CONSOLIDATED LICENSE APPLICATION

FOR

FRAMATOME ANP, INC.

MODEL 51032-1 SHIPPING CONTAINER

Certificate of Compliance No. 6581
Docket No. 71-6581

Prepared by

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Framatome ANP, Inc.

Consolidated License Application for Framatome ANP, Inc.
Model 51032-1 Shipping Container

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Nature of Changes

Item	Paragraph or Page(s)	Description and Justification
1.	Throughout	Siemens, Siemens Power Corporation and SPC changed to Framatome ANP and FANP, respectively. <u>Justification</u>: New company name.
2.	iv	Added Appendix VIII, Nuclear Criticality Safety Analysis, Model 51032-1 Shipping Container Supplemental Evaluation (L1, L2, and L4 Assembly Designs). <u>Justification</u>: This analysis was necessary to support the shipment of these four new fuel types (L1, L2, and L4) from the Richland site scheduled to begin in June 2003.
3.	2.1	Changed the tare weight of the packaging from 4000 ± 100 pounds to 4050 ± 150 to reflect the addition of ten former 51032-2 packagings to the 51032-1 fleet. <u>Justification</u>: The former 51032-2 packagings (docket no. 71-9252) weigh approximately 100 pounds more than the original 51032-1 packagings. The packagings are basically identical, the only difference being the separator blocks (the former 51032-2 packagings have an additional steel plate) and the size of the bolts and studs used to attach the separator blocks to the strongback (5/8" for the original 51032-1 packagings and 1" for the former 51032-2 packagings). These differences result in the approximately 100 pound difference in the tare weights. (See drawing EMF-309,813 R/2 Sheet 2, Option 2 for the 51032-2 design.) The fuel assembly restraining components for the strongback are identical for the two options (i.e. option 1 – original 510321-1 design and option 2 – 51032-2 design). This increase to the allowed tare weight of the packaging will not cause any significant reduction in safety margin.
4.	2.3	Grammatically corrected paragraphs one and two.

5.	3.1.26, 3.3.3, 6, & 10.1.4.1	Changed the maximum gross package weight from 7400 pounds to 7500 pounds. Justification: This change reflects the 100 pound tare weight increase described in Item 3 above. The Certificate of Compliance for the 51032-2 package allowed a maximum gross weight of 7500 pounds. The gross weight of the 51032-1 package used for the most severe 30-foot drop test (horizontal) was 7486 pounds (see Appendix IV, page IV-15). The maximum weight of the allowed contents will remain unchanged at 3400 pounds and the weight of the fuel assemblies or fuel rods and containers will not exceed the 1653 pound simulated assemblies used in the drop tests. Consequently, the structural calculations presented in this application and its appendices still hold true. Increasing the allowable maximum gross package weight by 100 pounds (14 pounds more than the drop tested weight) will not cause any significant reduction in safety margins.
6.	4.1	Changed EMF-1, "Quality Assurance Manual" to NFQM, U.S. Version, "Nuclear Fuel Business Group Quality Management Manual" to reflect new approved integrated quality manual.
7.	5 & 11.2	Changed Zircaloy and zircaloy to zirconium alloy. Justification: FANP uses a variety of approved zirconium cladding alloys, not just Zircaloy-2 or Zircaloy-4. This change will not cause any significant reduction in safety margins.
8.	6	Corrected reference to 10 CFR 71.71(a).
9.	9.9	Changed formula to 5 x 7500 = 37,500 pounds to reflect new maximum gross weight. Justification: The change is minimal and will not cause any significant reduction in safety margins.
10.	10.4	Changed "gross weight of 7400 pounds" to "gross weight ranging from 7406 – 7486 pounds". Justification: The change reflects the actual 30-foot drop test weights in Appendix IV.
11.	10.4	Changed "Fissile Class I, II, and III packages" to "fissile material packages". Justification: The Class I, II, and III are no longer used in the regulations.

12.	11.1	Added fourth paragraph to reference new Appendix VIII. Justification: As part of this submittal, this criticality analysis is required to support four new fuel types in this packaging.
13.	Table 11.1	Removed last row in the table that referenced the Fissile Class. Justification: Fissile Classes are no longer used in the regulations.
14.	12	Added Reference 4 for the 51032-2 certificate application. Justification: The ten former 51032-2 packagings are now incorporated into the 51032-1 certificate. The 51032-2 certificate was used to justify increasing the maximum gross weight of the 51032-1 package to 7500 pounds.
15.	Distribution	Updated Distribution

Contents

Appendices

Figures

Tables

1 Introduction

This application revision is for renewal of Certificate of Compliance No. 6581 for shipping container Model 51032-1. It is a stand alone, consolidated document which replaces all past applications and revisions. The major changes from previous applications are:

- The company name has been updated throughout.
- The maximum gross package weight changed from 7400 pounds to 7500 pounds.
- Appendix VIII has been added to demonstrate the safe use of the container for three new fuel types (L1, L2, and L4).

2 Package Description

As specified in 10 CFR 71.33, the Model 51032-1 shipping container and its contents are described herein. For ready reference, a listing of the safety and licensing related drawings is provided in Table 2.1.

The Model 51032-1 container is very similar to several containers which have been tested, licensed, and previously used (ref. JN-52, October 1971). These similar containers are listed below:

- Model UNC-2800, License No. SNM-777, Special Permit No. 5419 (see Ref. 1)
- Model 927A, 927B, 927C, License No. SNM-1067, Special Permit No. 6078 (see Refs. 2 and 3)

The design of the Model 51032-1 container is based on the Model 927C container. Throughout the application the Model 51032-1 container is compared to the Models UNC-2800, 927A, 927B, and 927C to demonstrate compliance with 10CFR71 requirements. Where necessary, additional engineering evaluations, including drop test data, are provided.

2.1 Model 51032-1 Container

The empty weight of the Model 51032-1 packaging is 4050 ± 150 pounds. Specific materials of construction, weights, dimensions, and fabrication methods of the packaging components are described below.

2.1.1 Container Description

The containment vessel, including stiffening rings, is a 43-inch diameter (nominal dimension) right cylinder 216 inches long, fabricated of 11-gauge (0.1196 inch) steel (see Figures 2.1 and 2.11). The containment vessel is fabricated in two sections: base and cover assemblies (see Figures 2.3 and 2.4). Continuous closure flanges are welded to the base and cover assemblies, and an "0" ring gasket is fitted between the mating flanges. Using 10 steel alignment pins permanently fixed to the closure flange of the base assembly, the two halves of the containment vessel are mated and sealed together with 58 closure bolts. Steel washers are inserted between the mating flanges to prevent excessive distortion of the "0" ring gasket as nuts are tightly seated complete the closure.

Seven steel stiffening rings (five rollover angles and two end rings) are welded to each of the base and cover assemblies to strengthen the containment vessel shell. Rollover rings are fabricated of 2½ x 2½ x 5/16 inch angles, and end rings are fabricated of 3½ x 2½ x 3/8 inch angles.

Four steel skids are welded to the base assembly. These skids support the package and are designed to permit bolting the stacking brackets when packages are stacked for storage or transport. Stacked packages, however, are not normally bolted together during transport.

Four sets (two per set) of stacking brackets are welded to the cover assembly.

Welded to each set of stacking brackets is a steel lifting lug. These lugs may be used to support the loaded package. Use has been shown not to generate stress in any material of the packaging in excess of its yield strength with a minimum safety factor of 3.4.

Two forklift pickup channels are welded to the base assembly to facilitate package handling.

Fourteen (seven per side) shock-mount support brackets are welded to the interior side of the base assembly shell. The weight of the fuel elements and the related support mechanism is transferred to these brackets through up to 14 shock mounts. (The actual number of shock mounts included in each package is dependent upon the weight of the fuel elements being transported.)

The minimum number of shock mounts as a function of the total package content weight is given in Section 2.1.2.

The shock-mounted strongback supports and protects the fuel elements. The standard strongback (see Figure 2.5) is designed to securely hold two long (or four short, see Figure 2.6) fuel elements in place with a minimum spacing of six inches between the two fuel element cavities formed by the strongback components. The main strongback member is a single "U"-shaped channel formed of ¼-inch steel. The standard strongback channel is about 196 inches long, 25-3/8 inches wide, and 12½ inches high.

Side and bottom steel angle supports are welded to the exterior of the strongback channel in seven locations on the standard strongbacks and five on the short strongbacks to provide rigidity and additional strength.

Separator blocks are bolted to the strongback channel such that the centerline of the spacer blocks corresponds to the centerline of the strongback channel. The number of blocks used in each package is dependent upon the weight of the fuel element to be transported. The minimum number required as a function of fuel element weight in pounds is specified in Section 2.1.2.

Fourteen steel angles are welded to the exterior sides (seven per side) of the strongback channel. During shipping, these angles secure the strongback to support tubes by a steel bolt, nut, and lock washer system (one each per lock-down angle).

Seven strongback support tubes provide support and hold the strongback assembly in place during shipping and storage. The support tubes are attached to the interior of the containment vessel through shock mounts (two per support tube), to the shock mount support brackets. The shock mounts minimize vibrational effects on the fuel elements during transport and handling. In the event of a fire severe enough to destroy the natural rubber portion of the shock mounts, the fuel elements remain in essentially the same position within the package as the result of the steel bolts, washers, and nuts incorporated into the shock mount assemblies (see Figure 2.7).

Steel end thrust brackets (see Figure 2.8) are bolted to the strongback at both ends of the fuel elements to prevent longitudinal movement. When shipping four fuel elements, a steel center thrust bracket (see Figure 2.6) is bolted into the strongback between fuel elements in each cavity. A handle is attached to the center thrust bracket to facilitate its removal from the strongback during unpacking operations.

There are no materials specifically used as non-fissile neutron absorbers or moderators in this packaging.

2.1.2 Fuel Element Clamps, Shock Mounts, and Separator Blocks

Fuel elements are clamped in-place within the strongback and restrained from lateral or vertical movement (see Figure 2.6). These clamping devices hold the fuel elements against the bottom and sides of the strongback channel such that the maximum fuel element separation distance is achieved. The adjustable clamps are mounted on steel angle brackets that extend laterally across the top of the strongback channel. These brackets are clamped to the top of the strongback channel. There are two types of clamps: one designed to clamp on the spacers of PWR fuel elements (see Figure 2.7), and the other designed to clamp between the spacers of BWR fuel elements (see Figure 2.9). BWR fuel element clamps are either steel or aluminum.

Fuel elements may not contain polyethylene shims between adjacent rows of fuel rods within the fuel elements.

When transporting fuel elements weighing in excess of 800 pounds, restraint bars are included in the package. Restraint bars consist of steel angle brackets that extend across the top of the strongback channel and are clamped to the strongback flanges in the same manner as are the full clamps. The restraint bars are provided for additional restraint in the event of an accident.

Strongback components required for each package vary with the size and weight of the fuel elements shipped. The limiting criteria are as follows:

1. The weight of the strongback and contained fuel per shock mount shall not exceed that of the drop tested package.
2. Full clamp assemblies used to retain fuel elements within the strongback shall not fail at forces required for failure of the shock mounts.
3. The weight of contained fuel per separator block shall not exceed that of the drop tested and analyzed package.

Equations for calculating the required number of shock mounts, full clamp assemblies, and separator blocks were derived from drop test results and component tests which assure compliance with the above noted criteria. The relationships and their bases are discussed in Section 10.1.2, and the number of various components calculated to be required for various package content weights are given in Tables 2.2 through 2.5.

The number of restraining bars employed for transporting fuel elements weighing in excess of 800 pounds shall be one fewer than the number of full clamps (i.e., N_c-1). In addition, half clamps are normally applied at the end of each fuel element but are not taken into account in this calculation. These half clamps provide some degree of conservatism. When four short fuel elements are transported in one container, W shall be the combined weight of the two fuel elements.

2.2 Containment Vessel Penetrations

There are no sampling ports or tie-down devices.

There are two valves on the containment vessel: one allows pressurization (with dry air or nitrogen) of the containment vessel, and the other is used for relieving the pressure prior to opening the vessel. As such, both valves are located in one end of the containment vessel.

These valves are not of safety significance. The containment vessel is not normally pressurized except for leak testing on an annual basis.

There are no structural or mechanical means provided or required for the transfer or dissipation of heat and there are no coolants utilized in the packages. (Decay heat for the unirradiated fuels to be transported is negligible, <20W).

2.3 Package Contents

Each fuel element is enclosed in an unsealed polyethylene sheath, the ends of which are neither taped nor folded in any manner that would prevent the flow of liquids into or out of the ends of sheathed fuel elements.

The maximum contents weight for the Model 51032-1 package is 3400 pounds.

Fuel assembly parameters are given in Section 11.

TABLE 2.1
SUMMARY LISTING OF APPLICABLE LICENSING DRAWINGS

Reference Figure No.	Drawing No. with Description
2.1	Fuel Packaging Model No. 51032-1 Isometric
2.2	EMF-309,813, Sheet 1, Rev. 2 – Shipping Container Model 51032-1 Assembly
2.2A	EMF-309,813, Sheet 2, Rev. 2 - Shipping Container Model 51032-1 Assembly
2.3	EMF-303,359, Rev. 7 – Base Assembly Model No. 51032-1 Shipping Container
2.4	EMF-303,360, Rev. 6 – Cover Assembly Model No. 51032-1 Shipping Container
2.5	EMF-303,898, Rev. 5 – Strongback Assembly Detail 51032-1 Shipping Container
2.6	EMF-300,607, Rev. 3 – Fuel Packaging Model No. 51032-1 Isometric
2.7	EMF-309,582, Rev. 0 – Typical PWR Container Shim Arrangement

TABLE 2.2
MODEL 51032-1 PACKAGE
SEPARATOR BLOCK REQUIREMENTS

Fuel Element[1] Weight (lbs.)	Required Number of Separator Blocks (minimum)
1650 ≥ W ≥ 1501	9
1500 ≥ W ≥ 1313	8
1312 ≥ W ≥ 1126	7
1125 ≥ W > 938	6
937 ≥ W	5

1 **When two fuel elements are shipped in the container, W is the weight of each. If four fuel elements are shipped, W is the combined weight of two fuel elements.**

TABLE 2.3
MODEL 51032-1 PACKAGE
SHOCK MOUNT REQUIREMENTS

Fuel Element[a] Weight (lbs.)	Required Number of Shock Mounts (minimum)
$1650 \geq W \geq 1329$	14
$1328 \geq W \geq 1008$	12
$1007 \geq W \geq 686$	10
$685 \geq W \geq 365$	8
$364 \geq W$	6

[a] **When two fuel elements are shipped in the container, W is the weight of each. If four fuel elements are shipped, W is the combined weight of two fuel elements.**

**TABLE 2.4
MODEL 51032-1 PACKAGE
PWR (STEEL) FUEL ELEMENT
CLAMP ASSEMBLY REQUIREMENTS**

Number of Shock Mounts	Required Number of Full Clamp Assemblies (minimum)	Fuel Element[a] Weight (lbs.)
14	9	1650 ≥ W ≥ 967
14	8	966 ≥ W ≥ 632
14	7	631 ≥ W ≥ 432
14	6	431 ≥ W
12	8	1328 ≥ W ≥ 1047
12	7	1046 ≥ W ≥ 632
12	6	631 ≥ W ≥ 406
12	5	405 ≥ W ≥ 265
12	4	264 ≥ W
10	6	1007 ≥ W ≥ 632
10	5	631 ≥ W ≥ 373
10	4	372 ≥ W ≥ 222
10	3	221 ≥ W
8	5	685 ≥ W ≥ 632
8	4	631 ≥ W ≥ 328
8	3	327 ≥ W
6	3	364 ≥ W ≥ 265
6	2	264 ≥ W

[a] When two fuel elements are shipped in the container, W is the weight of each. If four short fuel elements are shipped, W is the combined weight of two fuel elements.

**TABLE 2.5
MODEL 51032-1 PACKAGE
BWR (ALUMINUM) FUEL ELEMENT
CLAMP ASSEMBLY REQUIREMENTS**

Number of Shock Mounts	Required Number of Full Clamp Assemblies (minimum)	Fuel Element[a] Weight (lbs.)
14	10	887 ≥ W ≥ 640
14	9	639 ≥ W ≥ 474
14	8	473 ≥ W ≥ 356
14	7	355 ≥ W ≥ 267
14	6	266 ≥ W ≥
12	10	1363 ≥ W ≥ 1066
12	9	1065 ≥ W ≥ 711
12	8	710 ≥ W ≥ 498
12	7	497 ≥ W ≥ 356
12	6	355 ≥ W ≥ 254
12	5	253 ≥ W
10	8	1077 ≥ W ≥ 829
10	7	828 ≥ W ≥ 533
10	6	532 ≥ W ≥ 356
10	5	355 ≥ W ≥ 237
10	4	236 ≥ W
8	6	790 ≥ W ≥ 592
8	5	591 ≥ W ≥ 356
8	4	355 ≥ W ≥ 214
8	3	213 ≥ W
6	4	504 ≥ W ≥ 356
6	3	355 ≥ W

[a] **When two fuel elements are shipped in the container, W is the weight of each. If four short fuel elements are shipped, W is the combined weight of two fuel elements.**

FIGURE 2.1 EMF-309,813, Sheet 1, Rev. 2 - Shipping Container
M51032-1 Assembly

FIGURE WITHHELD UNDER 10 CFR 2.390

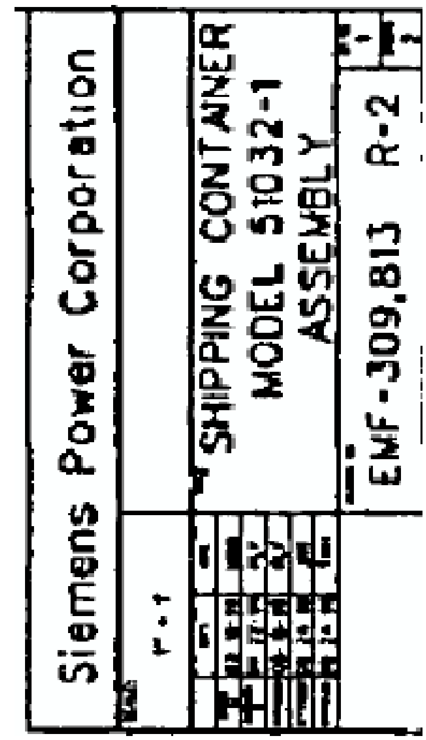

FIGURE 2.1 (cont.) EMF-309,813, Sheet 2, Rev. 2 - Shipping Container'M51032-1 Assembly

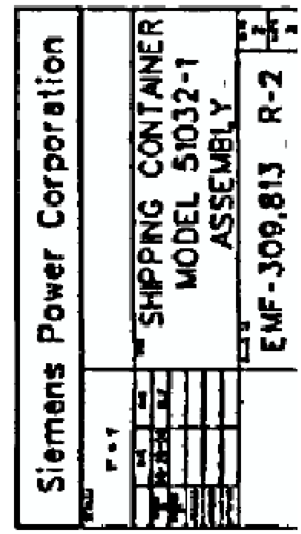

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 2.2 EMF-303,359, Rev. 7 - Base Assembly Model No. 51032
1 Shipping Container

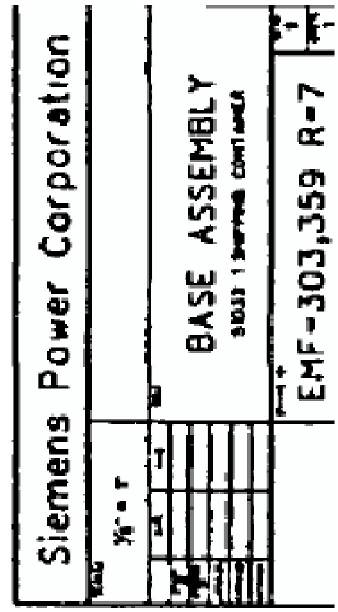

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 2.3 EMF-303,360, Rev. 6- Cover Assembly Model No. 51032-1 Shipping Container

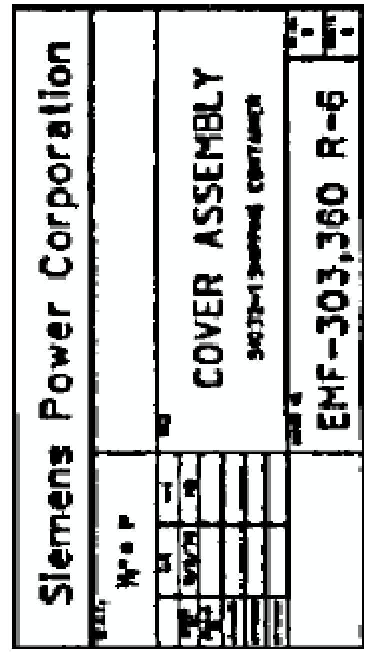

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 2.4 EMF-303,898, Rev. 5 - Strongback Assembly Detail 51032-1 Shipping Container

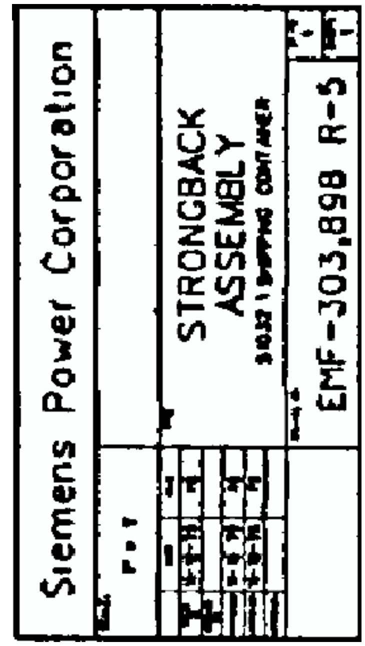

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 2.5 EMF-303,607, Rev. 3- Fuel Packaging Model No. 51032-1 Isometric

FIGURE WITHHELD UNDER 10 CFR 2.390

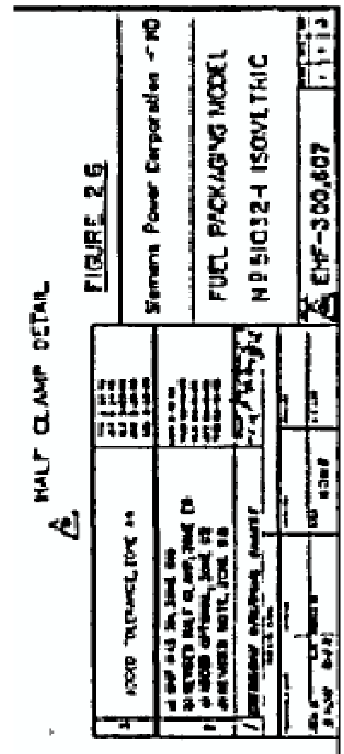

FIGURE 2.6 EMF-309,582, Rev. **0** - Typical PWR Container Shim Arrangement

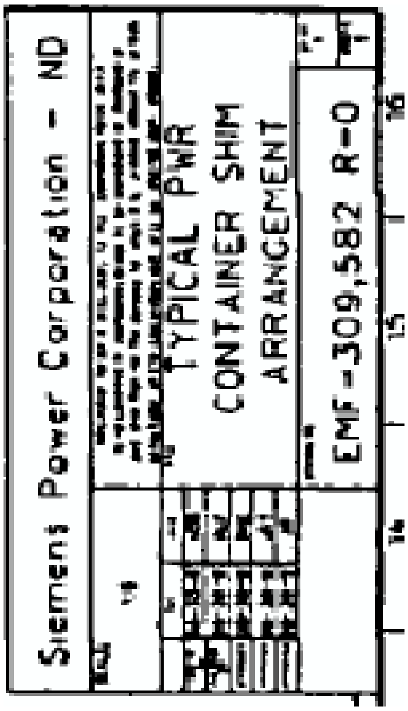

FIGURE WITHHELD UNDER 10 CFR 2.390

3 Package Handling

Controls and precautions to be exercised during transport, loading, unloading, and handling of the shipment, and in the event of an accident or a delay, are described herein.

Nuclear safety hazards to personnel (radiation, contamination, criticality) are minimal during these operations. The hazards more likely to result in injury to personnel are those associated with the physical handling of the heavy fuel elements and container components. Appropriate material handling equipment must be used; and caution is imperative to avoid pinch points or being struck, and to avoid damage to the fuel elements.

3.1 Package Loading

The procedure to be used to load fuel elements into the Model 51032-1 shipping container calls for lifting the strongback to the vertical position by pivoting the strongback lower end, placing the fuel elements into the strongback, and clamping the fuel elements at the upper and lower tie plates with half clamps while in the vertical position, and then lowering the strongback with fuel elements in the container and securing for shipment. A typical procedure follows:

1. Unbolt all closure bolts on the container and remove cover assembly.
2. Install the trunnion pivot pin and spacers.
3. Remove the upper thrust plate.
4. Remove the full clamps and restraint bars.
5. Remove the half clamps.
6. Inspect strongback for proper separator block spacing and thickness of support pads as required by the container arrangement drawing.
7. Free the strongback from the container by removing the hex nut and washer that secure the strongback to the shock mounts bolts.
8. Attach a crane hook to the U-bolt on the upper end of the strongback. Elevate the strongback until it is in the vertical position.
9. Install the two telescopic, strut-type stabilizer braces to the strongback, making sure these braces are adequately secured, ball lock pins in place.
10. Install lower fuel element support plates on the thrust plate (if required).
11. Introduce the first fuel element (hanging vertically) into the strongback.
12. Install the half clamps at the top and bottom of the fuel element.
13. Introduce the second fuel element into the strongback and secure in place with half clamps, along with the first element. If four elements are to be shipped, install the center thrust plate in the strongback, bolt securely in place. Install the third and fourth fuel elements and support them with half clamps at the top and bottom of the fuel element.
14. Support the strongback with a crane, remove the ball lock pins from stabilizer braces.
15. Remove telescopic, strut-type stabilizer braces and lower strongback with fuel elements into a horizontal position in the container.

