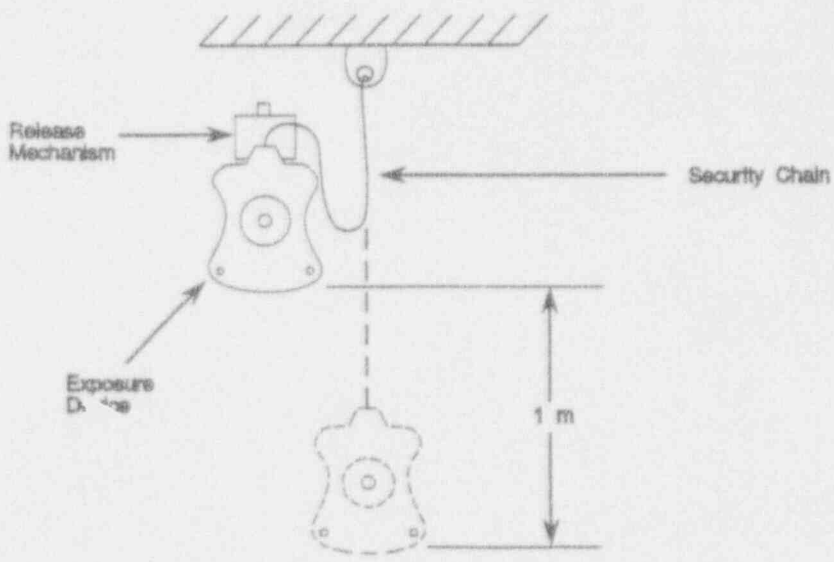

Figure 7
Handle Wrench Test

7-2-5-5 Procedure

1) Fasten the safety chain to the handle of the exposure device.
2) Suspend the exposure device so that it will drop 1 m when released. Make certain that the exposure device will not reach the ground or strike any obstructions when it is released.
3) Release the exposure device and allow it to drop freely.
4) Record any observations. Photographs and video tapes are required to support the observations.
5) Connect the remote control and projection sheath to the exposure device and perform 10 exposure cycles. This step may be performed at the completion of the Penetration Test of paragraph 7.2.10 at the discretion of the test engineer.

7-2-5-6 Data and Results

Observations shall be recorded. Photographs and video tapes will be taken. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles, loss of use of the handle or failure of the Radiation Shielding Test.

7-2-6 Water Spray Test

7-2-6-1 Purpose

The purpose of the Water Spray Test is to subject the device under test to a simulated rainfall of 50 mm per hour for at least one hour. This test would reveal any problems with packagings vulnerable to water saturation.

7-2-6-2 Discussion

The Water Spray Test is particularly intended for packagings where distance shielding may rely on non-metallic materials which are softened by water or materials bonded by water soluble glue. Since the structure of the exposure device is made entirely of metal, it is not vulnerable to such conditions. There is therefore no need to perform this test.

7-2-7 Immersion Test

7-2-7-1 Purpose

The purpose of this test is to verify that the exposure device will not suffer any damage when subjected to immersion in 15 m of water.

7-2-7-2 Discussion

The primary purpose of the Immersion Test is to demonstrate that a package can maintain its structural integrity when subjected to an external pressure. The Titan does not incorporate seals to prevent the influx of water, nor are any of its components sensitive to water. The source assembly has been demonstrated to meet Special Form requirements (Appendix B). Therefore, the Titan would not suffer any damage if immersed in water and there is no need to perform the Immersion Test.

7-2-8 Free Drop Test

7-2-8-1 Purpose

The free drop test is intended to simulate the type of shock that a package would experience if it were to fall off the platform of a vehicle or if it were dropped during handling.

7-2-8-2 Discussion

Since the Titan GRED will be subjected to a 9 m drop test, the requirements for the free drop test are exceeded and there is therefore no need to perform this test.

7-2-9 Stacking Test

7-2-9-1 Purpose

The stacking test is designed to simulate the loads pressing on a package over a prolonged period of time and is intended to ensure that the effectiveness of the shielding and containment systems will not be impaired

7-2-9-2 Discussion

Because of the shape of the Titan GRED, stacking of the device is improbable and nearly impossible. There is therefore no need to perform this test.

7-2-10 Penetration Test

7-2-10-1 Purpose

The purpose of this test is to demonstrate that the exposure device can withstand the impact that the device may receive during normal conditions of transport. The test simulates the exposure device being struck by a slender object such as a length of metal tubing or the handlebar of a falling bicycle. The test is a transport requirement (reference 6).

7-2-10-2 Equipment

The equipment required consists of a 32 mm bar and a guide tube to direct its fall. The bar shall have a hemispherical end and a mass of 6 kg. The exposure device shall have been subjected to the Handle Wrench Test of paragraph 7-2-5.

7-2-10-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-10-4 Approach

The bar will be dropped vertically so as to strike the exposure device at the following sensitive areas:

- bottom of exposure device
- side of exposure device
- front of lock
- side of lock

The height of the drop shall be 1 m measured from the lower end of the bar to the intended point of impact.

7-2-10-5 Procedure

1) Position the exposure device so that the target impact area is facing up.

2) Using the guide tube, adjust the relative position of the bar and the exposure device so that the bar will fall vertically and strike the target impact area when released.

3) Adjust the height between the bottom of the bar and the target impact area to 1m.

4) Release the bar.

5) Record any observations on the Penetration Test Data Sheet in Appendix A. Video tapes, sketches and photographs are required to support the observations.

6) Repeat steps 1 to 5 for all of the areas of the device listed in paragraph 7.2.10.4.

7) Connect the remote control and projection sheath to the exposure device and perform 10 exposure cycles.

7-2-10-6 Data and Results

Observations shall be recorded on the Penetration Test Data Sheet. Sketches, photographs and video tapes shall be taken. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles or failure of the Radiation Shielding Test.

7-2-11 Puncture Resistance Test

7-2-11-1 Purpose

The purpose of the Puncture Resistance Test is to simulate accident conditions and to demonstrate that the source is not accidentally exposed as a result.

7-2-11-2 Equipment

The equipment used for this test includes a 9 m drop tower, an unyielding surface and a mild steel pin with a diameter of 150 mm and a length of 200 mm. The exposure device shall have been subjected to the endurance test of paragraph 7-1-2.

7-2-11-3 Location

The Accidental Drop Test will be performed at AECL Research, Chalk River Laboratories, Chalk River, Ontario.

7-2-11-4 Approach

The test will consist of a 1 m drop onto the end of a cylindrical target such as to cause the maximum damage to the device under test. The target will be rigidly mounted perpendicularly to an unyielding surface. The surface consists of a 100 mm thick steel slab on a cubic block of

concrete measuring 3 m on each side. The concrete sits on bedrock.

7-2-11-5 Procedure

1) Suspend the exposure device in the upright orientation so that when released the lock will strike the pin. Hoist it so that the height measured between the upper surface of the pin and the bottom of the lock is 1 m.

2) Start the high-speed camera and release the exposure device.

3) Record the results, including observations, sketches and photographs of the damaged areas.

7-2-11-6 Data and Results

The Puncture Resistance Test shall be documented with high-speed video, photographs and sketches. The exposure device need not be operational after the test, however the radiation fields are not permitted to exceed 10 mSv/h (1 rem/h) at 1 m.

12 Accidental Drop Test

7-2-12-1 Purpose

The purpose of the Accidental Drop Test is to simulate an accidental impact and to demonstrate that the source will not be accidentally exposed as a result of such an impact.

7-2-12-2 Equipment

The equipment used for this test includes a 9 m drop tower and an unyielding surface. The exposure device shall have been subjected to a Puncture Resistance Test of paragraph 7-2-11.

7-2-12-3 Location

The Accidental Drop Test will be performed at AECL Research, Chalk River Laboratories, Chalk River, Ontario.

7-2-12-4 Approach

A total of three 9 meter drop tests will be completed using two prototype units. One prototype will be subjected to a 9 m upright drop followed by a 9 m oblique drop in the orientation shown in Figure 8. The second prototype will be subjected to a 9 m drop directly onto the lock. See reference 5 for further discussion on the drop orientations.

7-2-12-5 Procedure

1) Suspend the exposure device in the upright orientation and hoist it so that the height measured between the upper surface of the target and the lowest point on the exposure device is 9 m.

2) Start the high-speed camera and release the exposure device.

3) Record the results, including observations, sketches and photographs of the damaged areas.

4) Repeat steps 1 to 3 with the exposure device oriented for a corner drop as shown in Figure 8. Ensure that the centre of gravity of the exposure device is aligned vertically over the lower corner.

5) Repeat steps 1 to 3 with the exposure device oriented so that the primary impact will be on the lock.

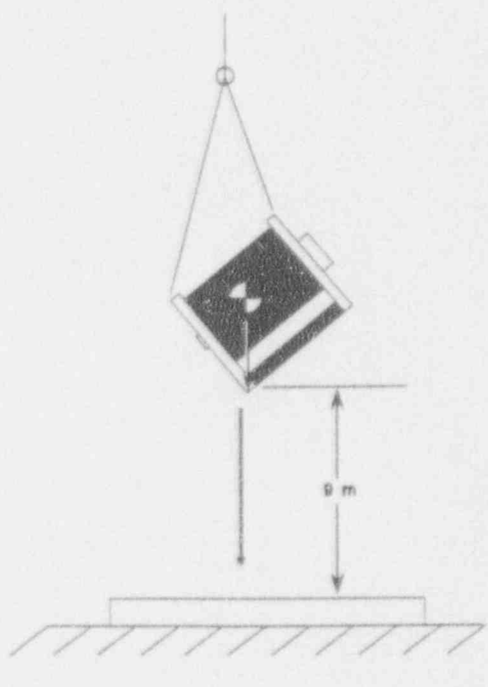

Figure 8
9 m Corner Drop Test

7-2-12-6 Data and Results

The Accidental Drop Test shall be documented with high-speed video, photographs and sketches. The exposure device need not be operational after the test, however the radiation fields are not permitted to exceed 10 mSv/h (1 rem/h) at 1 m.

7-2-13 Fire Test

7-2-13-1 Purpose

The purpose of the Fire Test is to measure the resistance of the test specimen to an accidental fire condition.

7-2-13-2 Discusion

The fire test is intended to demonstrate that the radioactive material's shielding and containment are not vulnerable to an accidental fire with a temperature of 800 °C and duration of 30 minutes.

The C990 source assembly has been demonstrated to meet special form requirements and can therefore withstand such a fire. The shielding material is depleted uranium which has a melting point of 1200 °C and will therefore survive a fire. The outer structure of the TITAN is made of titanium which has a melting point of 1670 °C and can also withstand a fire.

The only material susceptible to a fire is the epoxy foam which fills the void between the outer structure and the depleted uranium shield. The shield is structurally supported by means other than the epoxy foam and shielding provided by foam is insignificant. There is therefore no need to perform the fire test.

7-3 Tests On The Remote Control Device

7-3-1 Kinking Test

7-3-1-1 Purpose

The purpose of this test is to verify that the remote control cable and sheath can withstand the stress due to kinking that may occur during normal use.

7-3-1-2 Equipment

The remote control device will have been subjected to the Projection Under Stress Test of paragraph 7-1-1.

The test apparatus used is shown in Figure 9. The remote control sheath will be pulled manually, and the speed will be measured using an Ametek digital tachometer with a linear measurement adaptor.

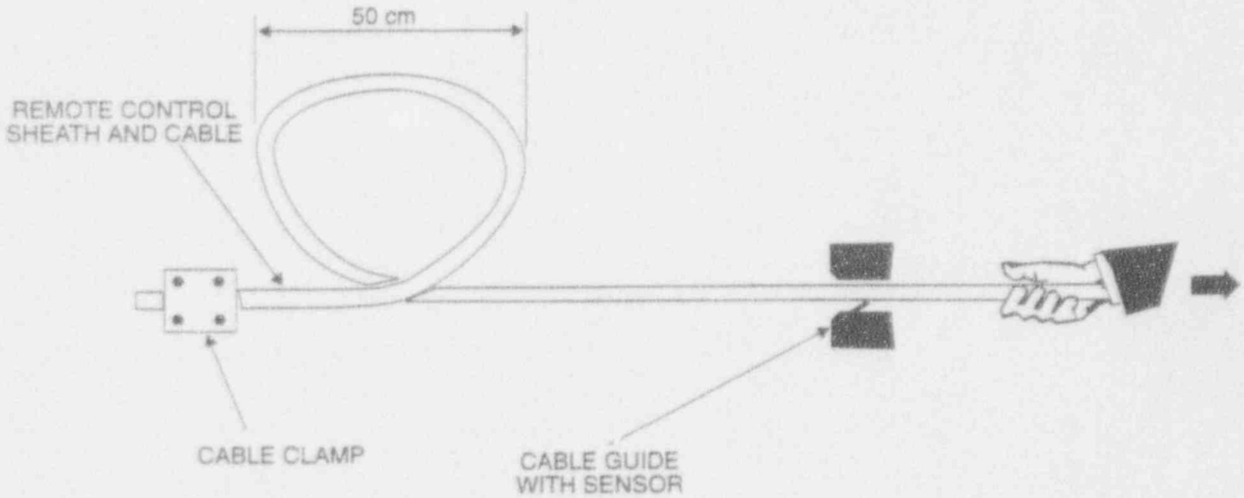

Figure 9
Remote Control Kinking Test Setup

7-3-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-3-1-4 Approach

The cable will be laid out on a flat surface with a 500 mm diameter loop and one end secured. The free end of the cable will be pulled at a rate of 2.0 m/s ± 10% until the loop has disappeared. The test will be repeated 10 times with loop in different locations.

7-3-1-5 Procedure

1) Arrange the control cable and sheath on the test apparatus with a loop 500 mm in diameter as shown in Figure 9.

2) Secure one end of the sheath using the clamp provided.

3) Pull the free end of the sheath at a speed of 2 m/s until the loop has disappeared.

4) Verify that the speed was between 1.8 m/s and 2.2 m/s. Record any observations on the Remote Control Kinking Test Data Sheet in Appendix A. Mark the sheath to indicate the location where the test was performed.

5) Repeat steps 1 to 4 with the loop at different locations on the sheath until 10 satisfactory tests have been performed.

7-3-1-6 Data and Results

All observations shall be recorded on the data sheet provided. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-3-2 Crushing Test

7-3-2-1 Purpose

The purpose of this test is to demonstrate that the remote control cable can withstand the stress of the heel of a 100 kg person impacting at a horizontal and vertical speed of 0.8 m/s.

7-3-2-2 Equipment

The test apparatus is shown in Figure 10. The remote control device shall have been subjected to the Kinking Test of paragraph 7-3-1.

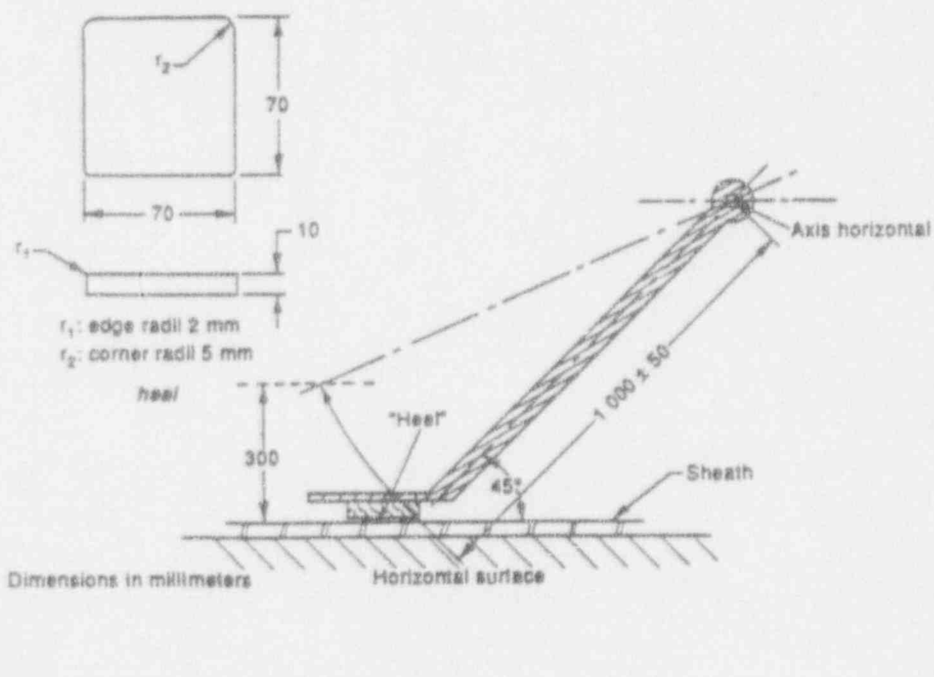

Figure 10
Crushing Test Setup

7-3-2-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-3-2-4 Approach

The apparatus to be used for the test is shown in Figure 10. The mass of the heel and crank shall be 15 kg. The test surface shall have a mass greater than 225 kg. The heel will be dropped from a height of 300 mm. The test will be repeated 10 times at different locations along the cable.

7-3-2-5 Procedure

1) Arrange the equipment as shown in Figure 10. The sheath shall contain the control cable. Fix the sheath using guides.

2) Raise the arm and verify that the height between the sheath and the heel in 300 mm.

3) Release the arm and allow the heel to swing freely down onto the sheath.

4) Record any observations on the Crushing Test Data Sheet in Appendix A. Mark the sheath to indicate the location where the test was performed.

5) Repeat steps 1 to 4 at 10 different points along the sheath. For five of the tests the projection side and reserve side of the sheath shall be superposed vertically. For the other five tests they shall be side by side. Note whether the control cable is in the projection sheath or reserve sheath or both.

7-3-2-6 Data and Results

The observations will be recorded on the data sheet provided. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-3-3 Tensile Test

7-3-3-1 Purpose

The purpose is to demonstrate that the control cable and sheath can withstand the tensile forces that may be encountered during use.

7-3-3-2 Equipment

The remote control device shall have been subjected to the Crushing Test of paragraph 7-3-2. The test apparatus is shown in Figures 11 and 12.

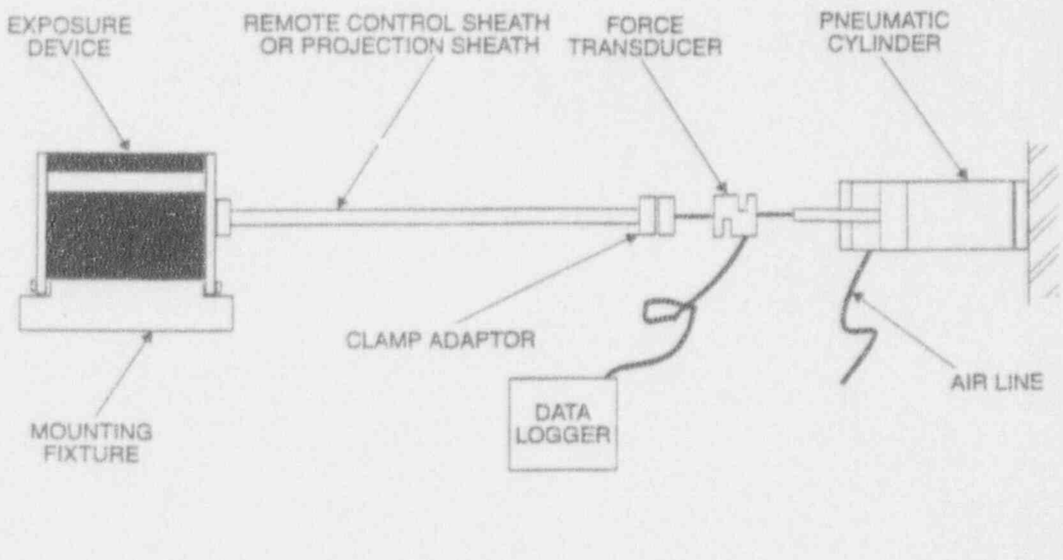

Figure 11

Remote Control Sheath & Projection Sheath Tensile Tests

7-3-3-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-3-3-4 Approach

This test consists of two parts; first the remote control sheath will be tested and then the control cable and crank mechanism will be tested.

In the first part of the test, the remote control sheath will be tested. A tensile force of 500 N (112 lb) will be applied for 30 seconds. The test will be repeated 10 times.

In the second part of the test, the crank mechanism will be secured and the crank arm will be immobilized. A source assembly will be connected to the control cable and a force of 1000 N (225 lb) will be applied to the free end of the source for 10 seconds. The test will be repeated 10 times.

7-3-3-5 Procedure

1) Secure the exposure device as shown in Figure 11.
2) Connect the remote control sheath to the exposure device.
3) Connect the tensioning apparatus to the crank mechanism using the clamp adaptor.
4) Apply a load of 500 N (112 lb) for 30 s.
5) Record any observations and include the plot of the force profile from the data logger with the results.
6) Repeat steps 4 and 5 until 10 tests have been performed.
7) Secure the remote control as shown in Figure 11. Immobilize the crank handle.
8) Connect a source assembly to the control cable.
9) Apply a force of 1000 N (225 lb) for 10 s to the lock ball on the source assembly.
10) Record any observations and include a plot of the force profile from the data logger with the results.
11) Repeat steps 9 and 10 until 10 tests have been performed.

7-3-3-6 Data and Results

The observations will be recorded and plots of the measured force profile will be provided. Each test will be video taped and the test setup will be photographed. The failure criteria will be failure of the final Projection Under Stress Test or failure of the source assembly (see paragraph 7.5.1.6).

7-4 Tests On The Projection Sheath

7-4-1 Kinking Test

7-4-1-1 Purpose

The purpose of this test is to verify that the projection sheath can withstand the stresses due to kinking that may occur during normal use.

7-4-1-2 Equipment

The projection sheath shall have been subjected to the initial projection Under Stress Test of paragraph 7-1-1. The test apparatus is shown in Figure 12.

7-4-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-4-1-4 Approach

One end of the projection sheath will be secured. A flat closed loop will be formed, with the fixed end under the loop. A hoop will secure the ends where they cross so that the loop cannot come undone, yet will still allow the sheath to slide. A force will be applied to the free end of the projection sheath at a tangent to the loop. The force will be applied such that it reaches 200 N (45 lb) in 5 seconds. The force will then be held for 10 seconds. The test will be repeated 10 times at the same place in the projection sheath.

7-4-1-5 Procedure

1) Arrange the projection sheath on the test apparatus with a loop 500 mm in diameter as shown in Figure 12. The fixed end of the sheath must be on the under side of the loop.

2) Close the clamping hoop over both ends of the sheath where they cross in the loop so that the sheath can still slide, yet the loop cannot become undone.

3) Secure the exposure device using the mounting fixture and attach the projection sheath to the exposure device. Attach the other end of the projection sheath to the tensile test apparatus.

4) Apply a force to the sheath so that the force reaches 200 N (45 lb) in 5 s. Maintain the force for 10 s.

5) Record any observations including the final diameter of the loop in the Projection Sheath Kinking Test Data Sheet in Appendix A. Attach the force measurement plot to the data sheet. Mark the sheath to indicate the location where the test was performed.

6) Repeat steps 1 to 5 with the loop always at the same location on the sheath until 10 tests have been performed.

7-4-1-6 Data and Results

All observations shall be recorded on the data sheet provided. The force measurement will be recorded automatically and a printout for each trial will be included with the results. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-4-2 Crushing Test

7-4-2-1 Purpose

The purpose of this test is to demonstrate that the projection sheath can withstand the stress of the heel of a 100 kg person impacting at a horizontal and vertical speed of 0.8 m/s.

7-4-2-2 Equipment

The projection sheath shall have been subjected to the Kinking Test of paragraph 7-4-1. The test apparatus is shown in Figure 10.

7-4-2-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

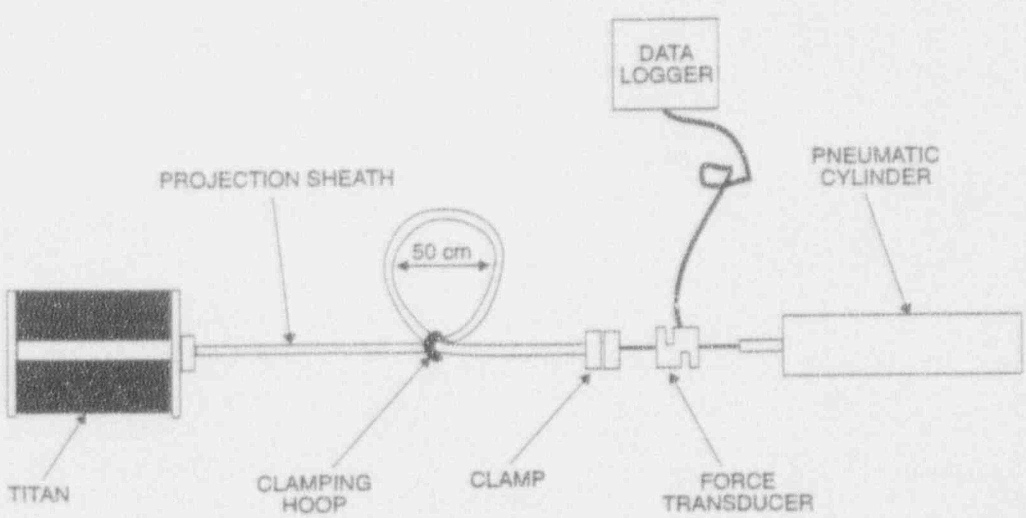

Figure 12
Projection Sheath Kinking Test

7-4-2-4 Approach

The apparatus to be used for the test is shown in Figure 10. The mass of the heel and crank shall be 15 kg. The heel will be dropped from a height of 300 mm. The test will be repeated 10 times at different locations along the sheath.

7-4-2-5 Procedure

1) Ar[illegible]pment as shown in Figure 10.

2) Raise [illegible] verify that the height between the sheath and the heel is 300 mm.

3) Release the arm and allow the heel to swing freely down onto the sheath.

4) Record any observations on the Crushing Test Data Sheet in Appendix A. Mark the sheath to indicate where the test was performed.

5) Repeat steps 1 to 4 at 10 different points along the sheath, one of which shall include a connection.

7-4-2-6 Data and Results

The observations will be recorded on the data sheet provided. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-4-3 Tensile Test

7-4-3-1 Purpose

The purpose of this test is to demonstrate that the projection sheath can withstand the tensile forces that may be encountered during use.

7-4-3-2 Equipment

The projection sheath shall have been subjected to the Crushing Test of paragraph 7-4-2. The test apparatus is shown in Figure 11.

7-4-3-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-4-3-4 Approach

The projection sheath will be connected to the exposure device and the exposure device will be fixed so that it cannot move during the test. A tensile force of 500 N (112 lb) will be applied to the sheath for 30 seconds. The test will be repeated 10 times.

7-4-3-5 Procedure

1) Secure the exposure device as shown in Figure 11.

2) Connect the projection sheath to the exposure device.

3) Connect the tensioning apparatus to the opposite end of the projection sheath using the clamp adaptor.

4) Apply a load of 500 N (112 lb) for 30 s.

5) Record any observations. Plot the force profile from the data logger and include it with the results.

6) Repeat steps 4 and 5 until 10 tests have been performed.

7-4-3-6 Data and Results

The observations will be recorded and each test will be video taped. The measured force profile will be plotted and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-5 Tests On The Source Assembly

7-5-1 Tensile Test

7-5-1-1 Purpose

The purpose of this test is to demonstrate that the source assembly can withstand the tensile forces that may be encountered during use.

7-5-1-2 Equipment

The source assembly shall have been subjected to the Projection Under Stress Test of paragraph 7-1-1.

7-5-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-5-1-4 Approach

A control cable will be attached to the source assembly and the opposite end of the source assembly will be fixed. A tensile force will be gradually applied to the control cable so as to attain a load of 1000 N (225 lb) after 10 seconds. The force will be maintained for 30 seconds. The test will be repeated 10 times.

The largest diameter of the locking ball will be fixed and the testing will be repeated.

7-5-1-5 Procedure

1) Measure the length of the source assembly. This must be done using a calibrated instrument. Record the measurement and the calibration date of the measuring device. Take a magnified photo of the source assembly and connector.

2) Attach a control cable connector to the source assembly.

3) Secure the opposite end of the source assembly (i.e., the capsule) using the source clamp provided.

4) Apply a tensile force gradually to the cable connector so as to reach 1000 N (225 lb) after 10 s.

5) Maintain this force for 30 s.

6) Record any observations on the Source Assembly Tensile Test Data Sheet in Appendix A. Plot the force profile from the data logger and attach the plot to the data sheet. After the testing, take a magnified photo of the source assembly connector.

7) Repeat steps 4 to 6 until 10 tests have been performed.

8) Repeat steps 3 to 7 with the locking ball secured.

7-5-1-6 Data and Results

The observations will be recorded on the data sheet provided. Each test will be video taped and the test setup will be photographed. The source assembly shall not show an elongation of more than 1% of its length.

8 REFERENCES

1) ANSI N432 "Radiological Safety for the Design and Construction of Apparatus for Gamma Radiography", August 1980

2) ANSI N43.9 "Gamma Radiography - Specifications for Design and Testing of Apparatus", October 1991.

3) Title 10, Code of Federal Regulations, Nuclear Regulatory Commission, Part 34 - Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations.

4) Title 10, Code of Federal Regulations, Nuclear Regulatory Commission, Part 71 - Packaging and Transportation of Radioactive Material.

5) TR-9240-N990, Safety Analysis Report for the Titan Radiography Device, Nordion International Inc.

6) Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990), IAEA Safety Series No. 6, IAEA, Vienna, 1990.

7) Transport Packaging of Radioactive Materials Regulations, Atomic Energy Control Act, SOR/91-304, 9 May 1991.

8) IS/QP 0052 N990, Quality Plan for the Nordion Titan Gamma Radiography Exposure Device.

APPENDIX A

Test Data Sheets

Projection Under Stress Test Data Sheet

Date ______________________________ Torque Meter Model ______________________________

Calibration Date ______________________________ Torque Meter Serial Number ______________________________

Trial Number	Maximum Torque Reading (N·m)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Has the equipment under test been subjected to the tests for conditions of normal use? Y ☐ N ☐

Test By ______________________________ Witness ______________________________

Project Engineer ______________________________

C990 Source Assembly Tensile Tэst Data Sheet

Source Assembly Serial No. ______________________

A. **Initial Measurement**

Micrometer Model No. ______________________

Serial No. ______________________

Calibration Due Date ______________________

Initial Length ______________________

Test Engineer or Technician ______________________ Date ______________________

B. **Additional Testing**

Was any additional testing performed on source assembly (e.g., endurance testing)? Y ☐ N ☐

If yes, indicate details of test (e.g., endurance test, date, first cycle no., last cycle no.)

____

____

____

C. **Tensile Test**

Force Transducer Model No. ______________________

Serial No. ______________________

Calibration Due Date ______________________

Test Force ______________________ N

Test Duration ______________________ s
(Attach a plot of the force measurement)

Test Engineer or Technician ______________________ Date ______________________

D. **Final Length Measurement**

Micrometer Model No. ______________________

Serial No. ______________________

Calibration Due Date ______________________

Final Length ______________________

Test Engineer or Technician ______________________ Date ______________________

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials

Radiation Shielding Test Data Sheet

Serial Number ______________________ Date ______________________

The device has been subjected to the following tests: ______________________

____

____

____

C990 Serial No. ______________________

Activity of test source at 1 m = 0 ______________________ R/h

divided by 0.55 R/h-Ci = ______________________ (curie content)

divided by 120Ci = ______________________ (extrapolation constant)

Maximum measured dose rates:

at 5 cm = ______________________ (a)

at 1 m = ______________________ (b)

Calculated dose rates

(a) divided by extrapolation constant = ______________________ at 5 cm

(b) divided by extrapolation constant = ______________________ at 1 m

Victoreen Model 471 Survey Meter

Serial Number ______________________ Calibration Due Date ______________________

Surveyor ______________________ QA Witness ______________________

Test Engineer ______________________ Project Engineer ______________________

Horizontal Shock Test Data Sheet

Titan Serial Number ______________________ Date ______________________

Orientation

Trial Number	Observations
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

Test Engineer ______________________ QA Witness ______________________

Project Engineer ______________________

Penetration Test Data Sheet

Impact Area	Observations
bottom of the exposure device	
side of the exposure device	
front of lock	
side of lock	

Date ____________________ Test Engineer ____________________

QA Witness ____________________ Project Engineer ____________________

Nordion Titan Radiation Survey Data Sheet

Titan Serial Number ____________________ Victoreen 471 Serial Number ____________________

Date ____________________ Calibration Due Date ____________________

	Radiation Survey Readings in mrem/h										
Position Readings at 5 cm from surface	1	2	3	4	5	6	7	8	9	10	11
	12	13	14	15	16	17	18	19	20	21	22
	23	24	25	26	27	28	29	30	31	32	33
	34	35	36	37	38	39	40	41	42	43	44
	45	46	47	48	49	50	51	52	53	54	55
	56	57	58	59	60	61	62	63	64	65	66
	67	68									
Readings at 1 m	Top		Bottom		Right		Left		Front		Back

Note:
The meter on the surface is actually measuring the value approximately 5 cm from the surface
(1 mrem/h = 10 usv/h)

Source Activity ____________________

Surveyor ____________________ Test Engineer ____________________

QA Witness ____________________ Project Engineer ____________________

Crushing Test Data Sheet

Device under test ______________________________

Trial Number	Location of Impact	Observations
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Date ______________________________ Test Engineer ______________________________

QA Witness ______________________________ Project Engineer ______________________________

Remote Control Kinking Test Data Sheet

Date ______________________________

Trial Number	Minimum Speed (ft/s)	Average Speed (ft/s)	Maximum Speed (ft/s)	Observations
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Test Engineer ______________________ Witness ______________________

Project Engineer ______________________

Projection Sheath Kinking Test Data Sheet

Trial Number	Observations (attach the force measurement plot)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Force Transducer Model No. ______________________ Serial No. ______________________

Calibration Due Date ______________________

Date ______________________ Test Engineer ______________________

QA Witness ______________________ Project Engineer ______________________

APPENDIX B

Special Form Radioactive Material Test Summary

Certificate, Sealed Source Classification
Designation and Performance (ANSI N542-1977)

SPECIAL FORM RADIOACTIVE MATERIAL TEST SUMMARY

The capsule model specified herein has been evaluated in accord with the International Atomic Energy Agency (I.A.E.A.) Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1985 Edition, Section VI, paragraphs 604-613 and 618.

TEST SUMMARY NO: 25

DATE: 1992 July 20

CAPSULE MODEL: C-990

CONTENTS: Iridium-192

DRWG NO: K122213-600

CAPSULE MATERIAL: 316L Stainless Steel

OVERALL DIAMETER: 0.187 inches

ENCAPSULATION: Single

OVERALL LENGTH: 0.775 inches

SPECIAL FORM REQUIREMENTS (1)

TEST	PASS	FAIL	METHOD	REMARKS
IMPACT (607)(618)	X		Comparison	Comments below
PERCUSSION (608)	X		Comparison	Comments below
BENDING (609)			Not required	
HEAT (610)	X		Comparison	Comments below
LEACHING (612)(613)	X		Comparison	Comments below

(1) See special form requirements on reverse side

COMMENTS:
The C-343 has been tested and has passed all Special Form tests, and has been certified to meet the requirements for Special Form via Certificate CDN/0001/S. Since the containment system for the C-990 is identical to the C-343, the C-990 also meets the requirements for Special Form.

This summary verifies that the described capsule model meets the requirements of Special Form in accord with the I.A.E.A. Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1985 Edition, Section VI, paragraphs 604-613 and 618.

Tested by: M. Krzaniak, P.Eng. [signature]
Title: Development Officer
Date: 92/07/21

Authorized: G.A. Burbidge [signature]
Title: Manager, Package Engineering
Date: 92/07/30

NORDION INTERNATIONAL INC.

CERTIFICATE

SEALED SOURCE
CLASSIFICATION DESIGNATION AND PERFORMANCE

Sealed sources are classified in accord with standards established by
THE AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) and
THE INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

CERTIFICATE NO: 76 **DATE:** 92 August 20

CAPSULE MODEL: C-990 **CONTENTS:** Iridium-192

DRWG. NO: K122213-600

CAPSULE MATERIAL: 316L Stainless Steel **OVERALL DIAMETER:** 0.187 inches

ENCAPSULATION: Single **OVERALL LENGTH:** 0.775 inches

ANSI CLASSIFICATION AND PERFORMANCE STANDARD (1) | **ANSI 77** C43515 |

CLASSIFIED PERFORMANCE STANDARD (2)

TEST	CLASS	METHOD	REMARKS
TEMPERATURE	4	Comparison	Pass (See Comments)
EXTERNAL PRESSURE	3	Comparison	Pass (See Comments)
IMPACT	5	Comparison	Pass (See Comments)
VIBRATION	1	No Test Reqd.	
PUNCTURE	5	Comparison	Pass (See Comments)

(1) See definition on reverse side
(2) See Table 1. Performance Standards on reverse side
(3) American National Standard N542-1977 is a revision of ANSI N5.10-1968

COMMENTS: The C-343 sealed source has been tested and found to meet the performance requirements of ANSI N542-1977 classification C43515. Since the containment system for the C-990 as identical to the C-343, the C-990 meets the same performance requirements.

It is hereby certified that the described sealed source meets the specified standard as prescribed in (3) American National Standard N542-1977 "Sealed Radioactive Sources, Classification". This standard complies with the classification and performance requirements of ISO 2919-1980(E).

Tested by M. Krzaniak, P.Eng. *Authorized* G.A. Burbidge

Title Development Officer *Title* Manager Package Engineering

Date M Krzaniak 92/08/25 *Date* GAB 92/08/25

NORDION INTERNATIONAL INC.

REFERENCES

[1] DEFINITION - CLASSIFICATION DESIGNATION:

The classification of a sealed source shall be designated by the code ANSI followed by two digits to indicate the year of approval of the American National Standard used to determine the classification followed by a letter and five digits.

The letter shall be either a C or an E. The letter C designates that the contained activity does not exceed the maximum levels established by ANSI. The letter E designates that the contained activity exceeds the maximum levels established by ANSI.

The first digit shall be the class number which describes the performance standards for temperature.

The second digit shall be the class number which describes the performance standards for external pressure.

The third digit shall be the class number which describes the performance standards for impact.

The fourth digit shall be the class number which describes the performance standards for vibration.

The fifth digit shall be the class number which decribes the performance standards for puncture.

[2] TABLE 1 - PERFORMANCE STANDARDS:

TEST	CLASS					
	1	2	3	4	5	6	X
Temperature	No Test	-40°C (20 min) +80°C (1h)	-40°C (20 min) +180°C (1h)	-40°C (20 min) +400°C (1h) and thermal shock 400°C to 20°C	-40°C (20 min) +600°C (1h) and thermal shock 600°C to 20°C	-40°C (20 min) +800°C (1h) and thermal shock 800°C to 20°C	Special Test
External Pressure	No Test	25 kN/m^2 abs. (3.6 lbf/in^2) to atmosphere	25 kN/m^2 abs. to 2 MN/m^2 (290 lbf/in^2) abs.	25 kN/m^2 abs. to 7 MN/m^2 (1015 lbf/in^2) abs.	25 kN/m^2 abs. to 70 MN/m^2 (10 153 lbf/in^2) abs.	25 kN/m^2 abs. to 170 MN/m^2 (24 656 lbf/in^2) abs.	Special Test
Impact	No Test	50 g (1.8 oz) from 1 m (3.28 ft) and free drop ten times to a steel surface from 1.5 m (4.92 ft)	200 g (7 oz) from 1 m	2 kg (4.4 lb) from 1 m	5 kg (11 lb) from 1 m	20 kg (44 lb) from 1 m	Special Test
Vibration	No Test	30 min 25 to 500 Hz at 5 g peak amp.	30 min 25 to 50 Hz at 5 g peak amp. and 50 to 90 Hz at 0.635 mm amp. peak to peak and 90 to 500 Hz at 10 g	90 min 25 to 80 Hz at 1.5 mm amp. peak to peak and 80 to 2000 Hz at 20g	Not Used	Not Used	Special Test
Puncture	No Test	1 g (15.4 gr) from 1 m (3.28 ft)	10 g (154 gr) from 1 m	50 g (1.76 oz) from 1 m	300 g (10.6 oz) from 1 m	1 kg (2.2 lb) from 1 m	Special Test

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APPENDIX 5. STRUCTURAL ANALYSIS OF LIFTING ATTACHMENTS

A5-1.0 INTRODUCTION

This appendix demonstrates that the Titan can safely withstand lifting forces expected under normal and abnormal conditions. Two cases are considered. In the first case the unit is lifted in the normal manner using the handle. In the second case, it is improperly lifted using one of the four mounting points found on each end plate.

A5-2.0 LIFTING VIA THE HANDLE

The Titan is shown in Figure A5.1. When lifted by its handle, forces are transferred to the end plates by the four #10 screws. This section shows that each attachment point is able to safely withstand a snatch lift. It is assumed that a snatch lift imposes a 3 g inertial load on the unit.

A5-2.1 Shear Failure of the Screws

The four screws are #10-32 UNF, Type 304 stainless steel. This material has a tensile strength of 85,000 psi and a yield strength of 35,000 psi.[6, p. 6-39] The tensile area for these screws is 0.0200 square inches.[7, p.798]

The shear yield strength of the screws is assumed to be 58 % of its yield strength , or 0.58(35,000) = 20,300 psi.[7, p.90]

Lifting via the handle causes shear stresses in the screws. The force required to cause shear yield is:

$$F = 20,300\ (.02) = 406\ \text{lb}$$

Since there are four screws, a load of 4(406) = 1624 lb is required to cause a screw to yield in shear. This is equivalent to an inertial load of 1624/45 = 36 g's. It is assumed that a snatch lift applies an inertial load of 3 g's. Therefore, the factor of safety on shear yield is 36/3 = 12.

A5-2.2 Shear Tearout Through the End Plates

Figure A5.2 shows the end plate It is 0.125 inch thick ASTM B265 Grade 2 titanium plate. This material has a tensile strength of 50,000 psi and a minimum yield strength of 40,000 psi.[8] It is assumed that the shear yield strength is 50 % of the yield strength, or 20,000 psi.

Shear tearout stress is given by:[7, p.780]

$$\tau_t = F/2at$$

where:
- F = applied force
- a = the closest distance from the hole to the edge of the plate
- t = the thickness of the plate

Solving for F, the force required to cause shear yield at a single hole is:

$$F = \tau_t * 2at$$

$$= (20,000)(2)(.25)(.125) = 1250 \text{ lb}$$

As there are four screws, a force of 5000 lb is required to cause the plate to yield. This is equivalent to an inertial load of 500/45 = 111 g's. It is assumed that a snatch lift applies an inertial load of 3 g's. Therefore, the factor of safety on plate yield is 111/3 = 37

A5-2.3 Tensile Failure of the Plate

Examination of Figure A5.2 shows the tensile area of the plate to be large in comparison with the shear area calculated in A5-2.2. It is also clear that tensile strength of materials exceeds shear strength. These two facts indicate that tensile failure of the plate is not a credible failure mechanism.

A5-3.0 LIFTING VIA THE MOUNTING POINT

As shown in Figure A5.2, the minimum distance from a mounting point to the edge of the plate is 0.25 inches. This is the same as the shear tearout distance of section A5.2. As all other parameters are the same as the case considered in A5-2.2, the force required to cause shear yield is 1250 lb. In other words, a single mounting point can withstand an inertial load of 1250/45 = 27 g's without yielding in shear. Thus, in the unlikely event that the Titan is lifted using a single mounting point, it is still able to withstand a 3 g snatch load without yieldin~.

A5-4.0 SUMMARY

This appendix has shown that the Titan lifting points have sufficient strength to withstand 3 g snatch lifts in normal and abnormal orientations. The minimum safety factor on yield was found to be 9. This large margin provides assurance that the Titan can be safely and easily handled.

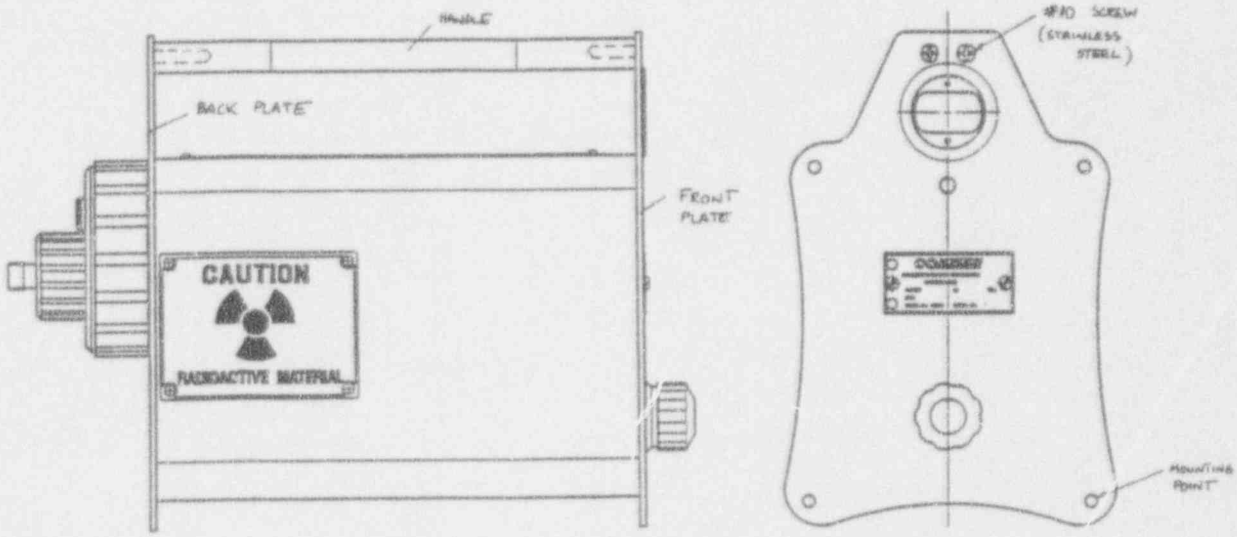


Figure A5.1 The Titan Gamma Radiography Exposure Device

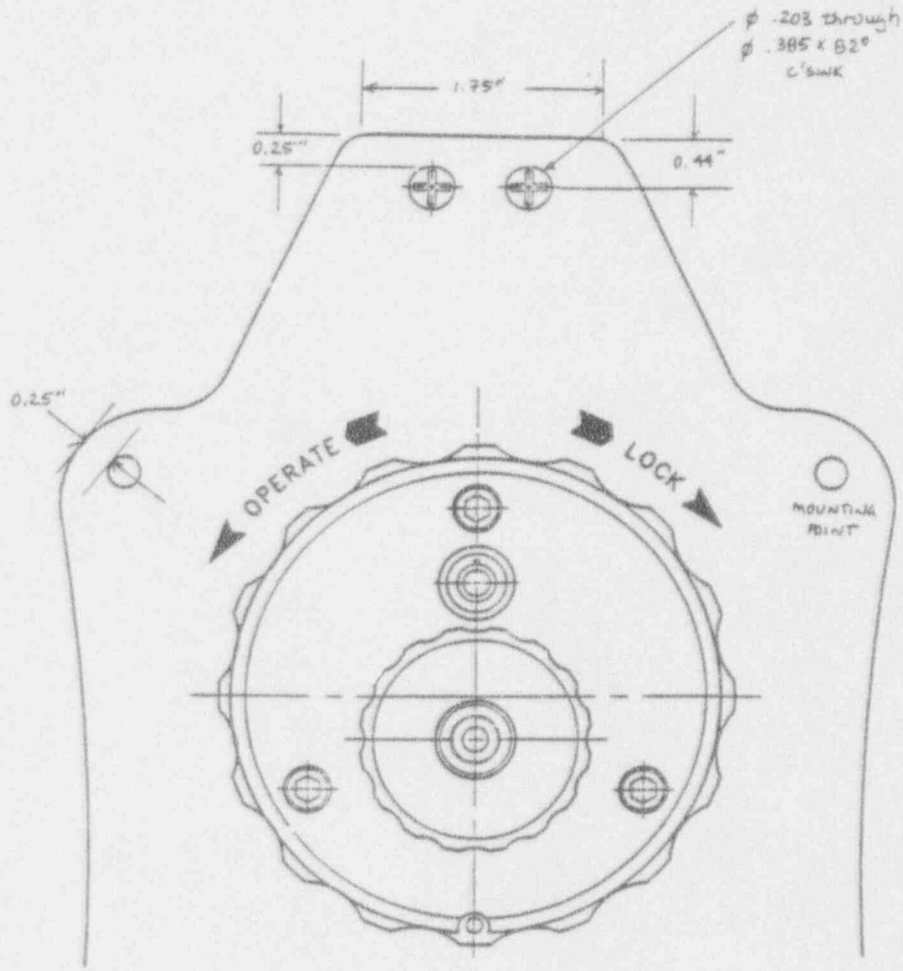


Figure A5.2 End Plate Geometry

APPENDIX 6. Sealed Source Classification Certificate for the C-990

CERTIFICATE

SEALED SOURCE
CLASSIFICATION DESIGNATION AND PERFORMANCE

Sealed sources are classified in accord with standards established by
THE AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) and
THE INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

CERTIFICATE NO: 76 **DATE:** 92 August 20

CAPSULE MODEL: C-990 **CONTENTS:** Iridium-192

DRWG. NO: K122213-600

CAPSULE MATERIAL: 316L Stainless Steel **OVERALL DIAMETER:** 0.187 inches

ENCAPSULATION: Single **OVERALL LENGTH:** 0.775 inches

ANSI CLASSIFICATION AND PERFORMANCE STANDARD (1) **ANSI 77** C43515

CLASSIFIED PERFORMANCE STANDARD (2)

TEST	CLASS	METHOD	REMARKS
TEMPERATURE	4	Comparison	Pass (See Comments)
EXTERNAL PRESSURE	3	Comparison	Pass (See Comments)
IMPACT	5	Comparison	Pass (See Comments)
VIBRATION	1	No Test Reqd.	
PUNCTURE	5	Comparison	Pass (See Comments)

(1) See definition on reverse side
(2) See Table 1. Performance Standards on reverse side
(3) American National Standard N542-1977 is a revision of ANSI N5.10-1968

COMMENTS: The C-343 sealed source has been tested and found to meet the performance requirements of ANSI N542-1977 classification C43515. Since the containment system for the C-990 is identical to the C-343, the C-990 meets the same performance requirements.

It is hereby certified that the described sealed source meets the specified standard as prescribed in (3) American National Standard N542-1977 "Sealed Radioactive Sources, Classification". This standard complies with the classification and performance requirements of ISO 2919-1980(E).

Tested by	M. Krzaniak, P.Eng.	*Authorized*	G.A. Burbidge
Title	Development Officer	*Title*	Manager Package Engineering
Date	MKrzaniak 92/08/25	*Date*	GAB 92/08/25

NORDION
INTERNATIONAL INC.

REFERENCES

(1) DEFINITION - CLASSIFICATION DESIGNATION:

The classification of a sealed source shall be designated by the code ANSI followed by two digits to indicate the year of approval of the American National Standard used to determine the classification followed by a letter and five digits.

The letter shall be either a C or an E. The letter C designates that the contained activity does not exceed the maximum levels established by ANSI. The letter E designates that the contained activity exceeds the maximum levels established by ANSI.

The first digit shall be the class number which describes the performance standards for temperature.

The second digit shall be the class number which describes the performance standards for external pressure.

The third digit shall be the class number which describes the performance standards for impact.

The fourth digit shall be the class number which describes the performance standards for vibration.

The fifth digit shall be the class number which describes the performance standards for puncture.

(2) TABLE 1 - PERFORMANCE STANDARDS:

TEST	CLASS						
	1	2	3	4	5	6	X
Temperature	No Test	-40°C (20 min) +80°C (1h)	-40°C (20 min) +180°C (1h)	-40°C (20 min) +400°C (1h) and thermal shock 400°C to 20°C	-40°C (20 min) +600°C (1h) and thermal shock 600°C to 20°C	-40°C (20 min) +800°C (1h) and thermal shock 800°C to 20°C	Special Test
External Pressure	No Test	25 kN/m^2 abs. (3.6 lbf/in^2) to atmosphere	25 kN/m^2 abs. to 2 MN/m^2 (290 lbf/in^2) abs.	25 kN/m^2 abs. to 7 MN/m^2 (1015 lbf/in^2) abs.	25 kN/m^2 abs. to 70 MN/m^2 (10 153 lbf/in^2) abs.	25 kN/m^2 abs. to 170 MN/m^2 (24 656 lbf/in^2) abs.	Special Test
Impact	No Test	50 g (1.8 oz) from 1 m (3.28 ft) and free drop ten times to a steel surface from 1.5 m (4.92 ft)	200 g (7 oz) from 1 m	2 kg (4.4 lb) from 1 m	5 kg (11 lb) from 1 m	20 kg (44 lb) from 1 m	Special Test
Vibration	No Test	30 min 25 to 500 Hz at 5 g peak amp.	30 min 25 to 50 Hz at 5 g peak amp. and 50 to 90 Hz at 0.635 mm amp. peak to peak and 90 to 500 Hz at 10 g	90 min 25 to 80 Hz at 1.5 mm amp. peak to peak and 80 to 2000 Hz at 20g	Not Used	Not Used	Special Test
Puncture	No Test	1 g (15.4 gr) from 1 m (3.28 ft)	10 g (154 gr) from 1 m	50 g (1.76 oz) from 1 m	300 g (10.6 oz) from 1 m	1 kg (2.2 lb) from 1 m	Special Test

NORDION INTERNATIONAL INC.
447 March Road, P.O. Box 13500, Kanata, Ontario, Canada K2K 1X8 Tel.: (613) 592-2790 Telex: (053) 4162 Fax: (613) 592-6937
447 chemin March, C.P. 13500, Kanata, Ontario, Canada K2K 1X8 Tél.: (613) 592-2790 Télex: (053) 4162 Fax: (613) 592-6937

SEALED SOURCE
CLASSIFICATION DESIGNATION AND PERFORMANCE CERTIFICATE

SEALED SOURCES ARE CLASSIFIED IN ACCORD WITH STANDARDS ESTABLISHED BY THE AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) COMMITTEE N43-3.3

DATE: 1983 May 5 CERTIFICATE NO: 53

CAPSULE MODEL: C-343

ENG. DRWG. NO: A17715/A CONTENTS: Iridium Pellets

OVERALL DIAMETER: 0.187" OVERALL LENGTH: 0.775"

CAPSULE MATERIAL: 316L Stainless Steel ENCAPSULATION: Single

ANSI CLASSIFICATION AND PERFORMANCE STANDARD (1) — ANSI 77 C 43515

CLASSIFIED PERFORMANCE STANDARD (2)			
TEST	CLASS	METHOD	REMARKS
TEMPERATURE	4	TEST	PASS (See Comments)
EXTERNAL PRESSURE	3	TEST	PASS (See Comments)
IMPACT	5	TEST	PASS (See Comments)
VIBRATION	1	NO TEST REQUIRED	
PUNCTURE	5	TEST	PASS (See Comments)

(1) SEE DEFINITION ON REVERSE SIDE.
(2) SEE TABLE 1. PERFORMANCE STANDARDS ON REVERSE SIDE.
(3) SEE NOTE ON REVERSE SIDE.

COMMENTS: All tests were performed on inactive capsules - with and without dummy source.

It is hereby certified that the described sealed source meets the specified standard as prescribed in (3) American National Standard N542-1977 "Sealed Radioactive Sources, Classification" This standard complies with the classification and performance requirements of ISO/DIS 2919.3

Signed J. Culbertson
Title Senior Metallurgical Technician
Date 1983 May 5

ATOMIC ENERGY OF CANADA LIMITED
COMMERCIAL PRODUCTS, OTTAWA CANADA

POA-043.1

AECL-CP
CAPSULE TESTING WORK SHEET

Date : 1983 May 4

test : TEMPERATURE

class : 4

ANSI - N542-1977 SEALED RADIOACTIVE SOURCES CLASSIFICATION

Capsule description : C-343 Radiography Capsule

model : C-343

content : Iridium Pellets

dimensions : OD = 0.187" Length = 0.775"

encapsulation : Single

reference : Drawing No. A17715/A

Leak Test Type : 1) VLBT - Sensitized
2) Water Pressurization Test

results : PASS

Comments : Because of the size of the capsule, two leak test methods were employed with increased sensitivity.

conducted by : J.P. Culbertson

approved by : J.P. Culbertson

AECL-CP
CAPSULE TESTING WORK SHEET

Date : 1983 May 4

test : EXTERNAL PRESSURE class : 3

ANSI - N542-1977 SEALED RADIOACTIVE SOURCES CLASSIFICATION

Capsule description : C-343 Radiography Capsule

model : C-343 content : Iridium Pellets

dimensions : OD = 0.187" Length = 0.775"

encapsulation : Single

reference : Drawing No. A17715/A

Leak Test Type : 1) VLBT - Sensitized
2) Water Pressurization Test results : PASS

Comments : Because of the size of the capsule, two leak test methods were employed with increased sensitivity.

conducted by : J.P. Culbertson approved by : J.P. Culbertson

AECL-CP
CAPSULE TESTING WORK SHEET

Date : 1983 May 4

test : IMPACT class : 5

ANSI - N542-1977 SEALED RADIOACTIVE SOURCES CLASSIFICATION

Capsule description : C-343 Radiography Capsule

model : C-343 content : Iridium Pellets

dimensions : OD = 0.187" Length = 0.775"

encapsulation : Single

reference : Drawing No. A17715/A

Leak Test Type : 1) VLBT - Sensitized
2) Water Pressurization Test results : PASS

Comments : Because of the size of the capsule, two leak test methods were employed with increased sensitivity.

conducted by : J.P. Culbertson approved by : J.P. Culbertson

AECL-CP

CAPSULE TESTING WORK SHEET

Date : 1983 May 4

test : PUNCTURE class : 5

ANSI - N542-1977 SEALED RADIOACTIVE SOURCES CLASSIFICATION

Capsule description : C-343 Radiography Capsule

model : C-343 content : Iridium Pellets

dimensions : OD = 0.187" Length = 0.775"

encapsulation : Single

reference : Drawing No. A17715/A

Leak Test Type : 1) VLBT - Sensitized
2) Water Pressurization Test

results : PASS

Comments : Because of the size of the capsule, two leak test methods were employed with increased sensitivity.

conducted by : J.P. Culbertson

approved by : J.P. Culbertson (signed) J. Culbertson

APPENDIX 7. Results of the Titan Radiation Survey

TITAN RADIATION SURVEY RESULTS

Kevin P.J. O'Hara
March, 1993

One Titan shield was surveyed on 1993 March 02; both Titan shields were surveyed on 1993 March 05. The effect of source position on external radiation fields and the effect of depleted uranium (DU) shrinkage on external radiation fields were investigated in greater detail.

