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Accession #: D196047872

Document #: SD-TP-OTR-002

Title/Desc:

TEST & EVALUATION REPORT FOR LITC ARROW PAK
PACKAGING DOCKET 95-40-7A TYPE A CONTAINER

Pages: 111

COMPLETE

ENGINEERING CHANGE NOTICE

Page 1 of 21. ECN No **620068**Proj.
ECN

2. ECN Category (mark one) Supplemental ☐ Direct Revision ☒ Change ECR ☐ Temporary ☐ Standby ☐ Supersedeure ☐ Cancel/void ☐	3. Originator's Name, Organization, MSIN, and Telephone No. D. L. Kelly/84400/G1-12/ 372-2276 5. Project Title/No./Work Order No. DOT-7A Test Program/TH540 8. Document Numbers Changed by this ECN (includes sheet no. and rev.) WHC-SD-TP-OTR-002, Rev. 0	3a. USQ Required? ☐ Yes ☒ No 6. Bldg./Sys./Fac. No. N/A 9. Related ECN No(s). N/A	4. Date 03/05/96 7. Approval Designator SQ 10. Related PO No. (LITCO/WHC) C95-K24120
11a. Modification Work ☐ Yes (fill out Blk. 11b) ☒ No (see Blks. 11b, 11c, 11d)	11b. Work Package No. N/A	11c. Modification Work Complete N/A Cog. Engineer Signature & Date	11d. Restored to Original Condition (Temp. or Standby ECN only) N/A Cog. Engineer Signature & Date
12. Description of Change This report now includes U.S. Department of Energy, Office of Facility Safety Analysis (DOE/EH-32) approval. Minor typographical errors corrected throughout the document.			
13a. Justification (mark one) Criteria Change ☐ Design Improvement ☐ Environmental ☐ Facility Deactivation ☐ As-Found ☐ Facilitate Const ☐ Const. Error/Omission ☐ Design Error/Omission ☐			
13b. Justification Details This report now includes U.S. Department of Energy, Office of Facility Safety Analysis (DOE/EH-32) approval. Minor typographical errors corrected throughout the document.			
14. Distribution (include name, MSIN, and no. of copies) C. R. Hoover G1-11 (1) D. L. Kelly G1-12 (8) D. W. McNally G1-11 (1) J. H. O'Brien G1-12 (1) DOT-7A Files G1-12 (1) Central Files A3-88 (orig + 1)		RELEASE STAMP MAR 14 1996 DATE: _____ STA: 34 HANFORD RELEASE ID: 22	

620068

Improvement	[]
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Environmental Permit

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Document Number Revision

Date _____

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ADDITIONAL

**TEST AND EVALUATION REPORT FOR LOCKHEED IDAHO
TECHNOLOGIES COMPANY, ARROW-PAK PACKAGING,
DOCKET 95-40-7A, TYPE A CONTAINER**

D. L. Kelly

Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: ECN# 620068 UC: 722
Org Code: 84400 Charge Code: TH540
B&R Code: Total Pages: 108

Key Words: Arrow-Pak, Test Report, DOT-7A, Type A, Radioactive material, Package, Packaging, LITCO, INEL

Abstract: This report incorporates the U.S. Department of Energy, Office of Facility Safety Analysis (DOE/EH-32) approval letter for packaging use. This report documents the U.S. Department of Transportation Specification 7A Type A (DOT-7A) compliance test results of the Arrow-Pak packaging. The Arrow-Pak packaging system consists of Marlex M-8000 Driscopipe, manufactured by Phillips-Driscopipe, Inc., and is sealed with two dome-shaped end caps manufactured from the same materials. The patented sealing process involves the use of electrical energy to heat opposing faces of the pipe and end caps, and hydraulic rams to press the heated surfaces together. This fusion process produces a homogeneous bonding of the end cap to the pipe. The packaging may be used with or without the two internal plywood spacers. This packaging configuration described in this report is designed to ship Type A quantities of solid radioactive materials.

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(2-89)
ERG (07-80)

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REPLY TO: EM-76:Wangler:3-5078
ATTN OF:

SUBJECT: APPROVAL OF ARROW-PAK AS A SPECIFICATION 7A PACKAGING

TO: T. Teynor, Director, Waste Programs Division, Richland Operations Office

The Arrow-Pak container (docket 95-40-7A) is hereby approved for use as a Department of Transportation Specification 7A Type A packaging. This is based upon our review of the Final Evaluation Report documenting the performance testing conducted on the packaging. The Final Evaluation Report and information pages prepared by Westinghouse Hanford Company are also approved.

If you need additional information, please contact me at 301-903-5078 or Ashok Kapoor at 301-903-6838.



Michael E. Wangler
Headquarters Certifying Official
Office of Transportation, Emergency
Management and Analytical Services, EM-76

cc: see next page

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WHC-SD-TP-OTR-002
Revision 1

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**FINAL EVALUATION REPORT FOR LOCKHEED IDAHO TECHNOLOGIES COMPANY,
ARROW-PAK PACKAGING, DOCKET 95-40-7A
TYPE A CONTAINER**

1.0 INTRODUCTION

1.1 BACKGROUND

This report documents the U.S. Department of Transportation Specification 7A Type A (DOT-7A) compliance test results of the Lockheed Idaho Technologies Company (LITCO) sponsored ARROW-PAK Packaging. The tested packaging was designed and constructed by Arrow Construction, Inc. (Arrow), of Montgomery, Alabama. The ARROW-PAK packaging configuration was evaluated and tested in October 1995, at the U.S. Department of Energy (DOE) approved test facility located at the Hanford site, in Richland, Washington.

The ARROW-PAK packaging system consists of a Marlex M-8000 Driscopipe, Series 8000 (gas) or Series 8600 (industrial) resin pipe, manufactured by Phillips-Driscopipe, Inc.¹, and is sealed with dome-shaped end caps manufactured from the same materials (refer to Appendix A, Figure A-1, of this report, for a diagram). A patented process, developed by Arrow, permanently seals the two end caps to the pipe body. The patented process involves the use of electrical energy to heat opposing faces of the pipe and end caps, and hydraulic rams to press the heated surfaces together. During the fusion process, the exterior and interior wall surface of the end caps and pipe create beaded edges. These edges protrude away from both the interior and exterior wall surface about 0.635-cm (0.25-in). A seam is visible; however, the seam does not run through the internal thickness of these component pieces. The fusion process produces a homogeneous bonding of the end cap to the pipe. The homogeneous bond extends over the full wall thickness of the packaging (refer to Section 2.1 of this report for further information regarding the homogeneous bond).

A total of two plywood spacers were used inside each of the two ARROW-PAK test units that were filled with simulated contents. It should be noted that the use of the plywood spacers is optional. The purpose of these spacers was to hold the simulated contents in place during the fusion process. Refer to Appendix B of this report for the assembly, loading, and closure procedure used for testing purposes. Basically, an end cap was fused to one end of the pipe/tube. This portion of the test unit was then filled with wrapped, lead bricks, leaving an estimated 5.08-cm (2-in) head space. Steel shot filled the void space between the bricks [leaving the 5.08-cm (2-in) head space]. A plywood spacer was placed at the "open" end of the pipe/tube. [The spacer needs to fit down snugly onto the layer of bricks and shot. It may be necessary to wrap the outside edge of the wooden spacer with several layers of tape so that the spacer does not move and/or shift.] The second end cap was filled with wrapped, lead bricks, leaving an estimated 5.08-cm (2-in) head space. Steel shot filled the void space between the bricks [leaving the 5.08-cm (2-in) head space]. The second plywood spacer was placed at the "open" end

¹Phillips-Driscopipe, Inc. is a subsidiary of Phillips Petroleum Company.

of the end cap, in the same manner as the first spacer. The second end cap was then fused to the pipe/tube piece that had previously been filled with simulated contents. **NOTE: Adequate space (about 5.08-cm [2-in]) is required for the placement of the wooden spacers to allow for fusion of the second end cap to the tube/pipe.**

Due to the complexity of the thermal sealing process and the machinery involved, the test units were filled with the simulated contents (wrapped, lead bricks and steel shot), assembled, loaded, and closed by Boh Brothers Construction Company, Inc. (Boh Brothers), New Orleans, Louisiana. (Boh Brothers is a subcontractor to Arrow.) The remainder of the simulated contents (fluorescein) was added at the DOE-approved test facility prior to testing. To add the fluorescein material and to verify the containment boundary of all the test units, the sponsor was responsible for drilling and tapping two holes into the center of one end cap on the two test units to be filled with the simulated test load (40-TU-01 and 40-TU-02), and one hole into the center of one end cap on the "empty" test unit (40-TU-03). The sponsor was also responsible for placing a suitable hex-socket plug into each of the holes. The hex-socket plugs were 1/2-inch normal pipe thread (NPT), and were flush or below the surface of the end caps. Refer to Appendix B, Figure B-1, for a diagram of the hole placements.

Two visits were made by the WHC test engineer to Boh Brothers. Both visits were to witness the loading, assembly, and closure of the three ARROW-PAK test units. The second trip was necessary as Arrow determined that a faulty pyrometer was used during the initial loading and closure procedure. The manufacturer's procedures state that the Phillips-Driscopipe, Marlex resin pipe, is to be heated to 260°C (500°F) prior to the fusion process. During the initial process, the pipe and end cap pieces "smoked." This was evidently not typical of the sealing process. Later, Arrow indicated that the temperature of the heater plate used prior to fusing the components together, reached 293°C (560°F). Phillips-Driscopipe (product manufacturer) could not guarantee that the higher temperature would not have a negative effect on the performance of the pipe. It was determined that the sealing process should be performed according to the manufacturer's procedures, rather than risk failure of the packaging during testing. Also, a question could be raised if the test packagings passed, that the test units passed due to the higher temperatures used to seal these packagings.

The test units that were initially filled with simulated contents were cut open on each side of the fusion joints, and the simulated contents removed. Although the length of the modified end caps was now slightly less (due to the fusion joint being cut off the packaging), the original end caps were reused for the actual test unit packagings. The sponsor desired being able to load as much content weight into the test units as possible. To compensate for the length of the HDPE material that was eliminated from the end caps, the length of the cylindrical tube/pipe section of the actual test units was slightly longer than the previous, initial test units.

The original (before facing) length of each end cap piece was 30.48-cm (12-in). The average, maximum amount removed from each end cap was 3.175-cm (1.25-in), making the new length of each end cap about 27.3-cm (10.75-in). A total, average, maximum length of 6.35-cm (2.5-in) was eliminated from the end caps. The average original (before facing) length of the cylindrical

pipe/tube was 127.0-cm (50.0-in). Because of the loss in length from cutting the end caps, it was decided to use new pipe/tube pieces. The new pipe/tube sections had an average length (before facing) of 133.35-cm (52.5-in). This was 6.35-cm (2.5-in) longer than the original test units. Prior to fusing the component pieces together, the end caps and pipe are faced, resulting in loss of high-density polyethylene (HDPE) material, which effects the total overall length of the packaging.

An advantage of the Marlex M-8000 resin pipe material, and fusion process used to permanently seal the ARROW-PAK packaging, is that the areas adjacent to the fusion joints may easily be cut apart if needed. The actual length of the tested packagings' end caps was less than the manufactured component. To compensate for the length of the HDPE material that was eliminated from the end caps, the actual length of the tested packagings' pipe/tube component was more than what was originally intended. The packaging's overall length was within the nominal design length (the average, overall length of all the ARROW-PAK test units [initial and actual] was 182.88-cm [72-in]). The maximum length of the tested packaging was 187.96-cm (74-in). The performance of the test units was such that it can be determined that these modified lengths did not have any impact on the packaging.

In both instances, the sponsor pressurized all three test units with compressed air to 55.2 kPa (8 psi). The fusion joints, plugged areas, and connections were coated with a solution of water and liquid dish soap. This was to ensure that all three test units were sound and did not leak prior to shipment to the DOE-approved test facility. Upon receipt of the three, actual test units by the DOE-approved test facility, an initial containment boundary verification (soap bubble test) was conducted prior to testing. This was to ensure that all three test units were sound, and that no damage occurred during transportation to the test facility. The center plug was removed from the end cap, and compressed nitrogen gas was connected to the test units. The internal pressure was increased to 27.6 kPa (4 psi), and held for 15 minutes. A low-viscosity soap bubble solution (i.e., "Snoop"²) was coated around the area where the end caps are fused to the cylindrical wall of the packaging. The plugged areas and connections were also checked for leakage. No bubbles or foam were detected. The remainder of the simulated contents (fluorescein) was then added prior to testing.

The maximum, overall length of the tested ARROW-PAK package is 187.96-cm (74-in). The maximum gross weight of the tested packaging is 519.82 kg (1146-lb). The ARROW-PAK packaging is designed to ship Type A, solid, radioactive materials, normal form, Form Number 1, Form Number 2, and Form Number 3.

All DOT-7A Type A requirements of 49 CFR are addressed whether the requirement is applicable to the tested package configuration. Type A tests performed included the vibration; water spray; penetration bar drop (1.0 m [3.3 ft]); compression; and 1.2 m [4 ft] drop test. Because of the permanent sealing process used, the soap-bubble test was performed after the vibration and the drop tests. This method, in combination with visual and black light inspection, was chosen for leak detection purposes.

²"Snoop" is a registered trademark of the Nupro Company.

Documentation is provided by this report to satisfy the requirements of 49 CFR 173.415(a), "Authorized Type A Packages," which states:

"U.S. Department of Transportation (DOT) Specification 7A (178.350 of this subchapter) Type A general packaging. Each shipper of a Specification 7A must maintain on file for at least one year after the latest shipment, and shall provide to DOT on request, a complete documentation of tests and an engineering evaluation or comparative data showing that the construction methods, packaging design, and materials of construction comply with that specification. Specification 7A packagings designed in accordance with the requirements of 178.350 in effect on June 30, 1983, and constructed prior to July 1, 1985, may continue to be used. Packagings either designed or constructed after June 30, 1985, must meet the requirements of 178.350 applicable at the time of their design or construction."

This document will serve to meet the above-stated requirements when the packagings are used as prescribed. In addition, a description of the packaging is provided with an illustration and/or drawings to allow the user/shipper to obtain the packaging and verify that the packaging hardware complies with all of the specifications of the tested packaging.

By itself, this document does not ensure total compliance with all documentation necessary for making a shipment of radioactive material. In addition to documentation of tests, the shipper must maintain on file other appropriate documentation such as comparison of the physical properties of the actual contents to be shipped with those of the simulated payload used in testing to demonstrate equivalency. Also, implementation and documentation of a quality control program are required.

1.2 CONTAINMENT BOUNDARY VERIFICATION

A hydrostatic pressure test was conducted to simulate reduction in ambient (external) pressure to 24.1 kPa (3.5 psia). Test unit 40-TU-03, which was basically an empty packaging, was used for this verification process. Upon receipt by the DOE-approved test facility, this test unit underwent an initial containment boundary verification (soap bubble test) as described in Section 1.1 of this report. This test unit was then filled with 100 cc (4 oz) of fluorescein, and underwent the water spray test, penetration bar drop, and compression test. Upon completion of these tests, the test unit was filled completely with water. The external surface was cleaned and checked with a black light for any trace of fluorescein. Compressed nitrogen gas was used to pressurize the internal cavity of the packaging to 80.66 kPa (11.7 psig). This pressure was held for 15 minutes. No leakage of water or fluorescein was observed under visual and black light inspection.

1.3 PURPOSE AND SCOPE

A design verification procedure (Kelly 1995a) was used to document that the packaging meets the design requirements of 49 CFR 173.24, 173.24a, 173.24b, 173.411, 173.412, and 173.462. Testing was performed to demonstrate that the packaging configuration noted in Sections 1.1 and 2.0 of this report meets the requirements for a DOT-7A Type A packaging (Kelly 1995b). Testing was performed in accordance with 49 CFR 173.465 using *DOT-7A Packaging Test Procedure* (Kelly 1995c).

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2.0 PACKAGING DESCRIPTION

2.1 DESIGN

The ARROW-PAK packaging system consists of a Marlex M-8000 Driscopipe, Series 8000 (gas) or Series 8600 (industrial) resin pipe, manufactured by Phillips-Driscopipe, Inc., and is sealed with dome-shaped end caps manufactured from the same materials (refer to Appendix A, Figure A-1, of this report, for a diagram). A patented process, developed by Arrow, permanently seals the two end caps to the pipe body. The patented process involves the use of electrical energy to heat opposing faces of the pipe and end caps, and hydraulic rams to press the heated surfaces together. During the fusion process, the exterior and interior wall surface of the end caps and pipe create beaded edges. The edges protrude away from both the interior and exterior wall surface about 0.635-cm (0.25-in). A seam is visible; however, the seam does not run through the interior thickness of these component pieces. The fusion process produces a homogeneous bonding of the end cap to the pipe. The homogeneous bond extends over the full wall thickness of the package.

The M-8000 Driscopipe (Series 8000 and 8600) has typically been used in commercial areas (i.e., natural gas lines, water lines, and in sewer treatment and utility applications). There is no negative history or known failure of the fusion joint areas when the patented, permanent seal technique has been applied in these noted applications. Prior to the 7A testing activities described in this report, coupons were cut from random sample specimens to observe the thoroughness of the homogeneous bonding of the end caps and pipe. The only evidence of a "seam" is indicated on the outer and inner wall surfaces where the fused beaded edge protrudes away from the wall surfaces. No visible weld is evident within the fused material.

Driscopipe Series 8000 and Series 8600 were tested as a part of the ARROW-PAK packaging. The pipe/tube comprising test unit 40-TU-01 was made from Series 8000, and the pipe/tube comprising test units 40-TU-02 and 40-TU-03 were made from Series 8600. Both product lines are extruded using only Phillips Chemical Company's Marlex 8000 polyethylene resin. This resin is a PE 3408 as listed by the Plastics Pipe Institute, is identified as Type III, C5, P34 per the American Society for Testing and Materials (ASTM) D1248, and has a cell classification of 355434C per ASTM D3350.

Both product lines are extruded using Phillips-Driscopipe's patented hard tooling polyethylene extrusion process, and each can be manufactured using the same manufacturing equipment. The materials differ only in the ASTM specifications to which they are certified. Polyethylene piping products intended for use in the distribution of natural gas must be manufactured in accordance with the requirements of ASTM D2513. This is a requirement of Part 192 of the Federal Minimum Safety Code for Transportation of Natural and Other Gases by Pipeline, as administered by the DOT. Piping produced for municipal and industrial applications are manufactured in accordance with the requirements of ASTM F714. In the areas where the specifications differ, ASTM D2513 is the more stringent of the two. Therefore, the product manufactured per ASTM D2513 equals or exceeds all requirements of ASTM F714.

A total of two plywood spacers were used inside each of the two ARROW-PAK test units that were filled with simulated contents. It should be noted that the use of the plywood spacers is optional. The purpose of these spacers was to hold the simulated contents in place during the fusion process. Refer to Appendix B for the assembly, loading, and closure procedure used for testing purposes. **NOTE: Adequate space (about 5.08-cm [2-in]) is required for the placement of the wooden spacers to allow for fusion of the second end cap to the tube/pipe.**

Refer to Section 2.1.2 and Appendix A of this evaluation report for the authorized ARROW-PAK packaging configuration. Loading of the approved test packaging weight may be found in Table 2-1. Packaging dimensions can be found in Table 2-2. Design measurements noted for this packaging are provided in English units and converted to metric units. Measurements are nominal (1 in = 2.54 cm).

Table 2-1. Approved Packaging Loading.

Item	Nominal Weight kg (lb)
Cylindrical Tube	24.95 (55.0)
End Caps (2 each)	5.67 (12.5) each
Content Fill Weight	483.53 (1066.0)
Gross Weight	519.82 (1146.0)

Table 2-2. Dimensions.