16. Install the upper thrust plate. Install all full clamps and restraint bars. In some cases, the half clamps may be replaced by full clamps.
17. Remove the trunnion pivot pin and spacers.
18. Bolt the strongback to the shock mount supports.
19. Install accelerometers in the shipping container, as necessary.
20. Inspect the inside of the container to assure that there are no loose articles within the container.
21. Place the cover on the base assembly of the shipping container using the 10 alignment pins on the base assembly flange to guide the cover assembly.
22. Secure the base and cover assemblies by tightening all 58 closure bolts.
23. Install a Type E security seal, as described in Regulatory Guide 5.15, at each end of the container.
24. Inspect the container for proper labeling necessary to meet Federal regulations.
25. Take required radiation readings.
26. Load packages onto or into the transport vehicle using either forklifts or an overhead crane with cables or chains attached to the four lifting lugs on the cover assembly. (A loaded container may weigh up to 7500 pounds.)
27. Stack packages two high (no higher), and secure them to the transport vehicle as shown in. Do not bolt packages together.
28. Record all data on a Shipping Record Sheet.

3.2 Transport Controls

Typical instructions given to drivers are described in the following paragraphs:

1. Drivers take custody of the shipment by signing a hand-to-hand receipt.
2. The unirradiated fuel elements involved with this shipment present no radiation hazards and require no special shielding. Radiation detection instruments and film badges will not be required during the transportation of this material.
3. Weigh the trucks at the nearest State of Washington scales. If an overweight condition is found, return to Framatome ANP, Inc. (FANP) to shift to the load.
4. Posted maximum speed limits must not be exceeded. Due to the extremely high value per load, drivers are cautioned to exercise the utmost care in the transportation of this material, and to operate transport units in a manner that will provide the least amount of shock and vibration to the lading.
5. Stop at all railroad crossings and proceed with caution.
6. Check all tires and tie-downs after first 50 miles and then at least every 4-6 hours, indicate on driver's log.
7. Report to Company dispatcher at least every 6 hours during the trip.

8. Promptly notify the dispatcher on duty in the event of a breakdown. **In the event of an accident or other emergency, notify the following promptly:**[2]

Carrier Dispatch	Telephone Number
Person's Name (Carrier)	Telephone Number
FANP Employees (2)	Telephone Number
FANP Security	Telephone Number

9. In case of a significant accident, also notify the United States Department of Energy Regional Coordinating Office in the area shown in. When notifying this agency, they should be advised that the shipment is unirradiated nuclear reactor fuel elements of not more than 5 percent enrichment. Also inform them of the extent of damage as it pertains to the shipping containers. An MSDS for UO_2 is included with driver's package.

10. Contact Carrier Dispatch or Person's Name (Carrier) if there are any questions regarding this move[1].

3.3 Unloading

The special controls and precautions to be exercised during unloading are detailed below:

1. Inspect the containers for any damage before unloading from the vehicle.
2. Notify FANP promptly of any damage and await FANP instructions for unloading.
3. If the containers are not damaged, remove them from the transport vehicle using a forklift or crane with adequate capacity. (The loaded containers may weigh up to 7500 pounds each.)
4. Place the containers in the unloading area and await approval by FANP before opening the containers.
5. After receiving approval from FANP to open the containers, remove the security seals record the numbers of the security seals on the Radioactive Material Receiving Inspection Record form.
6. Remove the 58 closure bolts securing the base and cover assemblies of the container.
7. Remove the container cover assembly.
8. Install the trunnion pivot pin and spacers.
9. Remove all clamps except half clamps.
10. Free the strongback from the container by removing the hex nut and washer that secure the strongback to the shock mount bolts.
11. Using an overhead crane, attach a crane hook to the U-bolt on the upper end of the strongback. Elevate the strongback and install the two telescopic, strut-type stabilizer braces to the strongback, making sure these braces are adequately secured with ball lock pins.
12. Elevate the strongback to the vertical position.

[2] The names and telephone numbers will be provided in the driver's instructions for each trip.

13. Using an overhead crane, secure one fuel element and remove the top and bottom half clamps. Remove the fuel element from the strongback.
14. Remove the remaining fuel element(s) by first securing each fuel element with the overhead crane, followed by removing the top and bottom half clamps, and then removing the fuel element from the strongback.
15. Record any damage to the fuel elements, and record an tripped accelerometers on the Radioactive Material Receiving Inspection Record form.
16. Lower strongback and reassemble containers for return shipment to original shipper.

3.4 Maintenance Program

The M51032-1 containers are maintained and repaired at FANP. The following steps are included in the maintenance and repair done at FANP.

1. Repair any holes.
2. Replace parts or work out dents greater than ½ inch deep.
3. Replace parts or do weld repair on broken welds, seams, damaged lugs, or damaged lifting handles.
4. Replace pressure relief valve which do not pass test or have been damaged.
5. Replace or repair gaskets which are damaged, brittle, or flat from overcompression.
6. Replace or repair damaged shock mounts.
7. Replace damaged or missing fasteners.
8. Repaint if needed.
9. Make sure container is clean and free of loose debris.
10. Perform annual gasket leak test (10 ±1" H_2O for 5 minutes).

4 Procedural Controls

4.1 Acceptance Tests

When new containers are fabricated by and purchased form a vendor, the provisions of NFQM, U.S. Version, "Nuclear Fuel Business Group Quality Management Manual" are invoked. The method of invocation is adherence to the terms of a Design Specification.

The Design Specification includes: general requirements for procurement, maintenance, modifications, repairs, and periodic and routine inspections; materials of construction; construction drawings; markings; quality assurance; right of access to the fabricator's plant and documentation; fabricator's certification; and receiving inspection. The drawings and markings mentioned above are those specified in the NRC Certificate of Compliance.

Acceptance testing includes examination of the fabricator's manufacturing and quality control records, inspection of manufacturing activities, receipt of fabricator's certification of compliance with the Design Specification and applicable regulatory requirements, and a receiving inspection both of required documentation and of the containers for conformance to specifications and drawings.

4.2 Use Inspections

Each package shall be inspected and released for use prior to loading fuel elements. The following items are included in such inspections:

1. Visually inspect the shipping container to assure that it has not been significantly damaged (no cracks, punctures, holes, or broken welds). Any welding required shall be per approved specifications.
2. Exterior stencils are in place and legible.
3. Closure bolts, washers, nuts, and sealing gasket are present and free of defects.
4. Visually inspect the strongback assembly to assure that it has not been significantly damaged (no broken welds, no broken nor bent members, and the assembly properly oriented within the containment vessel).
5. Visually inspect the shock mounts to assure that there are the proper numbers, that they are in the proper places and properly secured to the mounting brackets and support tubes.
6. Visually inspect fuel assembly clamps, retainer bars, bolts and nuts to assure that they are present and in good condition.
7. With each shipment of a container, the documentation and labeling for the proper classification of radioactive material is to be completed.

5 General Standards for Packaging

The materials from which the packaging is fabricated (steel, rubber padding, and gaskets), along with the contents of the package (zirconium alloy or stainless steel clad fuel rods, stainless steel and Inconel fuel element hardware and polyethylene wrapping), will not cause significant chemical, galvanic, or other reactions in air, nitrogen, or water atmospheres.

The positive fastening system has been previously described in Section 2.0. In addition, each package will be sealed with Type E tamper-indicating seals. These features prevent inadvertent and undetected opening.

The lifting system (four steel lugs welded to the cover assembly stacking brackets) has been analyzed to be capable of lifting an 8300 pound package without generating stress in any material of the packaging in excess of its yield strength with a minimum safety factor of 3.4 (see Appendix I). Alternatively, two forklift pickup channels (¼-inch steel), are welded to the bottom of the containment vessel base assembly to facilitate forklift handling. Administrative controls are used to prevent the lifting of stacked packages.

If the lifting system were to be subjected to an excessive load and fail, continued containment of the contents would not be jeopardized since the containment of the radioactive materials is not dependent upon the packaging. There are no shielding considerations involved.

Administrative controls prevent the use of any structural part of the package as a lifting device.

There is no identified system of tie-down devices on the packages. However, a combination of shoring, positioning studs, axial, and transverse chokers (chain or straps) is employed to secure packages to the transport vehicles. The only structural parts of the packaging which could be employed to tie the packages down are the stacking brackets and stiffening rings. There are eight stacking brackets per package and the analyses in Appendix II show that a minimum of two of these (per package) could be used in a "tie-down" arrangement (along with shoring and cross chokers). The stiffening rings are normally used as tie-down points. These are heavy members that can easily support the tie-down loads.

If the stacking brackets were to be subjected to an excessive load and fail, continued containment of the package contents would not be jeopardized since the containment of the radioactive materials is not dependent upon the packaging.

6 Structural Standards for Large Quantity Packaging

The Model 51032-1 packaging was analyzed according to the requirements of 10 CFR 71.71(a) and shown to satisfactorily withstand the specified loading. In performing the necessary calculations, the containment vessel shell was analyzed as a simple beam, without consideration being given to any reinforcing members. Data used in the calculations are listed below.

r_1 = 19 inches
r_2 = 19.1196 inches
5W = 5 x 7500 pounds
L = 210.25 inches

The calculated stress generated in the containment vessel shell due to this loading is less than 1/3 the yield stress.

It is not necessary to demonstrate that the containment vessel will withstand an external pressure of 20 psi absolute since the fuel rods themselves are designed to withstand much greater pressures in reactor cores. It is concluded, therefore, that there would be no loss of contents if the package were subjected to an external pressure of 20 psi absolute.

7 Criticality Standards for Fissile Material Packages

Packages have been designed, constructed, and the contents so limited such that each would be subcritical if water leaks into the containment vessel, and:

1. Water moderation of the contents occurs to the most reactive credible extent consistent with the chemical and physical form of the contents, and
2. The containment is fully reflected on all sides by water.

There are no liquids in these packages during normal transport.

The k-eff values for a single package are bounded by those given in Section 11.0 for arrays of packages.

8 Evaluation of a Single Package

The effect of the transport environment on the safety of individual packages, loaded as described in this application, has been evaluated as follows:

1. The ability of the package to withstand conditions likely to occur in normal transport has been assessed by comparison to previously tested and licensed packages of similar design and construction, supported by additional engineering evaluations where necessary. This assessment is presented in Section 9.0.
2. The effect on the package of hypothetical accident conditions has been assessed by comparison to previously tested and licensed packages of similar design and construction supported by additional engineering evaluations, a series of 30-foot drop tests on Model 51032-1 packages, and static tests of packaging components. This assessment is presented in Section 10.0.

Shipments were evaluated without consideration of the transport vehicle for both normal conditions of transport and hypothetical accident conditions.

9 Standards for Normal Conditions of Transport

The Model 51032-1 package has been designed and constructed, and the contents so limited (as described in Section 2.0) that the performance requirements specified in 10 CFR 71.71 are met when the package is subjected to the normal conditions of transport. The ability of the package to satisfactorily withstand the normal conditions of transport has been assessed as described below.

1. Heat. This test is not applicable to the package since the materials of construction of the packaging, the fuel cladding and the fuel (sintered oxides), can be subjected to much more elevated temperatures without significant detrimental effects.

2. Cold. This test is not applicable to the package since the materials of construction of the packaging, the fuel cladding, and the fuel are not significantly affected by the specified conditions.

3. Pressure. Due to the materials of construction, an external atmospheric pressure of 3.5 psi absolute will not significantly affect the package.

4. Vibration. The effects of vibration normally incident to transport were determined to be negligible on a similar package Model 927A. Analyses and road testing of Model 51032-1 package has demonstrated that no adverse effects occur to the package as a result of normal vibration incident during transportation (see Reference 2).

5. Water Spray. An unpressurized Model 51032-1 package was exposed to a water spray that kept the package completely wet for a period of 30 minutes and there was no in-leakage of water into the container vessel. Since water in-leakage is assumed for the criticality analysis, and since water will not affect the materials of construction of either the package or the fuel, water spraying for an additional 30 minutes, as required by 10 CFR 71.71(c)(6) was not considered necessary in the evaluation of the package.

6. Free Drop. The effects of the specified free drop test were determined to be negligible on a similar package (Model 927A, see Reference 2 and Appendix III). Furthermore, a series of three "most damaging" drop tests has been performed on the Model 51032-1 packaging (see Appendix IV).

7. Corner Drop. Not applicable.

8. Penetration. The penetration test was not performed. Puncture tests, however, as specified in 10 CFR 71.71(c)(10), were performed on two similar packages (Model 927A, see Reference 2, and Model UNC-2800, see Reference 1) without significant damage to the packages. This fact, along with the design and material of construction of the Model 51032-1 containment vessel, render incredible that the penetration test, as specified in 10 CFR 71.71(c)(10), could result in penetration into the containment vessel.

9. Compression. The "Compression Test" was not performed. It was demonstrated in Section 6.0, however, that the Model 51032-1 package will support a uniformly distributed load equal to five times its loaded weight 5 x 7500 = 37,500 pounds, which is greater than two pounds per square inch over the maximum horizontal cross section (2x43x217 = 18,660 pounds) without generating stress in any packaging material in excess of its yield stress. Also, the fact that these packages will be transported only by motor vehicles and cargo-only aircraft, coupled with the physical dimensions of the packaging, preclude them being stacked more than two high during transport.

As a result of the above assessment, it is concluded that under normal conditions of transport:

1. There will be no release of radioactive material from the containment vessel.
2. The effectiveness of the packaging will not be substantially reduced.
3. There will be no mixture of gases or vapors in the package which could, through any credible increase in pressure or an explosion, significantly reduce the effectiveness of the package.

Since there are no coolants involved, neither radioactive contamination of the primary coolant nor loss of coolant need be considered.

Also, as the result of the assessment described above, it is concluded that under normal conditions of transport:

1. The package will be subcritical (see Section 11.0 for criteria, assumptions, method of analysis, and results).
2. The geometric form of the package contents will not be substantially altered.
3. An unpressurized Model 51032-1 package has been subjected to a water spray test, and there was no leakage of water into the containment vessel.
4. There will be no substantial reduction in the effectiveness of the packaging; i.e.,
   a. The effective volume of the packaging on which nuclear safety is assessed will not be reduced by more than 5 percent.
   b. The effective spacing on which nuclear safety is assessed between the center of the containment vessel and the outer surface of the packaging will not be reduced by more than 5 percent.
   c. An aperture cannot occur in the outer surface of the packaging.

For the purpose of meeting the requirements of this section, the fuel rods are considered to be the containment vessel. Each fuel rod is certified to be leak-tight prior to use in the fuel elements.

10 Standards for Hypothetical Accident Conditions

The integrity of Model 51032-1 packaging when subjected to hypothetical accident conditions has been established through conservative design analyses and testing programs. Drop tests, as described below, were conducted with Model 51032-1 packages loaded with two simulated fuel elements weighing 1650 pounds each. The adequacy of Model 51032-1 packaging is thereby demonstrated for all FANP fuel elements weighing no more than 1650 pounds.

In addition to the package test data supplied in this application, test data on similar packages can be found in the references listed below.

1. Model UNC-2800; USNRC Certificate of Compliance No. 5419 (see Reference 1).
2. Models 927A, 927B and 927C; USNRC Certificate of Compliance No. 6078 (see References 2 and 3).

The Model 51032-1 container design is based on the Model 927C packaging. Changes were made where necessary to meet FANP specifications. In all structural and containment respects, however, the Model 51032-1 package equals or exceeds the capabilities of packages upon which the design is based.

Experience in use of the container has led to some desired minor design changes in internal components. The integrity of the components which have been changed is established by component tests as described.

Section 10.1 below establishes the integrity of the Model 51032-1 container for fuel elements weighing up to 1650 pounds.

10.1 Model 51032-1 Package

The Model 51032-1 package has been designed, constructed, and the contents so limited (as described in Section 2.0) that the performance requirements specified in 10 CFR 71.55(e) are met if the package is subjected to the hypothetical accident conditions specified in 10 CFR 71.73. The ability of the Model 51032-1 package to satisfactorily withstand the hypothetical accident conditions has been assessed as described below.

Free drop tests were performed with similar packages (Model 927A, see References 2 and 3, Model UNC-2800, see Reference 1, and Appendix III of this document), as well as with the Model 51032-1 package. A description of the drop tests on the Model 51032-1 package is provided in Appendix IV, and a summary of those tests is given below.

10.1.1 Model 51032-1 Container - Horizontal Cover Drop Evaluation

A Model 51032-1 package was loaded with two simulated full length fuel elements weighing 1653 pounds each. The gross weight of the dropped package was 7486 pounds. The package was turned over onto its cover, elevated so that the lowest point of the package (in a horizontal position) was 30 feet above the target surface and dropped onto its cover. This drop test was designed to determine the capability of the full clamps to hold the fuel elements in the strongback.

Upon impact, the base of the outer shell was drawn in about three inches at the center before the strongback shock mount system failed in tension. Although the full clamp cross members were deformed, they did not fail, and only one came loose from its clamped position at the strongback flange. The simulated fuel elements were retained in the strongback and the minimum 6-inch separation between the fuel elements was retained. The steel stiffener rings on the containment vessel cover were slightly deformed and the half clamps punctured the containment vessel when the strongback assembly broke loose from the base and impacted on the cover. The cover and base assemblies remained secured together around the flange connection. In its damaged condition, and as the package lay immediately following impact, the minimum distance between the top of the fuel elements and the outer edge of the deformed stiffener rings was 5 inches (3 inches between top of the fuel elements and the inner edge of the stiffener rings). See Appendix IV for further details.

10.1.2 Model 51032-1 Container - End Drop Evaluation

Another Model 51032-1 package was loaded as in Drop No. 1 except that the eight restraining bars were omitted as irrelevant for this drop orientation (gross weight equaled 7406 pounds). The package was set on its forward end, elevated so that the lowest point of the package (in a vertical position) was 30 feet above the target point and dropped onto its forward end. This drop test was designed to determine the capability of the end thrust plate to retain fuel elements in the strongback, and to obtain a maximum "g" value ("g" values obtained for each drop test are contained in the Test Report, Appendix IV).

Upon impact, the strongback shock mount bolts failed in shear and the forward end of the strongback impacted against the forward end of the containment vessel. The package remained vertical, free standing on its forward end. The only visible damage to the containment vessel was deformation of the flange connection on the forward end (three closure bolts sheared off), minor puncturing of the forward end of the containment vessel by the strongback, and the forward end of the strongback was crumpled back to the leading edges of the end thrust plate side plates (the end thrust plate is secured to the sides of the strongback by means of five ¾-inch bolts through each side plant and the sides of the strongback). Neither the thrust plate bolts nor the end thrust plate side plates, nor the end thrust plate exhibited any visible damage as the result of the drop test. The simulated fuel elements remained secured within the strongback, and the cover and base assemblies remained secured together around the flange connection except for the three closure bolts on the forward (impact) end.

10.1.3 Model 51032-1 Container - 75° Cover Corner Drop Evaluation

The package used in Drop No. 2 was rendered usable for an additional drop test by replacing the 14 shock mount bolts and straightening the closure flanges on the forward end. The package contents for Drop No. 3 was the same as for Drop No. 2 (gross weight = 7406 pounds). The package was set on its aft end and rigged such that it would land with its long axis at a 75° ± 1° angle with the horizontal and the cover toward the ground. The package was then elevated so that the lowest point of the package was 30 feet above the target surface and dropped only the aft cover corner at a 75° ± 1° angle. This drop test was designed to determine the capability of the flange closure bolts to withstand the maximum shearing force, and to demonstrate that the base and cover assemblies will remain secured together. Upon impact, the aft end of the cover crumpled, as did the leading corner of the strongback. Following initial impact, the package fell over onto its cover. The base and cover assemblies remained secured together;

only one closure bolt failed. Upon opening the package, it was observed that the strongback had broken free from the base assembly. The aft end thrust plate remained secured to the strongback, and the simulated fuel elements were retained within the strongback.

10.1.4 Package Component Tests and Evaluations

Performance criteria for package components were given in Section 2.1.2 which assure the safety of the container under hypothetical accident conditions. Drop tests clearly show the adequacy of the package configuration for a particular payload (fuel element) weight. These results can be extrapolated to other configurations to assure continued adequacy at lower fuel content weights with fewer separator blocks, clamp assemblies, and shock mounts. A discussion of each extrapolation is provided herein.

10.1.4.1 Model 51032-1 Separator Block Integrity

Separator blocks were not tested in the Model 51032-1 drop tests. The separator blocks and attachment method used in the Model 51032-1 shipping package are identical to those employed in the Applied Design shipping package 927C (Appendix III compares these shipping containers). The 927C package separator block arrangement was previously evaluated (see Reference 3). Since the maximum content weight for the 51032-1 container exceeds that of the 927C package, the total number of separator blocks that can be used is increased (see Appendix III). The maximum fuel element weight per separator block is, therefore, limited to that which was previously demonstrated to be adequate. In particular, the number of separator blocks (N_b) used is at least:

$$N_b \geq \frac{W}{187.5}$$

where W is the weight of one fuel element expressed in pounds, or if four fuel elements are contained, the combined weight of two fuel elements.

In the drop tests (see Appendix IV) the 51032-1 container was loaded with two simulated fuel elements 1650 lbs. each and eight separator blocks were used in the container. Therefore, assuming the load is uniformly distributed, each of the eight separators supported 206.25 lbs., which is greater than the 187.5 lbs.

The drop tests of the 51032-1 container clearly show the adequacy of the package configuration for a particular payload (fuel element) weight. The drop test results have been used to extrapolate to other configurations to assure continued adequacy at lower fuel content weights with fewer package components. Equations for calculating the required number of separator blocks were derived from the drop test results to assure compliance with the following performance criterion (see Section 2.1.2, pages 2-3 and 2-4):

> "The weight of contained fuel per separator block shall not exceed that of the drop tested and analyzed package."

The maximum overall mass of a loaded fuel container is 7500 lbs. Payload can be as small as 1874 lbs. for a combined minimum mass of 6974 lbs. - a change of 5.8% of the maximum mass.

It is assumed that the resulting accelerations in a 30 foot drop test will not change as consequence of the reduction in mass. This is a reasonable and conservative assumption as the mass variation is relatively small. Therefore, extrapolation of the required number of separators and other components is appropriate.

10.1.4.2 Fuel Element Clamps and Shock Mounts

The drop tested Model 51032-1 container was loaded with a total content (simulated fuel elements) weight 3300 pounds. The U-shaped strongback channel weighs approximately 700 pounds with the thrust plates, clamps, separator blocks, etc., in place the total weight supported by the shock mounts (fuel and packaging components) was approximately 4500 pounds.

The total weight associated with each of the 14 shock mounts, therefore, is 321.43 pounds. To comply with criterion #1 of Section 2.1.2, which assures proportional energy dissipation by the shock mounts at reduced content weights, the required relationship to be satisfied is as follows:

$$N_S \geq \frac{nW_{FE} + W_S}{321.43}$$

where:
N_S = the number of shock mounts
n = the number of contained fuel elements
W_{FE} = the weight in pounds of each fuel element
W_S = the weight in pounds of the strongback and attached components[3]

The drop test results clearly show the adequacy of the package configuration. The shock mounts are designed to be the weakest link (i.e., the most likely to fail) in the components securing the fuel element in the package.

Through the deformation process leading to eventual failure, the shock mounts absorb energy. The energy of the package is proportional to payload mass. The energy absorption capability of the shock mounts provided in the tested container was adequate to meet with required criterion. It is reasonable to assume that if the payload mass is increased or decreased, the energy absorption capability of the shock mounts needs to be changed proportionally in order to provide equivalent (same percentage) energy absorption capabilities.

In the cover drop test of the Model 51032-1 package, the shock mount bolts failed in tension. Tests of the 5/8-inch Grade 2 shock mount bolts indicate an ultimate strength in the range of 11,000 to 12,000 pounds. Hence, clamp loading/deformation is limited by tensile failure of the shock mount bolts. The maximum restraining force exerted by the shock mounts in the drop tested package was 168,000 pounds (14 x 12,000 pounds). Since the nine full clamp assemblies to retain the 3300 pound contents in the package did not fail in the cover drop test (the most severe test of the clamps and shock mounts), it can be stated that each clamp assembly is capable of restraining a load of at least 15,360 pounds. The required number of PWR (steel) full clamp assemblies at various content weights, therefore, can be determined from the relationship:

[3] Note that it is conservative to assume a fixed maximum weight for the strongback when computing shock mount requirements for lower fuel content weights. W_s was, therefore, assumed to be 1200 pounds for computing the required number of shock mounts for various fuel element weights given in Table 2.3.

$$N_C^{PWR} \geq \left(\frac{12}{15.36}\right)\left(\frac{N_S}{1+\frac{W_S}{nW_{FE}}}\right)$$

where: N_C^{PWR} = the number of PWR (steel) full clamp assemblies
N_S = the number of attached shock mount bolts
n = the number of fuel elements
W_{FE} = the weight in pounds of each fuel element
W_S = the weight of the strongback and attached components[4]

Due to the excessive weight of steel fuel clamps for packaging BWR fuel elements, FANP has designed the aluminum clamps shown in Figure 2.9. Tests on the aluminum clamps have shown that they will not fail and have only marginally larger deformation than the steel clamps used in the drop tests at forces of up to 6000 pounds per clamp (12,000 pounds per clamp assembly). (See Figure 10.1 for the comparison of the force deflection curves for the steel and aluminum clamps at applied forces of up to 6000 pounds. The tests were conducted with the force applied vertically against the clamp assembly as would occur in a cover drop accident.)

Although the aluminum BWR clamps may be adequate at forces of up to those assumed as the capability of PWR steel clamps (15,360 pounds), the test data support the use of assumed loadings of up to 12,000 pounds per clamp assembly. Again, assuming that the shock mounts exert a maximum restraining force of 168,000 pounds, the number of full clamp assemblies (aluminum clamps) required to limit the load on each to ≤ 12,000 pounds is as follows:

$$N_C^{BWR} \geq \frac{N_S}{1+\frac{W_S}{nW_{FE}}}$$

where: N_C^{BWR} = the number of BWR (aluminum) full clamp assemblies
N_S = the number of attached shock mount bolts
n = the number of fuel elements
W_{FE} = the weight in pounds of each fuel element
W_S = the weight of the strongback and attached components[5]

In summary, the cover drop test was designed to determine the capability of the full clamps to hold the fuel elements in the strongback (the most severe test of the clamps and shock mounts). The shock mounts failed in tension (as designed) and the full clamps were deformed, but did not fail. The fuel elements were retained in the strongback and the minimum six inch separation

[4] Note that it is conservative to assume a fixed minimum weight for the strongback when computing the required number of full clamp assemblies for various fuel content weights. W_S was, therefore, assumed to be the weight of strongback channel without attachments (i.e., 700 pounds) for computing the number of full clamps required to meet the criteria given in Section 2.1.2 for specific numbers of shock mounts at the various fuel element weights given in Table 2.4.