Measurement Geometry and Instrumentation

The distance between the shield's surface and the geometric centre of the instrument's sensitive volume was 50 mm. The measurement of the exposure rate at this distance from the surface shall be averaged over an area of 10 cm^2 with no linear greater than 5 cm. This field shall no exceed 50 mR/h (3.583 aA/kg). If this field requirement is achieved, the field requirments at the surface and 1 meter from the surface will be achieved.

Three instrument's were used for the survey. Instrument (1) is a GM tube which detects crack leakage more easily than an ion chamber because of its smaller sensitive volume. Instruments (2) and (3) are ion chambers which are closer to the requirements required by ANSI for radiation survey measurements.

(1) Bicron Surveyor 2000 GM Tube

S.N. 6-144-060
Calibrated on 93 Jan 26
Active Length 6 cm

(2) Bicron RSO-5 Ion Chamber

S.N. 6-144-107
Calibrated on 93 Jan 26
200 cubic cm volume

(3) Victoreen 471 Ion Chamber

S.N. 6-144-266
Calibration Due Date 93 March 24
485 cubic cm volume with an equilibrium cap

Instruments (1) and (3) were used for the first survey on 1993 March 02; Instruments (1) and (2) were used for the second survey on 1993 March 05.

Source Activity

The Ir-192 source activity was 119 Ci on 1993 March 01, using Nordion's exposure rate constant of 0.54 $R \cdot m^2/h \cdot Ci$. (ANSI uses an exposure rate constant of 0.48 $R \cdot m^2/h \cdot Ci$.)

Radiation Survey Results

The grid pattern used for the radiation surveys is illustrated in Figure 1. Each surface has been divided into a number of incremental areas. The radiation survey results for shield 1 on 1993 March 02 are summarized in Figure 2; the radiation survey results for shields #1 and #2 on 1993 March 02 are summarized in Figures 3 and 4 respectively.

Effect of Shrinkage on Measured Radiation Fields

Figure 5 shows the measured shrinkage in thousands of an inch (and mm) for Shield #2. (These measurements were performed by QNDE.)

Figure 6 shows the vertical plane of the Titan through the S-tube for Shield #2. The exposure rate measurements (mR/h) for a number of field points, the measured DU shrinkage (mm) and the estimated increase in DU (mm) to reduce fields to 50 mR/h are summarized for a number of points in that plane.

Figures 7 and 8 show the estimated increase in DU to reduce the fields at 50 mm to 50 mR/h for all measurement points for Shields #1 and #2 respectively.

TECHNICAL NOTE

For estimating the DU necessary to reduce fields to 50 mR/h, it is very important to distinguish the transmission of ^{192}Ir in depleted uranium from the transmission of ^{192}Ir in depleted uranium after transmission through about 40 mm of depleted uranium.

This is important since most low energy photons have been filtered out with this thickness of shield; the energy spectrum has become quite hard. (It will take more depleted uranium to reduce the fields after transmission through 40 mm DU.) For example, the half-value layer of Ir-192 in DU is approximately 1.5 mm; after transmission through 40 mm, the half-value layer is approximately 3.5 mm. Table 1 summarizes the transmission factors for a number of thicknesses of DU after transmission through about 40 mm of DU.

Table 1

Transmission of ^{192}Ir in DU after Transmission through 40 mm DU

Thickness of Depleted Uranium (mm)	Transmission Factor	Field Reduction (%)
0.5	0.90	10
1.0	0.82	18
1.5	0.75	25
2.0	0.67	33
2.5	0.62	38
3.0	0.55	45
3.5	0.51	49
4.0	0.46	54

The half-value layer of ^{192}Ir in stainless steel after transmission through 40 mm DU was measured to be 20 mm.

Effect of Source Position on Radiation Fields

For Shields #1 and Shield #2, the entire surface of the Titan was scanned using the Bicron Surveyor 2000 for a number of known source positions. (The Surveyor 2000 is better suited for detecting localized radiation fields due to its smaller sensitive volume.) The results are shown in Figures 9 and 10.

Figure 9 illustrates the maximum exposure rate at 50 mm as a function of source position for each surface. Figure 10 shows the same data except that the fields have been normalized to the field measurement with the source in the optimum position.

Summary

Radiography film will be used to map all six Titan surfaces. This is particulary important for mapping the riser of Shield #2. 100 mR/h could be measured with the GM tube while only 50 mR/h could be measured with the ion chamber.

In general there was a good correlation between the ion chamber measurements and the GM tube which indicates good field uniformity over the cross-sectional area of the ion chamber.

Shrinkage has accounted for some of the high field measurements. The original shield design assumed 0.7% linear shrinkage; some of the shrinkage measurements performed by QNDE show shrinkage much greater than 0.7%. A larger shrinkage factor can be used in the model; however, this will mean overshielding a large portion of the surface. The shield's manufacturer has estimated that the shrinkage is about 2.5%. Nordion must be certain that the shrinkage is reproducible; if not, it must be accounted for.

Overall, the radiation field measurements show a good degree of optimization. Depleted uranium will have to added in some areas due to shrinkage.

The position of the S-tube within the DU shield must be determined.

Lastly, it must be verified that the shields which have been produced are the shields which were calculated (with the exception of shrinkage). One method is to check the estimated DU thickness based on the digitized surface with the calculated DU thicknesses based on Nordion's model.

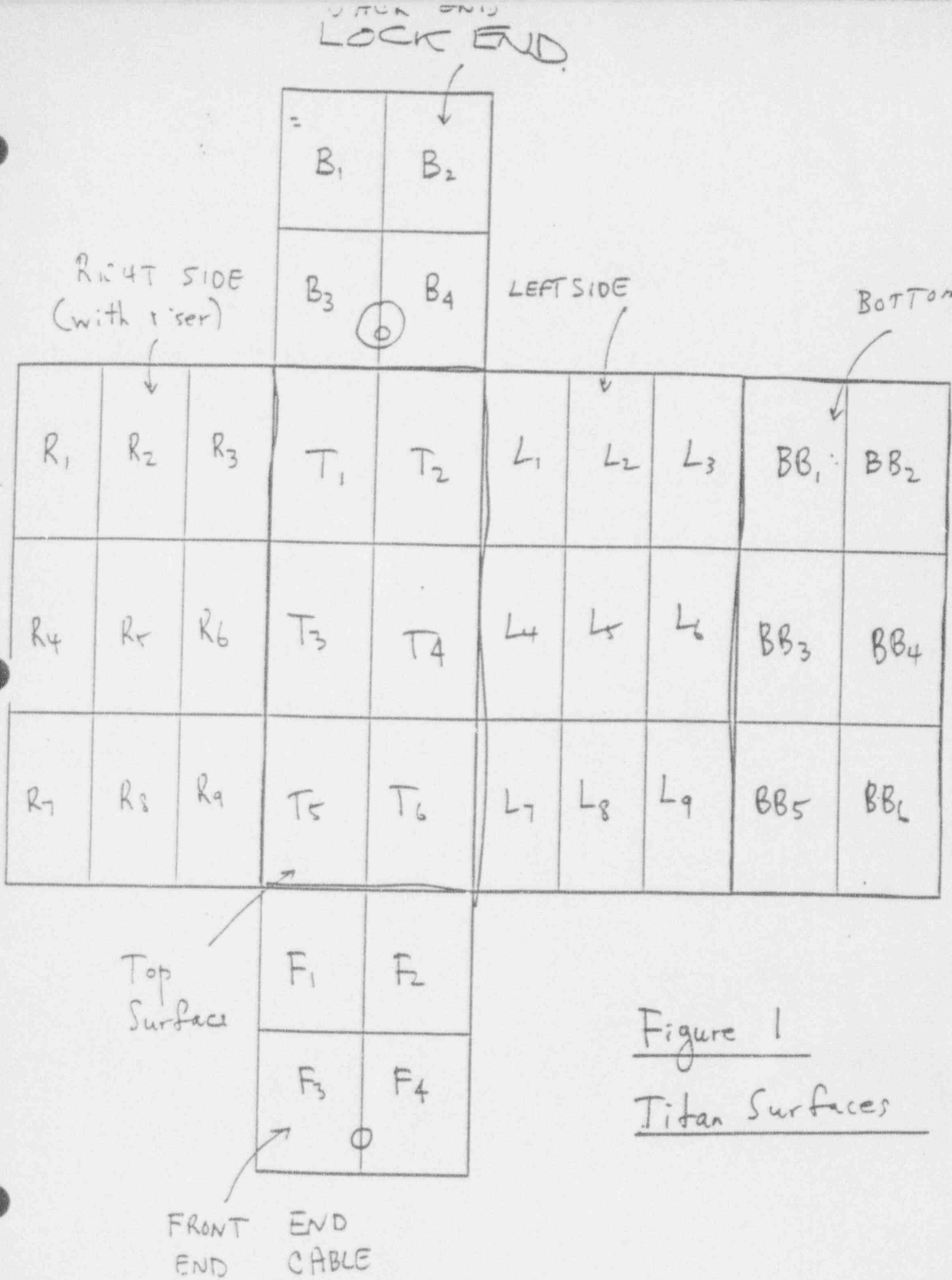


Figure 1

Titan Surfaces

LOCK END

Shield # 1
93 Mar C2

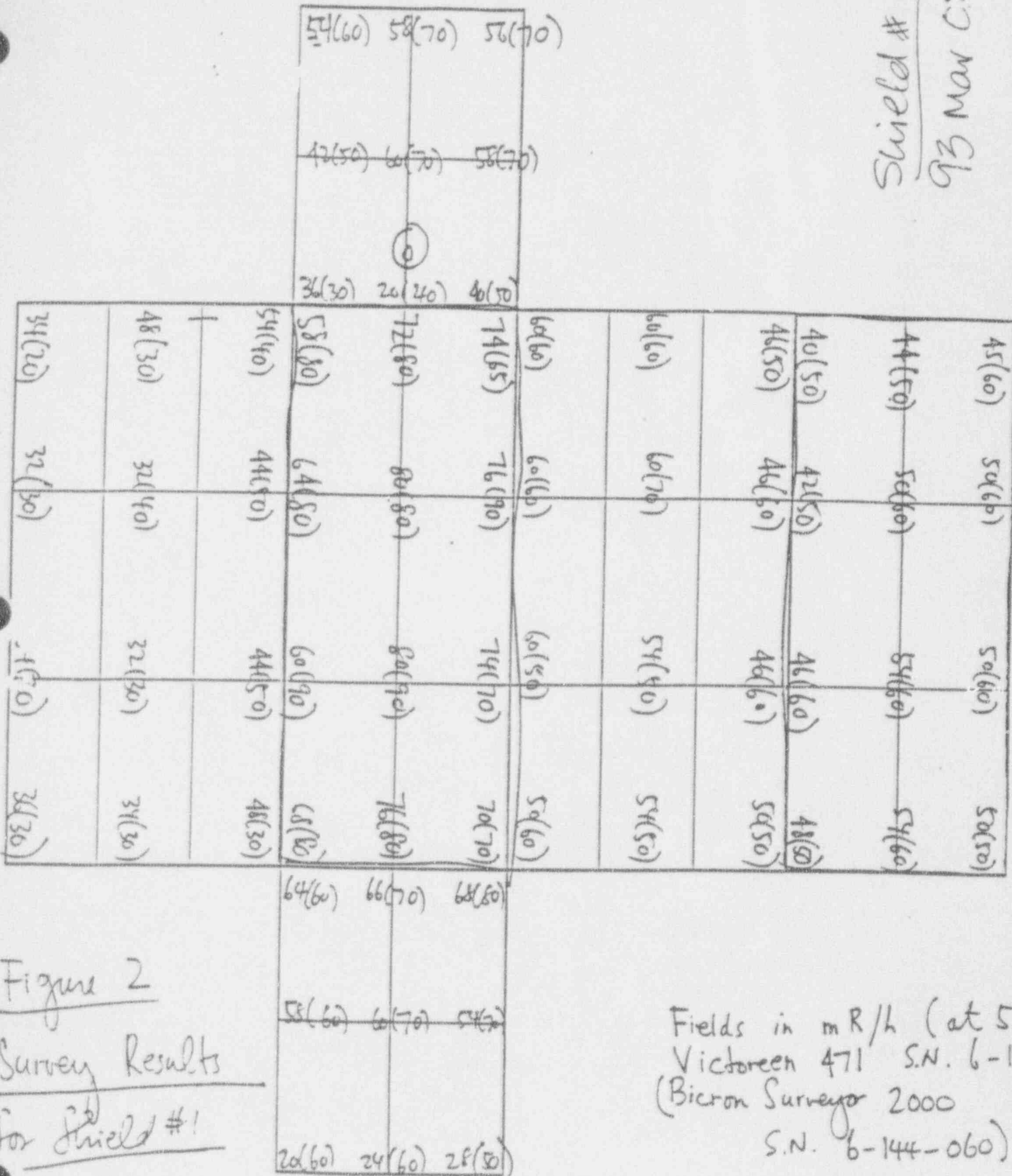


Figure 2
Survey Results
for Shield #1

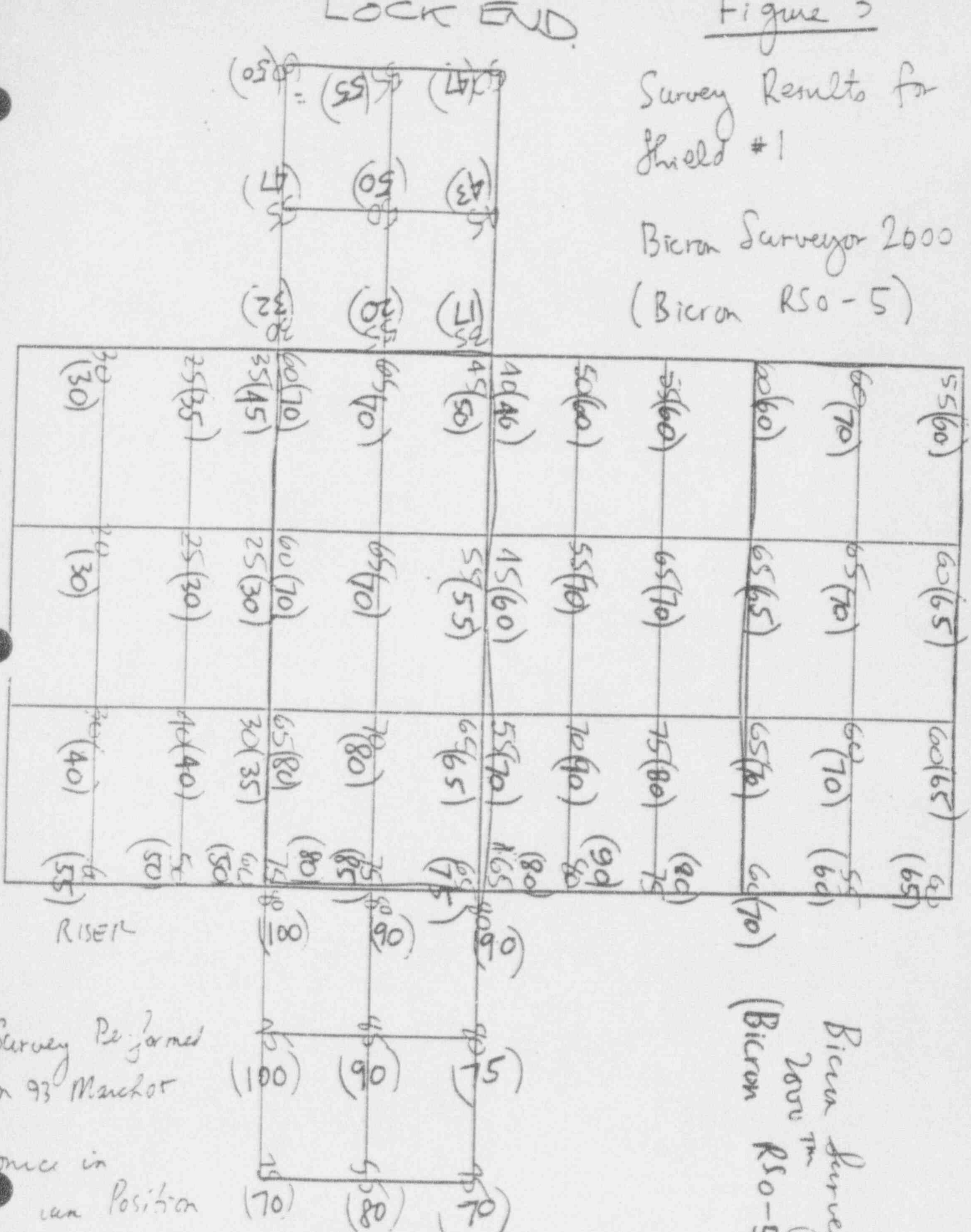
Fields in mR/h (at 50n
Victoreen 471 S.N. 6-144
(Bicron Surveyor 2000
S.N. 6-144-060)

A = 119 Ci ^{192}Ir (93 Mar

Figure 3

Survey Results for Shield #1

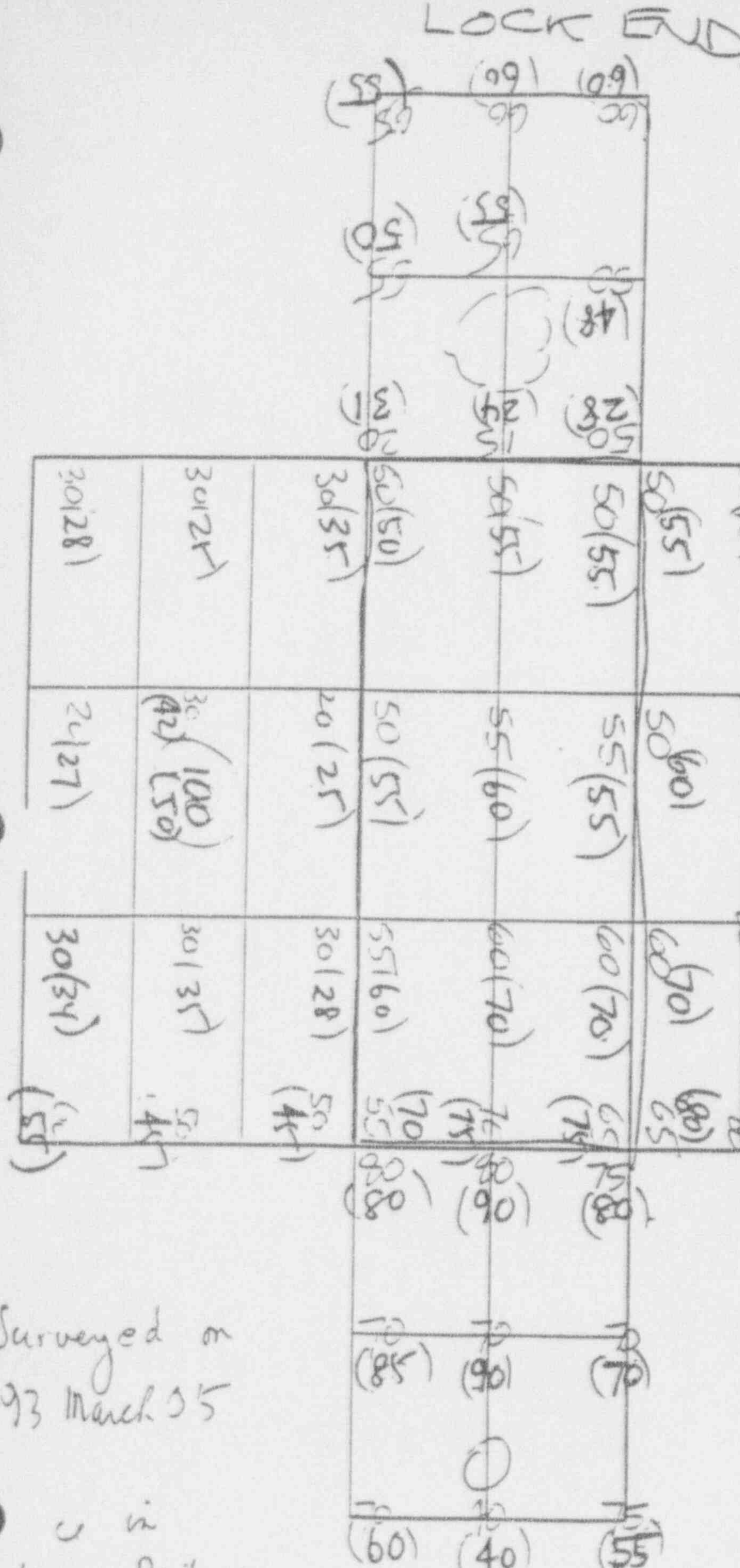
Bicron Surveyor 2000 (Bicron RSO-5)



Survey Performed on 9 March 93

Source in can Position

Figure 4



Survey Results for Shield #2

Bicron Surveyor 2000 (Bicron RSO-5)

Fields at 50 mm (mR/h)

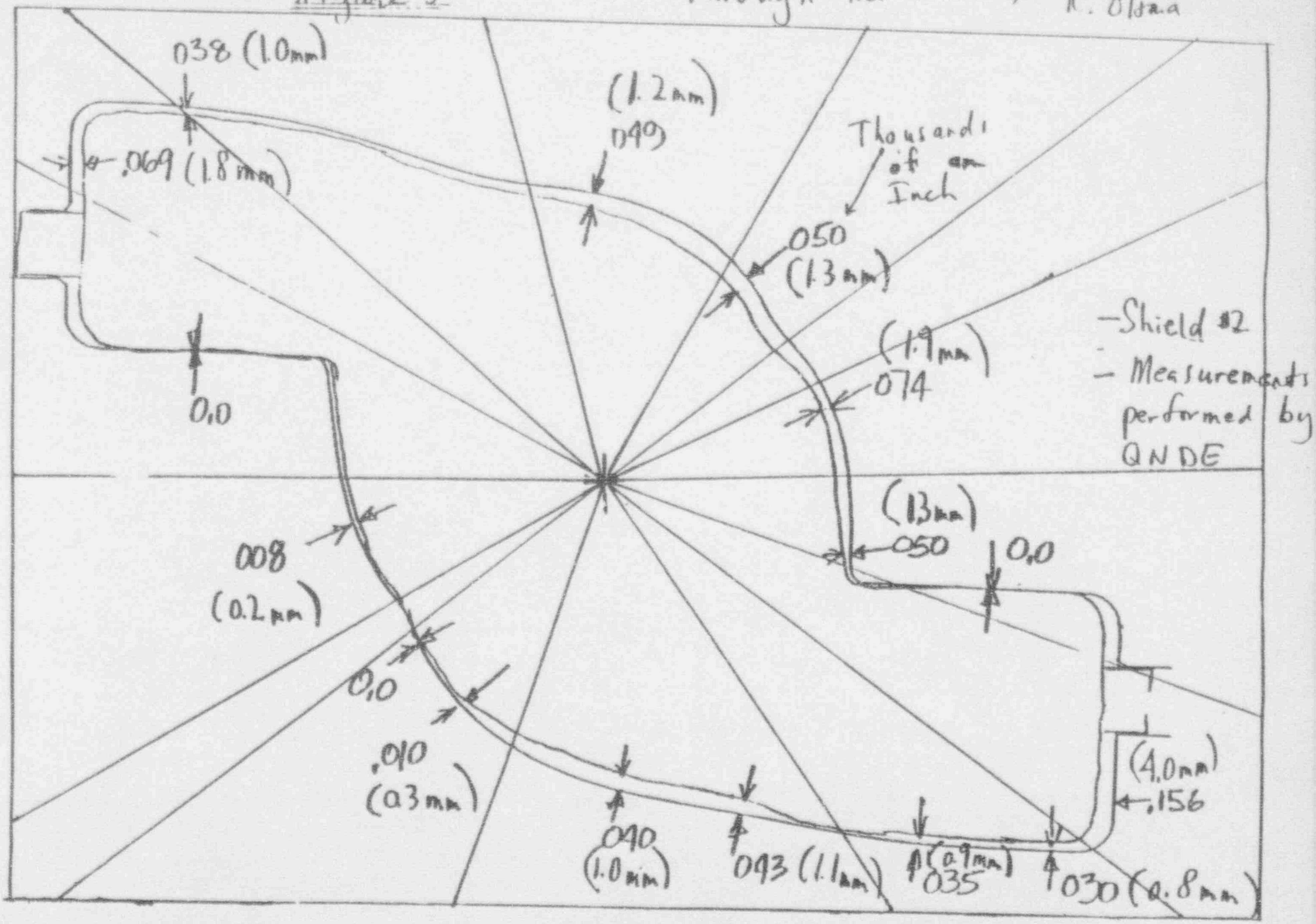
Surveyed on 23 March 95

" in optimum Position

Measured DU Shrinka, (Vertical Plane Through the S-tube) 93 M S

Figure 5

K. Olsma



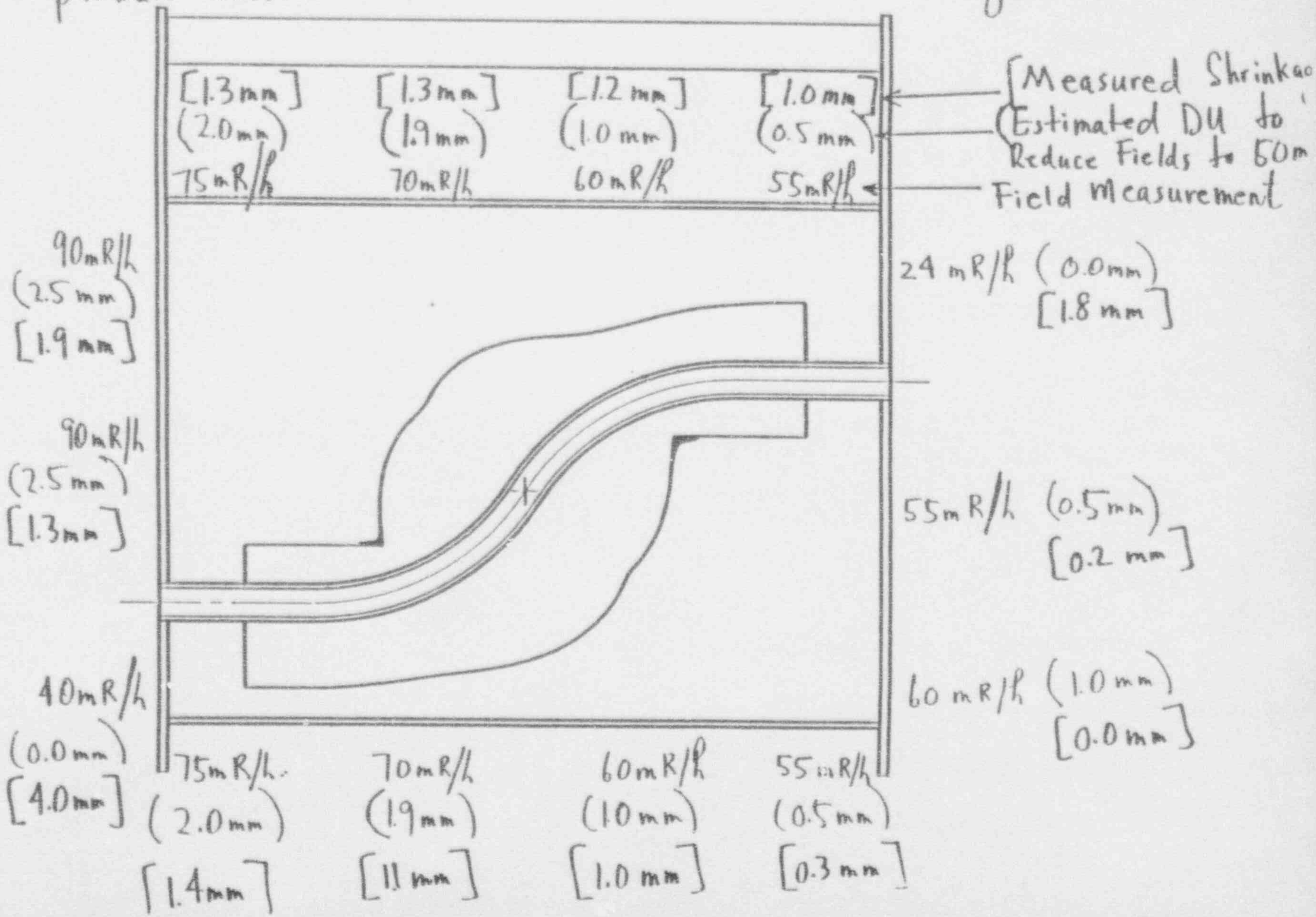
- Shield #2
- Measurements performed by QNDE

9? [illegible]. 11
K. Hara

Measurements with Bicron RSO-5 Ion Chamber
119 Ci ^{192}Ir (93 March 01)
Source in Optimum Position

Estimated DU thickness, figure, to reduce fields to 50 mR/h at 50 mm

Vertical Cross-Section through the S-tube



LOCK END

Source is in Optimum Position

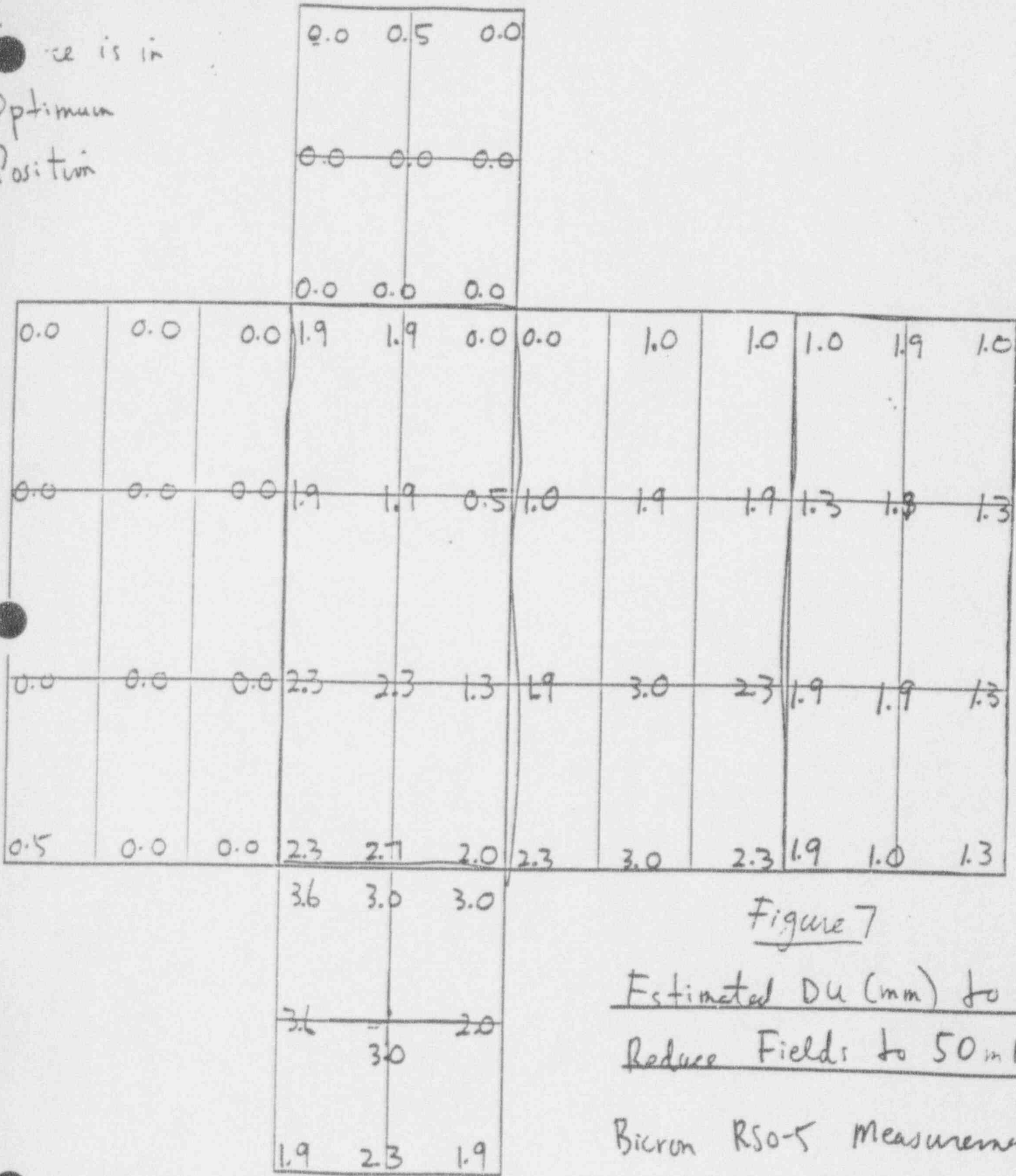


Figure 7

Estimated DU (mm) to Reduce Fields to 50 mR/h

Bicron RSO-5 Measurement

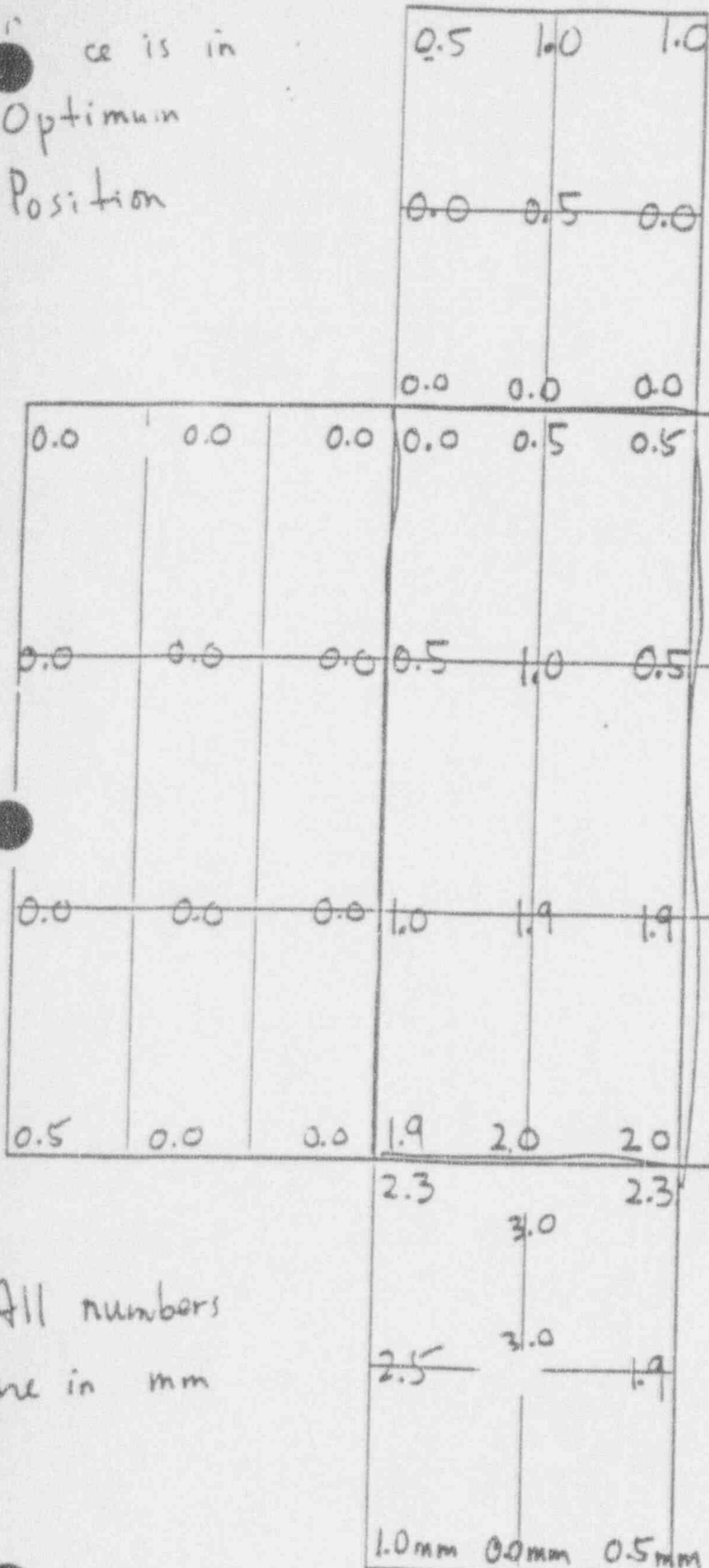
Shield #1

93 March 09

K. O'Hara

LOCK END

ce is in Optimum Position



END CABLE

All numbers are in mm

Figure 8

Estimated DU to Reduce Fields to 50 mR/h

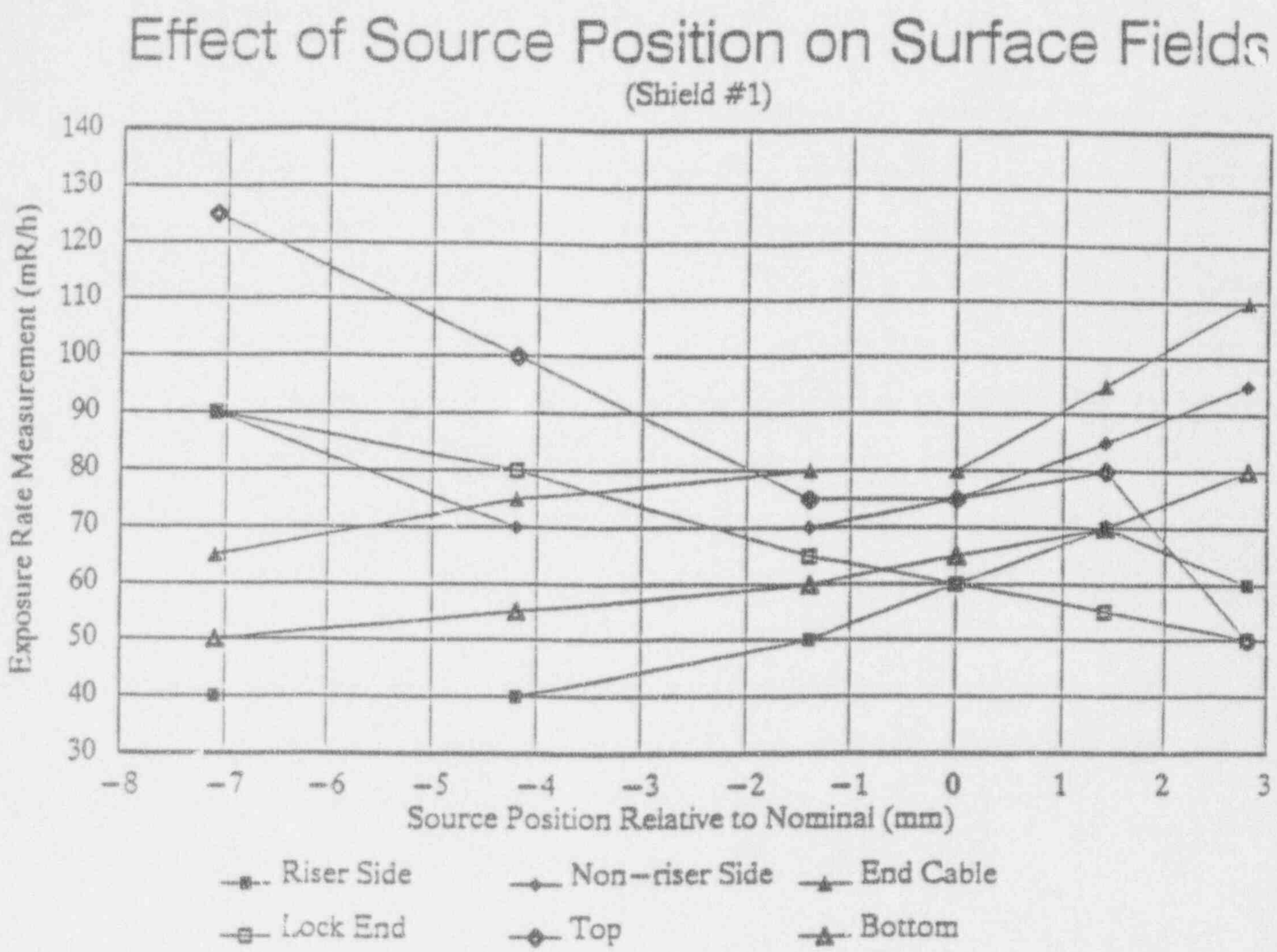
Bicron RSO-5 Measurements

Shield #2

93 March 09

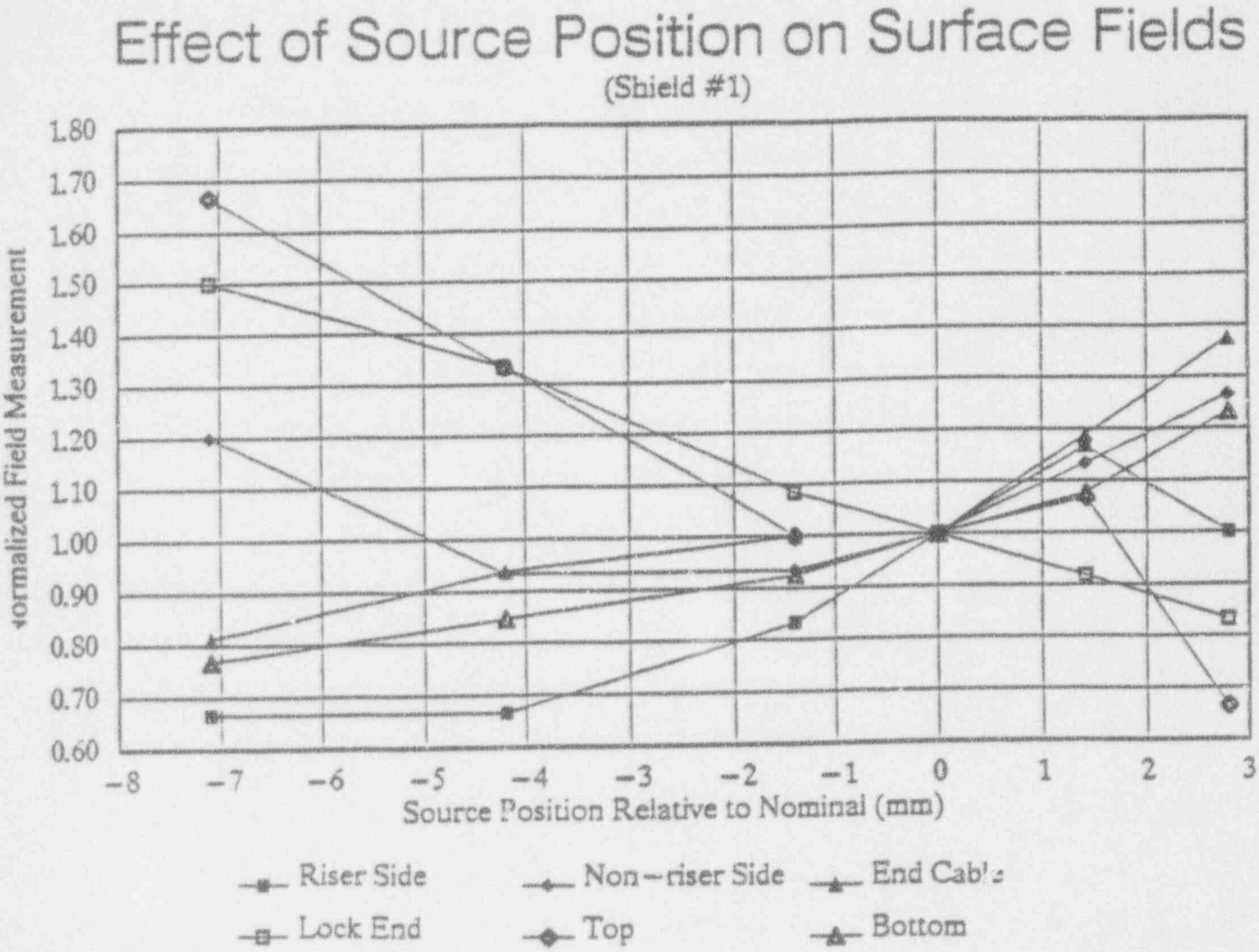
K. Ostara

Figure 9



Effect of Source Position on Surface Fields
(Shield #1)
Exposure Rate Measurement (mR/h)
140
130
120
110
100
90
80
70
60
50
40
30
−8
−7
−6
−5
−4
−3
−2
−1
0
1
2
3
Source Position Relative to Nominal (mm)
Riser Side
Non−riser Side
End Cable
Lock End
Top
Bottom

Figure 10



Effect of Source Position on Surface Fields
(Shield #1)
Normalized Field Measurement
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
−8
−7
−6
−5
−4
−3
−2
−1
0
1
2
3
Source Position Relative to Nominal (mm)
Riser Side
Non−riser Side
End Cable
Lock End
Top
Bottom

PART 3. ASSESSMENT WITH RESPECT TO 10 CFR PART 71[3]

1.0 GENERAL INFORMATION

This chapter presents an introduction and general description of the Titan Gamma Radiography Exposure Device.

1.1 Introduction

The Titan is a gamma radiography exposure device. It is designed in accordance with 10 CFR Part 34 and ANSI N432-1980.(References [1] and [2] respectively) These standards require the Titan to meet the requirements of 10 CFR Part 71.[3]

The Titan does not carry fissile material

1.2 Package Description

The Titan is shown in Figure 1.2-F1. It consists of a C-990 sealed source assembly containing up to 120 Ci (4.44 TBq) of Ir-192. The C-990 meets the requirements for Special Form Radioactive Material (CDN/0001/S) and is shown in Figure 1.2-F2.

The Titan is made from titanium, stainless steel, depleted uranium, lead and rigid epoxy foam. It consists of a predominantly titanium lock assembly, a titanium S-tube cast within a depleted uranium shield, all surrounded with epoxy foam inside an external titanium shell. It also includes a Source Guide Tube End Cap, which incorporates a wire seal in transport. The lock assembly includes a Bayonet End Cap which is installed whenever the unit is not in use.

1.2.1 Packaging

The Titan weighs 44 lbs (20 kg).

The basic materials of construction are: titanium, stainless steel, depleted uranium and epoxy foam.

There is no requirement for neutron absorbers or moderators.

The external dimensions of the unit are summarized below:

OVERALL LENGTH:	13 inches (330 mm)
WIDTH:	a maximum of 6.75 inches (171 mm)
HEIGHT:	10.13 inches (257 mm)

The S-tube has an inner diameter of 0.37 inches (9.4 mm).

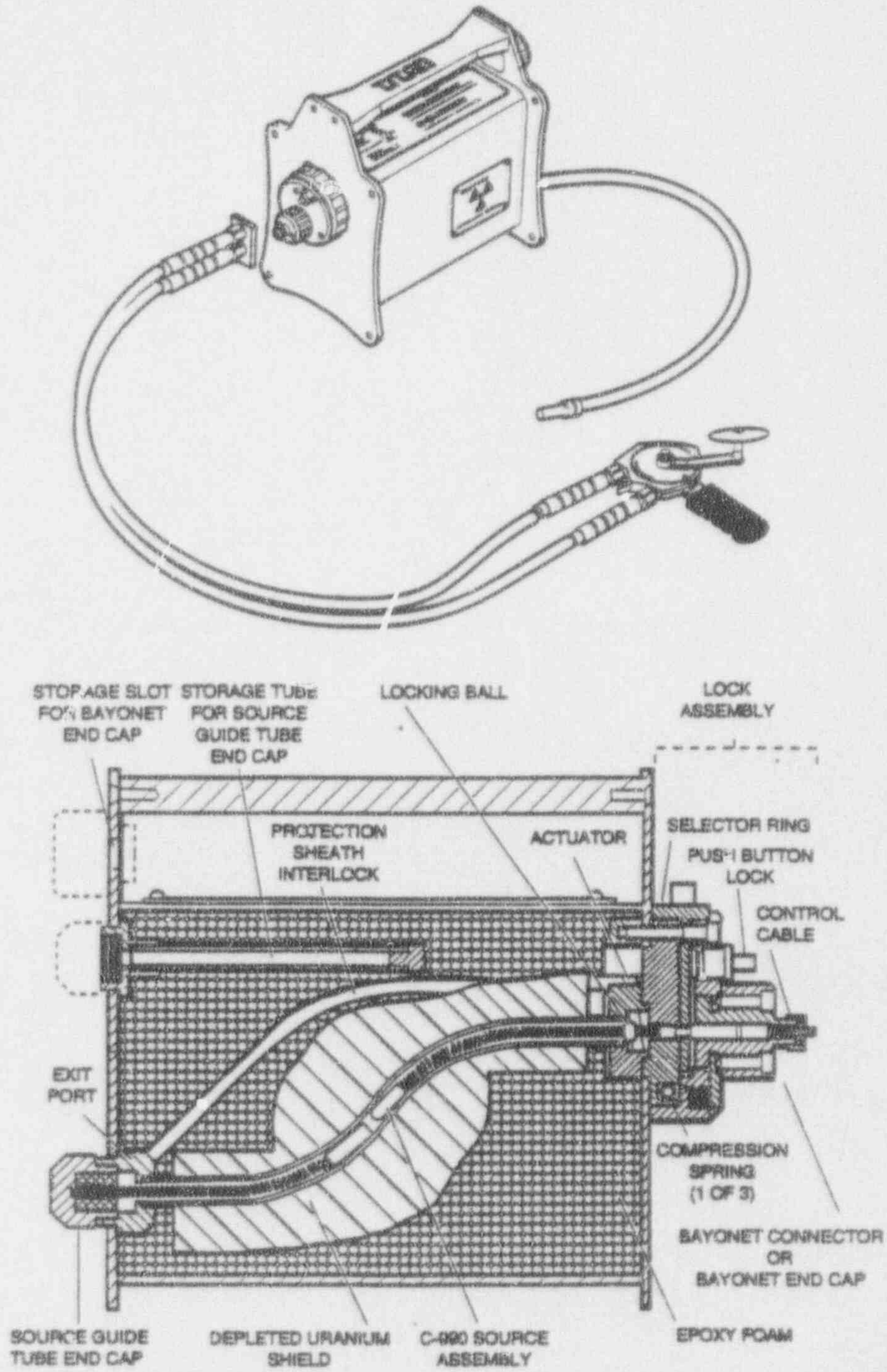


Figure 1.2-F1 The Titan Gamma Radiography Exposure Device

Parts list

1. Control cable
2. D898 Male connector
3. D899 Female connector
4. Locking pin
5. Locking collar
6. Compression spring
7. Spring pin
8. Connector cap
9. Crimp
10. Crimped and threaded locking ball
11. Pig tail cable
12. Crimp
13. Cap capsule
14. Active material: ^{192}Ir
15. Base capsule

Notes

1. Conforms to IAEA Special Form requirements (AECB Certificate No. CDN/0001/S)
2. Manufactured to Nordion Specification IS/TS 0010 C000
3. Used with the Titan Gamma Radiograpr y Exposure Device
4. The female connector has the following information engraved:
   DANGER
   RADIOACTIVE
   NII
   IR192 C990
   SERIAL NO. (as specified)

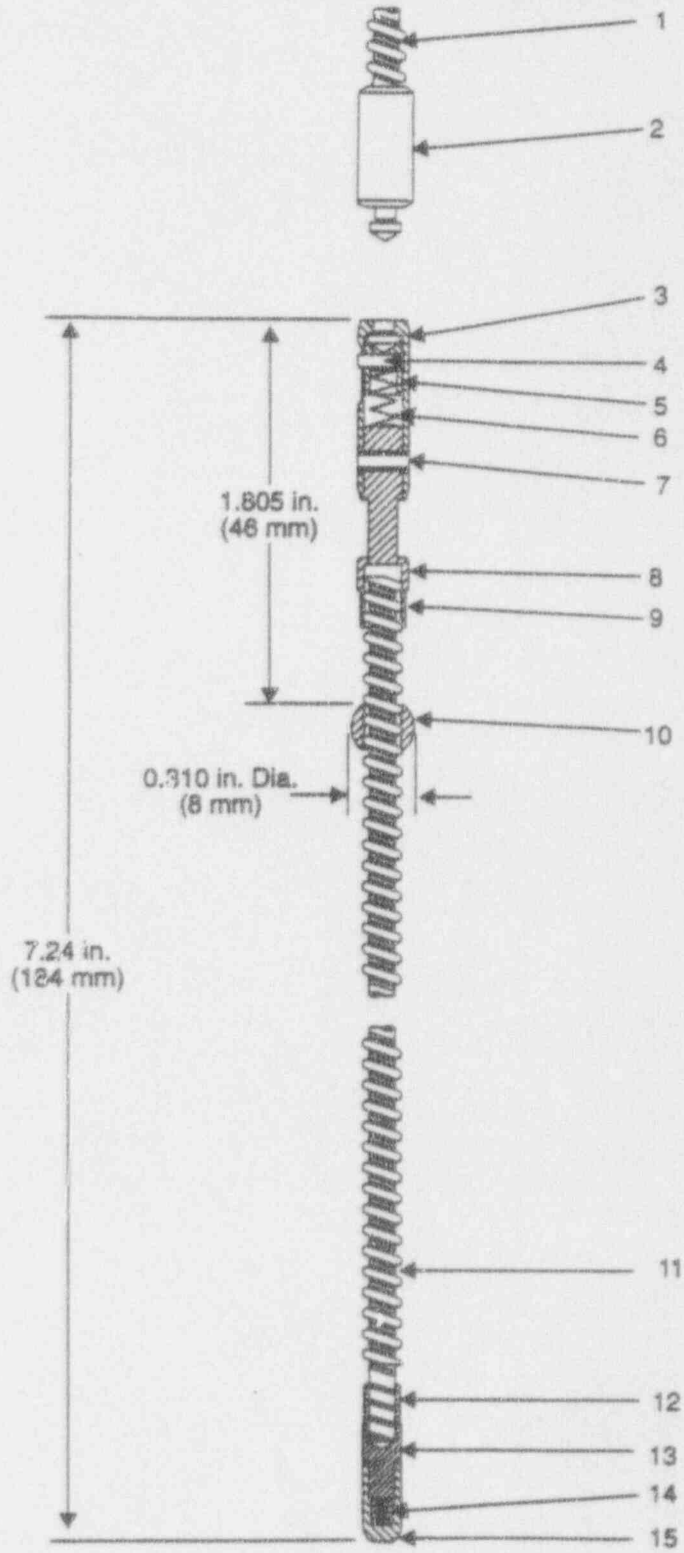


Figure 1.2-F2. The C-990 Sealed Source Assembly

There is no external impact protection, nor are there any internal structures. There are no receptacles, valves or sampling ports.

The relatively low heat generated by the radioactive contents is dissipated by natural convection from the surface of the unit. There are no coolants.

There are no inner or outer protrusions.

Lifting is done via the handle. The unit can be easily handled by one person.

During transport, the package is secured using straps.

The depleted uranium shield consists of a nominally 2 inch (50 mm) radius ball surrounding the C-990 plus additional projections used to attenuate scattered radiation. The depleted uranium shield is shown in section in Figure 1.2-F1. Details of the radiation shielding are discussed in Chapter 5.

There is no pressure relief system.

The depleted uranium shield, and epoxy foam are all welded within a titanium shell. The lock assembly is mounted onto the unit using three 1/4-20 screws. The Bayonet End Cap is installed in the Lock Assembly and secured using the Push Button Lock. The Source Guide Tube is threaded into an adaptor provided on the front of the unit.

Containment of the radioactive contents is provided by the C-990 source assembly. (See Figure 1.2-F2.) It meets the requirements for Special Form radioactive material. Certificate CDN/0001/S is provided in Appendix 1.3-B.

The C-990 is retained within the depleted uranium shield by the lock assembly.

A detailed information drawing is provided in Appendix 1.3-A.

1.2.2 Operational Features

The Titan is a relatively simple package with no specific operational procedures required after the unit has been prepared for shipment.

1.2.3 Contents of Packaging

The Titan is designed to carry up to 120 Ci (4.44 TBq) of Ir-192 in the C-990 sealed source assembly. The radioactive contents are in Special Form. (See Appendix 1.3B)

For the purpose of this submission, one Ci of Ir-192 is defined as the quantity of Ir-192 required to yield an exposure rate of 550 mrem/hr at a distance of 1 meter from the source.