Item	Measurements (Nominal)
Cylindrical Tube:	
Length (maximum)	127.0-cm (50.0-in)
Diameter	OD = 27.30-cm (10.75-in) ID = 22.34-cm (8.796-in)
Wall thickness	2.532-cm (0.997-in) (minimum)
End Caps (2 each):	
Length (maximum)	30.48-cm (12.0-in) (each)
Diameter	OD = 27.30-cm (10.75-in) ID = 22.34-cm (8.796-in)
End-cap thickness	2.532-cm (0.997-in) (minimum)
Overall Length (maximum)	187.96-cm (74.0-in)
Plywood Spacers (2 - optional):	
Top, OD	21.9-cm (8.625-in)
Bottom, OD	20.6-cm (8.125-in)
Thickness	1.9-cm (0.75-in)

2.1.1 Materials/Method of Construction

Refer to Table 2-3 for the ARROW-PAK packaging materials/method of construction information. The packaging configuration was tested as described in Section 1.1 of this report.

Table 2-3. Materials/Method of Construction.

Item/component	Description
Cylindrical pipe/tube	Phillips-Driscopipe, Inc. ^a ; Marlex M-8000 resin Series 8000 (gas) or Series 8600 (industrial).
End caps (2)	Phillips-Driscopipe, Inc.; 10 (SDR 11) IPS; Part No. 80M100110CPSTB.
Wooden spacers (2 - optional)	Plywood, 1.9-cm (0.75-in).

^aPhillips-Driscopipe, Inc., is a subsidiary of Phillips Petroleum Company.

2.1.2 Authorized Configuration

The authorized configuration consists of the cylindrical pipe/tube made of a Marlex M-8000 resin [either Series 8000 (gas) or Series 8600 (industrial)], manufactured by Phillips-Driscopipe, Inc., and sealed with two dome-shaped end caps manufactured from the same materials via a patented process developed by Arrow. Two optional plywood spacers may be used inside the ARROW-PAK packaging, as described in Section 1.1 and Appendix A, Figure A-1, of this report, to hold the contents into place during the sealing process.

The maximum, overall length of the tested ARROW-PAK package is 187.96-cm (74-in). The maximum gross weight of the packaging is 519.82 kg (1146-lb).

2.2 CONTAINMENT SYSTEM

The ARROW-PAK packaging provides primary containment via the permanent fusion of the cylindrical pipe/tube to the two end caps.

2.3 AUTHORIZED CONTENTS

The approved packaging system described in this report is designed to ship Type A quantities of solid radioactive materials, normal form.

The packaging described in this report is designed for transporting Form Numbers 1, 2, and 3 radioactive contaminated solid materials (Cruse, 1992). A description of each form is provided below.

- Form No. 1 - Solids of any particulate size.

A packaging certified for these contents is expected to contain radioactive contents of any representative particulate form.

- Form No. 2 - Solids of large particulate size only (cement grade sand or larger).

Contents of a corresponding particulate size, such as soil or construction debris. (Glass or plastic labware having fine particulate available for dispersion would not fit this category and would require a packaging certified for fine particulate, Form No. 1.)

- Form No. 3 - Solid material with no removable or dispersible contamination. (For definition, see 49 CFR 173.443, "Contamination Control.")

1. Metals with activation products;
2. Forms of metals/alloys/compounds of uranium, thorium;
3. Solid materials with the radioactive material firmly fixed in place, possibly by the application of a fixing media (paint, etc.);
4. Solidified material.

NOTE: This is an example only and each form must be analyzed for compliance with the "no removable or dispersible contamination" criterion found in 40 CFR 173.443. Additional restrictions on contents can be found in Section 6.0 of this report.

The simulated payload used in two test units was clean, noncontaminated, and taped lead bricks. Carbon steel shot was added as a filler material. It was estimated that the lead bricks made up 65% of the content fill weight (314.3-kg [693.0-lb]), and the steel shot made up 35% of the content fill weight (169.2-kg [373.0-lb]). Fluorescein was added as a tracer material. The third test unit was basically empty, and fluorescein was added as a tracer material. The maximum gross weight of the tested packaging is 519.82 kg (1146-lb).

3.0 EVALUATION CRITERIA

3.1 TEST CRITERIA

When subjected to the tests specified in 49 CFR 173.465, the packaging ~~will~~ prevent the following:

- Loss or dispersal of the radioactive contents
- Any significant increase in the radiation levels recorded or calculated at the external surfaces as compared to the condition before the test.

3.2 PASS/FAIL CRITERIA

For all tests, except where otherwise indicated, the packages tested were ~~considered~~ to fail if there was significant damage to the packaging and/or ~~loss~~ of the simulated load. Rupture or leakage from any of the packages ~~constitutes~~ failure.

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4.0 PREPARATION OF SPECIMENS FOR TESTING

NOTE: The bold text identifies the applicable Type A regulations outlined in 49 CFR.

4.1 PRELOADING INSPECTION - 49 CFR 173.462

- a. Each packaging was examined before testing to identify and record any faults or damage, including:

1. Divergence from the specifications or drawings.

The packaging components were as specified, except as follows:

- Due to permanency of the thermal sealing process, the sponsor was responsible for drilling and tapping two holes into the center of one end cap on the two test units to be filled with the simulated test load (40-TU-01 and 40-TU-02), and one hole into the center of one end cap on the "empty" test unit (40-TU-03). The sponsor was also responsible for placing a suitable hex-socket plug into each of the holes. The hex-socket plugs were 1/2-inch NPT, and were flush or below the surface of the end caps (refer to Appendix B, Figure B-1, for a diagram of the hole placements). The purpose of these holes was to enable the DOE-approved test facility the ability to add tracer material (fluorescein) to the test units. Also, the test units needed to undergo pressure tests for the containment boundary verifications, and this provided connection ports.

- Because of the extreme temperatures encountered during the fusion process of the initial test units, these test units were cut open on each side of the fusion joints, and the simulated contents removed. Although the length of the end caps was slightly less, due to the fusion joint being cut off the packaging, all the original end caps were reused for the actual test unit packagings. The sponsor desired being able to load as much content weight into the test units as possible, so the length of the cylindrical tube/pipe section of the actual test units was slightly longer than the previous, initial test units. This modification had no effect on the performance of the test units. Refer to Section 1.1 of this report for detailed information.

2. Defects in construction.

No defects in construction were found on any test units.

3. Corrosion or other deterioration.

No corrosion or other deterioration was found.

4. Distortion of features.

There were no observable distortions of features.

- b. Any deviation found under paragraph (a) of this section from the specified design shall be corrected or suitably taken into account in the subsequent evaluation.**

As stated in paragraph (a) of this section, the original packaging design was modified prior to testing. The addition of the plugs to one end of the end caps was taken into account during testing, and had no negative impact or effect on the performance of the test units or on the testing conducted.

The modified length of the end caps and pipe/tube had no negative impact or effect on the performance of the test units or on the testing conducted.

- c. The containment system of the packaging shall be clearly specified.**

Primary containment is provided by the permanent fusion of the cylindrical pipe/tube to the two end caps.

- d. The external features of the packaging shall be clearly identified so that reference may be made to any part of it.**

The external features of the packaging are clearly identifiable. External features consist of the cylindrical tube/pipe, two domed end caps, and two fusion joints.

4.2 TEST CONTENTS

The simulated payload used in two test units was clean, noncontaminated, and taped lead bricks. Carbon steel shot was added as a filler material. It was estimated that the lead bricks made up 65% of the content fill weight (314.3-kg [693.0-lb]), and the steel shot made up 35% of the content fill weight (169.2-kg [373.0-lb]). Fluorescein was added as a tracer material. The third test unit was basically empty, and fluorescein was added as a tracer material. The maximum gross weight of the tested packaging is 519.82 kg (1146-lb).

4.3 LOADING, ASSEMBLY, AND CLOSURE

A diagram of the as-tested packaging configuration is provided in Appendix A, Figure A-1, of this report. The packagings were assembled, loaded, and closed in accordance with the instructions as outlined in Appendix B of this report.

The ARROW-PAK packaging system, consisting of a Marlex M-8000 Driscopipe, Series 8000 (gas) or Series 8600 (industrial) resin pipe, is sealed with dome-shaped end caps manufactured from the same materials. The two end caps are permanently fused and sealed to the pipe body. This process involves the use

of electrical energy to heat opposing faces of the pipe and end caps, and hydraulic rams to press the heated surfaces together. The fusion process produces a homogeneous bonding of the end cap to the pipe.

A total of two plywood spacers were used inside each of the two ARROW-PAK test units that were filled with simulated contents. It should be noted that the use of the plywood spacers is optional. The purpose of these spacers was to hold the simulated contents in place during the fusion process.

Due to the complexity of the thermal sealing process and the machinery involved, the test units were filled with the simulated contents (wrapped, lead bricks and steel shot), assembled, loaded, and closed by Boh Brothers. The remainder of the simulated contents (fluorescein) was added at the DOE-approved test facility prior to testing.

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5.0 PACKAGING EVALUATION RESULTS

The following list shows the primary sections of 49 CFR applicable to Type A packaging:

NOTE: This list highlights the performance requirements and is not intended to present an all-encompassing list.

- 173.24 General Requirements for Packagings and Packages
- 173.24a Additional General Requirements for Non-Bulk Packagings and Packages
- 173.24b Additional General Requirements for Bulk Packagings
- 173.411 General Design Requirements
- 173.412 Additional Design Requirements for Type A Packages
- 173.415(a) Authorized Type A Packages
- 173.442 Thermal Limitations
- 173.461 Demonstration of Compliance with Tests
- 173.462 Preparations of Specimens for Testing
- 173.463 Packaging and Shielding - Testing for Integrity
- 173.465 Type A Packaging Tests
- 173.474 Quality Control for Construction of Packaging
- 173.475 Quality Control Requirements Prior to Each Shipment of Radioactive Material
- 178.3 Marking of Packagings
- 178.350 Specification 7A; General Packaging, Type A
- 178.608 Vibration Standard

5.1 DESIGN EVALUATION

NOTE: The bold text identifies the applicable Type A regulations outlined in 49 CFR.

Following is an evaluation of the ability of the packaging configuration to meet performance-related regulations. Compliance with all the indicated regulations will signify that the packagings have met the design and performance testing requirements for a DOT-7A Type A packaging.

5.1.1 49 CFR 173.24 - General Requirements for Packages and Packagings

- a. **Applicability.** Except as otherwise provided in this subchapter, the provisions of this section apply to--

- (1) Bulk and non-bulk packagings;
- (2) New packagings and packagings which are reused; and
- (3) Specification and non-specification packagings.

The packaging configuration has been tested and/or evaluated by WHC and meets DOT-7A Type A packaging criteria.

- b. Each package used for shipment of hazardous materials under this subchapter shall be designed, constructed, maintained, filled, its contents so limited, and closed so that under conditions normally incident to transportation--

- (1) Except as otherwise provided in this subchapter, there will be no identifiable (without the use of instruments) release of hazardous materials to the environment;

The packaging configuration meets the intent of this requirement as demonstrated by meeting the more severe Type A packaging requirements of 49 CFR 173.411, .412, and .465 as demonstrated in this report.

- (2) The effectiveness of the package will not be substantially reduced; for example, impact resistance, strength, packaging compatibility, etc. must be maintained for the minimum and maximum temperatures encountered during transportation;

The packaging configuration meets the intent of this requirement as demonstrated by meeting the more severe Type A packaging requirements of 49 CFR 173.411, .412, and .465 as demonstrated in this report.

- (3) There will be no mixture of gases or vapors in the package which could, through any credible spontaneous increase of heat or pressure, significantly reduce the effectiveness of the packaging.

It is the responsibility of the shipper to ensure that the payload will remain stable during transport. The shipper is responsible to ensure that there will be no mixture of gasses or vapors in the package which could, through any credible spontaneous increase of heat or pressure, significantly reduce the effectiveness of the packaging.

Per 49 CFR 173.412 (i) the ARROW-PAK's containment system was tested to ensure that it could withstand a pressure differential of 77.2 kPa (11.2 psi).

A hydrostatic pressure test was conducted to simulate reduction in ambient (external) pressure to 24.1 kPa (3.5 psia). Test unit 40-TU-03, which was basically an empty packaging, was used for this verification process. This test unit was filled with 100 cc (4 oz) of fluorescein, and then underwent the water spray test, penetration bar drop, and compression test. Upon completion of these tests, this test unit was then filled completely with water. The external surface was cleaned and checked with a black light for of any trace of fluorescein. Compressed nitrogen gas was used to pressurize the internal cavity of the packaging to 80.66 kPa (11.7 psig). This pressure was held for 15 minutes. No leakage of water or fluorescein was observed under visual and black light inspection.

c. **Authorized packagings.** A packaging is authorized for a hazardous material only if--

- (1) The packaging is prescribed or permitted for the hazardous material in a packaging section specified for that material in Column 8 of the section 172.101 Table and conforms to applicable requirements in the special provisions of Column 7 of the section 172.101 Table and, for specification packagings (including U.N. standard packagings), the specification requirements in parts 178 and 179 of this subchapter; or
- (2) The packaging is permitted under, and conforms to, provisions contained in sections 171.11, 171.12, 171.12a, 173.3, 173.4, 173.5, 173.7, 173.27, or 176.11 of this subchapter.

The packaging configuration, as documented herein, has been qualified to meet Specification 7A packaging requirements in accordance with 49 CFR 178.350. It is the responsibility of the shipper to ensure that the packagings used are in compliance with the design discussed in this report.

- d. **DOT specification and U.N. standard packagings.** For DOT specification packagings (including U.N. standard packagings), conformance to the applicable specifications in parts 178 and 179 of this subchapter is required in all details. For performance-oriented packagings covered by subpart L of part 178 of this subchapter, each packaging must be capable of meeting the performance test requirements specified in subpart M of part 178 of

this subchapter for the applicable packing group shown in Column 5 of the section 172.101 Table.

The packaging configuration, as documented herein, has been qualified to meet Specification 7A packaging requirements in accordance with 49 CFR 178.350. It is the responsibility of the shipper to ensure that the packagings used are in compliance with the design discussed in this report.

e. **Compatibility.**

- (1) Even though certain packagings are specified in this part, it is, nevertheless, the responsibility of the person offering a hazardous material for transportation to ensure that such packagings are compatible with their lading. This particularly applies to corrosivity, permeability, softening, premature aging and embrittlement.

It is the responsibility of the shipper to ensure that these design requirements have been properly addressed by the designer and fabricator.

Biodegradation and ultraviolet (UV) degradation of HDPE material has been extensively documented in literature. Biodegradation has been found to be virtually nonexistent, while extensive testing on the UV degradation of Marlex resin can be used to estimate that UV degradation would not affect the integrity of the Marlex ARROW-PAK for 100 to 300 years (Farnsworth, 1994).

The packaging configuration tested and/or evaluated meets this requirement.

- (2) Packaging materials and contents must be such that there will be no significant chemical or galvanic reaction between the materials and contents of the package.

It is the responsibility of the shipper to ensure that the contents will not react adversely with the packaging.

Significant data exist on HDPE damage from irradiation and corrosive chemicals. The irradiation data have shown that HDPE (in general) and Phillips-Driscopipe (in particular) have been resistant to gamma irradiation levels of up to 39 Mrad (Phillips-Driscopipe) and 100 Mrad (all HDPEs). No specific testing has been performed for Phillips' Marlex resin. The chemical corrosion data from Phillips-Driscopipe showed that Phillips' Marlex resin is resistant to nearly all forms of chemicals, with the exception of extremely concentrated acids (Farnsworth, 1994).

HDPE devices are susceptible to external and internal penetration by certain types of organic liquids and solvents. Liquids are not authorized for use in this packaging.

(3) Plastic packagings and receptacles.

- (i) Plastic used in packagings and receptacles must be of a type compatible with the lading and may not be permeable to an extent that a hazardous condition is likely to occur during transportation, handling or refilling.
- (ii) Each plastic packaging or receptacle which is used for liquid hazardous materials must be capable of withstanding without failure the procedure specified in Appendix B of this part ("Procedure for Testing Chemical Compatibility and Rate of Permeation in Plastic Packagings and Receptacles"). The procedure specified in Appendix B of this part must be performed on each plastic packaging or receptacle used for Packing Group I materials. The maximum rate of permeation of hazardous lading through or into the plastic packaging or receptacles may not exceed 0.5 percent for materials meeting the definition of a Division 6.1 material according to section 173.132 and 2.0 percent for other hazardous materials, when subjected to temperatures no lower than--
 - (A) 18 °C (64 °F) for 180 days in accordance with Test Method 1 in Appendix B of this part;
 - (B) 50 °C (122 °F) for 28 days in accordance with Test Method 2 in Appendix B of this part; or
 - (C) 60 °C (140 °F) for 14 days in accordance with Test Method 3 in Appendix B of this part.
- (iii) Alternative procedures or rates of permeation are permitted if they yield a level of safety equivalent to or greater than that provided by paragraph (e)(3)(ii) of this section and are specifically approved by the Associate Administrator for Hazardous Materials Safety.

The packaging configuration described is authorized for transportation of solids. It is the responsibility of the shipper to ensure that the contents will not react adversely with the container.

- (4) Mixed contents. Hazardous materials may not be packed or mixed together in the same outer packaging with other hazardous or nonhazardous materials if such materials are capable of reacting dangerously with each other and causing--
- (i) Combustion or dangerous evolution of heat;
 - (ii) Evolution of flammable or poisonous gases; or
 - (iii) Formation of unstable or corrosive materials.

Hazardous and/or nonhazardous materials will not be packed or mixed together so as to cause a reaction. The packaging configuration, as documented herein, has been qualified to meet Specification 7A packaging requirements in accordance with 49 CFR 178.350. It is the responsibility of the shipper to ensure that materials will not be combined so as to cause a reaction.

- (5) Packagings used for solids, which may become liquid at temperatures likely to be encountered during transportation, must be capable of containing the hazardous material in the liquid state.

The packaging configuration described in this report is authorized for solids.

It is the responsibility of the shipper to ensure that the packagings used are in compliance with the design discussed in this report.

f. Closures.

- (1) Closures on packagings shall be so designed and closed that under conditions (including the effects of temperature and vibration) normally incident to transportation--
 - (i) Except as provided in paragraph (g) of this section, there is no identifiable release of hazardous materials to the environment from the opening to which the closure is applied; and
 - (ii) The closure is secure and leakproof.
- (2) Except as otherwise provided in this subchapter, a closure (including gaskets or other closure components, if any) used on a specification packaging must conform to all applicable requirements of the specification.

Testing and evaluation of the packaging design indicates this requirement to be satisfied. The cylindrical tube/pipe and end caps are closed and sealed via a patented process developed by Arrow. This process involves the use of electrical energy to heat opposing faces of the pipe and end caps, and hydraulic rams to press the heated surfaces together. The result is a homogeneous bonding of the end cap to the pipe, with no internal evidence of a seam between components.

Vibration testing was conducted as described in Section 5.2.3 of this report. Damage received by the packaging as a result from this testing are described in Section 5.2.3.c of this report. After the vibration test, the packagings underwent a "soap bubble" test and were checked visually and under black light inspection. None were observed to have leakage of simulated contents.

- g. Venting. Venting of packagings, to reduce internal pressure which may develop by the evolution of gas from the contents, is permitted only when--
- (1) Transportation by aircraft is not involved;
 - (2) Except as otherwise provided in this subchapter, the evolved gases are not poisonous, likely to create a flammable mixture with air or be an asphyxiant under normal conditions of transportation;
 - (3) The packaging is designed so as to preclude an unintentional release of hazardous materials from the receptacle; and
 - (4) For shipments in bulk packagings, venting is authorized for the specific hazardous material by a special provision in the section 172.101 Table or by the applicable bulk packaging specification in part 178 of this subchapter.