[5] Note that it is conservative to assume a fixed minimum weight for the strongback when computing the required number of full clamp assemblies for various fuel content weights. W_S was, therefore, assumed to be the weight of the strongback channel without attachments (i.e., 700 pounds) for computing the number of full clamps required to meet the criteria given in Section 2.1.2 for specified numbers of shock mounts at the various fuel element weights as given in Table 2.5.

between the fuel elements was retained. This proved that the number of clamps and the numbers of shock mounts in the tested container were adequate.

Drop test results have been used to extrapolate to other configurations to assure continued adequacy at lower content weights with fewer package components.

In order to maintain the same relative strength between the different container components and to assure that the shock mounts absorb energy through the deformation process while the payload is secured, the number of full clamps needs to be adjusted as the number of shock mounts changes.

Equations for calculating the required number of full clamps were derived from drop test results to assure compliance with the following performance criterion (see Section 2.1.2):

> "Full clamps used to retain fuel elements within the strongback shall not fail at forces required for failure of the shock mounts."

10.2 Fuel Rod Drop Tests

To supplement information obtained from the package drop tests and assess the capability of fuel rods to withstand dynamic loads similar to those experienced under hypothetical accident conditions, drop tests were also performed with individual fuel rods. Details relative to those tests are presented in Appendix VI. Although the tests resulted in significant warping and bending of the individual fuel rods, in no case were any cracks or other breaches of the cladding detected. Each fuel rod was surveyed (using alpha sensitive detectors) after being tested and in no case was there any release of radioactive material.

10.3 Thermal Accident Test Considerations

Under thermal accident conditions (exposure to a thermal radiation environment of 1475°F for 30 minutes), with the exception of the BWR (aluminum) clamps, the integrity of all packaging materials significant to the continued safety of the container would be maintained. If BWR clamps were utilized and exposed to the specified thermal environment, it is possible that the clamps would melt. Should that occur, the fuel elements could be released and move into contact with the steel separator blocks and/or the steel clamp brackets which span the strongback (see Figure 2.2). Assuming that either or both of the above should occur, the minimum spacings between adjacent fuel elements assumed in related criticality safety evaluations (see Section 11) would be maintained. Hence, the safety of the package would be assured in the event of a thermal accident involving the Model 51032-1 package described herein.

10.4 Summary

The Model 51032-1 packaging, with a gross weight ranging from 7406-7486 pounds, satisfactorily passed a series of three "most damaging" 30 foot drop tests. These test results, coupled with the satisfactory results of 30-foot drop tests and other "hypothetical accident condition" tests and analyses performed on, or for, packaging Models UNC-2800, 927A, 927B and 927C and static tests on components of the package clearly demonstrate that the Model 51032-1 packaging meets the requirements for fissile material packages.

As a result of the above assessment, it is concluded that should the Model 51032-1 package be subjected to the hypothetical accident conditions:

1. A reduction of shielding is not applicable since shielding is neither required nor a design criteria; and
2. No radioactive material would be released from the package.

Also, as a result of the assessment described above, it is concluded that if subjected to the hypothetical accident conditions, the Model 51032-1 package would be subcritical assuming:

1. The fissile material is in the most reactive credible configuration consistent with the damaged condition of the packaging and the chemical and physical form of the contents.
2. Maximum credible water moderation of the contents consistent with the damaged conditions of the contents.
3. Full water reflection of the contents consistent with the damaged condition of the contents.

Refer to Section 11 for criticality safety criteria, assumptions, methods of analysis, and results.

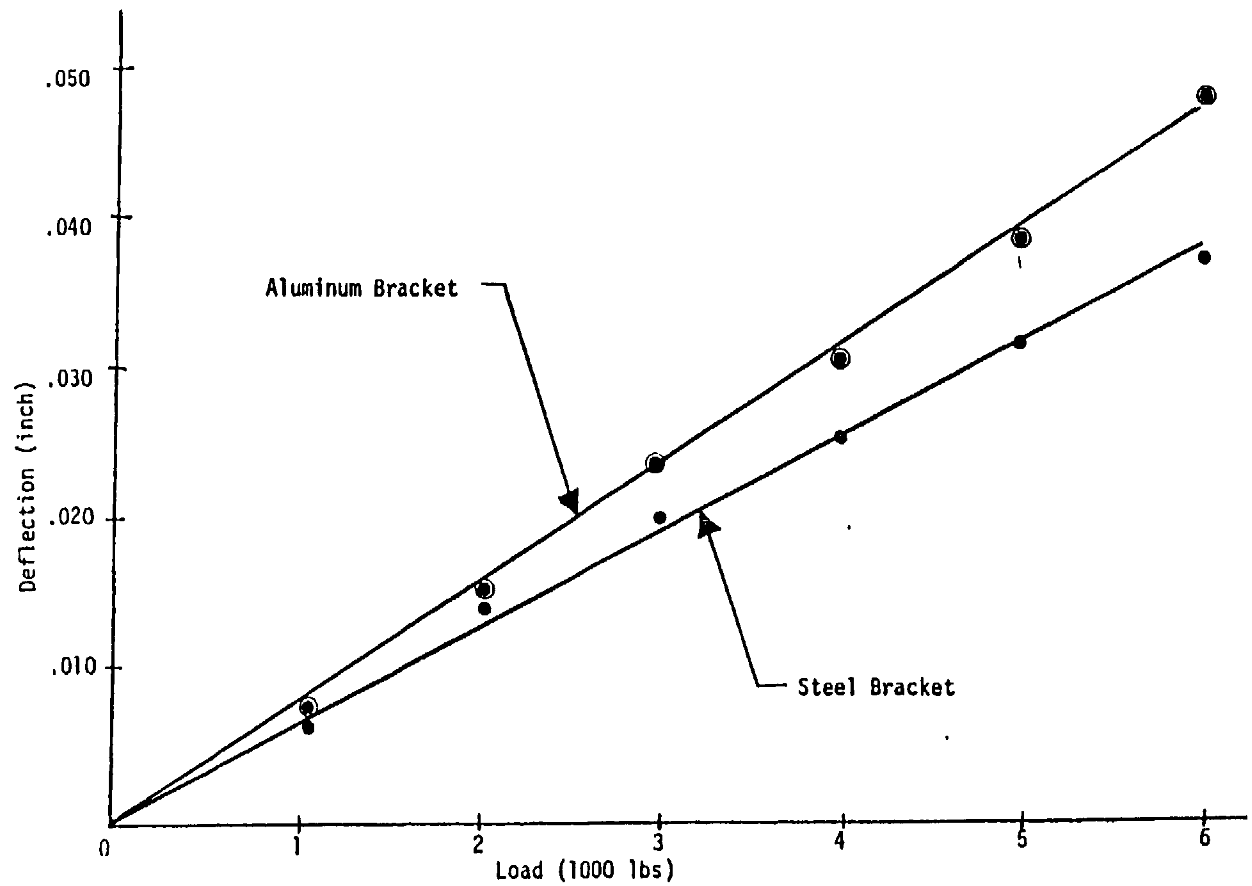

FIGURE 10.1 Steel and Aluminum Clamp Assembly Force Deflection Curve Comparison

11 Criticality Safety Analysis

11.1 Introduction and Summary

The Model 51032-1 package has been used for shipping finished fuel assemblies since the early 1970's. This package meets all criticality safety criteria for Fissile Class I shipments when loaded with the allowable assembly types or consolidated rods.

The allowable fuel types include one generic category with an assembly size up to 8.25 inches square and two other categories with an assembly size up to 8.45 inches square. In addition, a Schedule 40 steel pipe with a nominal OD of 5 inches may be used to hold any number of 5% (max.) enriched rods. One or two such pipes up to 196 inches long may be transported in each Model 51032-1 container.

Appendix VII provides a supplemental criticality safety analysis in support of a fifth fuel type, T15X15. This appendix also revises the concept of separate minimums for cladding wall thickness and pellet-clad gap to a minimum sum of those two dimensions for the four currently identified fuel types.

Appendix VIII provides a supplemental criticality safety analysis in support of three new fuel types, three 15x15 designs (L1 and L2) and one 17x17 design (L4).

All calculated k-eff data are less than 0.95. Because the parameters of the rod container fall well within those of the allowable fuel assembly types, it is obvious that any k-eff for shipping containers carrying pipe containers will be well below that of containers carrying fuel assemblies. Consequently, rod containers are not analyzed in this application.

11.2 Allowable Contents

Assemblies of UO_2 fuel rods with zircaloy or stainless steel cladding of nominal thickness and with nominal pellet-clad gap (radial) summed to not less than 0.023 inch. Rods containing gadolinia or other neutron absorbers are allowable but not required. The maximum length of the enriched zone is 196 inches and the maximum allowable bundle-average enrichment at any transverse section along the fuel length is 5.0%. Rod containers with rods as described are also allowed. Other limits and controls for these assemblies are listed in Table 11.1.

11.3 Description of Calculation Models

Details of the models are provided in the KENO-Va input listings and geometry plots in Section 11.6.

11.3.1 Normal Array Calculation Model

The packages were modeled with the strongback in the normal position and with the two assemblies in the normal position. An infinite array in a 42.24 inch square-pitch arrangement was modeled with dry conditions within the packages and optimum interspersed moderation between packages.

11.3.2 Damaged Array Calculation Model

The packages were modeled with the strongbacks shifted to produce the minimum possible bundle-bundle separations between adjacent packages. This occurs with the strongback shifted to the left or right by nearly three inches from center to where steel parts of the strongback (support brackets at bottom, upper edge of strongback at top) are contacting the steel shell. The bundle-bundle separations within packages were modeled at the minimum credible value; i.e., the bundles were both touching the separator blocks and they were shifted to the left or right edge of the strongback in the same direction as the strongback was shifted in the package to allow maximum possible interaction with bundles in adjacent packages. For this model the minimum horizontal edge-to-edge spacing between assemblies in adjacent packages is 6.5 inches. Arrays were modeled in a 39.24 inch square-pitch arrangement and in a 39.24 inch triangular-pitch arrangement; the reactivities of the two arrangements were not significantly different. The 39.24 inch pitch is very conservative considering the very slight deformation observed during 30-foot drop testing. The arrays modeled contained more than 250 packages; e.g., 11x12x2 arrays (264 units) with full water reflection or infinite arrays. Various degrees of moderation within and between packages were modeled to determine the peak reactivity condition.

11.4 Calculation Results

KENO-Va and CASMO-3G calculation results are used to demonstrate compliance with 10 CFR Part 71. CASMO was used primarily for sensitivity studies to determine the most reactive set of parameters and then KENO was used to replicate certain cases, including the peak reactivity. CASMO results do not have a Monte Carlo uncertainty which greatly facilitates sensitivity analyses. All calculations were based on fuel rods with a 196 inch long stack of pure UO_2 with an average density of 10.412 g/cc (95% TD) and with an enrichment of 5.0 wt.% U-235[6]. All fuel rods were clad with 0.020 inch thick Zircaloy. All packages modeled contained two fuel assemblies spaced six inches edge-to-edge by the minimum allowable number (5) of separator blocks. The 27-group cross section library from SCALE, as processed by NITAWL, was used in all KENO calculations. KENO calculations typically employed 80 generations of 400 neutrons to give a well-converged solution with a relatively small Monte Carlo uncertainty. Calculation results for the allowable contents are grouped together first for damaged conditions and then later for undamaged conditions.

11.4.1 Damaged Array Calculation Results

Finite arrays (11x12x2, 264 packages) were modeled for cases with low density water within and between packages. Infinite arrays were modeled for cases with full density water within packages. Since the neutron leakage from large flooded arrays is expected to be very small, the k-eff from finite arrays would be very close to the k-inf value. However, with low density water within and between packages, leakage effects may be significant. Several combinations of pellet and clad dimensions were modeled to demonstrate compliance.

[6] The use of 196 in. fuel length as the length of the container is conservative because it allows more end-to-end neutron interaction between fuel assemblies in adjacent containers than 196 in. of fuel in a 216 in. container. Likewise, the use of 5 wt% enriched UO_2 for the entire fuel column length is conservative in that natural ends are not modeled. In effect 5 wt% is the maximum pellet enrichment.

11.4.2 CASMO-KENO Comparison

Infinite arrays were modeled using CASMO-3G and KENO-Va. A comparison of the results from the two codes is provided in Table 11.2. The results from the two codes are very close.

CASMO was used to explore the effect of pellet and clad dimensions in infinite arrays of fully flooded (i.e., within and between) packages.

11.4.3 W15 Fuel Type Cases

The modeled arrangement of the W15 assembly is shown in Figure 11.1.

The data in Table 11.3 indicate that the most reactive rod parameters are maximum pellet diameter inside the minimum rod diameter.

Additional data on pellet/clad dimension effects and on moderation effects are in Table 11.4. The peak k-eff for category W15 fuel occurs with packages flooded. With flooding within packages, the effect of water density between packages is not significant. The finite arrays containing low density water are much less reactive than the flooded arrays. The highest one-sided 95% upper limit k-eff is 0.9444 (0.9376 + 1.67*0.0041).

11.4.4 W17 Fuel Type Cases

Similar calculations were performed for W17 fuel with the arrangement shown in Figure 11.2.

The k-eff data for Category W17 fuel at flooded (peak reactivity) conditions are listed in Table 11.5. The highest one-sided 95% upper limit is 0.9462 (0.9390 + 1.67*0.0043).

Finite arrays of damaged packages with low density water moderation were also modeled with W17 fuel. As shown in Table 11.6, the k-eff results are considerably lower than those at flooded conditions.

11.4.5 GEN1 Fuel Type Cases

Category GEN1 fuel was modeled as several lattice types (11x11, 14x14, 15x15, and 17x17) with all lattice locations occupied by fuel rods of variable diameter but with a fixed clad thickness of 0.020 inch and a fixed pellet-clad radial gap of 0.003 inch. The data in Table 11.7 show that GEN1 fuel is acceptable with dimensions up to 8.25 inches square for enrichments up to 5.0%. The calculation results include the optimum moderation conditions. To demonstrate that the effects of "water rods" (e.g., guide tubes) are acceptable, the 15x15 and 17x17 lattice types were also modeled with the 21 or 25 guide tubes in the same arrangement as used for the W15 and W17 calculations.

KENO replicates of two 17x17 cases were presented earlier in Table 11.2.

Finite arrays of damaged packages with low density water moderation were also modeled with GEN1 fuel. As shown in Table 11.8, the k-eff results are considerably lower than those at flooded conditions as was observed for the other fuel types.

11.5 Normal (Undamaged) Array

Infinite arrays of packages containing various assembly types were modeled using KENO-Va. The interspersed water density was modeled at several values to determine the optimum (Table 11.9).

Additional cases were calculated to verify that small amounts of moderating materials such as ethafoam and rubber inside the container but external to the fuel have no adverse effect. The model for these calculations was identical to that in Table 11.9 except that the indicated water density was also placed inside all available volume external to the fuel assembly, which was dry. The model in Table 11.9 had water between containers but not inside containers. The calculation results are in Table 11.10.

11.6 KENO-Va Input Listings and Geometry Plots

11.6.1 KENO Listing Most Reactive Case for Damaged Packages

```
M51032 SHIPPING CONTAINER, 5.0% 15x15, INF ARRAY, FLOODED
READ PARAMETERS
TME=9.7 GEN=80 NSK=0 NPG=400 LIB=41 TBA=0.3
FLX=YES FDN=YES XS1=YES NUB=YES PWT=YES
END PARAMETERS
READ MIXT SCT=2
MIX= 1
' 95%TD, 5.0% ENRICHED
  92235 1.175781E-03
  92238 2.205765E-02
  8016 4.646686E-02
MIX= 2
' ZIRCALOY
  40302 4.251812E-02
MIX= 3
' WATER, 100 VOL%
  8016 3.337967E-02
  1001 6.675933E-02
MIX= 4
' CARBON STEEL
  6012 3.921682E-03
  26000 8.350009E-02
END MIXT
READ GEOMETRY
UNIT 1
COM=" FUEL ROD (364/370/410-196L)                "
CYLI 1 1 0.46228 2P248.9199
CYLI 0 1 0.4699 2P248.9199
CYLI 2 1 0.5207 2P248.9199
CUBO 3 1 4P0.71501 2P248.9199
UNIT 2
COM=" GUIDE TUBE                                  "
```

```
CYLI  3 1 0.64897 2P248.9199
CYLI  2 1 0.69088 2P248.9199
CUBO  3 1 4P0.71501 2P248.9199
UNIT 3
COM=" 15X15 BUNDLE                                        "
ARRAY  1 2R-10.72515 -248.9199
UNIT 4
COM="  SEPARATOR BLOCK                                    "
' 6"W X 8"H X 9"L X 0.375" WALL, 39.2" CENTERS
CUBO  3 1 2P6.6675 2P9.2075 2P11.43
CUBO  4 1 2P7.6199 2P10.1599 2P11.43
CUBO  3 1 2P7.6199 10.1599 -10.1599 2P49.78399
UNIT 5
COM="  1X1X5 ARRAY OF SEP. BLOCKS                         "
'  FOR UPRIGHT STRONGBACK
ARRAY 2 -7.62 -10.16 -248.92
'  MATCH THE BUNDLE HEIGHT
CUBO  3 1 2P7.62 11.2904 -10.16 2P248.92

GLOBAL
UNIT 6
COM="STRONGBACK AT +X SIDE, BUNDLES SHIFTED TO +X "
'  BOTTOM EDGE (STEEL) OF SB AT Y=-2.8", FUEL BOTTOM AT -2.55"
' +X OUTER EDGE OF STRONGBACK AT 18.7925" MINUS 3.25" = 15.5425"
'  +X INNER EDGE AT 15.5425" MINUS 0.25" = 15.2925"
'  -X EDGE OF LEFT (-X) BUNDLE AT 15.2925-2(8.445)-6 = -7.5975"(19.2977cm)
ARRAY 3 -19.2977 -6.477 -248.92
CUBO  3 1 38.8429 -24.3396 24.638 -6.477 2P248.92
' ADD 0.25" STEEL AT +- X, -Y
REPL  4 1 2R0.635 0.0 0.635 2R0.0 1
'  INSIDE OF STEEL SHELL (MODERATION FILLED)
CYLI  3 1 48.26 2P248.92
'  ADD 0.1196" STEEL SHELL
CYLI  4 1 48.5637 2P249.2237
'  39.24" avg. CENTER-CENTER SPACING
CUBO  3 1 4P49.8348 2P249.2237
END GEOMETRY

READ ARRAY
ARA=1 NUX=15 NUY=15 NUZ=1
FILL
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  2  1  1  2  1  1  1  2  1  1  2  1  1
1  1  1  1  1  1  1  2  1  1  1  1  1  1  1
1  1  1  1  2  1  1  1  1  1  2  1  1  1  1
1  1  2  1  1  1  1  1  1  1  1  1  2  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  1  2  1  1  1  2  1  1  1  2  1  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  2  1  1  1  1  1  1  1  1  1  2  1  1
```

```
1 1 1 1 2 1 1 1 1 1 2 1 1 1 1
1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=1 NUY=1 NUZ=5 FILL F4 END FILL
ARA=3 NUX=3 NUY=1 NUZ=1 FILL 3 5 3 END FILL
END ARRAY

READ BOUNDS ALL=SPECULAR END BOUNDS

READ START NST=1 END START

READ PLOT
TTL=" YX SECTION   "
NCH=" UZ.S"
XUL=-48.6 XLR=48.6 YUL=48.6 YLR=-48.6 ZUL=0.0 ZLR=0.0
UAX=1.0 VDN=-1.0 NAX=120 LPI=6 END
TTL=" YX SECTION   "
NCH=" UZ.S"
XUL=0.0 XLR=48.6 YUL=48.6 YLR=-48.6 ZUL=0.0 ZLR=0.0
UAX=1.0 VDN=-1.0 NAX=120 LPI=6 END
END PLOT
END DATA
```

11.6.2 KENO Listing for Most Reactive Case for Undamaged Containers

```
M51032 SHIPPING CONTAINER, 5.0% 15x15
READ PARAMETERS
TME=9.7 GEN=80 NSK=0 NPG=400 LIB=41 TBA=0.3
FLX=YES FDN=YES XS1=YES NUB=YES PWT=YES
END PARAMETERS

READ MIXT SCT=2
MIX= 1
' 95%TD, 5.0% ENRICHED
   92235  1.175781E-03
   92238  2.205765E-02
   8016  4.646686E-02
MIX= 2
' ZIRCALOY
   40302  4.251812E-02
MIX= 3
' WATER, 4 VOL%
   8016  1.3352E-3
   1001  2.6704E-3
MIX= 4
' CARBON STEEL
   6012  3.921682E-03
   26000  8.350009E-02
END MIXT
```

```
READ GEOMETRY
UNIT 1
COM="  FUEL ROD (384/390/430-196L)                    "
CYLI  1 1 0.48768 2P248.9199
CYLI  0 1 0.4953 2P248.9199
CYLI  2 1 0.5461 2P248.9199
CUBO  0 1 4P0.71501 2P248.9199
UNIT 2
COM="  GUIDE TUBE                                      "
CYLI  0 1 0.64897 2P248.9199
CYLI  2 1 0.69088 2P248.9199
CUBO  0 1 4P0.71501 2P248.9199
UNIT 3
COM=" 15X15 BUNDLE                                     "
ARRAY  1 2R-10.72515 -248.9199
UNIT 4
COM="  SEPARATOR BLOCK                                 "
' 6"W X 8"H X 9"L X 0.375" WALL, 39.2" CENTERS
CUBO  0 1 2P6.6675 2P9.2075 2P11.43
CUBO  4 1 2P7.6199 2P10.1599 2P11.43
CUBO  0 1 2P7.6199 10.1599 -10.1599 2P49.78399
UNIT 5
COM="  1X1X5 ARRAY OF SEP. BLOCKS                      "
'  FOR UPRIGHT STRONGBACK
ARRAY 2 -7.62 -10.16 -248.92
'  MATCH THE BUNDLE HEIGHT
CUBO  0 1 2P7.62 11.2904 -10.16 2P248.92
GLOBAL
UNIT 6
COM="ASSEMBLIES CENTERED IN PACKAGE                    "
ARRAY 3 -29.0703 -10.72515 -248.92
CUBO  0 1 2P31.5912 20.3898 -10.72515 2P248.92
' ADD 0.25" STEEL AT +- X, -Y
REPL  4 1 2R0.635 0.0 0.635 2R0.0 1
'  INSIDE OF STEEL SHELL (MODERATION FILLED)
CYLI  0 1 48.26 2P248.92
'  ADD 0.1196" STEEL SHELL
CYLI  4 1 48.5637 2P249.2237
'   42.24" avg. CENTER-CENTER SPACING
CUBO  3 1 4P53.6448 2P249.2237
END GEOMETRY

READ ARRAY
ARA=1 NUX=15 NUY=15 NUZ=1
FILL
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  2  1  1  2  1  1  1  2  1  1  2  1  1
1  1  1  1  1  1  1  2  1  1  1  1  1  1  1
1  1  1  1  2  1  1  1  1  1  2  1  1  1  1
1  1  2  1  1  1  1  1  1  1  1  1  2  1  1
```

```
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 2 1 1 1 2 1 1 1 2 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 2 1 1 1 1 1 1 1 1 1 2 1 1
1 1 1 1 2 1 1 1 1 1 2 1 1 1 1
1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=1 NUY=1 NUZ=5 FILL F4 END FILL
ARA=3 NUX=3 NUY=1 NUZ=1 FILL 3 5 3 END FILL
END ARRAY

READ BOUNDS ALL=SPECULAR END BOUNDS

READ START NST=1 END START

READ PLOT
TTL=" YX SECTION   "
NCH=" UZ.S"
XUL=-53.6 XLR=53.6 YUL=53.6 YLR=-53.6 ZUL=0.0 ZLR=0.0
UAX=1.0 VDN=-1.0 NAX=120 LPI=6 END
TTL=" YX SECTION   "
NCH=" UZ.S"
XUL=0.0 XLR=53.6 YUL=53.6 YLR=-53.6 ZUL=0.0 ZLR=0.0
UAX=1.0 VDN=-1.0 NAX=120 LPI=6 END
END PLOT
END DATA
```

TABLE 11.1
FUEL ASSEMBLY PARAMETERS

Category/Parameter	W15	W17	GEN1	Rod Container
Assembly Type	15x15	17x17	Any	NA
Fuel Rods Per Assembly (max)	204	264	Any	Any
Nominal Rod Pitch (max), in	0.563	0.496	Any	Any
Nominal Clad OD (min), in	0.410	0.355	0.260	0.260
Nominal Clad OD (max), in	0.430	0.380	0.500	0.500
Assembly Size (nom), in	≤8.445	≤8.432	≤8.25	≤5.0
Maximum Assembly Average Enr., % U-235	5.0	5.0	5.0	5.0

The "assembly size" parameter, except for the rod container, is defined as the product of the rod pitch and the number of rods per edge (e.g., 8.445 = 15*0.563).