The iridium target material has the following nominal properties:[15]

1)	Density:	21 g/cc
2)	Melting Point:	2454 °C
3)	Physical Form:	0.005 inch (0.15 mm) thick x 0.106 inch (2.70 mm) diameter pellets
4)	Chemical Form:	> 99.5 % iridium
5)	Decay Heat(Ir-192):	6.1 mW/Ci

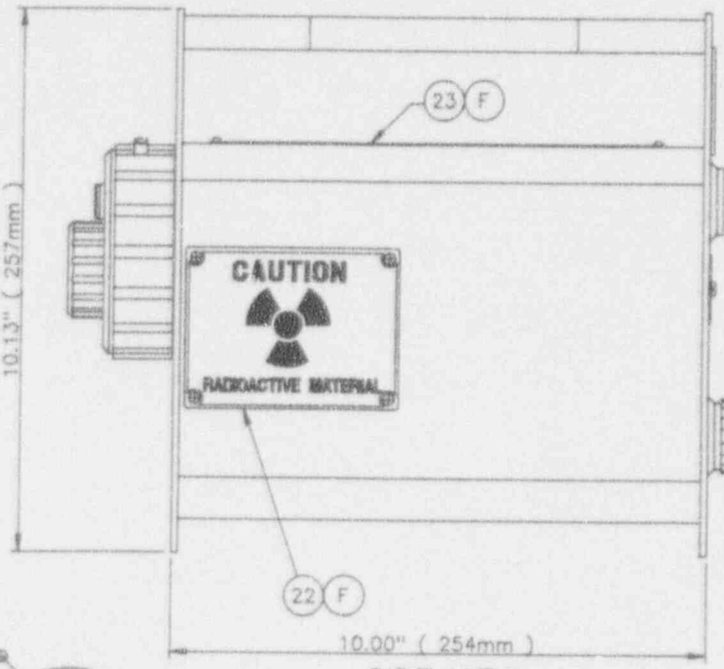
1.3 Appendices

This section contains the following appendices:

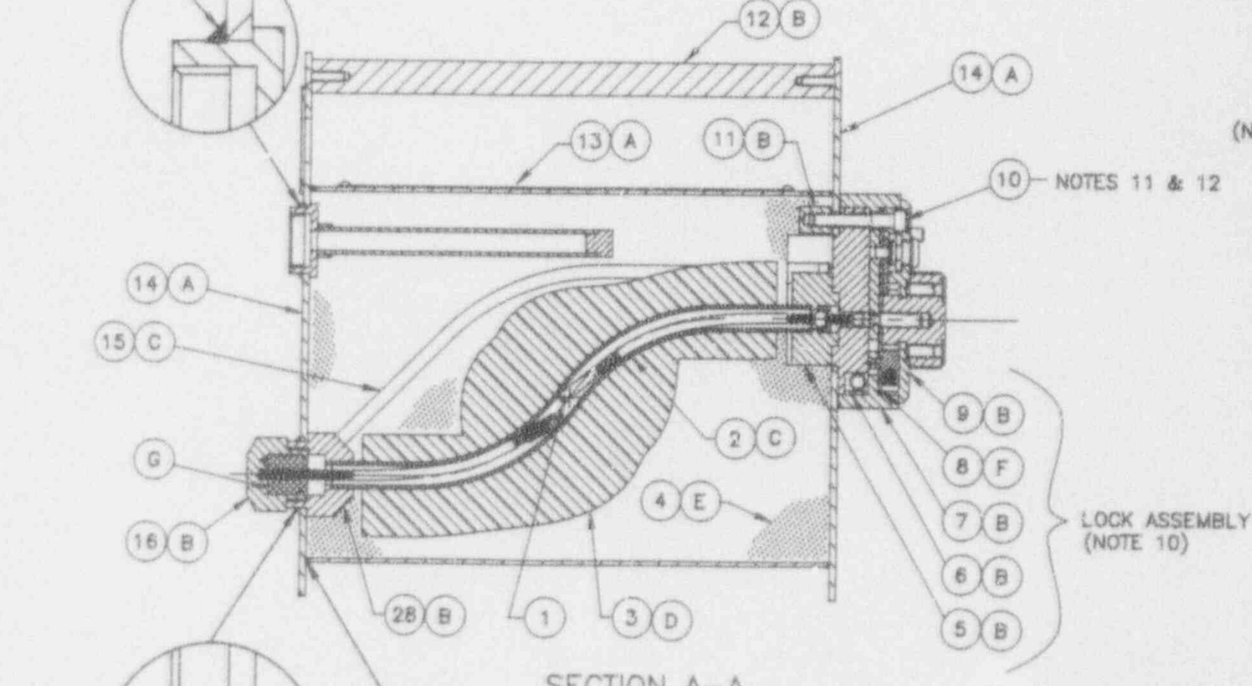
Appendix 1.3-A Titan General Information Drawing
Appendix 1.3-B Special Form Radioactive Material Certificate Number CDN/0001/S

Appendix 1.3-A Titan General Information Drawing

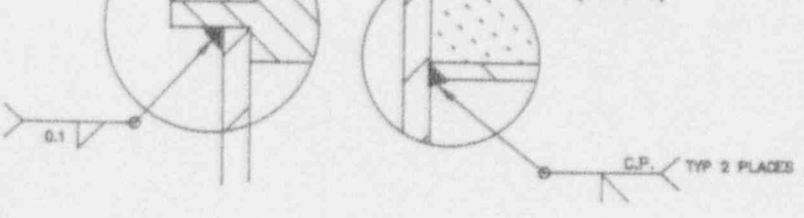
(Nordion Engineering Drawing K122213-501 rev. 1)



SIDE VIEW



SECTION A–A
(NOTE 9)



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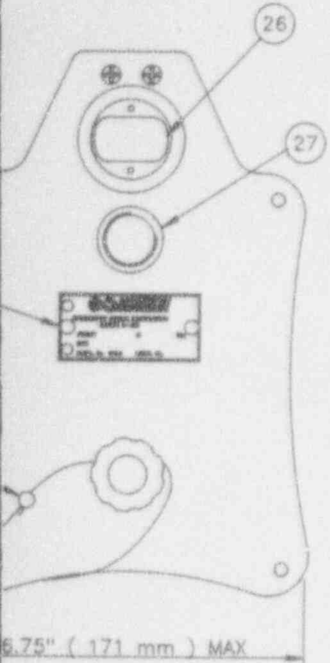
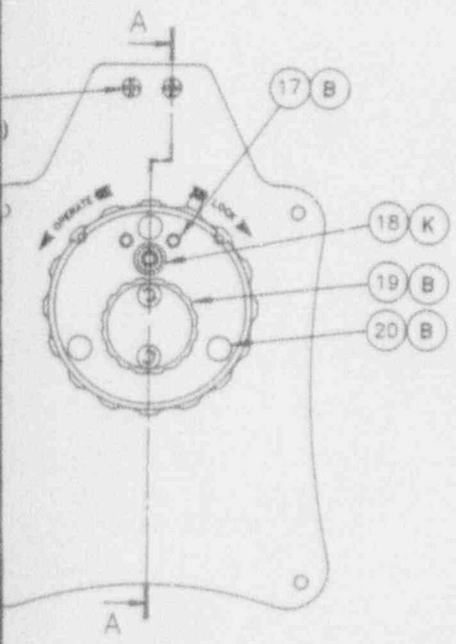


FRONT VIEW



BACK VIEW

NOTES :

1. GROSS WEIGHT - 44 lbs (20 Kg)
2. CAPACITY - 120 Ci (4.44 TBq) Ir-192
3. AECB PACKAGE DESIGN APPROVAL CERTIFICATE CDN/1038/B(U)-85
4. USNRC/USDOT CERTIFICATE USA/????/B(U)
5. C-990 SOURCE ASSEMBLY MEETS REQUIREMENTS FOR SPECIAL FORM RADIOACTIVE MATERIAL (AECB CERTIFICATE No CDN/0001/S
6. MANUFACTURE IN ACCORDANCE WITH NORDION SPECIFICATION IS/TS 0054 N990
7. OPERATED, MAINTAINED AND PREPARED FOR SHIPMENT IN ACCORDANCE WITH NORDION SPECIFICATION IS/OM 0090 N990
8. WELDING IN ACCORDANCE WITH ASME BPV CODE SECTION IX
9. ITEM (15) NOT SHOWN IN TRUE SECTION
10. LOCK ASSEMBLY INCLUDES SCREWS, SPRINGS AND STAINLESS STEEL PINS (NOT SHOWN)
11. TORQUED TO 80-90 in lbs
12. INCLUDES SEALANT

MATERIALS :

A. TITANIUM PLATE GRADE 2 (ASTM B-265)
B. TITANIUM BAR GRADE 2 (ASTM B-348)
C. TITANIUM TUBE GRADE 2 (ASTM B-338)
D. DEPLETED URANIUM (0.75% Ti - 18.6 g/cc DENSITY)
E. RIGID EPOXY FOAM(0.2 - 0.25 g/cc DENSITY)
F. STAINLESS STEEL PLATE (ASTM A-240)
G. COMMON LEAD (ASTM B-29)
H. STAINLESS STEEL (ASTM A-320 GRADE B8 CLASS 2)
J. BRASS SHEET (ASTM B-36)
K. CAMLOC # PTCL 66-1R1N1AA

ANSTEC APERTURE CARD

Also Available on Aperture Card

PARTS LIST :

1) C-990 SEALED SOURCE ASSEMBLY
2) S - TUBE
3) DEPLETED URANIUM SHIELD
4) EPOXY FOAM
5) ACTUATOR BLOCK
6) INNER PLATE
7) SELECTOR RING
8) COVER PLATE
9) OUTER PLATE
10) 0.25 - 20 UNC X 1.25 LONG SOCKET HEAD SCREW
11) THREADED BOSS
12) HANDLE
13) SHELL
14) END PLATES (2)
15) PROJECTION SHEATH INTERLOCK ASSEMBLY
16) SOURCE GUIDE TUBE END CAP ASSEMBLY
17) BUMPERS (2)
18) PUSH BUTTON LOCK
19) BAYONET END CAP
20) SCREW COVER
21) 0.190(#10)-32 UNC SCREWS
22) RADIATION CAUTION PLATES (2)
23) IDENTIFICATION PLATE
24) SOURCE IDENTIFICATION PLATE
25) WIRE SEAL
26) STORAGE RECEPTACLE FOR ITEM 19
27) STORAGE RECEPTACLE FOR ITEM 18
28) EXIT PORT

...N	DATE	BY	APPR

DRAWN: G. SHAW | DATE: 93oct13 | DRAFT. APPR'L: [signature]

MK | | | | [signature]

MECH. ENG. | ELECT. ENG. | CIVIL ENG. | PHYSICS | ENG. APPR'L

MATERIAL | FINISH

NORDION INTERNATIONAL INC.
KANATA ONTARIO CANADA

TITLE: TITAN G.R.E.D. INFO. DRAWING

...USED ON

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES.
TOLERANCES: DECIMALS .XX ± .XXX ± ANGLES ±

THIRD ANGLE PROJECTION

SIZE: B | DWG. NO. K122213-501 | ISSUE 1

SCALE | SHEET 1 OF 1

9402080118-07

Appendix 1.3-B Special Form Radioactive Material
Certificate Number CDN/0001/S

Certification

Atomic Energy Control Board | Commission de contrôle de l'énergie atomique

SPECIAL FORM RADIOACTIVE MATERIAL CERTIFICATE NO. CDN/0001/S, (REV. 12)

30-A2-187-0 September 3, 1992

The Atomic Energy Control Board hereby certifies that the capsules, as described below, have been demonstrated to meet the regulatory requirements prescribed for special form radioactive material as defined in the Canadian Transport Packaging of Radioactive Materials Regulations and in the IAEA Regulations*, subject to the following provisions.

CAPSULE IDENTIFICATION

Nordion International Inc., Capsule Assemblies as listed below.

CAPSULE DESCRIPTION

The radiography capsule assemblies, as listed below, consist of single-walled encapsulated Type 316L stainless steel construction with external dimensions 19.7 mm long by 4.75 mm diameter. The capsules are crimped onto a 3.2 mm diameter 7-19 or a 2.34 mm diameter 7-7 stainless steel aircraft cable assembly or 3.6 mm diameter Nuclear Iberica cable assembly, incorporating a variety of lengths, locking collars and end connectors which are specific to each capsule and their respective drawings:

CAPSULE	DRAWING	CAPSULE	DRAWING
C-141	A07123 Rev. A	C-262	A11542 Rev. C
C-142	A07117 Rev. A	XC-266	A12671 Rev. D
C-148	A07118 Rev. A	C-267	A12668 Rev. D
C-169	A07122 Rev. B	C-272	A12950 Rev. D
C-175	A07116 Rev. C	C-291	A13796 Rev. C
C-187	A07119 Rev. A	C-313	A16730 Rev. B
C-192	A07120 Rev. D	C-337	A16827 Rev. G
XC-237	A07737 Rev. B	C-340	A16833 Rev. H
C-245	A09425 Rev. G	C-343	A17715 Rev. D
C-259	A11539 Rev. F	C-357	K121110001 Rev. A
C-260	A11540 Rev. C	C-359	K121104002 Rev. B
C-261	A11541 Rev. E	C-361	K121104003 Rev. B
		C-369	K121104004 Issue B
		C-990	K122213-600 Issue 1

The following capsule assemblies are also authorized:

Capsule	Drawing No.	Length (mm)	Diameter (mm)	Encapsulation
C-164	A05488,(Rev.D)	14.9	3.99	single
C-204	A02029,(Rev.E)	15.0	5.5	single
C-181	A05800,(Rev.D)	16.5	11.6	single
C-349	A18351,(Rev.D)	[illegible].1	4.57	single
C-352	A18388,(Rev.C)	13.5	8.8	double
XC-234	A07516,(Rev.E)	9.78	6.1	single

AUTHORIZED RADIOACTIVE CONTENTS

Each capsule is authorized to contain not more than 1850 GBq (50 Ci) of cobalt-60 or 5550 GBq (150 Ci) of iridium-192, in the form of solid metal pellets.

EXPIRY DATE

This certificate expires May 31, 1996

W.R. Brown
Director
Radioisotopes and Transportation
Division

REFERENCE

* International Atomic Energy Agency Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1973 Revised Edition (as amended).

NOTES

1. Revision 4: June 7, 1983. Capsule C-343 added. Certificate renewed.
2. Revision 5: September 22, 1986. Certificate renewed.
3. Revision 6: April 3, 1987. Capsules C-349 and C-352 added.
4. Revision 7: April 18, 1989. Capsules C-357 and C-359 added. Certificate renewed.
5. Revision 8: August 24, 1989. Capsule C-361 added.
6. Revision 9: February 15, 1990. Capsule XC-234 added.
7. Revision 10: November 20, 1990. Capsule description revised and capsule C-369 added.
8. Revision 11. May 13, 1992. Certificate renewed.
9. Revision 12. September 3, 1992. Capsule C-990 added.

2.0 STRUCTURAL EVALUATION

This chapter describes the structural design of the Titan.

Two Titan prototypes have been fully tested in multiple drop orientations. The structural assessment draws heavily on the results of these tests, which are described in reference [5].

2.1 Discussion

The Titan is a small lightweight transport package. It has no external impact protection. Its main structural components are the titanium shell, the epoxy foam, the lock assembly, and the fittings retaining the S-tube and shield.

2.1.2 Design Criteria

Compliance is demonstrated through full scale testing. The structural design criteria were the successful completion of all the performance tests specified by ANSI N432-1980 and the successful completion of two full scale 1 m puncture tests and three full scale 9 m drop tests. These tests were to be performed on two prototypes. (All test requirements and criteria are described in Nordion Specification IS/DS 0055 N990, which is provided in Appendix 2.10-A.)

The results of tests relevant to the structural assessment are summarized in Table 2.1-T1. Their application to specific transport requirements is discussed elsewhere in this chapter.

Table 2.1-T1. Summary of Test Results Relevant to the Structural Design

Test	Notes	Result
Endurance Test	20,000 cycles.	Pass
Radiation Shielding Test	Radiation surveys completed on Serials 002 and 003 after full scale drop tests have been completed.	Pass
Horizontal Shock (See Note)	6 orientations, 20 impacts each. Push-button lock deforms	Fail (Note 1)
	Retest with bumpers(20 impacts). Outer Plate deforms.	Fail (Note 1)
	Retest with new Cover Plate (2 orientations, 20 impacts each).	Pass
Vertical Shock	100 impacts. No significant damage.	Pass
Handle Wrench	1.1 m drop snatch. No significant damage.	Pass
Penetration Test	4 impacts. No significant damage.	Pass
Puncture Resistance	2 prototypes tested. No significant damage observed as a result of three tests. (Note 2)	Pass
Accidental Drop	2 prototypes, 3 orientations tested. No excessive increase in fields. No loss of containment.	Pass

NOTES:

(1) The failures listed for the horizontal shock test relate to the inability of the unit to meet the performance requirements of ANSI N432-1980. (After the test, the unit was required to remain operational.) As a result of these failures, various design improvements were incorporated, which enabled the modified prototype to successfully complete this test. However, other than the insignificant deformations to the lock assembly, there was no significant damage to the unit. Even though it failed the ANSI requirement, it did not fail the transport requirements.

(2) Problems in maintaining an appropriate drop orientation required a total of three puncture tests to be performed.

(3) A full description of these tests and their results can be found in reference [5].

2.2 Weights and Centers of Gravity

The Titan weighs 44 lbs. It's centre of gravity is shown in Figure 2.2-F1.

2.3 Mechanical Properties of Materials

The mechanical properties of the materials used in this evaluation are presented in Table 2.3-T2.

TABLE 2.3-T2. Mechanical Properties of Materials

MATERIAL	YIELD STRENGTH (psi)	ULTIMATE TENSILE STRENGTH (psi)	SHEAR STRENGTH (psi)	SHEAR YIELD STRENGTH (psi)	REF
Type 304 Stainless Steel	35,000	85,000	-	20,300	[6,7]
Type 316L Stainless Steel	42,000	-	-	-	[13]
Grade 2 Titanium	40,000	50,000	-	20,000	[8]
Epoxy Foam		450	-	-	[16]

NOTES: 1) For titanium, the shear yield strength is assumed to be 50 % of the yield strength. For stainless steel, the shear yield strength is assumed to be 58 % of the yield strength.

2.4 General Standards for All Packages

This section assesses the Titan with respect to the requirements of 10 CFR Part 71, Section 71.43.

(a) The Titan is shown in engineering drawing K122213-501 (Appendix 1.3-A) and has dimensions larger than the 10 cm required by this paragraph of the Regulations.

(b) The wire seal on the source guide tube end cap and the push button lock both provide evidence that the Titan has not been opened.

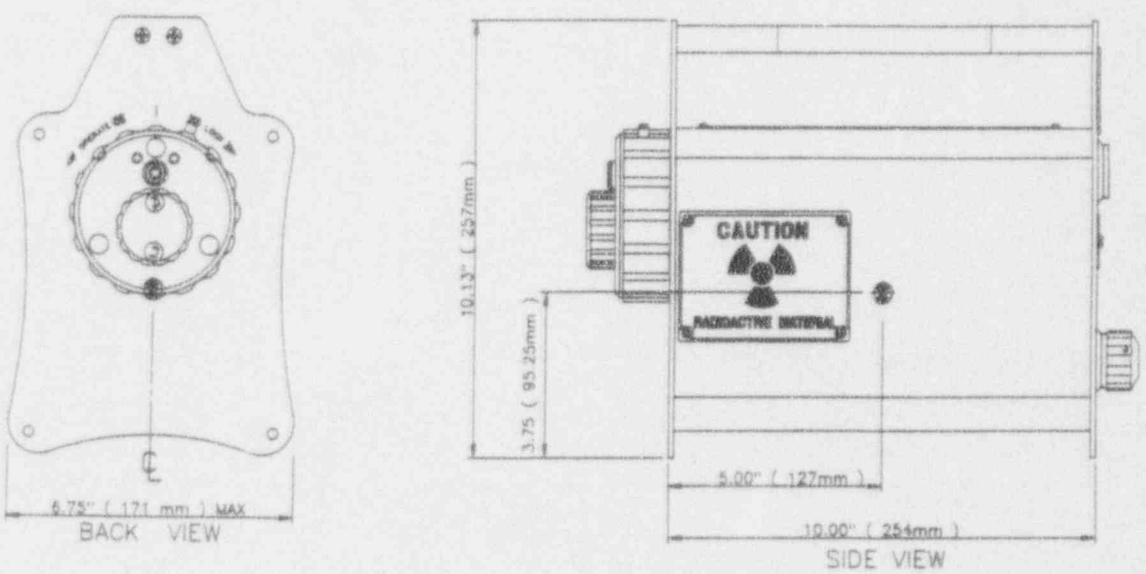


Figure 2.2-F1. Center of Gravity of the Titan

(c) The C-990 meets IAEA requirements for Special Form radioactive material and is the primary containment system. It is securely retained by the lock assembly whenever the selector ring is in the LOCK position. Full scale testing has shown that the C-990 is securely retained within the depleted uranium shield during the tests for normal and accident conditions of transport.

(d) See section 2.4.1.

(e) There are no valves on the Titan.

(f) See section 2.6.

(g) See section 3.4.2.

(h) There are no features on the Titan that allow for continuous venting during transport.

2.4.1 Chemical and Galvanic Reactions

The materials used in the Titan are physically and chemically compatible. Titanium and stainless steel alloys are used throughout the package because of their excellent corrosion resistance.

2.4.2 Positive Closure

The C-990 is a welded stainless steel source. It can be opened only by destroying it.

The C-990 is secured in the lock assembly by the selector ring in all positions except OPERATE. In transport the selector ring is maintained in the LOCK position. It cannot be turned into the operate position unless:

(a) the push button lock has been unlocked with an external key, and,

(b) the peripheral equipment (ie. the source guide tube and remote control) has been installed. (Refer to Part 2 of this report for a description of these components and their function.)

2.4.3 Lifting Devices

This section demonstrates that the Titan can safely withstand lifting forces expected under normal and abnormal conditions. Two cases are considered. In the first case the unit is lifted in the normal manner using the handle. In the second case, it is improperly lifted using one of the four mounting points found on each end plate.

LIFTING VIA THE HANDLE

The Titan is shown in Figure 2.4-F3. When lifted by its handle, forces are transferred to the end plates by the four #10 screws. This section shows that each attachment point is able to safely withstand a snatch lift. It is assumed that a snatch lift imposes a 3 g inertial load on the unit.

The four screws are #10-32 UNF, Type 304 stainless steel. This material has a tensile strength of 85,000 psi and a yield strength of 35,000 psi.[6, p. 6-39] The tensile area for these screws is 0.0200 square inches.[7, p.798]

The shear yield strength of the screws is assumed to be 58 % of its yield strength , or 0.58(35,000) = 20,300 psi.[7, p.90]

Lifting via the handle causes shear stresses in the screws. The force required to cause shear yield is:

$$F = 20,300\ (.02) = 406\ \text{lb}$$

Since there are four screws, a load of 4(406) = 1624 lb is required to cause a screw to yield in shear. This is equivalent to an inertial load of 1624/45 = 36 g's. It is assumed that a snatch lift applies an inertial load of 3 g's. Therefore, the factor of safety on shear yield is 36/3 = 12.

Figure 2.4-F4 shows the end plate. It is 0.125 inch thick ASTM B265 Grade 2 titanium plate. This material has a tensile strength of 50,000 psi and a minimum yield strength of 40,000 psi.[8] It is assumed that the shear yield strength is 50 % of the yield strength, or 20,000 psi.

Shear tearout stress is given by:[7, p.780]

$$\tau_1 = F/2at$$

where:
- F = applied force
- a = the closest distance from the hole to the edge of the plate
- t = the thickness of the plate

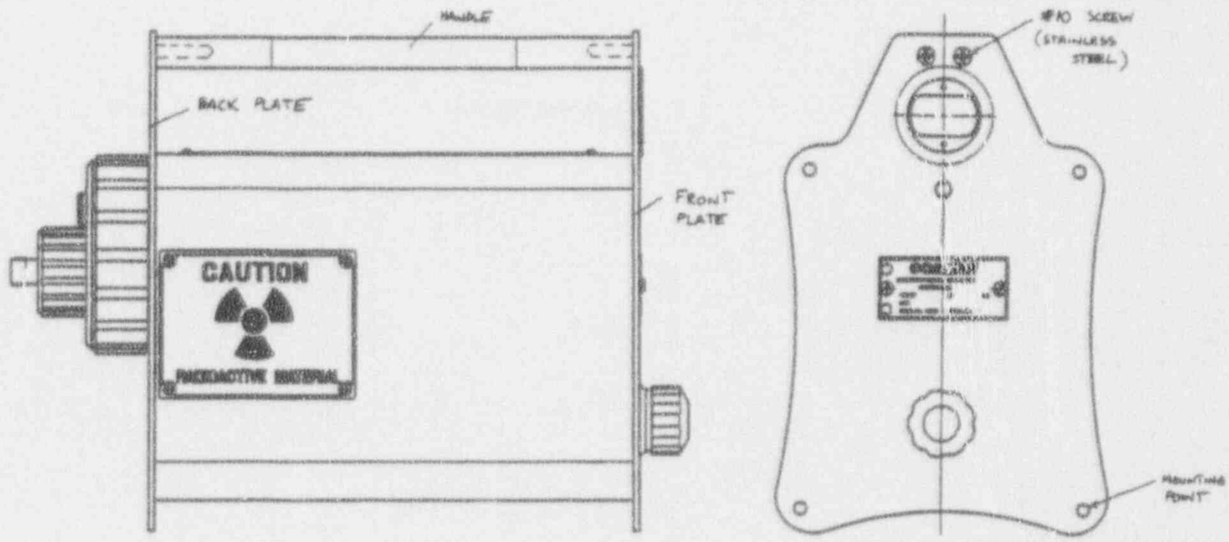


Figure 2.4-F3. Lifting Details for the Titan

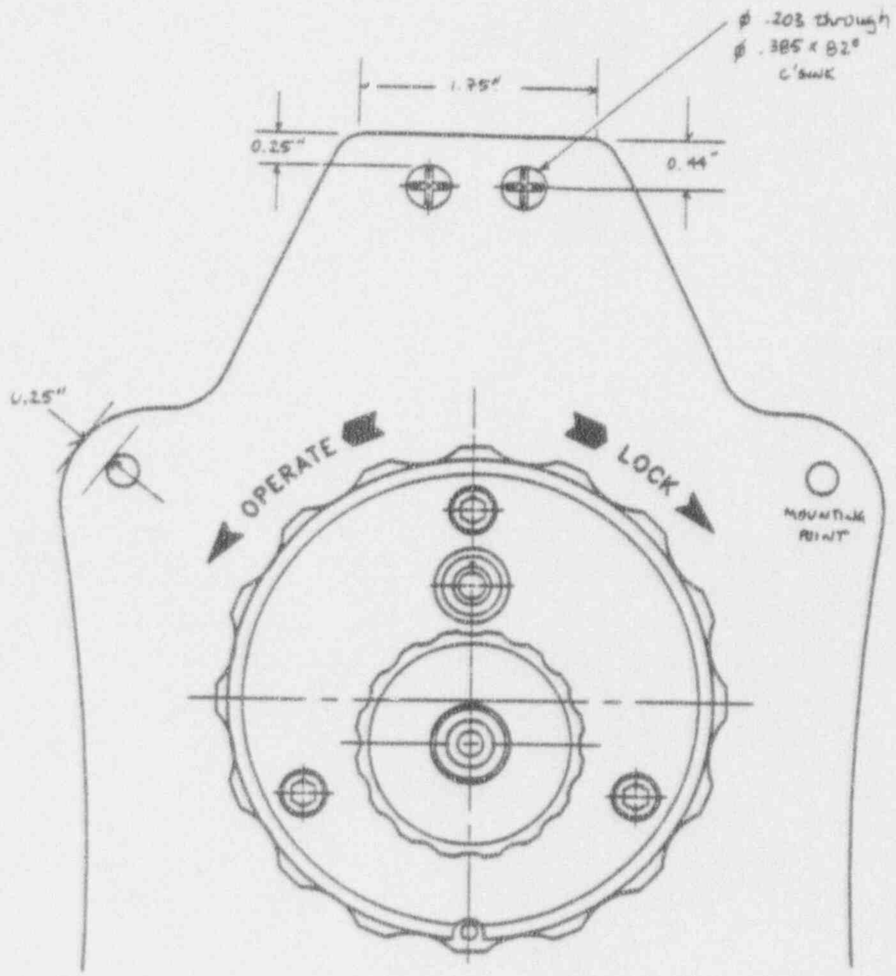


Figure 2.4-F4. End Plate Geometry

Solving for F, the force required to cause shear yield at a single hole is:

$$F = \tau_t * 2at$$

$$= (20,000)(2)(.25)(.125) = 1250 \text{ lb}$$

As there are four screws, a force of 5000 lb is required to cause the plate to yield. This is equivalent to ar inertial load of 500/45 = 111 g's. It is assumed that a snatch lift applies an inertial load of 3 g's. Therefore, the factor of safety on plate yield is 111/3 = 37

Examination of Figure F2.4-F4 shows the tensile area of the plate to be large in comparison with the shear area calculated in A10-2.2. It is also clear that tensile strength of materials exceeds shear strength. These two facts indicate that tensile failure of the plate is not a credible failure mechanism.

LIFTING VIA THE MOUNTING POINT

As shown in Figure F2.4-F4, the minimum distance from a mounting point to the edge of the plate is 0.25 inches. This is the same as the shear tearout distance calculated above. As all other parameters are the same as the case previously considered, the force required to cause shear yield is 1250 lb. In other words, a single mounting point can withstand an inertial load of 1250/45 = 27 g's without yielding in shear. Thus, in the unlikely event that the Titan is lifted using a single mounting point, it is still able to withstand a 3 g snatch load without yielding.

SUMMARY

This section has shown that the Titan lifting points have sufficient strength to withstand 3 g snatch lifts in normal and abnormal orientations. The minimum safety factor on yield was found to be 12. This large margin provides assurance that the Titan can be safely and easily handled.

2.4.4 Tiedown Devices

There are no specific tie-down points on the Titan. Typically, it will be secured using straps or other such hardware. It is the carrier's responsibility to securely stow the unit during transport. Appropriate guidelines are provided in Nordion Specification IS/OM 0090 N990, which may be found in appendix 2.10-B.

2.5 Standards for Type B and Large Quantity Packaging

This section assesses the Titan with respect to the requirements of 10 CFR Part 71, section 71.51.

(a)(1) When subjected to the tests for normal conditions of transport specified in 10 CFR Part 71, section 71.71, there will be no loss or dispersal of the radioactive contents, nor will there be a significant increase in external radiation fields. (This statement is justified in section 2.6.)

(a)(2) When subjected to the tests for normal conditions of transport specified in 10 CFR Part 71, section 71.73, there will be no loss or dispersal of the radioactive contents, nor will there be an increase in radiation fields in excess of 1 rem/hr at one meter from the external surface of the Titan. (This statement is justified in section 2.7.)

(b) The Titan does not require filters or mechanical cooling to meet the above requirements.

2.5.1 Load Resistance

The regulations require the Titan to withstand a stacking load of 5 x 44 = 220 lb without significant damage.

During the stacking test, each 0.12 inch thick x 10 inch high end plate is subjected to a 110 lb load. It is conservatively assumed that this load is applied over a 1 inch width. By inspection, this is a slender column. The Euler Buckling load for these conditions is:

$$P = \pi 2EI/L^2$$

where :
P = buckling load
E = Young's Modulus (15E6 psi [11])
I = moment of inertia

$= bh^3/12 = 1.4E-4\ in^4$

L = length

Substituting and solving leads to an Euler buckling load of 207 lb. Thus, even under these conservative loading assumptions, the Titan end plates have enough strength to support the 110 lb applied load.

2.5.2 External Pressure

The C-990 meets IAEA requirements for Special Form radioactive material. It will not be affected by an external pressure of 25 psi.

The epoxy foam alone has a compressive strength of 450 psi. [16] Therefore, even if the significant strength offered by the titanium shell is neglected, the external dimensions of the unit would remain unchanged.

The C-990 will also be undamaged by this test. The C-990 can be approximated as a thick walled cylindrical pressure vessel with an inner radius, a, of 0.055 inches and an outer radius, b, of 0.094 inches. The case of a thick walled pressure vessel under an external pressure load of q psi is considered by Roark.[12] The normal stresses in the longitudinal, circumferential and radial stresses are given by:

$$\sigma_1 = \text{longitudinal stress} = -qa^2/(a^2-b^2)$$

$$\sigma_2 = \text{circumferential stress} = -2qa^2/(a^2-b^2)$$

$$\sigma_3 = \text{radial stress} = -q$$

Substitution yields σ_1, σ_2 and σ_3 equal to 37, 75 and 25 psi respectively. These stresses are low in comparison with the 42,000 psi yield strength of the Type 316L stainless steel.[13] Therefore, there will be no damage to the containment system as a result of this test.

The C-990 is retained by the selector ring on the lock assembly. The selector ring is not sealed and is not vulnerable to an external pressure of 25 psi.

2.6 Normal Conditions of Transport

The tests for normal conditions of transport are specified in 10 CFR Part 71, section 71.71.

2.6.1 Heat

The thermal analysis for the normal conditions of transport is discussed in section 3.4.

2.6.1.1 Summary of Temperatures and Pressures

The maximum radioactive contents of the Titan generate less than 1 W of heat. Therefore, the temperatures throughout the package will be close to ambient.

The only component of the Titan that may be at a higher pressure than ambient is the C-990. Under normal conditions of transport, and at an ambient temperature of 38 °C, the temperature of the capsule is conservatively estimated to be 60 °C. Assuming it was loaded at 20 °C, the increase in pressure relative to the atmosphere can be estimated using the perfect gas relationship:

$$P_{op} = P_{load}T_{op}/T_{load} = 101 \text{ kPa } (333/293) = 115 \text{ kPa}$$

Thus, the maximum operating pressure is 14 kPa, or 2 psi. At this low pressure difference, no substantial stresses are imposed on the containment system.

2.6.1.2 Differential Thermal Expansion

The low amount of heat generated in the Titan results in small temperature gradients and, hence, negligible thermal stresses.

2.6.1.3 Stress Calculations

The stresses imposed by thermal gradients and pressure are negligible in comparison with the stresses imposed by the mechanical tests for the normal conditions of transport.

2.6.1.4 Comparison with Allowable Stresses

The Titan has been qualified through full scale testing. (See the discussion in Section 2.1.2.)

2.6.2 Cold

There are no liquids in the package.

The mechanical performance of the Titan has been tested at -40 °C. There were no significant findings.[5]

Grade 2 titanium has an impact strength of 26 ft lb in the annealed condition. [11, p.197] As such, it has an impact strength comparable to ferritic steels.

For ferritic steels, NUREG/CR-1815 states that an adequate margin of safety is achieved for ferritic steel sections less than 0.4 inches thick. The Titan end plates are 0.125 inches thick and the shell is 0.078 inches thick. Since the properties of titanium are similar to ferritic steels, and since brittle fracture is not a concern in ferritic steels less than 0.4 inches thick, brittle fracture will not be a concern in the Titan.

2.6.3 Pressure

The C-990 meets IAEA requirements for Special Form radioactive material. It will not be affected by a drop in pressure to 25 kPa.

The C-990 is retained by the selector ring on the lock assembly. The selector ring is not vulnerable to a drop in pressure to 25 kPa.

2.6.4 Vibration

Titan prototypes have completed many tests that demonstrate the ability of the package to withstand the effects of vibration and acceleration. In particular, successful completion of the endurance test, the horizontal and vertical shock tests, and the drop tests for accident conditions of transport proves that the fasteners used in the unit do not become loose or release during transport and routine operation. The test procedures can be found in Appendix 2.10-A and the results of these tests are discussed in reference [5].

2.6.5 Water Spray Test

The water spray test was not completed. The materials used in the Titan are not vulnerable to water damage.

2.6.6 Free Drop Test

The free drop test was not completed on prototype units. However, it is submitted that the Titan will meet the requirements of this test. This is justified as follows:

1) No damage was observed as a result of the 100 vertical drops, the 100 horizontal shock tests and the penetration test. For each of these, the epoxy foam was undamaged and intact. Furthermore, the lock position was unchanged.

2) Little damage was observed after the 1 m pin drops. Observed damage was limited to a bent end plate. The shell of the unit was undamaged and the lock position was unchanged.

3) The shield shifted approximately 5 mm during the 9 m drop and is expected to shift less because of the design improvements implemented under DCR 2787. (See the discussion of Part 2, Section 8.4.) If it is conservatively assumed that the shield shift is proportional to drop height, approximately 0.7 mm shield shift would be expected from the 1.2 m drop. The shield design allows for a 1.6 mm (0.063 inch) variation in source position. Therefore, this shift is within design parameters.

2.6.7 Corner Drop

As the Titan is not a fibreboard or wood package, this requirement does not apply.

2.6.8 Penetration

Titan serial 002 was subjected to 4 consecutive penetration tests. Damage was limited to some minor dents. There was no breach of the titanium shell. No significant damage to the lock was observed.[5]

2.6.9 Compression

The regulations require the Titan to be subjected to the greater of 5 times the mass of the package or 13 kgf/cm^2 (1.85 psi) multiplied by the projected area of the package. The projected area of the package is 450 cm^2 (70 in^2). Multiplying by 13 kgf/cm^2 results in an applied load of 59 kg(130 lb). Five times the weight of the package is 100 kg (220 lb). Therefore, it is necessary to show that the Titan can withstand a stacking load of 220 lb without significant damage.

During the compression test, each 0.12 inch thick x 10 inch high end plate is subjected to a 110 lb load. It is conservatively assumed that this load is applied over a 1 inch width. By inspection, this is a slender column. The Euler Buckling load for these conditions is:

$$P = \pi^2 EI/L^2$$

where : P = buckling load
E = Young's Modulus (15E6 psi [11])
I = moment of inertia

$= bh^3/12 = 1.4E-4\ in^4$

L = length

Substituting and solving leads to an Euler buckling load of 207 lb. Thus, even under these conservative loading assumptions, the Titan shell has enough strength to support the 110 lb applied load. Therefore, the unit will not be significantly affected by the compression test.

2.7 Hypothetical Accident Conditions

The Titan has been qualified by full scale testing. The test facility is described in reference [14], and consists of a steel plate mounted onto a concrete slab. The target mass is far greater than 1000 times the mass of the Titan.

2.7.1/2.7.2 Free Drop and Puncture Tests

Two Titan prototypes were subjected to a total of three one meter puncture tests and three 9 meter drop tests. These are termed drops 1 through 6 respectively and the orientations are summarized in Table 2 and reference [5]. Three pin drops were required as the lock assembly had only slight contact with the pin during the first drop. Thus drop 1 was repeated in the same orientation.

In each pin drop the unit was oriented such that the primary impact would be on the lock assembly. This was judged to be the most damaging orientation because of the following:

1) It directly affects the shielding system. Damage to the lock assembly has the potential to release the C-990 source assembly.

2) The light weight of the unit implies little damage to the external titanium shell. This can be justified by considering the following:

    a) There was relatively little damage resulting from drop 1.(See reference [5].) Damage was limited to some bending of the front plate of the unit.
    b) There was relatively little deformation to the shell as a result of the much more severe 9 meter corner and end drops.
    c) There was very little damage to the shell as a result of the horizontal shock test and the penetration test. The larger diameter of the pin used for the pin drop spreads the load over a larger area than the pins used in the horizontal shock and penetration tests. Therefore, less damage to the shell is expected from the pin drop.

Table 2. Drop Test Orientations

Drop Number	Drop Height	Orientation
1	1.05 meter onto pin	Aligned with lock assembly. Titan serial 002.
2	1.05 meter onto pin	Aligned with lock assembly. Repeat of Drop 1 using Titan serial 002.
3	1.05 meter onto pin	Aligned with lock assembly. Titan serial 003.
4	9.45 meter	Upright using serial 002.
5	9.45 meter	Top front corner, using serial 002.
6	9.45 meter	Onto lock assembly using serial 003

NOTE: The units were dropped from a 5 % greater height to offset the increase in weight required to pass the shielding test. (See Part 2, Section 8) However, the following analysis still refers to these drops as 1 m and 9 m drops even though the drop heights were 1.05 and 9.45 m respectively.

The puncture test was completed prior to the 9 meter drop as this sequence of tests is more damaging. Damage to the lock assembly resulting from the pin drop could weaken the unit for the more severe 9 m drop, increasing the risk of loss of the lock assembly.

The three drop orientations for the 9 m drops were judged to bound all drop orientations while providing objective evidence of the ability of the package to survive full scale drop tests. The orientations were chosen on the basis of the fact that they would cause the maximum shield shift and the most damage to the lock assembly. The goals were to demonstrate that the worst case shift of the shield would continue to satisfy the requirements of the regulations and to show that the lock assembly will retain the C-990 under direct loading.

The orientations were chosen on the following bases:

1) The upright drop imparts relatively high inertial loads to the unit and tends to force the shield through the base of the unit.
2) The top front corner drop provides the least surface area and hence results in the greatest deformation.
3) The combination of the upright and corner drops on a single unit bounds the damage expected from any single drop. While this is difficult to justify analytically, it is reasonable to assume that two drops in two different orientations are worse than any one single drop onto any part of the titanium shell. The damage to the epoxy foam during the first drop lessens the support offered to the depleted uranium during the second. As such, it will experience a greater shift as a result of the combined drops. This can be partially justified by comparing the results of drops 4 and 5 to drop 6. The shield shifted approximately 5 mm as a result of the combined drops, whereas there was negligible shift as a result of drop 6. (See reference [5].
4) The only time appreciable stresses are imparted to the lock is during a direct impact. Therefore, the worst damage to the lock assembly results from a drop directly onto it.
5) The only time significant stresses are imparted to the C-990 is during a direct impact onto the lock. The light weight of the C-990 combined with the flexibility of the teleflex cable make it impossible to damage the source containment system. The only way to damage the source assembly is to damage the portion in contact with the lock. Since

the lock only sees appreciable stresses during a direct impact, the only time the C-990 can be damaged is during a drop onto the lock.

The results of the drop tests are described in reference [5]. Radiation surveys completed after the drop showed a maximum radiation field of 1500 mrem/h on contact with the lock after extrapolation to a 120 Ci source. (See reference [5].) Using the inverse square law, the field 1 m from the lock is estimated to be 19 mrem/h, which is substantially less than the 1000 mrem/h allowed by the Regulations.

The only significant damage observed was the shift of the radiation shield after drops 4 and 5. It was found that the shield shifted about 5 mm (0.2 in) during the drops. This is significant as any movement outside of the lock assembly decreases the support offered to the shield in the subsequent fire test. Since the drop test, the design has been modified to allow for greater engagement of the S-tube within the exit port and the actuator block. (The engagement has been increased from 6.4 mm (0.25 in) to 9.5 mm (0.375 in).) This provides an additional safety margin to the design. It is submitted that the revised design will shift less than 5 mm for the following reasons.

1) Serial 002 was subjected to two 1.05 m drops and two 9.45 m drops. The observed 5 mm shift was at least partially due to the cumulative damage resulting from the two 9.45 m drops. A single drop will result in less than 5 mm shift.

   This can be partially justified by considering the results of the drop tests. Unit 003 was subjected to a puncture test and a 9 m drop test. There was no significant shift in the shield. Unit 002 was subjected to two puncture tests and two 9 m drop tests. Its shield shifted about 5 mm. (See reference [5].)

2) The increase in engaged length provides additional support against lateral motion.

This change has been implemented under Nordion Drawing Change Request (DCR) number 2767. It improves the safety of the package relative to the tests completed on prototype units.

A complete description of the test program including photographs is provided in reference [5].

2.7.3 Thermal

The thermal test is discussed in section 3.5.

Pressure increases as a result of the thermal test are not considered as, with the exception of the C-990, the Titan is not a sealed package.

The only material vulnerable to the fire test is the epoxy foam. It's function is to provide additional support to the depleted uranium shield during the 9 m drop test. As the drop test precedes the fire test, the loss of the foam during the fire is of no consequence.

2.7.4 Water Immersion

The Titan does not carry fissile material. This requirement does not apply.

2.7.5 Summary of Damage

The damage observed as a result of full scale testing is discussed in reference [5]. Post drop test radiation surveys showed prototype units to have radiation fields less than the 1 rem/hr required by the regulations.

2.8 Special Form

The C-990 meets the requirements for Special Form radioactive material. AECB Certificate CDN/0001/S is provided in appendix 2.10-C.

2.9 Fuel Rods

Fuel rods are not shipped in the Titan. This requirement does not apply.

2.10 Appendices

The section contains the following appendices:

APPENDIX 2.10-A: IS/DS 0055 N990 rev B.
APPENDIX 2.10-B: IS/OM 0090 N990 rev B.
APPENDIX 2.10-C: Special Form Certificate Number CDN/0001/S

APPENDIX 2.10-A: IS/DS 0055 N990 rev B.

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DESIGN SPECIFICATION

Test Plan for the Titan Gamma Radiography Exposure Device

IS/DS 0055 N990 (REV B)

CURRENT DATE: 93 MAY

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NOTE:
The portion of this text affected by the changes is indicated by a vertical line in the margins of the pages.

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1 INTRODUCTION

This document describes the detailed test plan for the Nordion Titan Gamma Radiography Exposure Device (GRED). The tests are required to demonstrate that the Titan meets the regulations for the design of gamma radiation exposure devices and the regulations for the safe transport of radioactive material (references 1, 3, 4, 6, 7). A description of the tests and detailed test procedures are included.

2 CLASSIFICATION

The Titan GRED is classified under ANSI N432(1980) as a Class P, Type 1, Type R exposure device. The testing described herein demonstrates that the device meets the requirements of this specification for a device of this type. Additional testing will be performed in order to support the design and to demonstrate that the Titan meets the transportation requirements for Type B(U) transport packaging (reference 6, 7).

3 PROJECT REQUIREMENTS

The guidelines for design, inspection ar testing within ANSI N432(1980) and ISO 9000(1987) will be followed throughout the project. Some requirements of the revised ANSI standard, ANSI N43.9(1991) have been adopted.

4 TEST REQUIREMENTS

Reference documents 1, 3, 4, 6 and 7 outline in detail the test requirements for gamma radiography equipment and transport packagings. Table 1 summarizes these test requirements. Details of the requirements are listed in section 7 of this test plan. Figure 1 illustrates the sequence and flow of these tests.

The C990 source assembly has been demonstrated to meet Special Form requirements and has been classified as C43515 according to ANSI N543(1977) (see Appendix B).

5 DEFINITIONS

Many documents govern the testing to be performed on the Titan. They use many terms which are sometimes interchangeable or which may have subtle differences in meaning. For the purposes of this Test Plan, the following definitions shall apply.

Exposure Device

A shielded device employing a sealed source designed to allow the controlled use of gamma radiation for the purpose of making a radiographic exposure.

GRED

Gamma Radiography Exposure Device. This term typically refers only to the exposure device, and not to the entire apparatus.

Locked Position

Condition of the exposure device when it is locked (with a key) in addition to being in the secured position.

Projection Sheath

A flexible tube for guiding the control cable and the attached source assembly from the exposure device to the working position. Also known as a source guide tube.

Quality Assurance Representative

A representative designated by Nordion's Quality Assurance Department whose responsibility is to verify that the testing has been conducted in accordance with the quality assurance requirements and that the test results are thoroughly recorded and are accurate.

Remote Control Device

A device enabling the sealed source to be moved to an exposing position by operation at a distance away from the exposure device. The remote control device includes the crank mechanism, control cable and sheath. The remote control sheath consists of a reserve side and a projection side (see Figure 12 for illustration).

Secured Position

Condition of the exposure device when the source assembly is fully shielded and restricted from movement.

Source Assembly

A complete assembly including a sealed source, a short length (150 mm) of cable, a locking ball and an end connector. The source assembly used in the Titan is called the "C990" (ref. drawing K12223-600 Rev. B).

Table 1 - Governing Specifications and Their Tests

Device Under Test	Test	Standard or Specification						
		Nordion IS/DS 0055	ANSI N432 (1980)	ANSI N43.9 (1991)	IAEA Safety Series No. 6	10CFR 34 (Radiography) see note 1	10CFR 71 (Transport) see note 2	ISO CD 3999
Entire Apparatus	Projection Under Stress	✗		✗				✗
	Endurance	20,000	20,000	50,000				50,000
Exposure Device	Radiation Shielding	✗	✗	✗	✗	✗	✗	✗
	Vibration	see note 3		✗			✗	✗
	Horizontal Shock	✗	✗	✗				✗
	Vertical Shock	✗	✗	✗				✗
	Handle Wrench	✗		✗				✗
	Lock Breaking							✗
	Water Spray	see note 3			✗		✗	
	Immersion	see note 3			✗		✗	
	Penetration	✗			✗		✗	
	Puncture Resistance	✗	✗	✗	✗		✗	✗
	Accidental Drop	✗	✗	✗	✗		✗	✗
	Fire	✗		✗	✗		✗	✗
	Corrosion	see note 3						✗
	Free drop Test	see note 3			✗			
	Stacking Text	see note 3			✗			
Remote Control Device	Kinking	✗	✗	✗				✗
	Crushing	✗	✗	✗				✗
	Tensile	✗	✗	✗				✗
Projection Sheath	Kinking	✗		✗		✗		✗
	Crushing	✗		✗		✗		✗
	Tensile	✗		✗		✗		✗
	Tightness							✗
Source Assembly	Tensile	✗	✗	✗				✗

Notes:
1) 10CFR 34 requires all of the tests from ANSI N432 (1980) in addition to those indicated.
2) 10CFR71 includes the following tests that will not be performed: Heat, cold, reduced external pressure, increased external pressure and compression.
3) Test will not be performed, but device is qualified by discussion.

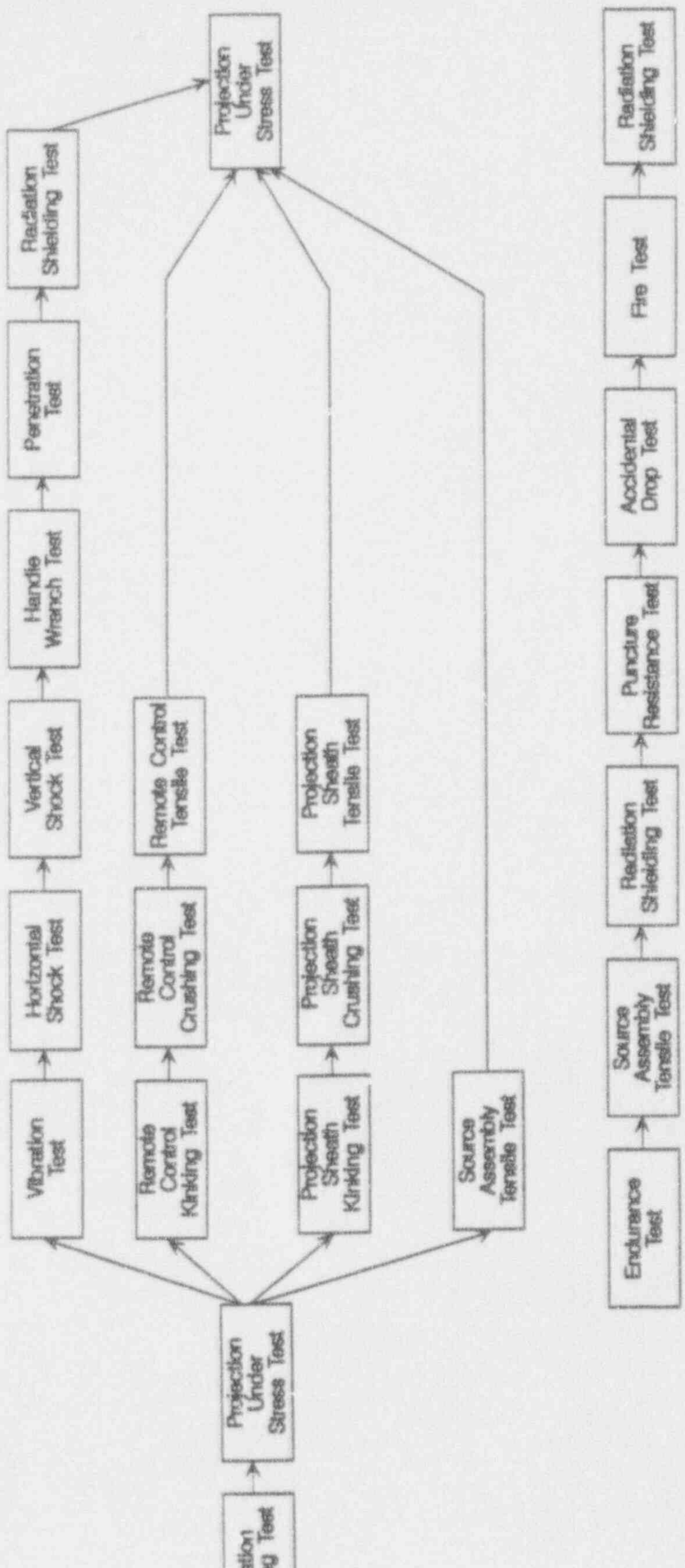

Figure 1
Test Flow Chart

6 QUALITY ASSURANCE REQUIREMENTS

The Nordion Titan project is managed in accordance with Nordion Specification IS/QP-0052-N990 and ISO 9000(1987). Testing will be performed in accordance with IS/QP-0052-N990.

6-1 Independent Testing

Where testing is performed by an organization independent of Nordion International, the testing and results will be documented by this independent organization. Where testing is performed by Nordion International, it will be thoroughly documented by the test engineer using sketches, photographs, video tapes and the Data Sheets in Appendix A. All test results will be validated by the project engineer. The testing will be witnessed by a Quality Control Representative where appropriate.

Representatives from the Canadian Atomic Energy Control Board will be invited to witness all testing.

6-2 Sub-Contractor's Quality Assurance

Sub-contractors must have a quality assurance system in accordance with ISO 9003 or CSA Z299.3. Quality system requirements include a quality policy, a quality system organization, quality records, a calibration system and personnel training. Sub-contractors will be evaluated on systems, procedures, and ability, prior to the start of testing.

6-3 Calibration

Equipment used for measuring test results shall be calibrated at the time of the test. The equipment calibration due date shall be recorded on the data sheets.

Calibration shall be performed by a qualified laboratory.

7 PROTOTYPE TESTING

7-1 Tests On The Entire Apparatus

7-1-1 Projection Under Stress Test

7-1-1-1 Purpose

The purpose of this test is to measure whether the torque required to drive and retract the source through a complete exposure cycle changes during a lifetime of normal use. This test is not a requirement of ANSI N432(1980). It is performed to verify the design and is based on the Projection Under Stress Test from ANSI N43.9(1991).

7-1-1-2 Equipment

The entire GRED apparatus shall be tested. Before the final test it will have been subjected to a variety of tests (see Figure 1). A torque meter Snap On model TBS2FUA will be employed.

7-1-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-1-1-4 Approach

The testing will be performed in two stages. Initial torque readings will be made on the new GRED equipment. Then, after a series of tests on the individual components, the measurements will be repeated.

The final torque measurements will be performed on equipment that has been subjected to the following tests:

- exposure device : horizontal shock, vertical shock, handle wrench and penetration
- remote control device : kinking, crushing, tensile
- projection sheaths : kinking, crushing, tensile
- source assembly: tensile

The test setup is shown in Figure 2. The bending radii for the remote control and projection sheath will be 500 mm.

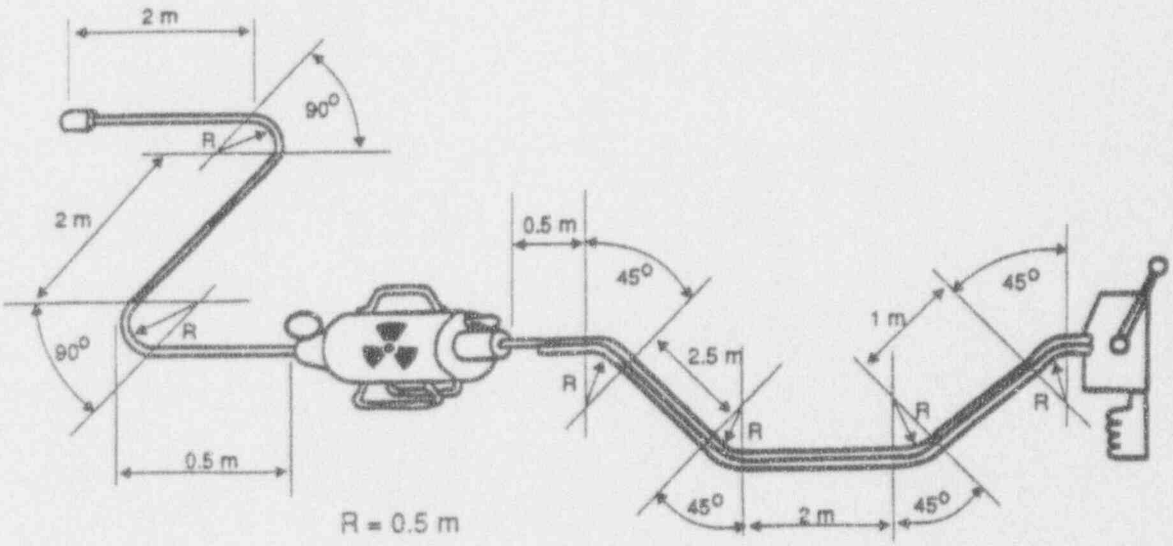

Figure 2
GRED Apparatus Endurance Test Configuration

Ten exposure cycles will be performed during which the maximum driving/retracting torque will be recorded.

7-1-1-5 Procedure

1) Set up the GRED equipment in the configuration shown in Figure 2. The bending radii at corners shall be 500 mm for the remote control and projection sheath. Connect the torque meter to the remote control crank mechanism.

2) Drive the source assembly to its fully extended position and then retract it fully. Care must be exercised in order not to measure the sharp rise in torque when the source reaches the end of its travel at each extreme.

3) Measure the driving torque and record the maximum value measured during the cycle.