There are no venting devices incorporated into this packaging.

Per 49 CFR 173.412 (i) the ARROW-PAK's containment system was tested to ensure that it could withstand a pressure differential of 77.2 kPa (11.2 psi).

A hydrostatic pressure test was conducted to simulate reduction in ambient (external) pressure to 24.1 kPa (3.5 psia). Test unit 40-TU-03, which was basically an empty packaging, was used for this verification process. This test unit was filled with 100 cc (4 oz) of fluorescein, and then underwent the water spray test, penetration bar drop, and compression test. Upon completion of these tests, this test unit was then filled completely with water. The external surface was cleaned and checked with a black light for any trace of fluorescein. Compressed nitrogen gas was used to pressurize the internal cavity of the packaging to 80.66 kPa (11.7 psig). This pressure was held for 15 minutes. No leakage of water or fluorescein was observed under visual and black light inspection.

h. Outage and filling limits--

- (1) *General.* When filling packagings and receptacles for liquids, sufficient ullage (outage) must be left to ensure that neither leakage nor permanent distortion of the packaging or receptacle will occur as a result of an expansion of the liquid caused by temperatures likely to be encountered during transportation. Requirements for outage and filling limits for non-bulk and bulk packaging are specified in section 173.24a(d) and 173.24b(a), respectively.
- (2) *Compressed gases and cryogenic liquids.* Filling limits for compressed gases and cryogenic liquids are specified in sections 173.301 through 173.306 for cylinders and sections 173.314 through 173.319 for bulk packagings.

The packaging configuration described and tested is not authorized for transportation of liquids.

The packaging configuration described and tested will not transport compressed gasses or cryogenic liquids.

- i. Air transportation. Packages offered or intended for transportation by aircraft must conform to the general requirements for transportation by aircraft in 173.27, except as provided in 171.11 of this subchapter.

The packaging configuration described and tested was not evaluated for transportation by aircraft.

5.1.2 49 CFR 173.24a - Additional General Requirements for Non-Bulk Packagings and Packages

- a. Packaging design. Except as provided in section 172.312 of this subchapter:

- (1) *Inner packaging closures.* A combination packaging containing liquid hazardous materials must be packed so that closures on inner packagings are upright.

The packaging configuration described and tested does not incorporate any inner packaging closures, and liquids are not authorized for use in the ARROW-PAK.

- (2) *Friction.* The nature and thickness of the outer packaging must be such that friction during transportation is not likely to generate an amount of heat sufficient to alter dangerously the chemical stability of the contents.

The nature and thickness of the packaging configuration is such that friction during transport will not generate any heating that would adversely affect the contents.

- (3) *Securing and cushioning.* Inner packagings of combination packagings must be so packed, secured and cushioned to prevent their breakage or leakage and to control their movement within the outer packaging under conditions normally incident to transportation. Cushioning material must not be capable of reacting dangerously with the contents of the inner packagings.

The ARROW-PAK is intended to ship radioactively contaminated lead. Simulated contents used during testing were wrapped lead bricks and steel shot. The lead bricks were tightly packed within the cavity of the ARROW-PAK. Steel shot was filled in the void space around the bricks. Refer to Appendix B of this report for a description as to how the test units were assembled, loaded, and closed for testing.

The shipper is responsible to ensure that the internal contents do not shift such that an increase in radiation of 20 percent or more is encountered (IAEA, 1985). It is the responsibility of the shipper to ensure that cushioning material is compatible with contents.

- (4) *Metallic devices.* Nails, staples and other metallic devices shall not protrude into the interior of the outer packaging in such a manner as to be likely to damage inner packagings or receptacles.

There are no metallic devices or protrusions that could cause failures.

- (5) *Vibration.* Each non-bulk package must be capable of withstanding, without rupture or leakage, the vibration test procedure specified in section 178.608 of this subchapter.

The packaging configuration passed this requirement. Type A packagings are required "to withstand the effects of any acceleration, vibration, or vibration resonance that may arise during normal transportation" [see 49 CFR 173.412 (e)]. The test identified in this section was applied to support the ability of the packaging to meet the requirement. Visual examination of the packaging identified no rupture or leakage.

The cylindrical tube/pipe and end caps are closed and sealed via a patented process developed by Arrow. This process involves the use of electrical energy to heat opposing faces of the pipe and end caps, and hydraulic rams to press the heated surfaces together. The result is a homogeneous bonding of the end cap to the pipe, with no internal evidence of a seam between components.

Vibration testing was conducted as described in Section 5.2.3 of this report. Damage received by the packaging as a result from this testing are described in Section 5.2.3.c of this report. After the vibration test, the packagings underwent a "soap bubble" test and were checked visually and under black light inspection. None were observed to have leakage of simulated contents.

b. Non-bulk packaging filling limits.

- (1) A single or composite non-bulk packaging may be filled with a liquid hazardous material only when the specific gravity of the material does not exceed that marked on the packaging, or a specific gravity of 1.2 if not marked, except as follows:
- (i) A Packing Group I packaging may be used for a Packing Group II material with a specific gravity not exceeding the greater of 1.8, or 1.5 times the specific gravity marked on the packaging, provided all the performance

criteria can still be met with the higher specific gravity material;

- (ii) A Packing Group I packaging may be used for a Packing Group III material with a specific gravity not exceeding the greater of 2.7, or 2.25 times the specific gravity marked on the packaging, provided all the performance criteria can still be met with the higher specific gravity material; and
- (iii) A Packing Group II packaging may be used for a Packing Group III material with a specific gravity not exceeding the greater of 1.8, or 1.5 times the specific gravity marked on the packaging, provided all the performance criteria can still be met with the higher specific gravity material.

This is not applicable to a Type A packaging as Type A packaging does not incorporate packing groups. Liquids are not authorized for use in the ARROW-PAK. The solid materials intended for shipment are limited in weight, to the as-tested weights identified during testing (Section 2.1, Table 2-1).

- (2) Except as otherwise provided in this section, a single or composite non-bulk packaging may not be filled with a solid hazardous material to a gross mass greater than the maximum gross mass marked on the packaging.

This is not applicable to a Type A packaging as the gross mass is not required to be marked on the packaging by the manufacturer.

- (3) A single or composite non-bulk packaging which is tested and marked for liquid hazardous materials may be filled with a solid hazardous material to a gross mass, in kilograms, not exceeding the rated capacity of the packaging in liters, multiplied by the specific gravity marked on the packaging, or 1.2 if not marked. In addition:
 - (i) A single or composite non-bulk packaging which is tested and marked for Packing Group I liquid hazardous materials may be filled with a solid Packing Group II hazardous material to a gross mass, in kilograms, not exceeding the rated capacity of the packaging in liters, multiplied by 1.5, multiplied by the specific gravity marked on the packaging, or 1.2 if not marked.
 - (ii) A single or composite non-bulk packaging which is tested and marked for Packing Group I liquid hazardous materials may be filled with a solid Packing Group III hazardous material to a gross mass, in kilograms, not exceeding the rated capacity of the packaging in liters, multiplied by 2.25, multiplied by the specific gravity marked on the packaging, or 1.2 if not marked.

- (iii) A single or composite non-bulk packaging which is tested and marked for Packing Group II liquid hazardous materials may be filled with a solid Packing Group III hazardous material to a gross mass, in kilograms, not exceeding the rated capacity of the packaging in liters, multiplied by 1.5, multiplied by the specific gravity marked on the packaging, of 1.2 if not marked.

This is not applicable to a Type A packaging as Type A packaging does not incorporate packing groups. Liquids are not authorized for use in the ARROW-PAK. The solid materials intended for shipment are limited in weight, to the as-tested weight identified during testing (Section 2.1, Table 2-1).

- (4) Packagings tested as prescribed in section 178.605 of this subchapter and marked with the hydrostatic test pressure as prescribed in section 178.503(a)(5) of this subchapter may be used for liquids only when the vapor pressure of the liquid conforms to one of the following:
 - (i) The vapor pressure must be such that the total pressure in the packaging [i.e., the vapor pressure of the liquid plus the partial pressure of air or other inert gases, less 100 kPa (15 psi) at 55 °C (131 °F), determined on the basis of a maximum degree of filling in accordance with paragraph (b)(1) of this section and a filling temperature of 15 °C (59 °F)], will not exceed two-thirds of the marked test pressure;
 - (ii) The vapor pressure at 50 °C (122 °F) must be less than four-sevenths of the sum of the marked test pressure plus 100 kPa (15 psi); or
 - (iii) The vapor pressure at 55 °C (131 °F) must be less than two-thirds of the sum of the marked test pressure plus 100 kPa (15 psi).

This is not applicable to Type A packaging as Section 178.605 does not pertain to specification packagings. The packaging configuration described and tested is authorized for transportation of radioactive solid materials.

Per 49 CFR 173.412 (i) the ARROW-PAK's containment system was tested to ensure that it could withstand a pressure differential of 77.2 kPa (11.2 psi).

- (5) No hazardous material may remain on the outside of a package after filling.

The amount of non-fixed (removable) radioactive contamination on the external surfaces of each package offered for shipment shall be kept as low as practicable (49 CFR 173.443). It is the responsibility of the shipper to ensure compliance with this requirement.

c. Mixed contents.

- (1) An outer non-bulk packaging may contain more than one hazardous material only when--
 - (i) The inner and outer packagings used for each hazardous material conform to the relevant packaging sections of this part applicable to that hazardous material;
 - (ii) The package as prepared for shipment meets the performance tests prescribed in part 178 of this subchapter for the packing group indicating the highest order of hazard for the hazardous materials contained in the package;
 - (iii) Corrosive materials (except ORM-D) in bottles are further packed in securely closed inner receptacles before packing in outer packagings; and
 - (iv) For transportation by aircraft, the total net quantity does not exceed the lowest permitted maximum net quantity per package as shown in Column 9a or 9b, as appropriate, of the section 172.101 Table. The permitted maximum net quantity must be calculated in kilograms if a package contains both a liquid and a solid.
- (2) A packaging containing inner packagings of Division 6.2 materials may not contain other hazardous materials, except dry ice.

The package is designed and tested for Type A radioactive material shipments only. It is the responsibility of the shipper to ensure that reactive hazardous components are not shipped together in a packaging, and that the package is in compliance with the above requirements.

- d. Liquids must not completely fill a receptacle at a temperature of 55 °C (131 °F) or less.

Liquids are not authorized for transport in the packaging configuration described in this report.

**5.1.3 49 CFR 173.24b - Additional General Requirements
for Bulk Packagings**

a. Outage and filling limits.

- (1) Liquids and liquefied gases must be so loaded that the outage is at least one percent of the total capacity of a cargo or portable tank, or compartment thereof, or at least one percent of the total capacity of the tank and dome for tank car and multi-unit tank car tanks at the reference temperature of 46 °C (115 °F) for uninsulated tanks and 41 °C (105 °F) for insulated tanks.
- (2) Hazardous materials may not be loaded into the dome of a tank car. If the dome of the tank car does not provide sufficient outage, vacant space must be left in the shell to provide the required outage.
- (3) Bulk packagings for materials poisonous by inhalation. For a material which meets the definition of poisonous by inhalation (see section 171.8 of this subchapter), the outage in a bulk packaging must be at least five percent of the total capacity of the tank or compartment at the reference temperature of 46 °C (115 °F) for uninsulated tanks and 41 °C (105 °F) for insulated tanks.

The above items do not apply as this is not a bulk packaging.

- b. Equivalent steel.** For the purposes of this section, stainless steel is steel with a guaranteed minimum tensile strength of 51.7 deka newtons per square millimeter (75,000 psi) and a guaranteed elongation of 40 percent or greater. Where the regulations permit steel other than stainless steel to be used in place of a specified stainless steel (for example, as in section 172.102 of this subchapter, special provision B30), the minimum thickness for the steel must be obtained from one of the following formulas, as appropriate:

Formula for metric units:

$$e_1 = (12.74e_0) / (Rm_1 A_1)^{1/3}$$

Formula for non-metric units:

$$e_1 = (144.2e_0) / (Rm_1 A_1)^{1/3}$$

Where:

e_0 = Required thickness of the reference stainless steel in millimeters or inches respectively;
 e_1 = Equivalent thickness of the steel used in millimeters or inches respectively;
 Rm_1 = Specified minimum tensile strength of the steel used in deka newtons per square millimeter or pounds per square inch respectively; and
 A_1 = Specified minimum percentage elongation of the steel used multiplied by 100 (for example, 20 percent times 100 equals 20). Elongation values used must be determined from a 50 mm or 2 inch test specimen.

This requirement is not applicable as this is not a bulk packaging. Also, there are no metals used in the packaging.

- c. Air pressure in excess of ambient atmospheric pressure may not be used to load or unload any lading which may create an air-enriched mixture within the flammability range of the lading in the vapor space of the tank.

This requirement is not applicable as this is not a bulk packaging. Also, air pressure is not used in the loading and unloading process.

- d. A bulk packaging may not be loaded with a hazardous material that:
 - (1) Is at a temperature outside of the packaging's design temperature range; or
 - (2) Exceeds the maximum weight of lading marked on the specification plate.

This requirement is not applicable as this is not a bulk packaging. Also, it is the responsibility of the shipper to ensure compliance with this requirement.

5.1.4 49 CFR 173.411 - General Design Requirements

Except for a package that contains a limited quantity or excepted instrument or article under Paragraphs 173.421 through 173.424, each package used for shipment of radioactive materials shall be designed so that:

- a. The package can be easily handled and properly secured in or on a conveyance during transport;

The packaging configuration tested meets this requirement. The outer diameter of the ARROW-PAK is 27.30-cm (10.75-in), and the maximum, overall length is 187.96-cm (74-in). The maximum gross weight of the assembled packaging is 519.82 kg (1146.0 lb). Handling of the ARROW-PAK shall be done in such a manner that it is not damaged by dragging over sharp objects or cut by chokers or lifting equipment. Chains or cable-type chokers must be avoided. This packaging configuration may be easily lifted and handled via the use of a forklift or nylon slings. The packaging may be properly secured during transport.

- b. A package with a gross weight exceeding 10 kilograms (22 pounds) and up to 50 kilograms (110 pounds) has a means for manual handling;

This requirement is not applicable as the packaging configuration tested exceeds 50 kg (110 lb).

- c. A package with a gross weight of 50 kilograms (110 pounds) or more can be safely handled by mechanical means;

This requirement is met as the packaging configuration tested has a gross weight of more than 50 kg (110 lb). Handling of the ARROW-PAK shall be done in such a manner that it is not damaged by dragging over sharp objects or cut by chokers or lifting equipment. Chains or cable-type chokers must be avoided. This packaging configuration may be easily lifted and handled via the use of a forklift or nylon slings.

- d. Each lifting attachment on the package, when used in the intended manner, with a minimum safety factor of three, does not impose an unsafe stress on the structure of the package. In addition, the lifting attachment shall be so designed that failure under excessive load would not impair the ability of the package to meet all other requirements of this subpart. Each attachment or other feature on the outer surface of the packaging that could be used to lift the package must be removable or otherwise capable of being made inoperable for transport, or shall be designed with strength equivalent to that required for lifting attachments;

There are no lifting attachments; therefore, this requirement is not applicable.

- e. The external surface, as far as practicable, may be easily decontaminated;

The packaging configuration tested meets the intent of this requirement. The exterior surface of the ARROW-PAK is made of HDPE material. This material is used throughout industry for radioactive and hazardous material shipments, and may be easily decontaminated if no degradation of the material has occurred due to exposure to incompatible materials.

Protrusions and crevices exist on the ARROW-PAK around the two fusion joint areas; however, the surface is smooth and this area can easily be decontaminated. It is the responsibility of the shipper to ensure that materials shipped in the container are compatible with each other and the container.

- f. The outer layer of packaging will avoid, as far as practicable, pockets or crevices where water might collect; and

The exterior of the packaging is HDPE pipe that has thermally fused end caps. The sealing process results in a homogeneous bonding of the end caps to the pipe. Protrusions and crevices exist on the ARROW-PAK around the two fusion joint areas; however, the external fusion rings are slight, and such that water will not collect.

Test unit 40-TU-03 was subjected to the water spray conditions for one hour with no adverse effect or loss of contents.

- g. Each feature that is added to the package at the time of transport, and that is not a part of the package, will not reduce the safety of the package.

No features are to be added at the time of transport.

5.1.5 49 CFR 173.412 - Additional Design Requirements for Type A Packages

In addition to meeting the general design requirements prescribed in Paragraph 173.411, each Type A packaging shall be designed so that:

- a. The smallest overall external dimension of the package is not less than 10 centimeters (4 inches);

The external dimensions of the packaging exceed the minimum dimensional requirement.

- b. The outside of the packaging incorporates a feature, such as a seal, that is not readily breakable, and that, while intact, is evidence that the package has not been opened. In the case of packages shipped in exclusive use closed transport vehicles, the cargo compartment may be sealed instead of the individual packages;

The tested packaging configuration meets this requirement. The ARROW-PAK is permanently sealed by using electrical energy to heat the opposing faces of the pipe and end caps, and a hydraulic ram presses the heated surfaces together. The result is a homogeneous bonding of the end cap to the pipe, with no internal evidence of a seam between the components. The use of additional tamper indication methods is not necessary for this packaging. The only method of opening the ARROW-PAK is to cut it open.

- c. As far as practicable, the external surfaces are free from protrusions and are designed and finished so that they can be easily decontaminated;

The tested packaging configuration meets this requirement. Protrusions and crevices exist on the ARROW-PAK around the fusion joint areas; however, the external fusion rings are slight.

The exterior surface of the ARROW-PAK is made of HDPE material. This material is used throughout industry for radioactive and hazardous material shipments, and may be easily decontaminated if no degradation of the material has occurred due to exposure to incompatible materials.

- d. Containment and shielding would be maintained during transportation and storage in a temperature range of -40 °C (-40 °F) to 70 °C (158 °F) with account being taken of the possibility of brittle fracture;

No shielding is used for the packaging configuration. Information received from Phillips-Driscopipe, Inc., states that the

polyethylene material used is ductile to -118°C (-180°F). The Marlex 8000 resin is capable of enduring exposure to 70°C (158°F) for an indefinite time period without thermal degradation.

- e. It is able to withstand the effects of any acceleration, vibration, or vibration resonance that may arise during normal transportation, without any deterioration of the effectiveness of closing devices or of the integrity of the package as a whole and without loosening or unintentional release of nuts, bolts, or other securing devices even after repeated use;

The packaging configuration passed this requirement. The test identified in 49 CFR 178.608 was applied to two packages to support the ability of the packaging to meet the requirement. Visual examination of the packaging identified no rupture or leakage.

The cylindrical tube/pipe and end caps are closed and sealed via a patented process developed by Arrow. This process involves the use of electrical energy to heat opposing faces of the pipe and end caps, and hydraulic rams to press the heated surfaces together. The result is a homogeneous bonding of the end cap to the pipe, with no internal evidence of a seam between components.

Vibration testing was conducted as described in Section 5.2.3 of this report. Damage received by the packaging as a result from this testing are described in Section 5.2.3.c of this report. After the vibration test, the packagings underwent a "soap bubble" test and were checked visually and under black light inspection. None were observed to have leakage of simulated contents.

- f. It includes a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by pressure that may arise within the package during normal transport. Special form, as demonstrated in accordance with Paragraph 173.469 may be considered as a component of the containment system;

The cylindrical tube/pipe and end caps are closed and sealed via a patented process developed by Arrow. This process involves the use of electrical energy to heat opposing faces of the pipe and end caps, and hydraulic rams to press the heated surfaces together. The result is a homogeneous bonding of the end cap to the pipe, with no internal evidence of a seam between components. The only method of opening the ARROW-PAK is to cut it open.