TABLE 11.2
CASMO-KENO COMPARISONS
INFINITE ARRAYS, FULLY FLOODED
DAMAGED PACKAGES

Fuel Category	Pellet OD (inch)	Clad ID (inch)	Clad OD (inch)	CASMO k-inf	KENO-Va k-inf
W15	0.364	0.370	0.410	0.9380	0.9376 ± 0.0039
W15	0.384	0.390	0.430	0.9262	0.9271 ± 0.0038
W17	0.309	0.315	0.355	0.9382	0.9390 ± 0.0043
W17	0.314	0.320	0.360	0.9355	0.9332 ± 0.0043
W17	0.334	0.340	0.380	0.9215	0.9218 ± 0.0040
GEN1 (17x17)	0.254	0.260	0.300	0.9352	0.9319 ± 0.0040
GEN1 (17x17)	0.284	0.290	0.330	0.9263	0.9209 ± 0.0040

TABLE 11.3
PELLET-CLAD DIMENSION EFFECTS FOR CATEGORY W15 FUEL
(15x15, 204 FUEL RODS)
INFINITE ARRAYS, FULLY FLOODED DAMAGED PACKAGES

Pellet OD (inch)	Clad ID (inch)	Clad OD (inch)	CASMO k-inf
0.364	0.370	0.410	0.9380
0.360	0.370	0.410	0.9356
0.350	0.370	0.410	0.9293
0.340	0.370	0.410	0.9225
0.374	0.380	0.420	0.9326
0.384	0.390	0.430	0.9262
0.380	0.390	0.430	0.9241
0.370	0.390	0.430	0.9186
0.360	0.390	0.430	0.9126

TABLE 11.4
PELLET-CLAD DIMENSION AND MODERATION EFFECTS FOR CATEGORY W15 FUEL (15x15, 204 FUEL RODS) DAMAGED PACKAGES

Water Density Within (%)	Water Density Between (%)	Pellet/Clad ID/ Clad OD(inch)	KENO-Va k-eff
11x12x2 Arrays with Full Water Reflection			
1	1	.384/.390/.430	0.6792 ± 0.0033
2	2	.384/.390/.430	0.7545 ± 0.0034
4	4	.384/.390/.430	0.7429 ± 0.0036
10	10	.384/.390/.430	0.6109 ± 0.0035
1	100	.384/.390/.430	0.4400 ± 0.0029
2	100	.384/.390/.430	0.4340 ± 0.0029
10	100	.384/.390/.430	0.4594 ± 0.0034
100	10	.384/.390/.430	0.9236 ± 0.0041
Infinite Array Results Below			
100	0	.384/.390/.430	0.9306 ± 0.0052
100	100	.384/.390/.430	0.9271 ± 0.0038
100	0	.364/.370/.410	0.9376 ± 0.0041
100	100	.364/.370/.410	0.9376 ± 0.0039
264 Package Array, Triangular Pitch, Full Water Reflection			
100	100	.364/.370/.410	0.9336 ± 0.0056

TABLE 11.5
PELLET-CLAD DIMENSION EFFECTS
FOR CATEGORY W17 FUEL
(17x17, 264 FUEL RODS)
INFINITE ARRAYS, FULLY FLOODED
DAMAGED PACKAGES

Pellet OD (inch)	Clad ID (inch)	Clad OD (inch)	CASMO k-inf	KENO k-eff
0.309	0.315	0.355	0.9382	0.9390 ± 0.0043
0.314	0.320	0.360	0.9355	0.9332 ± 0.0043
0.310	0.320	0.360	0.9327	
0.305	0.320	0.360	0.9292	
0.300	0.320	0.360	0.9255	
0.324	0.330	0.370	0.9291	
0.329	0.335	0.375	0.9255	
0.334	0.340	0.380	0.9215	0.9218 ± 0.0040

TABLE 11.6
PELLET-CLAD DIMENSION AND MODERATION EFFECTS FOR CATEGORY W17 FUEL (17x17, 264 FUEL RODS) DAMAGED PACKAGES

Water Density Within (%)	Water Density Between (%)	Pellet/Clad ID/ Clad OD(inch)	KENO-Va k-eff
11x12x2 Arrays with Full Water Reflection			
2	2	.334/.340/.380	0.7477 ± 0.0034
4	4	.334/.340/.380	0.7450 ± 0.0036

TABLE 11.7
PELLET-CLAD DIMENSION EFFECTS FOR CATEGORY GEN1 FUEL, 8.25" SQUARE ASSEMBLY FUEL RODS IN ALL ASSEMBLY LATTICE LOCATIONS INFINITE ARRAYS, FULLY FLOODED DAMAGED PACKAGES

Lattice Type	Clad OD (inch)	CASMO k-inf	CASMO k-inf (with guide tubes)
11x11	0.420	0.9323	
11x11	0.440	0.9368	
11x11	0.450	0.9379	
11x11	0.460	0.9382	
11x11	0.470	0.9378	
11x11	0.480	0.9368	
11x11	0.500	0.9329	
14x14	0.330	0.9327	
14x14	0.340	0.9360	
14x14	0.350	0.9380	
14x14	0.360	0.9387	
14x14	0.370	0.9382	
14x14	0.380	0.9364	
15x15	0.300	0.9270	
15x15	0.320	0.9354	
15x15	0.330	0.9372	
15x15	0.340	0.9375	0.9352
15x15	0.350	0.9363	0.9367
15x15	0.360	0.9339	0.9368
15x15	0.370	0.9301	0.9357
15x15	0.380	0.9251	
16x16	0.300	0.9345	
16x16	0.310	0.9371	
16x16	0.320	0.9367	
16x16	0.330	0.9353	
17x17	0.260	0.9198	
17x17	0.280	0.9318	
17x17	0.290	0.9345	
17x17	0.300	0.9352	0.9333
17x17	0.310	0.9348	0.9356
17x17	0.320	0.9310	0.9348
17x17	0.330	0.9263	

TABLE 11.8
PELLET-CLAD DIMENSION AND MODERATION EFFECTS FOR CATEGORY GEN1 FUEL DAMAGED PACKAGES

Lattice Type	Water Density Within (%)	Water Density Between (%)	Pellet/Clad ID/ Clad OD(inch)	KENO-Va k-eff
11x12x2 Arrays with Full Water Reflection				
11x11	2	2	.454/.460/.500	0.7405 ± 0.0032
11x11	4	4	.454/.460/.500	0.7229 ± 0.0038
17x17	2	2	.334/.340/.380	0.7477 ± 0.0034
17x17	4	4	334/.340/.380	0.7450 ± 0.0036

TABLE 11.9
INFINITE ARRAY CALCULATION RESULTS UNDAMAGED PACKAGES
DRY INTERNALLY KENO-Va RESULTS
ONE-SIDED 95% UPPER LIMIT

Fuel Type	Lattice Type	Rod Diameter (inch)	Interspersed Water (Vol%)	KENO (k-inf)
W15	15x15	0.430	1	0.8408 ± 0.0026
W15	15x15	0.430	2	0.8954 ± 0.0026
W15	15x15	0.430	3	0.9164 ± 0.0027
W15	15x15	0.430	4	0.9241 ± 0.0029
W15	15x15	0.430	5	0.9118 ± 0.0031
W15	15x15	0.430	7	0.8833 ± 0.0032
W15	15x15	0.430	10	0.8310 ± 0.0031
W15	15x15	0.430	20	0.3051 ± 0.0023
W15	15x15	0.430	90	0.3841 ± 0.0030
W15	15x15	0.430	100	0.3762 ± 0.0029
W17	17x17	0.380	2	0.8893 ± 0.0026
W17	17x17	0.380	3	0.9095 ± 0.0026
W17	17x17	0.380	4	0.9127 ± 0.0037
W17	17x17	0.380	5	0.9037 ± 0.0027
W17	17x17	0.380	6	0.8910 ± 0.0031
W17	17x17	0.380	10	0.8300 ± 0.0028
GEN1	17x17	0.380	2	0.8897 ± 0.0025
GEN1	17x17	0.380	3	0.9140 ± 0.0026
GEN1	17x17	0.380	4	0.9121 ± 0.0029
GEN1	17x17	0.380	5	0.9057 ± 0.0031
GEN1	17x17	0.380	10	0.8306 ± 0.0033
GEN1	11x11	0.500	2	0.8963 ± 0.0024
GEN1	11x11	0.500	3	0.9123 ± 0.0027
GEN1	11x11	0.500	4	0.9079 ± 0.0030

TABLE 11.10
INFINITE ARRAY CALCULATION RESULTS
UNDAMAGED PACKAGES
DRY FUEL-MODERATED ELSEWHERE
KENO-Va RESULTS
ONE-SIDED 95% UPPER LIMIT

Fuel Type	Lattice Type	Rod Diameter (inch)	Interspersed Water (Vol%)	KENO (k-inf)
GEN1	17x17	0.380	0.5	0.8533 ± 0.0026
GEN1	17x17	0.380	1	0.8996 ± 0.0024
GEN1	17x17	0.380	3	0.8410 ± 0.0034

FIGURE 11.1

ARRANGEMENT FOR TYPE W15

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	0	1	1	0	1	1	1	0	1	1	0	1	1
1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
1	1	1	1	0	1	1	1	1	1	0	1	1	1	1
1	1	0	1	1	1	1	1	1	1	1	1	0	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	0	1	1	1	0	1	1	1	0	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	0	1	1	1	1	1	1	1	1	1	0	1	1
1	1	1	1	0	1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
1	1	0	1	1	0	1	1	1	0	1	1	0	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

KEY: 1=FUEL, 0=WATER ROD

FIGURE 11.2

ARRANGEMENT FOR TYPE W17

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	1
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1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1
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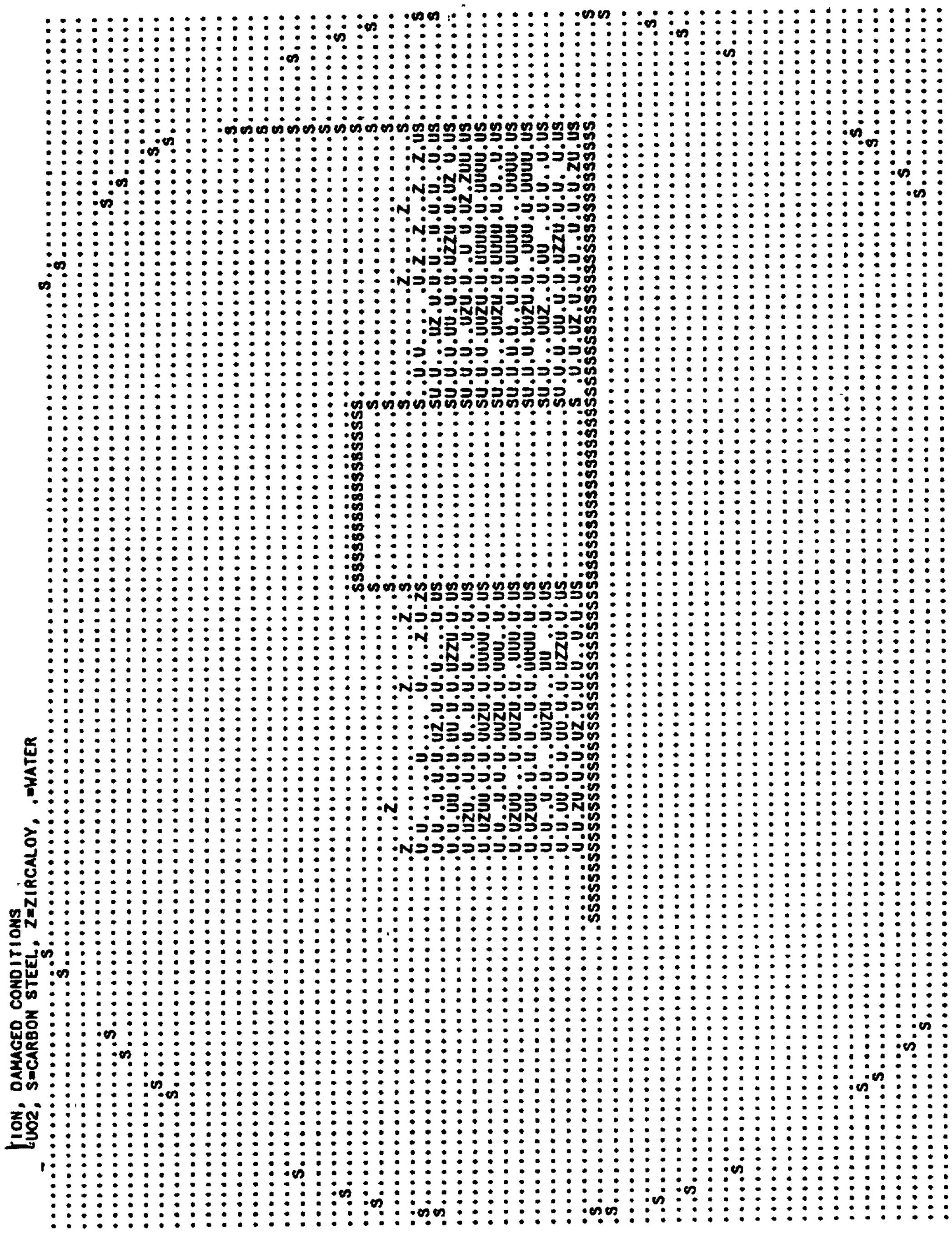
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

KEY: 1=FUEL, 0=WATER ROD

FIGURE 11.3



YX SECTION, DAMAGED CONDITIONS, DETAIL
KEY: U=UO2, S=CARBON STEEL, Z=ZIRCALOY, .=WATER

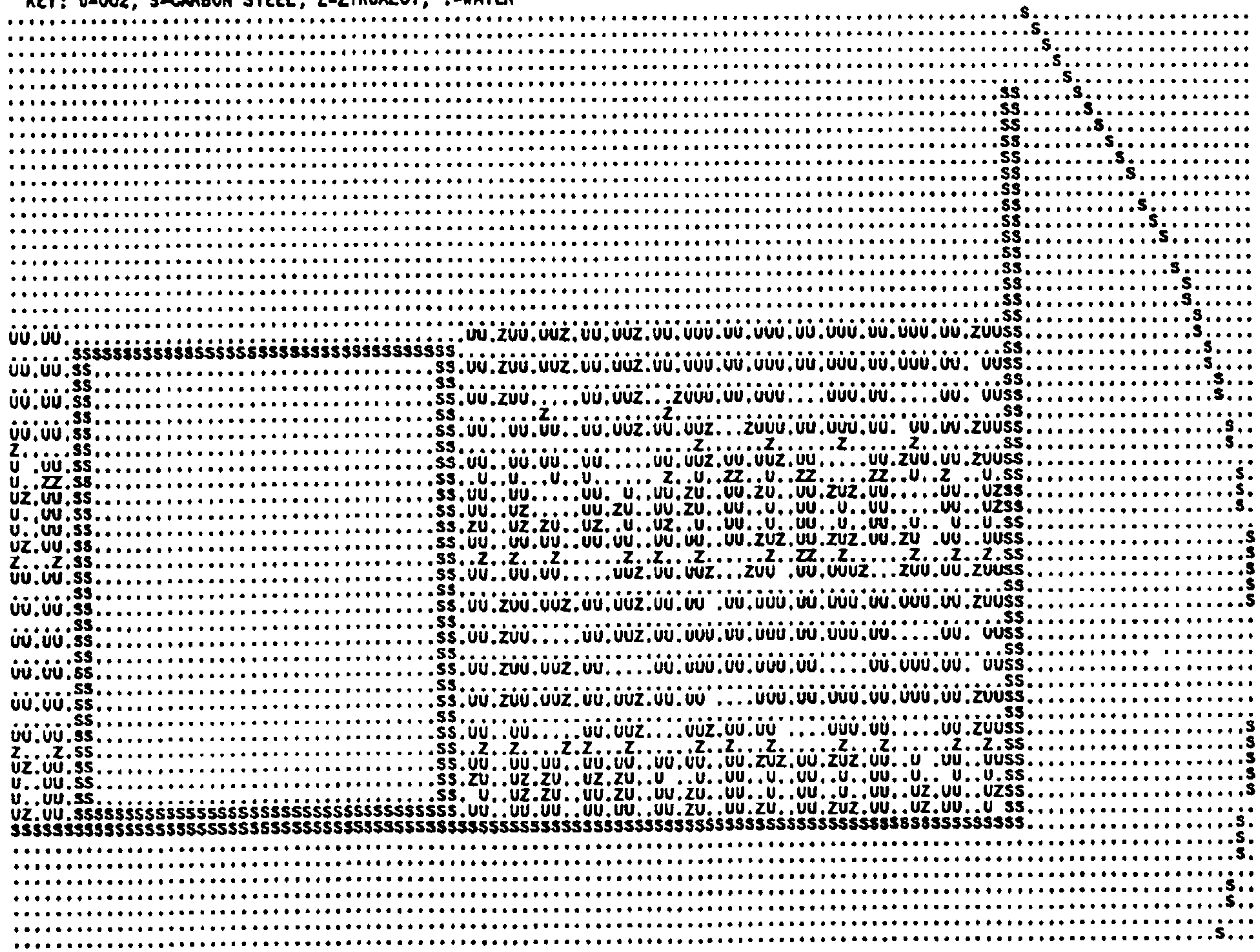


FIGURE 11.4

12 References

1. CONF-710801 (Volume 2) Health and Safety (TID-4500), "Proceedings, Third International symposium, Packaging, and Transportation of Radioactive Materials," August 1971, pp. 873-885.
2. Exhibit P, "Application for Licensing of Combustion Engineering, Inc., Shipping Container Model 927A," July 3, 1969, License SNM-1067, Docket No. 70-1100.
3. Exhibit P (including Appendix P-1), "Application for Licensing of Combustion Engineering, Inc., Shipping Containers Models 927B and 927C," February 23, 1971, License SNM-1067, Docket No. 70-1100.
4. "Application for the Use of the 51032-1 Shipping Container for Transport of Radioactive Materials", August 6, 1998, Docket No. 71-9252.

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APPENDIX I

APPLIED DESIGN COMPANY, INC. LIFT EYE ANALYSIS

APPLIED DESIGN COMPANY, INC.

CERTIFICATE OF COMPLIANCE

This will certify that the lift eyes on the cover of the Model 51032-1 Container are satisfactory for lifting the complete loaded container with a maximum weight of 6800 pounds using a four part sling with a maximum included angle between legs of 120 degrees.

This certification is based on the attached analysis. Test data are not available for a container weight of 6800 pounds.

W. J. Gowans

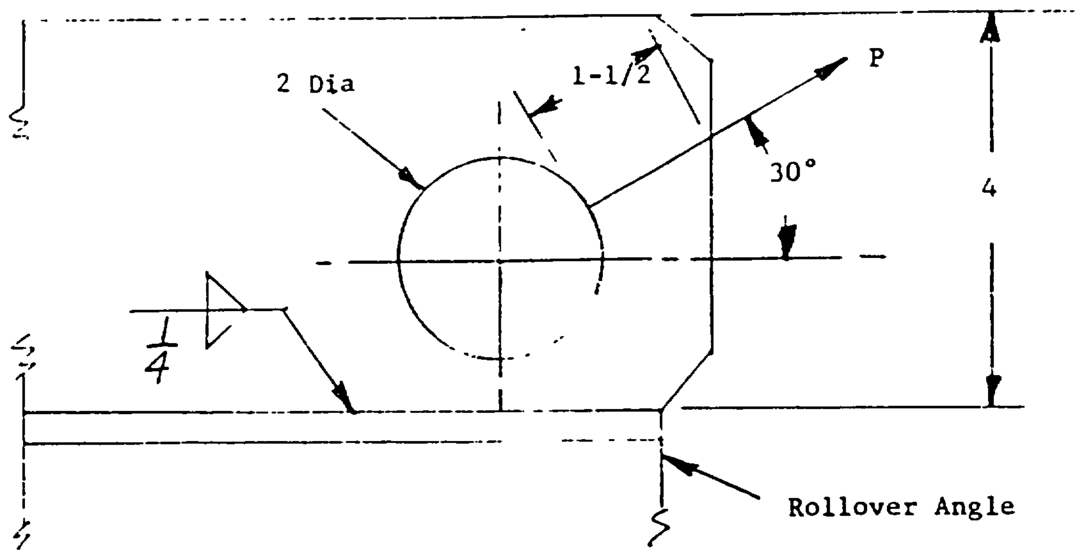
June 7, 1972

2465 SHERIDAN DRIVE • TONAWANDA, NEW YORK 14150 • TELEPHONE (716) 837-4400

JOB/EST. No. 2607-1 PAGE 1

TITLE Model 51032-1 Lift Eye Analysis DATE 6-7-72

BY WJG



Lift eye material: .375 thick ASTM A 283 Grade D
Minimum Yield Strength = 33,000 psi

Determine Load (P)

Container loaded weight = 6800 pounds
Assume that each of the four lift eyes carry equal load

Then $P = \frac{6800}{4 \sin 30^\circ} = 3400$ pounds

Investigate Lift Eye

Tensile area = .375 x 2 = .75 In^2

$Stress = \frac{P}{A} = \frac{3400}{.75} = 4500$ psi

$Factor\ of\ Safety = \frac{33,000}{4500} = 7$

Shear area = .375 x 1.5 = .562 In^2

$Stress = \frac{P}{A} = \frac{3400}{.562} = 6000$ psi

$Factor\ of\ Safety = \frac{33,000}{6000} = 5.5$

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2465 SHERIDAN DRIVE
TONAWANDA, NEW YORK

CALCULATION SHEET

JOB/EST. No. 2607-1

DATE 6-7-72

TITLE Model 51032-1 Lift Eye Analysis

BY WJG

Investigate weld

Assume that all of the load is carried by the lift eye to rollover angle weld.

Length 7 inches Size: 1/4 inch fillet

Assume conservatively that the weld will carry 2000 pounds per linear inch

capacity = 7 x 2000 = 14,000 pounds

factor of safety = $\frac{14,000}{3400} = 4$

Assume that all of this load is carried by the rollover to shell weld

Length = $\left(\frac{38\pi}{2} - 6\right) \times \frac{2.5}{4}$ = 34 inches

Size: 1/8 inch fillet - assume conservatively 1000 pounds per linear inch

Capacity = 34 x 1000 = 34,000 pounds

Factor of safety = $\frac{34,000}{3400} = 10$

Note that increasing the total weight of the package to 8300 pounds decreases the lowest factor of safety to ∿ 3.37 from ∿ 4.11. Thus, the lift eyes on the cover of the Model 51032-1 and 51032-1a shipping containers continue to be safisfactory for lifting the entire loaded package of total weight up to 8300 pounds, under the restrictions mentioned above.

APPENDIX II

STRUCTURAL ANALYSIS OF MODEL 51032-1

PACKAGING TIE-DOWN SYSTEM

APPENDIX II

Structural Analysis of Model 51032-1 Packaging Tie-Down System

Purpose

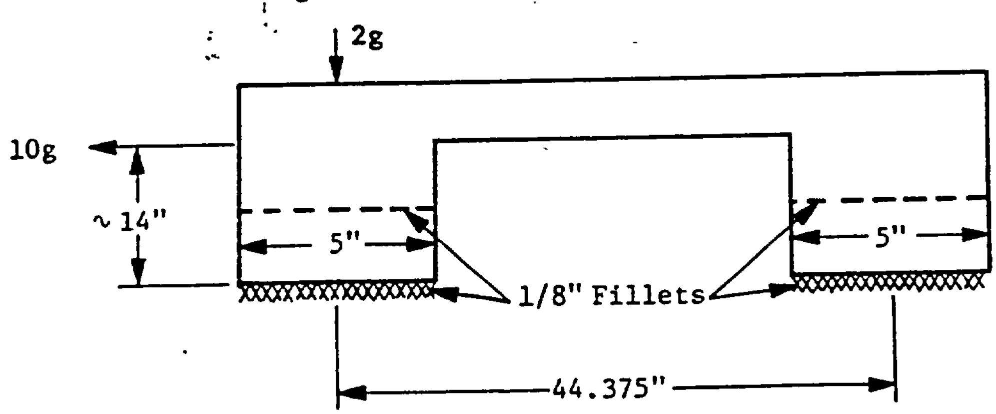
Assure that the Model 51032-1 packaging stacking brackets have adequate structural integrity for use in a tie-down system.

Criteria

The brackets and welds must not yield under a load applied to the package center of gravity having a vertical component of 2 g's, a horizontal component in the direction of vehicle travel of 10 g's, and a transverse horizontal component of 5 g's.

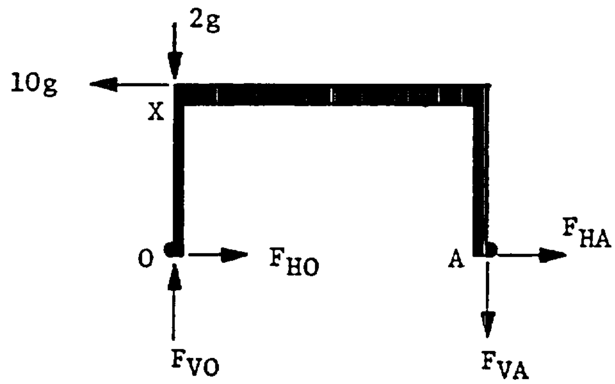
Assumptions

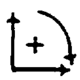
1. Maximum gross weight of package: 7400 pounds.
2. Stacking bracket dimensions as specified on ADC Drawing Nos. 51032-1-003 and 51032-1-161.
3. Adequate shoring and system of cross chokers will be employed (not attached to the stacking brackets) to accommodate any transverse loading.
4. That while local yielding might occur at the point of choker attachment, the weld connection between stacking bracket and containment vessel shell is most susceptible to yield.
5. All vertical and horizontal (except transverse) loading is carried by the stacking bracket (actually, positioning studs, cross chokers and friction loading will reduce the loading on the stacking brackets) as shown in the diagram below.



Analysis

Constructing a free-body diagram of a loaded stacking bracket as shown below:



where:  = sign convention,

$\Sigma F_X = 0,$

$\therefore F_{HO} + F_{HA} = 74{,}000$ lb. (a)

$\Sigma F_Y = 0,$

$\therefore F_{VO} - F_{VA} = 14{,}800$ lb. (b)

$\Sigma M_O = 0,$

$\therefore F_{VA} = 23{,}346.5$ lb. (c)

Substituting (c) into (b) . . . .

$F_{VO} = 23{,}346.5 + 14{,}800 = 38{,}146.5$ lb.

To analyze the end where the chokers are attached (max. S):

$$S = \frac{F_{VO}}{(\cos 45°)(b)(L)} , \qquad (1)$$

where: S = normal stress (psi)

F_{VO} = force in the vertical direction (38,146.5 lb.)

b = weld leg width (0.125 in.)

L = weld leg length (10 in.)

$\therefore$ S = 43,163 psi.

Also, $S_s = \frac{F_{HO}}{(\cos 45°)(b)(L)}$, (2)

where: S_s = shear stress (psi)

F_{HO} = shear force (74,000 #/2 = 37,000 lb)

$\therefore$ S_s = 41,867 psi.

Applying the maximum shear stress theory:

$$\tau = \left[(S_s)^2 + (S/2)^2\right]^{\frac{1}{2}},$$

where: τ = maximum shear stress (psi) (3)

$\therefore$ τ = 47,100 psi if only one stacking bracket were used, or 23,550 psi if two stacking brackets were used as the tie down system.

The yield stress ($S_{y-min.}$) for mild steel coated electrodes, as welded, is 42,000 psi[1], and for shear $S_{\sigma y-min.}$ = 0.6(42,000) = 25,200 psi.

Conclusion

Two chokers must be attached to two separate stacking brackets on each package to assure protection against yielding under the assumed loading.

The minimum "tie-down" requirements for Model 51032-1 packages are shown in Drawing No. JN-300,608, Rev. ~~1~~. 3

[1] Churchill & Austin, Weld Design, Prentice Hall.