4) Repeat the process 10 times and record the data on the Projection Under Stress Test Data Sheet provided in Appendix A. Be certain to fill out all of the information requested on the data sheet. The test engineer must sign the data sheet and a quality control representative must witness the test setup and at least one cycle of the testing. The test results must be validated by the project engineer.

5) Steps 1 to 5 are to be repeated once the equipment has been subjected to the tests for conditions of normal use listed in paragraph 7.1.1.4.

7-1-1-6 Data and Results

The test data shall be recorded on the form provided in Appendix A. All of the required information must be completed. An increase in drive torque of 25% or more shall constitute a failure.

7-1-2 Endurance Test

7-1-2-1 Purpose

The purpose of this test is to repeatedly operate the apparatus in order to determine its resistance to fatigue, and to measure any wear on the equipment components. After 20,000 cycles, an exercise will be performed in order to demonstrate that the source assembly will not disconnect when projected out of an open projection sheath.

7-1-2-2 Equipment

The automated endurance test equipment illustrated in Figure 3 will be used to perform the cycling. Impressions of the source tube will be made using Dow Corning Mold Making Compound DC HSII.

7-1-2-3 Location

With the exception of the thermal cycling this test shall be performed at Nordion International Inc., Kanata, Ontario.

7-1-2-4 Approach

The equipment will be subjected to continuous cycling for 20,000 cycles.

At the completion of 20,000 cycles, 50 cycles will be performed with the end of the projection sheath open. During these exposures, the source assembly will extend at least 1 meter out of the projection sheath. This additional test is not a requirement of ANSI N432(1980). Rather it is a requirement of ANSI N43.9(1991) that has been adopted to prove that the source assembly will not accidentally disconnect or snag outside the projection sheath.

At the conclusion of the test, 100 cycles will be performed with the exposure device at -40°C, and an additional 100 cycles will be performed at +55°C. These cycles are not a requirement of ANSI N432(1980) and will be performed after the completion of the 50,000 cycles. The entire remote control and projection sheath need not be exposed to the temperature extremes and these peripherals may be shorter than those used for the Endurance Test at ambient temperature.

After having been subjected to the endurance test, the source assembly will undergo the Tensile Test of paragraph 7.5.1.

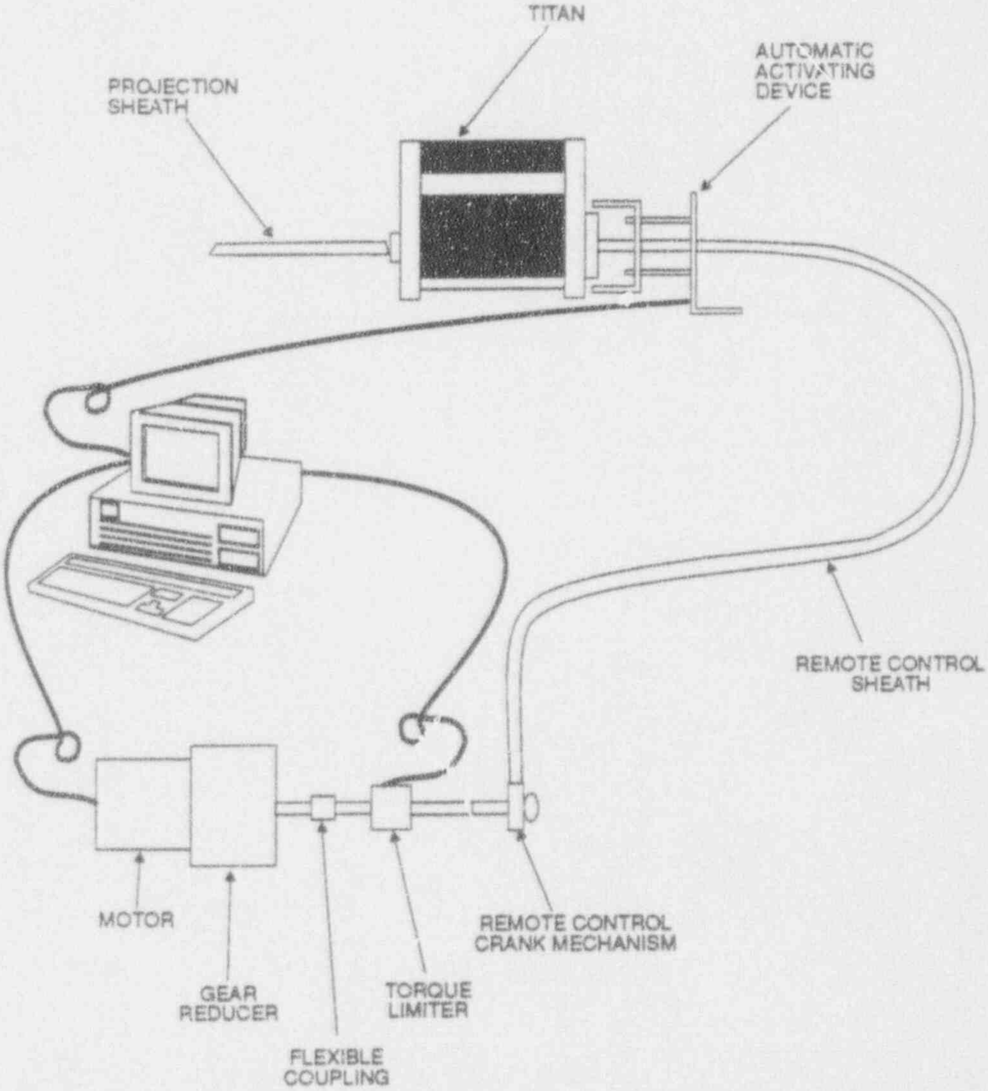

Figure 3
Endurance Test Setup

The test setup is shown in Figures 2 and 3. The automatic test apparatus shall meet the following requirements:

Minimum speeds : rotating 180 RPM
linear 0.75 m/s

The torque that the apparatus exerts at each extreme shall be determined by measuring the force experienced by the drive cable during manual operation. The test apparatus will then be adjusted accordingly.

7-1-2-5 Procedure

1) Measure the length of the dummy source assembly. Record the measurements and the source assembly serial number on the C990 Source Assembly Tensile Test Data Sheet, as this length will be required for comparison at the completion of testing. Record the tolerance associated with the length measurement and the calibration date of the instrument.

2) Check the integrity of the source tube by taking an internal impression using Dow Corning Mold Making Compound DC HSII.

3) Connect the equipment under test as shown in Figures 2 and 3.

4) Start the automated test equipment and verify that the counters are working properly. Check that the source assembly is travelling from the secured position, to the fully extended position and back. Record the date, time and cycle number on the Endurance Test Log Sheet in Appendix A. Be certain to initial every entry on the Log Sheet.

5) Regularly check the test apparatus for proper function or any incidents. An incident includes test startup or shutdown, failures or any other test anomalies.

6) Record any incidents on an Endurance Test Log Sheet provided in Appendix A. The date and time of each incident must be recorded and initialled. If the incident results in the shutdown of the test apparatus, it must be witnessed by a Quality Assurance Representative before the apparatus may be restarted. Disposition must be given by the project engineer.

7) Once 20,000 cycles have been completed, the end of the projection sheath shall be opened to allow the source assembly to pass through. 50 cycles shall be performed during which the source assembly shall extend at least 1 m from the projection sheath.

8) At the completion of the testing, the apparatus shall be moved to an environmental test chamber where the equipment shall be subjected to 100 cycles at temperature of -40°C. The remote control device and projection sheath do not need to be entirely exposed to the temperature extreme, and these peripherals may be shorter than those used for the Endurance Test at ambient temperature.

9) Repeat step 8 with the temperature stabilized at +55°C.

10) Remove the dummy source assembly. Tag and identify it, as a Tensile Test will be performed on it as per paragraph 7.5.1.

11) Check the integrity of the source tube by taking an internal impression using Dow Corning Mold Making Compound DC HSII.

7-1-2-6 Data and Results

Any start up, shut down or maintenance action shall be recorded on the Endurance Test Log Sheet. Photographs of any failures or maintenance actions are required. Failure criterium shall be failure of the apparatus to remain completely operational after 20,000 cycles. Additionally, the integrity of the sealed source and the encasement of the depleted uranium shielding must not be breached through wear after 20,000 cycles. An impression of the inside of the source tube will be made before and after the test.

7-2 Tests On The Exposure Device

7-2-1 Radiation Shielding Test

7-2-1-1 Purpose

The purpose of this test is to determine the exposure rate from the device to assure that the

dose rates in the vicinity of the device are within the limits specified.

7-2-1-2 Equipment

The Radiation Shielding Test will be performed on new exposure devices prior to the commencement of any mechanical testing, after the Penetration Test, after the Endurance Test, and if possible, after the tests for accident conditions. The measurements will be made on exposure devices with the end caps installed.

The Victoreen Model 440 and Model 660 survey meters will be used for measurements. Substitute survey meters may be used provided that the meter used to measure the exposure rate at 50 mm from the surface does not average over an area greater than 10 cm^2 and has a sensitive volume with no linear dimension greater than 5 cm. The meter used to measure the exposure rate at 1 m from the surface must average over an area no greater than 100 cm^2 and its sensitive volume must have no linear dimension greater than 20 cm.

7-2-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-1-4 Approach

A detailed survey will be performed on the two prototypes when they are new. Measurements will be made at every node on the grid system shown in Figure 4. In locations where the fields are relatively high, the hot spots will be located and identified in relation to the grid system. Radiation field measurements made after the exposure device has been subjected to testing will not be as thorough. They will be limited to areas of the device which have been affected or damaged by the testing.

A sample source is to be used for the measurement and the exposure rate is to be extrapolated to the maximum rating of 4.44 TBq (120 Ci) for the device. The extrapolation is not to exceed a factor of 10, but the source should approach an activity of 4.44 TBq (120 Ci) as safely and as practically as possible.

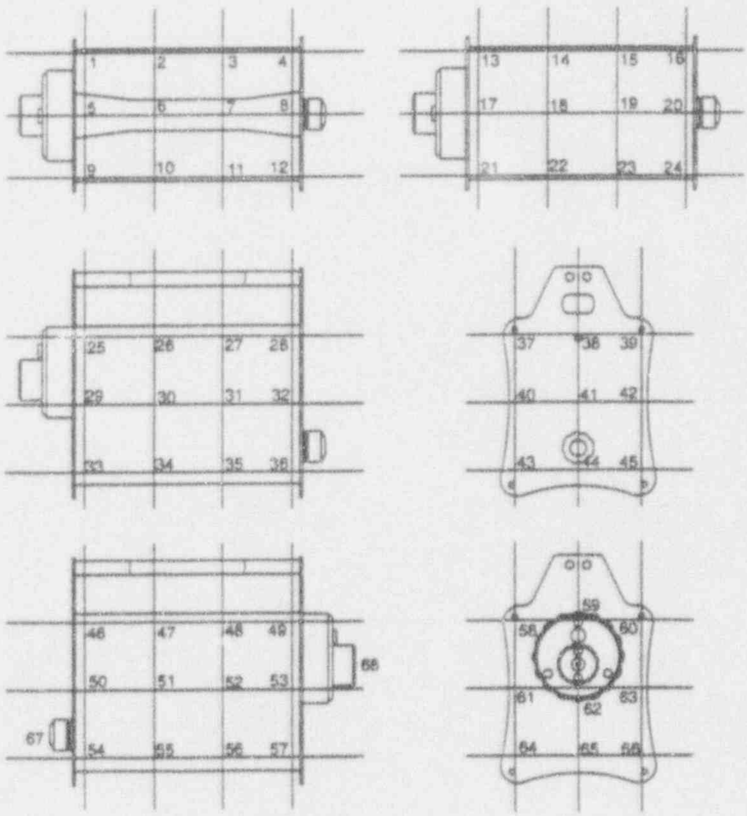

Figure 4
Radiation Survey Grid System

The maximum specified dose rates are as follows:

- 2 mSv/hr (200 mrem/h) on surface
- 0.5 mSv/hr (50 mrem/h) at 50 mm from the surface
- 0.02 mSv/hr (2 mrem/h) at 1 m from the surface

The activity of the source will be determined based on 0.55R/h-Ci at 1m for Ir-192.

If it is not possible to load a source assembly into the device after the tests for accident conditions, then a radiation shielding analysis will be performed to determine the exposure rate at this time.

7-2-1-5 Procedure

1) Measure the fields from the sample source and record the field output at 1m on the Radiation Shielding Test Data Sheet.

2) Observing the required safety procedures, install the sample source in the exposure device.

3) Using the Victoreen Model 471 Survey Meter measure the fields 50 mm from the surface of the exposure device at each of the nodes identified on the 3 inch grid system in Figure 4. Allow the meter reading to stabilize for 5 seconds at each node before recording the measurement. Record each measurement on the Radiation Survey Data Sheet, and record the maximum reading on the Radiation Shielding Test Data Sheet.

4) Measure the fields at 1 m from each of the 6 faces of the exposure device. Record the measurements on the Radiation Survey Data Sheet, and record the maximum reading on the Radiation Shielding Test Data Sheet.

5) After the initial Radiation Shielding Survey on the exposure device, it is only necessary to make readings at locations on the device that are likely to have been affected by the testing.

6) Record all of the data on the Data Sheets, including the date, activity of the test source, serial number of the exposure device, and calibration data for the test equipment. Complete all of the calculations on the Radiation Shielding Test Data Sheet.

7-2-1-6 Data and Results

The measured field for the source and the activity calculation shall be shown on the Radiation Shielding Test Data Sheet. The extrapolation calculation shall also be recorded on the data sheet.

Fields in excess of the following constitute a failure:

- 2 mSv/hr (200 mrem/h) on surface
- 0.5 mSv/hr (50 mrem/h) at 50 mm from the surface
- 0.02 mSv/hr (2 mrem/h) at 1 m from the surface

7-2-2 Vibration Test

7-2-2-1 Purpose

The purpose of this test is to determine the resistance to the exposure device to the vibration that it may encounter during normal service. This test is not a requirement of ANSI N432(1980).

7-2-2-2 Discussion

The vibration test is intended to reveal any environmental effects that may occur during normal service. Examples of such effects include loosening of fasteners, component fatigue, chafing between parts and cracking or rupturing of structural members. The Titan is a welded structure, and any threaded fasteners are fixed with thread sealant. Additionally, the enclosure is injected with an epoxy foam which fills all internal voids. The Titan is therefore not susceptible to the environmental effects caused by vibration and there is no need to perform the vibration test.

7-2-3 Horizontal Shock Test

7-2-3-1 Purpose

The purpose of the Horizontal Shock Test is to test the resistance of the device to the shocks that may be encountered during normal service.

7-2-3-2 Equipment

The equipment used for the Horizontal Shock Test is shown in Figure 5. The exposure device shall have been subjected to the Projection Under Stress Test of paragraph 7-1-1 prior to the Horizontal Shock Test.

7-2-3-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-3-4 Approach

The Horizontal Shock Test consists of pendulum swings of the device into a rigidly mounted cylindrical steel bar. The exposure device will be suspended such that it just touches the target when at rest. The release position will be a point where the center of gravity of the device is 100 mm above its rest position. The steel bar will have a diameter of 50 mm and a length of 300 mm. It will be mounted to a rigid object with a mass of at least 225 kg. 20 impacts will be performed on each of the following areas:

- side of the exposure device
- side of the lock
- face of the lock
- bottom of the exposure device
- side of projection sheath connector
- face of projection sheath connector

7-2-3-5 Procedure

1) Connect the device under test to the suspension chain. Adjust the height and orientation so that the device will strike the pin in the desired location.
2) Measure the height to the bottom of the exposure device.
3) Swing the exposure device back until the height to the bottom of the device has increased by 100 mm.
4) Release the exposure device and allow it to swing into the target.

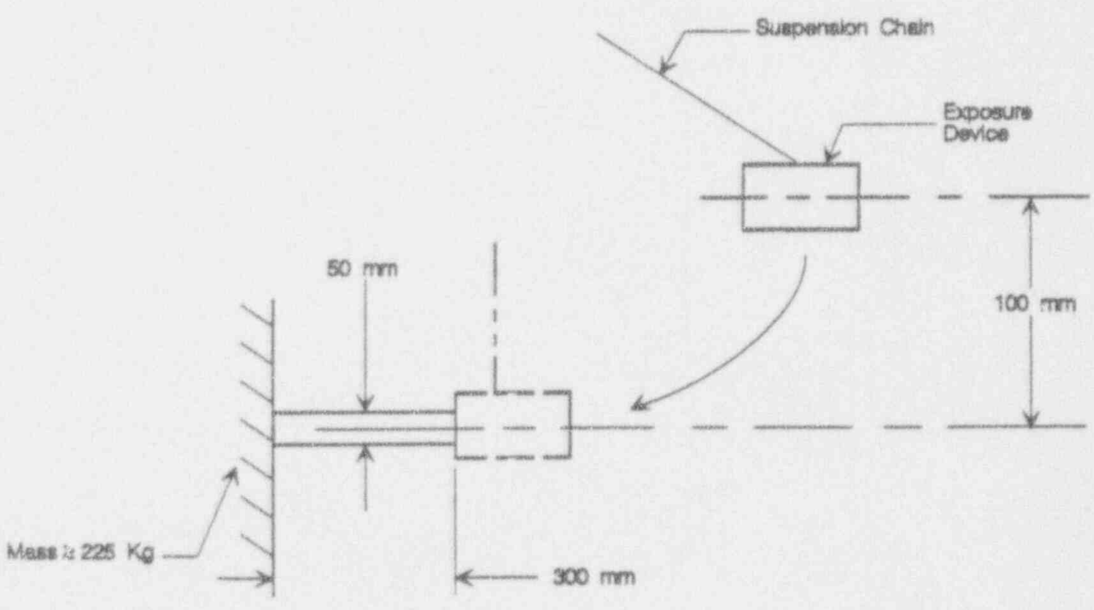

Figure 5
Horizontal Shock Test

5) Record any observations on the Horizontal Shock Test Data Sheet in Appendix A. Video tapes and photographs are required.

6) Repeat steps 3 to 6 until the device has been subjected to 20 impacts in the same area.

7) Repeat step 1 to 6 until each of the areas listed in paragraph 7.2.3.4 has been tested.

8) Connect the remote control and the projection sheath to the exposure device and perform 10 exposure cycles. This step may be performed at the completion of the Penetration Test of paragraph 7.2.10 at the discretion of the test engineer.

7-2-3-6 Data and Results

The date of the testing and the observations after each impact shall be recorded on the Horizontal Shock Test Data Sheet. Video tapes and photographs of each impact area shall be taken as a minimum. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles or failure of the Radiation Shielding Test.

7-2-4 Vertical Shock Test

7-2-4-1 Purpose

The purpose of the Vertical Shock Test is to test the resistance of the device to the shocks that may be encountered during normal service.

7-2-4-2 Equipment

The test equipment is shown in Figure 6. The exposure device shall have been subjected to the Horizontal Shock Test of paragraph 7.2.3.

7-2-4-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-4-4 Approach

The vertical shock consists of a drop from a height of 150 mm in the normal carrying position. The impact surface will consist of a rigid body with a mass greater than 225 kg covered by 25 mm of plywood. 100 shocks will be performed.

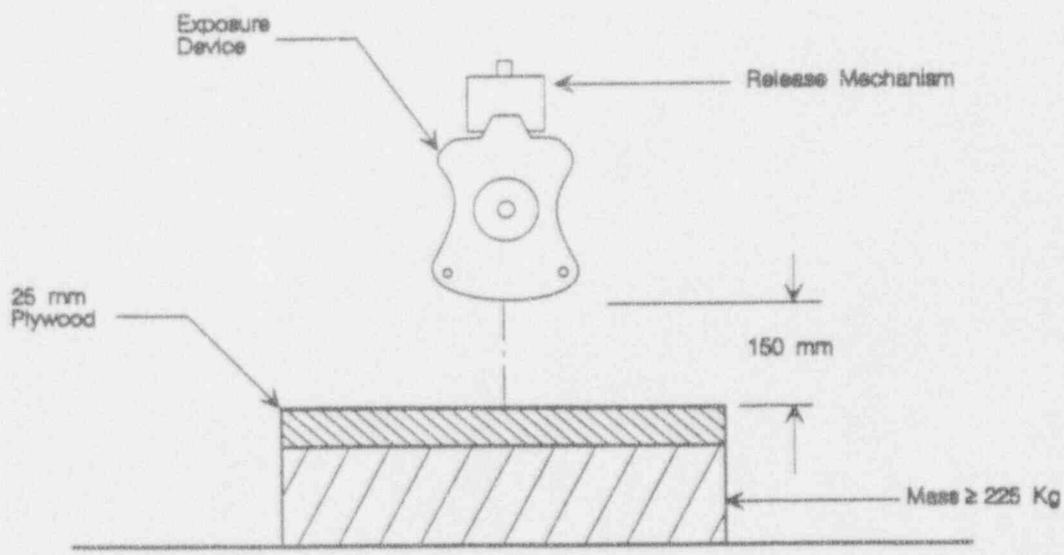

Figure 6
Vertical Shock Test

7-2-4-5 Procedure

1) Attach the exposure device to the release mechanism and verify that the height to the bottom of the exposure device is 150 mm.

2) Release the exposure device and allow it to fall onto the target.

3) Record any observations. Video tapes and photographs are required.

4) Repeat steps 1 to 3 until 100 shocks have been performed.

5) Connect the remote control and the projection sheath to the exposure device and perform 10 exposure cycles. This step may be performed at the completion of the Penetration Test of paragraph 7.2.10 at the discretion of the test engineer.

7-2-4-6 Data and Results

The date of the testing and the observations after each impact shall be recorded. Video tapes and photographs shall be taken. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles or failure of the Radiation Shielding Test.

7-2-5 Handle Wrench Test

7-2-5-1 Purpose

The purpose of this test is to demonstrate that the carrying handle is able to withstand the wrenching force applied to it when the device is dropped while tethered to a security chain. This test is not a requirement of ANSI N432(1980). It is a requirement of ANSI N43.9(1991) and has been adopted because it is considered to be an important verification of the design.

7-2-5-2 Equipment

The test equipment is shown in Figure 7. The exposure device shall have been subjected to the Vertical Shock Test of paragraph 7-2-4.

7-2-5-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-5-4 Approach

The device will be dropped 1 m while attached to a chain. The upper end of the chain will be attached to a rigid mounting point.

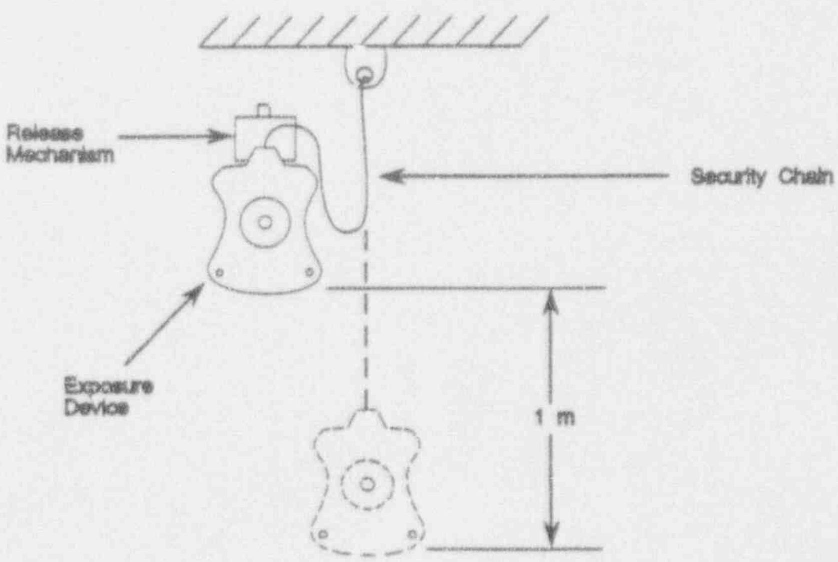

Figure 7
Handle Wrench Test

7-2-5-5 Procedure

1) Fasten the safety chain to the handle of the exposure device.
2) Suspend the exposure device so that it will drop 1 m when released. Make certain that the exposure device will not reach the ground or strike any obstructions when it is released.
3) Release the exposure device and allow it to drop freely.
4) Record any observations. Photographs and video tapes are required to support the observations.
5) Connect the remote control and projection sheath to the exposure device and perform 10 exposure cycles. This step may be performed at the completion of the Penetration Test of paragraph 7.2.10 at the discretion of the test engineer.

7-2-5-6 Data and Results

Observations shall be recorded. Photographs and video tapes will be taken. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles, loss of use of the handle or failure of the Radiation Shielding Test.

7-2-6 Water Spray Test

7-2-6-1 Purpose

The purpose of the Water Spray Test is to subject the device under test to a simulated rainfall of 50 mm per hour for at least one hour. This test would reveal any problems with packagings vulnerable to water saturation.

7-2-6-2 Discussion

The Water Spray Test is particularly intended for packagings where distance shielding may rely on non-metallic materials which are softened by water or materials bonded by water soluble glue. Since the structure of the exposure device is made entirely of metal, it is not vulnerable to such conditions. There is therefore no need to perform this test.

7-2-7 Immersion Test

7-2-7-1 Purpose

The purpose of this test is to verify that the exposure device will not suffer any damage when subjected to immersion in 15 m of water.

7-2-7-2 Discussion

The primary purpose of the Immersion Test is to demonstrate that a package can maintain its structural integrity when subjected to an external pressure. The Titan does not incorporate seals to prevent the influx of water, nor are any of its components sensitive to water. The source assembly has been demonstrated to meet Special Form requirements (Appendix B). Therefore, the Titan would not suffer any damage if immersed in water and there is no need to perform the Immersion Test.

7-2-8 Free Drop Test

7-2-8-1 Purpose

The free drop test is intended to simulate the type of shock that a package would experience if it were to fall off the platform of a vehicle or if it were dropped during handling.

7-2-8-2 Discussion

Since the Titan GRED will be subjected to a 9 m drop test, the requirements for the free drop test are exceeded and there is therefore no need to perform this test.

7-2-9 Stacking Test

7-2-9-1 Purpose

The stacking test is designed to simulate the loads pressing on a package over a prolonged period of time and is intended to ensure that the effectiveness of the shielding and containment systems will not be impaired

7-2-9-2 Discussion

Because of the shape of the Titan GRED, stacking of the device is improbable and nearly impossible. There is therefore no need to perform this test.

7-2-10 Penetration Test

7-2-10-1 Purpose

The purpose of this test is to demonstrate that the exposure device can withstand the impact that the device may receive during normal conditions of transport. The test simulates the exposure device being struck by a slender object such as a length of metal tubing or the handlebar of a falling bicycle. The test is a transport requirement (reference 6).

7-2-10-2 Equipment

The equipment required consists of a 32 mm bar and a guide tube to direct its fall. The bar shall have a hemispherical end and a mass of 6 kg. The exposure device shall have been subjected to the Handle Wrench Test of paragraph 7-2-5.

7-2-10-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-2-10-4 Approach

The bar will be dropped vertically so as to strike the exposure device at the following sensitive areas:

- bottom of exposure device
- side of exposure device
- front of lock
- side of lock

The height of the drop shall be 1 m measured from the lower end of the bar to the intended point of impact.

7-2-10-5 Procedure

1) Position the exposure device so that the target impact area is facing up.

2) Using the guide tube, adjust the relative position of the bar and the exposure device so that the bar will fall vertically and strike the target impact area when released.

3) Adjust the height between the bottom of the bar and the target impact area to 1m.

4) Release the bar.

5) Record any observations on the Penetration Test Data Sheet in Appendix A. Video tapes, sketches and photographs are required to support the observations.

6) Repeat steps 1 to 5 for all of the areas of the device listed in paragraph 7.2.10.4.

7) Connect the remote control and projection sheath to the exposure device and perform 10 exposure cycles.

7-2-10-6 Data and Results

Observations shall be recorded on the Penetration Test Data Sheet. Sketches, photographs and video tapes shall be taken. Failure criteria shall be failure of the device to complete 10 satisfactory exposure cycles or failure of the Radiation Shielding Test.

7-2-11 Puncture Resistance Test

7-2-11-1 Purpose

The purpose of the Puncture Resistance Test is to simulate accident conditions and to demonstrate that the source is not accidentally exposed as a result.

7-2-11-2 Equipment

The equipment used for this test includes a 9 m drop tower, an unyielding surface and a mild steel pin with a diameter of 150 mm and a length of 200 mm. The exposure device shall have been subjected to the endurance test of paragraph 7-1-2.

7-2-11-3 Location

The Accidental Drop Test will be performed at AECL Research, Chalk River Laboratories, Chalk River, Ontario.

7-2-11-4 Approach

The test will consist of a 1 m drop onto the end of a cylindrical target such as to cause the maximum damage to the device under test. The target will be rigidly mounted perpendicularly to an unyielding surface. The surface consists of a 100 mm thick steel slab on a cube block of

concrete measuring 3 m on each side. The concrete sits on bedrock.

7-2-11-5 Procedure

1) Suspend the exposure device in the upright orientation so that when released the lock will strike the pin. Hoist it so that the height measured between the upper surface of the pin and the bottom of the lock is 1 m.

2) Start the high-speed camera and release the exposure device.

3) Record the results, including observations, sketches and photographs of the damaged areas.

7-2-11-6 Data and Results

The Puncture Resistance Test shall be documented with high-speed video, photographs and sketches. The exposure device need not be operational after the test, however the radiation fields are not permitted to exceed 10 mSv/h (1 rem/h) at 1 m.

-12 Accidental Drop Test

7-2-12-1 Purpose

The purpose of the Accidental Drop Test is to simulate an accidental impact and to demonstrate that the source will not be accidentally exposed as a result of such an impact.

7-2-12-2 Equipment

The equipment used for this test includes a 9 m drop tower and an unyielding surface. The exposure device shall have been subjected to a Puncture Resistance Test of paragraph 7-2-11.

7-2-12-3 Location

The Accidental Drop Test will be performed at AECL Research, Chalk River Laboratories, Chalk River, Ontario.

7-2-12-4 Approach

A total of three 9 meter drop tests will be completed using two prototype units. One prototype will be subjected to a 9 m upright drop followed by a 9 m oblique drop in the orientation shown in Figure 8. The second prototype will be subjected to a 9 m drop directly onto the lock. See reference 5 for further discussion on the drop orientations.

7-2-12-5 Procedure

1) Suspend the exposure device in the upright orientation and hoist it so that the height measured between the upper surface of the target and the lowest point on the exposure device is 9 m.

2) Start the high-speed camera and release the exposure device.

3) Record the results, including observations, sketches and photographs of the damaged areas.

4) Repeat steps 1 to 3 with the exposure device oriented for a corner drop as shown in Figure 8. Ensure that the centre of gravity of the exposure device is aligned vertically over the lower corner.

5) Repeat steps 1 to 3 with the exposure device oriented so that the primary impact will be on the lock.

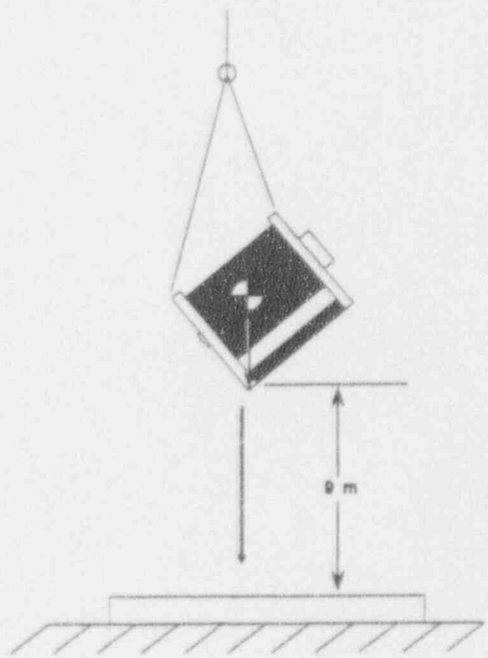

Figure 8
9 m Corner Drop Test

7-2-12-6 Data and Results

The Accidental Drop Test shall be documented with high-speed video, photographs and sketches. The exposure device need not be operational after the test, however the radiation fields are not permitted to exceed 10 mSv/h (1 rem/h) at 1 m.

7-2-13 Fire Test

7-2-13-1 Purpose

The purpose of the Fire Test is to measure the resistance of the test specimen to an accidental fire condition.

7-2-13-2 Discusion

The fire test is intended to demonstrate that the radioactive material's shielding and containment are not vulnerable to an accidental fire with a temperature of 800 °C and duration of 30 minutes.

The C990 source assembly has been demonstrated to meet special form requirements and can therefore withstand such a fire. The shielding material is depleted uranium which has a melting point of 1200 °C and will therefore survive a fire. The outer structure of the TITAN is made of titanium which has a melting point of 1670 °C and can also withstand a fire.

The only material susceptible to a fire is the epoxy foam which fills the void between the outer structure and the depleted uranium shield. The shield is structurally supported by means other than the epoxy foam and shielding provided by foam is insignificant. There is therefore no need to perform the fire test.

7-3 Tests On The Remote Control Device

7-3-1 Kinking Test

7-3-1-1 Purpose

The purpose of this test is to verify that the remote control cable and sheath can withstand the stress due to kinking that may occur during normal use.

7-3-1-2 Equipment

The remote control device will have been subjected to the Projection Under Stress Test of paragraph 7-1-1.

The test apparatus used is shown in Figure 9. The remote control sheath will be pulled manually, and the speed will be measured using an Ametek digital tachometer with a linear measurement adaptor.

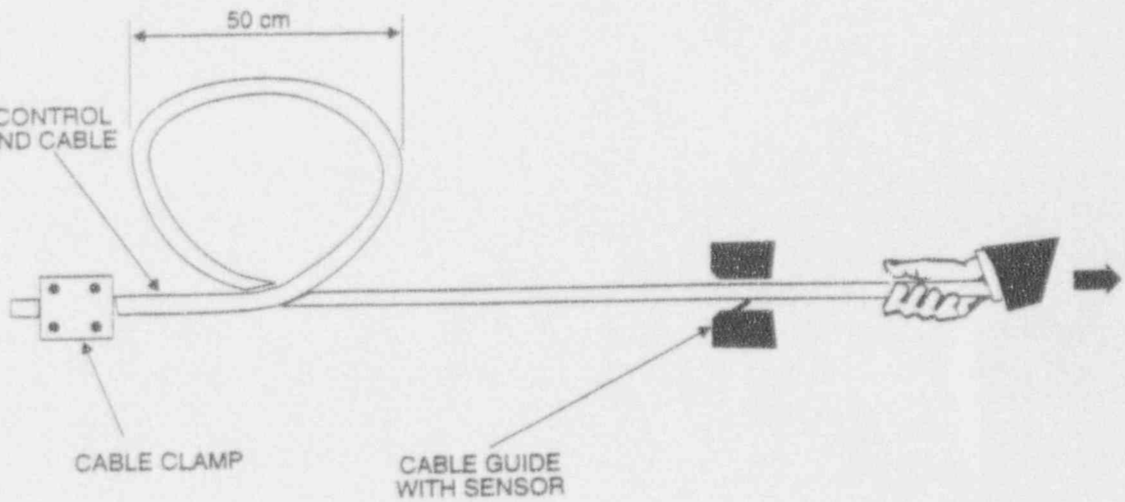

Figure 9
Remote Control Kinking Test Setup

7-3-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-3-1-4 Approach

The cable will be laid out on a flat surface with a 500 mm diameter loop and one end secured. The free end of the cable will be pulled at a rate of 2.0 m/s ± 10% until the loop has disappeared. The test will be repeated 10 times with loop in different locations.

7-3-1-5 Procedure

1) Arrange the control cable and sheath on the test apparatus with a loop 500 mm in diameter as shown in Figure 9.

2) Secure one end of the sheath using the clamp provided.

3) Pull the free end of the sheath at a speed of 2 m/s until the loop has disappeared.

4) Verify that the speed was between 1.8 m/s and 2.2 m/s. Record any observations on the Remote Control Kinking Test Data Sheet in Appendix A. Mark the sheath to indicate the location where the test was performed.

5) Repeat steps 1 to 4 with the loop at different locations on the sheath until 10 satisfactory tests have been performed.

7-3-1-6 Data and Results

All observations shall be recorded on the data sheet provided. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-3-2 Crushing Test

7-3-2-1 Purpose

The purpose of this test is to demonstrate that the remote control cable can withstand the stress of the heel of a 100 kg person impacting at a horizontal and vertical speed of 0.8 m/s.

7-3-2-2 Equipment

The test apparatus is shown in Figure 10. The remote control device shall have been subjected to the Kinking Test of paragraph 7-3-1.

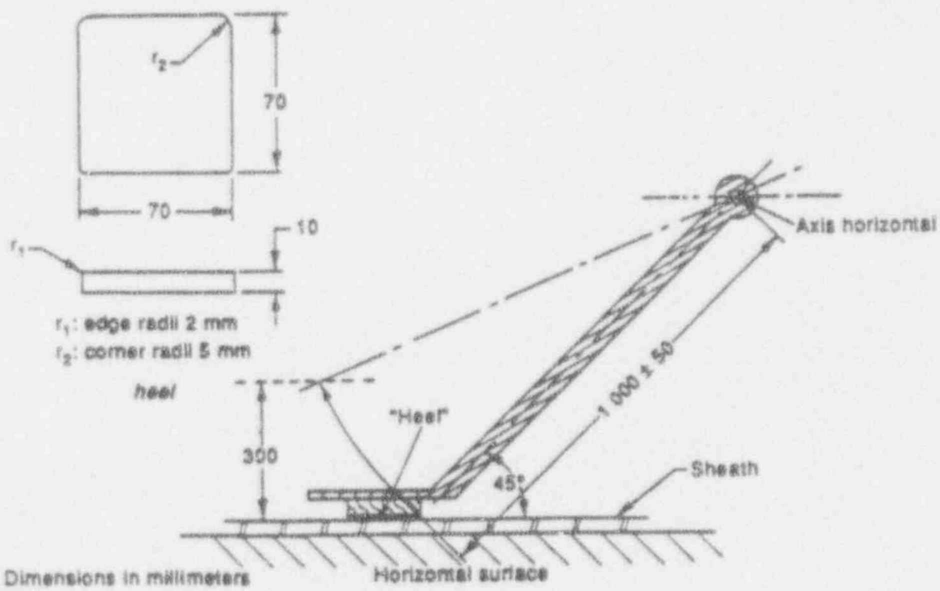

Figure 10
Crushing Test Setup

7-3-2-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-3-2-4 Approach

The apparatus to be used for the test is shown in Figure 10. The mass of the heel and crank shall be 15 kg. The test surface shall have a mass greater than 225 kg. The heel will be dropped from a height of 300 mm. The test will be repeated 10 times at different locations along the cable.

7-3-2-5 Procedure

1) Arrange the equipment as shown in Figure 10. The sheath shall contain the control cable. Fix the sheath using guides.

2) Raise the arm and verify that the height between the sheath and the heel in 300 mm.

3) Release the arm and allow the heel to swing freely down onto the sheath.

4) Record any observations on the Crushing Test Data Sheet in Appendix A. Mark the sheath to indicate the location where the test was performed.

5) Repeat steps 1 to 4 at 10 different points along the sheath. For five of the tests the projection side and reserve side of the sheath shall be superposed vertically. For the other five tests they shall be side by side. Note whether the control cable is in the projection sheath or reserve sheath or both

7-3-2-6 Data and Results

The observations will be recorded on the data sheet provided. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-3-3 Tensile Test

7-3-3-1 Purpose

The purpose is to demonstrate that the control cable and sheath can withstand the tensile forces that may be encountered during use.

7-3-3-2 Equipment

The remote control device shall have been subjected to the Crushing Test of paragraph 7-3-2. The test apparatus is shown in Figures 11 and 12.

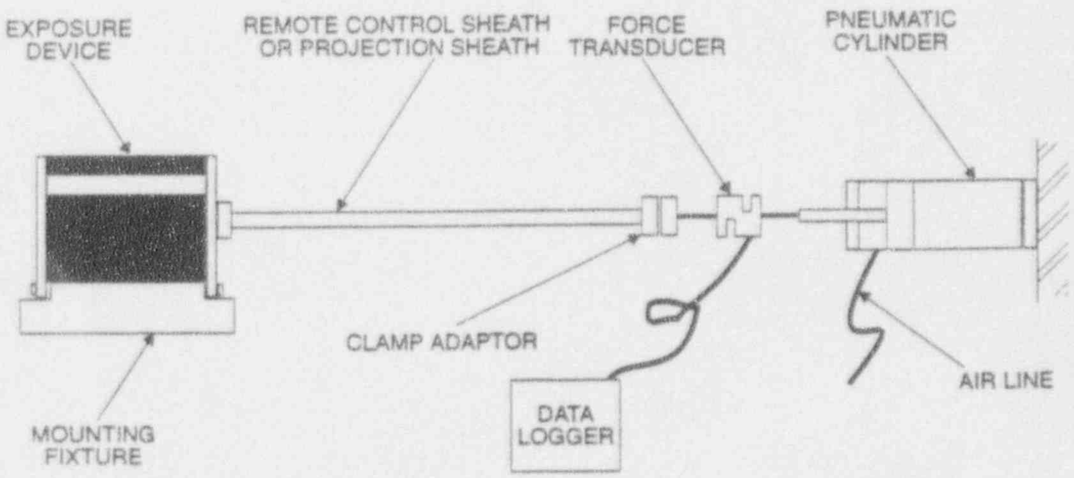

Figure 11

Remote Control Sheath & Projection Sheath Tensile Tests

7-3-3-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-3-3-4 Approach

This test consists of two parts; first the remote control sheath will be tested and then the control cable and crank mechanism will be tested.

In the first part of the test, the remote control sheath will be tested. A tensile force of 500 N (112 lb) will be applied for 30 seconds. The test will be repeated 10 times.

In the second part of the test, the crank mechanism will be secured and the crank arm will be immobilized. A source assembly will be connected to the control cable and a force of 1000 N (225 lb) will be applied to the free end of the source for 10 seconds. The test will be repeated 10 times.

7-3-3-5 Procedure

1) Secure the exposure device as shown in Figure 11.

2) Connect the remote control sheath to the exposure device.

3) Connect the tensioning apparatus to the crank mechanism using the clamp adaptor.

4) Apply a load of 500 N (112 lb) for 30 s.

5) Record any observations and include the plot of the force profile from the data logger with the results.

6) Repeat steps 4 and 5 until 10 tests have been performed.

7) Secure the remote control as shown in Figure 11. Immobilize the crank handle.

8) Connect a source assembly to the control cable.

9) Apply a force of 1000 N (225 lb) for 10 s to the lock ball on the source assembly.

10) Record any observations and include a plot of the force profile from the data logger with the results.

11) Repeat steps 9 and 10 until 10 tests have been performed.

7-3-3-6 Data and Results

The observations will be recorded and plots of the measured force profile will be provided. Each test will be video taped and the test setup will be photographed. The failure criteria will be failure of the final Projection Under Stress Test or failure of the source assembly (see paragraph 7.5.1.6).

7-4 Tests On The Projection Sheath

7-4-1 Kinking Test

7-4-1-1 Purpose

The purpose of this test is to verify that the projection sheath can withstand the stresses due to kinking that may occur during normal use.

7-4-1-2 Equipment

The projection sheath shall have been subjected to the initial projection Under Stress Test of paragraph 7-1-1. The test apparatus is shown in Figure 12.

7-4-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-4-1-4 Approach

One end of the projection sheath will be secured. A flat closed loop will be formed, with the fixed end under the loop. A hoop will secure the ends where they cross so that the loop cannot come undone, yet will still allow the sheath to slide. A force will be applied to the free end of the projection sheath at a tangent to the loop. The force will be applied such that it reaches 200 N (45 lb) in 5 seconds. The force will then be held for 10 seconds. The test will be repeated 10 times at the same place in the projection sheath.

7-4-1-5 Procedure

1) Arrange the projection sheath on the test apparatus with a loop 500 mm in diameter as shown in Figure 12. The fixed end of the sheath must be on the under side of the loop.

2) Close the clamping hoop over both ends of the sheath where they cross in the loop so that the sheath can still slide, yet the loop cannot become undone.

3) Secure the exposure device using the mounting fixture and attach the projection sheath to the exposure device. Attach the other end of the projection sheath to the tensile test apparatus.

4) Apply a force to the sheath so that the force reaches 200 N (45 lb) in 5 s. Maintain the force for 10 s.

5) Record any observations including the final diameter of the loop in the Projection Sheath Kinking Test Data Sheet in Appendix A. Attach the force measurement plot to the data sheet. Mark the sheath to indicate the location where the test was performed.

6) Repeat steps 1 to 5 with the loop always at the same location on the sheath until 10 tests have been performed.

7-4-1-6 Data and Results

All observations shall be recorded on the data sheet provided. The force measurement will be recorded automatically and a printout for each trial will be included with the results. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-4-2 Crushing Test

7-4-2-1 Purpose

The purpose of this test is to demonstrate that the projection sheath can withstand the stress of the heel of a 100 kg person impacting at a horizontal and vertical speed of 0.8 m/s.

7-4-2-2 Equipment

The projection sheath shall have been subjected to the Kinking Test of paragraph 7-4-1. The test apparatus is shown in Figure 10.

7-4-2-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

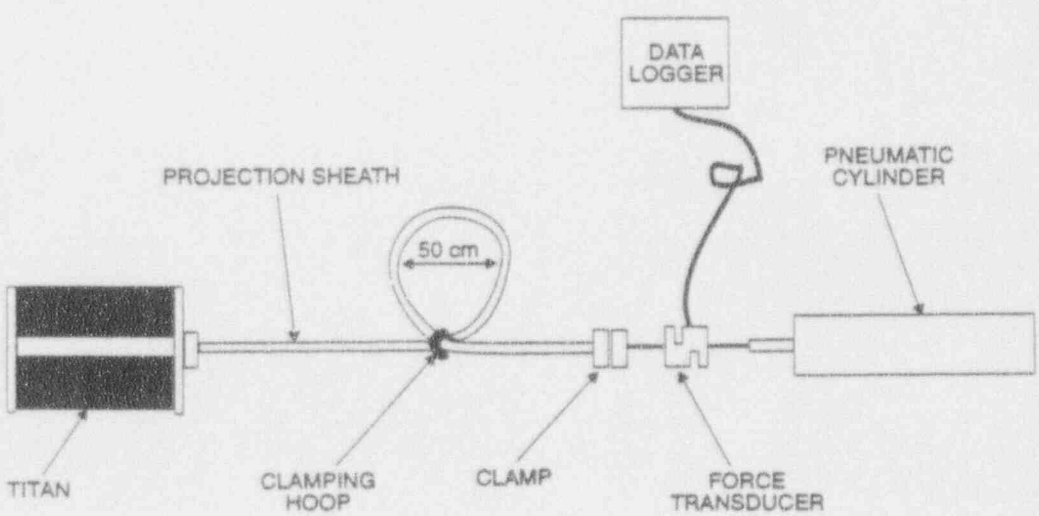

Figure 12
Projection Sheath Kinking Test

7-4-2-4 Approach

The apparatus to be used for the test is shown in Figure 10. The mass of the heel and crank shall be 15 kg. The heel will be dropped from a height of 300 mm. The test will be repeated 10 times at different locations along the sheath.

7-4-2-5 Procedure

1) Arrange the equipment as shown in Figure 10.
2) Raise the arm and verify that the height between the sheath and the heel is 300 mm.
3) Release the arm and allow the heel to swing freely down onto the sheath.
4) Record any observations on the Crushing Test Data Sheet in Appendix A. Mark the sheath to indicate where the test was performed.
5) Repeat steps 1 to 4 at 10 different points along the sheath, one of which shall include a connection.

7-4-2-6 Data and Results

The observations will be recorded on the data sheet provided. Each trial will be video taped and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-4-3 Tensile Test

7-4-3-1 Purpose

The purpose of this test is to demonstrate that the projection sheath can withstand the tensile forces that may be encountered during use.

7-4-3-2 Equipment

The projection sheath shall have been subjected to the Crushing Test of paragraph 7-4-2. The test apparatus is shown in Figure 11.

7-4-3-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-4-3-4 Approach

The projection sheath will be connected to the exposure device and the exposure device will be fixed so that it cannot move during the test. A tensile force of 500 N (112 lb) will be applied to the sheath for 30 seconds. The test will be repeated 10 times.

7-4-3-5 Procedure

1) Secure the exposure device as shown in Figure 11.
2) Connect the projection sheath to the exposure device.
3) Connect the tensioning apparatus to the opposite end of the projection sheath using the clamp adaptor.
4) Apply a load of 500 N (112 lb) for 30 s.
5) Record any observations. Plot the force profile from the data logger and include it with the results.
6) Repeat steps 4 and 5 until 10 tests have been performed.

7-4-3-6 Data and Results

The observations will be recorded and each test will be video taped. The measured force profile will be plotted and the test setup will be photographed. The failure criterium will be failure of the final Projection Under Stress Test.

7-5 Tests On The Source Assembly

7-5-1 Tensile Test

7-5-1-1 Purpose

The purpose of this test is to demonstrate that the source assembly can withstand the tensile forces that may be encountered during use.

7-5-1-2 Equipment

The source assembly shall have been subjected to the Projection Under Stress Test of paragraph 7-1-1.

7-5-1-3 Location

The testing will be performed at Nordion International, Kanata, Ontario.

7-5-1-4 Approach

A control cable will be attached to the source assembly and the opposite end of the source assembly will be fixed. A tensile force will be gradually applied to the control cable so as to attain a load of 1000 N (225 lb) after 10 seconds. The force will be maintained for 30 seconds. The test will be repeated 10 times.

The largest diameter of the locking ball will be fixed and the testing will be repeated.

7-5-1-5 Procedure

1) Measure the length of the source assembly. This must be done using a calibrated instrument. Record the measurement and the calibration date of the measuring device. Take a magnified photo of the source assembly and connector.

2) Attach a control cable connector to the source assembly.

3) Secure the opposite end of the source assembly (i.e., the capsule) using the source clamp provided.

4) Apply a tensile force gradually to the cable connector so as to reach 1000 N (225 lb) after 10 s.

5) Maintain this force for 30 s.

6) Record any observations on the Source Assembly Tensile Test Data Sheet in Appendix A. Plot the force profile from the data logger and attach the plot to the data sheet. After the testing, take a magnified photo of the source assembly connector.

7) Repeat steps 4 to 6 until 10 tests have been performed.

8) Repeat steps 3 to 7 with the locking ball secured.

7-5-1-6 Data and Results

The observations will be recorded on the data sheet provided. Each test will be video taped and the test setup will be photographed. The source assembly shall not show an elongation of more than 1% of its length.

8 REFERENCES

1) ANSI N432 "Radiological Safety for the Design and Construction of Apparatus for Gamma Radiography", August 1980

2) ANSI N43.9 "Gamma Radiography -- Specifications for Design and Testing of Apparatus", October 1991.

3) Title 10, Code of Federal Regulations, Nuclear Regulatory Commission, Part 34 - Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations.

4) Title 10, Code of Federal Regulations, Nuclear Regulatory Commission, Part 71 - Packaging and Transportation of Radioactive Material.

5) TR-9240-N990, Safety Analysis Report for the Titan Radiography Device, Nordion International Inc.

6) Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990), IAEA Safety Series No. 6, IAEA, Vienna, 1990.

7) Transport Packaging of Radioactive Materials Regulations, Atomic Energy Control Act, SOR/91-304, 9 May 1991.

8) IS/QP 0052 N990, Quality Plan for the Nordion Titan Gamma Radiography Exposure Device.

APPENDIX A

Test Data Sheets

Projection Under Stress Test Data Sheet

Date ______________________________ Torque Meter Model ______________________________

Calibration Date ______________________________ Torque Meter Serial Number ______________________________

Trial Number	Maximum Torque Reading (N·m)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Has the equipment under test been subjected to the tests for conditions of normal use? Y ☐ N ☐

Test By ______________________________ Witness ______________________________

Project Engineer ______________________________

C990 Source Assembly Tensile Test Data Sheet

Source Assembly Serial No. ____________________

A. Initial Measurement

Micrometer Model No. ____________________

Serial No. ____________________

Calibration Due Date ____________________

Initial Length ____________________

Test Engineer or Technician ____________________ Date ____________________

B. Additional Testing

Was any additional testing performed on source assembly (e.g., endurance testing)? Y ☐ N ☐

If yes, indicate details of test (e.g., endurance test, date, first cycle no., last cycle no.)

____

____

____

C. Tensile Test

Force Transducer Model No. ____________________

Serial No. ____________________

Calibration Due Date ____________________

Test Force ____________________ N

Test Duration ____________________ s
(Attach a plot of the force measurement)

Test Engineer or Technician ____________________ Date ____________________

D. Final Length Measurement

Micrometer Model No. ____________________

Serial No. ____________________

Calibration Due Date ____________________

Final Length ____________________

Test Engineer or Technician ____________________ Date ____________________

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials

Radiation Shielding Test Data Sheet

Serial Number ______________________ Date ______________________

The device has been subjected to the following tests: ______________________

____

____

____

C990 Serial No. ______________________

Activity of test source at 1 m = 0 ______________ R/h

divided by 0.55 R/h-Ci = ______________ (curie content)

divided by 120Ci = ______________ (extrapolation constant)

Maximum measured dose rates:

at 5 cm = ______________ (a)

at 1 m = ______________ (b)

Calculated dose rates

(a) divided by extrapolation constant = ______________ at 5 cm

(b) divided by extrapolation constant = ______________ at 1 m

Victoreen Model 471 Survey Meter

Serial Number ______________________ Calibration Due Date ______________________

Surveyor ______________________ QA Witness ______________________

Test Engineer ______________________ Project Engineer ______________________

Horizontal Shock Test Data Sheet

Titan Serial Number ______________________ Date ______________________

Orientation

Trial Number	Observations
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

Test Engineer ______________________ QA Witness ______________________

Project Engineer ______________________

Penetration Test Data Sheet

Impact Area	Observations
bottom of the exposure device	
side of the exposure device	
front of lock	
side of lock	

Date ______________________ Test Engineer ______________________

QA Witness ______________________ Project Engineer ______________________

Nordion Titan Radiation Survey Data Sheet

Titan Serial Number ______________________ Victoreen 471 Serial Number ______________________

Date ______________________ Calibration Due Date ______________________

Radiation Survey Readings in mrem/h											
Position Readings at 5 cm from surface	1	2	3	4	5	6	7	8	9	10	11
	12	13	14	15	16	17	18	19	20	21	22
	23	24	25	26	27	28	29	30	31	32	33
	34	35	36	37	38	39	40	41	42	43	44
	45	46	47	48	49	50	51	52	53	54	55
	56	57	58	59	60	61	62	63	64	65	66
	67	68									
Readings at 1 m	Top		Bottom		Right		Left		Front		Back

Note:

The meter on the surface is actually measuring the value approximately 5 cm from the surface
(1 mrem/h = 10 usv/h)

Source Activity ______________________

Surveyor ______________________ Test Engineer ______________________

QA Witness ______________________ Project Engineer ______________________

Crushing Test Data Sheet

Device under test ______________________

Trial Number	Location of Impact	Observations
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Date ______________________ Test Engineer ______________________

QA Witness ______________________ Project Engineer ______________________

Remote Control Kinking Test Data Sheet

Date ______________________________

Trial Number	Minimum Speed (ft/s)	Average Speed (ft/s)	Maximum Speed (ft/s)	Observations
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Test Engineer ______________________________ Witness ______________________________

Project Engineer ______________________________

Projection Sheath Kinking Test Data Sheet

Trial Number	Observations (attach the force measurement plot)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Force Transducer Model No. ______________________ Serial No. ______________________

Calibration Due Date ______________________

Date ______________________ Test Engineer ______________________

QA Witness ______________________ Project Engineer ______________________

APPENDIX B

Special Form Radioactive Material Test Summary

Certificate, Sealed Source Classification
Designation and Performance (ANSI N542-1977)

SPECIAL FORM RADIOACTIVE MATERIAL TEST SUMMARY

The capsule model specified herein has been evaluated in accord with the International Atomic Energy Agency (I.A.E.A.) Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1985 Edition, Section VI, paragraphs 604-613 and 618.

TEST SUMMARY NO: 25

DATE: 1992 July 20

CAPSULE MODEL: C-990

CONTENTS: Iridium-192

DRWG NO: K122213-600

CAPSULE MATERIAL: 316L Stainless Steel

OVERALL DIAMETER: 0.187 inches

ENCAPSULATION: Single

OVERALL LENGTH: 0.775 inches

SPECIAL FORM REQUIREMENTS (1)

TEST	PASS	FAIL	METHOD	REMARKS
IMPACT (607)(618)	X		Comparison	Comments below
PERCUSSION (606)	X		Comparison	Comments below
BENDING (609)			Not required	
HEAT (610)	X		Comparison	Comments below
LEACHING (612)(613)	X		Comparison	Comments below

(1) See special form requirements on reverse side

COMMENTS:
The C-343 has been tested and has passed all Special Form tests, and has been certified to meet the requirements for Special Form via Certificate CDN/0001/S. Since the containment system for the C-990 is identical to the C-343, the C-990 also meets the requirements for Special Form.

This summary verifies that the described capsule model meets the requirements of Special Form in accord with the I.A.E.A. Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1985 Edition, Section VI, paragraphs 604-613 and 618.

Tested by	M. Krzaniak, P.Eng. [signature]	Authorized	G.A. Burbidge [signature]
Title	Development Officer	Title	Manager, Package Engineering
Date	92/07/21	Date	92/07/30

NORDION INTERNATIONAL INC.