Per 49 CFR 173.412 (i) the ARROW-PAK's containment system was tested to ensure that it could withstand a pressure differential of 77.2 kPa (11.2 psi).

A hydrostatic pressure test was conducted to simulate reduction in ambient (external) pressure to 24.1 kPa (3.5 psia). Test unit 40-TU-03, which was basically an empty packaging, was used for this verification process. This test unit was filled with 100 cc (4 oz) of fluorescein, and then underwent the water spray test, penetration bar drop, and compression test. Upon completion of these tests,

this test unit was then filled completely with water. The external surface was cleaned and checked with a black light for any trace of fluorescein. Compressed nitrogen gas was used to pressurize the internal cavity of the packaging to 80.66 kPa (11.7 psig). This pressure was held for 15 minutes. No leakage of water or fluorescein was observed under visual and black light inspection.

- g. The materials of the packaging and any components or structures are physically and chemically compatible with each other and with the contents, taking into account the behavior of each under irradiation;

The materials of the packaging configuration are physically and chemically compatible with each other. It is the responsibility of the shipper to ensure that the contents are compatible with the packaging.

HDPE material has been used as construction material for piping, containers, and lining of steel containers. HDPE material has been tested and is structurally and environmentally suitable for commercial applications. HDPE packagings are used in the management of wastes for transporting, storing, and/or disposing of radioactive, mixed radioactive-hazardous, and hazardous wastes. The advantage of HDPE packagings is a marked resistance to leaking, leaching, and corrosion (Farnsworth, 1994).

Significant data exist on HDPE damage from irradiation and corrosive chemicals. The irradiation data have shown that HDPE (in general) and Phillips-Driscopipe (in particular) have been resistant to gamma irradiation levels of up to 39 Mrad (Phillips-Driscopipe) and 100 Mrad (all HDPEs). No specific testing has been performed for Phillips' Marlex resin. The chemical corrosion data from Phillips-Driscopipe showed that Phillips' Marlex resin is resistant to nearly all forms of chemicals, with the exception of extremely concentrated acids (Farnsworth, 1994).

- h. For each component of the containment system account is taken, where applicable, of radiolytic decomposition of materials and the generation of gas by chemical reaction and radiolysis;

It is the responsibility of the shipper to ensure that the effects of radiation from the payload will not degrade the performance of the packaging through gas generation, chemical reaction, or radiolysis.

- i. The containment system will retain its radioactive contents under the reduction of ambient pressure to .25 kilograms per square centimeter (3.5 pounds per square inch);

The ARROW-PAK packaging provides primary containment via the permanent fusion of the cylindrical pipe/tube and two end caps.

The packaging described in this report passed the required pressure conditions. The ARROW-PAK's containment system was tested to ensure

that it could withstand a pressure differential of 77.2 kPa (11.2 psi).

A hydrostatic pressure test was conducted to simulate reduction in ambient (external) pressure to 24.1 kPa (3.5 psia). Test unit 40-TU-03, which was basically an empty packaging, was used for this verification process. This test unit was filled with 100 cc (4 oz) of fluorescein, and then underwent the water spray test, penetration bar drop, and compression test. Upon completion of these tests, this test unit was then filled completely with water. The external surface was cleaned of any trace of fluorescein, and checked with a black light. Compressed nitrogen gas was used to pressurize the internal cavity of the packaging to 80.66 kPa (11.7 psig). This pressure was held for 15 minutes. No leakage of water or fluorescein was observed under visual and black light inspection.

- j. Each valve through which the radioactive contents could otherwise escape is protected against damage and unauthorized operation and, except for a pressure relief device, has an enclosure to retain any leakage;

There are no valves used in this packaging configuration; therefore, this requirement is not applicable.

- k. Any radiation shield that encloses a component of the packaging specified as part of the containment system will prevent the unintentional escape of that component from the shield;

Shielding is not a component of this packaging system; therefore, this requirement is not applicable. The ARROW-PAK packaging provides primary containment via the permanent fusion of the cylindrical pipe/tube and two end caps.

- l. Failure of any tie down attachment of the packaging under excessive load will not impair the ability of the package to meet other requirements of this subpart;

There are no tie-down attachments on the packagings; therefore, this requirement is not applicable.

- m. When subjected to the tests specified in Paragraph 173.465 or evaluated against these tests by any of the methods authorized by Paragraph 173.461(a), the packaging will prevent:

- (1) Loss or dispersal of the radioactive contents; and
- (2) Any significant increase in the radiation levels recorded or calculated at the external surfaces for the condition before the test.

The shipper must ensure that the amount of radiation at any surface of the packaging would not increase by more than 20% as a result of the decrease in distance to the center of the package load (IAEA, 1985).

n. Each packaging designed for liquids will:

- (1) Meet the conditions prescribed in paragraph (m) of this section when subjected to the tests specified in Paragraph 173.466 or evaluated against these tests by any of the methods authorized by Paragraph 173.461(a);
- (2) For any package with a liquid volume not exceeding 50 cubic centimeters (1.7 fluid ounces), have sufficient suitable absorbent material to absorb twice the volume of the liquid contents. The absorbent material shall be compatible with the package contents and suitably positioned to contact the liquid in the event of leakage; and
- (3) For any package with a liquid volume exceeding 50 cubic centimeters (1.7 fluid ounces), either:
 - (i) Have sufficient absorbent material as prescribed in paragraph (n) (2) of this section; or
 - (ii) Have a containment system composed of primary inner and secondary outer containment components designed to assure retention of the liquid contents within the secondary outer components in the event that the primary inner components leak; and

Liquids are not authorized for use in this packaging configuration; therefore, this requirement is not applicable.

- o. Each package designed for compressed or uncompressed gases other than tritium or argon-37 not exceeding 200 curies will be able to prevent loss of contents when the package is subjected to the tests prescribed in 173.466 or evaluated against these tests by any of the methods authorized by Paragraph 173.461(a).

Compressed or uncompressed gases are not authorized for use in this packaging configuration; therefore, this requirement is not applicable.

5.1.6 49 CFR 173.442 - Thermal Limitations

Each package of radioactive material shall be designed, constructed, and loaded so that:

- a. The heat generated within the package because of the radioactive contents will not, at any time during transportation, affect the integrity of the package under conditions normally incident to transportation; and

- b. The temperature of the accessible external surfaces of the loaded package will not, assuming still air in the shade at an ambient temperature of 38 °C (100 °F), exceed either;

- (1) 50 °C (122 °F) in other than an exclusive use shipment; or
- (2) 82 °C (180 °F) in an exclusive use shipment.

It is the responsibility of the shipper to ensure that the design and construction capabilities have been properly addressed by the designer and fabricator. The shipper is responsible to ensure that the contents of the package are properly loaded within the thermal design limitations.

5.1.7 49 CFR 178.3 - Marking of Packagings

- a. Each packaging manufactured to a DOT specification or a UN standard shall be marked as follows:

- (1) In an unobstructed area with letters and numerals identifying the standards or specification (e.g., UN 1A1, DOT 4B240ET, etc.).
- (2) Unless otherwise specified in this part, with the name and address or symbol of the manufacturer, or, for a UN standard packaging, the approval agency certifying compliance with the UN standard. Symbols, if used, must be registered with the Associate Administrator for Hazardous Materials Safety. Duplicate symbols are not authorized.
- (3) The markings must be stamped, embossed, burned, printed or otherwise marked on the packaging, to provide adequate accessibility, permanency, contrast, and legibility so as to be readily apparent and understood.
- (4) Unless otherwise specified, letters and numerals must be at least 12.0 mm (0.47 inches) in height except that for packagings of less than or equal to 30 L (7.9 gallons) capacity for liquids or 30 kg (66 pounds) capacity for solids, the height must be at least 6.0 mm (0.2 inches).

- b. Packagings may be marked with the United Nations symbol and packaging identification code as provided in this subchapter, in the ICAO Technical Instructions or in Annex 1 to the IMDG Code, provided the person applying these marks has established that the packaging conforms to the applicable provisions of this subchapter, the ICAO Technical Instructions or Annex 1 to the IMDG Code, respectively.

- (1) If an indication of the State in whose territory the specified tests are carried out, or of the State authorizing the allocation of the mark, is required by this part (see paragraph 178.503 of this part), the letters "USA" shall be used if the manufacturing and testing occurs in the United States.

- (2) If an indication of the name of the manufacturer or other identification of the packaging as specified by the competent authority is required, the name and address or symbol of the person making the mark shall be entered. Symbols, if used, must be registered with the Associate Administrator for Hazardous Material Safety. Duplicate symbols are not authorized.
- (3) Packagings manufactured to UN standards in accordance with this subchapter shall be marked as prescribed in paragraph 178.503 of this part.
- c. Where a packaging conforms to more than one UN standard or DOT specification, the packaging may bear more than one marking, provided the packaging meets all the requirements of each standard or specification. Where more than one marking appears on a packaging, each marking must appear in its entirety.

It is the responsibility of the shipper to ensure that the above requirements have been properly addressed by providing assurance that the packagings have been correctly marked as a Type A packaging, including identification of the manufacturer.

The ARROW-PAK packaging was tested only to DOT-7A Type A packaging requirements, as is to be used only for radioactive material transportation. The use of any additional markings would require additional testing of the packaging to ensure the packaging met that standard/specification.

5.2 COMPLIANCE TEST EVALUATION

5.2.1 49 CFR 173.465 – Type A Packaging Tests

- a. The proposed packaging with proposed contents must be capable of withstanding the tests prescribed in this section. One prototype may be used for all tests if the requirements of paragraph (b) of this section are complied with.
- b. **Water Spray Test.** The water spray test must precede each test or test sequence prescribed in this section. The water spray test shall simulate exposure to rainfall of approximately 5 centimeters (2 inches) per hour for at least one hour. The time interval between the end of the water spray test and the beginning of the next test shall be such that the water has soaked-in to the maximum extent without appreciable drying of the exterior of the specimen. In the absence of evidence to the contrary, this interval may be assumed to be two hours if the water spray is applied from four different directions simultaneously. However, no time interval may elapse if the water spray is applied from each of the four directions consecutively.

The water spray test was successfully conducted on test unit 40-TU-03 (Series 8600 pipe). This was basically an empty test unit that had been filled with 100 cc (4 oz) of fluorescein. The test unit was subjected to the water spray conditions for 1 hour with no negative effect on the packaging. No further water spray tests were conducted as there was no absorption of water nor loss of contents.

- c. **Free Drop Test.** The free drop test consists of a fall onto the target in a manner that causes maximum damage to the safety features being tested, and:
1. For packages weighing 5,000 kilograms (11,000 pounds) or less, the distance of the fall measured from the lowest point of the packaging to the upper surface of the target shall not be less than 1.2 meters (4 feet).
 2. For packages weighing more than 5,000 kilograms (11,000 pounds), the distance of the fall shall not be less than the distance specified in Table 11, for the applicable packaging weight:

**TABLE 11:
FREE-FALL DISTANCE FOR PACKAGING WEIGHING MORE THAN 5,000 KILOGRAMS.**

PACKAGING WEIGHT		FREE-FALL DISTANCE	
KILOGRAMS	POUNDS	FEET	METERS
>5,000 TO 10,000...	>11,000 TO 22,000...	3	0.9
>10,000 TO 15,000...	>22,000 TO 33,000...	2	0.6
More than 15,000...	More than 33,000...	1	0.3

Test packagings undergoing the 1.2-m (4-ft) drop test were test unit 40-TU-01 and 40-TU-02. Test unit 40-TU-01 was made from Series 8000 pipe, and test unit 40-TU-02 was made from Series 8600 pipe.

The water spray test was conducted on test unit 40-TU-03 prior to the 1.2-m (4-ft) drop test. As the water spray test had no negative effect on the tested packaging configuration, the water spray test was not conducted on the two test units (40-TU-01 and 40-TU-02) used for the drop tests described below. The vibration test was conducted on test units 40-TU-01 and 40-TU-02 prior to the 1.2-m (4-ft) drop test being conducted.

The packagings shown in Table 5-1 were subjected to drop tests from a height of 1.2 m (4 ft).

Table 5-1. Drop Tests - 1.2 m (4 ft).

Package No.	Gross wt. kg (lb)	Drop orientation
40-TU-01	519.8 (1146)	Vertical, to impact flat onto the end cap without plugs
40-TU-01	519.8 (1146)	Horizontal, to impact flat onto the side wall of the packaging
40-TU-01	519.8 (1146)	Center of gravity (CG), to impact the edge of the end cap without plugs
40-TU-01	519.8 (1146)	Vertical, to impact flat onto the end cap with plugs
40-TU-02	507.6 (1119)	Vertical, to impact flat onto the end cap without plugs
40-TU-02	507.6 (1119)	Horizontal, to impact flat onto the side wall of the packaging
40-TU-02	507.6 (1119)	CG, to impact the edge of the end cap without plugs
40-TU-02	507.6 (1119)	CG, to impact the edge of the end cap with plugs

Results:

Test Unit 40-TU-01: This test unit was filled with simulated contents of noncontaminated, wrapped lead bricks and steel shot, and contained two plywood spacers (refer to Appendix B for assembly, loading, and closure procedure used for testing). Fluorescein was added for leak detection purposes. This test unit measured a total length of 187.96-cm (74-in). The gross weight of this test unit was 519.8 kg (1146 lb). This test unit underwent and passed a total of four drops.

Drop #1 - this orientation was vertical to impact flat onto the end cap without plugs. Minor damage resulted in slight scarring of the HDPE material on the end cap at the point of impact. The impact point and fusion joints were checked visually and under black light conditions. There was no indication of leakage of simulated contents.

Drop #2 - this orientation was CG (10° angle) to impact the edge of the end cap without plugs. Damage resulted in a slight circular flattening at the area of impact on the edge of the end cap. This circular flattening had a diameter of 5.08-cm (2-in). No damage resulted from the slap-down. The impact point and fusion joints were checked visually and under black light conditions. There was no indication of leakage of simulated contents.

Drop #3 - this orientation was horizontal to impact flat onto the side wall of the package. Damage resulted in slight flattening of the beaded

edge along the fusion joints. The beaded edge of the fusion joint, near the end cap without the plugs, flattened slightly over a length of 7.62-cm (3-in). The beaded edge of the fusion joint near the end cap with the plugs flattened slightly over a length of 6.99-cm (2.75-in). There was no flattening of the pipe or end caps. The fusion joints were checked visually and under black light conditions. There was no indication of leakage of simulated contents.

After the third drop, a soap bubble test was conducted to verify the containment of this test unit prior to conducting the fourth drop. The center plug was removed from the end cap, and compressed nitrogen gas was connected to test unit 40-TU-01. The internal pressure was increased to 27.6 kPa (4 psi), and held for 15 minutes. A low-viscosity soap bubble solution (i.e., "Snoop") was coated around the connections, plug, cylindrical side, and area where the end caps are fused to the cylindrical wall of the packaging. No bubbles or foam were detected. The area was also checked with a black light for detection of fluorescein. No indication of leakage was detected. The fourth drop was then conducted.

Drop #4 - this orientation was vertical to impact flat onto the end cap with the plugs. The test unit impacted flat onto the designated end cap, the package pivoted, and slapped down onto the edge of the drop pad. The package then rolled off the drop pad. Damage resulted in a minor scratch measuring 39.37-cm (15.5-in), diagonal, along the sidewall of the cylindrical pipe/tube, and near the center of the package. One end cap received a minor gouge when it hit an unidentified object when the packaging rolled off the test pad. Each dome-shaped end cap incorporates a flat, circular base piece, measuring 6.35-cm (2.50-in) in diameter, and located at the center axis of the packaging's domed end. This base piece is raised slightly from the domed end, and is a result of the process used by the manufacturer in molding this component. The flat base piece pulled outward slightly, around the entire circumference of the base piece. All noted damaged areas were checked under black light conditions. There was no indication of leakage of simulated contents. The fusion joints were checked visually and under black light conditions. There was no indication of leakage of simulated contents.

After the fourth drop, a soap bubble test was conducted to verify the containment of this test unit. The center plug was removed from the end cap, and compressed nitrogen gas was connected to test unit 40-TU-01. The internal pressure was increased to 27.6 kPa (4 psi), and held for 15 minutes. A low-viscosity soap bubble solution (i.e., "Snoop") was coated around the connections, plugs, cylindrical side, and area where the end caps are fused to the cylindrical wall of the packaging. The area of the end cap containing the 6.35-cm (2.50-in) flat base piece was coated with "Snoop." No bubbles or foam were detected from any of the specified locations. These areas were also checked with a black light for detection of fluorescein. No indication of leakage was detected.

Test Unit 40-TU-02: This test unit was filled with simulated contents of noncontaminated, wrapped lead bricks and steel shot, and contained two plywood spacers (refer to Appendix B for assembly, loading, and closure

procedure used for testing). Fluorescein was added for leak detection purposes. This test unit measured a total length of 184.15-cm (72.5-in). The gross weight of this test unit was 507.6 kg (1119 lb). This test unit underwent and passed a total of four drops.

Drop #1 - this orientation was vertical to impact flat onto the end cap without plugs. The test unit impacted flat onto the designated end cap, the package pivoted and fell against a turnbuckle and beam located near one edge of the drop pad, then slapped down onto the edge of the drop pad. The package then rolled off the drop pad. One end cap was gouged slightly from striking the turnbuckle. Minor damage resulted in slight scarring of the HDPE material from the package rolling off the test pad. Damage resulting from the slap-down was visible along the beaded edge of the fusion joint, which had slight flattening over a length of 5.08-cm (2-in). All noted and damaged areas were checked visually and under black light conditions. The fusion joints were checked visually and under black light conditions. There was no indication of leakage of simulated contents.

Drop #2 - this orientation was CG (10° angle) to impact the edge of the end cap without plugs. Damage resulted in a slight dimpling of the HDPE material having a diameter of 2.54-cm (1-in) at the area of impact on the edge of the end cap. No damage resulted from the slap-down. The impact point and fusion joints were checked visually and under black light conditions. There was no indication of leakage of simulated contents.

Drop #3 - this orientation was horizontal to impact flat onto the side wall of the package. Damage resulted in slight flattening of the beaded edge of the fusion joint. Each beaded edge of the fusion joints flattened a length of 6.35-cm (2.50-in). There was no flattening of the pipe or end caps. The fusion joints were checked visually and under black light conditions. There was no indication of leakage of simulated contents.

After the third drop, a soap bubble test was conducted to verify the containment of this test unit prior to conducting the fourth drop. The center plug was removed from the end cap, and compressed nitrogen gas was connected to test unit 40-TU-02. The internal pressure was increased to 27.6 kPa (4 psi), and held for 15 minutes. A low-viscosity soap bubble solution (i.e., "Snoop") was coated around the connections, plugs, cylindrical side, and area where the end caps are fused to the cylindrical wall of the packaging. No bubbles or foam were detected. The area was also checked with a black light for detection of fluorescein. No indication of leakage was detected. The fourth drop was then conducted.

Drop #4 - this orientation was CG (10° angle) to impact the edge of the end cap with the plugs. Damage resulted in a slight dimpling [diameter of 2.54-cm (1-in)] of the HDPE material at the point of impact on the edge of the end cap. No damage resulted from the slap-down. Each dome-shaped end cap incorporates a flat, circular base piece, measuring 6.35-cm (2.50-in) in diameter, and located at the center axis of the packaging's domed end. This base piece is raised slightly from the domed end, and is a result of the process used by the manufacturer in molding

this component. The flat base piece pulled outward slightly, halfway around the circumference of the base piece. This area was checked under black light conditions. There was no indication of leakage of simulated contents. The fusion joints were checked visually and under black light conditions. There was no indication of leakage of simulated contents.