APPENDIX III

APPLIED DESIGN COMPANY, IN.

REPORT 2526A

Report No. 2526A
Engineering Analysis
for
Shipping and Storage Container
for
Fuel Assembly
for
Jersey Nuclear Company
Richland, Washington

APPLIED DESIGN COMPANY, INC.
Tonawanda, New York 14150

September 17, 1971

Report No. 2526A
Engineering Analysis
for
Shipping and Storage Container
for
Fuel Assembly
for
Jersey Nuclear Company
Richland, Washington

Jersey Nuclear Company Purchase Order No. R985 is dated July 8, 1971 and is placed on Applied Design Company. This purchase order covers the design, fabrication and test of Fuel Assembly Shipping Containers in accordance with Jersey Nuclear Purchase Specification JNPS-7 which is dated June 28, 1971.

A portion of this purchase order covers the supply of data which is necessary to obtain a license from the Atomic Energy Commission and the Department of Transportation. It is the purpose of this engineering analysis to supply this data.

SUMMARY:

This engineering analysis proves that the container is equal to or greater in strength than two similar containers which have been previously licensed. Accordingly, it is concluded that this container includes the required structural integrity to be qualified as a licensed container.

DISCUSSION:

This analysis compares the structural capability of Applied Design Company (ADC) Model 51032-1 Container with ADC Models 927A and 927C Containers.

ADC Model 927A Container satisfactorily passed the applicable AEC tests and is licensed. Special Permit No. 6078 is assigned to this container. The Model 927A was designed to carry the Palisades Fuel Assembly.

ADC Model 927C Container is also licensed. Special Permit No. 6078 Revision 1 is assigned. The Model 927C is a modification of the Model 927A and is 28-inches longer. There are other structural differences that will be discussed later. This container is designed to carry two fuel assemblies that are slightly heavier than the maximum weight listed in Specification JNPS-7.

The design of ADC Model 51032-1 Container is based on the Model 927C Container. Only those changes were made that were necessary to meet

the requirements of Specification JNPS-7. Each load carrying member of the container is discussed in the following paragraphs.

The external container is identical to the Model 927C Container. There are no structural changes. The capability of the container structure was proven by test of the Model 927A Container.

The elastic suspension is identical to the Model 927C Container. There are 14 mounts in the Models 51032-1 and 927C Container, 12 in the Model 927A Container. The addition of one pair of mounts maintains the same mount spacing in all three containers. Structural components of the suspension system including mount brackets, mounts and support tubes are identical to the Model 927C Container. The load on each mount is maintained at a nearly constant level by varying the number of mounts in accordance with the weight of the lading. The actual static load imposed on each mount is shown in the calculations in Appendix I.

The strongback structure is identical to the Model 927C strongback except for the addition of holes and slots to permit positioning of support pads and separators. This strongback is substantially stronger and stiffer than the strongback that was tested in the Model 927A Container. The strongback consists of one formed piece of metal with the same stiffening angles as were used on the Model 927A strongback. The Model 927A strongback consisted of two formed side rails welded to the stiffening angles. The lading was supported on a separate structure bolted to the stiffening angles.

The end thrust brackets are similar to the thrust brackets in the Models 927A and 927C Containers. The section modulus is greater as is shown by the calculations in Appendix I. Attachment of the brackets to the strongback is identical to the Models 927A and 927C Containers.

The section modulus of the center thrust bracket is approximately equal to the thrust brackets in the Models 927A and 927C Containers, although maximum load imposed on this bracket is only one-third of that imposed on the end brackets. Strength of attachment bolts is approximately 40% of the end thrust brackets. This results in a reduced stress in the attachment bolts which is approximately 82.5% of the end bracket bolts.

Clamp assemblies that retain the two large fuel assemblies are identical to the clamp assemblies in the Models 927A and 927C

Containers. This clamp assembly was modified to accommodate the smaller fuel assemblies: An extension was added to the fixed portion of the assembly and a smaller adjustable clamp was designed. This provides a structure that is substantially equal to the clamps for the large fuel assemblies while the maximum load imposed is less than one-half of that incurred in the large fuel assembly clamps.

The separators are identical to those in the Model 927C Container except for length. The separators in this container are longer to permit longitudinal adjustment. Attachment of the separators to the strongback is identical to the Model 927C Container.

Total length of separators is 76.5 inches, an increase of 27 per cent over total separator length in the Model 927C Container. This increases the amount of structure available for the containment of the fuel assemblies during any sidewise loading which might be imposed. The strongback is designed such that the separators can be arranged to limit the distance between any adjacent separator to a maximum of 14-inches.

APPLIED DESIGN COMPANY, INC.
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CALCULATION SHEET

JOB LIST. No. 2526-1

PAGE 1

TITLE Appendix I to Engineering Analysis for Jersey Nuclear Company

DATE 2-31-71

BY NJG

Weight on Shock Mounts

Assembly	Weight	Qty	Suspended Weight	No. of Mounts	Weight per Mount
CY	1400	2	4000	14	285
Pol	1350	2	3900	14	279
BR	480	4	3120	12	260
BR	480	2	2160	8	270
OC	680	2	2560	10	256
HB	225	2	1650	6	275

Strongback weight ≈ 1200 pounds

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CALCULATION SHEET

III-6 XN-52, Rev. 1

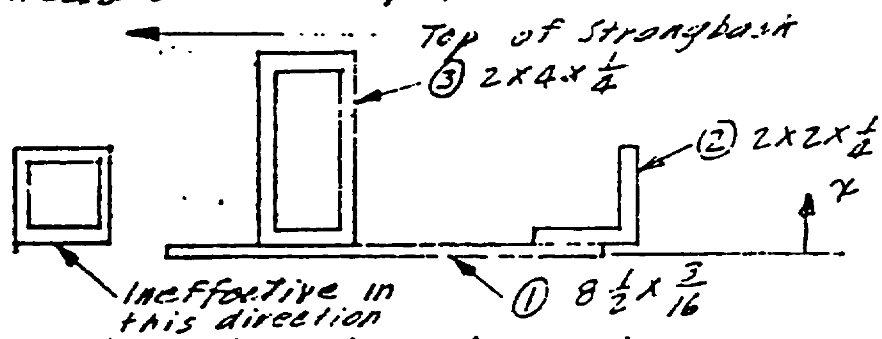
JOB EST. No. 2526-1 PAGE 2

TITLE Appendix I to Engineering Analysis for Jersey Nuclear Company DATE 8-31-71

BY WJG

Compare Thrust Bracket Section Moduli

Models 927A & 927C



Elem	A	x	Ax	Ax²	ΔIx
1	1.59	.09	.14	.01	—
2	.94	.78	.73	.57	.35
3	2.75	2.19	6.02	11.00	5.37
Σ	5.28		6.89	11.58	5.72

$\bar{x} = \frac{\Sigma Ax}{\Sigma A} = \frac{6.89}{5.28} = 1.3$ IN. $c = 4.19 - 1.3 = 2.89$ IN.

$I_x = \Sigma \Delta I_x + \Sigma Ax^2 - \Sigma A \times \bar{x}^2$

$= 5.72 + 11.58 - 5.28 \times 1.3^2$

$= 8.36$ IN.^{4}

$Z_x = \frac{I}{c} = \frac{8.36}{2.89} = 2.9$ IN.^{3}

APPLIED DESIGN COMPANY, INC.
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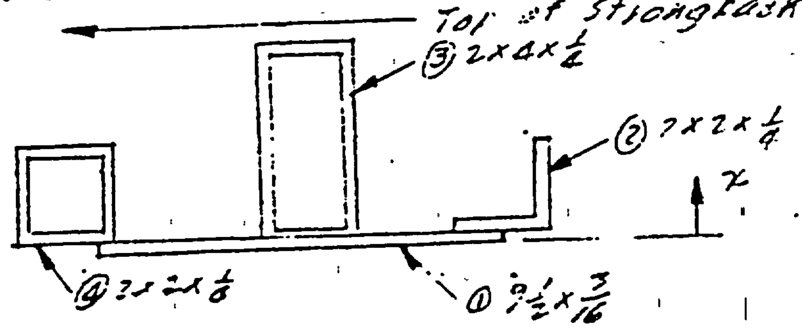
CALCULATION SHEET

JOB / EST. No. 2526-1
PAGE 3
DATE 8-31-71
TITLE Appendix I to Engineering Analysis for Jersey Nuclear Company
BY [illegible]

Model 51032-1 End Thrust Brackets



Elem	A	x	Ax	Ax²	AI_x
1	1.78	.09	.16	.01	—
2	.94	.78	.73	.57	.35
3	2.75	2.19	6.02	13.15	5.37
4	1.75	1.19	2.08	2.48	.91
Σ	7.22		8.99	16.21	6.63

$$\bar{x} = \frac{\Sigma Ax}{\Sigma A} = \frac{8.99}{7.22} = 1.24 \text{ IN.} \qquad C = 4.19 - 1.24 = 2.95 \text{ IN.}$$

$$I_x = \Sigma AI_x + \Sigma Ax^2 - \Sigma A \times \bar{x}^2$$

$$= 6.63 + 16.21 - 7.22 \times 1.24^2$$

$$= 11.74 \text{ IN.}^4$$

$$Z_x = \frac{I}{C} = \frac{11.74}{2.95} = 3.98 \text{ IN.}^3$$

$$\text{Increase}(Z_x) = \frac{3.98 - 2.9}{2.9} \times 100 = 37\%$$

APPLIED DESIGN COMPANY, INC.
2465 SHERIDAN DRIVE
TONAWANDA, NEW YORK

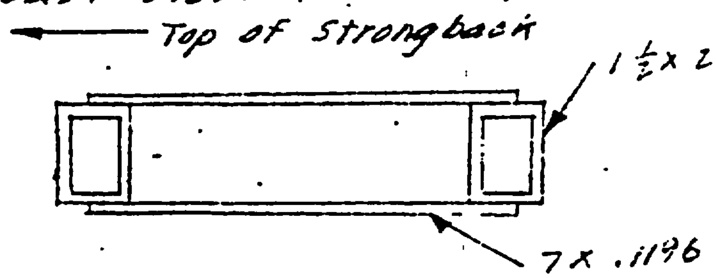
CALCULATION SHEET

JOB/EST. No. 2526-1 PAGE 4

TITLE Appendix I to Engineering Analysis for Jersey Nuclear Company DATE 8-31-71

BY W.J.E.

Model 51032-1 Center Thrust Bracket



$I_{Tubes} = \frac{2}{12}(1.5 \times 2^3 - 1 \times 1.5^3) = 1.44$

$I_{Plates} = 2 \times .875 \times 1.06^2 = 1.97$

$I = 1.44 + 1.97 = 3.41 \ in.^4$

$Z = \frac{I}{C} = \frac{3.41}{1.12} = 3.36 \ in.^3$

Increase $= \frac{3.36 - 2.9}{2.9}$ [illegible] $= \underline{16\%}$

APPENDIX IV

30-FOOT DROP TEST PROCEDURE AND REPORT

PACKAGING MODEL 51032-1

JERSEY NUCLEAR COMPANY

SHIPPING CONTAINER MODEL No. 51032-1

30-FOOT DROP TESTS PROCEDURE

Procedure Prepared By ____ 9/21/72

Instrumentation ____ 9-28-72

Structural ____ 9/27/72

Procedure Approved By

____ 9-28-72
Manager, Materials

____
Manager, Projects

____
Manager Quality Assurance & Licensing

____
Manager, Manufacturing

JERSEY NUCLEAR SHIPPING CONTAINER MODEL No. 51032-1
30-FOOT DROP TEST PROCEDURE

TEST REQUIREMENTS

It has been determined that in order to obtain a shipping license for Jersey Nuclear fuel assemblies, using the Jersey Nuclear Shipping Container Model No. 51032-1, additional testing of the container will be required. AEC Regulations 10 CFR 71 Appendix B states in part "A free drop through a distance of 30 feet onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected." In order to fully satisfy this regulation, two, and preferably three, separate drop tests will be conducted.

It is Jersey Nuclear's understanding that the remaining tests required for the container are the 30 foot drop tests, and that all other tests required by the AEC Regulations have previously been satisfied.

OBJECTIVE

The objective of this test procedure is to provide a step-by-step sequence of events to be followed in conducting the AEC required tests on the Jersey Nuclear Shipping Container, see attached drawing JN-20001. The test will consist of two, and preferably three, separate tests, using the same container with a 3,306 pound pay load from an elevation of 30 feet. The first drop will be with the longitudinal axis in a horizontal plane and the package so positioned that the container will impact on the cover, see attached drawing JN-600,864 "Drop Test #1." The second drop will be with the longitudinal axis in a vertical plane and the package so positioned that the container will strike the forward end, see attached drawing JN-600,864

"Drop Test #2." The third drop, if conducted, will be with the longitudinal axis at a 75° angle from the horizontal so positioned that the container will strike the top corner of the cover, see attached drawing JN-600,864 "Drop Test #3."

SITE PREPARATION

Agreement has been reached with Donald Douglas Labs to use an existing concrete slab that is located on Douglas property just east of the J.A. Jones facilities in North Richland.

1. In order to accurately determine the thickness of the existing slab, small diameter holes shall be drilled in the area of the test position. After the slab thickness has been determined, H. P. Estey will determine the acceptability of the slab.
2. After the slab has been accepted, five (5) 4' x 8' x ½" steel plates shall be installed as a cover for the concrete. The plates shall be butt welded together, with skip welds, to form a pad 20' x 8' x ½". The plate shall be anchored to the concrete pad using 3/4" Philips "Red Head" bolts on 4' centers around the outside edge.

SIMULATED FUEL BUNDLES

Two simulated fuel bundles, as shown in the attached drawing JN-600,860 shall be fabricated and installed in the shipping container. The simulated fuel bundles are representative of the heaviest fuel bundles that Jersey Nuclear anticipates being shipped for several years. (Net weight of the two simulated bundles = 3300 pounds; Gross weight of package = 7300 pounds.)

DROP TESTS

The actual test shall consist of two, and perferably three, separate drops: (1) Horizontal Position, (2) Vertical Position, and (3) 75° Angle Position.

1. Horizontal Position Test

The first drop shall be with the longitudinal axis of the container in the horizontal plane. The container shall be so positioned that it will strike the top cover upon impact. See attached drawing JN-600,864 "Drop Test #1."

Three accelerometers shall be used for this test. One shall be placed on the strongback inside the container and two on the outer shell, so positioned that they will be on the upper portion of the shell when the container is dropped. See attached drawing JN-20002 for positioning of the accelerometers. The Jersey Nuclear Mobile Instrumentation van will be used to provide the necessary recording instruments to obtain time versus acceleration charts for the test. Two types of accelerometers will be used in the drop test; specifically unbonded strain gage and piezoelectric crystal. The unbonded strain gage accelerometers are Statham Instrument Co., Model A5, oil filled and have a natural resonant frequency of about 1300 Hz, and a damping of 0.7, which provide a frequency flat to about 1000 Hz. The crystal accelerometers are PCB Piezotronics Inc., Model 302A, and have a mounted resonant frequency in excess of 30,000 Hz, with a usable frequency response from 1 Hz to 5000 Hz. The range of the accelerometers vary from ± 200g to ± 500g.

Prior to the placement of the cover on the container, the relative position of the simulated fuel bundles shall be measured and recorded.

Dimensions between each bundle and the dimensions between the strongback and the outer container shall be recorded. These same dimensions shall be measured after the test and included in the test report.

After all instrumentation is checked out and after it has been verified that all interested parties are present, the container shall be hoisted directly over the steel pad to an elevation of 30 feet, as measured from the lowest portion of the suspended container. Sufficient guy lines shall be attached to adequately control the sway of the suspended load. Upon a signal from the test director, the quick release devise shall be actuated and the load allowed to fall onto the steel pad.

After this drop, the cover shall be removed and all components examined very closely. Particular attention shall be paid to all structural welds. Photographs shall be taken as necessary to record the condition of the container, particularly the indentation and collapse of cover. Sufficient measurement shall be taken to compute distance to wall from fuel bundle. The instrumentation charts shall be reviewed and verification received that adequate data was obtained from the accelerometers.

At this point a determination will be made as to the advisability of using this container for the second test or whether it would be advisable to use a second container for the second drop test.

2. Vertical Position Test

The second drop test shall be with the longitudinal axis of the container in a vertical plane. The container shall be so positioned that it will strike on the forward end. See attached drawing JN-600,864 "Drop Test #2."

Three accelerometers shall be used for this test. One shall be placed on the forward end of the strongback inside the container and

two on the outer shell - one on the end of the container away from the impact area and one on the outer shell of the cover. See attached drawing JN-20002 for positioning of the accelerometers. The Jersey Nuclear Mobile Instrumentation van will be used to provide the necessary instruments to obtain time versus acceleration charts for the test. The same accelerometers used for the horizontal test will be used for the vertical test.

Prior to the placement of the cover on the container, the relative position of the simulated fuel bundles shall be measured and recorded. Dimensions between each bundle and the dimensions between the strong-back adn the outer container shall be recorded. These same dimensions shall be measured after the test and included in the test report.

After all instrumentation is checked out and after it has been verified that all interested parties are present, the container shall be hoisted directly over the steel pad to an elevation of 30 feet, as measured from the lowest portion of the suspended container. Sufficient guy lines shall be attached to adequately control the sway of the suspended load. Upon a signal from the test director, the quick release devise shall be actuated and the load allowed to fall onto the steel pad.

After this drop, the cover shall be removed and all components examined very closely. Particular attention shall be paid to all structural welds, and the condition of the forward end thrust plate. Photographs shall be taken as necessary to record the condition of the container. The instrumentation charts shall be reviewed and verification received that adequate data was obtained from the accelerometers.

At this point a determination will be made as to the advisability of using this container for the third test. The third drop test is a

desirable test but not mandatory; therefore, a third container will not be utilized for the third test. If the same container was used for the first two tests, it shall be used for the third test. If a different container was used for each of the first two tests, the best of these containers shall be used for the third test.

3. 75° Position Test

The third drop test shall be with the longitudinal axis of the container at a 75° angle from the horizontal. The container shall be positioned that it will strike on the top corner of the cover. See attached drawing JN-600,864 "Drop Test #3."

Three accelerometers shall be used for this test. One shall be placed on the forward end of the strongback inside the container and two on the outer shell - one on the lower shell and one on the cover. The Jersey Nuclear Mobile Instrumentation van will be used to provide the necessary instruments to obtain time versus acceleration charts for the test. The same accelerometers used for the first two tests will be used for this test.

Prior to the placement of the cover on the container, the relative position of the simulated fuel bundles shall be measured and recorded. Dimensions between each bundle and the dimensions between the strong-back and the outer container should be recorded. These same dimensions shall be measured after the test and included in the test report.

After all instrumentation is checked out and after it has been verified that all interested parties are present, the container shall be hoisted directly over the steel pad to an elevation of 30 feet, as measured from the lowest portion of the suspended container. Sufficient

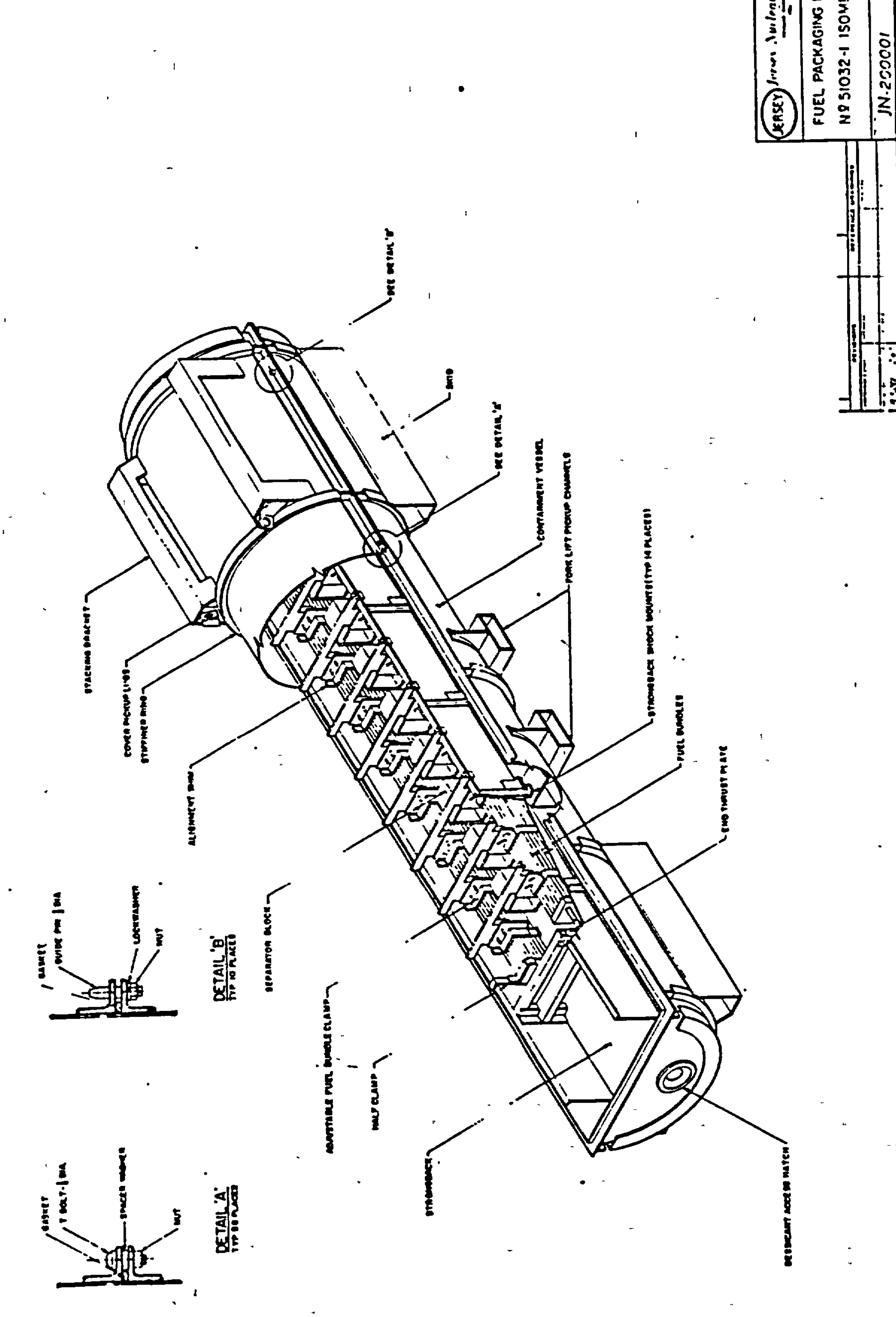
guy lines shall be attached to adequately control the sway of the suspended load. Upon a signal from the test director the quick release devise shall be actuated and the load allowed to fall onto the steel pad.

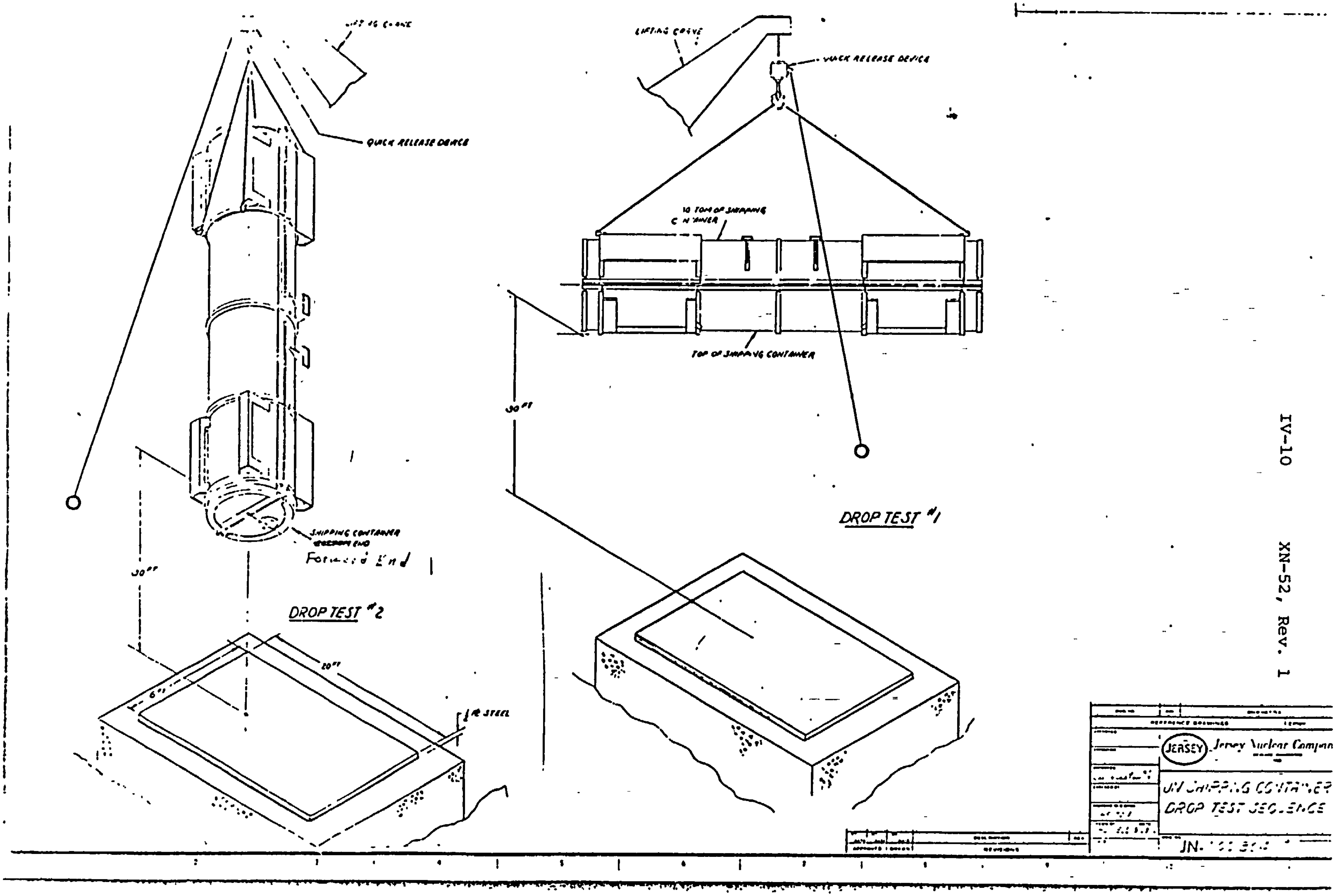
After this drop, the cover shall be removed and all components examined very closely. The primary purpose of this third test is to test the closure bolts, therefore, particular attention should be paid in the examination of the closure bolts after this drop. Photographs shall be taken as necessary to record the condition of the container and the closure bolts. The instrumentation charts shall be reviewed and verification received that adequate data was obtained from the accelerometers.