CERTIFICATE

SEALED SOURCE
CLASSIFICATION DESIGNATION AND PERFORMANCE

Sealed sources are classified in accord with standards established by
THE AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) and
THE INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

CERTIFICATE NO: 76 **DATE:** 92 August 20

CAPSULE MODEL: C-990 **CONTENTS:** Iridium-192

DRWG. NO: K122213-600

CAPSULE MATERIAL: 316L Stainless Steel **OVERALL DIAMETER:** 0.187 inches

ENCAPSULATION: Single **OVERALL LENGTH:** 0.775 inches

ANSI CLASSIFICATION AND PERFORMANCE STANDARD (1) **ANSI 77** C43515

CLASSIFIED PERFORMANCE STANDARD (2)

TEST	CLASS	METHOD	REMARKS
TEMPERATURE	4	Comparison	Pass (See Comments)
EXTERNAL PRESSURE	3	Comparison	Pass (See Comments)
IMPACT	5	Comparison	Pass (See Comments)
VIBRATION	1	No Test Reqd.	
PUNCTURE	5	Comparison	Pass (See Comments)

(1) See definition on reverse side
(2) See Table 1. Performance Standards on reverse side
(3) American National Standard N542-1977 is a revision of ANSI N5.10-1968

COMMENTS: The C-343 sealed source has been tested and found to meet the performance requirements of ANSI N542-1977 classification C43515. Since the containment system for the C-990 as identical to the C-343, the C-990 meets the same performance requirements.

It is hereby certified that the described sealed source meets the specified standard as prescribed in (3) American National Standard N542-1977 "Sealed Radioactive Sources, Classification". This standard complies with the classification and performance requirements of ISO 2919-1980(E).

Tested by M. Krzaniak, P.Eng. Authorized G.A. Burbidge

Title Development Officer Title Manager Package Engineering

Date M. Krzaniak 92/08/25 Date GAB 92/08/25

NORDION INTERNATIONAL INC.

REFERENCES

(1) DEFINITION - CLASSIFICATION DESIGNATION:

The classification of a sealed source shall be designated by the code ANSI followed by two digits to indicate the year of approval of the American National Standard used to determine the classification followed by a letter and five digits.

The letter shall be either a C or an E. The letter C designates that the contained activity does not exceed the maximum levels established by ANSI. The letter E designates that the contained activity exceeds the maximum levels established by ANSI.

The first digit shall be the class number which describes the performance standards for temperature.

The second digit shall be the class number which describes the performance standards for external pressure.

The third digit shall be the class number which describes the performance standards for impact.

The fourth digit shall be the class number which describes the performance standards for vibration.

The fifth digit shall be the class number which describes the performance standards for puncture.

(2) TABLE 1 - PERFORMANCE STANDARDS:

TEST	CLASS						
	1	2	3	4	5	6	X
Temperature	No Test	-40°C (20 min) +80°C (1h)	-40°C (20 min) +180°C (1h)	-40°C (20 min) +400°C (1h) and thermal shock 400°C to 20°C	-40°C (20 min) +600°C (1h) and thermal shock 600°C to 20°C	-40°C (20 min) +800°C (1h) and thermal shock 800°C to 20°C	Special Test
External Pressure	No Test	25 kN/m^2 abs. (3.6 lbf/in^2) to atmosphere	25 kN/m^2 abs. to 2 MN/m^2 (290 lbf/in^2) abs.	25 kN/m^2 abs. to 7 MN/m^2 (1015 lbf/in^2) abs.	25 kN/m^2 abs. to 70 MN/m^2 (10 153 lbf/in^2) abs.	25 kN/m^2 abs. to 170 MN/m^2 (24 656 lbf/in^2) abs.	Special Test
Impact	No Test	50 g (1.8 oz) from 1 m (3.28 ft) and free drop ten times to a steel surface from 1.5 m (4.92 ft)	200 g (7 oz) from 1 m	2 kg (4.4 lb) from 1 m	5 kg (11 lb) from 1 m	20 kg (44 lb) from 1 m	Special Test
Vibration	No Test	30 min 25 to 500 Hz at 5 g peak amp.	30 min 25 to 50 Hz at 5 g peak amp. and 50 to 90 Hz at 0.635 mm amp. peak to peak and 90 to 500 Hz at 10 g	90 min 25 to 80 Hz at 1.5 mm amp. peak to peak and 80 to 2000 Hz at 20g	Not Used	Not Used	Special Test
Puncture	No Test	1 g (15.4 gr) from 1 m (3.28 ft)	10 g (154 gr) from 1 m	50 g (1.76 oz) from 1 m	300 g (10.6 oz) from 1 m	1 kg (2.2 lb) from 1 m	Special Test

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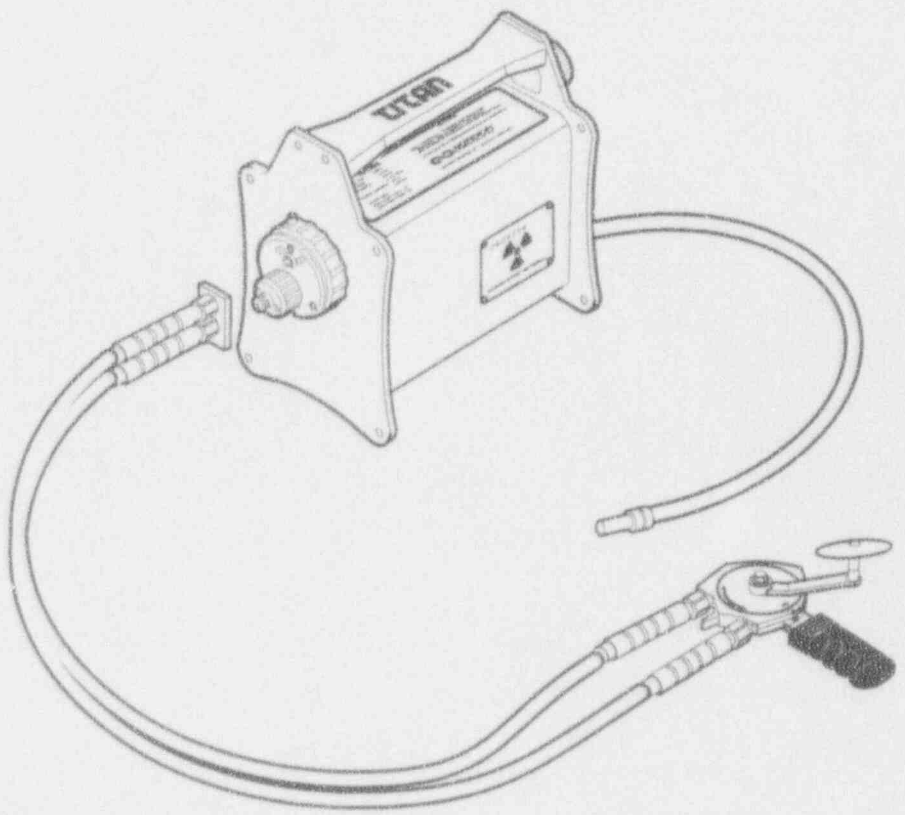
APPENDIX 2.10-B: IS/OM 0090 N990 rev B.

TITAN™

Gamma Ray Projector User's Manual



TITAN™

User's Manual

IS/OM 0090 N990 (Rev B)
October 1993

Nordion Customer Service
1-800-267-6211

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Chapter One

Introduction

1-1 GENERAL

The Nordion TITAN is a Gamma Ray Projector built to handle the most demanding industrial radiography applications. Designed to fit pipes more securely, the TITAN is rugged, reliable, easy to handle and can stand up to the toughest working conditions. The Nordion C-990 is the Source Assembly used for TITAN radiographic exposures.

1-2 REGULATORY REQUIREMENTS

The operation of this radiographic product is subject to regulations. Please check with your national and local authorities.

1-2-1 Packaging

This product meets USNRC, USDOT, AECB and IAEA regulations for Type B(U) packages. No overpack is required.

1-2-2 Source Assembly (C-990)

Nordion C-990 source capsules meet IAEA requirements for Special Form radioactive material (AECB Certificate No. CDN/0001/S). Replacement sources are normally shipped to a licensed user in a Source Changer.

1-2-3 Source Changer

Source Changers must conform to IAEA Type B(U) requirements. See Chapter Six —*Source Changer*.

1-3 OPERATOR'S RESPONSIBILITIES

The TITAN and its peripheral equipment have been designed in accordance with various international standards and regulations. Full compliance with these standards requires operator cooperation.

Operator's responsibilities include:

a) Obtaining and obeying local and national regulations. The TITAN must be operated by trained and licensed personnel. Records of training must be maintained by the user.

b) Using safe practices and operating the unit in accordance with this manual. You must read and fully understand this manual before operating the TITAN.

c) Inspecting and maintaining the unit according to this manual. Modifications to the unit or its peripheral equipment are not permitted. See Chapter Five - *Maintenance*.

d) Maintaining inspection and maintenance records.

e) Attaching an owner's label and a current source identification label. Source serial numbers and TITAN serial numbers should be tracked.

f) Locking and safely storing the unit when it is not in use.

g) Safely securing the unit in transport away from the public and photographic materials. Transportation of the unit must be in accordance with this manual and local/national regulations. See Chapter Four- *Transportation and Storage*.

h) Keeping emergency procedures and shipping papers in accessible and readily visible areas in the transport vehicle.

i) Reporting incidents and accidents to the local competent authority.

Chapter Two

Description

2-1 GENERAL

Described as the "light heavyweight", the Nordion TITAN has an optimized shield design within a lightweight titanium case. The TITAN projector is curved to fit pipes more securely and its broad base provides greater stability. See Figure 2-1—*Main Components of the Nordion TITAN.*

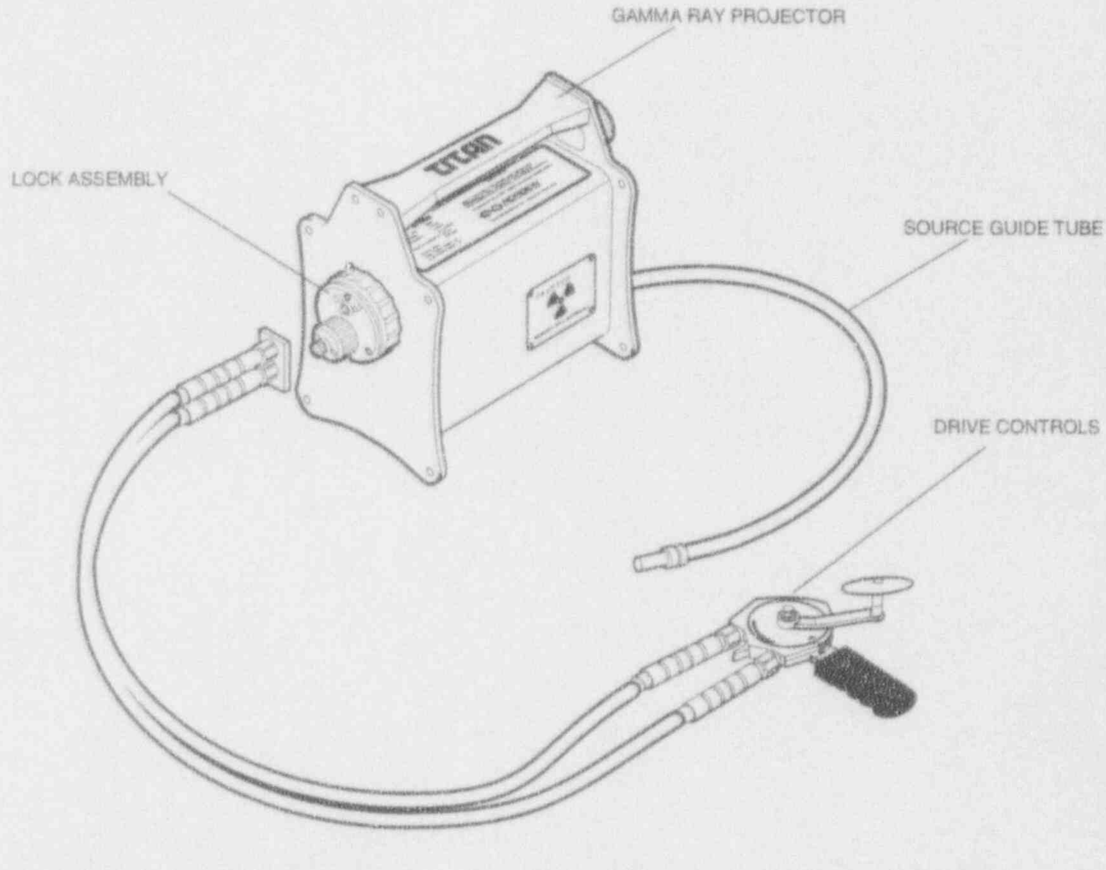

Figure 2-1
Main Components of the Nordion TITAN

2-2 SPECIFICATIONS

Isotope:	—	Ir-192
Half-Life:	—	73.8 days
Capacity:	—	120 Ci (4.44 TBq)
Shielding:	—	30 lbs. (13.5 kg) depleted uranium metal
Projector:	—	All titanium Length: 12.0 in. (305 mm) Width: 6.75 in. (171 mm) Height: 10.13 in. (257 mm) Weight: 44.0 lbs. (20 kg) including shielding
Pistol Grip Control:	—	Weight: 3.85 lbs. (1.75 kg)
Source Guide Tube:	—	Length: 7.0 to 21.0 ft. (2.1 m to 6.4 m) Weight: 1.4 lbs. to 4.4 lbs. (0.65 kg to 2.0 kg)
Drive Controls	—	Length: 25 ft. (7.6 m) Weight: 14 lbs. (6.4 kg) including Teleflex Cable (manufactured by Teleflex Inc.), Cable Sheath, and Bayonet Connector
Operating Specifications:	—	Standard Cable Sheath length on Drive Controls is 25 ft. (7.6 m) Standard source can travel up to 21 ft. (6.4 m)

2-3 PERIPHERAL COMPONENTS

2-3-1 Drive Controls

The Drive Controls include a steel Teleflex Cable which is projected by a Pistol Grip Control. A male connector on the Teleflex Cable attaches to the female connector on the Source Assembly and moves within a flexible teflon lined Cable Sheath covered in yellow PVC.

A radiographic source within the TITAN is connected to the Teleflex Cable and a Cable Sheath is fitted to the Lock Assembly. When turned in a counter clockwise direction, the Pistol Grip Control transfers the source out of the projector and through the Cable Sheath to the exposure position. A clockwise rotation retracts the source back into the projector. The TITAN recognizes the return of the Source Assembly, and automatically secures the source in the stored (shielded) position.

2-3-2 Source Guide Tube

The Source Guide Tube includes a protective yellow PVC cover. It consists of up to three 7 ft. (2.1 m) lengths. Two lengths of the Intermediate Section connected together with a Terminating Section provide a total length of 21 ft. (6.4 m).

The Terminating Section has a Source Stop and must always be used to positively locate the source. The Source Stop avoids accidental ejection and also prevents debris from jamming the source in an exposed position. See Figure 2-1—*Main Components of the Nordion TITAN.*

2-3-3 Source Assembly (C-990)

The **TITAN** is designed to operate with a Nordion C-990 source. Iridium 192 is sealed within the source capsule and crimped to a short length of Teleflex Cable. The opposite end of the Source Assembly has a connector for positive attachment to the Drive Controls. See Figure 2-2—*Source Assembly (C-990).*

The Source Assembly meets IAEA requirements for Special Form radioactive material (AECB Certificate CDN/0001/S).

Figure 2-2
Source Assembly (C-990)

2-4 DEFINITIONS

This section defines components and terms that appear in this guide. The component names or terms, **shown in bold**, are followed by alternate names within **[square brackets]**. All Component Names are capitalized throughout the main body of the text. See Figure 2-1 —*Main Components of the Nordion TITAN* and Figure 3-1 —*TITAN Cross-section.*

Actuator Pin:—A mechanical component inside the Selector Ring that holds the Selector Ring in the 'OPERATE' position.

Bayonet End Cap: —Plugs the Entry Port when the Drive Controls are not connected to the Gamma Ray Projector.

Cable Sheath: —A flexible stainless steel casing with a protective bright yellow PVC cover that is used in the Source Guide Tube and in the Drive Controls.

Collimator: [beam limiter] —A device used to limit the size, shape, and direction of the primary radiation beam. It is attached to the Source Stop.

Drive Controls: [controls, drive cable, control cable] —A manual device attached to the Gamma Ray Projector that enables the Source Assembly to be exposed or retracted. It consists of the following:

a) **Teleflex Cable** - 50 ft. (15.2 m) long and housed within the Cable Sheath.

b) **Cable Sheath** - two 25 ft. (7.6 m) lengths.

c) **Bayonet Connector** - affixed to the Cable Sheath, it is attached to the the Projector using a push and twist motion.

d) **Pistol Grip Control** - a manual remote control device attached to the opposite end of the Cable Sheath used to project and retract the Source Assembly to perform an exposure.

Entry Port: —Where the Drive Controls are connected to the Gamma Ray Projector.

Exit Port: —Where the Source Guide Tube is connected to the Gamma Ray Projector and where the source is projected from the exposure device.

Gamma Radiography System: —All components necessary to make radiographic exposures, including the Gamma Ray Projector, Source Assembly, Drive Controls, and other components associated with positioning the source such as the Source Guide Tube, Source Stop, and Collimators.

Gamma Ray Projector: [exposure device, gamma ray exposure device (GRED), projector] —A shielded device that permits the controlled projection of a sealed source for the purposes of radiography.

Interlock:—The Interlock is a mechanical connection between the Exit Port and the Selector Ring. This feature of the **TITAN** requires connecting the Source Guide Tube to the projector before the Selector Ring can be turned to the 'OPERATE' position. See Figure 3-1—*TITAN Cross-section*.

Lock Assembly:—An assembly consisting of the Selector Ring, an inner plate assembly and an outer plate assembly. See Figure 5-1—*Exploded View of Lock Assembly*. The Lock Assembly secures the Source Assembly when in the "store" position.

Locking Pin:—A small pin on the side of the Source End Connector that is used to push down the Source Assembly's spring loaded locking collar to permit connection of the female Source Assembly Connector to the male Teleflex Cable connector.

Push Button Lock: [lock] —A lock that, when engaged, prevents the rotation of the Selector Ring.

Radiation Safety Officer:—The person selected to be responsible for radiation safety in an organization. Also called by other names such as "Radiation Protection Officer" and "Radiation Safety Manager."

Selector Ring: —Two-positions: 'LOCK' and 'OPERATE'. While in the 'LOCK' position, the source is secured in the shielded position within the projector. When in the 'OPERATE' position the source may be projected from the shield.

Source Assembly: [pigtail, source] —A component that includes a small capsule containing iridium 192, and a connector that attaches to the drive cable. The connector and capsule are crimped onto a short length of cable.

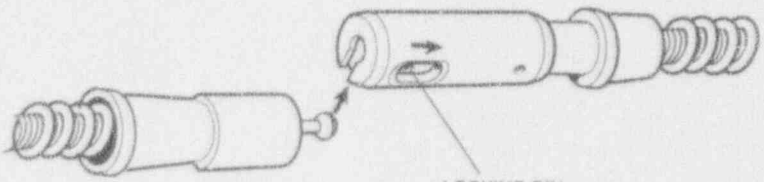

Figure 2-3
Source End Connector

Source Changer: —Used to transport new sources to the customers and return old sources to Nordion.

Source End Connector:—The female connector at the end of the Source Assembly that mates with the male connector on the Teleflex Cable (See Locking Pin). Refer to Figure 2-3—*Source End Connector*.

Source Guide Tube: [projection sheath] —A flexible tube for guiding the sealed source from the Gamma Ray Projector to the Source Stop. It may be up to 21 feet long consisting of the following sections:

a) **Terminating Section:** (7 ft. long) - section to which the Source Stop is attached.

b) **Intermediate Section:** (7 ft. long) - used between the TITAN and the terminating section.

Source Guide Tube End Cap: —Plugs the Exit Port when the Source Guide Tube is not connected to the Gamma Ray Projector.

Source Stop: [end stop, exposure head] —Locates the sealed source at the desired focal position. It is attached permanently to the Terminating Section of the Source Guide Tube.

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Chapter Three

Operation

3-1 GENERAL

The portability and light weight of the TITAN makes operation easy. Nordion's Gamma Ray Projector is shielded and self-contained. This unit uses a C-990 source for the radiographic inspection of steel and light alloy sections.

The TITAN 's titanium case contains a radiation shield of depleted uranium. Through computer analysis all excess weight has been removed to form a fully optimized radiation shield.

3-1-1 Component Overview

The TITAN , as shown in Figure 3-1—*TITAN Cross-section*, consists of the following:

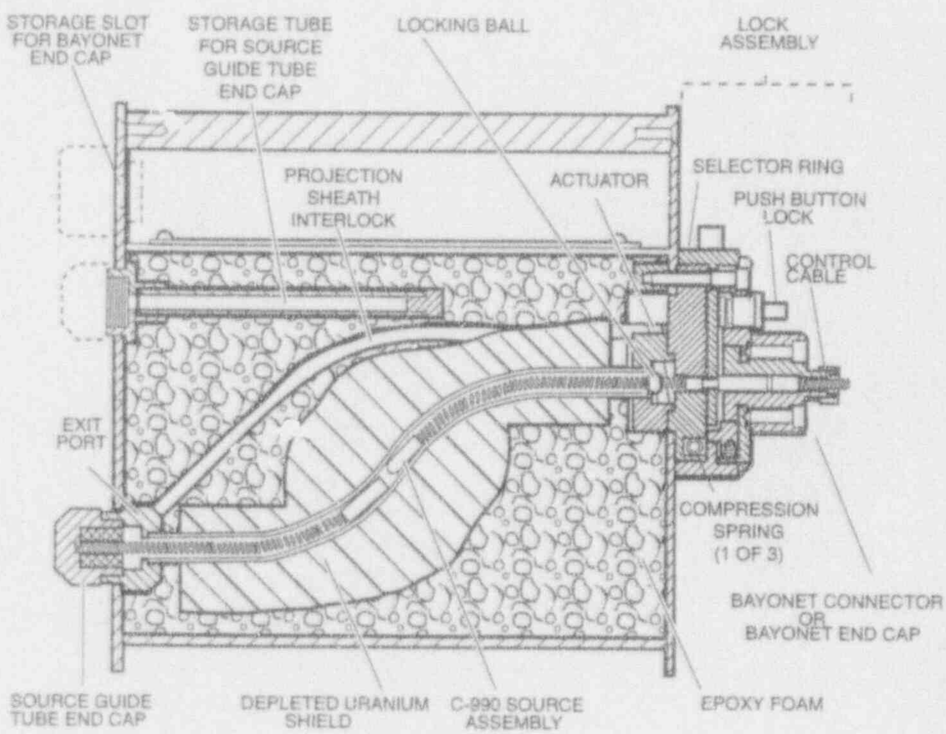

Figure 3-1
TITAN Cross-s‹ction

- an S-tube, cast within a depleted uranium shield,
- a Lock Assembly, including the Selector Ring
- a Push Button Lock
- a C-990 sealed Source Assembly,
- a port for the attachment of a Source Guide Tube,
- a port for the attachment of a Drive Control.

Entry & Exit Ports—The Entry Port and Exit Port at either end of the S-tube are sealed using end caps. A Bayonet Connector attaches the Drive Controls at the Entry Port and a threaded connector fastens the Source Guide Tube at the Exit Port.

End Caps—Each Port has a mating End Cap that is stored on the case when the unit is in use.

3-2 OPERATING PRINCIPLES

3-2-1 Overview

At the start of an exposure cycle, the C-990 is secured in the centre of the S-tube, the Selector Ring is in the 'LOCK' position, the Bayonet and Source Guide Tube End Caps are installed, and the Push Button Lock is pushed in with its key removed. This is termed "Transportation Mode" and in this configuration all requirements for the transport of radioactive materials are satisfied.

In Transportation Mode, it is impossible to remove the Bayonet End Cap. It is also impossible to turn the Selector Ring into the 'OPERATE' position.

To perform an exposure, the radiographer unlocks the Push Button Lock. This allows the Bayonet End Cap to be removed from the Selector Ring and allows access to the C-990 Source End Connector. The Teleflex Cable is then connected to the C-990 Source Assembly, and the Drive Controls are attached to the Lock Assembly. At this point, the Teleflex Cable and the Source Assembly are fully connected. However, the Interlock prevents the Selector Ring from moving into the 'OPERATE' position. The Source Guide Tube End Cap is then removed. Attaching the Source Guide Tube releases the Interlock and allows the Selector Ring to be turned counterclockwise into the 'OPERATE' position. The motion is resisied by springs that bias the Selector Ring toward its 'LOCK' position. Once the Selector Ring has been rotated into the 'OPERATE' position, an Actuator Pin prevents the spring from returning the Selector Ring to 'LOCK.

In the 'OPERATE' position, the Source Assembly is free to exit from the shield. The radiographer then uses the Drive Controls to project the source to the exposure site.

Once the exposure has been completed, the C-990 Source Assembly is retracted into the shield. As it approaches the 'LOCK' position, its locking ball engages an actuator. The Actuator Pin becomes disengaged and allows the Selector Ring to spring back into the 'LOCK' position. This action automatically secures the Source Assembly in the depleted uranium shield.

If additional exposures are planned, the Selector Ring is turned back to the 'OPERATE' position and the cycle repeats. Otherwise, the Drive Controls and Source Guide Tube are removed from the unit, the appropriate End Caps are fastened to the Entry and Exit Ports, and the Push Button Lock is pressed in. This returns the unit to Transportation Mode.

The safety features built into the TITAN require that to expose the source, you must:

- unlock the Push Button Lock
- securely connect the Teleflex Cable to the Source End Connector
- attach the Source Guide Tube(s),
- attach the Drive Controls,
- turn the Selector Ring to the 'OPERATE' position.

3-3 SITE SAFETY PRECAUTIONS

Only perform radiography in a restricted area where boundaries are clearly defined. Place appropriate radiation warning signs and physically secure the area against unauthorized entry. The radioactive source emits high levels of radiation and therefore it is a good practice to operate the system from as great a distance as possible.

Operation Distance Calculation —To calculate the minimum distance for operation, use the inverse square law: that is, double the distance results in quarter the level of radiation.

3-3-1 Personnel Precautions

> **WARNING:** All personnel shall wear a Thermal Luminescent Dosimeter (TLD) and shall carry a radiation survey meter capable of measuring dose rates of 0.02 mSv/h (2 mrem/h) to 100 mSv/h (10 rem/h) .

In some countries, including Canada and the United States, regulations require a direct reading dosimeter to be worn in addition to the TLD. Some countries also recommend an audible "beeper" pocket alarm. Check with your local authorities.

> CAUTION: Food and drink should not be permitted in the vicinity during the operation of the projector.

3-4 OPERATING PROCEDURES

3-4-1 Inspection

A daily inspection and the required maintenance procedures must be completed prior to using the TITAN. Refer to Chapter Five.

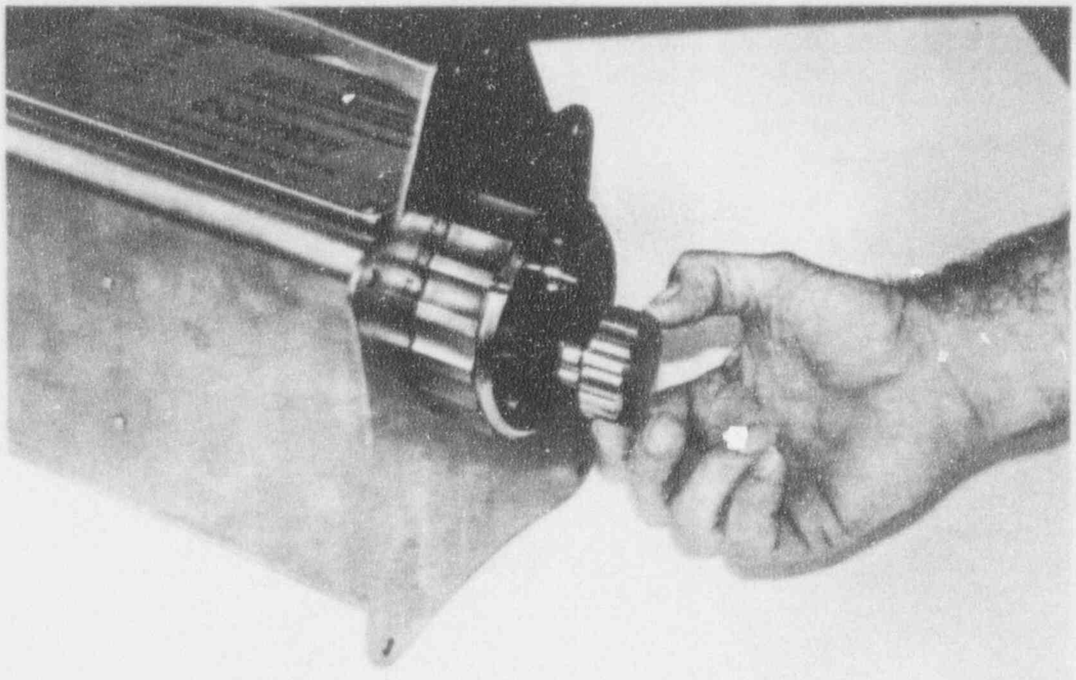

Figure 3-2

Removing the Bayonet End Cap

> **WARNING**: Proper operating procedures and regular inspection and maintenance will ensure that the TITAN operates safely.

3-4-2 Source Guide Tube Layout

1. Secure the Source Stop of the Terminating Section at the radiographic focal position. Use of a collimator is recommended.
2. Determine the position of the TITAN and lay out the Source Guide Tube as straight as possible. Avoid bend radii less than about half a meter (20 inches) to prevent restricting the source movements. Do not connect the Source Guide Tube to the TITAN at this stage.

> CAUTION: Ensure that the Source Guide Tube does not contact any surface at a temperature greater than 60°C (140°F).

> CAUTION: Position the projector and peripherals in a manner that minimizes the risk of accidental damage caused by crushing or by falling objects (vehicles or closing doors).

> **WARNING:** Ensure that the "available length" of the Teleflex Cable on the Drive Controls is greater than the total length of the Source Guide Tube. If the Teleflex Cable is shorter than the Source Guide Tube, the source cannot be projected all the way to the Source Stop and correctly placed for exposure.

3-4-3 Connecting The Drive Controls

3. Unlock the Push Button Lock with the key.

4. Turn the Bayonet End Cap counterclockwise to remove it. See Figure 3-2—*Removing the Bayonet End Cap.*

5. Secure the Bayonet End Cap in its storage position on the front of the TITAN just below the handle.

6. Crank the Pistol Grip Control and expose the male portion of the Teleflex Cable (the ball-end of the cable).

7. Locate the TITAN 's Source End Connector and press back the spring-loaded Locking Pin with a thumb nail. See Figure 3-3—*Engaging the Source End Connector.*

8. Engage the male and female portions of the swivel coupling. Ensure that the spring loaded Locking Pin returns to its original position and the connection is secure.

9. Insert the Bayonet Connector and rotate it clockwise 90 degrees. The Drive Controls are now coupled to the projector. It should engage freely. If any force is required, then a correct connection has not been made. See Figure 3-4—*Connecting the Bayonet Connector.*

> **WARNING:** Difficulty in attaching the Bayonet Connector, may indicate that a proper source connection has not been made or that the Selector Ring requires maintenance. Investigate and take appropriate action before proceeding further.

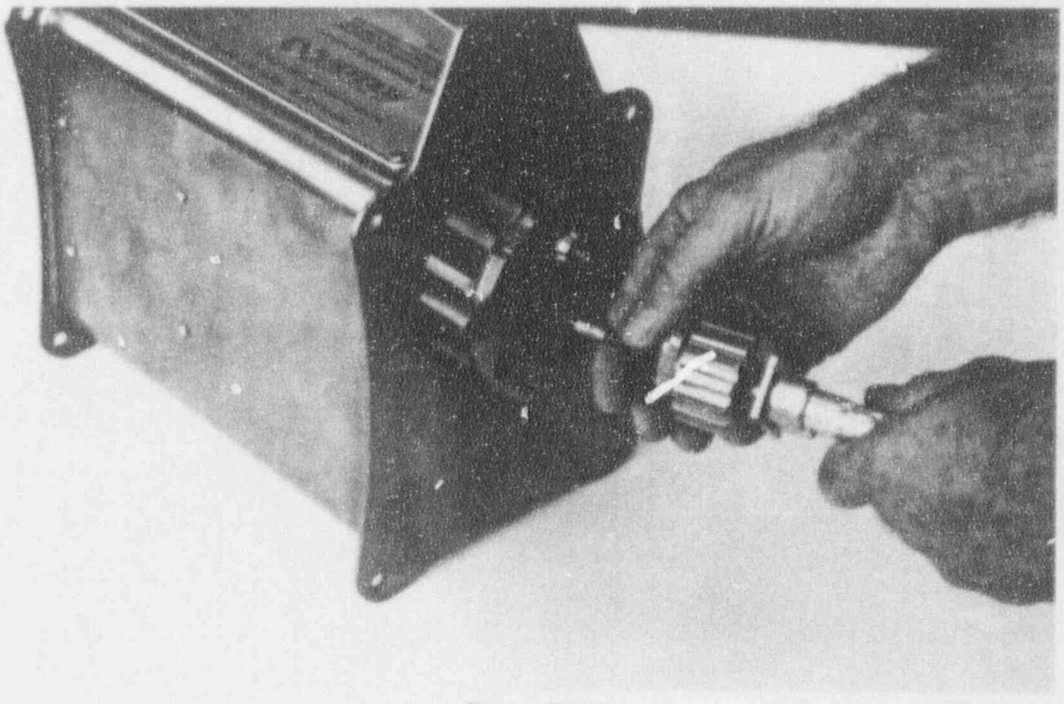

Figure 3-3

Engaging the Source End Connector

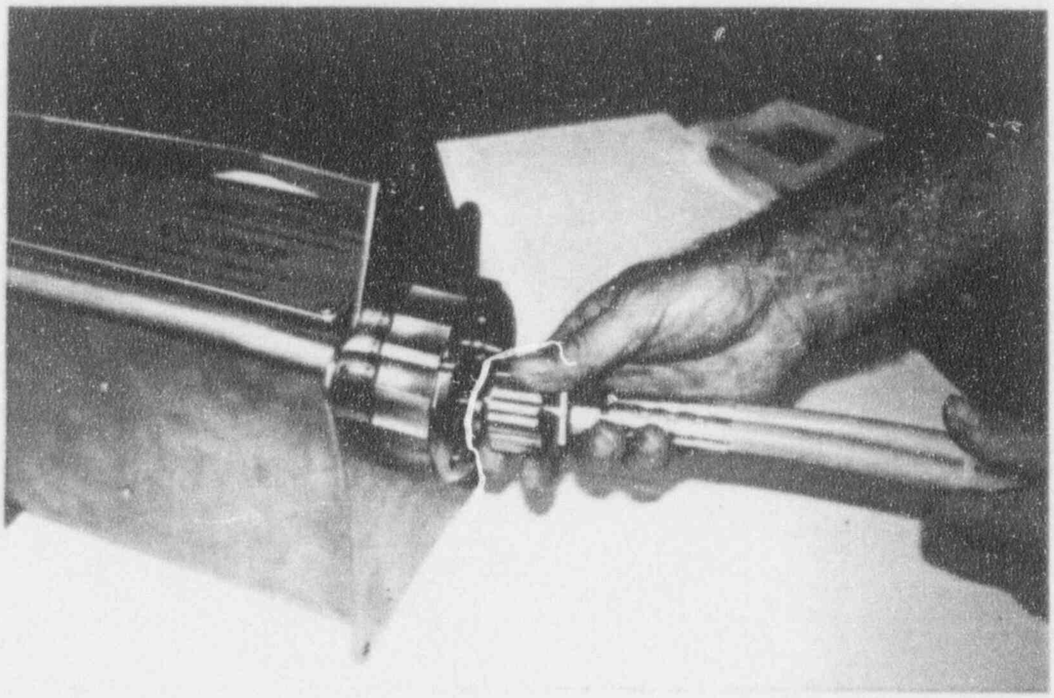

Figure 3-4

Connecting the Bayonet Connector

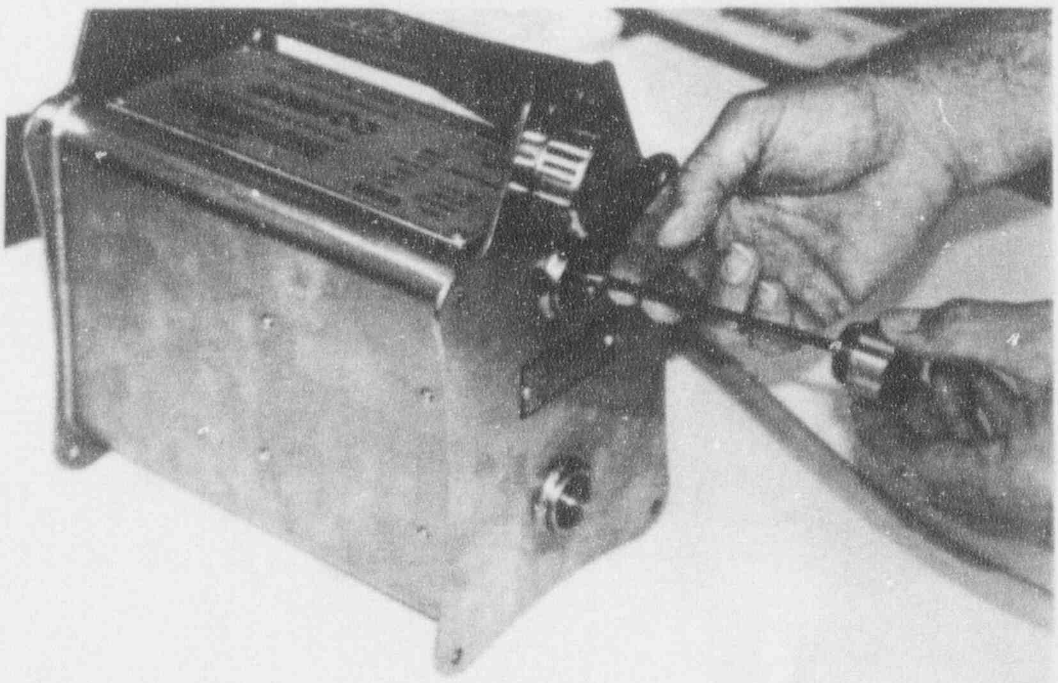

Figure 3-5

Store End Caps on the TITAN

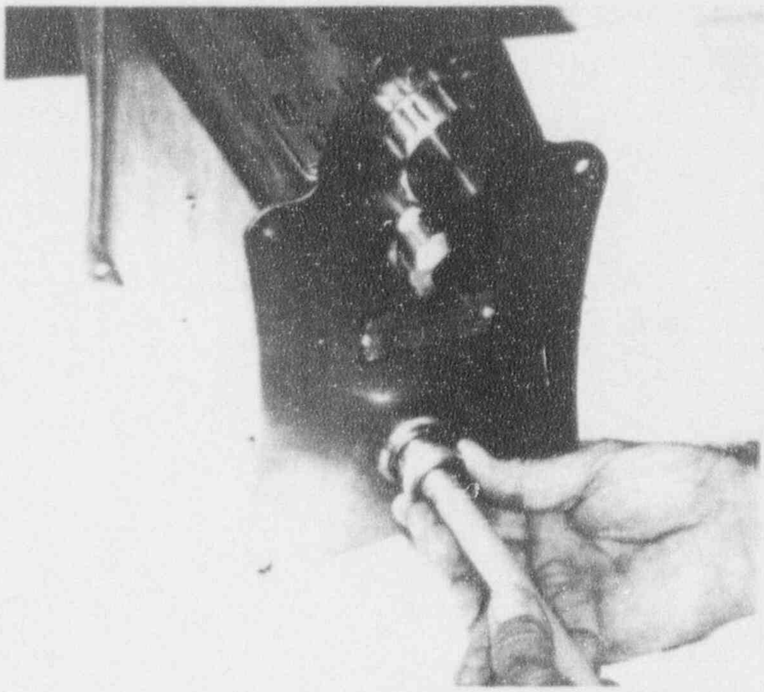

Figure 3-6

Connecting Source Guide Tube

10. Keep the Selector Ring in the 'LOCK' position until you are ready to start the exposure.

3-4-4 Performing a Radiographic Exposure

11. Unfasten the Source Guide Tube End Cap from the projector and install it in the storage receptacle. See Figure 3-5—*Store End Caps on the TITAN.*

> **WARNING:** Once the Source Guide Tube End Cap is removed, higher radiation fields will come out the Exit Port. DO NOT come into the path of the radiation beam emitted from the open Exit Port.

12. Connect the Source Guide Tube securely. See Figure 3-6—*Connecting Source Guide Tube.*
13. Check the surface of the projector with the area radiation survey meter. This is a precaution only to ensure that the meter responds to radiation. Record the radiation levels for later verification that the source is in the shielded position after exposure.
14. Verify that the Intermediate and Terminating Sections are correctly connected.
15. Ensure that no unauthorized personnel are inside the Restricted Area or Exposure Room. Make sure that warning signs are posted.
16. Rotate the Selector Ring counterclockwise to the 'OPERATE' position. When the indicator points to 'LOCK', the Source Assembly is secured in the shielded position. When the Indicator points to 'OPERATE', the Source Assembly is free to travel.

> NOTE: *Excessive tension in the Teleflex Cable (for example, the Pistol Grip Control is snagged) may prevent the Selector Ring from remaining in the 'OPERATE' position.*

17. Position yourself at the Drive Controls and verify that all personnel have left the restricted area.
18. Rapidly rotate the Pistol Grip Control in the 'EXPOSE' direction (counterclockwise) to transfer the source out of the TITAN and into the radiographic focal position. There will be some resistance when the source reaches its stop. DO NOT USE EXCESSIVE FORCE.
19. Set the brake to 'ON', at the Pistol Grip Control, to prevent any movement of the source during exposure.

3-4-5 Exposure

The measured exposure time starts from the moment the source reaches the stop.

Survey meter readings observed during the projection operation will significantly increase from background to a high level as the source leaves the TITAN. Readings will fall as the source moves into the collimator (if used) and remain steady throughout the exposure. Actual survey meter readings will depend on the source activity, distance, collimators, shielding and backscatter (building materials, especially steel, will generate significant amounts of scatter).

20. Observe the readings during the sequence of changes. Use the survey meter to check the boundary dose rate, but spend as little time as possible in the restricted area to minimize personal exposure.
21. At the end of the exposure time, set the brake to 'OFF' and rapidly turn the crank on the Pistol Grip Control in the 'RETRACT' (clockwise) direction until the crank comes to a stop. Check that the Selector Ring has returned to the 'LOCK' position by turning the hand crank counterclockwise. If the Source Assembly cannot be moved, the Selector Ring should be in the 'LOCK' position.
22. Set the brake to 'ON'.

> **WARNING**: Always check radiation fields as you approach the TITAN. This is the primary means of checking that the source is safely stored.

23. Survey the unit. Radiation fields should be the same as they were at the start of the exposure. Pay special attention to the fields at the Exit Port.

> **WARNING:** If the source is still exposed, attempt to store it properly by cranking it a short distance out into the Source Guide Tube and retracting it. If it cannot be stored after a few attempts, treat the situation as an **EMERGENCY**. See 7-2—*Emergency Procedures*.

3-4-6 Preparing for Storage or Transport

The following procedure shall be completed every time the TITAN is to be moved.

24. Unfasten the Source Guide Tube and replace it with the Source Guide Tube End Cap.
25. Replace the plastic caps or fasten both open ends of the Source Guide Tube together to form a closed loop.
26. Remove the Bayonet Connector.
27. Disengage the Source Assembly from the Teleflex Cable.
28. Replace the Bayonet End Cap in the Entry Port.
29. Press in the Push Button Lock.

> **WARNING:** The TITAN should always be locked when not under direct surveillance of a licensed radiographer or assistant.

30. Check the entire surface of the TITAN with a survey meter. When loaded with 120 Ci of Ir-192 in a C-990, the radiation field should not exceed 200 mrem/h on contact with the unit, 50 mrem/h 50 mm (2 inches) from the surface and 2 mrem/h one metre (39.4 inches) from the surface.

> **WARNING**: If the radiation fields exceed the above limits, treat the situation as an **EMERGENCY**. Do not proceed further unless the cause of the high field has been determined and corrected.

31. If the TITAN is to be stored or transported, install a wire seal between the Source Guide Tube End Cap and one of the four holes provided on the front of the unit.

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Chapter Four

Transportation and Storage

4-1 REGULATIONS

Canada—In Canada, the governing regulations are the Transportation of Dangerous Goods (TDG) Regulations and the Transport Packaging of Radioactive Materials Regulations, SOR/83-740, including all amendments.

United States—In the United States, the transport of Radiography Projectors and Source Changers is governed by 10 CFR Part 71, and 49 CFR Parts 171 through 179.

International—IAEA Safety Series No. 6, 1985 Edition (As Amended 1990), guides the transportation of radioactive materials internationally.

4-2 RECEIVING GAMMA PROJECTORS AND SOURCE CHANGERS

When shipping a radioactive package, the consignee must make arrangements for receiving prior to shipment. Upon notification of arrival, the package shall be promptly picked up at the carrier's terminal.

1. Upon receipt of the **TITAN**, measure the radiation fields at the surface of the package and at 1 meter. These should not exceed 2 mSv/h (200 mrem/h) at the surface and 20 μ Sv/h (2 mrem/h) at 1 meter.

   > **WARNING:** If the package has been damaged and the fields exceed these limits, treat the situation as an **EMERGENCY**. Isolate and secure the package in a restricted area. Contact the appropriate authorities and your Radiation Safety Officer. See 7-2—*Emergency Procedures*.

2. Inspect the **TITAN** for damage. Check the condition of the wire seal.

   > **WARNING:** If the package has been tampered with or damaged, contact your Radiation Safety Officer for further instructions. Do not proceed further unless authorized to do so.

3. Record the radiation levels in the receiving report. Enter the isotope (iridium 192), activity, **source model number and serial number**.

4-3 STORAGE/TRANSPORT

When preparing the TITAN for storage or transport, ensure that:

- the Selector Ring is in the 'LOCK' position;
- the Bayonet End Cap is installed and the Push Button Lock is engaged;
- the Source Guide Tube End Cap is installed.

> CAUTION: the End Caps on the TITAN Gamma Ray Projector provide additional radiation shielding. Always install the End Caps when the projector is not in use.

- the plastic dust caps on the Drive Controls and Source Guide Tube fittings are installed.

> NOTE: *The ends of Intermediate Sections of the Source Guide Tube can be threaded together rather than using the dust caps.*

- When not in use for extended periods, store the TITAN Gamma Ray Projector in a dry, clean and secure area. Lock and secure the storage area to prevent unauthorized entry.
- The door to the storage area must have a warning label with the trefoil symbol indicating the presence of radioactive material. The radiation levels at the outside wall of the radioactive materials storage area must be within the limits permitted for the general public.

4-4 SHIPPING

Prior to transport, ensure that the unit has been properly prepared for transport. Refer to section 3-4-6 for additional instructions.

> WARNING: Never ship a unit that has been tampered with or damaged.

The TITAN Gamma Ray Projector is licensed as a Type B(U) transport package and needs no overpack. The level of removable contamination must not exceed 4 Bq (0.0001 μ Ci) per cm^2, averaged over an area of 300 cm^2.

Two completed category labels must be added to opposite sides of the TITAN. The radioactive isotope (^{192}Ir), the activity in bequerels (Bq) or curies (Ci) and the transport index (TI) must be recorded on the label. To determine the transport index, the maximum radiation level in mrem/h is measured at a distance of 1 meter. For example, a package with a maximum field of 17 μ Sv/h (1.7 mrem/h) at 1 meter would have a TI of 1.7.

Guidance on the completion of the category labels can be found in Table 4-1.

Do not cover or remove any of the permanently affixed plates on the device, as this would violate shipping regulations by obscuring important information.

Refer to Figure 4-1—*Radioactive Material Category Labels.*

> WARNING: DO NOT ship the package if the dose rates exceed 2 mSv/h (200 mrem/h) at its surface or 20 µ Sv/h (2 mrem/h) at 1 metre from any surface. If radiation fields exceed these limits, treat the situation as an EMERGENCY. Do not proceed further until the cause of the high radiation field has been determined and corrected.

Table 4-1
Package Label Requirements

Label	Radiation Level at External Surface of Package	Transport Index (T.I.)[1]
RADIOACTIVE I (WHITE)	Not more than 0.005 mSv/h ($\leq$ 0.5 $mrem/h$)	0
RADIOACTIVE II (YELLOW)	More than 0.005 mSv/h (0.5 $mrem/h$) But not more than 0.5 mSv/h (50 $mrem/h$)	More than 0 But not more than 1
RADIOACTIVE III (YELLOW)	More than 0.5 mSv/h (50 $mrem/h$) But not more than 2 mSv/h (200 $mrem/h$)	More than 1 But not more than 10

[1] T.I. - Radiation level in microsieverts per hour at 1 metre from the external surface of the package divided by 10. (This is equivalent to the radiation level in mrem/h at 1 metre from the external surface of the package.)

Figure 4-1

Radioactive Material Category Labels

The **TITAN** shall be securely stowed in the transport vehicle and shall not be carried in passenger compartments. Acceptable means of securing the unit include passing straps between the handle and the main body and fastening the straps to dedicated fittings. Use of a securely mounted box or drum is preferred.

A radiation survey must be completed prior to transport.

The **TITAN** may only be shipped if:

1) Radiation dose rates to occupants are less than 20 μ Sv/h (2 mrem/h)
2) Radiation levels from the external surface of the vehicle are less than 2 mSv/h (200 mrem/h)
3) Radiation levels at 2 metres from any point on the external surface of the vehicle are less than 0.1 mSv/h (10 mrem/h).
4) The sum of transport indexes from all packages on the vehicle is less than 50 if the shipment is not under Exclusive Use. (The sum of the transport indexes must be less than 100 for Exclusive Use shipments.)

> **WARNING:** Transport Regulations do not allow persons other than the driver and assistants to be in vehicles containing packages bearing Category II - Yellow or Category III - Yellow labels.

4-4-1 Preparing Shipping Documents

Prepare the shipping documents and include them with each shipment. The shipping papers must include:

a) The information "RADIOACTIVE MATERIAL, SPECIAL FORM, N.O.S., UN2974".
b) The United Nations Class Number "7".
c) The name and symbol of the radionuclide, "^{192}Ir".
d) The maximum activity of the ^{192}Ir during transport expressed in units of Terabecquerels (TBq) or curies (Ci).
e) The category of the package (i.e. I-white, II-yellow, III-yellow).
f) The Transport Index (TI).
g) USNRC Certificate of Compliance No. USA/XXXX/B(U) and Canadian AECB Approval Certificate No. CDN/1038/B(U)-85 and Special Form Certificate of Approval No. CDN/0001/S.
h) The Shipper's declaration:

   "I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked and labelled, and are in all respects in proper condition for transport by (air, sea, road, and rail) according to the applicable international and national governmental standards."

In the United States use the following declaration:

"This is to certify that the above named materials are properly classified, described, packaged, marked and labelled and are in proper condition for transportation according to the applicable regulations of THE DEPARTMENT OF TRANSPORTATION."

i) The shipper must sign and date the declaration. The declaration and signature must appear on the same page that contains the particulars of consignment listed above.

> **WARNING:** It is the consignor's responsibility to ensure that the TITAN is prepared for shipment in accordance with all pertinent regulations and this manual. It is the carrier's responsibility to placard the transport vehicle in accordance with these same regulations.

4-4-2 Handling

The TITAN is a portable device designed to be carried by one person. When moving the Gamma Ray Projector, remove the Drive Controls and Source Guide Tube, and replace the end caps.

Care must be exercised at all times to minimize radiation exposure. For example, no person should sit on the projector or loiter nearby. Personal dosimeters should be worn at all times. Only trained personnel should handle the equipment.

4-4-3 Placards

Canada

Canadian regulations require placards to be applied to all four sides of the vehicle whenever radioactive materials are shipped. For radioactive Category I or II shipments, non-retroreflective 250 mm × 250 mm placards must be used. For radioactive Category III shipments, the placards must be retroreflective. We recommend that you carry spare placards in case one is lost during transport.

> **WARNING:** Regardless of which placard is used, it must be removed upon entry to the USA and, if necessary, replaced with appropriate placards conforming to USA regulations (see below).

United States

In the United States, vehicles are only placarded when radioactive Category III Shipments are made. The placards are non-retroreflective, and contain the word "RADIOACTIVE." They must be attached to all four sides of the transport vehicle.

Rest of the World

Refer to IAEA Safety Series No. 6, 1985 Edition (As Amended 1990) and applicable national or local standards for placarding requirements for other countries.

4-4-4 Shipping an Empty TITAN

In order to safely transport the TITAN as an empty package, the spent source must be stored within a Source Changer and replaced with a dummy source assembly. In addition, each step of section 3-4-6 and the following must be completed:

1) Check the external surfaces of the TITAN for contamination. The level of removeable contamination must not exceed 4 Bq (0.0001 µ Ci/ cm^2, averaged over an area of 300 cm^2.

2) Perform a radiation survey around the unit.

3) *If the maximum radioactive field on contact is less than 5 µ Sv/h (0.5 mrem/h) and there is no measurable field 1 metre from the package then* label the package with the proper shipping name (Radioactive Material, articles manufactured from depleted uranium, UN 2909) and with the words:

   "Exempt from specification, packaging, shipping paper and certification, marking and labeling and exempt from the requirements of Parts 171-178 per 49 CFR 173.421-1 and 49 CFR 173.424."

   Include a notice containing the name of the consignee with the shipping documents. The notice should include 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."

4) *If the maximum radiation field on contact exceeds 5 µ Sv/h (0.5 mrem/h) , attach the appropriate radioactive category label (see Table 4-1).* Label the package with the proper shipping name (Radioactive Material, LSA, n.o.s, UN 2912) and complete the shipping papers in accordance with section 4-4-1.

Chapter Five

Maintenance

5-1 MAINTENANCE REQUIREMENTS

The TITAN is designed to operate with little maintenance. However, periodic inspections are required to ensure that the equipment is in proper operating condition. These inspections range from simple daily examination to more detailed inspections and procedures to be completed at every source change. An annual maintenance procedure must also be completed once per year, or more frequently if the unit has been used under severe operating conditions. A recommended maintenance schedule is provided in Table 5.1.

All inspections should be recorded in a dedicated log book. Any component that fails an inspection shall be repaired or replaced before the unit is returned to service.

> **WARNING:** Inspect all equipment prior to use. Failure to remove damaged equipment from service may result in serious injury or death.

Maintenance shall be completed by trained and qualified personnel. All replacement components shall conform to Nordion Specifications. We recommend maintenance by an authorized service depot. Contact Nordion International Customer Service for the depot nearest you.

5-2 DAILY INSPECTION

The following items must be checked daily to ensure safe operation.

5-2-1 Gamma Ray Projector

a) Check that the unit, the Drive Controls and the Source Guide Tube have completed a quarterly inspection within the last three months and an annual inspection within the past year. If the unit is due for one of these inspections, complete the daily inspection procedure and refer to the appropriate section below.

b) Perform a routine radiation survey around the TITAN projector. The survey should be completed with the Source Guide Tube End Cap and Bayonet End Cap installed. When loaded with 120 Ci of iridium 192 in a C-990, the radiation field on contact with the surface shall not exceed 200 mrem/h on contact, 50 mrem/h 50 mm (2 inches) from the surface, and 2 mrem/h one metre (39.4 inches) from the surface.

> **WARNING**: If radiation fields exceed the above limits, treat the situation as an **EMERGENCY**. Do not proceed further until the cause of the high field has been determined and corrected.

c) Wipe test the external surface of the TITAN. The method used shall be capable of detecting any contamination in excess of 4 Bq/cm^2 (0.0001 μ Ci/cm^2)

> **WARNING:** Any projector contaminated in excess of 4 Bq/cm^2 (0.0001 μ Ci/cm^2) shall be quarantined and the cause of the contamination determined. Contact your Radiation Safety Officer for additional instructions. Do not proceed further unless authorized to do so.

d) Visually examine the external surface of the unit. Verify that all warning and identification labels are legible and securely attached and that there is no damage to the titanium shell.

e) Verify that the Bayonet End Cap cannot be removed from the unit while the Push Button Lock is in its locked position.

f) Check the operation of the Push Button Lock. It should lock and unlock freely.

g) Check that the handle is secure.

h) Check the threads on the end cap storage tube for damage. Clean if necessary.

> NOTE: *The following steps should be completed during your first exposure cycle. Refer to Chapter Three for Operating Procedures.*

i) Remove and examine the Source Guide Tube End Cap. Check the condition of the threads and ensure that the lead insert and teleflex plug are secure within it.

j) Check the operation of the Bayonet Connector. It should freely engage with the Lock Assembly.

k) Check the operation of the Selector Ring. Ensure that it turns freely into the 'OPERATE' position and that it returns to the 'LOCK' position at the end of the first exposure. Difficulty in turning the Selector Ring into the 'OPERATE' position indicates that some obstruction is present. Refer to 5-4 Annual Maintenance.

5-2-2 Drive Controls

a) Examine the Cable Sheaths for cuts, dents and broken or loose fittings. Damage to the stainless steel tube requires the Cable Sheaths be removed from service. Damage to the yellow PVC casing may be repaired using water resistant vinyl tape.

b) Verify that the plastic end caps on the Control Cable and Source Guide Tube are present and in good condition. Replace as necessary.

c) Nordion recommends daily examination of the male connector on the Teleflex Cable using a GO-NO GO gauge. Refer to Nordion Inspection Procedure IS/OP 0046 C000. (See Appendix B.)

d) Check the Pistol Grip Control for damage or loose components. Check the operation of the brake. With the brake in the 'OFF' position, ensure the crank rotates smoothly.