After the fourth drop, a soap bubble test was conducted to verify the containment of this test unit. The center plug was removed from the end cap, and compressed nitrogen gas was connected to test unit 40-TU-02. The internal pressure was increased to 27.6 kPa (4 psi), and held for 15 minutes. A low-viscosity soap bubble solution (i.e., "Snoop") was coated around the connections, plug, cylindrical side, and area where the end caps are fused to the cylindrical wall of the packaging. The area of the end cap containing the 6.35-cm (2.50-in) flat piece was coated with "Snoop." No bubbles or foam were detected from any of the specified locations. These areas were also checked with a black light for detection of fluorescein. No indication of leakage was detected.

3. For Fissile Class II packagings, the free drop specified in subparagraph (1) or (2) of this paragraph shall be preceded by a drop from a height of 0.3 meter (1 foot) on each corner. For cylindrical packagings, the 0.3 meter (1 foot) drop shall be onto each of the quarters of each rim.

The packaging configuration will not be authorized for Fissile Class II materials; therefore, this requirement is not applicable.

4. For fiberboard or wood rectangular packages not exceeding 50 kilograms (110 pounds) in weight, a separate specimen of the proposed packaging shall be subjected to a free drop onto each corner from a height of 0.3 meter (1 foot).

This requirement is not applicable to the packaging configuration tested.

5. For fiberboard cylindrical packages weighing not more than 100 kilograms (220 pounds) a separate specimen of the proposed packaging shall be subjected to a free drop onto each of the quarters of each rim from a height of 0.3 meter (1 foot).

This requirement is not applicable to the packaging configuration tested.

6. The target shall have a flat, horizontal surface of such mass and rigidity that any increase in its resistance to displacement or deformation upon impact by the specimen would not significantly increase the damage to the specimen.

The test pad used meets this requirement.

The DOE-approved test facility, located at the Hanford site, utilizes a test pad that is located in the 305 Building. This pad is an 11,868-kg (26,165-lb), 2.1-m (84-in) square, indoor

test pad consisting of a 5-cm (2-in) thick steel top plate, a 10-cm (4-in) thick steel intermediate plate, and a 61-cm (2-ft) thick reinforced concrete base. The pad is located in a 4.6-m (15-ft) deep pit with a 3.0 by 3.7-m (10 by 12-ft) opening.

- d. **Compression Test.** The compression test shall last for a period of at least 24 hours and consists of a compressive load equivalent to the greater of the following:
1. Five times the weight of the actual package; or
 2. 1300 kilograms per square meter (265 pounds per square foot) multiplied by the vertically projected area of the package. The compressive load shall be applied uniformly to two opposite sides of the packaging specimen, one of which must be the base on which the package would normally stand.

Test unit 40-TU-03 (Series 8600 pipe) was used for this test. This was basically an empty packaging; 100 cc (4 oz) of fluorescein was added for leak detection purposes.

The water spray and penetration (1-m [3.3-ft]) tests were conducted on this test unit prior to conducting the compression test. The compressive load was determined by using five times the weight of the packaging as it is greater than the weight of the vertically projected area of the packaging. A load of 2920.0 kg (6437.5 lb) was applied uniformly to two opposite sides of test unit 40-TU-03, one of which was the base on which the package would normally stand (horizontally).

When the weight was removed from this test unit, the ARROW-PAK's end caps and pipe/tube remained round. Only the beaded edge along the fusion joint areas were observed to have minor damage. On the side of the packaging that was in contact with the concrete floor, both beaded edges of the fusion joints were slightly flattened over a length of 5.715-cm (2.25-in). The side of the packaging that was in contact with the weight, the beaded edges of the fusion joints flattened slightly over a length of 5.715-cm (2.25-in) on one end of the package, and 6.35-cm (2.50-in) on the opposite end of the package.

The compression test was successfully conducted on this test unit, for a total duration of 41.5 hours.

- e. **Penetration Test.** For the penetration test the packaging specimen shall be placed on a rigid, flat, horizontal surface that will not move while the test is being performed. The test shall consist of:
1. A bar of 3.2 centimeters (1.25 inches) in diameter with a hemispherical end weighing 6 kilograms (13.2 pounds) being dropped with its longitudinal axis vertical, onto the center of the weakest part of the packaging specimen, so that, if it penetrates far enough, it will hit the containment system. The bar must not be deformed by the test; and

2. The distance of the fall of the bar measured from its lower end to the upper surface of the packaging specimen shall not be less than 1 meter (3.3 feet).

The penetration test was successfully conducted on test unit 40-TU-03 (Series 8600 pipe). This was basically an empty packaging; 100 cc (4 oz) of fluorescein was added for leak detection purposes.

The water spray test was conducted on this test unit prior to conducting the penetration test. Immediately after the water spray test was conducted and before the packaging could dry, the subject test unit underwent the 1 m (3.3 ft) penetration test. The package was laid horizontally onto its side, and the penetration bar was dropped to hit the cylindrical tube/pipe, at the center of the package. The point of impact caused the HDPE material to dimple slightly, and measured 1.27-cm (0.50-in) across. This minor damage was observed under a black light, and no leakage of simulated contents was detected.

5.2.2 49 CFR 173.466 - Additional Tests for Type A Packagings Designed for Liquids and Gases

In addition to the tests prescribed in 173.465, Type A packaging designed for liquids and gases shall be capable of withstanding the following tests:

1. Free Drop Test. The packaging specimen shall fall onto the target in a manner which will cause it to suffer the maximum damage to its containment. The distance of the fall measured from the lowest part of the packaging specimen shall not be less than 9 meters (30 feet).

This packaging is not authorized for transport of liquids and/or gases; therefore, this test is not required.

2. Penetration Test. The specimen must be subjected to the test specified in 173.465(e) except that the distance of the fall shall be 1.7 meters (5.5 feet).

This packaging is not authorized for transport of liquids and/or gases; therefore, this test is not required.

5.2.3 49 CFR 178.608 - Vibration Standard

- a. Each packaging must be capable of withstanding, without rupture or leakage, the vibration test procedure outlined in this section.
- b. Test method.
 - (1) Three sample packagings must be filled and closed as for shipment.
 - (2) The three samples must be placed on a vibrating platform that has a vertical or rotary double-amplitude (peak-to-peak

displacement) of one inch. The packages should be constrained horizontally to prevent them from falling off the platform, but must be left free to move vertically, bounce, and rotate.

- (3) The test must be performed for one hour at a frequency that causes the package to be raised from the vibrating platform to such a degree that a piece of material of approximately 1.6 mm (0.063 inch [1/16 inch]) thickness (such as steel strapping or paperboard) can be passed between the bottom of any package and the platform.
 - (4) Immediately following the period of vibration, each package must be removed from the platform, turned on its side, and observed for any evidence of leakage.
 - (5) Other methods, at least equally effective, may be used, if approved by the Associate Administrator for Hazardous Material Safety.
- c. Criteria for passing the test. A packaging passes the vibration test if there is no rupture or leakage from any of the packages. No test sample should show any deterioration which could adversely affect transportation safety or any distortion liable to reduce packaging strength.

The packaging configuration passed this requirement. Visual examination of the packaging identified no rupture or leakage. Type A packagings are required "to withstand the effects of any acceleration, vibration, or vibration resonance that may arise during normal transportation" [49 CFR 173.412 (e)]. The test identified in this section was applied to support the ability of the packaging to meet the requirement.

Vibration testing was conducted for 1 hour on each of the test units filled with the simulated contents. The two test units used were 40-TU-01 (Series 8000 pipe) and 40-TU-02 (Series 8600 pipe).

NOTE: The vibration test that was conducted on test unit 40-TU-01 was conducted for one-half hour, and stopped when mechanical difficulties occurred with the shaker table. Vibration testing resumed the next day, and was conducted for another half hour on test unit 40-TU-01.

Damage observed from the vibration test was as follows:

40-TU-01: The beaded edges of the fusion joints flattened from the direct impact of the packaging bouncing horizontally on the vibration table. Each beaded edge in this location was mashed down, level with the side wall of the cylindrical tube/pipe. As the beaded edge normally protrudes about 0.635-cm (0.25-in) away from the side wall of the cylindrical packaging, the mashing effect was concave in appearance. This mashing, or flattening, measured 2.54 to 3.175-cm (1 to 1.25-in) across a 10.16-cm (4-in) length on one end of the packaging, and measured 1.905 to 2.54-cm (0.75-in to

1-in) across an 8.255-cm (3.25-in) length on the opposite end of the packaging. There was also slight scuffing of the HDPE material along the cylindrical tube/pipe from the packaging bending and bouncing on the vibration table. The beaded edges of the fusion joints that hit up against the side of the vibration table showed a slight amount of flattening that measured 1.905-cm (0.75-in) in length.

40-TU-02: The beaded edges of the fusion joints flattened from the direct impact of the packaging bouncing horizontally on the vibration table. Each beaded edge in this location was mashed down, level with the side wall of the cylindrical tube/pipe. As the beaded edge normally protrudes about 0.635-cm (0.25-in) away from the side wall of the cylindrical packaging, the mashing effect was concave in appearance. This mashing, or flattening, measured 2.54 to 3.175-cm (1 to 1.25-in) across an 8.89-cm (3.5-in) length on one end of the packaging, and measured 1.905 to 2.54-cm (0.75-in to 1-in) across a 7.62-cm (3-in) length on the opposite end of the packaging. There was also slight scuffing of the HDPE material along the cylindrical tube/pipe from the packaging bending and bouncing on the vibration table. The beaded edges of the fusion joints that hit up against the side of the vibration table showed a slight amount of flattening that measured 1.905-cm (0.75-in) in length.

Both test units underwent a "soap bubble" test to ensure the containment of the packagings remained intact. The center plug was removed from the end cap, and compressed nitrogen gas was connected to the test units. The internal pressure was increased to 27.6 kPa (4 psi), and held for 15 minutes. A low-viscosity soap bubble solution (i.e., "Snoop") was coated around the area where the end caps are fused to the cylindrical wall of the packaging. Also, all the connections were checked for leakage. No bubbles or foam were detected. No fluorescein was indicated under black light inspection.

A third test unit, filled with simulated contents, was not available. All three test units (two filled and one empty) were transported via highway from New Orleans, Louisiana, to Richland, Washington, over a four-day time period. Based on the distance and duration of this transport, and the performance of the two test units that underwent the vibration test described in this section, it was determined that no further vibration testing was necessary.

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6.0 CONCLUSION

The evaluation and testing indicates that the packaging configuration identified meets applicable DOT-7A Type A design and compliance test requirements. The packagings should be loaded, assembled, and closed as described in this document (Section 4.3 and Appendix B). Deviations from the approved, tested packaging system configuration will require retesting or approval by the U.S. Department of Energy. The following restrictions/specifications shall be observed:

1. The pipe shall be homogenous throughout and free of visible cracks, holes, voids, foreign inclusions, or other deleterious defects, and shall be identical in color, density, melt index, and other physical properties throughout.
2. The shipper shall ensure that the amount of radiation at any surface would not increase by more than 20%.
3. During handling, care must be exercised to avoid cutting or gouging the Marlex pipe and/or end caps. When lifting fused sections of pipe, chains or cable-type chokers must be avoided. Nylon slings are preferred. Spreader bars are recommended when lifting long fused sections.
4. The use of the plywood spacers is optional. If the spacers are used, adequate space is required to account for the fusion process. The spacer needs to fit down snugly onto the packaging contents. It may be necessary to wrap the outside edge of the spacer with several layers of tape so that the spacer does not move and shift.
5. The joining method of the end caps to the pipe/tube shall be the butt fusion method, and be in accordance with the pipe manufacturer's recommendations. Socket fusion shall not be used. The fusion equipment used in the joining procedures must meet the manufacturer's temperature requirements of 260°C (500°F), alignment, and 1034.2 kPa (150 psi) interfacial fusion pressure.
6. For heavy, bulky materials (e.g., concrete chunks, motors, pumps, and SWBs), equipment or materials with sharp corners or protrusions, or material/equipment geometries that could result in highly localized forces, the shipper must ensure that the contents are securely fastened/positioned within the package to prevent damage within the packaging.
7. The maximum gross weight for the packaging configuration is shown in Table 6-1.

The shipper is the organization that actually uses the packagings and therefore is responsible to make sure they are used in accordance with their designs. The shipper shall ensure that the design is suitable in all respects for the contents to be shipped. If it is not suitable, testing/analysis must be conducted and documented to demonstrate Specification 7A compliance with

the actual contents. The design will dictate many of the limits placed on the contents, such as mass and physical form.

The manufacturer(s) of the packaging described herein is responsible for using materials, processes, and controls in the packaging fabrication that are equivalent to those used in the fabrication of the test unit packagings.

Table 6-1. Approved Packaging Loading.

Item	Nominal Weight kg (lb)
Cylindrical Tube	24.95 (55.0)
End Caps (2 each)	5.67 (11.5) (each)
Content Fill Weight	483.53 (1066.0)
Gross Weight	519.82 (1146.0)

7.0 QUALITY ASSURANCE PROGRAM

The quality assurance program implemented by the shipper's organization must implement actions to provide adequate confidence that the shipment will comply with the regulations. The following regulatory requirements address quality control applicable to Type A packaging.

Paragraphs 173.474 and 173.475 that are restated below provide the quality control elements prescribed in 49 CFR. These requirements must be met for all shipments.

173.474. Quality Control for Construction of Packaging

- a. Prior to the first use of any packaging for the shipment of radioactive material, the shipper shall determine that:
 - 1. The packaging meets the quality of design and construction requirements as specified in this subchapter; and
 - 2. The effectiveness of the shielding, containment, and, when required heat transfer characteristics of the package, are within the limits specified for the package design.

173.475. Quality Control Requirements Prior to Each Shipment of Radioactive Materials

Before each shipment of any radioactive materials package, the shipper shall ensure by examination or appropriate tests, that:

- a. The packaging is proper for the contents to be shipped;
- b. The packaging is in unimpaired physical condition, except for superficial marks;
- c. Each closure device of the packaging, including any required gasket, is properly installed, secured, and free of defects;
- d. For fissile material, each moderator and neutron absorber, if required, is present and in proper condition;
- e. Each special instruction for filling, closing, and preparation of the packaging for shipment has been followed;
- f. Each closure, valve, or other opening of the containment system through which the radioactive content might escape is properly closed and sealed;
- g. Each packaging containing liquid in excess of an A₂ quantity and intended for air shipment has been tested to show that it will not leak under an ambient atmospheric pressure of not more than 0.25 atmosphere, absolute, (0.25 kilograms per square centimeter or 3.6 pisa). The test must be conducted on the entire containment

system, or on any receptacle or vessel within the containment system, to determine compliance with this requirement.

- h. The internal pressure of the containment system will not exceed the design pressure during transportation; and
- i. External radiation and contamination levels are within the allowable limits specified in this subchapter.

It is critical that controls are in place to ensure that the packaging hardware to be used complies with the specifications given for the packaging hardware tested, described, and evaluated in this document. Each shipper must have a documented program that describes how this is achieved, and the degree of certainty, in addition to documentation (audit trail) that demonstrates compliance. The quality assurance program is mandated in DOE Order 5480.3, *Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes* (DOE 1985).

8.0 PRIMARY USER/MANUFACTURER

Site/Contact/Phone

Address

Dr. Harley Reno
(208) 526-9865

Lockheed Idaho Technologies Company
P.O. Box 1625
Idaho Falls, Idaho 83415-2113

Packaging Manufacturer

Arrow Construction, Inc.
216 Gunn Road
P.O. Box 240427
Montgomery, Alabama 36124

(205) 271-6185

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9.0 REFERENCES

- 49 CFR, "Transportation," Parts 100 to 177 and Parts 178 to 199, *Code of Federal Regulations*, as amended.
- Cruse, J. M., 1992, *Test and Evaluation Document for DOT Specification 7A Type A Packaging*, WHC-EP-0558, Rev. 3, Westinghouse Hanford Company, Richland, Washington.
- DOE, 1985, *Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes*, DOE Order 5480.3, U.S. Department of Energy, Washington, D.C.
- Farnsworth, R. K., (et al.), 1994, *Demonstration and Evaluation of Arrow Construction's ARROW-PAK as an Alternative macro and Improved Container for Mixed Waste Storage*, EGG-WTD-11240, Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho.
- IAEA, 1985, *IAEA Safety Standards, Safety Series No. 6*, 1985 edition, Regulations for the Safe Transport of Radioactive Material, International Atomic Energy Agency, Vienna, Austria.
- Kelly, D. L., 1995a, *DOT-7A Type A Packaging Design Guide*, WHC-SD-TP-RPT-017, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Kelly, D. L., 1995b, *Test Plan for Lockheed Idaho Technologies Company ARROW-PAK Packaging, Docket 95-40-7A, Type A Container*, WHC-SD-TP-OTP-002, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Kelly, D. L., 1995c, *DOT-7A Packaging Test Procedure*, WHC-SD-TP-RPT-018, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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10.0 GLOSSARY

ABBREVIATIONS AND ACRONYMS

Arrow	Arrow Construction, Inc.
ASTM	American Society for Testing and Materials
Boh Brothers	Boh Brothers Construction Company
CG	center of gravity
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DOT-7A	U.S. Department of Transportation Specification 7A Type A
HDPE	high-density polyethylene
LITCO	Lockheed Idaho Technologies Company
NPT	normal pipe thread
UV	ultraviolet
WHC	Westinghouse Hanford Company

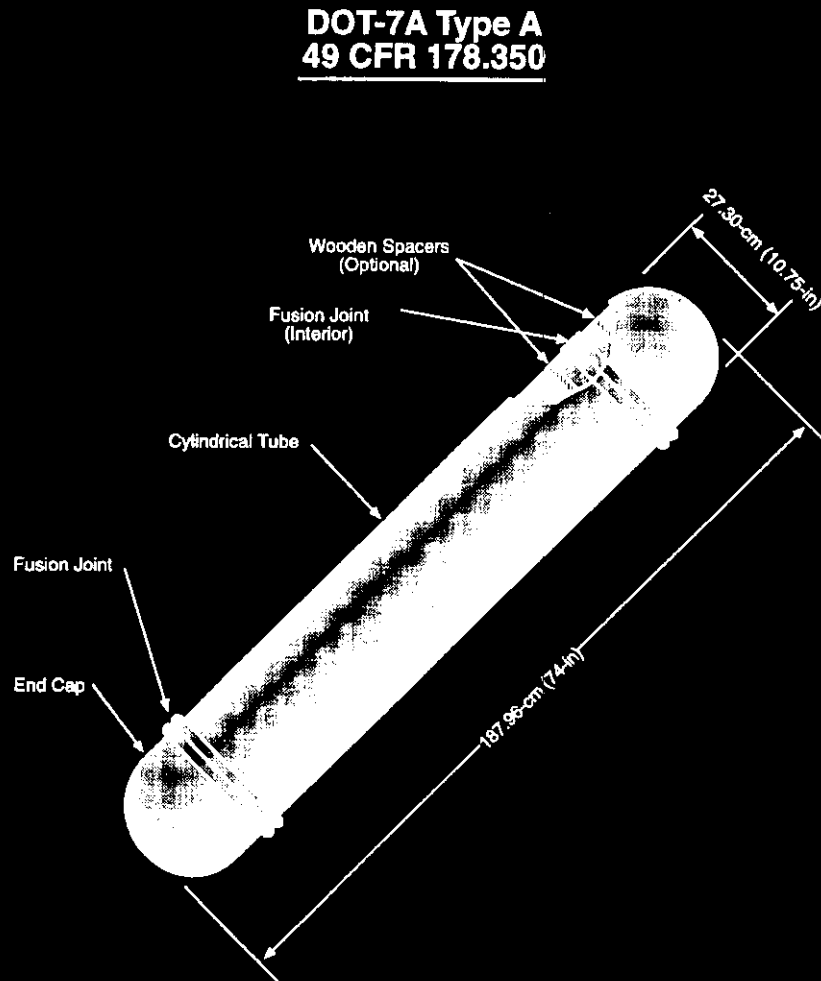
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APPENDIX A

ARROW-PAK PACKAGING CONFIGURATION

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Figure A-1. Tested ARROW-PAK Configuration.