TEST REPORT

At the conclusion of the two, and possibly three, drop tests, all data including photographs shall be accumulated and test report prepared by the test director. This test report will be turned over to the Jersey Nuclear QA & Licensing Personnel for further analysis and submission to the AEC. The test report shall include the following list of photographs.

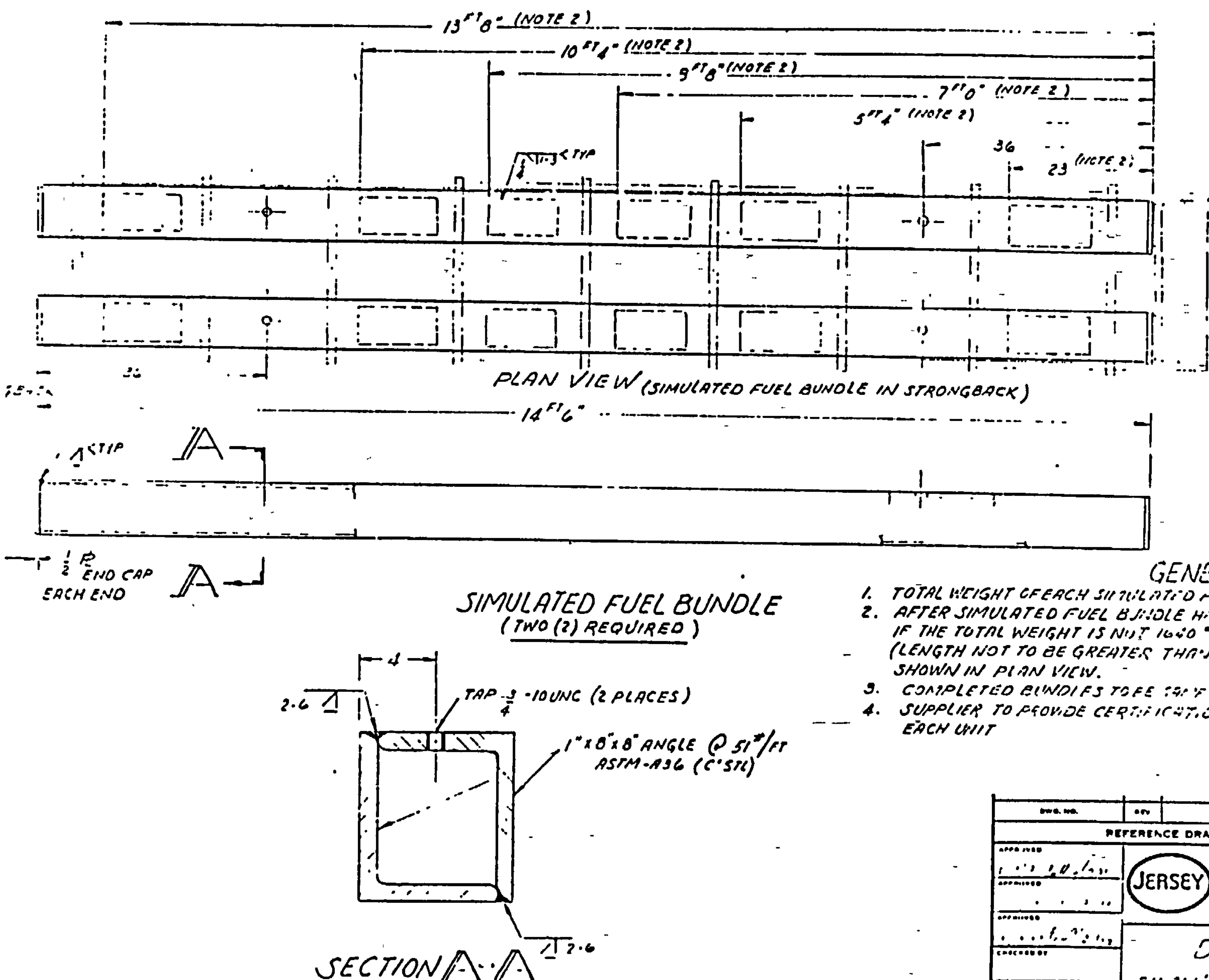
1. Dummie fuel in container - open container
2. Accelerometer attachments for each drop
3. Container suspended 30 feet -- for each drop
4. Post drop container condition for each drop


Jersey Nuclear Company
FUEL PACKAGING MODEL
Nº 51032-1 ISOMETRIC
JN-200001
SEE DETAIL 'B'
SEE DETAIL 'A'
CONTAINMENT VESSEL
FORK LIFT PICKUP CHANNELS
STRONGBACK SHOCK MOUNTS (TYP 14 PLACES)
FUEL BUNDLES
END THRUST PLATE
STACKING BRACKET
COVER PICKUP LUGS
STIFFENER RING
ALIGNMENT RING
SEPARATOR BLOCK
ADJUSTABLE FUEL BUNDLE CLAMP
HALF CLAMP
STRONGBACK
DESICCANT ACCESS HATCH
DETAIL 'B'
DETAIL 'A'
NUT



LIFTING CRANE
QUICK RELEASE DEVICE
TOP OF SHIPPING CONTAINER
30 FT
DROP TEST #1
SHIPPING CONTAINER
Forward End
30 FT
DROP TEST #2
20 FT
Jersey Nuclear Company
DROP TEST SEQUENCE

... G CONTAINER STRONGBACK



GENERAL NOTES:

1. TOTAL WEIGHT OF EACH SIMULATED FUEL B...
2. AFTER SIMULATED FUEL BUNDLE HAS BEEN ... IF THE TOTAL WEIGHT IS NOT 1640 # ADD ... (LENGTH NOT TO BE GREATER THAN 12 ... SHOWN IN PLAN VIEW.
3. COMPLETED BUNDLES TO BE ... WEIGHT ...
4. SUPPLIER TO PROVIDE CERTIFICATION ... EACH UNIT

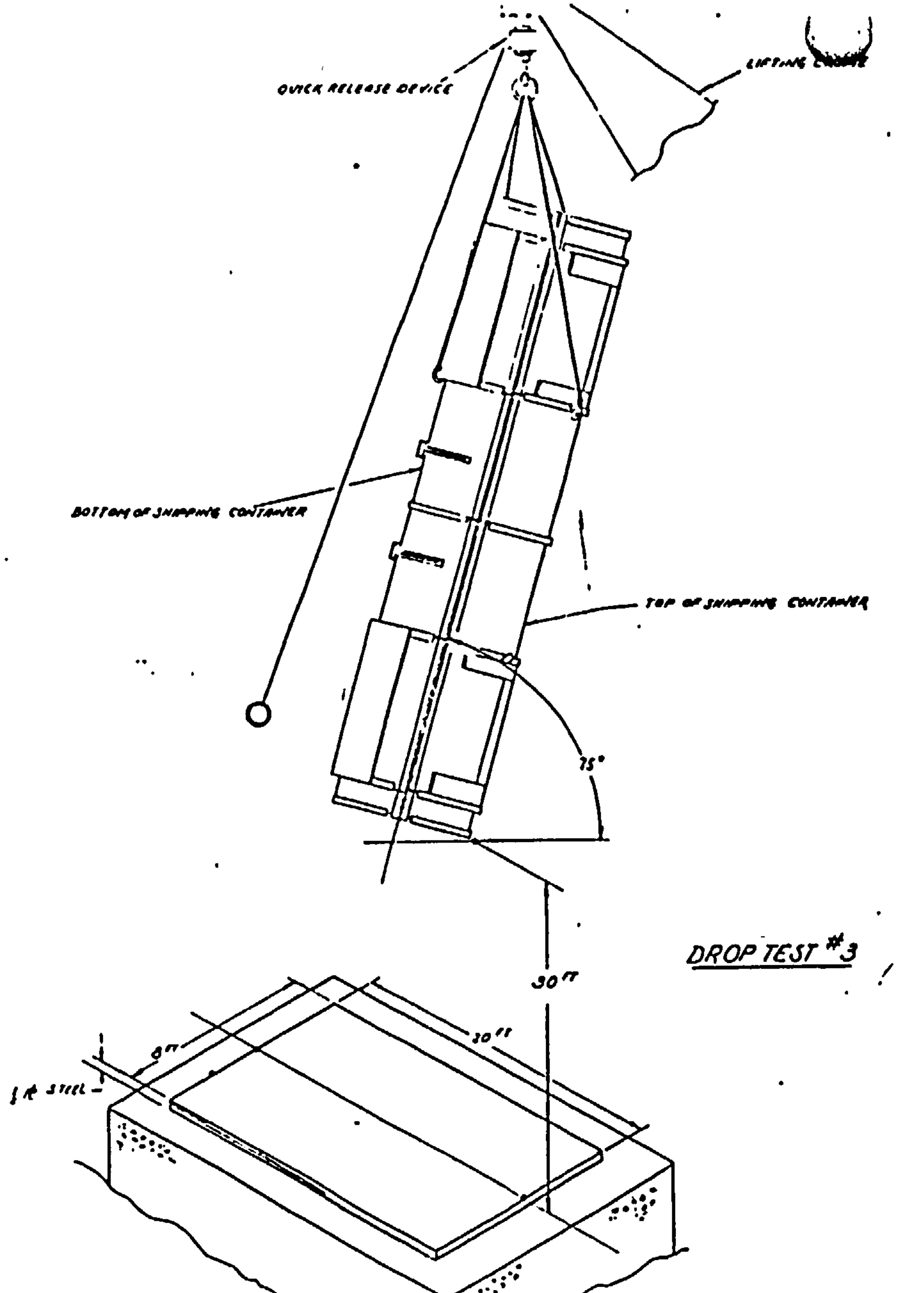
DWG. NO.	REV	DRAWING TITLE
REFERENCE DRAWINGS		

JERSEY — Jersey Nuclear Company

SIMULATED FUEL ...

DWG NO. JN-...

BY	BY	BY	DESCRIPTION	REV
APPROVED			REVISIONS	



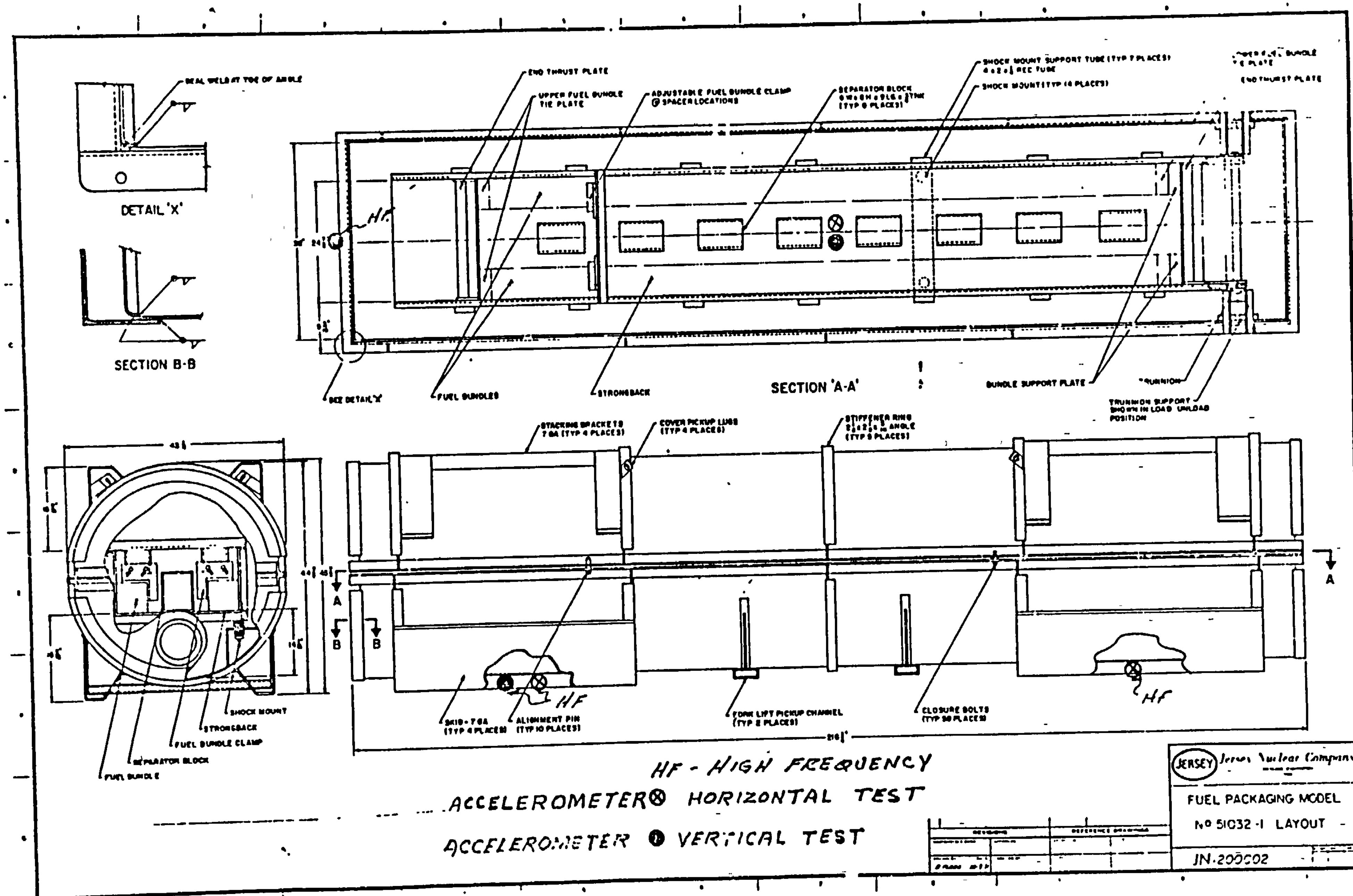
DROP TEST #3

Jersey Nuclear Comp

JN SHIPPING CONTAINE

DROP TEST SEQUENC

JN-599, 5:4


DETAIL 'X'
SECTION B-B
SECTION 'A-A'
END THRUST PLATE
UPPER FUEL BUNDLE TIE PLATE
ADJUSTABLE FUEL BUNDLE CLAMP @ SPACER LOCATIONS
SEPARATOR BLOCK
SHOCK MOUNT SUPPORT TUBE
SHOCK MOUNT (TYP 4 PLACES)
SEE DETAIL 'X'
FUEL BUNDLES
STRONGBACK
BUNDLE SUPPORT PLATE
TRUNNION
TRUNNION SUPPORT SHOWN IN LOAD UNLOAD POSITION
STACKING BRACKETS
COVER PICKUP LUGS (TYP 4 PLACES)
STIFFENER RING
SKID
ALIGNMENT PIN (TYP 10 PLACES)
FORK LIFT PICKUP CHANNEL (TYP 2 PLACES)
CLOSURE BOLTS
SHOCK MOUNT
STRONGBACK
FUEL BUNDLE CLAMP
SEPARATOR BLOCK
FUEL BUNDLE
HF
HF - HIGH FREQUENCY
ACCELEROMETER ⊗ HORIZONTAL TEST
ACCELEROMETER ● VERTICAL TEST
JERSEY Jersey Nuclear Company
FUEL PACKAGING MODEL
Nº 51032-1 LAYOUT
JN-200002

JERSEY NUCLEAR COMPANY, INC.

SHIPPING CONTAINER MODEL NUMBER 51032-1

30 FOOT DROP TEST REPORT

J. W. Helton
Projects Section
Jersey Nuclear Company

JERSEY NUCLEAR COMPANY
SHIPPING CONTAINER MODEL No. 51032-1
30 FOOT DROP TEST REPORT

GENERAL

On October 31, 1972 and November 1, 1972, Jersey Nuclear conducted three separate drop tests on their fuel shipping containers. One container was used for the horizontal test and a different container was used for both the vertical and the 75° test. All tests were conducted in strict compliance with the attached approved test procedure.

The gross weights of the various tests are shown below:

Horizontal Test:

Shipping Container	4,100 lbs.
Simulated Fuel	3,306
Brackets (8) C10 lbs.	80
	7,486 lbs.

Vertical Test:

Shipping Container	4,100 lbs.
Simulated Fuel	3,306
	7,406 lbs.

75° Test:

Shipping Container	4,100 lbs.
Simulated Fuel	3,306
Brackets (2) C10 lbs.	20
	7,426 lbs.

CONCLUSION

The shipping container successfully met the requirements of AEC 10 CFR 71 with regard to the "Free Drop" test.

TEST SITE

The test pad was prepared in strict compliance with the approved test procedure. Attached is a letter from H. P. Estey attesting to the acceptability of the test pad.

All three crops were conducted on the same pad and there were no signs of concrete cracking or spalling and the ½" steel plate remained undamaged throughout all tests.

SIMULATED FUEL BUNDLES

In accordance with the test procedure and Jersey Nuclear drawing JN-600,860, two simulated fuel bundles were fabricated by Metalfab, Inc. Attached is a letter of certification attesting to the fact that each bundle weighted 1,653 ± 2 pounds. The bundles were fabricated in fuel compliance with referenced drawing.

Jersey Nuclear Company
Internal Correspondence

IV-17

XN-52, Rev. 1

DATE October 3, 1972

TO J. W. Helton

FROM H. Paul Estey

SUBJECT Unyielding Surface for Transport Packaging Drop Test

REFERENCE:

I have surveyed the proposed drop site and have evaluated the adequacy of the concrete pad/steel plate arrangement as a suitable "essentially unyielding" surface.

The following data and information were used in the evaluation.

- Concrete Slab
  - 6 inches thick (based on 7 core drillings),
  - reinforcing steel,
  - 150 $\#/ft^3$
  - 30 x 50 foot continuous area,
  - total weight = 112,500 pounds;
- Steel Target Plate
  - 1/2 inch thick carbon steel,
  - 8 x 20 foot continuous area,
  - 486.75 $\#/ft^3$,
  - total weight = 3245 pounds,
  - steel plate redheaded to the concrete slab on 4 ft. centers around the perimeter of the plate.
- Minimum Mass of Target
  - $M_T = M_C + M_S$,

    $= 112{,}500 + 3245 = 115{,}745$ pounds
- Mass of Loaded Transport Package
  - $M_P = 7300$ pounds.

It is seen that the ratio of $M_T/M_P \approx 16$. IAEA defines an unyielding surface as $M_T/M_P \geq 10$. Therefore, it is concluded that the proposed concrete pad/steel plate arrangement is adequate.

HPE:jak

FABRICATION

STEEL SUPPLIES

Metalfab Inc. Steel

IV-18

ERECTION

CRANE SERVICE

XN-52, Rev. 1

• • • • TELEPHONE 967-2946 • • •
5302 W. VanGiesen • Richland, Wash. 99352

"Quality Products Built With Pride"

October 4, 1972

RECEIVED
OCT 11 1972
JJW. HELTON

Jersey Nuclear Company
2101 Horn Rapids Road
Richland, WA 99352

Gentlemen:

We hereby certify that we have witnessed the weighing of each fuel bundle made under your P. O. No. 15235. They each weigh 1,653 pounds, plus or minus 2 pounds.

Very truly yours,

METALFAB INC.

Herb Ganz
President

Witness

Witness

HORIZONTAL DROP TEST

The simulated fuel bundles were installed in shipping container number 6251. The container was selected completely at random by the test director from the storage area. All standard hardware (shock mounts, thrust plates, upper and lower tie plates, adjustable fuel bundle clamps, etc) were used. In addition to the nine standard fuel bundle clamps, eight additional clamps were installed. The additional clamps were not in contact with the fuel bundles but were clamped across the edges of the strong back to act as safety clamps in the event the adjustable fuel bundle clamps became loose. The accelerometer was installed on the strongback in accordance with the test procedure and then the top cover was installed.

On the afternoon of October 30, 1972, the loaded shipping container was transported to the test site. The rigging was adjusted for a true horizontal lift and the outside instrumentation was installed and checked out.

On the morning of October 31, 1972, the first drop test was conducted. The loaded fuel container was lifted 30 feet off the test pad and with the use of a quick release device, the load was instantaneously released and allowed to free fall the 30 feet to the test pad. As well as could be detected visually, the container struck the test pad on a perfectly horizontal plane. The container was then turned over on its bottom pads and the cover removed.

Interior examination revealed that the strong back remained totally inside the container and that the fuel elements remained totally inside the strong back. Almost all of the fuel bundle clamps showed pronounced bowing; however, only one clamp came completely loose. Most of the bolts attaching the strong back cross beam to the strong back failed allowing the strong back to contact the top cover. The outside of the container showed pronounced bowing since the stacking brackets struck the pad first. The center portion of the container bowed until it struck the pad.

Attached is a copy of several internal and external measurements taken both before and after the horizontal test. Also attached are several sequential photographs taken prior to, during and after the horizontal drop. Data strips which show the acceleration of the impact are also attached.

DATE .. SUBJECT CONTAINER DROP TEST SHEET NO. 1 OF 3

KD. BY .. DATE SPACING DIMENSIONS BEFORE JOB NO.

AND AFTER EACH DROP

HORIZONTAL TEST

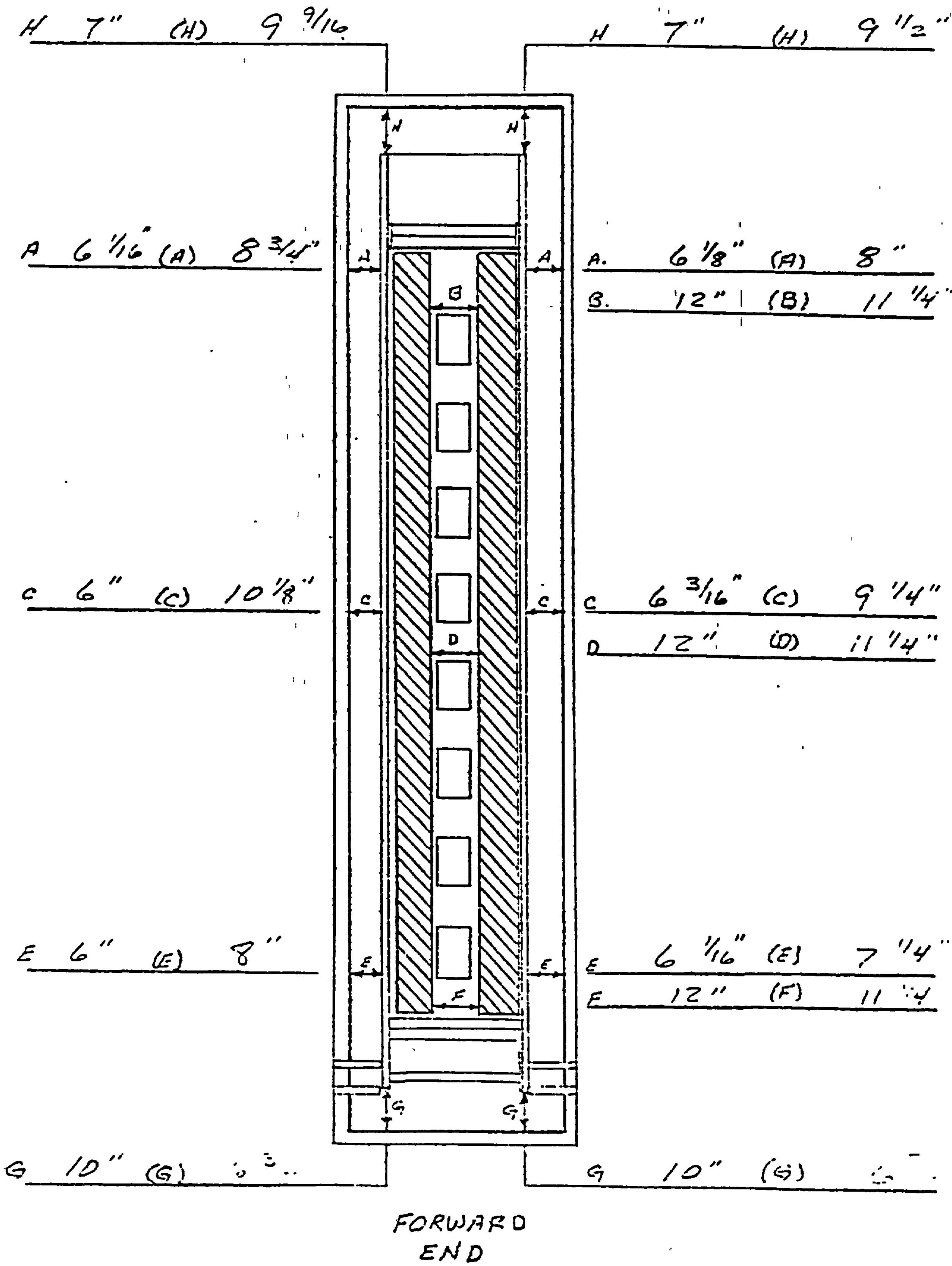
XN-52, Rev. 1

CONTAINER # 625

IV-20

A - BEFORE TEST

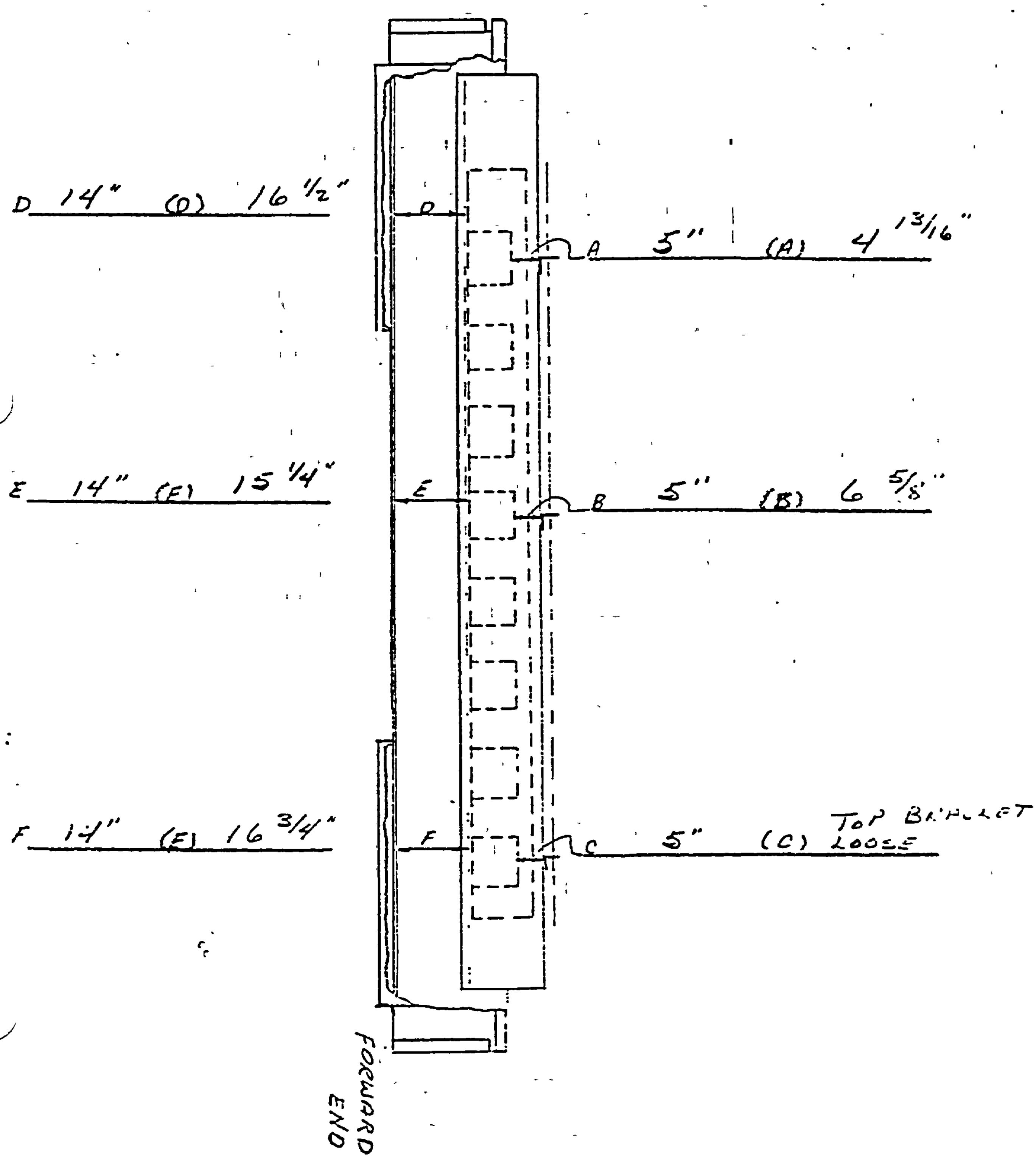
(A) - AFTER TEST



DATE	SUBJECT Container Drop Test	SHEET NO. 2 OF -
KD. BY DATE	Spacing Dimensions Before And After Each Drop. Horizontal Test	JOB NO.