5-2-3 Source Guide Tube

a) Examine the Intermediate and Terminating Sections for cuts, dents and broken or loose fittings. Remove the Source Guide Tubes from service if the stainless steel tubes are damaged. Damage to the yellow PVC casing may be repaired using water resistant vinyl tape.

b) Verify that the plastic end caps are present and in good condition. Replace as necessary.

c) Examine each section of the Source Guide Tube for obstructions. Check the condition of the threads. Clean or repair as necessary.

5-3 QUARTERLY INSPECTION

A quarterly inspection shall be completed at every source change, or once every three months, whichever comes first. It includes a daily inspection plus the following procedures.

> **WARNING:** The following procedures shall only be completed with the C-990 Source Assembly safely stored within a Source Changer. Source transfers should only be completed by trained and licensed personnel.

5-3-1 Source Transfer Procedure

Refer to Chapter Six and your Source Changer's User's Instructions for procedures to safely transfer and store an active Source Assembly. Use a survey meter to check that the Source Assembly has been safely stored.

Once the active Source Assembly is safely stored in the Source Changer, disconnect it from the Teleflex Cable and replace it with a dummy source assembly. (Dummy Source Assemblies can be obtained from Nordion.)

5-3-2 Gamma Ray Projector

a) Retract the dummy source assembly into the TITAN. Verify that the Selector Ring returns to the 'LOCK' position.

b) Disconnect the source transfer hose from the TITAN. Test the function of the Interlock. It should NOT be possible to rotate the Selector Ring into the 'OPERATE' position.

c) Install the terminating section of the Source Guide Tube.

d) Remove the Bayonet Connector and disconnect the dummy Source Assembly from the Teleflex Cable. Reinstall the Bayonet End Cap and verify that the Selector Ring CANNOT be turned into the 'OPERATE' position.

e) Remove the Bayonet End Cap. Without connecting the dummy Source Assembly to the Teleflex Cable, try to install the Bayonet Connector. Verify that interference between the unconnected Source Assembly and the male connector prevents the Bayonet Connector from being installed.

> **WARNING:** Do not force the Bayonet Connector into the Lock Assembly as this may damage the male connector.

f) Connect the dummy Source Assembly to the Teleflex Cable and install the Bayonet Connector. Turn the Selector Ring into the 'OPERATE' position. Verify that the Bayonet Connector CANNOT be removed from the Lock Assembly.

g) Perform ten test exposures using the dummy Source Assembly. Verify that the Selector Ring snaps cleanly back into the 'LOCK' position at the end of each exposure cycle.

h) Remove Source Guide Tube and perform a swipe test on the S-tube using a pipe cleaner. The test method used should be able to detect any contamination in excess of 4 Bq/cm^2 (0.0001 μ Ci/cm^2).

> **WARNING:** Any projector contaminated in excess of 4 Bq/cm^2 (0.0001 μ Ci/cm^2) shall be quarantined and the cause of the contamination determined. Contact your Radiation Safety Officer for additional instructions. Do not proceed any further unless authorized to do so.

5-3-3 Source Assembly

Return to the Source Changer and inspect the exposed end of the Source Assembly for wear or other damage. Use a GO-NO GO gauge in accordance with Nordion Procedure IS/OP 0046 C000 (See Appendix B). This test shall be completed on the Source Assembly that will be installed in the TITAN.

> **WARNING:** Any Source Assembly failing this test shall not be used. Use of a damaged Source Assembly could result in serious injury or death.

5-3-4 Drive Controls and Source Guide Tube

a) Return the dummy Source Assembly to the TITAN projector and remove the Bayonet Connector.

b) Disconnect the Teleflex Cable from the Source Assembly. Clean and examine the male connector using a GO-NO GO gauge. Refer to Nordion Procedure IS/OP 0046 C000 (Appendix B).

5-4 ANNUAL MAINTENANCE

Annual maintenance shall only be completed by trained personnel and requires the purchase of a TITAN Maintenance Kit. The contents of the kit include an approved lubricant, a thread sealant, nine replacement springs, two spring pins and three replacement cover caps.

> **WARNING:** The following procedure shall only be completed with the C-990 Source Assembly safely stored within a Source Changer. Source transfers shall only be completed by trained and licensed personnel.

5-4-1 Source Transfer Procedure

Refer to Chapter Six and your Source Changer's User's Instructions for procedures to safely transfer and store an active Source Assembly. Check that the source has been properly stored using a survey meter.

Once the active Source Assembly is safely stored in the Source Changer, disconnect it from the Teleflex Cable and replace it with a dummy Source Assembly.

5-4-2 Gamma Ray Projector

Annual inspection consists of the complete breakdown, cleaning and lubrication of the Lock Assembly. It also includes the replacement of several springs within the Lock Assembly.

An exploded view of the Lock Assembly is provided in Figure 5-1. The Lock Assembly has three main components, the Selector Ring, the Outer Plate Subassembly and the Inner Plate Subassembly.

The Outer Plate Subassembly consists of several pins and springs all retained by a Cover Plate. It also includes the Push Button Lock. The Cover Plate is attached using four 0.112(#4)-40 UNC flat head screws.

The Inner Plate Subassembly includes the Actuator Block, the Actuator and the Actuator Spring. These are secured to the Inner Plate by two 0.190(#10)-32 UNF cap screws. There are also three compression springs loosely held within slots in the Inner Plate.

The Selector Ring includes an Actuator Pin and an Interlock Pin. The Actuator Pin is longer than the Interlock Pin and both pins include springs that fit into the Outer Plate

Subassembly. The underside of the Selector Ring includes three nubs that compress springs when the Selector Ring is rotated into the 'OPERATE' position.

> CAUTION: Wear safety glasses during this procedure. Handle all springs with caution as they may fly out of the lock assembly.

a) Use the parts list provided with your maintenance kit to check that you have all the components required to complete the annual maintenance procedure.

b) Retract the dummy Source Assembly into the projector. Verify that the Selector Ring has returned to the 'LOCK' position.

c) Drill out the three screw caps from the Outer Plate of the Lock Assembly. Removing these caps allows access to the three 0.25-20 UNC socket head cap screws that hold the lock assembly to the TITAN.

d) Remove the three socket head cap screws. Remove the complete Lock Assembly. Disassemble it slowly, taking care not to lose any pins or springs.

> NOTE: *It is easier to remove the complete Lock Assembly from the* TITAN *prior to disassembling the Lock Assembly.*

e) Check for cracks or other such damage to the epoxy foam.

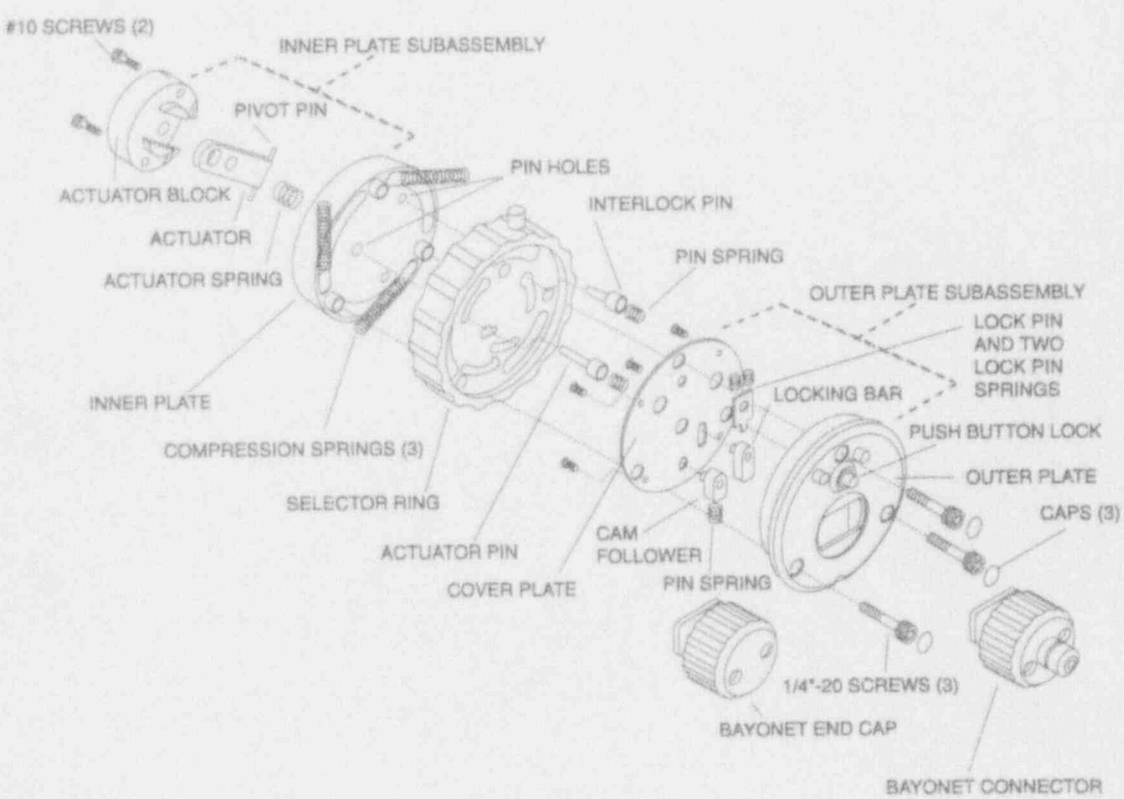

Figure 5-1
Exploded View of Lock Assembly

Inner Plate Subassembly

f) Remove the two screws from the Actuator Block and disassemble it. Clean the Actuator and the Actuator Block. Discard the old Actuator Spring. Check for excessive wear in the Actuator using the dummy Source Assembly. It should be IMPOSSIBLE to pass the locking ball through the Actuator.

g) Clean the Inner Plate.

h) Lubricate the Pivot Pin with Felpro C5A and place the Actuator in the Actuator Block. Ensure that the Spring Counterbore faces the Inner Plate. Install the new Actuator Spring in the Inner Plate. Place the Actuator Block in the register on the Inner Plate, taking care to align the counterbore with the spring. Use the thread sealant provided in the maintenance kit to install the two #10 Cap Screws.

Selector Ring

i) Clean the Selector Ring, the Actuator Pin and Interlock Pin. Check the fit of the pins in their respective slots. They should move freely within the slots and should smoothly engage in their holes. Check for wear around the base of the head of the pins.

j) Check for burrs and sharp edges on the Selector Ring and, if necessary, file them off.

k) Check the condition of the three nubs on the underside of the Selector Ring. Ensure that they are secure within the Selector Ring.

Outer Plate Subassembly

l) Check the operation of the Push Button Lock and replace it if necessary.

m) Remove the four cover plate screws and the cover plate. Use caution as the Cover Plate retains three loaded compression springs.

n) Remove and clean the Locking Bar, Lock Pin and Cam Follower. Clean the Cover Plate and the Outer Plate. Ensure that the slots for the Locking Bar, Lock Pin and and Cam Follower are thoroughly cleaned.

o) Replace the Lock Pin Springs and Cam Follower Spring with the new ones provided in the maintenance kit. Lightly lubricate the pins with Felpro C5A and reinstall them in the Outer Plate. Using the thread sealant provided in the maintenance kit, install the cover plate using the four #4 screws. Ensure that the screws are flush with the surface of the cover plate.

> NOTE: *If the screws protrude from the Cover Plate, they may interfere with the smooth rotation of the Selector Ring.*

p) Lightly lubricate the Inner Plate including the three compression spring slots and the internal surfaces of the Selector Ring. Install new compression springs in the slots of the Inner Plate as shown in Figure 5-1. Leave the free ends of the springs extended from the slots.

> NOTE: *The Selector Ring Parts are precision machined components. Too much grease will cause interference. Use only a very thin film of lubricant.*

q) Align the Pin Slots in the Selector Ring with the Pin Holes in the Inner Plate. Rotate the Selector Ring so that the three nubs engage the exposed compression springs on the Inner Plate. Lower the Selector Ring onto the Inner Plate until the Compression Springs and the Selector Ring snap into position. Verify that the Pin Slots are aligned with the Pin Holes. The Selector Ring should now be in the 'LOCK' position.

r) Rotate the Selector Ring toward the 'OPERATE' position and install the dummy Source Assembly.

s) Lightly lubricate and install the Actuator Pin and the Interlock Pin. The Actuator Pin is longer than the Interlock Pin and goes in the Pin Hole aligned with the end of the Actuator It should not engage its hole at the end of its slot when the Selector Ring is in the 'LOCK' position. The Interlock Pin should engage in its hole.

t) Install new pin springs in the heads of the Actuat~r Pin and Interlock Pin.

u) Lightly lubricate the outer diameter and flange of the Outer Plate Subassembly and mount it on the Selector Ring. Ensure that the Pin Springs are aligned with the holes in the Outer Plate. If necessary, depress the Locking Bar until the Outer Plate snaps into position.

v) Using a thread sealant, reinstall the Lock Assembly using the three 1/4 - 20 socket head cap screws. Torque each screw evenly to 80-90 in- lbs.

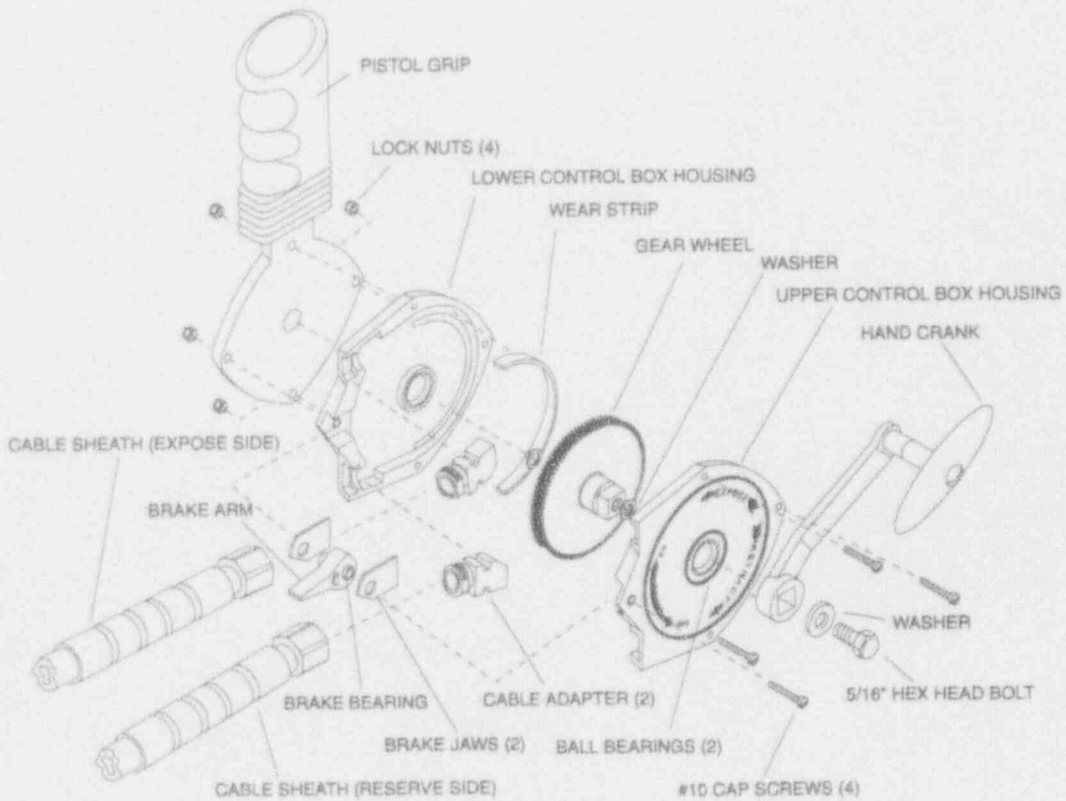

Figure 5-2
Exploded View of Pistol Grip Control

w) Perform a quarterly inspection to verify the function of the reassembled unit and all safety features. Once the quarterly inspection has been successfully completed, install the three Screw Cover Caps using the sealant provided in the maintenance kit.

5-4-3 Drive Controls

Annual inspection of the Drive Controls consists of the complete breakdown, cleaning and lubrication of the Pistol Grip Assembly, the Control Cable Sheaths and the Teleflex Cable.

An exploded view of the Pistol Grip Control is provided in Figure 5-2. Its main components are the Pistol Grip, the Hand Crank, the Control Box Housing, the Gear Wheel, the Brake and the Wear Strip.

a) In a clean area, straighten out the Control Cable Sheath. Pull out and coil the Teleflex Cable until you feel some resistance. This indicates that the Stop Spring has engaged the gear wheel. Do not use excessive force as this may damage the stop spring or the gear wheel.

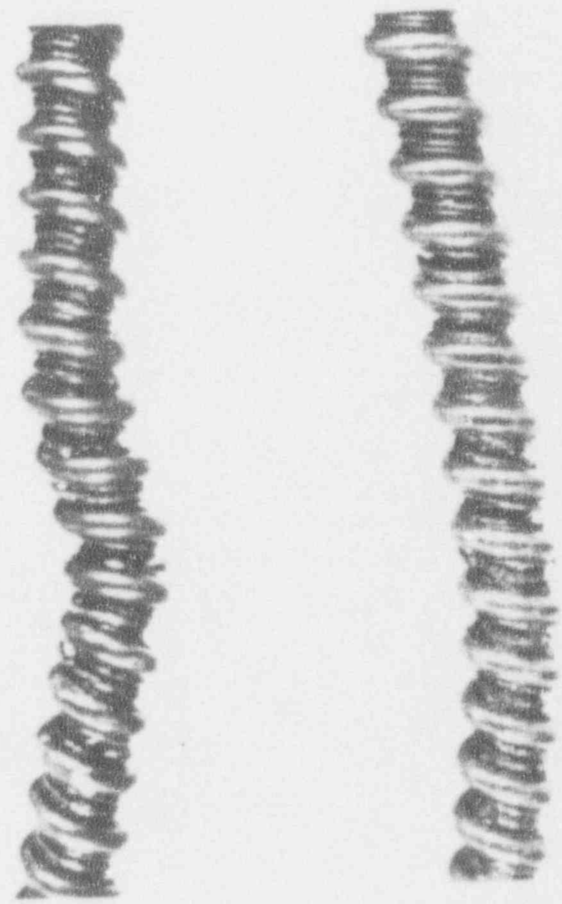

Figure 5-3
Examples of Teleflex Cable Defects

> NOTE: *The Teleflex Cable coil diameter should not be less than 30 cm (12 inches).*

b) Disconnect the Reserve Tube from the Pistol Grip Assembly and remove the Stop Spring. This allows the rest of the Teleflex Cable to be removed from the Pistol Grip Assembly.

c) Examine the Teleflex Cable for kinks and frays. Examples of Teleflex Cable Defects are shown in Figure 5-3. If no damage is observed, clean the drive cables using a brush and a degreaser.

> **WARNING:** Use of damaged Drive Controls increases the risk of a stuck source.

d) Clean the male connector and check that the crimped connection between the male connector and the Teleflex Cable is secure. Examine the male connector using a GO-NO GO gauge. Refer to Nordion Procedure IS/OP 0046 C000 (See Appendix B).

e) Remove the Bayonet Connector from the Control Cable Sheath and check that it swivels freely. Remove the spring pins, clean and lubricate the moving parts with Felpro C5A. Reassemble using the new spring pins provided in the maintenance kit.

f) Label the Cable Sheaths and remove them from the Pistol Grip. (Labels are necessary to replace the Cable Sheaths in the same orientation.)

g) Flush both Cable Sheaths with a solvent degreaser. Blow compressed air through the sheaths until they are dry.

> CAUTION: Perform this operation under well ventilated conditions and in accordance with the degreaser manufacturer's safety procedures.

h) Soak a cloth with solvent degreaser and wipe the external surfaces of the Cable Sheaths while checking for cuts, dents or other such damage. Verify that the Cable Sheaths flex smoothly and easily without crunching. Damage to the stainless steel tube requires that the Cable Sheaths be removed from service. Damage to the outer PVC casing may be repaired using water resistant vinyl tape.

i) Check the area around the Cable Sheath Connectors for damage. Ensure that the Connectors are securely fastened to the Control Cable Sheath.

j) Verify that the Cable Sheaths are 25 ft. (7.6 m) long.

5-4-4 Pistol Grip Control

> CAUTION: Wear safety glasses while performing this procedure. The Pistol Grip Control contains a Wear Strip that may fly out once the Control Box Housing is opened.

a) Remove the 5/16 hex head bolt and the washer from the Hand Crank. This allows the Hand Crank to be removed form the Control Box Housing.

b) Remove the four #10 round head cap screws from the Control Box Housing.

c) While holding the Cable Adapters, **SLOWLY** remove the upper Control Box Housing.

d) Remove and clean the Wear Strip.

e) Remove and degrease the Gear Wheel. Check for bent or broken teeth.

> **WARNING:** Damaged Gear Wheels increase the risk of a stuck source. Replace damaged components prior to use.

f) Remove and clean the Cable Adapters.

h) Remove and clean the brake arm, brake jaws and brake bearing.

i) Clean both halves of the Control Box Housing. Check that the ball bearings turn freely.

j) Install one Cable Adapter in the lower Control Box Housing.

k) CAREFULLY place one end of the Wear Strip against the installed Cable Adapter, and fit the Wear Strip in the track provided in the Control Box Housing.

l) Install the other Cable Adapter.

m) Install Gear Wheel Washers on each side of Gear Wheel Shaft, and install the Gear Wheel in the Control Housing. Take care not to contact the Wear Strip as this may cause it to fly out of the track.

n) Replace the brake jaws, brake arm and brake bearing as shown in Figure 5-2.

o) Install the upper Control Box Housing and check that the Gear Wheel spins freely.

p) Reinstall the four #10 cap screws and lock nuts through the pistol grip and Control Box Housing.

q) Replace the Hand Crank and washer using the 5/16 hex head bolt.

r) Install the Cable Sheath on the Cable Adapter that fits on the 'EXPOSE' side of the Pistol Grip Assembly. It should be replaced in the same orientation it was in at the start of this procedure. Do not install the Reserve Tube.

s) Replace the Bayonet Connector.

t) Lightly oil the Teleflex Cable, place it into the Cable Sheath and feed it into the Control Box Housing. Turn the crank to expose a short length of the Teleflex Cable on the 'RETRACT' side and reinstall the Stop Spring.

u) Reinstall the Reserve Tube.

v) Replace cable ties as necessary.

5-4-5 Source Guide Tubes

a) Soak a cloth with solvent degreaser and wipe the external surfaces of the Source Guide Tubes while checking for cuts, dents or other such damage. Verify that the Intermediate and Terminating Sections flex smoothly and easily without crunching. Damage to the stainless steel tube requires that the Cable Sheaths be removed from service. Damage to the outer PVC casing may be repaired using water resistant vinyl tape.

b) Check the area around the fittings for damage. Ensure that the fittings are securely fastened to the Intermediate and Terminating Sections. Verify that the threads on the fittings are undamaged.

c) Soak a swab in solvent degreaser and run it through the Source Guide Tube until it emerges clean. Ensure that no foreign material remains in the tubes.

d) Drop a dummy Source Assembly through the Source Guide Tube. It should pass freely through the length of the Source Guide Tube and into the Source Stop.

e) Verify that the Intermediate and Terminating Sections are 7 feet (2.1 metre) long.

TABLE 5-1

TITAN Recommended Maintenance Schedule				
Step	LEGEND: X = Required R = Recommended - = Not Required	Daily	Quarterly (Source Change)	Annual
Gamma Ray Projector				
1	Check due date for quarterly and annual inspection	X	-	-
2	Complete radiation survey	X	X	X
3	Check external surfaces for contamination	X	X	X
4	Check labels and general appearance	X	X	X
5	Check function of Push Button Lock	X	X	X
6	Check that handle is secure	X	X	X
7	Check End Cap Storage Tube	X	X	X
8	Check Condition of Source Guide Tube End Cap	X	X	X
9	Check engagement of Bayonet Connector	X	X	X
10	Check for smooth operation of Selector Ring	X	X	X
11	Verify function of Interlock	-	X	X
12	Verify that Selector Ring cannot be turned into OPERATE with End Cap installed	-	X	X
13	Verify that Selector Ring cannot be turned into OPERATE if Source is misconnected	-	X	X
14	Verify that Bayonet Connector cannot be removed with the Selector Ring in the OPERATE position	-	X	X
15	Perform ten test exposures with dummy Source Assembly	-	X	X
16	Check the S-tube for contamination	-	X	X
17	Check contents of maintenance kit	-	-	X
18	Breakdown, clean, replace springs and reassemble Lock Assembly	-	-	X
Source Guide Tube				
1	Check external surface for damage	X	X	X
2	Check fittings	X	X	X
3	Check condition of plastic end caps	X	X	X
4	Check for obstructions	X	X	X
5	Pass dummy Source Assembly	R	X	X

TITAN Recommended Maintenance Schedule				
Step	LEGEND: X = Required R = Recommended - = Not Required	Daily	Quarterly *(Source Change)*	Annual
6	Verify length	R	R	X
Drive Controls				
1	Check external surface for damage	X	X	X
2	Check condition of plastic end caps	X	X	X
3	Check Pistol Grip Control for damage or loose parts	X	X	X
4	Check swivel on Bayonet Connector	R	X	X
5	Clean, inspect and oil Teleflex Cable	-	R	X
6	Remove and clean Cable Sheaths	-	-	X
7	Check Cable Sheath Connectors	R	R	X
8	Verify Length	-	X	X
9	Breakdown, clean and reassemble Pistol Grip Control	-	-	X
10	Check Gear Wheel for damage	-	-	X

Source Assembly Maintenance Summary		
Item	Frequency	Maintenance
1.	Weekly	CLEAN male and female connectors. LUBRICATE female connector.
2.	Weekly	CHECK functioning of source locking collar
3.	Monthly	INSPECT source and drive cable connectors using the test gauge
4.	As required	VERIFY length of teleflex drive cable
5.	As required	CLEA[illegible]ography equipment
6.	As required	RECORD all maintenance and repairs in the log book

Chapter Six

Source Changer

6-1 GENERAL

This section describes the storage and shipping of radioactive Source Assemblies and is applicable to all gamma radiography sources contained in a Source Changer. Source Changers are used to transport new and depleted sources to and from Nordion and the customer.

> **WARNING:** The C-990 may only be shipped in a licensed Source Changer. Ensure that your changer is licensed for the C-990. If in doubt, contact Nordion International Inc.

6-2 CHANGING A SOURCE

6-2-1 Regulations

Canada—In Canada, the governing regulations are the Transportation of Dangerous Goods (TDG) Regulations and the Transport Packaging of Radioactive Materials Regulations, SOR/83-740, including all amendments.

United States—In the United States, the transport of Radiography Projectors and Source Changers is governed by 10 CFR Part 71, and 49 CFR Parts 171 through 179.

International—IAEA Safety Series No. 6, 1985 Edition (As Amended 1990), guides the transportation of radioactive materials internationally.

6-2-2 Prerequisite for Changing a Source

The user must be trained and qualified to carry out a source change. The operator must carry a TLD, direct reading dosimeter, and alarm. The operator must also use a calibrated area radiation survey meter that is capable of measuring from 0.02 mSv/h (2 mrem/h) to 100 mSv/h (10 rem/h).

6-2-3 Receiving Source Changers

When shipping a radioactive package, the consignee must make arrangements for receiving prior to shipment. Upon notification of arrival, the package shall be promptly picked up at the carrier's terminal.

a) Upon receipt of the Source Changer, measure the radiation fields at the surface of the package and at 1 meter. These should not exceed 2 mSv/h (200 mrem/h) at the surface and 100 μ Sv/h (10 mrem/h) at 1 meter.

> **WARNING:** If the package has been damaged and the radiation fields exceed these limits, treat the situation as an **EMERGENCY**. Isolate and secure the package in a restricted area. Contact the appropriate authorities and your Radiation Safety Officer. See 7-2—*Emergency Procedures*.

b) Inspect the Source Changer for damage. Check the condition of the wire seal.

> **WARNING:** If the package has been tampered with or damaged, contact your Radiation Safety Officer for further instructions. Do not proceed further unless authorized to do so.

c) Record the radiation levels in the receiving report. Enter the isotope (iridium 192), activity, **source model number and serial number**. In addition, **record the model number and serial number** of the Source Changer.

d) Read the User's Instructions that accompany the Source Changer.

6-2-4 Source Changer

Many different models of Source Changers may be used for changing a source. Please refer to the User's Guide that comes with the Source Changer.

6-2-5 Shipping

Refer to your Source Changer's User's Instructions for directions on preparing your Source Changer for transport.

> **WARNING:** Never ship a Source Changer that has been tampered with or damaged. Ensure that your Source Changer is licensed to carry the C-990.

Chapter Seven

Safety

7-1 GENERAL

As an operator, you are required to operate the TITAN in accordance with this manual and local/national regulations. The operating instructions and information presented here are intended only for the use of licensed personnel. Read and fully understand this manual before beginning operations. You are advised to:

- operate the equipment according to the instructions contained herein,
- observe all CAUTIONS and WARNINGS,
- ensure proper maintenance of the equipment,
- ensure that **only** properly instructed personnel are permitted to operate the TITAN .

As an operator of the TITAN , you are required to have the qualifications specified jointly by your Local Regulatory body and Principal Owner Licensee.

7-1-1 Safety Features

The TITAN incorporates an important new safety feature for Gamma Ray Projectors. That is, you cannot release the source from the Gamma Ray Projector unless you have secured both the Source Guide Tube and the Drive Controls. This feature significantly reduces the possibility of an accidental source disconnect through operator error.

7-2 EMERGENCY PROCEDURES

7-2-1 Operating Emergencies

> **WARNING:** DO NOT handle an unshielded source. Sources emit high levels of radiation . Close contact may cause severe injury or death.

In the event of an emergency, STAY CALM and consider the proper course of action. The following steps should be completed before any remedial action is taken:

a) **Immediately move away from the exposed source.**

Increasing the distance between yourself and the radiation source decreases your radiation dose. DO NOT PANIC if you cannot immediately shield the source.

b) **Establish a restricted area.**

Using a survey meter, check the restricted area boundaries and adjust them if necessary. Ensure that no one enters the restricted area. Do not leave the restricted area unattended.

c) **Get Assistance**

Remain in the area until help arrives and someone is able to provide assistance. Arrange to have your Radiation Safety Officer (RSO) contacted.

d) **Wait for Qualified Personnel to Arrive**

Well planned remedial action usually makes it possible to retrieve a source with little operator exposure. Source retrieval should only be performed by specially trained personnel. DO NOT ATTEMPT ANYTHING THAT YOU HAVE NOT BEEN TRAINED TO DO. If necessary, contact Nordion International Inc., at **1-800-267-6211**.

7-2-2 Transport Emergencies

The following emergency procedure does not apply to vehicle malfunctions where it can be readily determined that the radioactive material and the TITAN have not been disturbed.

In the event of a transportation emergency, **do not leave the vehicle unattended**. Arrange for a passing motorist to contact police.

When obtaining assistance in the case of an emergency, the information contained in shipping papers and emergency procedures should enable responsible persons to prepare a timely and effective response. Ensure that this information is kept in a readily accessible and visible area in the transport vehicle.

Transport regulations require carriers, organizations or persons transporting a radioactive material package that is involved in an accident to notify the appropriate authority that an accident has occurred in the area under their jurisdiction. Appendix C contains a list of appropriate agencies.

Accidents

In the event of an accident, the following steps should be taken;

a) Render first aid, if necessary.

b) Perform a radiation survey. Set up a restricted area if the source becomes exposed.

c) Notify the police. DO NOT LEAVE THE PACKAGE UNATTENDED. Arrange for a passing motorist to get help. Indicate if an ambulance is required.

d) Notify your Radiation Safety Officer. DO NOT leave the area without ensuring that the police will keep unauthorized personnel outside the restricted area.

e) Arrange for your Radiation Safety Officer to contact the appropriate regulatory agencies (See Appendix C.)

f) Delay clean up until properly trained personnel arrive.

Fire

In the event of a fire, the following steps should be taken;

a) Render first aid, if necessary.

b) Small fires can be extinguished with dry chemical (CO_2) extinguishers and large fires with foam or water from UPWIND, and at a maximum distance. Fumes should be assumed to be toxic. Large fires should be left to trained firemen.

c) Perform a radiation survey. Set up a restricted area if the source becomes exposed.

d) Notify the police. DO NOT LEAVE THE PACKAGE UNATTENDED. Arrange for a passing motorist to get help. Indicate if an ambulance is required.

e) Notify your Radiation Safety Officer. DO NOT leave the area without ensuring that the police will keep unauthorized personnel outside the restricted area.

f) Arrange for your Radiation Safety Office to contact the appropriate regulatory agencies. (See Appendix C.)

g) Delay clean up until properly trained personnel arrive.

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Chapter Eight

Warranty

8-1 TITAN WARRANTY

Nordion International Inc. makes the following warranties with respect to its products:

I. Sealed Sources: —Sealed sources shall conform to current Nordion specifications and shall be free from any material defect in workmanship or materials at the time of delivery.

II. Equipment: Nordion International Inc.—Gamma Ray Projectors and peripheral equipment will be free from any material defect in workmanship or materials for a period of one (1) year from the date of shipment of product to customer.

III. Parts: —Replacement parts supplied by Nordion shall be free from any material defect in workmanship or materials for a period of thirty (30) days from the date of shipment of product to customer.

Nordion's only obligation with respect to the warranties herein shall be to repair, or at its sole discretion, to replace defective products or parts thereof.

Customer shall return product to a Nordion authorized repair centre for repair or replacement, freight prepaid. Customer shall be responsible for preparing the product for shipment in accordance with local laws and regulations.

Under no circumstances should the customer return product to Nordion International Inc. without obtaining a product return authorization (P.R.A.) number from Nordion.

All warranty obligations of Nordion International Inc. shall cease and have no effect if the products are subjected to accident, abuse, misuse, alteration or neglect.

The warranties contained herein are expressly in lieu of and exclude all other express or implied warranties including, but not limited to, warranties of merchantibility and fitness for a particular purpose, use or application.

8-2 TITAN - INSPECTION AND RETURN OF PRODUCTS

All shipments shall be inspected on receipt by the buyer unless otherwise instructed by Nordion International Inc. Any defects shall be promptly communicated to the shipper and Nordion International Inc. in writing within ten (10) days of receipt of the product. No product shall be returned without a Nordion product return authorization (P.R.A.) number. Products returned shall be at the buyer's sole risk and expense. The buyer shall pay a re-stocking charge in respect of such products.

8-3 LIMITATION OF LIABILITY

Nordion's liability to the buyer for damages, howsoever caused, shall not exceed payment actually received by Nordion International Inc. for the product furnished, or to be furnished, as the case may be, and in no event shall Nordion International Inc. be liable for indirect, contingent, special or consequential damages (including loss of profit).

8-4 INDEMNITY

Customer shall indemnify Nordion for, and save Nordion harmless from, all losses, costs or damages suffered or incurred in respect of damage or destruction of property, personal injury or death which may be caused by or arise from, either wholly or in part, the use of products or customer's negligence, acts or omissions.

Appendix A

Troubleshooting

SYMPTOM	PROBLEM	SOLUTION
Cannot turn Selector Ring to 'OPERATE'.	Key is locked.	UNLOCK key.
	Bayonet Connector is not connected properly.	CHECK first to ensure that Source Assembly is properly connected. CONNECT Bayonet Connector. See 3-4-3 Operation Procedures "Connecting the Drive Controls."
	Source Guide Tube is not connected.	CONNECT Source Guide Tube. See 3-4 Operation Procedures.
Selector Ring does not easily turn to the 'OPERATE' position.	Teleflex Cable is pushing against inner plate in Lock Assembly.	RELIEVE compression by turning Pistol Grip Control crank clockwise.
	Lock is contaminated with foreign material.	CLEAN projector. See Chapter Five Maintenance
Selector Ring snaps back to the 'LOCK' position when turned to 'OPERATE'.	Teleflex Cable has disengaged the Stop Pin from the Selector Ring.	RELIEVE tension by turning Pistol Grip Control Crank counterclockwise.
Selector Ring does not snap back automatically to 'LOCK' when the source is retracted.	Source is not fully retracted.	RETRACT source fully.
	Source Assembly or Teleflex Cable is damaged.	REPLACE damaged Source Assembly or Teleflex cable. Always use a survey meter when approaching the projector. See 7-2 Emergency Procedures.
	Lock Assembly is contaminated with foreign material.	CLEAN projector. See Chapter Five Maintenance.

SYMPTOM	PROBLEM	SOLUTION
Cannot connect Teleflex Cable to Source Assembly.	Source Assembly Lock Pin has seized.	LUBRICATE Source Assembly Lock Pin. See Chapter Five Maintenance.
	Source Assembly Connector or Teleflex Cable Connector is damaged.	REPLACE Source Assembly and/or Teleflex Cable.
Cannot connect Bayonet Connector to the Gamma Ray Projector.	Teleflex Cable has not been connected first to the Source Assembly.	CONNECT Teleflex Cable to Source End Connector.
Cannot disconnect Bayonet Connector.	Source is not fully shielded.	RETURN source to fully shielded position by turning Pistol Grip Control Crank.
	Selector Ring has not fully retracted to the 'LOCK' position.	ROTATE the Selector Ring completely clockwise. Always use a survey meter when approaching the projector.
	Push Button Lock is locked.	UNLOCK Push Button Lock with key.
Pistol Grip Control is difficult to turn.	Brake is engaged on Pistol Grip Control.	UNLOCK Brake.
	Pistol Grip Control is contaminated with foreign material.	CLEAN Pistol Grip Control and replace any damaged parts. See Chapter Five Maintenance.
	Teleflex Cable is kinked, frayed or otherwise damaged.	REPLACE Teleflex Cable. See Chapter Five Maintenance.
	Cable Sheath or Source Guide Tube is kinked, crushed or otherwise damaged.	ADJUST Cable Sheath or Source Guide Tube. See Chapter Five Maintenance.

Appendix B

IS/DS 0046 C000

NORDION
INTERNATIONAL INC.
447 March Road, P.O. Box 13500, Kanata, Ontario, Canada, K2K 1X8
Tel: (613) 592-2790, Telex: (053) 4162, Telefax (613) 592-6937

OPERATING PROCEDURE

IS/OP 0046 C000

Maintenance Instructions for Cable-Type Radiography Sources

DATE	REV.	COMMENTS/AFFECTED PAGE	PREPARED BY	REVIEWED BY	APPROVED BY
90 JUL	0	Original Issue	A.W. Gunter	W.H. Pettipas	G. A. Burbidge
				P.L. Larabie	
93 AUG	A	DC 90614	M. Krzaniak	B. Menna	G. A. Burbidge
93 SEP	B	DC 90627	B. Menna	M. Krzaniak/	G. A. Burbidge
			B Menna	P. Larabie	GAB
				MKrzaniak	
				PL	

NOTE:
The portion of this text affected by the changes is indicated by a vertical line in the margins of the pages.

1 SCOPE

This document describes the maintenance procedures for Nordion cable-type radiography sources. The test gauge (Figures 3 and 4) is used to test the operation of D898 and D899 connectors for the cable-type radiography sources listed in Table 1.

Table 1

Source Type	Female Connector	Male Connector
C-337	D898F	D898
C-340	D899	D898
C-343	D899	D898
C-359	D899	D898
C-361	D899	D898
C-990	D899	D898

2 GENERAL INSTRUCTIONS FOR CONNECTORS AND SOURCES

It is recommended that you perform the following steps as a matter of habit. If your radiography equipment is in high use, it is advisable to perform these steps more frequently than indicated.

Table 2 summarizes these detailed procedures.

WARNING

> **Always check that the source is secured in its shielded position in the Gamma Ray Projector or Source Changer before performing any maintenance action.**

(1) Clean both male and female connectors weekly, using any high grade commercial organic solvent.

(2) Lubricate the female connector weekly, using a light oil such as WD-40.

(3) Check weekly that the spring loaded locking collar is functioning properly (see Figure 1). Ensure that it returns to the fully closed position after it has been released.

Table 2
Maintenance Summary

Item	Frequency	Maintenance
1.	Weekly	**CLEAN** male and female connectors. **LUBRICATE** female connector.
2.	Weekly	**CHECK** functioning of source locking collar
3.	Monthly	**INSPECT** source and drive cable connectors using the test gauge
4.	As required	**VERIFY** length of teleflex drive cable
5.	As required	**CLEAN** radiography equipment
6.	As required	**RECORD** all maintenance and repairs in the log book

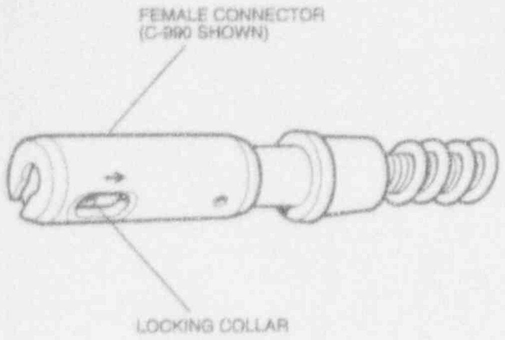

Figure 1

Operation of locking collar

4) Inspect the source end connector and drive cable male connector monthly according to the procedures of Section 3. Remove the source or drive cable from service if it has been damaged or fails any of the tests described in Section 3.

...RNING

> **Never use your Nordion source with anything other than a Nordion male connector on the end of your drive cable. It is dangerous to use other manufacturers' male connectors with Nordion sources.**

5) Verify that the length of the remote control drive cable is correct (see Figure 2). Disconnect the reserve side of the remote control sheath from the end plug. For a 25 foot remote control, when the drive cable is fully retracted, the end of the teleflex cable should be 8 inches short of the end of the reserve sheath. Remember to install the stop-spring when adjusting or replacing the drive cable. This procedure is particularly important for users of the Nordion TITAN Gamma Ray Projector or other projectors that automatically secure the source. The cable length must be checked once on existing equipment and then only when the drive cable is replaced.

6) Keep your drive controls and source guide tubes clean and dry. Always clean your accessories inside and out after working in a harsh environment.

7) Always store your radiography equipment in a clean, dry and secure storage area.

8) Follow the maintenance procedures and user's instructions in your gamma projector's operating manual. Record all maintenance in the equipment log book.

9) Call Nordion Customer Service if you have questions or problems with any of these procedures. 1-800 267-6211.

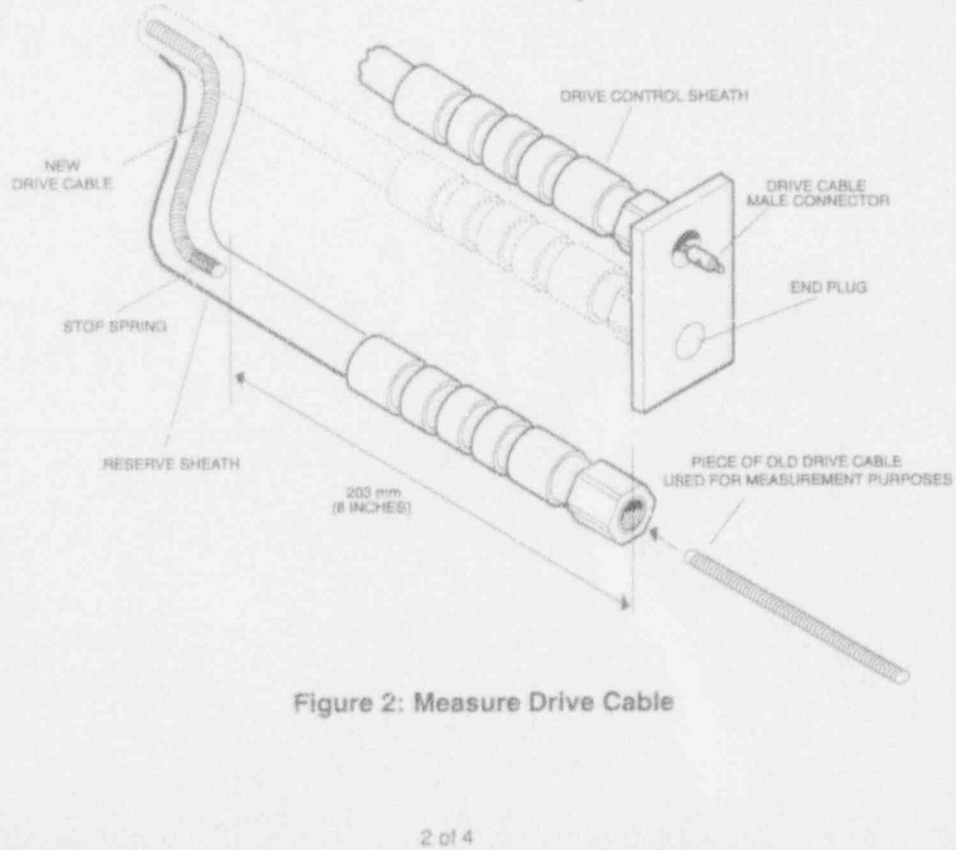

Figure 2: Measure Drive Cable

3 TEST GAUGE INSTRUCTIONS

CAUTION

Do not attempt to force the connectors through any of the holes or slots of the test gauge. This may damage the connector and cause unnecessary wear to the test gauge.

Check the source connector and the drive cable connector monthly using the test gauge. The connectors must pass all of the following tests. If a connector fails one or more of these tests, it must be removed from service immediately.

3-1 Male Connector (See Figure 3)

NOTE

Use the D898 side of the test gauge to perform all of the tests on the male D898 connectors.

(1) Place the male connector perpendicular to the plane of the test gauge.

(2) Check that the ball DOES NOT pass through hole "A". Should the ball pass through hole "A", this would indicate excessive wear on the ball.

(3) Place the male connector perpendicular to the plane of the test gauge.

(4) Check that the neck DOES NOT pass through slot "B". Should the neck pass through slot "B", this would indicate excessive wear on the neck.

(5) Place the male connector parallel to the plane of the test gauge.

(6) Check that the connector DOES NOT go through opening "C". Should the connector pass through opening "C", this would indicate that the neck had been stretched, due to excessive pull force.

3-2 Female Connector (See Figure 4)

NOTE

Use the D899 side of the test gauge to test all female connectors listed in Table 1.

(1) Place the female connector perpendicular to the plane of the test gauge.

(2) Check that the connector DOES pass through hole "D". Should the connector not pass through hole "D", this would indicate stretch of the connector due to excessive pull force.

NOTE

On the C-990 source assembly there is a roll pin pressed through the source just above the notch in the connector. It is not necessary for this pin to pass through hole "D" on the gauge.

(3) Place the female connector parallel to the plane of the test gauge.

(4) Check that the connector DOES NOT fit on pin "E". Should the connector fit on pin "E", this would indicate excessive wear of the female connector.

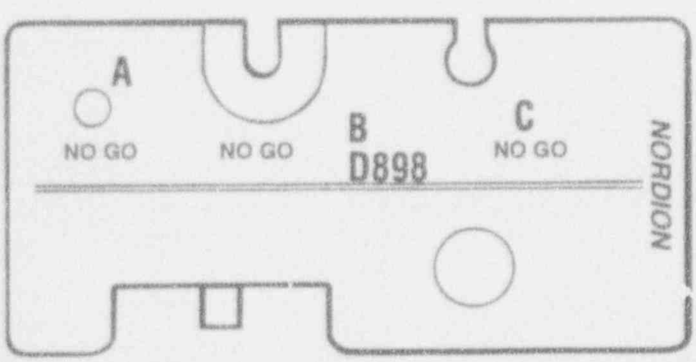

Figure 3

Gauge Orientation for Male Connectors

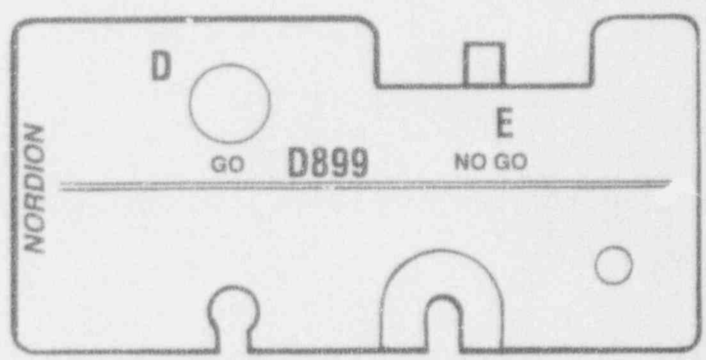

Figure 4

Gauge Orientation for Female Connectors

4 REFERENCES

1. Nordion Engineering Drawing, A16843, *D898, D899 Connector Test Gauge.*

2. Nordion Engineering Drawing, A17714, *Connector Body Female (D899).*

3. Nordion Engineering Drawing, A16828, *Connector Body Female (D898F).*

4. Nordion Engineering Drawing, A16832, *D898 Male Connector, Cable End.*

Appendix C

Regulatory Agencies

C-1 CANADA

AREA	REPRESENTATIVE	PLACE	TELEPHONE	
National	Atomic Energy Control Board	Ottawa	613	995-0479
	Transport Canada	Ottawa	613	996-6666
	Environment Canada	Hull	819	997-3742
Newfoundland	Dept. of Employment & Labour Relations	St. John's	709	729-2644
Prince Edward Island	P.E.I. Dept. of Health & Social Services	Charlottetown	902	368-4996
Nova Scotia	N.S. Dept. of Health	Halifax	902	424-4077
New Brunswick	N.B. Dept. of Health - Lab	Fredericton	506	453-2067
	N.B. Dept. of Health	Fredericton	506	453-2933
	St. John Regional Hospital	St. John	506	648-6852
Quebec	Atomic Energy Control Board	Laval	514	667-6360
Ontario	Ontario Ministry of Labour	Toronto	416	235-5922
	Atomic Energy Control Board	Mississauga	416	821-7760
Manitoba	Department of Environment, Work Place Safety and Health	Winnipeg	204	945-7008
			204	945-7039
			204	944-4888
Saskatchewan	Department of Labour	Regina	306	787-4538
			306	933-7775
	University of Saskatchewan	Saskatoon	306	966-4675
Alberta	Compliance Information Centre	Edmonton	403	422-9600
	Atomic Energy Control Board	Calgary	403	292-5181
	Alberta Labour	Edmonton	403	427-2691
British Columbia	B.C. Ministry of Health	Vancouver	604	660-6633
	Environmental Health Protection Services	Vancouver	604	660-6633
	Radiation Protection Services	Vancouver	604	660-6633
Northwest Territories	N.W.T. Pollution Control Division	Yellowknife	403	873-7654
	N.W.T. Occupational Health & Safety Division	Yellowknife	403	873-7468

C-2 UNITED STATES

AGREEMENT STATES

A state that has an agreement with the Nuclear Regulatory Commission allowing the state to regulate certain activities using radioactive materials, for example, gamma radiography using iridium-192 or cobalt-60 sources.

Alabama 205-261-5313
Bureau of Radiological Health
Environmental Health Administration
Room 314, State Office Building
Montgomery, Alabama 36130

Arizona 602-255-4845
Arizona Radiation Regulatory Agency
4814 South 40th Street
Phoenix, Arizona 85040

Arkansas 501-661-2301
Division of Radiation Control and Emergency Management
Arkansas Department of Health
4815 West Markham Street
Little Rock, Arkansas 72205-3867

California 916-445-4931
916-322-2073
Radiologic Health Branch
Department of Health
714 P Street, Room 498
Sacramento, California 95814

Colorado 303-331-8480
Radiation Control Division
Office of Health Protection
Department of Public Health
4210 East 11th Avenue
Denver, Colorado 80220

Florida 904-487-1004
Office of Radiation Control
Department of Health and Rehabilitative Services
1317 Winewood Boulevard
Tallahassee, Florida 32399-0700

Georgia 404-894-5795
Radiological Health Section
Department of Human Resources
Room 600 - 878 Peachtree Street
Atlanta, Georgia 30309

Idaho 208-334-5879
Compliance Section
Idaho Department of Health and Welfare
Statehouse, Boise, Idaho 83720

Illinois 217-785-9868
Department of Nuclear Safety
1035 Outer Park Drive
Springfield, Illinois 62704

Iowa 515-281-3478
Bureau of Radiological Health
Iowa Department of Health
Lucas State Office Building
Des Moines, Iowa 50319

Kansas 913-296-1542
Bureau of Air Quality and Radiation Control
Department of Health and Environment
Forbes Field, Building 321
Topeka, Kansas 66620

Kentucky 502-564-3700
Radiation Control Branch
Department of Health Services
Cabinet for Human Resources
275 East Main Street
Frankfort, Kentucky 40621

Louisiana 504-925-4518
Nuclear Energy Division
Office of Air Quality and Nuclear Energy
P O. Box 14690
Baton Rouge, Louisiana 70898

Maryland 301-631-3300
Center for Radiological Health
Department of the Environment
2500 Broening Highway
Baltimore, Maryland 21224

Mississippi 601-354-6657/6670
Division of Radiological Health
State Board of Health
3150 Lawson Street
P.O. Box 1700
Jackson, Mississippi 39215-1700

Nebraska 402-471-2168
Division of Radiological Health
State Department of Health
301 Centennial Mall South
P.O. Box 95007
Lincoln, Nebraska 68509

Nevada 702-687-5394
Radiological Health Section
Health Division
Department of Human Resources
505 East King Street, Room 202
Carson City, Nevada 89710

New Hampshire 603-271-4588
Radiological Health Program
Bureau of Environmental Health
Division of Health Services
Health and Welfare Building,
Hazen Drive, Concord,
New Hampshire 03301

New Mexico 505-827-2959
Community Services Bureau
Environmental Improvement Division
Department of Health and Environment
1190 St. Francis Drive
Santa Fe, New Mexico 87505

New York 518-473-0048
Division of Policy Analysis and Planning
2 Rockefeller Plaza
Albany, New York 12223

North Carolina 919-741-4283
Department of Environment, Health and Natural Resources Division of Radiation Protection
P.O. Box 27687 Raleigh,
North Carolina 27603-7687

North Dakota 701-224-2348
Division of Environmental Engineering
Radiological Health Program
State Department of Health
1200 Missouri Avenue
Bismarck, North Dakota 58502-5520

Oregon 503-229-5797
Radiation Control Section
Department of Human Resources
1400 South West Fifth Avenue
Portland, Oregon 97201

Rhode Island 401-277-2438
Radioactive Materials and X-Ray Programs
Rhode Island Department of Health
Cannon Building, Davis Street
Providence, Rhode Island 02908

South Carolina 803-734-4700
Bureau of Radiological Health
South Carolina Department of Health and Environmental Control
J. Marion Sims Building
2600 Bull Street, Columbia,
South Carolina 29201

Tenn. ee 615-741-7812
Division of Radiological Health
TEKRA Building, 150 9th Avenue, N.
Nashville, Tennessee 37219-5404

Texas 512-835-7000
Bureau of Radiation Control
Texas Department of Health
1100 W. 49th Street
Austin, Texas 78756

Utah 801-538-6734
Bureau of Radiation Control
State Department of Health
288 North 1460 West
P.O. Box 16690
Salt Lake City, Utah 84116-0690

Washington 206-586-8949
Office of Radiation Protection
Department of Social Health Services
Mail Stop LE-13
Olympia, Washington 98504

Updated lists of state addresses and telephone numbers are available upon request from:

Office of Governmental and Public Affairs USNRC
Washington D.C. 20555
(301) 492-0326

United States Nuclear Regulatory Commission Regional Offices

Region	Address	Telephone
I	631 Park Avenue, King of Prussia, Pennsylvania 19406	215-337-5000
II	101 Mariett^ Street, NW, Atlanta, Georgia 30323	404-331-4503
III	799 Roosevelt Road, Glen Ellyn, Illinois 60137	312-795-5500
IV	611 Ryan Plaza Drive, Arlington, Texas 76011	817-860-8100
V	1450 Maria lane, Walnut Creek, California 94596	415-943-3700

APPENDIX 2.10-C: Special Form Certificate Number CDN/0001/S

Certification

Atomic Energy Control Board | Commission de contrôle de l'énergie atomique

SPECIAL FORM RADIOACTIVE MATERIAL CERTIFICATE NO. CDN/0001/S, (REV. 12)

30-A2-187-0 September 3, 1992

The Atomic Energy Control Board hereby certifies that the capsules, as described below, have been demonstrated to meet the regulatory requirements prescribed for special form radioactive material as defined in the Canadian Transport Packaging of Radioactive Materials Regulations and in the IAEA Regulations*, subject to the following provisions.

CAPSULE IDENTIFICATION

Nordion International Inc., Capsule Assemblies as listed below.