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APPENDIX B**ASSEMBLY, LOADING, AND CLOSURE FOR TESTING PURPOSES****B1.0 GENERAL INFORMATION**

Refer to Appendix A of the Test Plan (Kelly, 1995b) for a sketch of the ARROW-PAK configuration being tested. The ARROW-PAK packaging system consists of a Marlex-resin pipe manufactured by Phillips-Driscopipe, Inc., and is sealed with end caps manufactured from the same materials via a patented process developed by Arrow Construction, Inc. The patented process involves the use of electrical energy to heat opposing faces of the pipe and end caps, and hydraulic rams to press the heated surfaces together. The result is a homogeneous bonding of the end cap to the pipe.

B2.0 INSTRUCTIONS

NOTE: Due to the complexity of the thermal sealing process and the machinery involved, the test units will be partially filled with simulated contents and sealed at Boh Brothers Construction Company, Inc., New Orleans, Louisiana. The WHC test and/or project engineer(s) will witness the loading and sealing process prior to testing. The sponsor is responsible for ensuring that all three test units are sound and do not leak prior to shipment to the DOE-approved test facility for Type A testing. The remaining simulated contents, a tracer material used for leak testing, will be added at the DOE-approved test facility.

Three test units will be supplied for testing purposes. Two 25.4-cm (10-in) diameter ARROW-PAKs will be filled with simulated contents of clean, noncontaminated, taped lead bricks. Carbon steel shot will be added as a filler material.

NOTE: The sponsor is responsible for drilling and tapping two holes into the center of one end cap, on each of these test units. The sponsor is responsible for placing a suitable hex-socket plug into each of the holes. It is suggested that the hex-socket plugs be 1/2-inch normal pipe thread (NPT), and be flush or below the surface of the end caps. Refer to Figure B-1 for diagram of hole placement on these two test units.

A third ARROW-PAK will be left empty.

NOTE: The sponsor is responsible for drilling and tapping a hole into one end cap. The sponsor is responsible for placing a suitable hex-socket plug into the hole. It is suggested that the hex-socket plugs be 1/2-inch NPT, and be flush or below the surface of the end cap. Refer to Figure B-1 for diagram of hole placement on this test unit.

¹Phillips-Driscopipe, Inc., is a subsidiary of Phillips Petroleum Company.

Figure B-1. Diagram for Recommended Hole Placements for Testing.



B3.0 ASSEMBLY

1. Follow the manufacturer's instructions for fusion unit setup, calibration, loading of tubing onto the fusion unit, facing, heating, fusing, and unloading of the packaging assembly from the fusion unit. Follow the manufacturer's instructions for appropriate cool down period. (Information on this process has been included at the end of this Appendix.)
2. Fuse one of the end caps that has had the appropriate hole(s) drilled and tapped into it (for testing purposes only), to the pipe. Remove this partial assembly from the fusion unit.

B4.0 LOADING CONTENTS

NOTE: The dimensions of the lead bricks used during testing are 5x10x20-cm (2x4x8-in).

1. Load lead bricks into the first end cap. About four lead bricks will fit into an end cap.
2. Load lead bricks, vertically, into the cylindrical tube. The bricks should fit snugly into the packaging. Four lead bricks should fit snugly across the diameter of the ARROW-PAK cylindrical tube.
3. Continue to fill the cylindrical tube with lead bricks. Leave an estimated 5.08-cm (2-in) space between the last level of bricks and the top of the tube.
4. Fill the void space within cylindrical tube and first end cap with steel shot. Leave an estimated 5.08-cm (2-in) space between the steel shot and the top of the tube.

NOTE: Adequate space is required for the placement of a wooden spacer and to allow for fusion of the second end cap to the cylindrical tube.

5. Place a plywood spacer on top of the simulated load. Pound the spacer down into the tube about 5.08-cm (2-in), until it is touching the simulated contents. The purpose of this spacer is to keep the simulated load in place while the second end cap is fused onto the cylindrical tube.

NOTE: The spacer needs to fit down snugly onto the layer of bricks and shot. It may be necessary to wrap the outside edge of this spacer with several layers of tape so that the spacer does not move and shift.

6. Load lead bricks into the second end cap. About four lead bricks will fit into an end cap. Leave an estimated 5.08-cm (2-in) space between the bricks and the top of the second end cap.

7. Fill the void space within the second end cap with steel shot. Leave an estimated 5.08-cm (2-in) space between the steel shot and the top of the tube.

NOTE: Adequate space is required for the placement of a wooden spacer and to allow for fusion of the second end cap to the cylindrical tube.

8. Place a plywood spacer on top of the simulated load. Pound the spacer down into the tube about 5.08-cm (2-in), until it is touching the simulated contents. The purpose of this spacer is to keep the simulated load in place while the second end cap is fused onto the cylindrical tube.

NOTE: The spacer needs to fit down snugly onto the layer of bricks and shot. It may be necessary to wrap the outside edge of this spacer with several layers of tape so that the spacer does not move and shift.

B5.0 CLOSURE

1. Follow the manufacturer's instructions for fusion unit setup, calibration, loading of tubing onto the fusion unit, facing, heating, fusing, and unloading of the packaging assembly from the fusion unit. Follow the manufacturer's instructions for appropriate cool down period. (Information on this process has been included at the end of this Appendix.)

B6.0 ADDITION OF TRACER MATERIAL

1. Prior to testing at the approved DOE-test facility, tracer material for leak detection purposes will be added to the test units.
2. The tracer material will be added by removing one of the plugs that is located on an end cap from each test unit.
3. Tracer material used will be as follows:
 - Fluorescein will be added to the two test units containing the simulated contents of lead bricks and steel shot.
 - The third, empty, test unit, will be filled with about 1/2 cup of fluorescein.
4. Secure the plug, once the tracer material has been added.

Note: An appropriate thread sealer, such as Teflon tape, may need to be applied to the thread plugs to assure that there is no leakage in this area during testing.

5. Ensure that the exterior of the test units is clean, and no trace of fluorescein exists. Use a light water mist and black light for detection of tracer material.

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DUCTILE PE PIPE SPECIFICATION
BLACK, HIGH DENSITY, VERY HIGH MOLECULAR WEIGHT POLYETHYLENE
PRESSURE AND GRAVITY FLOW PIPE
DRISCOPIPE 8000/8600 SERIES
FOR OVERLAND, BURIED, AND INDUSTRIAL USE IN SIZES 1" TO 54" IPS

I. FORWARD

This specification has been prepared in consultation with pipe manufacturers to define the characteristics and properties for black polyethylene pipe of high density and extra-high weight-average molecular-weight. This is issued to satisfy the needs of users and manufacturers for a complete specification and to reflect the 1990's advances in testing, technology and quality.

II. SCOPE

This specification governs the material, pipe, fittings, butt fusion and general construction practice of HDPE pipe and includes the following reference specifications:

Reference Specifications

1. ASTM D-638 - Test Method for Tensile Properties of Plastics
2. ASTM D-7900 - Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
3. ASTM D-1238 - Test Method for Flow Rates of Thermal Plastics by Extrusion Plastometer
4. ASTM D-1248 - Specification for Polyethylene Plastics Molding and Extrusion Materials.
5. ASTM D-1505 - Test Method for Density of Plastics by the Density Gradient Technique.
6. ASTM D-1599 - Test Method for Short Time Hydraulic Failure Pressure of Plastic Pipe, Tubing and Fittings
7. ASTM D-1693 - Test Method for Environmental Stress Cracking of Ethylene Plastics
8. ASTM D-2122 - Method for Determining Dimensions of Thermal Plastic Pipe and Fittings
9. ASTM D-2837 - Method for obtaining Hydrostatic Design Basis for Thermal Plastic Pipe Materials
10. ASTM D-3350 - Specification for Polyethylene Plastics Pipe and Fittings Material
11. ASTM F-1248 - Determination of Environmental Stress Crack Resistance (ESCR) of Polyethylene Pipe
12. ASTM D-4218 - Test Method for Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
13. ASTM F-714 - Standard Specification for Polyethylene Plastic Pipe Based on Outside Diameter
14. ASTM D-2513 - Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings

III MATERIAL

Materials used for the manufacture of polyethylene pipe and fittings shall be very high molecular weight, high density ethylene/hexene copolymer PE 3408 polyethylene resin meeting the above listed physical property and pipe performance requirements:

The polyethylene pipe MANUFACTURER shall provide certification that stress regression testing has been performed on the specific product. The said certification shall include a stress life curve per ASTM D-2837. The stress regression testing shall have been done in accordance with ASTM D2837, and the manufacturer shall provide a product supplying a minimum hydrostatic design basis (HDR) of 1,600 psi as determined in accordance with ASTM D2837.

Further, the material shall be listed by PPI (the Plastic Pipe Institute, a division of the Society of the Plastics Industry) in PPI TR-4 with a 73 degree F hydrostatic design stress rating of 800 psi and a 140 degree F hydrostatic design stress rating of 400 psi. The PPI Listing shall be in the name of the pipe manufacturer, and shall be based on ASTM D2837 and PPI TR-3 testing and validation of samples of the pipe manufacturer's production pipe.

The Manufacturer's certification shall state that the pipe was manufactured from one specific resin in compliance with these specifications. The certificate shall state the specific resin used, its source and list its compliance to these specifications.

IV. PIPE EXTRUSION

The pipe shall be extruded using a melt homogenizing/plasticating extruder and "appropriate" die. The extruder screw design should be customized for the HDPE being processed to minimize melt fracture of the molecular structure thus reducing the molecular weight and changing some physical properties from resin to pipe. The resin should be processed at its melt temperature of 415 degrees F to 525 degrees F.

V. PIPE AND FITTINGS

Pipe

Pipe supplied under this specification shall have a nominal IPS (Iron Pipe Size) OD unless otherwise specified. The SDR (Standard Dimension Ratio), and the pressure rating of the pipe supplied shall be as specified by the engineer. Pipe is to be manufactured from Driscopipe Marlex M-8000 resin and bear Driscopipe label of 8000 for gas or 8600 for industrial applications.

The pipe shall be produced with the nominal physical properties outlined in Section III, and to the dimensions and tolerances specified in ASTM F-714. Additionally, the pipe shall be inspected per industry accepted manufacturer standards for:

* Diameter	* Straightness
* Wall Thickness	* Ovality
* Concentricity	* Toe-In
* Quick Burst Pressure and Ductility	* Overall Workmanship
* Joint Length	* Inspection on ID & OD
	* Print Line

The pipe shall contain no recycled compound except that generated in the manufacturer's own plant from resin of the same specification from the same raw material. The pipe shall be homogenous throughout and free of visible cracks, holes, voids, foreign inclusions, or other deleterious defects and shall be identical in color, density, melt index and other physical properties throughout.

Pipe Performance

The pipe shall be in compliance with the physical and performance requirements of Section III of this specification. Specifically, the pipe will be extruded from resin meeting specifications of ASTM D3350 with a cell classification of PE 355434C and ASTM D1248 pipe grade resin type III, Class C, Category 5, grade P34 polyethylene compound. The pipe shall exhibit the short term tensile and compressive physical properties listed in Section III. And the pipe shall provide the long term endurance characteristics recognized by: the compressed pipe ring environmental stress crack resistance greater than 1000 hours; the slow crack growth resistance greater than 32 days; and the impact strength (toughness) greater than 84 in-lb/in notch.

Fittings

The standard HDPE fittings shall be standard commercial products manufactured by injection molding or by extrusion and machining, or, shall be fabricated from PE pipe conforming to this specification. The fitting shall be fully pressure rated by the manufacturer to provide a working pressure equal to the pipe for 50 years of service at 73.4 degrees F with an included 2:1 safety factor. The fittings shall be manufactured from the same resin type, grade and cell classification as the pipe itself. The manufacture of the fittings shall be in accordance with good commercial practice to provide fittings homogeneous throughout and free from crack, holes, foreign inclusions, voids or other injurious defects. The fitting shall be as uniform as commercially practicable in color, opacity, density and other physical properties. The minimum "quick-burst" strength of the fittings shall not be less than that of the pipe with which the fitting is to be used.

VI. JOINING

Sections of polyethylene pipe should be joined into continuous lengths on the job site above ground. The joining method shall be the butt fusion method and shall be performed in strict accordance with the pipe manufacturer's recommendations. The butt fusion equipment used in the joining procedures should be capable of meeting all conditions recommended by the pipe manufacturer, including, but not limited to, temperature requirements of 500 degrees F, alignment and 150 psi interfacial fusion pressure.

Butt fusion joining shall be 100% efficient offering a joint weld strength equal to or greater than the tensile strength of the pipe. Socket fusion shall not be used. Extrusion welding or hot gas welding of HDPE shall not be used for pressure pipe applications nor in fabrications where shear or structural strength is important. Flanges, unions, transition fittings and some mechanical couplers may be used to mechanically connect HDPE pipe without butt fusion. Refer to the manufacturer's recommendations.

VII. QUALITY & WORKMANSHIP

The pipe and fitting manufacturer's production facilities shall be open for inspection by the owner or his designated agents. During inspection, the manufacturer shall demonstrate that he has facilities capable of manufacturing the pipe and fittings required by this specification, that a quality control program meeting the minimum requirements of D2513 and ASTM F714 is in use, and that facilities for performing the tests required by this specification are in use.

The engineer may request certification that the pipe produced is represented by the quality assurance data. Additionally, test results from the manufacturer's testing which show the pipe does not meet appropriate ASTM standards of manufacturer's representation, will be cause for rejection of the pipe represented by the testing. These tests may include density and flow rate measurements from samples taken at selected locations within the pipe wall and thermal stability determinations according to ASTM D3350, 10.1.9.

The owner or the specifying engineer may request certified lab data from the manufacturer to verify the physical properties of the materials supplied under this specification or at his own expense may take random samples for testing by in independent laboratory.

QA Deviations -

If an approved supplier must supply material that does not meet all requirements of this specification, he must notify the specification engineer via a written description of the deviation with data that shows the magnitude of the deviation, the justification for the deviation from this specification, and the worst case, long term impact of the deviation on the project. The decision, prior to shipment, to accept material deviating from this specification shall be the responsibility of the specifying engineer.

QA Verification -

The owner or the specifying engineer may request certified lab data to verify the physical properties of the compounded materials supplied under this specification, or, may have random samples taken and have them tested by in independent laboratory. Such testing will be at expense of the party requiring verification testing. Requests for verification must be submitted in writing and mutually acceptable arrangements made.

QA Rejection -

Polyethylene pipe and fittings may be rejected in whole or in part by the specification engineer for failure to meet any of the requirements of this specification.

QA Records-

QA/QC records shall be maintained intact for a minimum of one year from date of production.

VIII. Pipe Marking

During extrusion production, the HDPE pipe shall be continuously marked with durable printing following this format:

1. Nominal Size	10"
2. Dimension Ratio	SDR 11
3. Pressure Rating	160 psi
4. Type	(Trade Name)
5. Material Classification	PE3408
6. Certification Bases	ASTM F714
7. Blank Position for NSF/FM Use	NSF-PW
8. Pipe Test Category	C3
9. Plant	R... for Pryor
10. Extruder Number	#5
11. Date	06 Oct 89
12. Operator Number	55
13. Shift Letter	A
14. Resin Supplier Code	P

EXAMPLE: 10" IPS SDR 15.5 110 psi (Trade Name) PE 3408 ASTM F-714 NSF-pw C3 P5 06FEB89 55A P

IX. Pipe Packaging, Handling, Storage

The manufacturer shall package the pipe in a manner designed to deliver the pipe to the project neatly, intact, and without physical damage. The transportation carrier shall use appropriate method and intermittent checks to insure the pipe is properly supported, stacked, and restrained during transport such that the pipe is not nicked, gouged, or physically damaged.

Pipe shall be stored on clean, level ground to prevent undue scratching or gouging of the pipe. If the pipe must be stacked for storage, such stacking shall be done in accordance with the pipe manufacturer's recommendations. The handling of the pipe shall be done in such a manner that it is not damaged by dragging over sharp objects or cut by chokers or lifting equipment.

Sections of pipe having been discovered with cuts or gouges in excess of 10% of the wall thickness of the pipe shall be cut out and removed. The undamaged portions of the pipe shall be rejoined using the butt fusion joining method.

Fused segments of pipe shall be handled so as to avoid damage to the pipe. When lifting fused sections of pipe, chains or cable type chokers must be avoided. Nylon slings are preferred. Spreader bars are recommended when lifting long fused sections. Care must be exercised to avoid cutting or gouging the pipe.

X. Construction Practice

Construction and installation shall be performed in compliance with the manufacturers Design Guidelines and Installation Guidelines, and this specification.

1. Trench Construction

The trench and trench bottom should be constructed. Trenching should be done in accordance with ASTM-D-2321 - Section 7.

2. Embedment Material

Embedment materials should be Class I, Class II, or Class III materials as defined by ASTM-D-2321-Section 6. The use of Class IV and Class V materials for embedment is not recommended and should be done only with the approval of the engineer.

3.2.2 McElroy Fusion Unit Descriptions

As previously stated, two different McElroy fusion machines will be used to perform the fusion operations. The McElroy No. 412 will be used to fuse the 6-in. and 10-in. diameter containers and the No. 1236 will be used to fuse the 28-in. diameter containers. The difference between the two machines is that the No. 1236 uses automated hydraulic cylinders to position the heater plate, tubing clamps and facer, whereas these functions are performed manually on the No. 412. Detailed step-by-step procedures for operating the McElroy No. 412 operations and 1236 fusion machines are presented in Appendix A.

The hydraulic pump for the McElroy No. 412 is powered by a gasoline engine that is also connected to a 220 V, 60 Hz, single phase, 3.0 kW capacity alternator to power the heater plate. All these items are mounted on the chassis of the fusion unit. Power for the No. 1236's electrically driven hydraulic pump and heater plate is provided by a separate, stand alone gasoline powered generator that provides 230 V, 60 cycle, 3-phase power with a rating of 30 KVA. Details of the operation of each Fusion Unit are described below.

3.2.2.1. McElroy No. 412 Fusion Unit Operations:

SETUP

The unit is positioned outside of the warehouse, in an area free from hazardous vapors. It is then secured in place by setting the break provided on the rear left tire, and chocking the tires. The gasoline engine is started to provide power to the hydraulic pump and electrical power to the heater plate.

CALIBRATION

While the heater plate is coming up to operational temperature (410°F for the 6-in. MACRO, 500°F for the 10-in. MACRO), the pressure regulators used to control the facing pressure, heating pressure, and fusing pressure are adjusted to the appropriate setting by the operator. It takes approximately 20 to 25 minutes for the heater plate to reach operational temperature. The temperature is displayed by a dial thermometer located on the perimeter of the heater plate. The heater plate resides in an insulated cradle when not in use.

LOADING

The HDPE tubing is loaded into the double clamshell clamps located on the left side of the machine facing the controls. The end cap is placed in the single clamshell on the right side of the machine. The clamps are secured by manual screw jacks. After the first end cap-to-sleeve fusion is completed, the loading of lead or lead filled containers will be accomplished using a

combination of manual labor and lifting slings. The lead that is placed in each container is expected to be approximately 65 wt% lead bricks (2-in. x 4-in. x 8-in.) and 35 wt% lead shot.