XN-52, Rev. 1

IV-21



	DATE	SUBJECT CONTAINER DROP TEST	SHEET NO. 3 OF 3
KD. BY	DATE	OUTER DIMENSIONS BEFORE AND AFTER EACH DROP HORIZONTAL TEST	JOB NO.

XN-52, Rev. 1

IV-22

AFTER TEST

FORWARD END

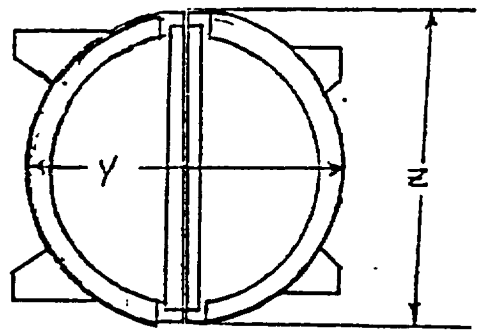
(Y) 40 7/16"

(Z) 41 15/16"

REAR END

(Y) 40 3/8"

(Z) 41 7/8"



BEFORE TEST

FORWARD END

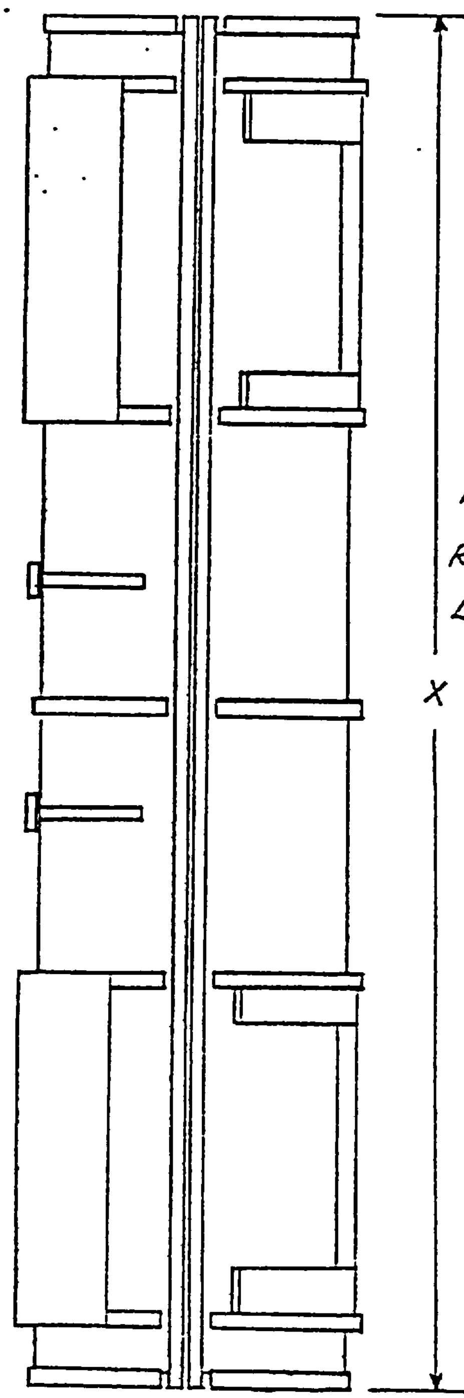
Y 40 1/8"

Z 41 7/8"

REAR END

Y 40 1/4"

Z 41 7/8"



(X) DIMENSIONS

(TOP) 17' 11 7/8"

(BOTTOM) 17' 10 5/8"

(RIGHT) 17' 11 1/8"

(LEFT) 17' 11 1/2"

"X" DIMENSIONS

TOP 18' 1 1/2"

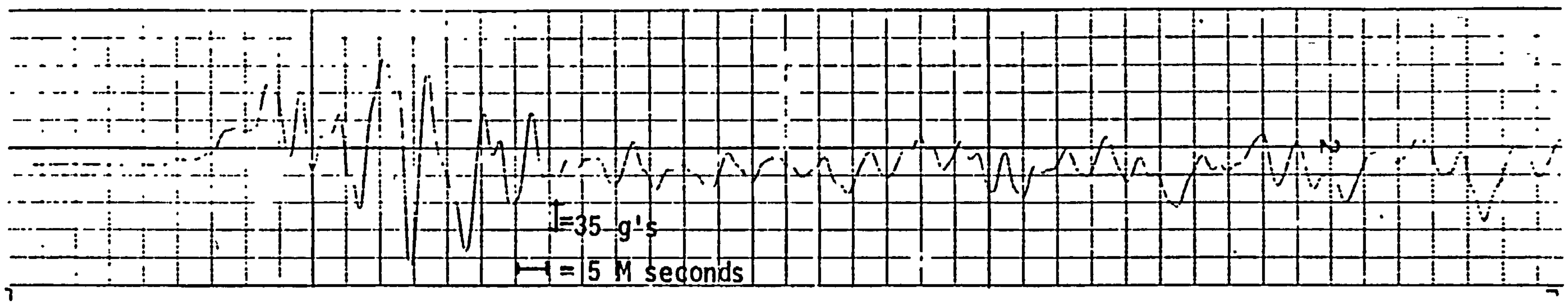
BOTTOM 18' 5/8"

RIGHT SIDE 17' 11 1/8"

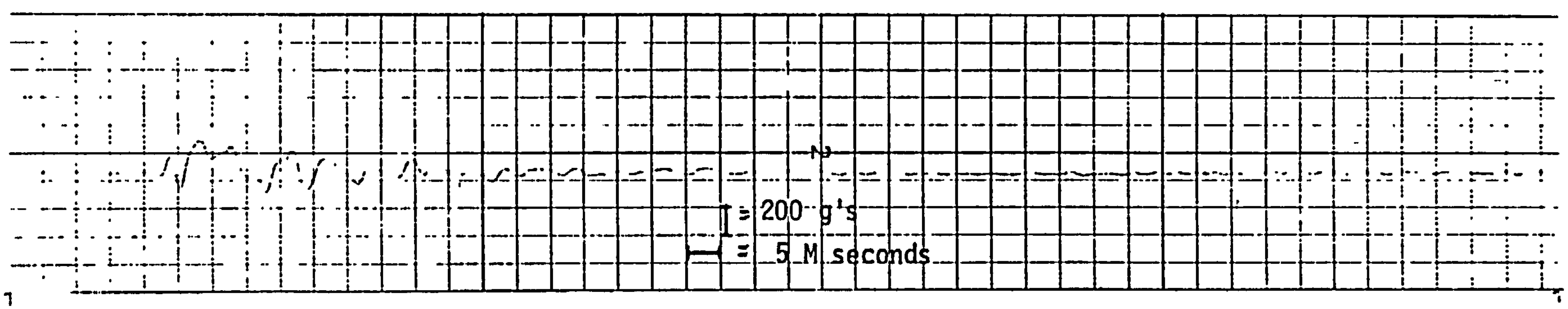
LEFT SIDE 17' 11 1/4"

JERSEY NUCLEAR SHIPPING CONT[illegible] - 30 FOOT DROP TEST

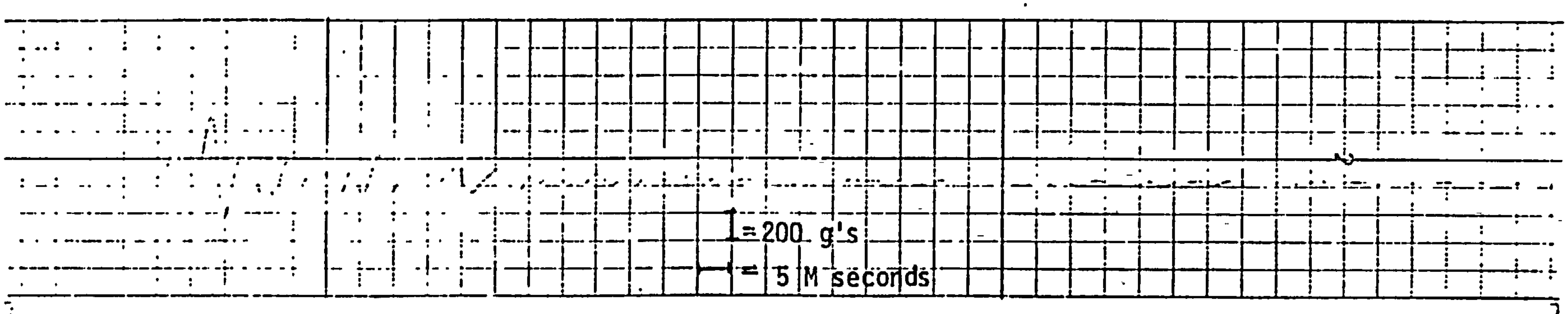
TEST NO. 1 - HORIZ[illegible]L COVER DROP



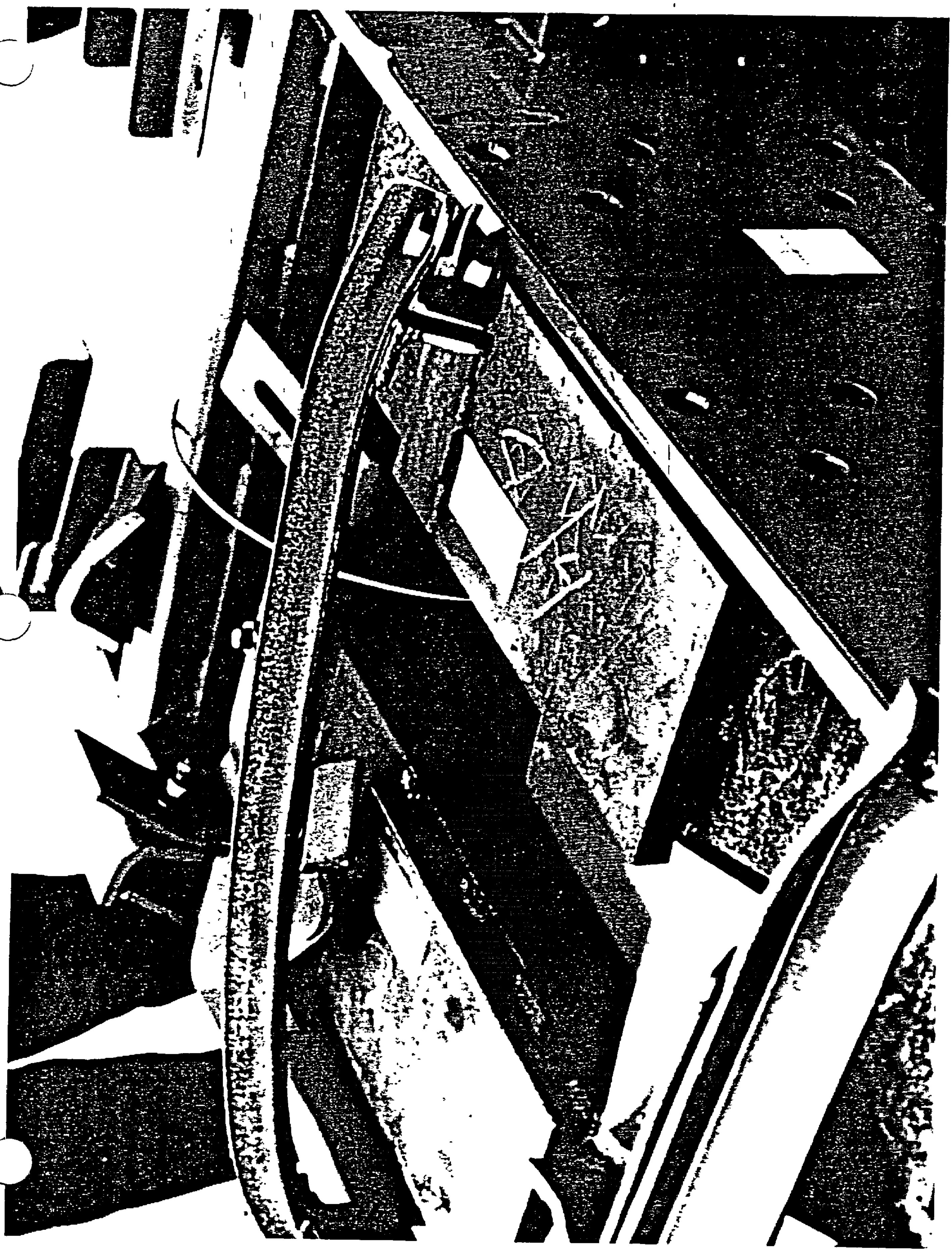
STRONGBACK

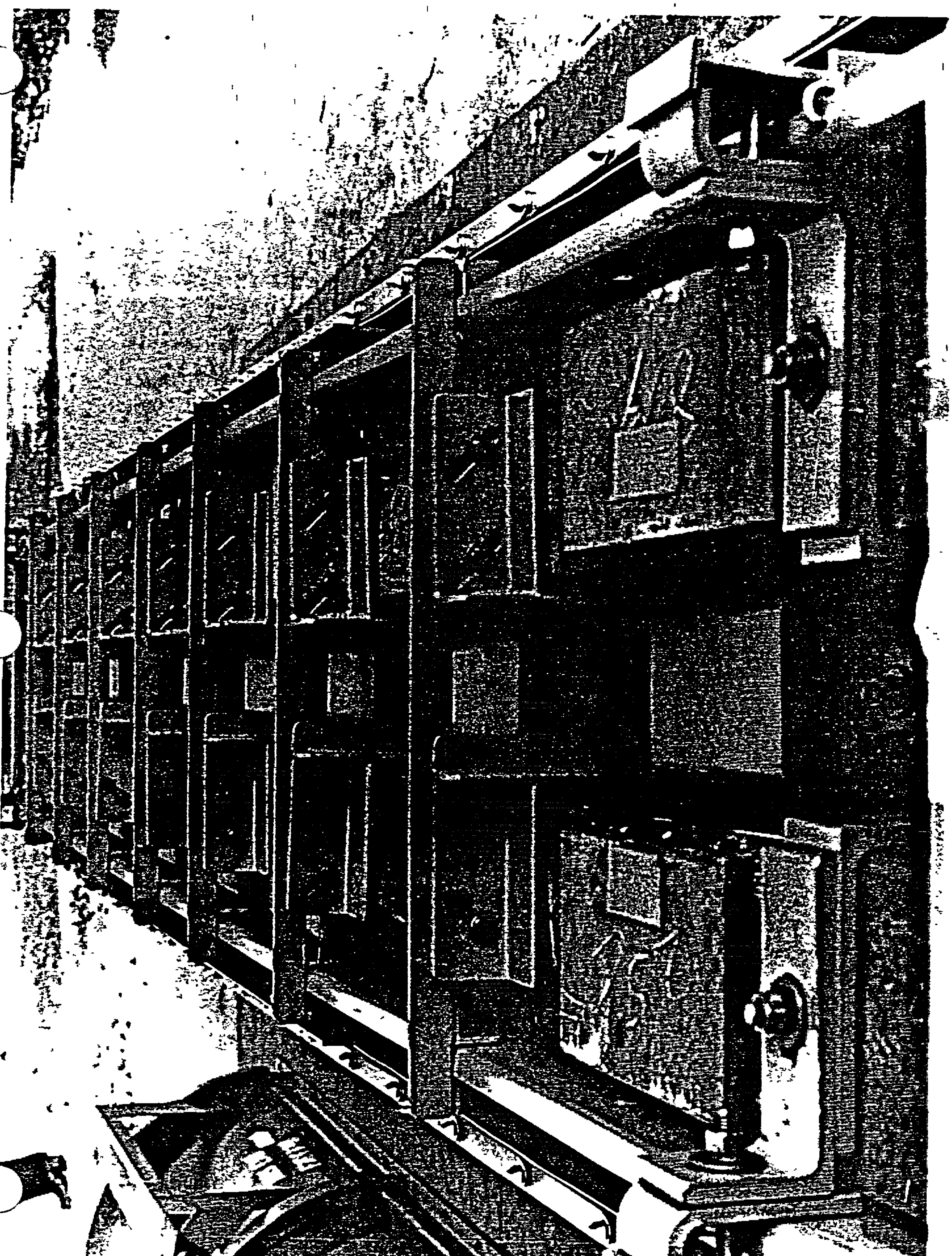


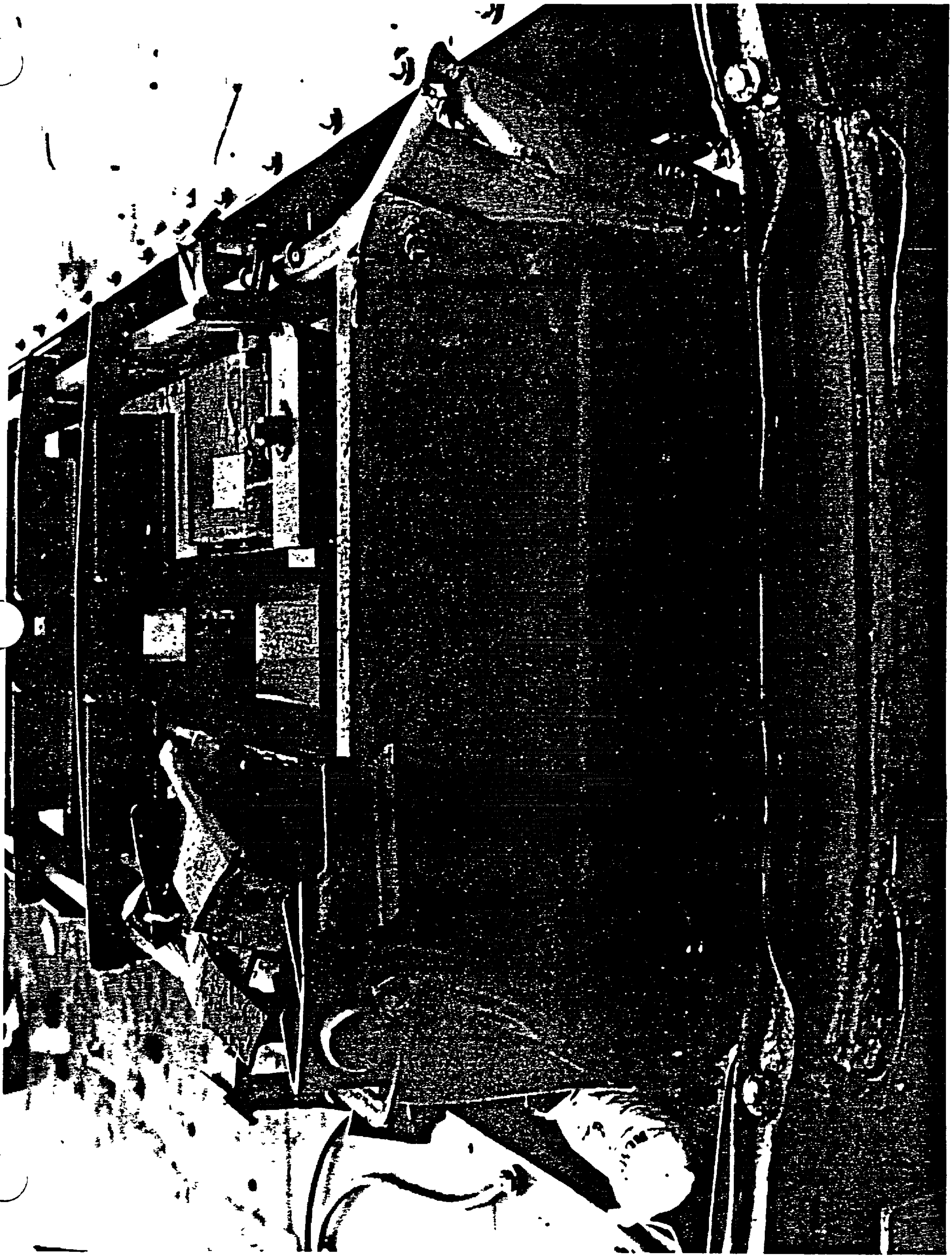
CONTAINER SHELL (EAST END)