CAPSULE DESCRIPTION

The radiography capsule assemblies, as listed below, consist of single-walled encapsulated Type 316L stainless steel construction with external dimensions 19.7 mm long by 4.75 mm diameter. The capsules are crimped onto a 3.2 mm diameter 7-19 or a 2.34 mm diameter 7-7 stainless steel aircraft cable assembly or 3.6 mm diameter Nuclear Iberica cable assembly, incorporating a variety of lengths, locking collars and end connectors which are specific to each capsule and their respective drawings:

CAPSULE	DRAWING	CAPSULE	DRAWING
C-141	A07123 Rev. A	C-262	A11542 Rev. C
C-142	A07117 Rev. A	XC-266	A12671 Rev. D
C-148	A07118 Rev. A	C-267	A12668 Rev. D
C-169	A07122 Rev. B	C-272	A12950 Rev. D
C-175	A07116 Rev. C	C-291	A13796 Rev. C
C-187	A07119 Rev. A	C-313	A16730 Rev. B
C-192	A07120 Rev. D	C-337	A16827 Rev. G
XC-237	A07737 Rev. B	C-340	A16833 Rev. H
C-245	A09425 Rev. G	C-343	A17715 Rev. D
C-259	A11539 Rev. F	C-357	K121110001 Rev. A
C-260	A11540 Rev. C	C-359	K121104002 Rev. B
C-261	A11541 Rev. E	C-361	K121104003 Rev. B
		C-369	K121104004 Issue B
		C-990	K122213-600 Issue 1

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

The following capsule assemblies are also authorized:

Capsule	Drawing No.	Length (mm)	Diameter (mm)	Encapsulation
C-164	A05488,(Rev.D)	14.9	3.99	single
C-204	A02029,(Rev.E)	15.0	5.5	single
C-181	A05800,(Rev.D)	16.5	11.6	single
C-349	A18351,(Rev.D)	[illegible].1	4.57	single
C-352	A18388,(Rev.C)	13.5	8.8	doubl[illegible]
XC-234	A07516,(Rev.E)	9.78	6.1	single

AUTHORIZED RADIOACTIVE CONTENTS

Each capsule is authorized to contain not more than 1850 GBq (50 Ci) of cobalt-60 or 5550 GBq (150 C[illegible]) of iridium-192, in the form of solid metal pellets.

EXPIRY DATE

This certificate expires May 31, 1996

W.R. Brown
Director
Radioisotopes and Transportation Division

REFERENCE

* International Atomic Energy Agency Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1973 Revised Edition (as amended).

NOTES

1. Revision 4: June 7, 1983. Capsule C-343 added. Certificate renewed.
2. Revision 5: September 22, 1986. Certificate renewed.
3. Revision 6: April 3, 1987. Capsules C-349 and C-352 added.
4. Revision 7: April 18, 1989. Capsules C-357 and C-359 added. Certificate renewed.
5. Revision 8: August 24, 1989. Capsule C-361 added.
6. Revision 9: February 15, 1990. Capsule XC-234 added.
7. Revision 10: November 20, 1990. Capsule description revised and capsule C-369 added.
8. Revision 11. May 13, 1992. Certificate renewed.
9. Revision 12. September 3, 1992. Capsule C-990 added.

3 THERMAL EVALUATION

3.1 Discussion

The Titan does not include a fireshield or insulation of any kind. Heat dissipation is via natural convection from the surface of the package. All materials used in the package continue to be effective over the temperature range expected during transport.

The only material vulnerable to the fire test is the epoxy foam. However, this is of little consequence as its only function is to provide additional support to the depleted uranium shield during the 9 m drop test. After the drop test, the depleted uranium shield will be adequately secured by the actuator block and exit port. No increase in radiation field is expected relative to the dropped condition.

The titanium and depleted uranium components of the Titan all have melting points in excess of 800 °C. They will not be significantly affected by the regulatory fire test.

The radioactive contents meet the requirements for Special Form radioactive material. Therefore, they will not be significantly affected by the regulatory fire test.

3.2 Summary of Thermal Properties of Materials

The melting points of the materials used in the Titan are presented below. No value is provided for the epoxy foam as it is assumed that it has been lost during the fire test.

Material	Melting Point (°C)	Reference
Depleted Uranium	1130	[13]
Steel	1427	[13]
Titanium	1690	[13]
Iridium	2454	[15]
Lead	327	[13]

Where applicable, additional thermal properties are presented in the body of this chapter.

3.3 Technical Specification of Components

Component technical specifications are described in chapter 8.

3.4 Thermal Evaluation for Normal Conditions of Transport

Steady State Temperature

In still air, and for smooth surfaces, Jennings suggests a heat transfer coefficient of 8 W/m^2C.[9] 120 Ci of Ir-192 generates about 1 W of heat. It is assumed that heat is transferred via all four sides and the top surface of the Titan. It is also assumed that the ambient temperature is 38 °C.

The areas of each of the surfaces are calculated to be:

$$A_{top} = 4.84*(10) = 48.4 \text{ in}^2 = 0.031 \text{ m}^2$$

$$A_{sides} = 2*(7)*(10) = 140. \text{ in}^2 = 0.090 \text{ m}^2$$

$$A_{ends} = 2*\left(\frac{4.84+5.78}{2}\right)*(7) = 74.3 \text{ in}^2 = 0.048 \text{ m}^2$$

$$A_{total} = \quad = 263 \text{ in}^2 = 0.17 \text{ m}^2$$

Under these conditions, the surface temperature of the unit is found to be:

$$T_S = Q/hA + T_A = 1/(8)(0.17) + 38 = 38.7\ ^\circ C$$

As this is less than 50 °C, this requirement of the regulations is satisfied.

Solar Heating

To calculate the surface temperature of the Titan under solar heat load conditions, it is assumed that the top surface is subjected to a heat flux of 800 W/m^2 and that the two sides, the front, and the back of the Titan each receive 200 W/m^2.

TOP:	800 W/m^2 (1x .031 m^2)	=	25. W
SIDES:	200 W/m^2 (2x .045 m^2)	=	18. W
FRONT/BACK:	200 W/m^2 (2x .024 m^2)	=	9.6 W
	TOTAL	=	53 W

This heat is dissipated by natural convection and by radiation. In mathematical form:

$$Q = hA(T_s - T_a) + \sigma EA\ (T_s^4 - T_a^4)$$

where:
- Q = the heat dissipated (54 W)
- A = the total surface area (0.17 m^2)
- h = the heat transfer coefficient = 8 W/m^2C [9]
- T_s = the surface temperature
- T_a = the ambient temperature = 38 °C = 311 K
- σ = Stefan-Boltzman constant = 5.669E-8 W/m^2K^4
- E = emissivity of titanium = 0.31 [10]

Solving yields a surface temperature of 68 °C. This temperature will have no significant effect on the package or its contents.

3.5 Hypothetical Accident Thermal Evaluation

The only material vulnerable to the fire test is the epoxy foam. However, this is of little consequence as it's only function is to provide additional support to the depleted uranium shield during the 9 m drop test. After the drop test, the depleted uranium shield will be adequately secured by the actuator block and exit port. No increase in radiation field is expected relative to the dropped condition.

The titanium and depleted uranium components of the Titan all have melting points in excess of 800 °C. They will not be significantly affected by the regulatory fire test.

The radioactive contents meet the requirements for Special Form radioactive material. Therefore, they will not be significantly affected by the regulatory fire test.

3.6 Appendix

There are no appendices to this chapter.

4. CONTAINMENT

4.1 Containment Boundary

The C-990 meets the requirements for Special Form radioactive material and is the containment system. Appendix 2.10-C includes a copy of the Special Form certificate for the C-990.

There are no penetrations into the C-990. It is a welded capsule.

Full scale testing has shown the C-990 to be effectively retained in the shield during the tests for the accident conditions of transport.

4.2 Containment Requirements for Normal Conditions of Transport

The C-990 meets the requirements for Special Form radioactive material. This demonstrates its ability to retain its contents under the normal conditions of transport.

4.3 Containment Requirements for Accident Conditions of Transport

The C-990 meets the requirements for Special Form radioactive material. This demonstrates its ability to retain its contents under the accident conditions of transport.

4.4 Appendix

There are no appendices to this chapter.

5. SHIELDING EVALUATION

5.1 Discussion and Results

The design of the radiation shield for the Titan is described in Appendix 5.5-A. The shield has been optimized with respect to its weight. The method for generating the shield is described in appendix 5.5-A.

The Titan is designed for the maximum radiation fields listed below:

i) 200 mrem/h on contact with the surface of the unit;
ii) 50 mrem/h 50 mm from the surface of the unit
iii) 2 mrem/h 1 m from the surface of the unit.

The critical requirement is ii). Satisfying this requirement means that the other two are satisfied as well.

The design of the depleted uranium shield is described in Appendix 5.5-A. The results of the radiation surveys are found in Table 5.1. For normal conditions of transport, the maximum field on contact with the surface was found to be 190 mrem/hr and the maximum transport index was found to be 2.6. These fields are within the regulatory limits for transport.

Following the tests for accident conditions of transport, the shifting of the radiation shield resulted in a maximum radiation field of 1500 mrem/hr on contact, when the survey results are extrapolated to 120 Ci. (The actual radiation survey was done using a 72 Ci source.[5]) This is equivalent to a field of about 19 mrem/hr, 1 meter from the surface. This is significantly less than the 1000 mrem/hr allowed by the regulations.

As mentioned earlier, the Titan failed the 50 mrem/h requirement and new shields are being fabricated. An additional 0.7 kg (1.5 lb) of shielding will be added. This will decrease the values of Table 5.1 by a factor of 2.

Table 5.1 Summary of Maximum Dose Rates (mrem/hr)

	Package Surface			3 feet from Surface of Package		
NORMAL CONDITIONS	Side	Top	Bottom	Side	Top	Bottom
Gamma	190	175	145	1.5	2.6	1.9
Neutron	0	0	0	0	0	0
Total	190	175	145	1.5	2.6	1.9
HYPOTHETICAL ACCIDENT CONDITIONS	Side	Top	Bottom	Side	Top	Bottom
Gamma	1500[1]	420	200	19	6.1	2.6
Neutron	0	0	0	0	0	0
Total	1500	420	200	19	6.1	2.6

NOTES: 1) The maximum radiation field was observed at the lock assembly. The maximum field on contact with the side of the unit was found to be 460 mrem/hr and the field on contact with the front of the unit was found to be 60 mrem/hr.
2) Values 3 feet from the package were calculated using the inverse square law.

5.2 Source Specification

5.2.1 Gamma Source

The Titan is designed to transport 120 Ci of Ir-192 all contained in the C-990 Special Form Sealed Source. For the purpose of this safety analysis report, one curie Ir-192 is defined as the activity needed to produce 0.55 R/h at one meter.

The photon energies emitted from Ir-192 are summarized in Table 5.2. 99% of the radiation field is due to photon energies greater than 600 keV.

5.2.2 Neutron Source

Neutron sources are not shipped in the Titan.

5.3 Model Specification

The design of the radiation shield is discussed in Appendix 5.5-A.

5.4 Shielding Evaluation

The radiation shield has been evaluated by radiation surveys taken before and after the tests for accident conditions of transport. The results are found in reference [5] and are summarized in Table 5.1.

Table 5.2. Gammay Decay Source Strength for Ir-192.[17]

$^{192}_{77}$Ir(73.831 8 d)

Mode: β-(95.4 1 %), ϵ(4.6 1 %)
Δ: -34857 5 keV
SpA: 9211.3 Ci/g
Prod: ^{191}Ir(n,γ); ^{192}Os(d,2n)

Photons (^{192}Ir)

⟨γ⟩=813 7 keV

γ_{mode}	γ(keV)	γ(%)†
Os L_ℓ	7.822	0.027 3
Pt L_ℓ	8.266	0.076 7
Os L_α	8.904	0.60 4
Os L_η	9.337	0.0083 5
Pt L_α	9.435	1.64 9
Pt L_η	9.975	0.0270 13
Os L_β	10.469	0.63 3
Pt L_β	11.174	1.77 11
Os L_γ	12.213	0.113 11
Pt L_γ	13.025	0.317 25
Os $K_{\alpha2}$	61.485	1.16 5
Os $K_{\alpha1}$	63.000	2.00 8
Pt $K_{\alpha2}$	65.122	2.66 7
Pt $K_{\alpha1}$	66.831	4.56 12
Os $K_{\beta1}$'	71.313	0.69 3
Os $K_{\beta2}$'	73.643	0.174 7
Pt $K_{\beta1}$'	75.634	1.59 4
Pt $K_{\beta2}$'	78.123	0.415 11
γ_βE2+21%M1	136.34347 18	0.181 8
γ_β[E1]	177.00 3	0.0073 7
γ_ϵE2+9.1%M1	201.3805 6	0.455 10
γ_ϵE2	205.79581 6	3.18 7
γ_ϵ[[illegible]+E2]	219.221 7	~0.0016
γ_ϵE2+5.8%M1	283.2671 6	0.252 14
γ_βE2+1.9%M1	295.9582 1	28.3 5
γ_βE2+1.8%M1	308.45689 11	29.3 5
γ_βE2	316.50789 11	83.0 17
γ_ϵE2+17%M1	329.348 7	0.0160 22
γ_ϵE2	374.5204 8	0.709 14
γ_βM1+E2	416.4714 3	0.667 13
γ_ϵ[E2]	420.601 7	0.064 6
γ_βE2	468.07151 18	47.7 10
γ_ϵE2+1.5%M1	484.6473 4	3.13 6
γ_β	485.60 19	0.0022 9
γ_ϵE2	489.0626 6	0.432 9
γ_βE2	588.5845 5	4.47 9
γ_βE1	593.48 3	0.043[illegible] 14
γ_βE2+28%M1	604.41463 12	8.23 14
γ_βE2	612.4[illegible]561 [illegible]	5.34 9
γ_ϵ[E2]	703.86[illegible] 7	0.0058 13
γ_βE2	884.5418 5	0.284 6
γ_βE1	1061.55 3	0.0523 10
γ_βE2	1090.01 19	0.0011 4
γ_β	1378.05 3	0.0016 4

† uncert(syst): 3.1% for ε, 0.47% for β-

Atomic Electrons (^{192}Ir)

⟨e⟩=45.2 4 keV

e_{bin}(keV)	⟨e⟩(keV)	e(%)
11 - 60	1.44	10.1 6
61 - 110	0.099	0.154 7
122 - 165	0.998	0.767 18
174 - 217	1.102	0.562 8
218	4.15	1.91 5
219	2.2×10^{-5}	$\sim1\times10^{-5}$
230	4.07	1.77 5
236	0.011	<0.009
238	10.6	4.46 11
241 - 284	2.49	0.882 14
293 - 294	0.637	0.217 6
295	1.88	0.639 17
296 - 302	0.647	0.218 5
303	4.52	1.49 4
304	0.0003	<0.0002
305	1.86	0.608 17
306 - 312	0.326	0.1063 20
313	1.15	0.365 10
314 - 362	1.04	0.33 3
364 - 375	0.01519	0.00412 6
390	3.96	1.02 3
398 - 421	0.331	0.081 5
456 - 489	1.88	0.411 6
510 - 534	1.52	0.290 4
575 - 612	0.474	0.0801 14
630 - 665	0.00035	5.5 12 $\times10^{-5}$
690 - 739	0.00013	1.8 5 $\times10^{-5}$
754 - 768	6.7×10^{-6}	$\sim9\times10^{-7}$
871 - 885	0.00349	0.000400 8
977 - 1012	0.00088	8.9 3 $\times10^{-5}$
1041 - 1090	0.000181	1.72 4 $\times10^{-5}$
1364 - 1378	1.4×10^{-5}	$\sim1\times10^{-6}$

Continuous Radiation (^{192}Ir)

⟨β-⟩=171 keV;⟨IB⟩=0.123 keV

E_{bin}(keV)		⟨ ⟩(keV)	(%)
0 - 10	β-	0.177	3.54
	IB	0.0086	
10 - 20	β-	0.52	3.48
	IB	0.0079	0.055
20 - 40	β-	2.03	6.8
	IB	0.0141	0.049
40 - 100	β-	13.1	19.0
	IB	0.031	0.049
100 - 300	β-	84	44.5
	IB	0.040	0.025
300 - 600	β-	70	18.0
	IB	0.0053	0.00153
600 - 669	β-	0.74	0.119
	IB	3.5×10^{-4}	5.7×10^{-7}

5.5 Appendix

This section contains the following:

Appendix 5.5-A: Design of the Radiation Shield

Appendix 5.5-A Design of the Radiation Shield

INTRODUCTION

The shielding for the Titan Gamma Radiography Exposure Device was designed to meet the requirements of ANSI N432-1980, Radiological Safety for the Design and Construction of Apparatus for Gamma Radiography with a source activity of 120 Ci (4.44 TBq) Ir-192. (One curie Ir-192 is defined as the activity needed to produce 0.55 R/h at one meter.) The maximum allowable exposure rate at 50 mm from the surface for a Class P Exposure Device is 50 mrem/h. Although three field measurements are described in the standard, the field at 50 mm is the worst case. That is, if the dose equivalent rate is less than or equal to 50 mrem/h at 50 mm, the field will be less than 200 mrem/h on contact and less than 2 mrem/h at 1 m from the surface.

PRIMARY SHIELDING

Depleted uranium (DU) with a mass density of 18.4 g/cm^3 is used as the shielding material. (The actual DU density is a nominal 18.6 g/cc.) The thickness of DU needed to reduce the dose equivalent rate to 50 mrem/h at 50 mm from contact is determined from the equation:

$$X_{50mm} = 120Ci * 550 \frac{mrem}{hCi} * (100^2/x^2) * \exp(-4.25t + 0.63t^2 - 0.0556t^3)$$

where: x = distance between the source point and field point.

exp(f(t)) = represents the transmission of Ir-192 radiation in DU

X_{50mm} = the field 50 mm from the surface (50 mrem/h)

The transmission function used in this equation is verified by direct comparison against published transmission curves [eg. ICRP 33] and a Microshield 4.0 generated transmission curve. The transmission factor takes into account the build-up factor. The use of the inverse-square law is justified since the distance to the field point is large relative to the source dimensions. A comparison between the generated equation and these transmission curves is provided in Figure 1.

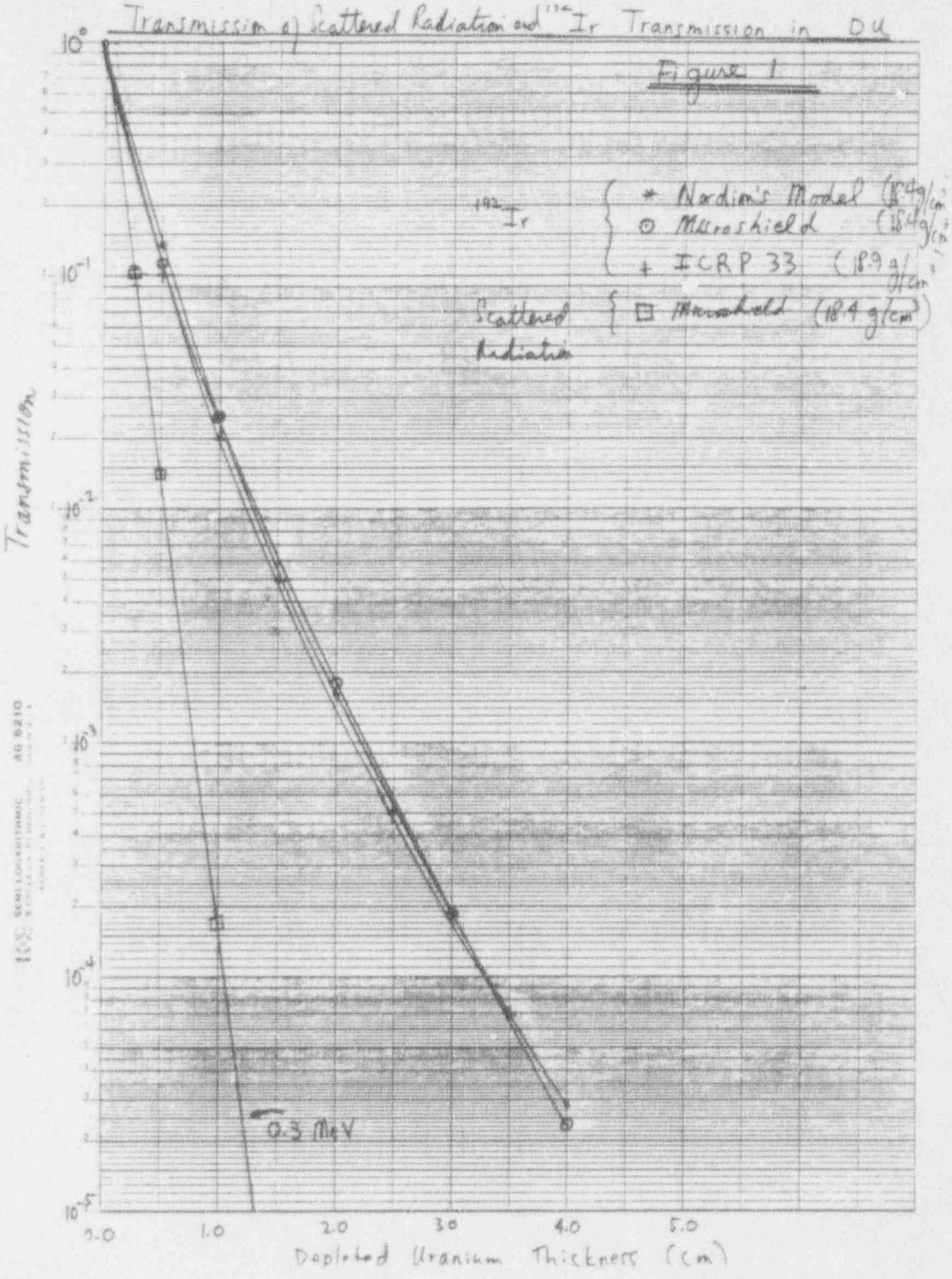

Figure 1. Transmission of Scattered Radiation and Ir-192 Transmission in Depleted Uranium

Let the origin of the xy plane be defined as the geometric centre of the S tube. Initially the xy plane is defined in the vertical plane. The thickness of DU is calculated for field points with a resolution of 3.5° from 0° to approximately 180°. This results in 51 data points to which a function is fit using cubic spline interpolation. The y axis is then rotated 5° about the x axis and this process is continued until the original xy plane has been rotated through 180°. A surface is then fit to these 36 cubic splines forming half the primary shield.

This method of shield generation created wiggles (ie. discontinuities) at several locations on the shield surface thus making the shield unmanufacturable. These discontinuities were removed by regenerating the cubic splines while ignoring the data points in the area of the discontinuity. Further wrinkles were removed by grinding the pattern.

Ir-192 decays via electron capture and beta emission. The resultant energy spectrum is rather complicated. Although the gamma photon spectrum ranges from approximately 200 keV to almost 900 keV, the most significant gamma photons are those with energies greater than 600 keV. Their contribution to the external radiation field is greater than 99%.

The primary shield takes into account the potential variations in source position. The tolerance in the source position was assumed to be + 1.6 mm.

SECONDARY SHIELDING

Two factors are used to reduce the contribution to the exposure rate made by radiation propagating out the S tube duct.

(i) The Ir-192 source cannot 'see' the duct because of the source cable and end cable. Any radiation which exits the duct undergoes multiple scattering. The resultant energy spectrum is highly degraded. Since the exposure rate is directly proportional to the photon energy and photon flux, the exposure rate is reduced accordingly.

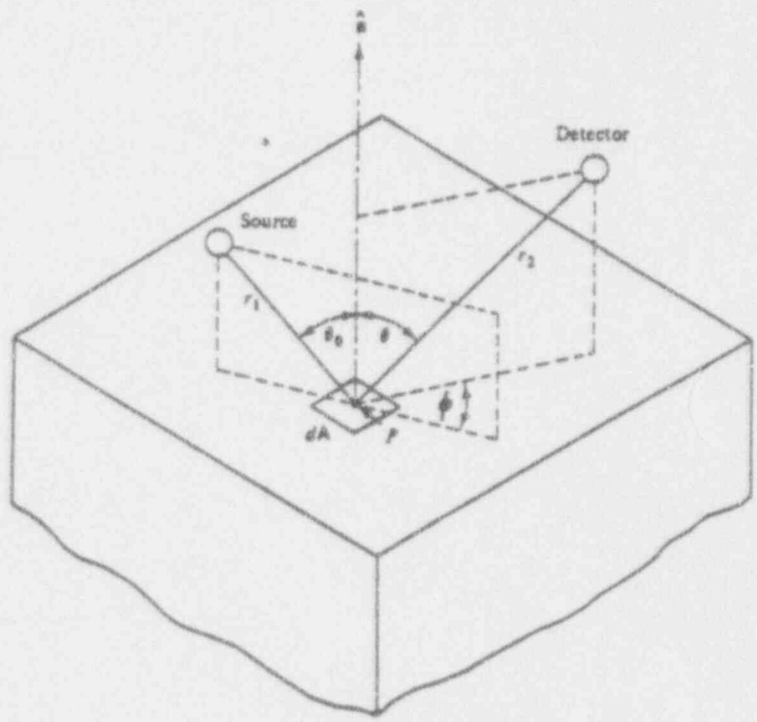

Figure 2. Reflection by a Differential Area of Radiation from a Point Source

(ii) The backscattering or reflection of photons is a problem of fundamental importance in radiation shielding. The quantities that characterize the reflection probability are called albedos. A beam of incident photons of energy E_o interacts with a surface under an angle θ_o and is scattered at the incremental area dA through a polar angle θ and deviated through an azimuthal angle ϕ. (See Figure 2.) The exposure rate at the field point due to this scattered radiation is:

$$X = \{X_o \cdot \cos\theta_o \cdot dA \cdot \alpha(E_o, E, \theta, \phi)\}/r_2^2$$

where: X_o = is the exposure rate incident on incremental area dA;

E = is the Compton scattered gamma photon, and

α = is the differential exposure albedo.

There is no published data for exposure albedos for Ir-192 incident on depleted uranium. The expcsure rate albedo was taken to be 1%. (Justification is given shortly.)

Secondary shielding is incorporated in areas where primary radiation can escape after one scattering event (except in the areas where the radiation can escape by propagating down the tube axis). (See Figure 3.) Primary radiation scattered through 130° towards P1 represents the case where the scattered radiation will 'see' a minimum amount of secondary shielding (since the scattered radiation has normal incidence). Assuming 0.88 MeV primary photons (representing the maximum gamma energy for Ir-192) and pure compton scattering, the scattered photon energy incident on point P1 will be 0.23 MeV. To maintain a conservative factor, transmission curves of 0.3 MeV radiation in DU were used to determine the thickness of the secondary shielding (13 mm).

The maximum energy of the radiation scattered toward P2 is approximately 0.4 MeV. Although this is greater than the 0.3 MeV used to determine the secondary shield, a level of conservatism is retained due to the obliqueness of the radiation scattered through the secondary shield.

A modest level of justification for this methodology is that the transmission factor for Ir-192 (at 0.8 MeV) in 40 mm DU corresponds to the transmission factor for 0.3 MeV radiation in 13 mm DU. (The primary shield thickness is approximately 40 mm.) A relatively large degree of conservatism helps to overcome the lack of published data for scattering albedos (Ir-192 on DU).

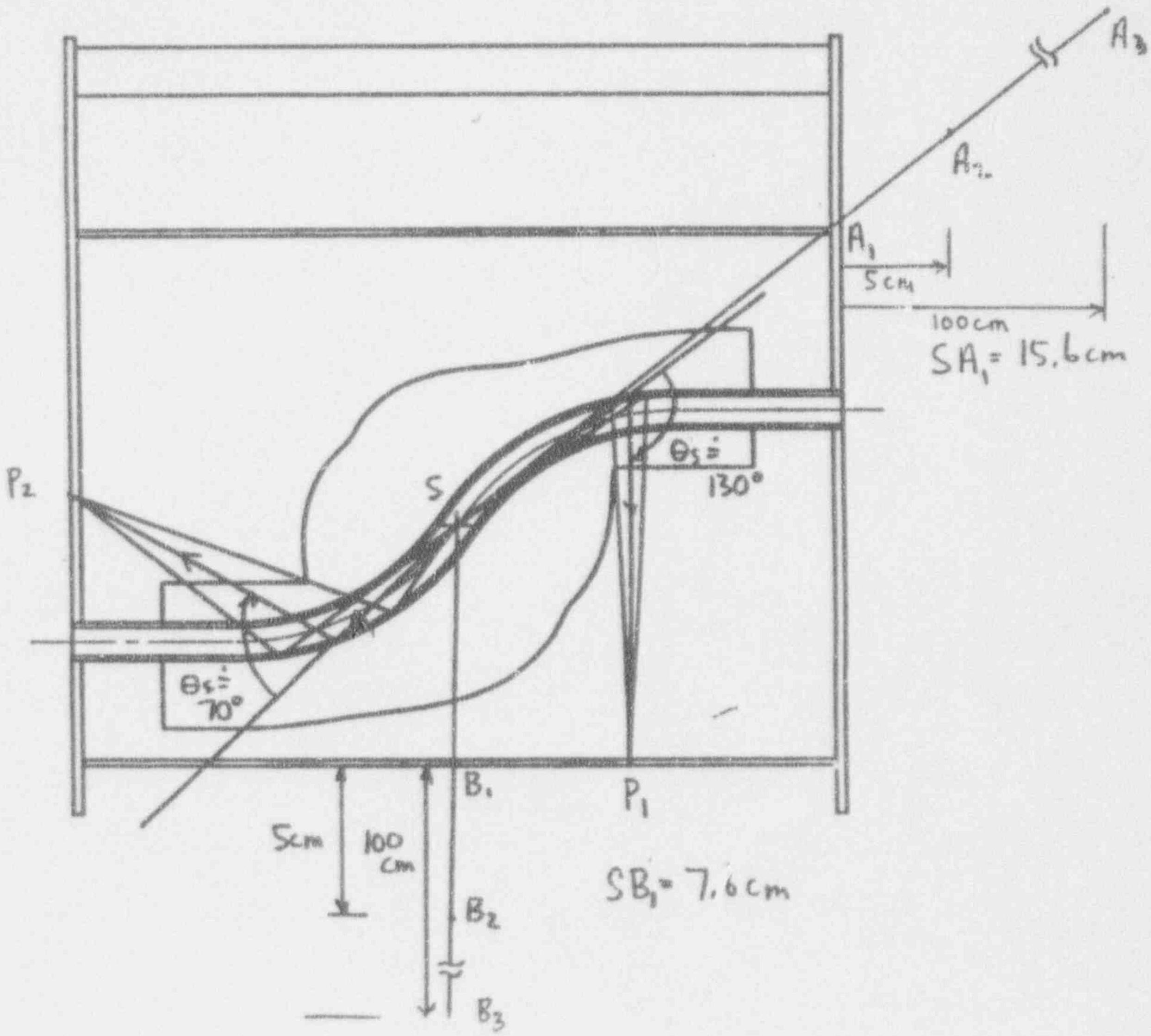

Figure 3. Secondary Shield Geometry

RADIATION FIELD SURVEY

The maximum dose equivalent rates allowed at the surface, at 5 cm from the surface and 1 meter from the surface for a Class P exposure device are 200 mrem/h, 50 mrem/h and 2 mrem/h respectively. If a field of 50 mrem/h is measured at 5 cm from surface, it can be shown using the inverse-square law that the maximum contact field will be approximately 140 mrem/h and the maximum field at 1 meter from contact will be approximately 1.6 mrem/h.

6. CRITICALITY

The Titan does not carry any fissile material. Therefore, the regulations for materials carrying fissile materials do not apply.

7. OPERATING PROCEDURES

Operation, inspection of the Titan is required to be carried out in accordance with Nordion specification IS/OM 0090 N990. (See Appendix 2.10-B.)

7.1 Procedures for Loading the Package

The applicable sections of IS/OM 0090 N990 are section 3-4-6 "Preparing for Storage or Transport" and chapter 4 "Transportation and Storage."

7.2 Procedures for Unloading the Package

A source changer is used to load and unload the Titan. Operators are required to be trained in the source changing procedure, which varies between source changer models.

The basic elements of a source transfer are:

1) Connecting the drive control to the spent source assembly. (See section 3-4-3 of IS/OM 0090 N990)
2) Connecting one end of the source changer's transfer hose to the exit port.
3) Connecting the other end of the transfer hose to the empty channel of the source changer.
4) Transferring the spent source to the source changer, and locking it in place. (See section 3-4-4 of IS/OM 0090 N990.)
5) Disconnecting the transfer hose from the source changer and disconnecting the drive cable from the spent source.
6) Connecting the drive cable to the new source.
7) Connecting the transfer hose to the source changer channel containing the new source.
8) Unlocking the new source and transferring it to the Titan. (See section 3-4-5 of IS/OM 0090 N990.)
9) Preparing the Titan for transport or storage. (See section 3-4-6 of IS/OM 0090 N990.)

7-3 Preparing an Empty Package for Shipment

The Titan is a gamma radiography exposure device, and normally contains an iridium source. However, instructions for shipping an empty Titan are contained in section 4-5 of IS/OM 0090 N990.

7-4 Appendix

There are no appendices to this chapter.

8 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

This chapter discusses the acceptance tests and maintenance program for the Titan. The Nordion quality assurance program for design and manufacture is described in Nordion specification IN/QA 0224 Z000, which is provided in Appendix 8.3-A. (USNRC Quality Assurance Program Approval Number 71-0703.) Specific technical requirements for the Titan are provided in IS/TS 0054 N990, which can be found in Appendix 8.3-B. Ongoing maintenance is the responsibility of the user and the requirements are detailed in IS/OM 0090 N990, which can be found in Appendix 2.10-B.

8.1 Acceptance Tests

The manufacture of the Titan is done in accordance with Nordion Specification IS/TS 0054 N990. This specification includes basic requirements for raw material and component inspection as well as specific acceptance tests for the assembled unit. This specification is included in Appendix 8.3-B.

8.1.1 Visual Inspections

Visual and mechanical inspections are required to be completed during manufacture. In particular, it is ensured that:

1) there is no interference between parts, unless specifically required by the engineering drawings;
2) all fasteners are installed; and,
3) all safety features are in place.

These requirements are detailed in IS/TS 0054 N990. (See Appendix 8.3-B.)

8.1.2 Structural and Pressure Tests

Inspections and tests ensuring the structural integrity of the Titan are an integral part of the manufacturing process. Critical materials, components, welding supplies, fasteners, etc. are all subject to the requirements of IS/TS 0054 N990. Welds are inspected using a dye penetrant procedure. Materials certificates are obtained for critical components and mechanical inspections are completed prior to assembly.

There are no pressure tests since the Titan is not a sealed package.

Should any component fail an inspection requirement, and the part is to be used in a production unit, disposition is given in accordance with section 6-1 of IS/TS 0054 N990.

8.1.3 Leak Tests

The Titan is not a sealed package and no leak tests are required.

The containment system for the unit is the C-990 Special Form capsule. (See the discussion of Chapter 4.) It is manufactured in accordance with Nordion Specification IS/TS 0010 C000, which is found in Appendix 8.3-C.

8.1.4 Component Tests

8.1.4.1 Valves, Rupture Discs and Fluid Transfer Devices

The Titan does not include any valves, rupture discs or fluid transfer devices. Therefore, this section does not apply.

8.1.4.2 Gaskets

The Titan does not include gaskets. Therefore, this section does not apply.

8.1.4.3 Miscellaneous

The Titan is designed and has been tested to demonstrate compliance with all requirements for safety and use prescribed by the regulations. The Quality Program governing the manufacture of the Titan ensures that it is manufactured in accordance with the prescribed requirements. There are no additional components affecting the safety of the unit that have not been considered in the technical specification.

8.1.5 Tests for Shielding Integrity

Radiation shielding tests and their acceptance criteria are discussed in section 6-8 of IS/TS 0054 N990.

8.1.6 Thermal Acceptance Tests

There are no thermal acceptance tests for the Titan. See Chapter 3 for a full discussion of the thermal characteristics of the Titan.

8.2 Maintenance Program

Maintenance is the responsibility of the user. Maintenance requirements for the Titan are described in chapter 5 of IS/OM 0090 N990, which is found in appendix 7.4-A.

8.2.1 Structural and Pressure Tests

The annual maintenance procedure includes a visual inspection of the external surface of the unit. (See IS/OM 0090 N990.)

There are no specific requirements for pressure testing as the Titan is not a sealed package.

8.2.2 Leak Tests

There are no specific requirements for leak testing as the Titan is not a sealed package.

8.2.3 Subsystem Maintenance

Maintenance requirements for the C-990 and the Titan are discussed in chapter 5 of IS/OM 0090 N990.

8.2.4 Valves, Rupture Discs and Gaskets

The Titan does not include any valves, rupture discs or gaskets. This section of the regulations does not apply.

8.2.5 Shielding

Routine radiation surveys are required to be completed daily. (See IS/OM 0090 N990.)

8.2.6 Thermal

There are no specific thermal tests for the Titan. (See section 8.1.6.)

8.2.7 Miscellaneous

Not applicable. (See section 8.1.4.3.)

8.3 Appendices

This section contains the following appendices:

Appendix 8.3-A IS/QA 0224 Z000 rev. A
Appendix 8.3-B IS/DS 0054 N990 rev. B
Appendix 8.3-C IS/TS 0010 C000 rev. C

Appendix 8.3-A IS/QA 0224 Z000 rev. A

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QUALITY ASSURANCE

IN/QA 0224 Z000

Radioactive Material Transport Package Quality Plan

CURRENT DATE: 92 June

DATE	ISSUE	COMMENTS/AFFECTEDPAGE	PREPARED BY	REVIEWED BY	APPROVED BY
92 June	A	Original Issue	See	Validation	Sheet

NOTE:
The portion of this text affected by the changes is indicated by a vertical line in the margins of the pages.

VALIDATION

Nordion International Inc.

Submitted by:	Manager, Package Engineering	92/06/24 Date
Reviewed by:	Manager, Quality Assurance	92/06/24 Date
	Manager, Engineering Services	92-06-24 Date
	Manager, Safety, Environment & Regulatory Affairs	1992/06/24 Date
Authorized by:	Vice-President, Isotope Products	92/06/24 Date
	Vice-President, Industrial Irradiation	92.06.24 Date
	Vice-President, Human Resources & Operations' Services	92.06.24 Date

1 SCOPE

This Quality Plan describes the activities associated with the design, fabrication, assembly, testing, maintenance, repair, modification, and use of Nordion radioactive material (RAM), transport packaging. It identifies the activities, responsibilities, and action necessary to ensure that a transport package meets all regulatory, customer, and Nordion Quality Assurance Program requirements. This Plan also applies to the activities of Nordion suppliers of transport packaging or components.

2 APPLICABLE DOCUMENTS

2-1 Nordion International Inc. *Quality Assurance Program* IN/QA 0148 Z000

2-2 Nordion International Inc. *Quality Assurance Program for Delivery of a Type B Radioactive Material Package to a Carrier for Transport* IN/QA 0120 F000

2-3 IAEA Safety Standards, Safety Series No. 6 *Regulations for the Safe Transport of Radioactive Material 1985 Edition (As Amended 1990)*

2-4 IAEA Safety Standards, Safety Series No. 37 *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition)*

2-5 US-NRC Regulatory Guide 7.10, *Establishing Quality Assurance Programs for Packaging used in the Transport of Radioactive Material*

2-6 US-NRC Regulatory Guide 7.9 *Standard Format and Content of Part 71 Applications for Approval of Packaging of Type B, Large Quantity, and Fissile Radioactive Material*

2-7 US-NRC Regulation 10 CFR 71 *Packaging of Radioactive Material for Transportation and Transportation of Radioactive Materials Under Certain Conditions*

2-8 Transport Packaging of Radioactive Materials Regulations, Canada Atomic Energy Control Act, SOR/91-304, May 9, 1991

2-9 International Standard ISO 9001 *Quality systems - Model for quality assurance in design/development, production, installation and servicing*

3 QUALITY POLICY

It is Nordion International Inc. management's policy that this Quality Plan complies with Nordion's Quality Assurance Program. The Quality Plan is used to ensure that the specified requirements of transport packaging for radioactive material comply with pertinent regulatory requirements. This Plan defines the standard operating practices that prescribe the measures used to control the activities affecting the radioactive material transport package quality. It establishes a documented system of management controls that provide confidence in the quality of all associated work activities.

4 ORGANIZATION

4-1 Structure and Authority

This section describes the Nordion organization for quality-related activities. The structure of the organization is shown in Figure 1. Responsibility assignments for each function involved in quality -related activities for transport packages are described below:

President, Nordion International Inc.

The President has the primary responsibility to ensure that the Quality Plan conforms to the Nordion Quality Assurance Program including the principles set out in the Nordion Quality Commitment.

Vice-President, Industrial Irradiation Division

The Vice-President is responsible for establishing and maintaining a Quality Assurance Program for RAM transport package used for the Division's products. He is also responsible for adhering to the requirements of applicable codes, standards, regulations, and of the customer.

Vice-President, Isotope Products Division

The Vice-President is responsible for establishing and maintaining a Quality Assurance Program for RAM transport package used for the Division's products. He is also responsible for adhering to the requirements of applicable codes, standards, regulations, and of the customer.

Vice-President, Human Resources & Operations' Services Division

The Vice-President is responsible for ensuring that the Nordion Quality Commitment is reflected in company-wide policies and procedures that help to ensure the safety of the workplace, environment, and the products. In addition the Vice-President is responsible for the development and maintenance of the Nordion Quality Assurance Program.

Manager, Quality Assurance

The authority for the administration of the Quality Assurance Program is delegated to the Manager, Quality Assurance, who reports to the Vice-President, Human Resources & Operations' Services

Manager, Safety, Environment & Regulatory Affairs

The Manager, Safety, Environment & Regulatory Affairs reports to the Vice-President, Human Resources &

Operations' Services. The Manager is responsible for ensuring that the RAM packages comply with the pertinent regulations, and that they are safely handled and maintained. The Manager is also responsible for verifying that all regulatory submissions for RAM transport package certification are accurate and complete. In addition, the Manager coordinates the communications between Nordion and the competent authorities.

Manager, Engineering Services

The Manager, Engineering Services reports to the Vice-President, Industrial Irradiation Division and is responsible for assuring that Nordion's radioactive material transport packages are designed, specified and tested to meet the regulatory and quality requirements. The Manager is also responsible for maintaining and enforcing a Quality Plan for the activities under that Manager's control.

Manager, Package Engineering

The Manager, Package Engineering reports to the Manager, Engineering Services. The Manager is responsible for the design of Nordion's radioactive material packages and ongoing technical support. The Manager is also responsible for the establishment of the Quality Plan.

Project Engineer

The Project Engineer reports to the Manager, Package Engineering, and is responsible for design projects from inception to completion. This includes the preparation of specifications, manufacturing requirements, and testing of designs.

Manager, Purchasing

The Manager, Purchasing reports to the Vice-President, Finance. The Manager is responsible for maintaining a Quality Plan that manages material and service suppliers so that externally manufactured RAM transport packaging meet Nordion's specifications.

Manager, Cobalt Operations

The Manager, Cobalt Operations reports to the Vice-President Industrial Irradiation Division. The Manager is responsible for maintaining the Quality Plan for all RAM transport packaging loading and loading facilities. The Manager is also responsible for Quality Control of all RAM packaging and components.

Manager, Source Production

The Manager, Source Production reports to the Manager, Cobalt Operations. The Manager is responsible for preparing for shipment RAM transport packages to procedure, and for control of all loading processes. This includes work instructions, production staff training, and the maintenance of the packaging.

Quality Control Technician

Reports to the Manager, Cobalt Operations with the responsibility of ensuring that quality control functions are carried out properly.

Manager, Isotope Production

The Manager, Isotope Production reports to the Vice-President Isotope Products Division. The Manager is responsible for maintaining the Quality Plan for all RAM transport packaging loading and loading facilities. The Manager is also responsible for the Isotope Products container management system. The system ensures that shipping, inspection and maintenance procedures are followed.

Manager, Vancouver Operations

The Manager, Vancouver Operations reports to the Vice-President Isotope Products Division. The Manager is responsible for maintaining the Quality Plan for all RAM transport packaging loading and loading facilities at Vancouver. The Manager is also responsible for the maintenance of RAM transport packaging.

Manager, Isotope Products Quality Control

The Manager, Isotope Products Quality Control reports to the Vice-President Isotope Products Division. The Manager verifies that the Isotope Products container management system effectively complies with this Quality Plan's requirements.

Director, Industrial Sales & Service

The Director, Industrial Sales & Service reports to the Vice-President, Industrial Irradiation Division. For this Quality Plan the Director is responsible for clearly communicating specifications to the customer. Special or custom use of RAM transport packaging requires that there be adequate contact between Nordion and its customers to clearly convey needs and capabilities.

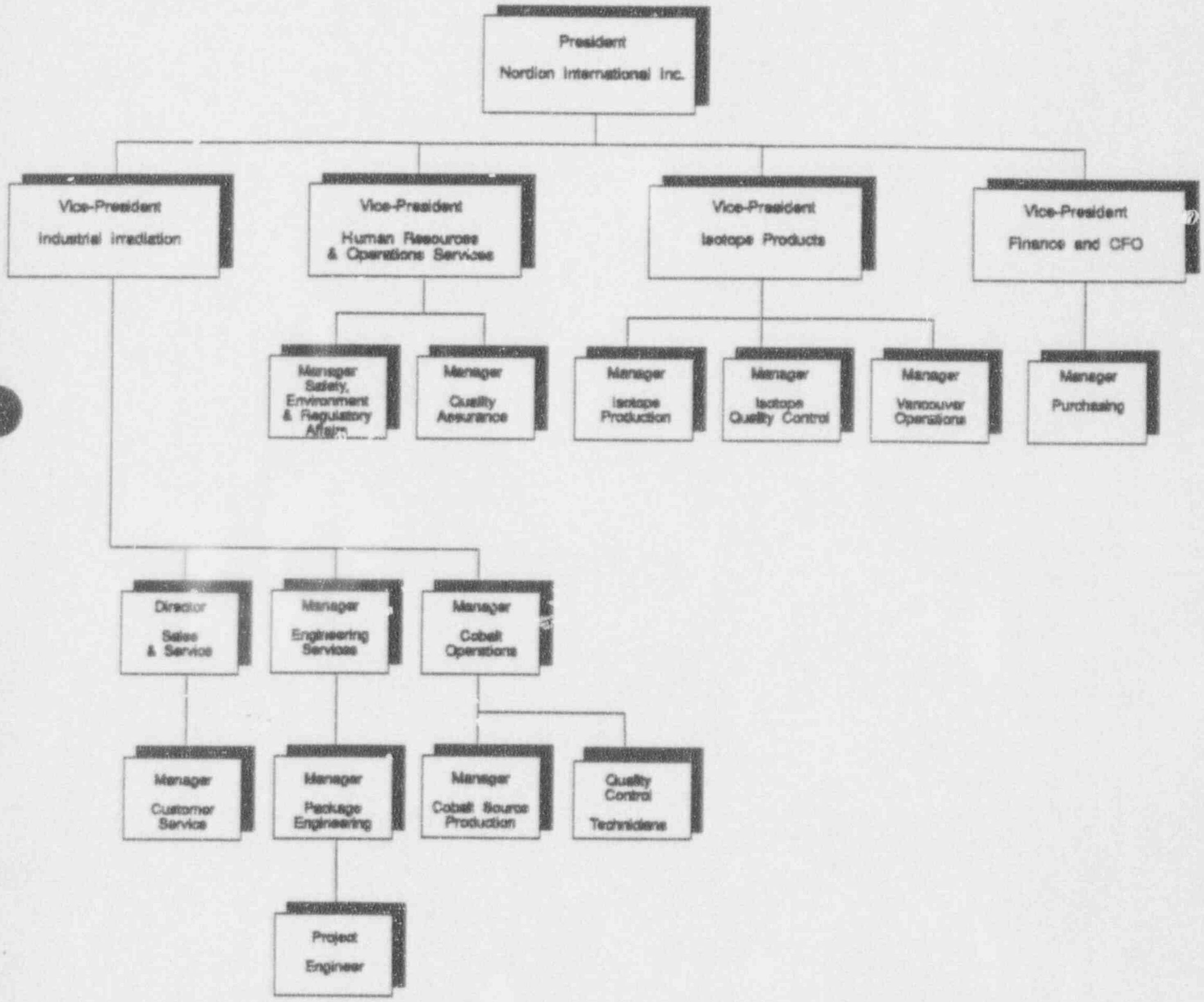
Manager, Customer Service

The Manager, Customer Service reports to the Director, Industrial Sales & Service. The Manager is responsible for ensuring that Industrial Irradiation Division's RAM transport packages used in the field, are properly checked during both source loading and unloading. Also, that the packages comply with all regulatory requirements associated with use in that location.

NORDION INTERNATIONAL INC.

Quality Assurance Organization

Radioactive Material Transport Packages



4-2 Management Review

4-2-1 —Quality Assurance is responsible for developing, implementing, and internally auditing, the application of quality assurance within the organizational units at Nordion, and reporting the audit results to line management, senior management, and the President.

4-2-2 —Through the Vice-President of each organizational unit, senior management regularly reviews the quality system, related policies and specific procedures to ensure their effectiveness and compliance to codes, regulations and standards. In addition, they assess the results of all internal and external quality audits.

4-2-3 —At a minimum, senior management conducts a yearly review of Quality Assurance Programs to inform the cognizant Vice-Presidents and the President of significant conditions adverse to the adequacy and effectiveness of the programs.

4-3 Training

4-3-1 —Nordion defines training requirements for all key roles affecting safety of RAM transport. Actual training is tracked against requirements including technical knowledge, control of process, specific skills and general theory in quality issues, safety, and company policies.

4-3-2 —Detailed instruction for the carrying out of training is provided in each Division's administrative procedures. The significant requirements are summarized below:

a) all personnel involved in the transport of radioactive material receive training in radiation safety and transport regulations,

b) specific qualification, training, and certification requirements are determined on an individual basis by line management. This determination is based on: the type of work, potential effect on quality, and the applicability of codes, standards or regulations,

c) the line managers are responsible, with Human Resources, for maintaining records of staff selection, qualification, certification, and training. They also provide for the necessary training, and evaluate needs during staff performance reviews.

d) retraining is on an established predetermined frequency.

5 Quality Elements

This section describes the procedures and methods that govern activities affecting quality. It tells how quality is achieved; conformance controlled and verified.

5-1 Contract Review

RAM transport packaging is used to transport Nordion products to customers. The transport packaging requirements are based on the type of radioactive material, activity, containment, and the specified quantity of material. It is the responsibility of Sales to see that contracts meet the specified requirements. Authority for selection of transport packaging is through the operating groups.

Proposed uses of transport packaging which may not meet the specified requirements are referred to the Manager, Package Engineering for review with cognizant Managers. Each nonstandard application is reviewed for its capability to meet the standard, code, and regulatory requirements and regulatory approval is obtained before use of any unapproved packaging combinations.

Any changes requested by the customer are referred to the Manager, Package Engineering for reevaluation.

5-2 Design Control

Procedures are in place to control and verify that the RAM transport packaging design complies with all specified requirements. Procedures are in place for the identification, documentation, and appropriate review and approval of drawings and specifications. Engineering Services controls design changes in the same manner as the original documentation.

5-2-1 Design Planning and Activity Assignment —Written plans are prepared for design and verification activities for each new or modified RAM package design at project initiation. The Manager, Package Engineering assigns the project to qualified personnel equipped with the resources necessary to prepare a fully compliant design.

Each plan contains reference to:

a) design input needs,

b) radioactive material transport packaging specification,

c) applicable codes and standards,

d) planned verification and design review, (a minimum of two reviews exists - concept and final review),

e) identification of organizational and technical interfaces,

f) list of personnel to be kept informed and/or to approve documents.

The concept review includes input from internal customers and others who are involved in the management of RAM transport packaging.

5-2-2 Design Input—The Project Engineer verifies design input requirements for adequate identification and documentation. Design input verification involves, but is not limited to:

a) performance and functional criteria,

b) applicable codes and standards,

c) regulatory requirements,

d) environmental conditions,

e) documentation, training, maintenance and inspection plans,

f) the need for Special Form Material Certification for the sealed source if initial evaluation of radioactive material transport packaging/device or sealed source/packaging combinations indicate a need.

Incomplete, ambiguous, or conflicting requirements are resolved by the Project Engineer with the responsibility for drawing up the requirements.

5-2-3 Design Output—Design output is documented and expressed in terms of requirements, calculations, tests, and analysis. The design output shall:

a) meet the design input requirements,

b) contain results of tests completed or reasoned argument that the RAM transport package meets test criteria.

c) show design analysis in sufficient detail to allow verification of the adequacy of the design and conformity to appropriate regulatory requirements whether or not these have been stated in the Design Plan,

d) identify design characteristics that are crucial to the safety and function of the radioactive material transport package and if required, a detailed safety analysis of the design,

e) include a licensing application submission in suitable detail to meet requirements of regulatory guidelines, (see regulatory section 5-5). The extent of the analysis and testing chosen must be appropriate to prove the validity of the design.

f) include engineering drawings,

g) include a Technical Specification, (see 5-2-6).

5-2-4 Design Verification —Designs and associated design documents are reviewed to ensure that they meet specified design requirements. Design verification is performed by qualified staff using design reviews and/or testing. The Manager, Package Engineering determines the extent of verification required. This decision is based on complexity, novelty, degree of standardization, and safety implications. The Design Plan identifies the verification requirements. All verification activities are documented. The nature of the verification process must conform to applicable codes and standards. The process involves:

a) qualification testing or comparison review according to applicable IAEA standards and competent regulatory authority regulations. Requirements, procedures, data, assumptions, and results are documented and filed. Results are evaluated against specified acceptance criteria. The conclusions of the tests or comparisons are recorded and filed in the transport package engineering files.

b) design review by qualified persons other than those who executed the design. The independent reviews determine if the design methods are appropriate and correctly applied. The reviewers verify that the assumptions and simplifications used are justifiable, and the design interfaces are properly addressed. Reviews are conducted before design release. They are documented, and include decisions on actions requested.

5-2-5 Design Changes

The Nordion design change system is used for the control of drawings and supporting documentation. A request for changes to the design of RAM transport packages are initiated by a written Design Change Request to the Manager, Package Engineering for acceptance. All changes to the design of RAM transport packages are reviewed by the Project Engineer. The proposed changes are also reviewed and approved by the Manager, Package Engineering; Manager, Quality Assurance; Manager, Cobalt Operations; and/or Manager, Isotope Production.The Project Engineer documents the change description, the reasons for it, and the implications. The method and extent of the design verification are dependant upon the extent and nature of the changes. The Project Engineer identifies the necessary recipients of the revised design documents. An advance notice of an impending revision is made by the issue of an Engineering Change Notice.

5-2-6 Technical Specification

The Technical Specification is an integral part of the design documentation. It establishes the technical requirements for manufacture, assembly, inspection, test and delivery for each model of transport packaging. The Specification defines:

a) applicable engineering drawings,

b) applicable standards,

c) Nordion specifications and procedures,

d) quality program standards and codes required for manufacture. The manufacturer's quality program is subject to International Standard ISO 9002 or CSA Standard Z299.3-85, and the following system functions from CSA Standard Z299.2-85:

1. Handling and Storage
2. Production
3. Corrective Action

The code requirement for welding and welder qualification is ASME BPV Code Section IX,

e) requirements for inspection and test documentation according to requirements of CSA Standard Z299.3-85 or ISO 9002,

f) manufacturing procedures covering Nordion requirements for welding, fitting and machining, surface finish and cleanliness, lead pouring and bonding, and painting.

g) nonconformance and corrective action as in Supplier Quality Guidelines, Nordion Quality Assurance Manual,

h) inspection requirements,

i) tests for welds, mechanical, lead bonding, radiation shielding, and leakage testing,

j) requirements for supplier history file,

5-3 Document Control

Documents and data that relate to the needs of the Quality Plan are controlled according to established procedures.

Each cognizant group manager is responsible for ensuring that filing, recording, storage, retrieval, and issue of radioactive material transport package documents is according to the Quality Assurance Manual procedure for Document Control. RAM transport package documents are typically design documents, procedures, specifications, procurement documents, test results, design reports and changes, and QA documents used in RAM package design projects. Nordion procedures for document identification and control apply. Technical Specifications are controlled by Engineering Services in the same way as drawings. A master list is in place to identify the current revision of drawings, Technical Specifications and procedures. Documents are stored in secure areas such as: Central Records, Technical Specification and drawing vault.

5-4 Procurement Control

5-4-1 —Policy and Procedures are in place to ensure that the purchased RAM transport packaging, components, materials, and services conform to specified requirements. These requirements are outlined in Technical Specifications prepared for each model of RAM transport packaging type.

5-4-2 —Suppliers are selected based on their ability to meet the quality requirements. The review is initiated by the Manager, Purchasing with the participation of QA and Package Engineering personnel. Measures are in place, through purchasing and QA policies and procedures, for the evaluation, selection and approval of suppliers. The supplier selection must be made from in Technical Specifications prepared for each model of RAM transport packaging type.

5-4-2 —Suppliers are selected based on their ability to meet the quality requirements. The review is initiated by the Manager, Purchasing with the participation of QA and Package Engineering personnel. Measures are in place, through purchasing and QA policies and procedures, for the evaluation, selection and approval of suppliers. The supplier selection must be made from Nordion's approved vendor list. If a new supplier is to be selected, they are to be approved following Quality Assurance procedures. Suppliers are subject to periodic audits by Nordion QA to verify their continuing ability to carry out quality requirements.

5-4-3 —It is the responsibility of the Project Engineer to ensure that the purchasing documents clearly describe the material required. The key document for the information necessary for manufacture is in the Technical Specification, (see section 5.2.6).

5-4-4 —Each order for a transport packaging requires certain control activities and records, specifically:

a) purchase requisitions are reviewed by Quality Assurance for adherence to the quality assurance procedures, and requirements,

b) selected suppliers are on Nordion's approved vendors list or qualified by audit or independent inspection,

c) suppliers' Inspection and Test Plans are reviewed and approved, before manufacture, by Project Engineer and Manager, Quality Assurance.

d) on completion of final inspection the supplier sends a Quality Assurance Release Form and supporting documentation to the Manager, Quality Assurance who forwards the form to the responsible Quality Control group for verification. Incoming inspection is performed according to the Inspection and Test Plan and results noted on the Quality Assurance Release Form. The completed form is sent to the Manager, Quality Assurance who signs off if the inspection is satisfactory and manufacturing history file complete.

e) requests for disposition of nonconformances must be submitted to Nordion's purchasing department in writing. The Material Review Board review requests to determine the disposition of the nonconformance. Repairs are always reinspected to requirements decided by the Material Review Board.