FACING

The facer is then rotated into position between the two pieces to be fused. The facer is sandwiched between the two pieces by activating a set of hydraulic cylinders applying a slight pressure. The facer is operated hydraulically and rotates at approximately 30 RPM. The surfaces to be fused are simultaneously planed establishing clean and parallel surfaces for fusing. After the two mating surfaces have been sufficiently planed, the alignment of the two surfaces is checked and, if necessary, reface until proper alignment is achieved.

HEATING

After the two mating surfaces have been planed, the facer is manually rotated out of position and is manually replaced by the heating plate. The two surfaces to be fused are hydraulically brought in contact with the heater plate under light pressure (close to zero). After a bead of heated material measuring 3/16- to 1/4-in. thick is formed at the circumference of each HDPE piece, the hydraulic pressure is released and the hot plate is manually removed.

FUSING

After the heater plate is removed, the hydraulic cylinders are actuated bringing the two heated surfaces together under a compressive load. The surfaces are held under sustained hydraulic pressure and allowed to cool for a period of approximately 35 minutes. This ensures a single monolithic bond of fused material.

UNLOADING

The fused pieces are then removed from the machine by releasing the screw jacks securing clamshell clamps. If the fusion is only on the first end cap-to-sleeve, there is no need for any special handling equipment (due to the lightness of the material). However, after completing the second fusion on both the 6-in. and 10-in. MACROs, special handling procedures shall be used to safely remove the completed HAZ-PAKs from the fusion machine. The special handling procedures are needed due to the 200-500 lb of lead that are to be in each MACRO. For the demonstration at IDAHO FALLS a forklift with a sling system will be used to load and unload the HDPE pieces.

SUBSEQUENT FUSING

In the event of subsequent fusing, the same operations are followed to fuse other sections of the HDPE sleeves. To fuse a different diameter, the internal jaw inserts on each clamshell clamp are replaced with jaw inserts conforming to the new diameter. The process of loading, facing, heating, and fusing is then repeated.

SHUTDOWN

Upon completion of the fusing process, the gasoline engine on the No. 412 Fusion Unit will be turned off removing hydraulic pressure to the cylinders and power to the heater plate. This will be followed by cleanup of the area.

3.2.2.2. McElroy No. 1236 Fusion Unit Operations:

SETUP

The unit is positioned in an area free from hazardous vapors, and then secured in place by setting the brake provided on the left rear wheel, and chocking the wheels. The generator unit is then positioned outside of the warehouse, but near the No. 1236 Unit, at a distance that will allow adequate working space around the fusion unit. Consideration should be given, where the placement of the generator is concerned, to route the power cord in a manner to prevent it from being driven over by the forklift and out of the operator's way.

ALIGNMENT/CALIBRATION

During the IDAHO FALLS demonstration the end cap holder/alignment fixture will be positioned in the fusion unit and then secured using the hydraulic clamps. The end cap will be placed on the fixture then centered with the mating piece using the adjusting screws for proper alignment. Upon completion of the loading, the generator unit is started, providing electrical power to operate the hydraulic pump and the heater plate. The hydraulic pressure regulators, used to control the facing pressure, heating pressure, and fusing pressure, are then adjusted accordingly.

LOADING

HDPE sleeves are easily handled with forklifts, synthetic web slings, and spreader bars. After the end cap has been loaded and positioned, a 28-in. diameter x 60-in. section of HDPE sleeve will be loaded into the No. 1236 using a forklift and material handling equipment. The HDPE is then secured in place using the hydraulic clamps. Once the HDPE has been fused to form the

HAZ-PAK, it will be removed from the fusion unit. Using material handling equipment and a forklift, an empty 55 gallon drum will then be loaded into the HAZ-PAK.

FACING

Facing of the two surfaces to be mated is accomplished by hydraulically positioning the facer between the section of HDPE sleeve and the end cap, applying a slight hydraulic pressure to maintain the two surfaces in contact with the facer, and turning on the facer which rotates at approximately 30 RPM. The surfaces to be fused are simultaneously planed establishing a clean and parallel surface for fusing. After the two mating surfaces have been sufficiently planed, the facer is then hydraulically rotated out of position. Alignment of the two surfaces is checked and, if necessary, refaced until proper alignment is achieved.

HEATING

The heater plate takes approximately 30 to 45 minutes to reach proper operating temperature (410-F). When the heater plate has reached operating temperature, it is hydraulically rotated into position. The surfaces to be fused are then hydraulically positioned against the heater plate under light pressure (close to zero). The HDPE pieces are heated until a 3/16- to 1/4-in. wide uniform bead forms around the circumference of the two sections.

FUSING

Upon completion of the heating sequence, the heater plate is hydraulically rotated out of position and the two surfaces are compressed together under sustained hydraulic pressure and allowed to cool for approximately 35 minutes. This ensures a single monolithic bond of fused HDPE material.

SUBSEQUENT FUSING

In the event of subsequent fusings, as in the case of a sleeve to sleeve fuse, during the Pre-Operational Test, the newly fused HDPE can be removed from the No. 1236, as mentioned in "LOADING", and cut using a band saw or hot wire. The process of loading, facing, heating, and fusing is then simply repeated.

SHUTDOWN

Upon completion of the Pre-Operational Demonstration, the No. 1236 Fusion Unit will be shutdown by releasing all hydraulic pressure and turning off the heater plate. The electrical generator may then be turned off and clean-up of the area initiated.

**McELROY NO. 618 HYDRAULIC FUSION UNIT
INSTRUCTION MANUAL**

GENERAL DESCRIPTION OF UNIT

The McElroy 618 Fusion Unit is a self-contained unit designed to butt fuse polyolefin pipe from 6" IPS (6 5/8" OD) minimum to 18" IPS (18" OD) maximum.

Weight is 1200 lbs. Overall dimensions are 46" wide x 51" high x 82" long. With reasonable maintenance and care, this machine will give years of satisfactory service. Although all parts are designed for and protected against the elements, inside storage is preferable. The McElroy shipping and storage container also provides an inventory control of auxiliary parts.

DESCRIPTION OF COMPONENTS

Clamping Unit

While on the wagon, the clamping unit consists of two fixed jaws and two hydraulically operated movable jaws bolted to the frame.

The two hydraulic jaws and the inner fixed jaw are attached together, and can be unbolted from the wagon frame and removed for remote operation. For this we offer optional hydraulic extension hoses.

For hazardous environments the jaw works must be removed from the cart. There must be sufficient hose and cable length for the cart to remain in a safe location.

Wagon

This compact and self-contained fusion system is mounted on a four-wheel wagon for mobility and movement along a pipe line. The front axle has an automotive spindle-type steering, controlled by the tongue. The tongue has a ring on the end to slip over a ball hitch so that the unit may be conveniently maneuvered at the job site. The cart is not designed for over-road towing.

!!! WARNING !!!

TOWING AT SPEEDS GREATER THAN 5 MPH CAN RESULT IN MACHINE DAMAGE AS WELL AS INJURY. ALWAYS TRANSPORT THE MACHINE BY FLATBED TRUCK OR SIMILAR MEANS.

Engine

A 16 HP Kohler "Cast Iron" electric-start, industrial quality, gasoline engine drives the hydraulic pump for fusion force and power of the facer motor, and a 3.0 KW/220V (1) Phase, 60 Hz, alternator to power the heater plate.

Pump

The Oil Gear pressure compensated pump should be set at 1100 PSI and 5.5 GPM.

Oil Reservoir

The reservoir is incorporated in the wagon frame. The oil level should remain visible in the sight gauge in the side of the filler spout. Never allow dirt or other foreign matter to enter the open tank. Use Sunmark 2105 or equivalent. Refer to Hydraulic Fluids Recommendations included with this manual.

Filter

This unit is equipped with a 10 Micron Filter on the suction side of the pump. Replace filter and oil approximately every 500 hours of operation.

Hydraulic Manifold Block

Mounted on this block are (1) carriage control valve, (1) selector valve, (3) pressure valves and (1) 1500 PSI gauge. The carriage control valve is mounted on top with the gauge. The selector valve, mounted on the front, selects a reduced pressure from one of the pressure reducing valves. Each pressure reducing valve is labeled with a different function; top for facing pressure, middle for heating pressure and bottom for fusion pressure.

Lift Roller Control

The control valve is located under the inner fixed jaw. Pull to lift and push to lower the pipe lift cylinder.

Hydraulic Cylinders

The two carriage cylinders and the lift cylinder have air bleed screws and must be bled if the system ever runs low on oil or leaks air on suction side of pump. The bleeding procedure for this unit is listed below:

1. Tilt unit so the fixed jaw end is higher than the opposite end.
2. Shift the directional control and move the carriage to the fixed jaw end. Adjust the pressure to approximately 50-100 PSI before proceeding to step 3.

3. Loosen the bleed plug on one cylinder next to the fixed jaw.
4. Hold pressure on the cylinder until no air is indicated and quickly retighten the plug.
5. Repeat this operation on the opposite cylinder.
6. Tilt the unit so the opposite end is higher than the fixed jaw end. Move the carriage to the end opposite the fixed jaw and repeat the above procedure on that end of the cylinders.

The lift cylinder also has adjustable cushions on each end of stroke to reduce the shock at end of stroke.

Facer

The facer is of the McElroy rotating planer-block design and each face contains (3) cutter blades. The block rotates on sealed ball bearings and is chain driven by a hydraulic motor. The facer is packed with a high temperature grease at assembly. This grease should be good for the life of the unit.

The facer weighs approximately 135 lbs. and is pivoted on a shaft attached to the two movable jaws. It is supported by a facer pivot shaft, guided by the cylinder rods, and will face all sizes of pipe from 4" IPS to 12" IPS. It has a release mechanism on the pivot side for quick and easy removal from the unit and is provided with a lifting ring for handling with hoist (by others) for remote operation.

!!! WARNING !!!

DO NOT LIFT THE FUSION UNIT WITH THIS LIFTING EYE. THE RING IS NOT DESIGNED TO LIFT THE ENTIRE WORKS. ATTEMPTING TO DO SO CAN RESULT IN SEVER MACHINE DAMAGE AS WELL AS INJURY.

Alternator

On an 3.0 YCB-3S or 220V, 1 Phase, 60 Hz belt driven generator, refer to enclosed manufacturer's manual.

!!! CAUTION !!!

THIS ALTERNATOR IS DESIGNED TO SUPPLY POWER TO THE HEATER ONLY. PLUGGING ANY LIGHTS OR APPLIANCES INTO ALTERNATOR WILL CAUSE THE CIRCUIT TO BE BROKEN.

Heater

!!! DANGER !!!

THE HEATER IS NOT EXPLOSION PROOF! FOR OPERATION IN HAZARDOUS ENVIRONMENTS, DISCONNECT THE HEATER FROM THE POWER SOURCE BEFORE ENTERING THE DANGEROUS AREA. FAILURE TO DO SO WILL RESULT IN EXPLOSION AND DEATH.

The heater assembly has cast in place Calrod Units and contains a thermostwitch for temperature control and a dial type thermometer for temperature observation.

There are two heater assemblies: one for 18"-10" IPS pipe (3000 watts), one for 6"-12" IPS pipe (3000 watts). The 6"-12" heater weighs approximately 30 lbs. and the 18"-10" heater weighs 43 lbs. Each heater has two handles for ease of positioning. A scabbard type storage box is available.

!!! WARNING !!!

INCORRECT TEMPERATURE ADJUSTMENT CAN RESULT IN INJURY AS WELL AS MACHINE DAMAGE. FOLLOW THESE INSTRUCTIONS CAREFULLY.

To adjust heater temperature:

1. Disconnect electric plug to avoid electric shock.
2. The heater thermostwitch adjustment shaft protrudes thru the heater handle base. Turn the adjustment shaft clockwise to lower temperature, counter-clockwise to raise temperature. One revolution equals about 100° F.
3. Reconnect electric plug and allow heater to stabilize at new temperature (5 to 10 minutes) after each adjustment.

!!! CAUTION !!!

INCORRECT HEATING TEMPERATURE CAN RESULT IN BAD FUSION JOINTS. CHECK HEATER PLATE PERIODICALLY WITH A TEMPILSTIK OR PYROMETER FOR SURFACE TEMPERATURE, AND MAKE NECESSARY ADJUSTMENTS.

Pipe Support Stands

For fixed fusion installation, install pipe support stands about 20' in front and behind the unit, and adjust to proper height.

When moving the unit from joint to joint, an optional pipe support trailer is available. It is pulled behind the unit, and incorporates a jack to obtain the proper height.

MC ELROY NO. 618 HYDRAULIC FUSION UNIT
INSTRUCTION MANUAL

OPERATING INSTRUCTIONS

!!! WARNING !!!

KEEP CLEAR OF JAW AREA. UNIT OPERATES UNDER PRESSURE AND CAN CRUSH HANDS, ARMS, OR OTHER BODY PARTS. BE AWARE OF YOURSELF AND OTHERS WHEN OPERATING THIS UNIT.

Before starting unit, the following checkout and lubrication should be performed to insure trouble-free operation and optimum life of the unit.

1. Engine Oil Level Dip Stick - Do not screw in for proper reading. (Refer to engine manual for further instructions.)
2. Hydraulic Fluid Level - Check for oil in sight gauge on filler spout and add if necessary. Use Sunmark 2105 or equivalent oil.
3. Fuel - Fill the tank with unleaded gasoline in a nonhazardous area.

!!! DANGER !!!

SPARKS COULD IGNITE GASOLINE, CAUSING EXPLOSION AND DEATH. DO NOT SMOKE OR OPERATE UNIT WHEN FILLING WITH GAS.

4. Grease all zerk fittings one shot each week.

Start-Up Procedure

!!! DANGER !!!

DO NOT OPERATE ENGINE IN A HAZARDOUS ENVIRONMENT. THE ENGINE SHOULD ALWAYS REMAIN IN A SAFE LOCATION. REMOVE FACER AND TOP WORKS AND ATTACH HOSES.

1. Disconnect heater plug and open facer operating valve before starting engine.
2. To start engine, close choke (move lever away from engine), turn switch to "ON", and press starter button.

3. Open choke as engine warms up. Engine speed is governor controlled and has been factory set to obtain 255 no load Volts, or 230 full load Volts from the alternator. DO NOT EXCEED 255 NO LOAD VOLTS.
4. Close facer operating valve.
5. Plug in heater in a NONHAZARDOUS environment. Allow unit to run long enough to bring heater to temperature before attempting to fuse pipe.

Check Hydraulic Pressure

The pressure gauge indicates the pressure at the carriage control valve. How much pressure depends on the position of the selector valve and the pressure set on the (3) pressure reducing valves. With the selector valve up, the facing pressure can be set (80 - 100 PSI). Shift the selector valve to center and the heating pressure can be set. If heating pressure is not required, set the pressure reducing valve at its lowest setting. With the selector valve down, the fusion pressure can be set. The heating and fusion pressures can be calculated using the enclosed nomogram.

The hydraulic pump is set at 1100 PSI from the plant. When facing SDR 11 and thicker wall pipe, it is necessary to increase the pump pressure to 1400-1500 PSI. To increase the pressure, shift the selector valve to the down (fusion) position and screw the bottom pressure reducing valve "IN" as far as it will go. The actual pump pressure should be shown on the pressure gauge at the manifold block.

With the pump running and the system deadheading with no motion occurring, loosen the locknut on the pressure adjusting screw (see pump specification sheet for location) and turn it clockwise to increase the pressure. Watch the pressure gauge on the manifold block and retighten the locknut on the adjusting screw when the desired pressure is reached. Then back off the lower pressure reducing valve to the required fusion pressure.

Butt Fusion Procedure

1. Open upper jaws and insert pipe in each pair of jaws with applicable inserts installed. Let end of pipe protrude about 1½" - 2" past face of jaw.
2. Lower facer into place.
3. With the carriage control valve lever, move the carriage toward the fixed clamps, while watching the gap at each end of the facer rest buttons. When the pipe is in contact with the facer, this gap indicates the amount of material that will be trimmed from the pipe end.
4. Tighten the clamp screw knobs on the outside clamps.

5. Snug down the inside clamp knobs.
6. Turn facer on by opening facer operating valve on top 90°. Be sure selector valve handle is in "UP" position. Move the control valve lever all the way toward the facer. Allow facer to cut until the rest buttons are against the stops on either side of the facer.
7. Turn off the facer motor.
8. Move carriage to the right.
9. Swing facer to storage position.
10. Move carriage to the left until ends of pipe butt together.
11. Check pipe joint for proper alignment. The pipe ends should be flush with each other. To check misalignment between the jaws (hi/lo), use a pencil or similar object between the jaws to look for ridges. If any exist, tighten the high side to align.

!!! WARNING !!!

DO NOT USE FINGERS TO CHECK FOR HI/LO. THE UNIT IS UNDER PRESSURE AND SLIPPAGE COULD RESULT IN CRUSHED FINGERS. ALWAYS STAY CLEAR OF JAW AREA.

If pipe is lined up, proceed with Step 12. If pipe is not lined up, tighten high side clamp to bring into alignment.

12. Move carriage to the right.
13. Check heater temperature. HEATER PLATE SHOULD BE CHECKED PERIODICALLY WITH A TEMPILSTIK OR PYROMETER FOR CORRECT SURFACE TEMPERATURE.
14. Move selector valve handle to bottom position.
15. Insert heater on rods between pipe ends.

!!! DANGER !!!

THE HEATER IS NOT EXPLOSION PROOF! FOR OPERATION IN HAZARDOUS ENVIRONMENTS, DISCONNECT THE HEATER FROM THE POWER SOURCE BEFORE ENTERING THE DANGEROUS AREA. FAILURE TO DO SO WILL RESULT IN EXPLOSION AND DEATH.

16. Move the carriage to the left, bringing the heater into contact with both pipe ends.
17. Move selector valve to center position. If heating pressure is not required, quickly return carriage control valve to neutral position.
18. After following the pipe manufacturer's suggested heating procedure, shift carriage control valve to neutral position and then the selector valve down to fusion position.
19. Move the carriage to the right just enough to remove the heater. Remove the heater.
20. Quickly move the carriage to the left, bringing the pipe ends together under the pipe manufacturer's recommended pressure. Allow joint to cool under pressure according to pipe manufacturer's recommendations. If working in a hazardous environment, plug the heater into power source outside of hazardous environment between joints to maintain operating temperature.

!!! CAUTION !!!

FAILURE TO FOLLOW PIPE MANUFACTURER'S HEATING AND COOLING PRESSURE, TEMPERATURE, AND TIME RECOMMENDATIONS, CAN RESULT IN BAD JOINTS.

21. Shift the carriage control valve to the neutral position.
22. Loosen clamp screws on movable jaws and move carriage to the right enough to open the jaw to the left of the facer.
23. Loosen clamp screws on fixed jaws and open jaws.
24. Raise pipe with hydraulic lift.
25. Move unit to end of pipe or pull pipe to rear through the jaws until the end of the pipe is protruding $1\frac{1}{2}$ " - 2" past the jaw face.
26. Insert new joint of pipe in movable jaws and repeat procedure, starting with Step 1.