5-5 Regulatory

5-5-1 —The Manager, Safety, Environment & Regulatory Affairs is responsible for ensuring that all regulatory requirements are identified and met.

5-5-2 —The Manager, Package Engineering is responsible for ensuring that the design of the RAM transport package meets the applicable requirements. This includes the performance of tests or comparison to existing designs.

5-5-3 —Notwithstanding national codes, standards, and regulations, the standard for design of a radioactive material transport package is: IAEA Safety Standards, Safety Series No. 6 *Regulations for the Safe Transport of Radioactive Material 1985 Edition (As Amended 1990)*

5-5-4 —All new RAM transport package designs must be evaluated to the applicable requirements. The evaluation is part of a safety analysis submission to the pertinent authorities. No packaging design can be used before the evaluation is complete and a license has been issued. The Project Engineer is responsible for preparing an application for each new or modified RAM transport package design.

5-5-5 —The application for certification of a radioactive material transport package includes at least the following:

a) package description detailing radioactive contents, containment system, shielding, and operational features,

b) structural evaluation including but not limited to:

1) structural design

- design criteria referencing requirements for packages as in IAEA Safety Series 6
- mechanical properties of structural materials
- weights and centres of gravity

2) general requirements for packages such as:

- lifting devices
- closure methods
- tiedown devices
- load resistance
- external pressure
- chemical and galvanic reactions

3) requirements for Type B packages:

- load resistance
- external pressure

4) conditions of transport,

c) accident analysis, based on IAEA or national competent authority regulatory requirements,

d) overview drawing,

e) Special Form evaluation, as applicable,

f) test results, and/or comparison evaluations.

5-6 Inspection and Maintenance

5-6-1 Inspection Plans—There are written plans for inspections performed during the life cycle of RAM transport packaging. These plans outline the type of inspection or testing to be undertaken. For each RAM transport packaging type an inspection and maintenance plan is prepared. The plans include, as applicable:

a) new packaging first-off inspection and acceptance requirements,

b) periodic inspections after shipment, and before reuse,

c) annual inspection and maintenance,

d) inspection and maintenance checklists,

e) instructions for special tests such as: leak testing, pressure tests, shielding tests, etc.,

f) quality records to be kept.

5-6-2 Incoming Inspection—RAM packaging and components are inspected to the established quality level in the applicable Technical Specification for the packaging. Inspection and testing during manufacture are carried out by a qualified supplier using the Inspection and Test Plan approved by Nordion's Project Engineer and Manager, Quality Assurance.

New suppliers or changes to existing production methods must be approved by Nordion Quality Assurance in conjunction with Package Engineering, the cognizant Production group, and Purchasing. Confirmation testing of their incoming RAM transport packaging or components is carried out at Nordion irrespective of inspections completed by the supplier. These tests are normally performed on three separate production lots before full acceptance of the supplier's Quality Assurance Program if warranted by frequency of ordering. Acceptance is based on Nordion tests and audit of the supplier's Quality Assurance Program. Quality Assurance maintains continual surveillance of an active supplier.

Incoming inspection is usually carried out in the following manner:

a) Purchasing, Stores checks that all incoming material reference the proper Purchase Order number. Stores confirm that the quantity is correct, and the paperwork is with the package. Stores notify the Quality Control representative for Isotope Production or Cobalt Operations that the material is in Stores.

b) Upon receipt, the Quality Control representative for Isotope Production or Cobalt Operations examines the packaging and components or materials using appropriate Inspection and Test Plans.

c) First-off inspection is done by the cognizant Quality Control group. Test results are submitted to the Project Engineer, Manager, Source Production, and Quality Assurance for approval.

5-6-3 In-process Inspection—The supplier of RAM packaging or critical packaging components must show with written procedures and documented test results that the process meets the requirements.

In use packaging is periodically inspected to the appropriate Maintenance Procedure by Cobalt Operations or Isotope Production, depending on ownership of packaging.

Customer Services (Installation) including Nordion agents follow IN/QA 0120 F000 *Quality Assurance Program for Delivery of a Type B Radioactive Material Package to a Carrier* and pertinent installation instructions.

5-6-4 Final Inspection —Final inspection of the packaging is completed by the supplier following inspection and test plans approved by Nordion.

5-6-5 Inspection, Measuring and Test Equipment —All measuring and test equipment used for controlling processes and verifying product quality is calibrated against certified equipment having a known relationship to national standards. If no standard exists, accepted values are derived from accepted values of national physical constants.

The calibration of inspection and production measuring and testing equipment is the functional responsibility of the Cobalt Operations and Isotope Products Quality Control groups. The calibration of radiation monitoring equipment is carried out by Safety, Environment and Regulatory Affairs. Calibration procedures exist for each type of measuring and test equipment, and include:

a) Equipment Description

b) Identification Number

c) Location

d) Calibration interval

e) Calibration check method

f) Acceptance criteria

g) Action to be taken when results are not satisfactory.

Records of calibration status are maintained in the appropriate equipment files.

Manufacturers of packaging and components are required to maintain calibrated equipment to specified standards. Verification is through Nordion Quality Assurance audit.

5-7 Handling, Storage, and Shipping

5-7-1 —The Project Engineer identifies, in the Technical Specification, the requirements for handling and storing, and the critical functions where abuse and misuse may result in damage or deterioration of packaging or components. Cobalt Operations and Isotope Production maintain procedures for safeguards against damage. Storage areas have access restricted, and special handling equipment is used. Areas and equipment are audited annually by Quality Assurance to verify that proper practices are in place and maintained.

5-7-2 —All loaded RAM transport packages are checked before shipment following established procedures. These include Preparation for Shipment, and User's Instruction Documentation. The shipping documentation is also reviewed, transport index determined, and the package labelled.

5-7-3 —Carriers are provided with a Nordion guideline information booklet and must be certified by training in Transportation of Dangerous Goods (Class 7) to meet Canadian transport regulations.

5-8 Nonconformance Control and Corrective Action

Following the procedures in the Quality Assurance Manual, disposition of nonconforming material is reviewed and the activity recorded. The system requires that the disposition of nonconformances be requested in writing. The responsibility for review and the authority for disposition rests with the Material Review Board (MRB). The membership of the MRB consists of representatives from:

- Cobalt Operations for Industrial Irradiation Division,
- Isotope Production for Isotope Products Division,
- Quality Control representative from the appropriate Division,
- Quality Assurance,
- Package Engineering,
- Purchasing.

Nonconforming material is reviewed for disposition as:

- to its integrity if reworked to the specified requirements with reinspection,
- to acceptance as-is,
- to rejection and scrapping.

Description of the nonconformity, and action taken is recorded and maintained in the Unit History File.

Cobalt Operations or Isotope Production management, depending on ownership, reviews maintenance reports annually or more frequently if there is a need. The

5-9 Quality Records

5-9-1 —Records are maintained to show that the specified quality requirements were met, and the quality system operates correctly. Pertinent supplier quality records are an element of these data. The nature of the quality records is identified in the manufacturing plans. These records are maintained as a Unit History File for each radioactive material transport packaging run. As a minimum, the following records form a Unit History File:

a) Table of Contents

b) Supplier History File for components used, including, but not limited to:

- Nordion QA Release Form,
- Inspection and Test Plans,
- completed inspection records,
- list of drawings and specifications used,
- copies of Deviation Disposition Requests (DDRs)
- Certified material test reports,
- Certified NDE reports,
- Welders' qualification certificates,
- radiation survey data and film.

c) reference to Manufacturing Plan used,

d) completed process, inspection, measurement, test records,

e) completed copies of Deviation Disposition Requests,

f) Release for Shipment forms (normally stored in the Unit History File),

g) Quality Control Checklists for 'empty' transport packagings

(maintained in the Unit History Files),

5-9-2 —Records are maintained in climate-controlled, secured areas with limited access at Nordion.

5-9-3 —Retention periods set for Quality records relevant to RAM transport packaging are:

a) RAM transport packaging

- Permanent, (life of packaging) history files

b) Design records

- Permanent, (life of packaging + 15 years)

c) Procurement records

- Permanent, (life of packaging)

d) Quality control records

- Permanent, (life of packaging)

e) QA Programs

- Until replaced or updated + 2 years

Details of retention periods for specific records are detailed in the Quality Records procedure in the Quality Assurance Manual.

5-10Audits

5-10-1 —Internal audits are performed by, or under the direction of, Quality Assurance. The audit team members are selected by the Manager, Quality Assurance. The members are appropriately qualified, and not directly involved with the area to be audited. The lead auditor is a member of Quality Assurance trained in audit techniques. RAM transport package handling and storage is audited annually and the results are reported to the Executive Management Committee.

5-10-2 —External audits of the manufacture of transport packaging are completed annually by Quality Assurance or an independent surveyor qualified by Nordion Quality Assurance. A potential new supplier is audited prior to issue of a contract, and a surveillance program is established for the first production run or prototype. A formal report is issued by Quality Assurance to the Executive Management Committee, Divisional Management Committee as well as

Assurance to the Executive Management Committee, Divisional Management Committee as well as Purchasing, Package Engineering, and Cobalt Operations or Isotope Production.

5-10-3 —All audits are carried out in accordance to CAN/CSA Q10011-91

Appendix 8.3-B IS/DS 0054 N990 rev. B

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TECHNICAL SPECIFICATION

Technical Specification for the Titan Gamma Radiography Exposure Device

IS/TS 0054 N990

CURRENT DATE: 93 AUG

DATE	ISSUE	COMMENTS/AFFECTED PAGE	PREPARED BY	REVIEWED BY	APPROVED BY
92 Nov	A	Original Issue	M. Krzaniak	P. Larabie /	G. Burbidge
				R. Goddard	
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			M Krzaniak	R Goddard	GAB

NOTE:
The portion of this text affected by the changes is indicated by a vertical line in the margins of the pages.

1 SCOPE

This specification establishes the technical requirements for the manufacture, assembly, inspection and delivery of the Titan Gamma Radiography Exposure Device (GRED).

2 DESCRIPTION

The Titan is a gamma radiography exposure device designed to meet the requirements of ANSI N432-1980.[1] It is also designed to meet the 1985 requirements for Type B(U) transport packagings.[2,3] The Quality Plan for the Titan is described in reference [4].

The Titan consists of a titanium S-tube cast within a depleted uranium shield. The S-tube contains the C-990 sealed iridium source. The shield is surrounded with epoxy foam and contained within a titanium shell.

The unit is equipped with several interlocks designed to prevent the accidental and/or unauthorized exposure of the radiation source.

3 APPLICABLE DRAWINGS

Nordion shall maintain a list of current drawings and shall submit the list to the Vendor on the date of tendering documents. In the event that drawings listed in the contract documents are revised, new drawings and a new list shall be submitted to the Vendor. However, only the final drawing list shall be included in the unit history file.(See section 6-9.)

If certain requirements or data on the drawings conflict with the requirements of this specification, the governing requirements shall be at the discretion of the Purchaser.

4 APPLICABLE STANDARDS

The documents listed in Appendix A form an integral part of this specification, where applicable. They do not, however, supersede the requirements of this specification. If there is any conflict between this specification and the listed documents, the governing requirements are those specified herein.

5 REQUIREMENTS

All components as shown on the applicable drawings shall be fabricated, assembled, inspected, and prepared for delivery by the contractor as specified herein. Final acceptance of the packaging shall be dependent upon successful completion of all tests and checks specified in Section 6 of this specification. The Vendor shall maintain a close liaison with the Purchaser, or his authorized representative, throughout all phases of the work.

5-1 Code Requirements

This specification is subject to CSA Standard CAN3-Z299.3-85, plus the following system functions from CAN3-Z299.2-85:

1) Documentation
2) Handling and Storing
3) Production
4) Packaging and Shipping
5) Corrective Action

The Vendor shall maintain a system of internal audit and corrective action to monitor and support the quality assurance system. Records of internal audits are the sole property of the Vendor. However, evidence of the audit program and a functioning corrective action system shall be provided to the Purchaser upon request.

5-2 Manufacturing Drawings

The drawings listed in the contract documents are design and reference manufacturing drawings. The Vendor may make his own workshop drawings. Such shop drawings shall be submitted to the Purchaser for approval at least one week before the start of the component's manufacture. Approval by the Purchaser of such shop drawings shall not relieve the Vendor from the responsibility for any errors or omissions therein.

The Vendor shall control drawings, including previous revisions, in a manner that conforms to the requirements of CAN-CSA-Z299.2 clause 3.5.3.

Storage and Handling of Materials and Components

Storage and handling of all materials and processed sub-assemblies shall be carried out in a manner that ensures their positive identification during manufacture and assembly. The requirements of CAN-CSA-Z299.2, clause 3.5.12 shall apply.

The materials identification requirements are detailed in Section 6-3 of this specification. It is the Vendor's responsibility to develop packaging and delivery systems in accordance with CAN-CSA-Z299.2 clause 3.5.15.

5-4 Manufacturing Procedures

5-4-1 Workmanship

Workmanship shall be of high quality in accordance with practice pertinent to the manufacture of steel structures. The packaging is subject to Purchaser's quality surveillance.

The Vendor is required to develop manufacturing processes that consistently meet the specified requirements of clauses 3.5.13 and 3.5.14 CAN-CSA-Z299.2.

5-4-2 Manufacturing Control Plan and Special Process Procedures

A Manufacturing Control Plan and special process procedures shall be prepared by the Vendor according to the requirements of CAN-CSA-Z299.2 and this specification. Two copies of the special process procedures shall be submitted for the Purchaser's approval at least one (1) week prior to manufacture. One approved copy will be returned to the Vendor.

Special Processes include, but are not limited to:

1) Welding

2) Painting

3) Titanium cleaning and handling

4) Component identification

5-4-3 Welding

Welding shall be according to ASME BPV Code Section IX.

The Vendor shall submit a detailed welding procedure for approval by the purchaser at least one (1) week prior to beginning production.

Welding electrodes, flux and other materials to be used shall be certified to the applicable specifications.

Welding procedures, based on standards other than those specified above, must be submitted for approval at the time of quotation.

Welders, who shall perform welding for this contract, and who are qualified to standards other than those specified above, must submit their qualifications for approval.

Unless approved by the Purchaser, local heating shall not be used for any purpose whatsoever. Excessive force shall not be used for fit-up or in closing the work.

5-4-4 Fitting and Machining

As a minimum requirement, the dimensions and tolerances called for on the Purchaser's drawings and on the approved shop drawings shall be met. All surface finishes shall be in accordance to the finish noted on the drawings and shall be compatible with associated dimensional tolerances and fits.

5-4-5 Surface Finish and Cleanliness

All welded surfaces shall be smooth and shall merge smoothly into the parent metal. All gouges, scratches, or other marks shall be removed.

All scale, oxide, weld spatter, oil, chips, and other foreign material shall be completely removed from all exposed parts. All surfaces that cannot be cleaned after assembly shall be free of all foreign material (including temporary rust protective coatings) prior to assembly.

Stainless steel and titanium parts shall be processed and handled in such a way as to minimize contamination by iron, grit, lead, halogens, and sulphur. Only clean, stainless steel brushes, and iron-free grinding wheels shall be used on stainless steel surfaces. Only clean, sharp silica sand shall be used for grit blasting. Shot peening or blasting is not permitted.

All stainless steel parts not identified for painting shall be cleaned to an approved manufacturer's procedure.

The cleaning procedure shall be submitted to the Purchaser for approval before use. Cleaning materials shall not exceed the following level of contaminants:

1) total halogens to be less than 100 ppm

2) total sulphur to be less than 1% by weight

3) total iron to be less than 10 ppm

Titanium parts shall be descaled and cleaned. The cleaning procedure shall be considered to be a special process and subject to the Purchaser's approval. All components shall be protected and covered to prevent damage, corrosion, and the entry of foreign material. The Titan shall be supplied with all surfaces suitably protected against corrosion during shipment and storage at an indoor, unheated site. The methods of protection for all stages shall be subject to the Purchaser's approval. All components shall be clearly marked with their part numbers, and the method of marking shall be considered to be a special process.

5-4-6 Coatings

The primary radiation shield is a depleted uranium alloy (0.75 % Ti) casting coated with an approved paint. The coating shall be applied in accordance with the manufacturer's instructions.

6 INSPECTION, TESTS AND DOCUMENTATION

The Vendor shall provide all testing and inspection services and facilities except where otherwise specified. The inspection work shall be under control of a competent chief inspector, whose prime responsibility is inspection, and who is independent of production.

The Vendor shall prepare a detailed Inspection and Test Plan, including Inspection Check Sheets and Inspection Procedures according to the requirements of CAN-CSA-Z299.3 clause 3.5.6 and this specification.

Where specified by the Purchaser prior to the start of manufacture, actual component dimensions shall be recorded. Pass/fail statements are discouraged.

Statistics shall be used as specified by the Purchaser to demonstrate consistency within and between batches.

Two copies of the Inspection and Test Plan including Inspection Check Sheets and Inspection Procedures shall be submitted to the Purchaser at least one (1) week prior to manufacture. One approved copy of each will be returned to the Vendor.

Inspection by the Purchaser or his authorized representative shall not in any way relieve the Vendor of any of the inspection duties called for herein.

If deemed necessary, the Purchaser shall have the right to specify additional inspection or testing. Such inspection and testing shall be at the expense of the Purchaser.

The Vendor shall maintain records of all inspections and tests that shall be available for review by the Purchaser or his authorized representative. It shall be possible to trace these records for any unit serial number.

6-1 Non-Conformance and Corrective Action

If any part, component, or assembly fails to meet an inspection or t st requirement specified herein, and the Vendor proposes to use the part in a production unit, the Vendor shall notify the Purchaser according to the requirements of QAP-B-03 Quality Bulletin-Supplier Quality Guidelines, of the Nordion International Inc., Industrial Irradiation Division Quality Assurance Manual.

The Vendor must obtain written permission from the Purchaser before any remedial action is taken.

If remedial action, including associated redesign, is likely to affect the results of tests or work previously completed, appropriate reinspection and testing shall be carried out. The repair, the rework, and the Quality Control procedures necessary to ensure a satisfactory repair shall be subject to approval by the Purchaser.

Full documentation of all of the above shall be maintained so that nonconformance can be evaluated and corrected.

6-2 Reinspection

At the request of the Purchaser, the Vendor shall reinspect any component or material. Any defects so revealed shall be cause for rejection of the component, or alternatively, for remedial action and subsequent reinspection. All costs of reinspection shall be borne by the Vendor. If no unacceptable defects are revealed, reinspection requested by the Purchaser shall be at the Purchaser's expense.

6-3 Materials and Component Inspection

6-3-1 General Requirements

The Vendor shall establish a system of sub-supplier management and raw material control whereby:

(a) Specification of materials and components is clearly stated in the purchase documents;

(b) test requirements are documented;

(c) test reports are reviewed against the requirements;

(d) supplier performance is monitored and communicated back to the supplier on a regular basis.

6-3-2 Raw Materials

Materials and components used in the construction and assembly of the packaging and its associated equipment shall be as specified on the applicable drawings. If materials, or components are to be substituted, then the substitution must be approved by the Purchaser. Where proprietary parts or materials are specified, it is the Vendor's responsibility to ensure that they conform to the standards given in the manufacturer's specifications.

Certification of materials by the Vendor is required in the form of Certified Material Test Reports (CMTR's), Mill Certificates, or Certificates of Compliance. This documentation shall be included in the History File described in Section 6-9 of this specification.

The Vendor is responsible for setting up systems to enable batch tracing to be carried out. Such systems shall be submitted to the Purchaser for approval.

6-3-3 Purchased Mechanical Components

All purchased components shall be as specified on the manufacturing drawings. Proof shall be in the form of permanent markings, (such as model or part numbers) or statements of compliance by the supplier.

6-4 Weld Tests

The root pass of the weld and the completed weld, indicated on the drawings by the symbol L.P., shall be inspected to and meet the requirements of, the methods of ASTM E165, Standard Methods for Liquid Penetrant Inspection. The root pass shall be inspected on both sides where possible.

Mechanical discontinuities at the surface will be indicated by bleeding out of the penetrant. However, localized surface imperfections such as those that may occur from machining marks or surface conditions may produce similar indications that are irrelevant to the detection of unacceptable discontinuities.

Any indication that is believed to be irrelevant shall be regarded as a defect and shall be re-examined to verify whether or not actual defects are present. Surface conditioning may precede the re-examination. Irrelevant indications and broad areas of pigmentation that mask defects are unacceptable.

Relevant indications are those that result from mechanical discontinuities. Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications that are circular or elliptical with length less than three times the width.

The acceptance criteria for liquid penetrant inspection of the welds shall be as follows:

1) No more than five (5) linear indications.

2) Maximum size of a linear indication to be 0.08 in (2 mm) long.

3) Adjacent linear indications to be 1.0 in (25.4 mm) apart.

The Vendor shall submit a detailed liquid penetrant inspection procedure to the Purchaser for approval.

The liquid penetrant inspection shall be carried out by an inspector certified to Standard CGSB 48-GP-9.

6-5 Mechanical Tests

6-5-1 Dimensions

As specified by the Purchaser, the packagings and all attachments, and associated equipment, shall be inspected by the Vendor at all stages of manufacture and assembly to verify that the dimensions, fit, alignment, and surface finish are in accordance with the requirements shown on the Vendor's shop drawings, and on the drawings referred to in Section 3 of this specification. The reference temperature for dimensions shall be 20°C (68°F). The inspection shall also verify that the workmanship and cleanliness are in accordance with the requirements of this specification.

6-5-2 Operation

Prior to casting, the critical dimensions of the S-tube specified by the Purchaser shall be recorded. In addition, the ovality of the tube shall be tested by passing a 0.350 inch (9 mm) diameter stainless steel sphere through its length. The sphere shall be able to roll through the entire length of the tube and out.

The ovality test shall be repeated after casting.

The Vendor shall test the assembled Titan for freedom of operation using an inactive C-990 source assembly. A minimum of 10 cycles shall be completed for each unit. Each cycle shall consist of:

(a) attaching a projection sheath and control cable to the unit,

(b) turning the lock into the OPERATE position,

(c) projecting the dummy source assembly to the end of the projection sheath,

(d) returning the dummy source to its shielded position and,

(e) removing the projection sheath and bayonet connector. It is not necessary to disconnect the control cable from the dummy source assembly.

The lock shall move freely into the OPERATE position and shall snap freely into the LOCK position once the dummy source assembly returns to its stored position. The dummy source assembly shall travel smoothly and freely through the projector and the projection sheath.

The Vendor shall complete the quarterly inspection procedure as per the requirements of Nordion Specification IS/OM 0090 N990.

The results of these operation tests shall be included in the unit history file described in section 6-9.

6-6 Alpha/Beta Contamination Test

The coated depleted uranium alloy casting shall be checked for alpha and beta contamination according to the Vendor's procedure. The test procedure shall be submitted for the Purchaser's approval at least one (1) week prior to beginning production. The surface shall have less than 10^{-4} microcurie/cm^2 (4 Bq/cm^2) of alpha and beta contamination.

The same alpha and beta contamination test shall be applied to the internal surface of the S-tube and the external surface of the assembled unit.

6-7 Epoxy Foam Dens'

The Titan shall be weighed imr ediately before and after each installation of epoxy foam. The weight in grams, and the corresponding average density of the foam shall be calculated and included in the unit history file. (See Section 6-9.) Any unit with a total foam density less than 0.2 g/cc shall be rejected.

6-8 Shield Tests

6-8-1 Depleted Uranium Casting

Each completed depleted uranium casting shall be weighed and the weight (in grams) recorded and included in the Unit History file. (See Section 6-9).

As specified by the Purchaser, preliminary shielding tests may be required prior to final assembly. The results of such tests shall be included in the unit history file. However, the governing requirement shall be the successful completion of the radiation shielding test on the assembled unit. (See Section 6-8-2)

6-8-2 Radiation Shielding Test

Each assembled Titan shall be subjected to a radiation shielding test. The test procedure shall be submitted for the Purchaser's approval at least one (1) week prior to beginning production. The Purchaser shall have the right to attend the test. The shielding test shall consist of:

1) Loading the unit with 100 effective Ci (3.7 TBq) of Ir-192 in a C-990 sealed source. The effective Ci shall be based on an exposure rate constant of 550 mrem/hr/Ci at a distance of 1 m from the sealed source.

2) Measuring the radiation field on the surface, 50 mm from the surface and 1 metre from the surface of the unit.

3) Fixing radiographic film to the external surface of the unit in a manner that ensures that any defects in the casting will become apparent on the film.

The radiation field shall not exceed:

a) 167 mrem/hr (1.67 mSv/hr) at any external surface of the Titan.

b) 41 mrem/hr (0.41 mSv/hr) at 50 mm from any external surface of the unit.

c) 1.7 mrem/hr (0.017 mSv/hr) at one metre from any external surface of the Titan.

Extrapolation of dose rates shall be permitted provided that the source strength is not less than 60 effective Ci (2.2 TBq) of Ir-192.

Any unit that does not satisfy these requirements shall be rejected.

6-9 Documentation

The Vendor shall prepare and maintain records which shall be available to the Purchaser during the period of manufacture. These shall be compiled, as the work proceeds, into a bound 8 1/2" x 11" History File which shall be turned over to the Purchaser with the Quality Assurance Release Form for each batch run of items (if applicable). The run components shall be kept segregated until the Quality Assurance Release Form is accepted by The Purchaser.

The History file shall contain the following:

1) Table of Contents.

2) History File release or transmittal.

3) Q.A. Release Form No. QAP-SF-06.1A. (Nordion International Inc., Industrial Irradiation Division Quality Assurance Manual.)

4) Copies of all purchase orders.

5) List of approved Manufacturing Control Plan, Special Process Procedures, Inspection and Test Procedures, and Inspection and Test Plan including Inspection Check Sheets.

6) Completed Inspection and Test Check Sheets and Reports.

7) List of drawings and specifications with current revisions in effect at the time of manufacture, and the serial numbers of the units manufactured.

8) Copies of all Deviation Disposition Requests (DDR's) signed by the Purchaser's Engineering Department on Nordion Form No. QAP-SF-14.

9) Certified Material Test Reports (CMTR's) or Mill Certificates or Certificates of Compliance, certifying all materials used are as specified.

10) Certified NDE reports, shielding tests, etc., and personnel qualifications where applicable.

11) Any other documents requested by the Purchaser in the contract documents.

7 DELIVERY

The Vendor shall obtain from the Purchaser, prior to delivery, the Nordion International Inc. Quality Assurance release of the Titan GRED and the History File release or transmittal.

The Vendor shall be responsible for proper packing of the Titan to ensure protection during shipment and for arranging delivery to the Purchaser.

8 SERVICING

The Vendor shall maintain service records for all service work performed on Titan units both under warranty and after the warranty has expired. These records shall include at a minimum:

1) Serial number and date of manufacture.

2) An assessment of the condition of the unit, and the date it was received.

3) A description of the work performed and the date it was completed.

4) Test results demonstrating the adequacy of the repair.

The Vendor shall supply copies of the service reports to the Purchaser upon request.

9 CUSTOMER FEEDBACK

The Vendor and the Purchaser shall each establish effective systems for recording customer feedback and complaints relating to the Titan. Both parties shall provide copies of the feedback to the other within one month of their receipt. Where appropriate, a system for Corrective Action will be applied to resolve design or manufacturing problems.

10 REFERENCES

[1] ANSI N432-1980, Radiological Safety for the Design and Construction of Apparatus for Gamma Radiography, American National Standards Institute, 15 August, 1980

[2] SOR/91-304, Transport Packaging of Radioactive Materials Regulations, Atomic Energy Control Act (Canada), 9 May, 1991

[3] IAEA Safety Series No. 6, Regulations for the Safe Transport of Radioactive Material 1985 Edition (As Amended 1990), International Atomic Energy Agency, 1990

[4] Quality Plan for the Titan Gamma Radiography Exposure Device, Nordion Specification IS/QP 0052 N990.

APPENDIX A -Applicable Standards

ASTM Volumes 01.01, 01.03, 01.04, 01.05, 02.04, 03.01, 03.02, 03.03, 03.05 (As applicable).

ANSI B18.2 Square Hexagonal Bolts and Nuts.

ANSI B18.3 Socket Cap, Shoulder and Set Screws.

CSA B1.1 Unified Screw Threads.

CSA B95 Surface Texture, Waviness and Lay.

ASME BPV American Society of Mechanical Engineers BPV Code Section IX: *Welding and Brazing Qualifications.*

ASME BPV American Society of Mechanical Engineers BPV Code Section II: *Material Specifications, Parts A, B, C.*

CGSB 48-GP-9 *Certification of Nondestructive Testing Personnel.*

CSA CAN3-Z299.0-86, *Guidelines for Selecting and Implementing the CAN3-Z299-85 Quality Assurance Program Standards.*

CSA CAN3-Z299.2-85 *Quality Assurance Program - Category 2.*

CSA CAN3-Z299.3-85 *Quality Assurance Program - Category 3.*

Appendix 8.3-C IS/TS 0010 C000 rev. C

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TECHNICAL SPECIFICATION

IS/TS 0010 C000

Technical Specification for Radioisotope Capsules and Sources

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NOTE:
The portion of this text affected by the changes is indicated by a vertical line in the margins of the pages.

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1 SCOPE

This specification establishes the technical requirements for the manufacture, assembly, inspection and delivery of radioisotope sources & capsules.

It also covers the complete assembly, including all sub-assemblies and components of the sources and capsules, whether subcontracted or not. The Vendor shall be responsible for ensuring that all applicable sections of this specification have been met.

1-1 Definitions

The following definitions apply in this specification:

Capsule: Components comprising the source assembly.

Vendor: The party who agrees to supply the materials or perform the services as required by Nordion International Inc.

Purchaser: Nordion International Inc.

Source: A term used to describe an encapsulation that contains sealed radioactive material.

NOTE

To avoid repetition in this specification, the words "sources" and "capsules" have been used interchangeably. All requirements apply to both equally.

2 GENERAL INFORMATION

2-1 Applicable Capsules & Sources

This Technical Specification applies to sources and capsules listed in Appendix A. Detailed manufacturing and inspection requirements are detailed in Sections 3 and 4 of this specification. As not all requirements apply to all capsules and sources, Table 1 is provided, which gives a matrix of the applicable specifications for each of the capsules.

2-2 Applicable Drawings

The drawings for the capsules are listed in Appendix A, which is an integral part of this Specification. The applicable issues are those effective on the date of tendering documents. In the event that certain requirements or data on the drawings conflict with the requirements of this specification, the governing requirements shall be at the discretion of the Purcha

The Vendor shall notify the Purchaser of any error or omission in the applicable drawings. Failure to do so shall not relieve the Vendor of any responsibility to produce a product that is acceptable to the Purchaser, and that meets all the requirements called for in Section 4.

2-3 Applicable Standards

The documents listed in Appendix B form an integral part of this specification, where applicable. They do not however, override the requirements of this specification. If there are equivalent standards that the Vendor prefers, such standards must be submitted to the Purchaser for approval. Approval by the Purchaser shall not relieve the Vendor from his responsibility to meet the requirements of this specification.

2-4 Nordion Specifications

The Nordion specifications and procedures listed in Appendix C are primarily for use by Nordion. Should the Vendor be required to meet any of these standards, he shall be given a copy of the applicable standards and be so advised with the Request for Quotation.

3 REQUIREMENTS

3-1 General

All components as shown on the applicable drawings shall be fabricated, assembled, inspected, and prepared for delivery by the Vendor as specified herein. Final acceptance of the source assembly shall be dependent upon passing all tests and checks specified in Section 4 of this specification. The Vendor shall maintain a close liaison with an authorized Nordion representative throughout all phases of the work.

Table 1
Matrix of Applicable Sections of this Specification

CAPSULE	3.1	3.2	3.3	3.4	3.5.1	3.5.2	3.5.3#	3.5.4	3.5.5	3.5.6	3.5.7	3.5.8	3.5.9	4.0	4.1	4.2	4.3*	4.4*	4.5*	4.6	4.7	4.8
C-324 Type 1	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
C-324 Type 2	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
C-265	X	X	X	X	X			X	X			X	X	X	X	X	X			X		X
C-181	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
XC-192	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X		X
C-204	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
XC-234	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
C-245	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X		X
XC-266	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X		X
C-337	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C-340	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C-343	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C-349	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
C-352	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
C-164	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
TC-346	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
C-357	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
C-359	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C-361	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C-369	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C-990	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C-140	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X
C-163	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X		X		X
C-168	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X		X		X

* *- Includes subsections.*
# *- By Nordion only.*

3-2 Code Requirements

This specification shall be subject to the CSA Standard CAN3-Z299.3-85 issue, and the following three system functions from CSA CAN3-Z299.2-85:

(1) Handling and Storing

(2) Production

(3) Corrective Action

3-3 Manufacturing Drawings

The drawings listed in the contract documents are reference design and manufacturing drawings. The Vendor may make his own workshop drawings. Such drawings shall be submitted for approval by the Purchaser, 3 weeks prior to the start of that component's manufacture. Approval by the Purchaser of Vendor's shop drawings shall not relieve the Vendor from responsibility for any errors or omissions therein.

3-4 Storage and Handling of Materials and Components

Materials and components used in the construction and assembly of the capsule shall be as specified on the applicable drawings. If the materials or the components are to be substituted, then the substitution must be subject to approval by the Purchaser. Where proprietary parts or materials are specified, it is the Vendor's responsibility to ensure that they conform to the standards given in the manufacturer's specifications.

For those components and assemblies required to meet the quality verification requirements of CSA Z299.2-85:

i) Certification of materials by the Vendor is required in the form of Certified Material Test Reports (CMTR's), Mill Certificates, or Certificates of Compliance. This documentation shall be included in the History File described in Section 4-8 of this specification.

ii) Storage and handling of all materials and processed subassemblies shall be carried out in a manner that ensures their positive identification during manufacture and assembly. The requirements of section 3.5.12 of CSA Z299.2-85 shall apply.

Handling of all materials used in sealed source fabrication shall be such that any scratching, denting, or marking of any kind is minimized.

3-5 Manufacturing Requirements

3-5-1 Manufacturing Control Plan—A Manufacturing Control Plan and special process procedures shall be prepared by the Vendor according to the requirements of CSA Z299.2-85 and this specification. Two copies of the special process procedures shall be submitted to the Purchaser at least three weeks prior to manufacture for approval. One approved copy of each will be returned to the Vendor.

3-5-2 Inactive Welding—The Vendor shall submit a detailed welding procedure for approval by the Purchaser at least 3 weeks prior to beginning production.

Welding electrodes, flux, and other materials to be used shall be certified to applicable specifications.

Welders, who shall perform welding for this contract must submit their qualifications for approval.

Production welds require a minimum of 80% penetration. Figure 1 illustrates the correct methods for measuring the penetration requirements for side & end welds. The Vendor should demonstrate, by in-process control, that he meets this requirement. In the absence of in-process control, the Vendor shall make a test weld on a dummy capsule by each individual welder at the start of each production run and once for every subsequent 25 capsules processed.

The test sample(s) shall be inspected according to Section 4-4, "Macro Examination of Welds".

Cleaning of stainless steel parts shall be in accordance with the recommendations and precautions of ASTM A380.

3-5-3 Active Welding—Active welding will be performed by Nordion. The general requirements described in Section 3-5-2 (above) also apply to active welding.

Specific active welding requirements are listed in Appendix C. The appropriate specification is indicated on the drawing and must be strictly adhered to.

$$\% \text{ Weld Penetration} = \frac{Tw}{Tt} \times 100$$

Where Tw = Distance to intersection of weld penetration & material joint
Tt = Capsule wall thickness

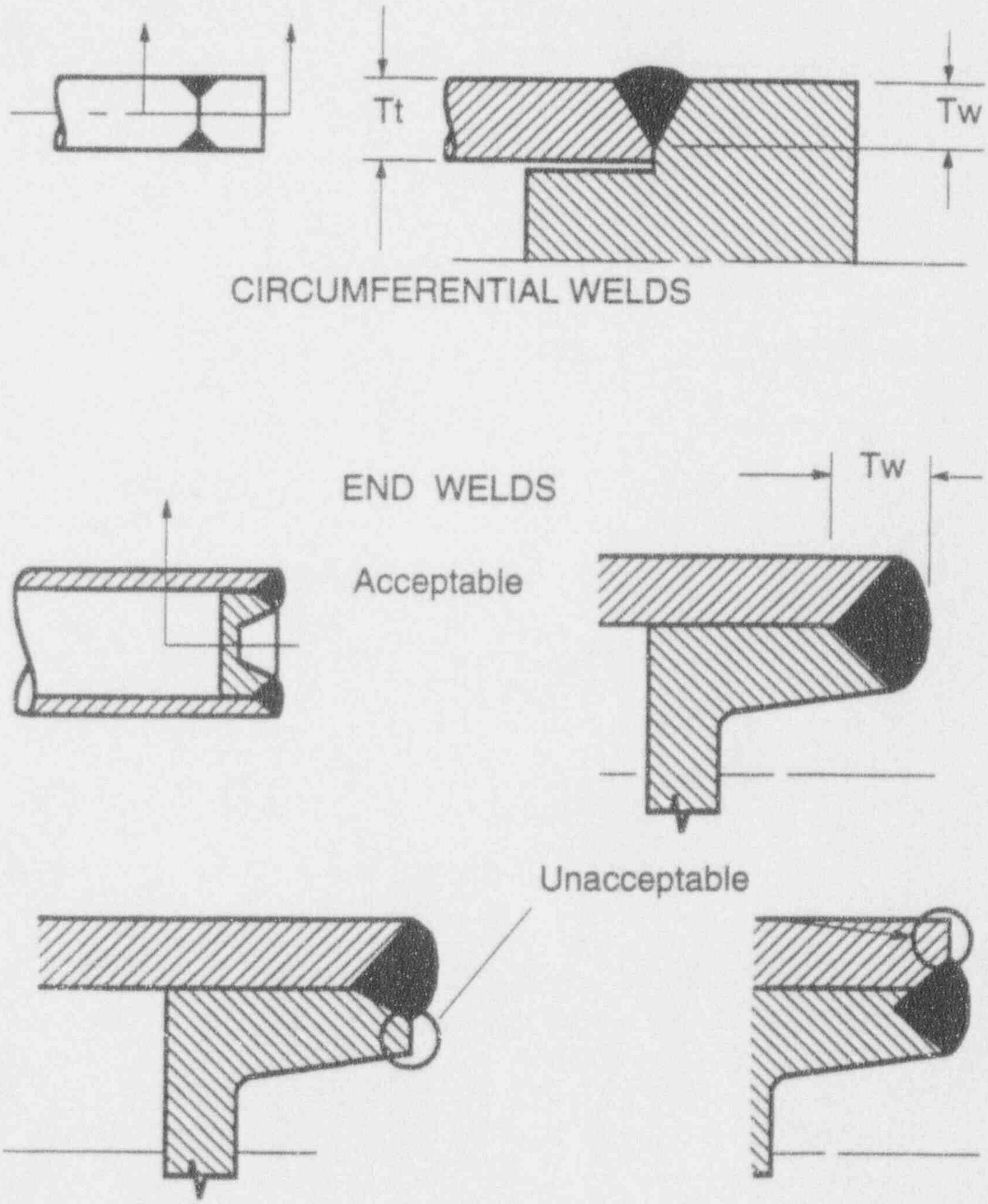

Figure 1
Weld Penetration

3-5-4 Fitting and Machining—The dimensions, tolerances, and surface finishes called for on the applicable drawings shall be met. Any discrepancies in requirements shall be reported to the Purchaser immediately.

For side welded capsules, the base capsule and cap capsule end faces must mate properly with no visible gap between the end faces.

3-5-5 Tooling—Any tooling manufactured by the Vendor shall be manufactured in accordance to this specification.

All measuring gauges and/or special tooling used to verify or preset dimensions shall be checked according to the CSA Quality Verification requirements described in Section 3-2.

Sources or capsules manufactured with new tooling shall be tested and inspected according to Section 4-6. Production using new tooling may only begin once the tooling has been approved by the Purchaser and up-to-date tooling drawings have been submitted to the Purchaser.

Tooling drawings shall be re-submitted to the Purchaser if the tooling has been modified, re-designed, or at the Purchaser's request.

3-5-6 Heat Treating—The C-337, C-340, C-343, C-359, C-361, C-369, and C-990 capsules all contain parts that require special heat treatment to obtain a specific hardness, grain structure, and phase composition. The heat treating procedure and the raw material stock size are specified on the drawing. This procedure will give the required material properties for the specified stock material.

The Vendor may propose an alternative material size and/or heat treating procedure. Such alternatives must be submitted to the Purchaser for approval at least 3 weeks prior to the start of manufacture.

3-5-7 Crimping—Crimping shall only be done with Purchaser approved tooling (Section 3-5-5) and in-process control production procedures.

Production crimping shall be inspected according to Section 4-5.

3-5-8 Surface Finish and Cleanliness—All welded surfaces shall be smooth and shall merge smoothly into the parent metal. All gouges, scratches, or other marks shall be removed.

All scale, oxide, weld spatter, oil, chips, and other foreign material shall be completely removed from all exposed parts. All surfaces that cannot be cleaned after assembly shall be cleaned of all foreign material (including temporary rust protective coatings) prior to assembly.

Stainless steel parts shall be processed and handled in such a way as to minimize contamination by iron, grit, lead, halogens, and sulphur. Only clean stainless steel brushes, and iron-free grinding wheels shall be used on stainless steel surfaces. Only clean, sharp silica sand shall be used for grit blasting. Shot peening or blasting is not permitted.

3-5-9 Cleaning, Packing, Storage & Shipping—Upon completion all parts shall be cleaned. Stainless steel components shall be cleaned according to ASTM A380, section 8. Two copies of the Vendor's cleaning procedures shall be submitted for approval to the Purchaser at least 3 weeks prior to manufacture.

All components shall be individually wrapped and placed in packages that identify the capsule type and serial numbers. They shall be stored in such a manner that they will not become distorted or damaged during transit. All components shall be handled in accordance with the procedures described in Section 3-4.

If components are to be stored for an extended period, they shall be stored in a dry, clean area.

4 INSPECTION, TESTS, AND DOCUMENTATION

The Vendor shall provide all testing and inspection services and facilities except where otherwise specified. The inspection work shall be under the control of a competent chief inspector, whose prime responsibility is inspection, and who is independent of production.

The Vendor shall prepare a detailed Inspection and Test Plan including Inspection Check Sheets and Inspection Procedures according to the requirements of CSA Z299.3 - 85 and this specification.

Two copies of the Inspection and Test Plan including Inspection Check Sheets and Inspection Procedures shall be submitted to the Purchaser at least three weeks prior to manufacture for approval. One approved copy of each will be returned to the Vendor.

Inspection by the Purchaser or his authorized representative shall not in any way relieve the Vendor of any of the inspection duties called for herein.

If deemed necessary, the Purchaser shall have the right to specify additional inspection or testing. Such inspection and testing shall be at the expense of the Purchaser.

The Vendor shall maintain records of all inspections and tests that shall be available for review by the Purchaser or his authorized representative.

In all cases the following are minimum requirements. The Purchaser will consider alternate methodologies, such as the use of statistical process control which provides greater assurance of control.

4-1 Non-Conformance and Corrective Action

If any part, component or assembly fails to meet an inspection or test requirement specified herein, the Vendor shall notify the Purchaser. The Vendor must obtain written permission from the Purchaser before any remedial action is taken.

If remedial action, including associated redesign, is likely to affect the results of tests or work previously completed, appropriate reinspection and testing shall be carried out. The repair, the rework, and the Quality Control procedures necessary to ensure a satisfactory repair shall be subject to approval by the Purchaser.

Full documentation of any of the above shall be maintained so that non-conformance can be evaluated and corrected.

4-2 Reinspection

At the request of the Purchaser, the Vendor shall reinspect any component or material. Any defects so revealed shall be cause for rejection of the component, or alternatively, for corrective action and subsequent reinspection. All costs of reinspection shall be borne by the Vendor; however if no unacceptable defects are revealed, reinspection requested by the Purchaser shall be at the Purchaser's expense.

4-3 Materials and Component Inspection

4-3-1 Raw Materials—Certification of materials by the Vendor is required in the form of Certified Material Test Reports (CMTR's), Mill Certificates, or Certificates of Compliance. This documentation shall be included in the History File described in Section 4-8 of this specification.

4-3-2 Purchased Mechanical Components—All purchased components shall be as specified on the engineering drawings. Proof shall be in the form of permanent markings (such as model or part numbers) or Certificates of Compliance by the supplier.

4-4 Macro Examination of Welds

This method of examination is used for rapid determination of test weld penetration for stainless steel capsules. The sectioning and examination procedures for the C-324 titanium capsule are described in Nordion Procedure IS/OP 0068 C324.

4-4-1 Sectioning— Care should be taken to avoid excessive heat generation during cutting operations.

4-4-2 Finishing—Stainless steel samples shall be sectioned with a saw and then wet ground to a surface achieved with a 600 grit silicon carbide abrasive to remove all saw marks.

4-4-3 Etching—Stainless steel samples shall be immersed in a solution of aqua regia (1 volume of HNO_3 to 3 volumes of HCl).

Samples shall be observed during the process of etching (approximately 2 to 3 minutes). As soon as the weld geometry becomes visible, the samples are removed from the solution and thoroughly rinsed with water.

4-4-4 Requirements—A weld is acceptable if the following requirements are met (Figure 1):

(i) *Prototype capsules:* a minimum of 100% weld penetration.
Production capsules: a minimum of 80% weld penetration.

(ii) General weld appearance is satisfactory.

4-5 Tensile Crimp Testing - Production

All crimp connections on the sources listed in Table 2 shall be tensile tested according to the procedures described in the following sections. The Vendor shall provide the Purchaser with a record of the results of all such tests.

Table 2
Pull Tested Sources

Capsule No.	Description or Use
C-192	Radiography Capsule for Sarnia Inspection
C-245	Radiography Capsule Assembly
XC-266	Radiography Capsule for Sinco Supply
C-337	For Tech. Ops. Camera #660 Source Assembly
C-340	For Budd 520 Camera Source Assembly
C-343	For Spec 2-T Camera Source Assembly
C-359	For Gamma Century SA & 35-SA Camera Source Assembly
C-361	For Tech-Ops #533 Camera Source Assembly
C-369	For Nuclear Iberica NI-202 Camera Source Assembly
C-990	For Nordion Titan Camera Source Assembly

4-5-1 In Process Testing—The following tests shall be performed on the crimped connections for each production run. Three capsule assemblies shall be pull tested to failure: the first, last and one selected at random from each production run (i.e. three (3) in total per run).

(1) Fix the connector end of the source capsule assembly and attach a pull device to the locking ball. Apply an increasing tensile load until failure occurs. Record the load and location of failure.

(2) Fix the source end of the source capsule assembly and attach a pull device to the portion of the assembly (connector end or locking ball) that did not previously fail. Apply an increasing tensile load until failure occurs. Record the load and location of failure.

(3) Similarly pull test the capsule source end to cable crimp and record the failure load.

Should any capsule connector end, locking ball, or source end fail at less than 270 lb (Table 3), the Production run shall not proceed until the cause of failure has been determined and the source capsule has met the minimum (270 lb) pull test requirements.

Table 3
Crimp Failure Loads

Capsule Source End	$\geq 270\ lb_f$
Locking Ball	$\geq 270\ lb_f$
Connector	$\geq 270\ lb_f$

For purposes of crimped connection testing, a production run consists of the crimping of identical parts. More than one capsule type can be involved. Vendor supplied assemblies may be tested using an alternate plan subject to prior Nordion approval.

4-6 First-Off Testing & Inspection

Before regular production can begin using new tooling, a first-off inspection must be performed by Nordion. A minimum of five samples must be manufactured using the new tooling and submitted to the Purchaser for approval. Upon approval, regular production may begin.

A first-off inspection is also required:

(i) if tooling is redesigned or modified

(ii) at the Purchaser's request

(iii) if the manufacturing procedures are changed.

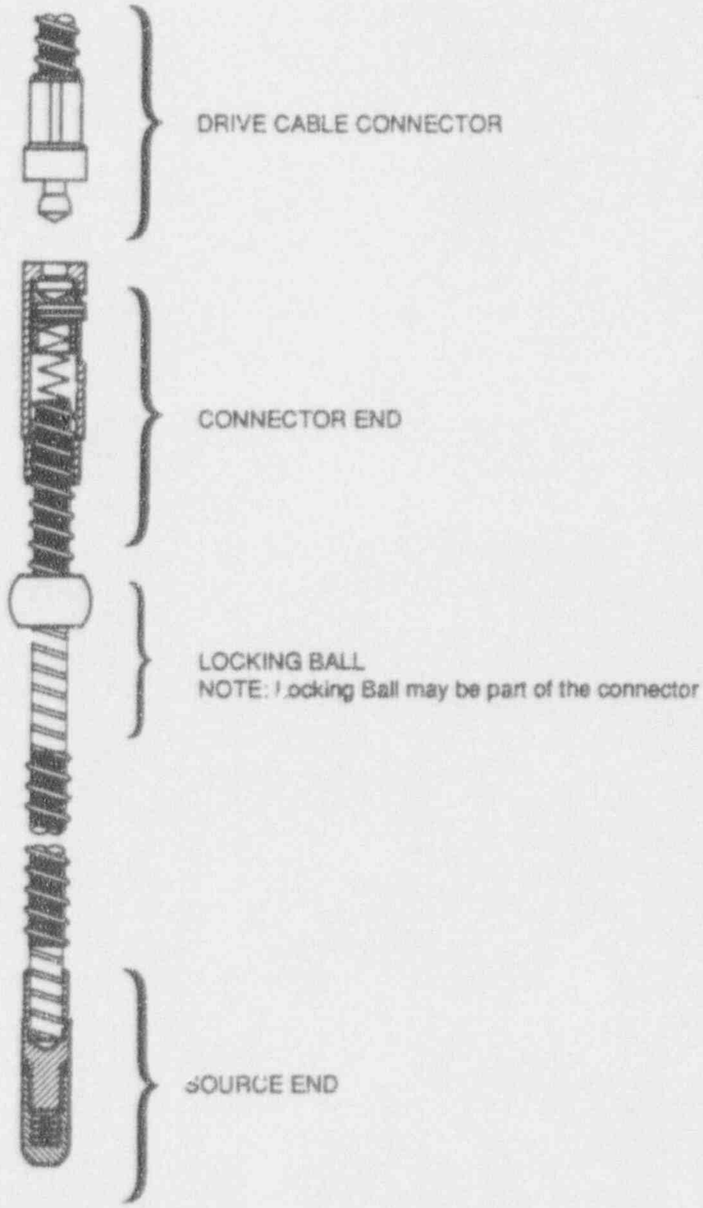

Figure 2
Typical Pull Tested Source

4-7 Hardness Testing

All hardness testing as specified on the drawings, shall be performed in accordance to ASTM E18. Testing shall be performed on the unmachined bar stock of the appropriate diameter, as specified on the part drawing material specification. Equipment and procedures shall be in accordance to the above specification.

For conversion, the procedures described in ASTM D140, "Standard Hardness Conversion Tables for Metals", shall be used.

4-8 Documentation

The Vendor shall prepare and maintain records that shall be available to the Purchaser during the period of manufacture. These shall be compiled, as the work proceeds, into a bound 8½" × 11" (or the equivalent SI metric size) History File that shall be turned over to the Purchaser with the Quality Assurance Release Form for each batch run of items. The run components shall be kept segregated until the Quality Assurance Release Form is accepted by the Purchaser.

The History file is to contain the following:

1. Table of Contents.
2. History File release or transmittal.
3. Q.A. Release Form No. QAP-SF-06.1A, (Nordion International Inc. Quality Assurance Manual) for product.
4. Copies of Purchase Order and all amendments if applicable.
5. List of approved Special Process Procedures, Inspection Procedures, and Inspection and Test Plan including Inspection Check Sheets.
6. Completed Inspection and Test Check Sheets and Reports.
7. List of Drawings and Specifications with current revisions in effect at the time of manufacture, and the serial number of the capsules manufactured.
8. Copies of all original Deviation Disposition Requests (DDR's) signed by the Purchaser's Engineering Dept. on Nordion Form QAP-SF-14.
9. Certified Material Test Reports (CMTR's), Mill Certificates, or Certificates of Compliance, certifying all materials used are as specified.
10. Certified NDE reports, leak test reports, etc. and personnel qualifications where applicable.
11. Any other documents requested by the Purchaser in the contract documents.

APPENDIX A
Applicable Capsules and Drawings

Capsule Type	Description	Engraving ID	Assembly Drawing	Detail Drawing
C-324 Type 1	I-125 Source (T_i)	AD	K121004003	K121010006, K121010007
C-324 Type 2	I-125 Source (T_i)	AE	K121004004	K121010008, K121010009
C-265	X-Ray Fluorescence	AC	A12355	A12356, A12357
C-181	Radiography Capsule Ass'y	BA	A05800	A05796, A05797, A05798, A05799
C-192	Radiography Capsule for Sarnia Insp.	BB	A07120	A07121, A07736, A03334
C-204	Radiography Capsule	BC	A02029	A02030, A02031, A17720
XC-234	Radiography Capsule for Consumers	BD	A07516	A07517, A07518, A07519, A10304, A17720
C-245	Radiography Capsule (Budd)	BE	A09425	A03334, A07736, A17720, A09403, A09266, A09268, A11354, A11355, A11356, A11357
XC-266	Radiography Source Capsule for Sinco	BF	A12671	A12670, A03334, A07736
C-337	Iridium-192 Cable Source Assembly	BG	A16827	A16828, A16829, A16846, A03334, A03335, A17720
C-340	Iridium-192 Cab[illegible]urce Assembly	BH	A16833	A17714, A17716, A17720, A03334, A03335, A16829, A16849
C-343	Iridium-192 Cable Source Assembly	BI	A17715	A17714, A17717, A17720, A16829, A16849, A03334, A03335
C-349	Iridium-192 Capsule Ass'y	BJ	A18351	A18353, K113217027, K113217035
C-352	Iridium-192 Capsule Ass'y	BK	A18388	A16637, A16640, A17720, A18351

APPENDIX A
Applicable Capsules and Drawings(Cont'd)

Capsule Type	Description	Engraving ID	Assembly Drawing	Detail Drawing
C-164	SRC-3 Radiography Capsule Ir-192	BL	A05488	—
	SRC-3 Radiography Capsule Co-60	CA	A05488	—
	SRC-3 Radiography Capsule Sb-124	DA	A05488	—
TC-346	Bulk Iridium Shipping Capsule	BM	A17724	A17722, A17723
C-357	Iridium-192 Stand-Alone Source Capsule	BN	K1121104001	K121110001, A03335
C-359	Iridium-192 Cable Source Assembly	BO	K121104002	K121113001, A17714, A16829, A03334, A17720, A16849
C-361	Iridium-192 Cable Source Assembly	BP	K121104003	K121113002, A17714, A03334, A03335, A16829, A17720, A16849
C-369	Iridium-192 Cable Source Assembly	BQ	K121104004	A03334, A03335, A17720
C-990	Iridium-192 Cable Source Assembly	C990	K122213600	A17714, K122213-601, A16829, A03334, A03335, A16849, K122213-602, A17720
C-140	Cobalt-60 Radiography Source (Type 1 to 5)	CB	A05519	A05520, A05525, A05526, A05527
			A05532 (Type 5 Only)	A05528, A05529, A05530, A05531, A05533, A05534
C-163	Cobalt-60 Radiography Source	CC	A05663	
C-168	Cobalt-60 Radiography Source	CD	A04141	A04142, 04143

APPENDIX B
Applicable Standards

ASTM Volumes	01.01, 01.03, 01.04, 01.05, 02.04, 03.01, 03.03, 03.05 (As Applicable)
CSA B1.1	Unified Screw Threads
CSA B95	Surface Texture
CGSB-48-GP-9	Certification of Non-destructive Testing Personnel
CSA CAN3-Z299.2-85	Quality Assurance Program - Category 2
CSA CAN3-Z299.3-85	Quality Assurance Program - Category 3
ASME BPV Section IX	American Society of Mechanical Engineers, BPV Code Section IX: Welding and Brazing Qualifications
ASME BPV Section II	American Society of Mechanical Engineers, BPV Code Section II: Material Specifications
ANSI Standard N432	Radiological Safety for the Design and Construction of Apparatus for Gamma Radiography
ANSI Standard N542	Sealed Radioactive Sources, Classification
ISO 2919	Sealed Radioactive Sources — Classification

APPENDIX C
Applicable Nordion Specifications and Procedures

Nordion Spec. No.	Title
DG 0042 A000	Sealed Source Fabrication (Short Term Warranty)
DG 0043 Z000	Micro examination of Welds
DG 0044 G000	Macro examination of Welds
DG 0046 C000	Internal Air Pressure Test
DG 0048 Z000	Dye Penetrant Test
DG 0052 C000	Vacuum Liquid Bubble Test
IS/OP 0040 C000	Procedure for Engraving Radioactive Source Capsules

Nordion Spec. No.	Title
DG 0050 C000	Hot Liquid Bubble Test
DG 0065 G000	Dry Wipe Test
DG 0148 C000	Ultrasonic Decontamination Procedure (Low Output Sources)
IS/OP 0031 Z000	Procedure to Check Ultrasonic Tank Operations
IS/OP 0034 Z000	Charcoal Adsorption Leak Test
IS/OP 0068 C324	Operating Procedure for Sectioning and Examining C-324 Capsule welds.

PART 4: REFERENCES

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