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APPENDIX C

PHOTOGRAPHS

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Photo C-1. Water Spray Test.
(40-TU-03)



Photo C-2. Penetration Bar Drop.
(40-TU-03, 1-m [3.3-ft])

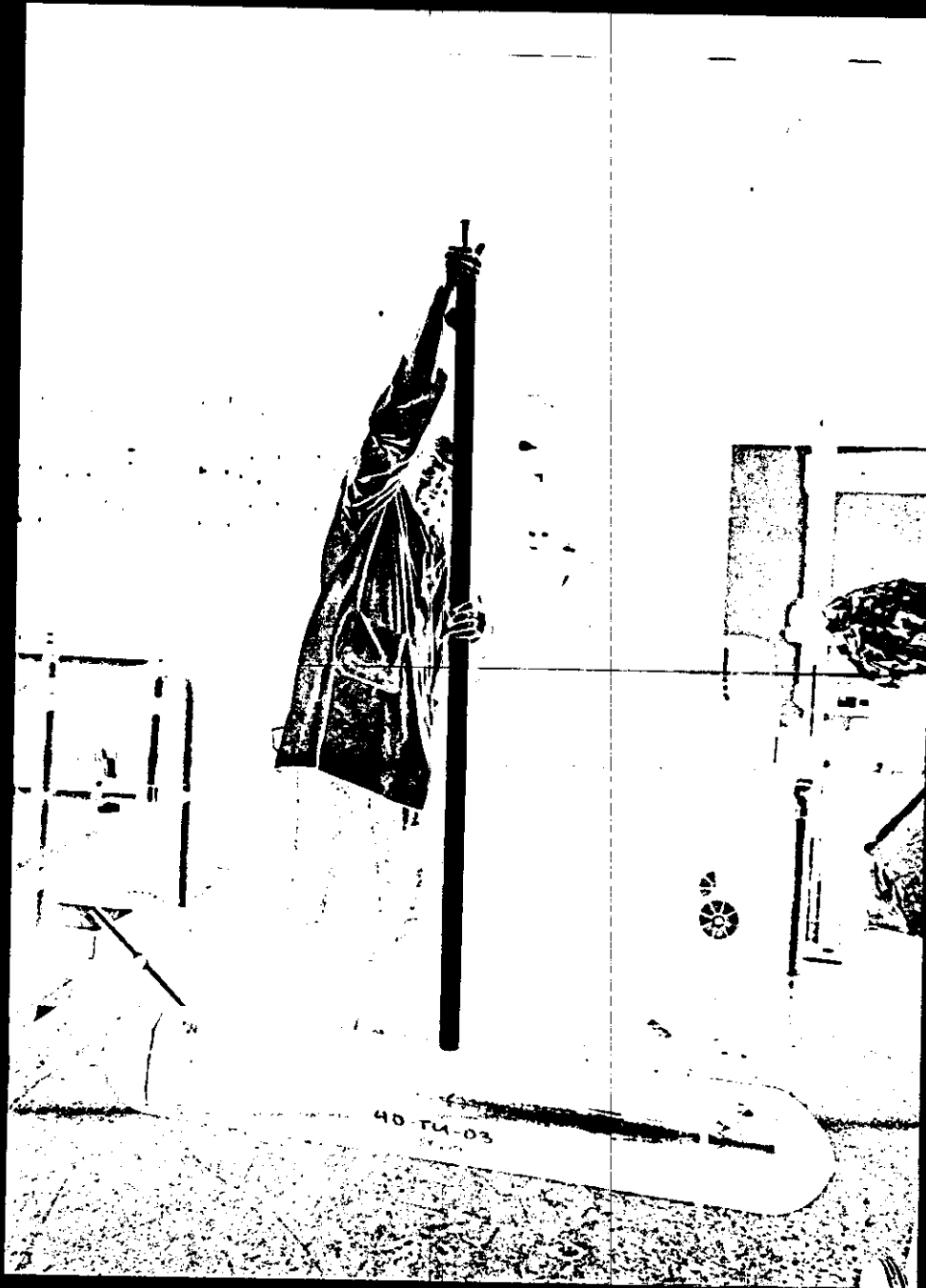


Photo C-3. Compression Test.
(40-TU-03, 2920.0-kg [6437.5-lb])



Photo C-4. Compression Test.
(40-TU-03)

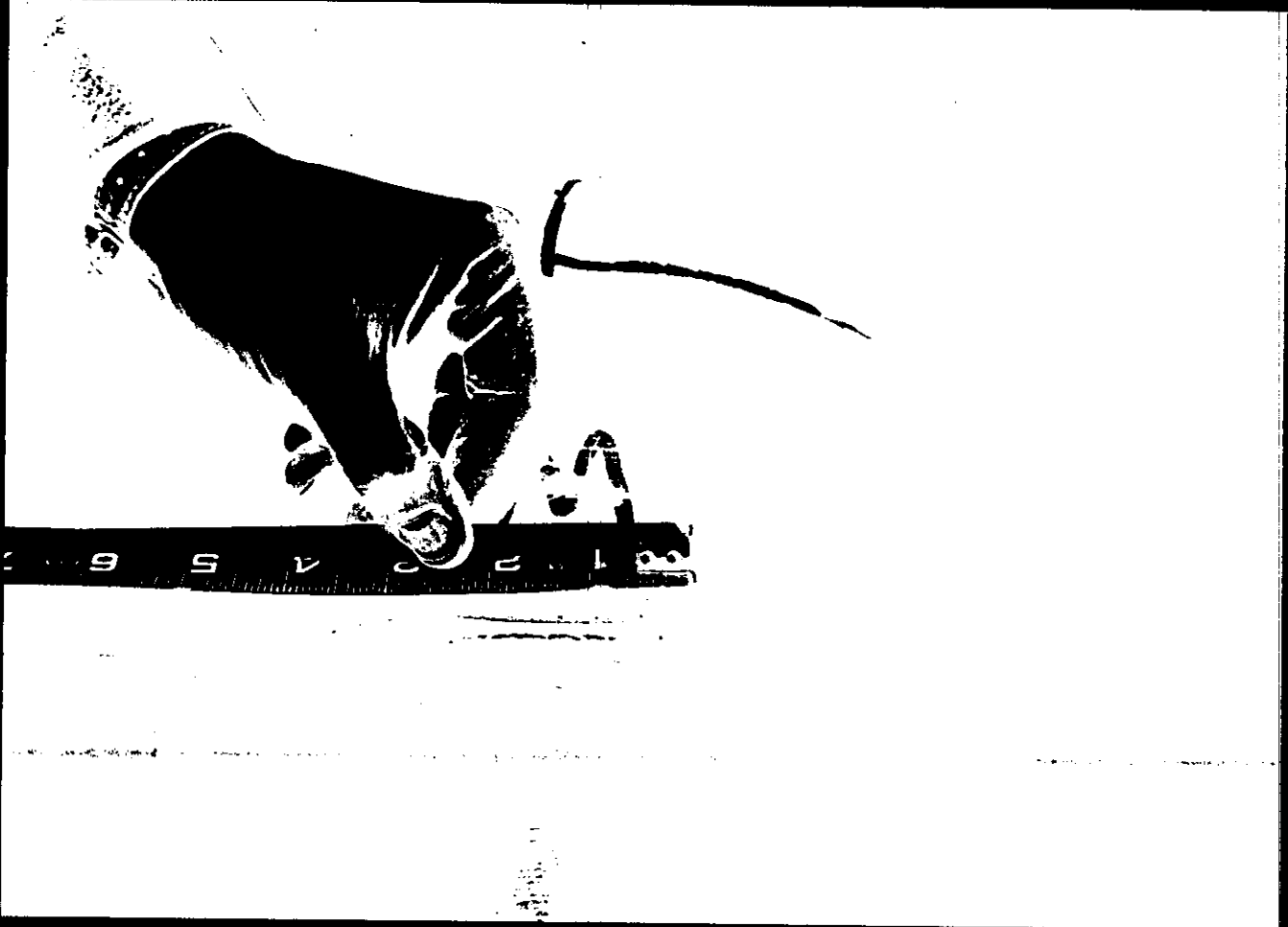


Photo C-5. Vibration Test.
(40-TU-01)

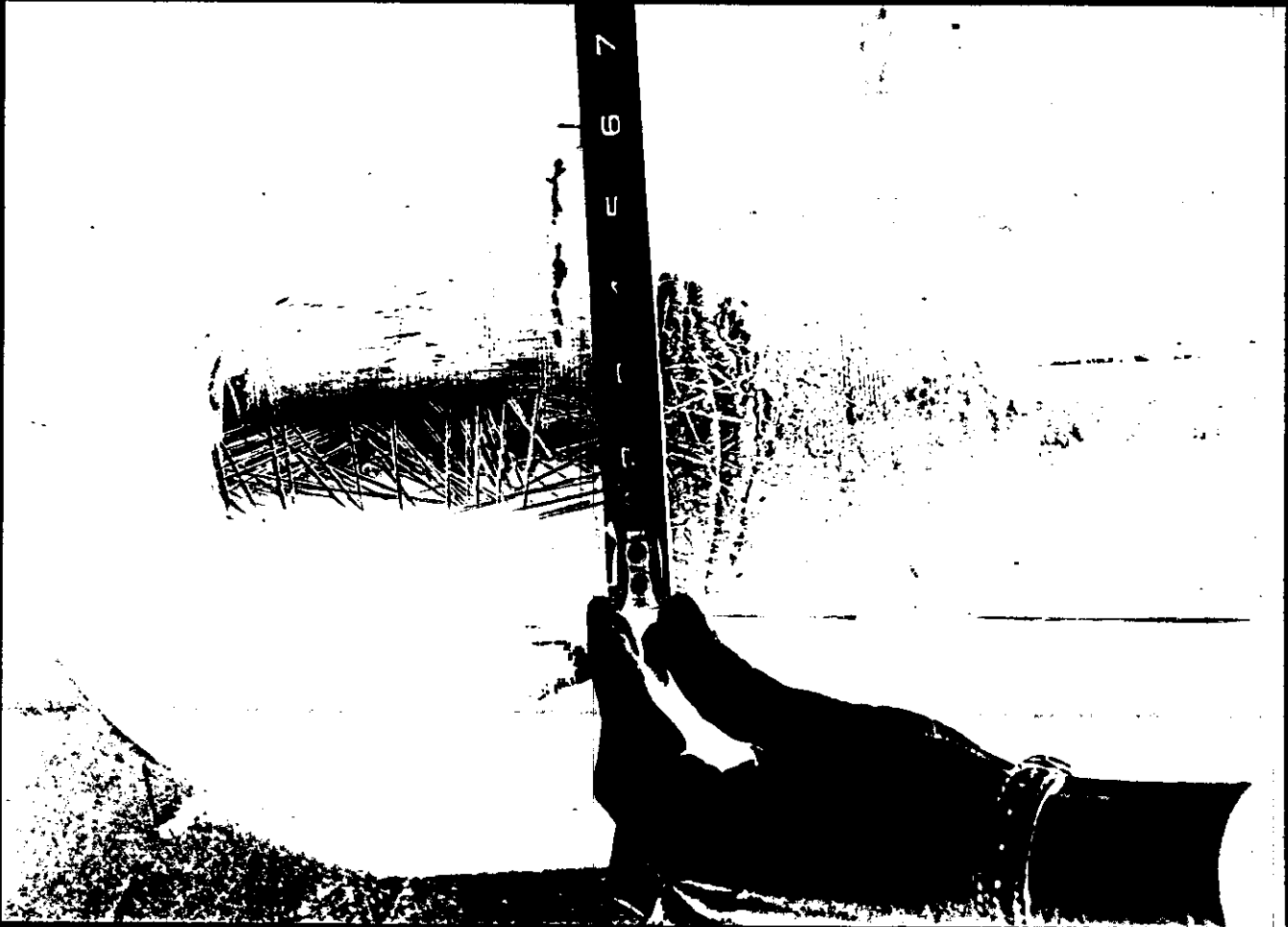


Photo C-5 Vibration Test.
(40-TU-02)



Photo C-7. 1.2-m (4-ft) Drop Test.
(40-TU-02, CG onto Corner of End Cap with Plugs)

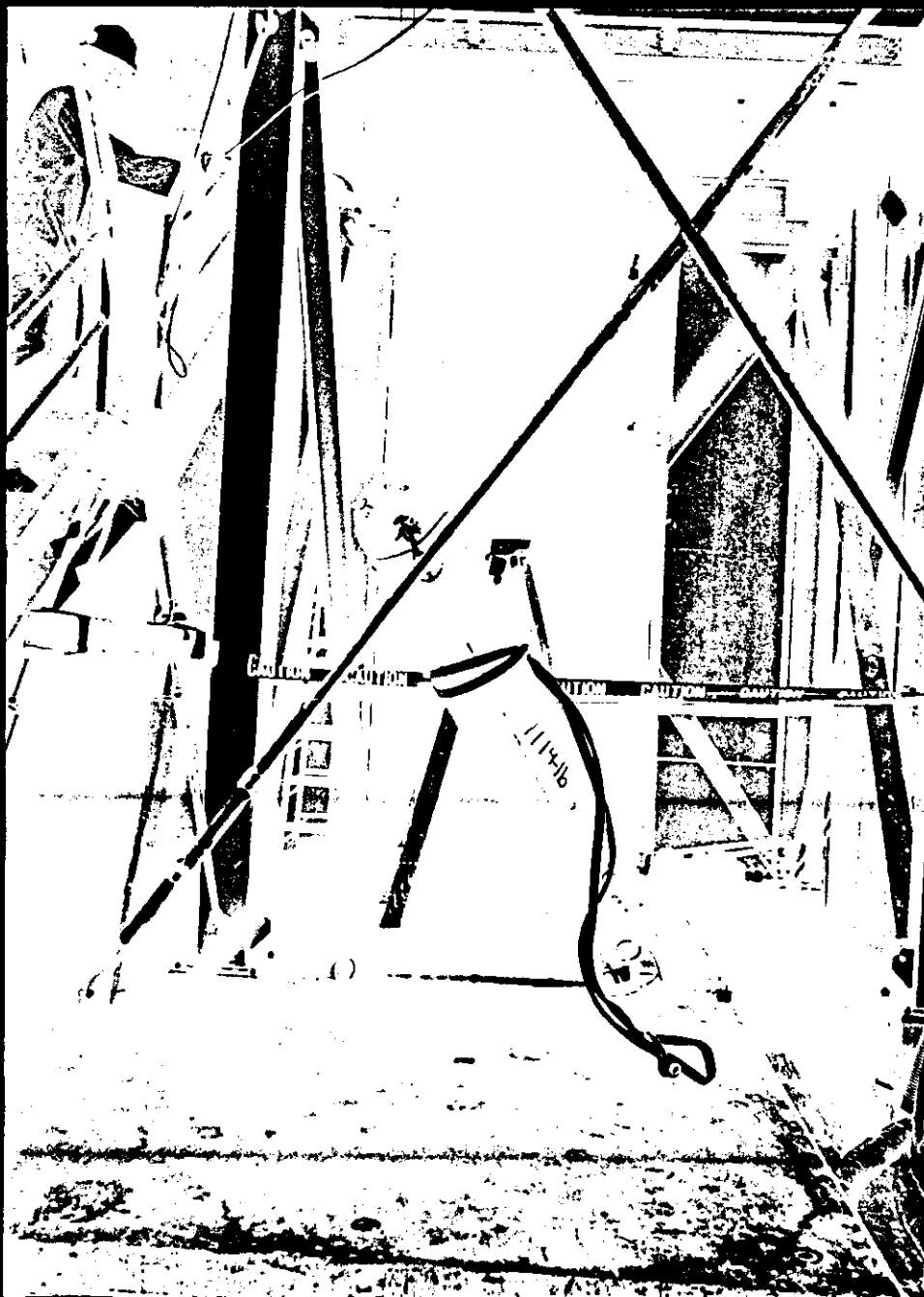


Photo C-8. 1 2-m (4-ft) Drop Test.
(40-TU-02, CG onto Corner of End Cap with Plugs)



Photo C-9. 1.2-m (4-ft) Drop Test.
(40-TU-01, Flat onto End Cap with Plugs)

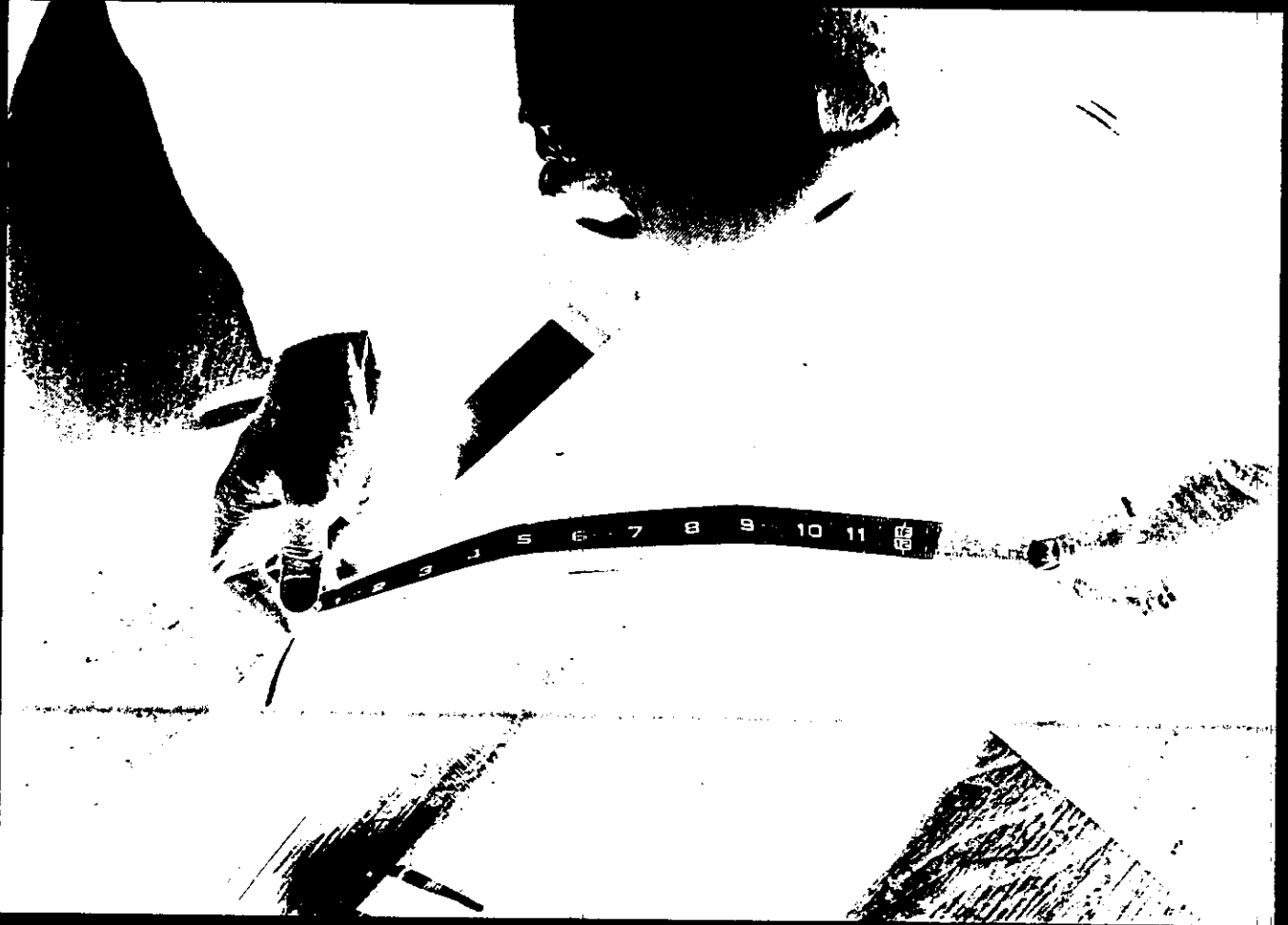


Photo C-10. 1 2-m (4-ft) Drop Test.
(40-TU-01, Flat onto End Cap with Plugs)



Photo C-11. 1.2-m (4-ft) Drop Test.
(40-TU-02, Flat onto Horizontal Side)



Photo C-12. 1.2-m (4-ft) Drop Test.
(40-TU-02, Flat onto Horizontal Side)