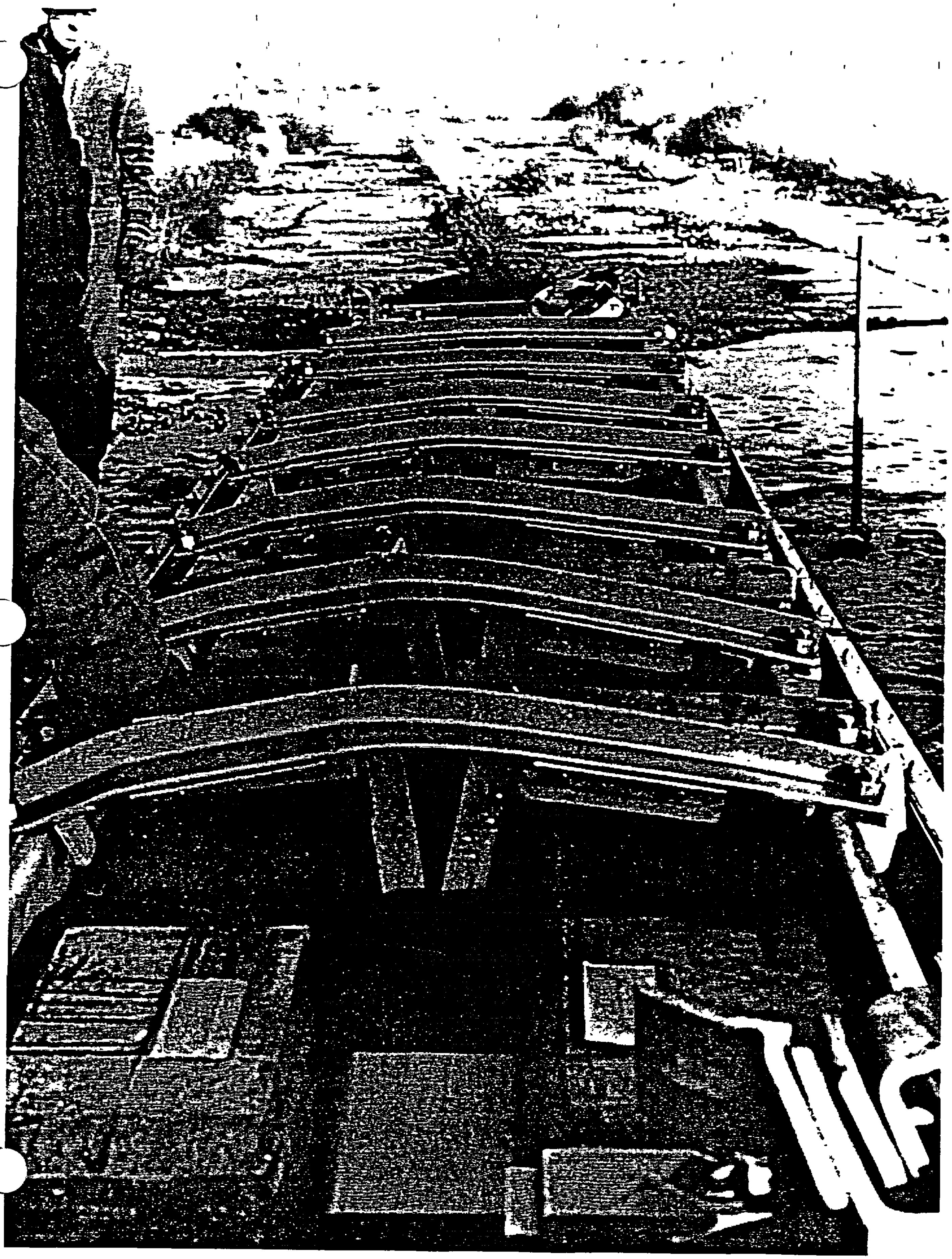


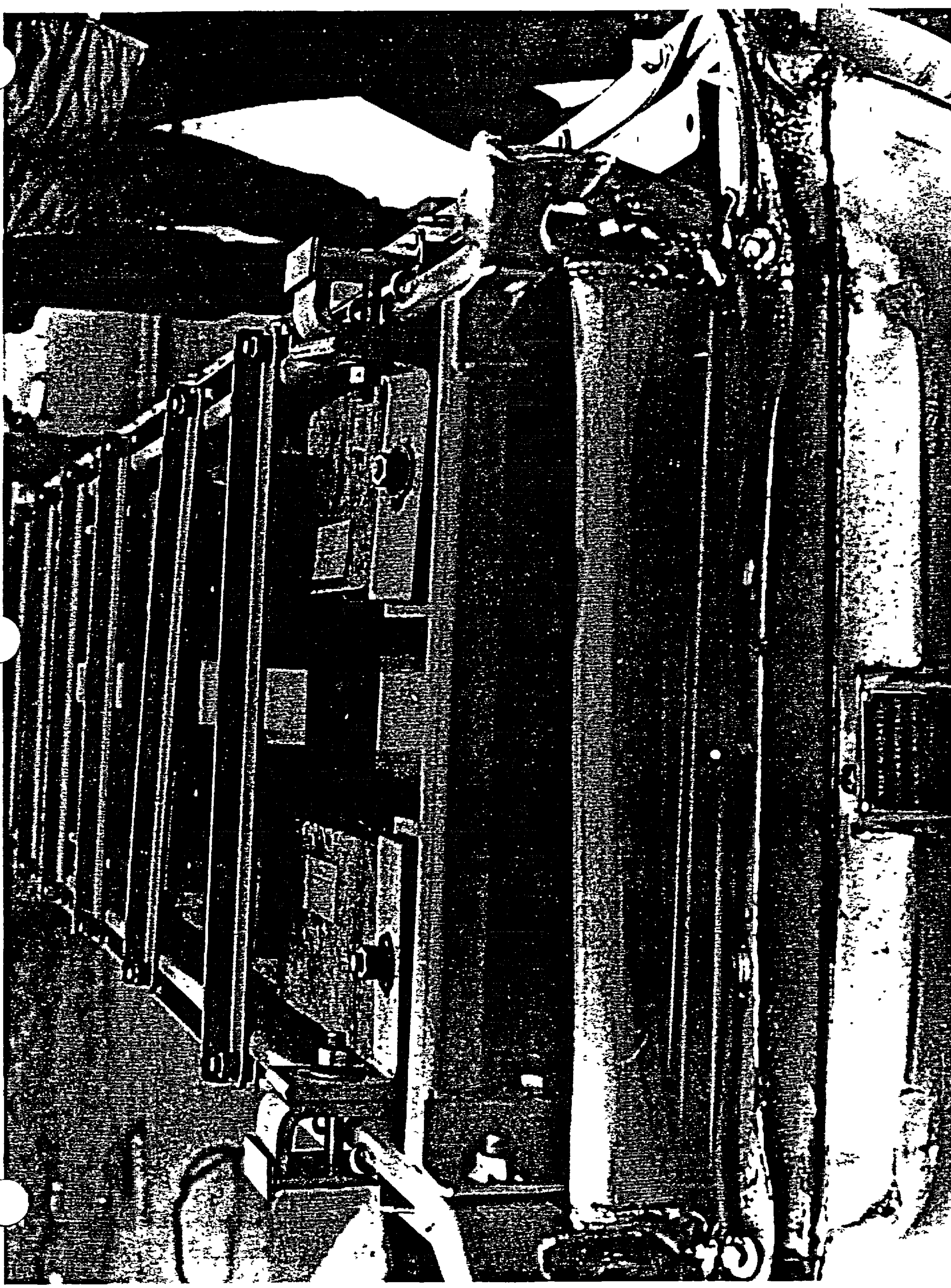
CONTAINER SHELL (WEST END)

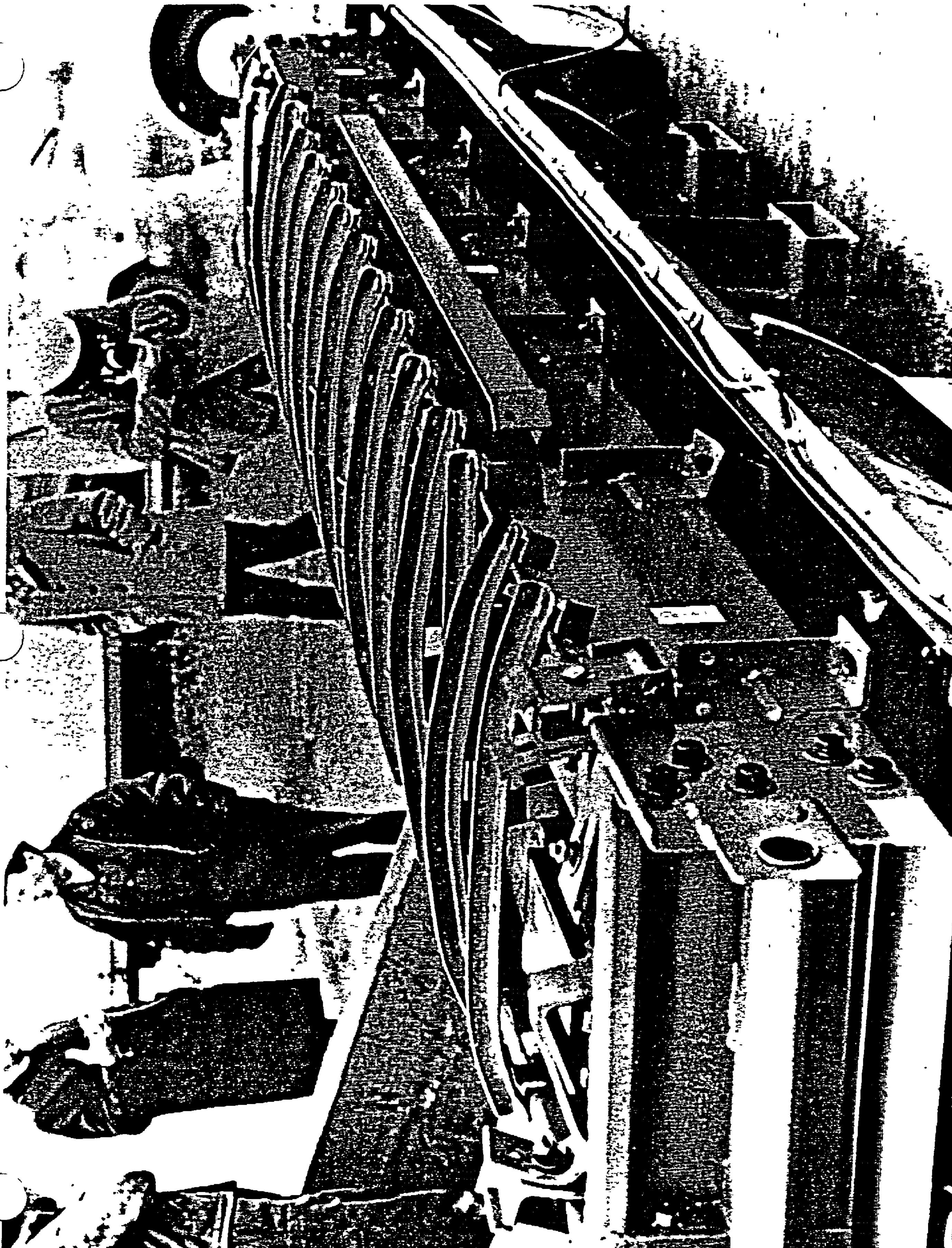


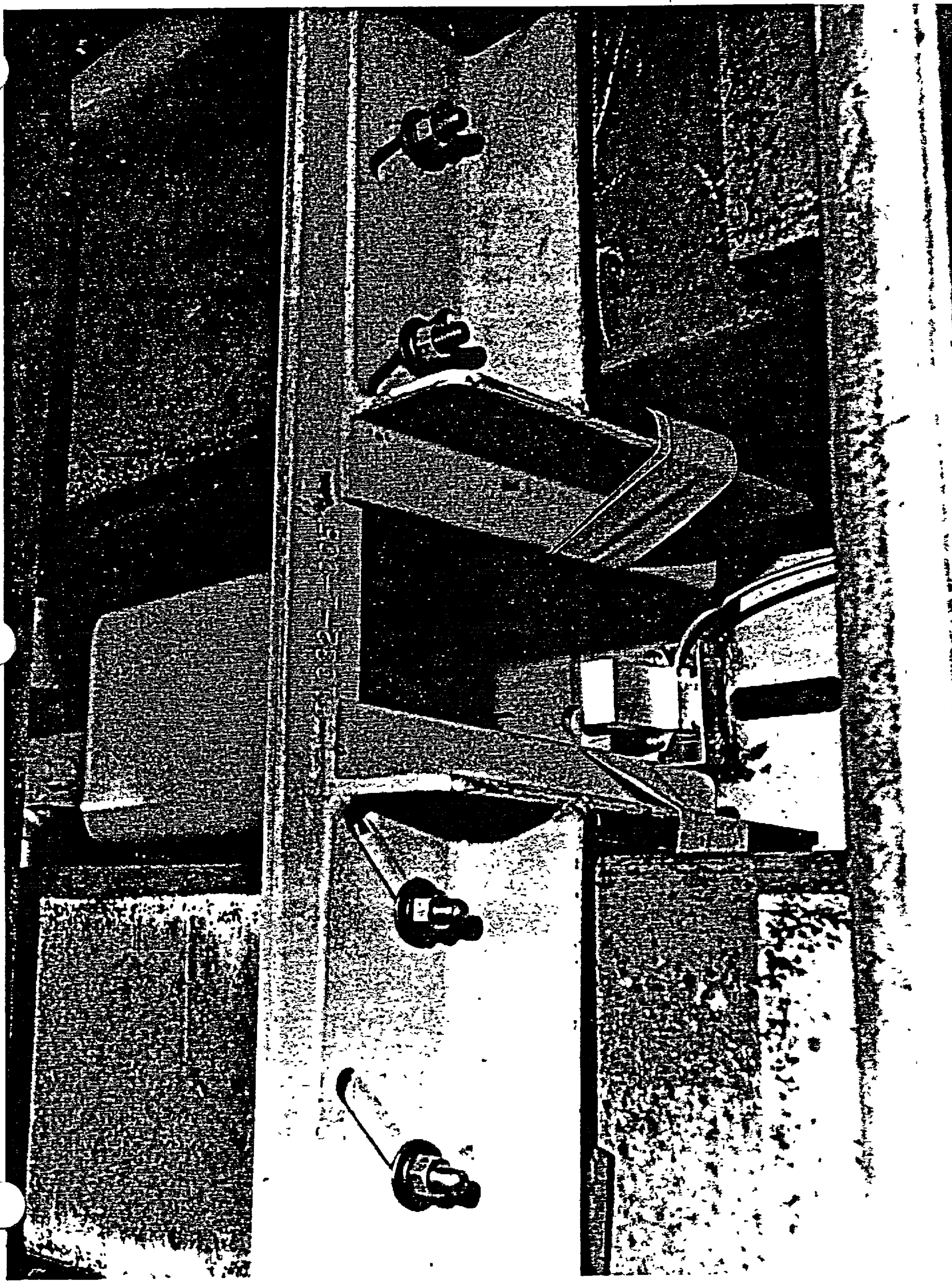


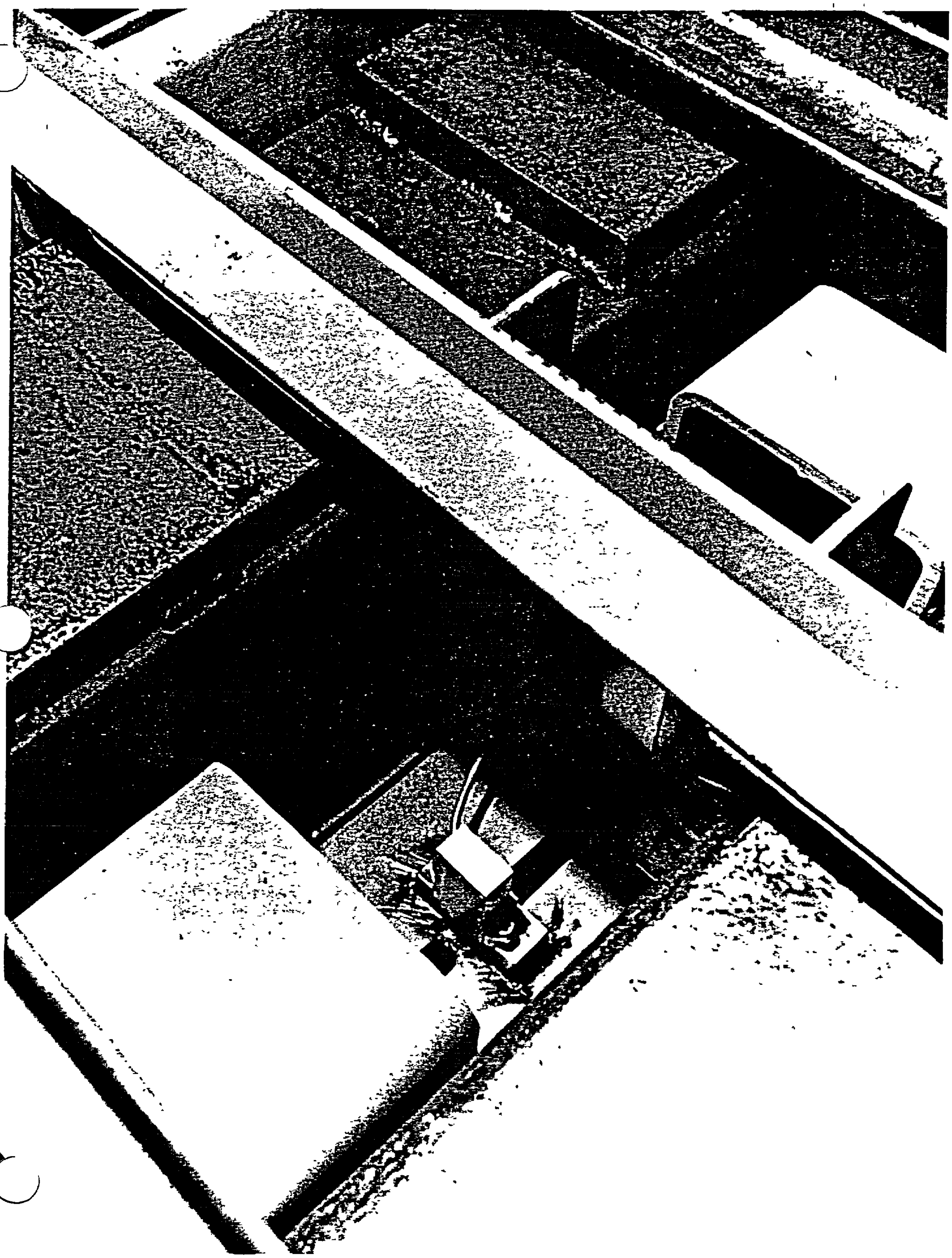


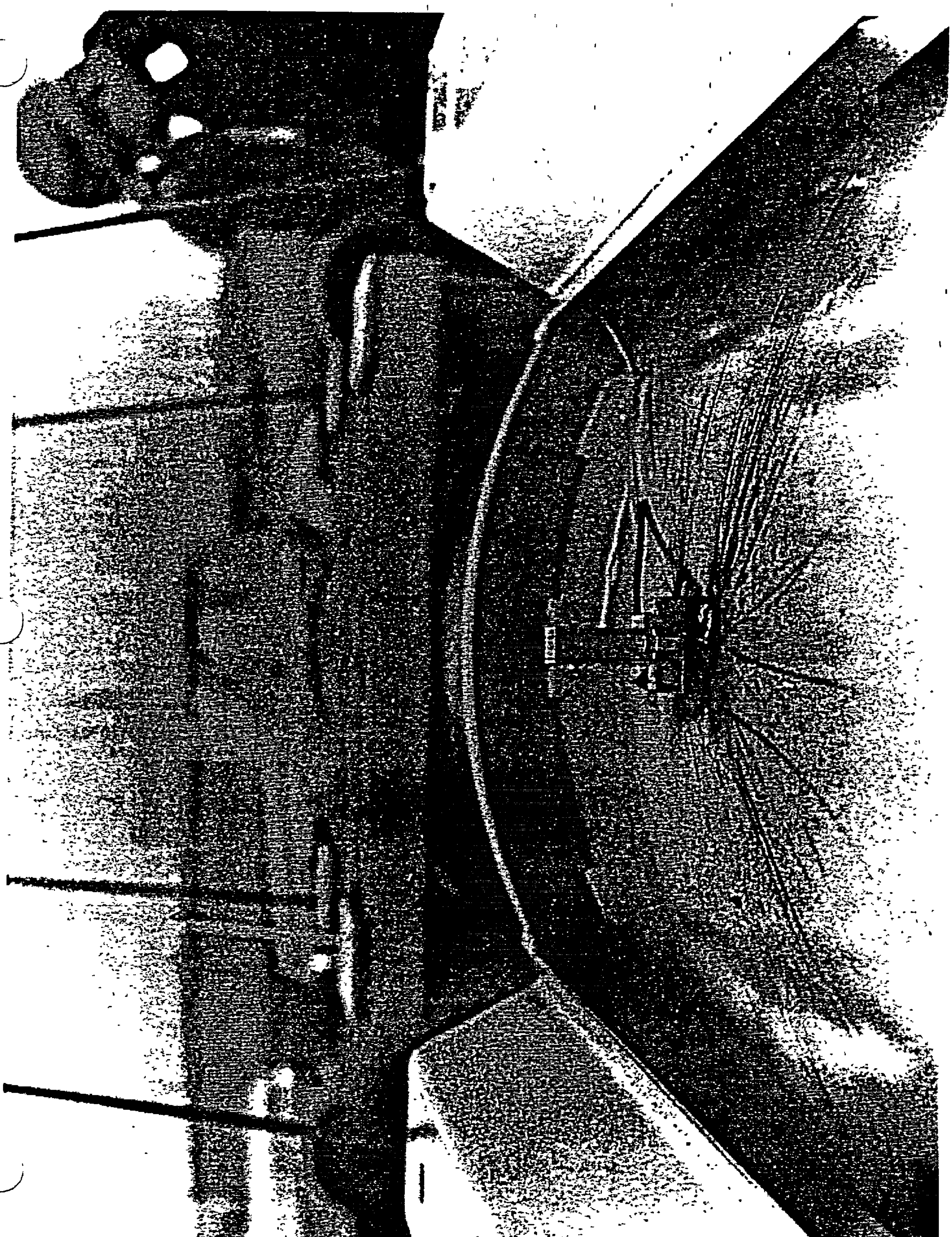


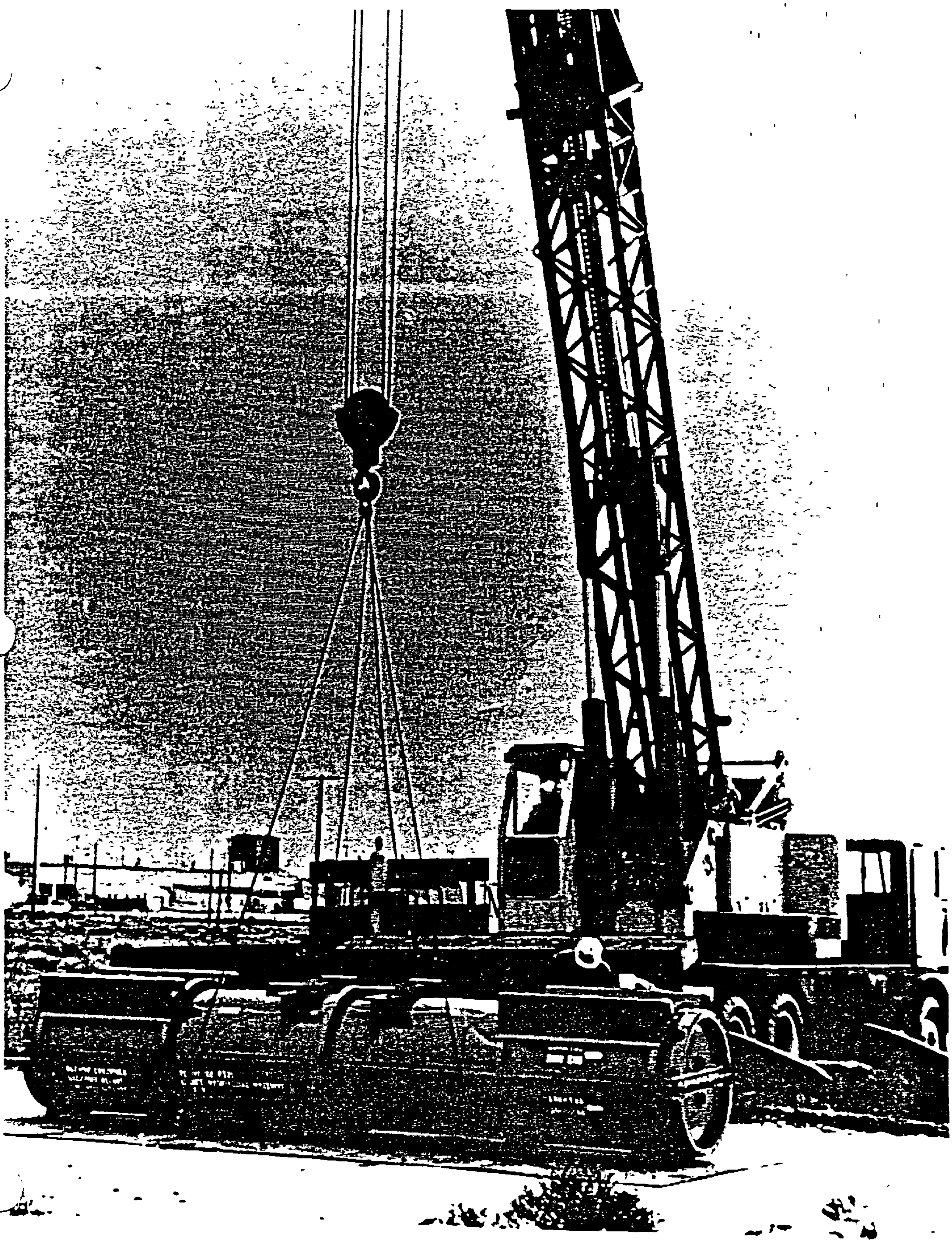


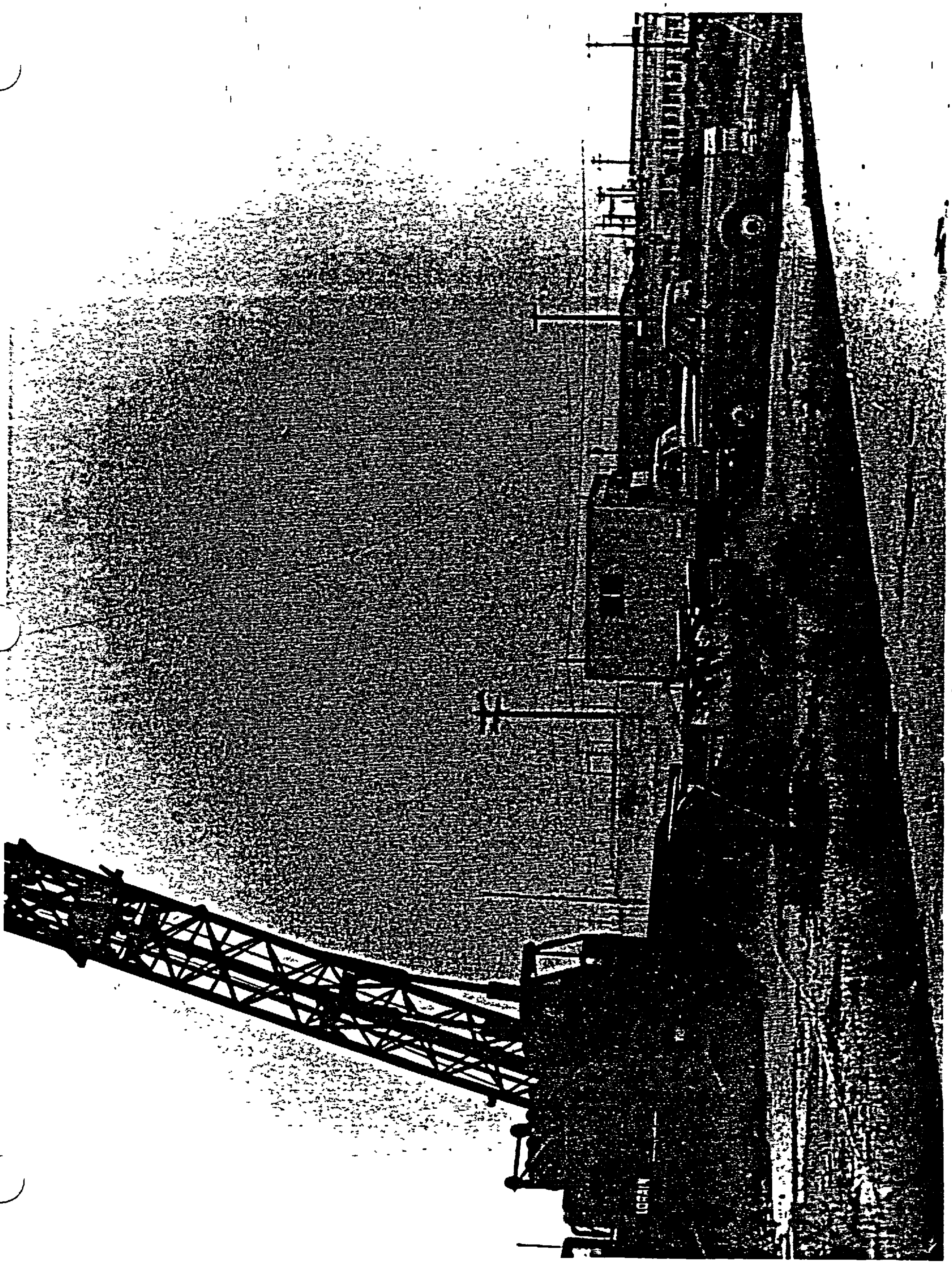


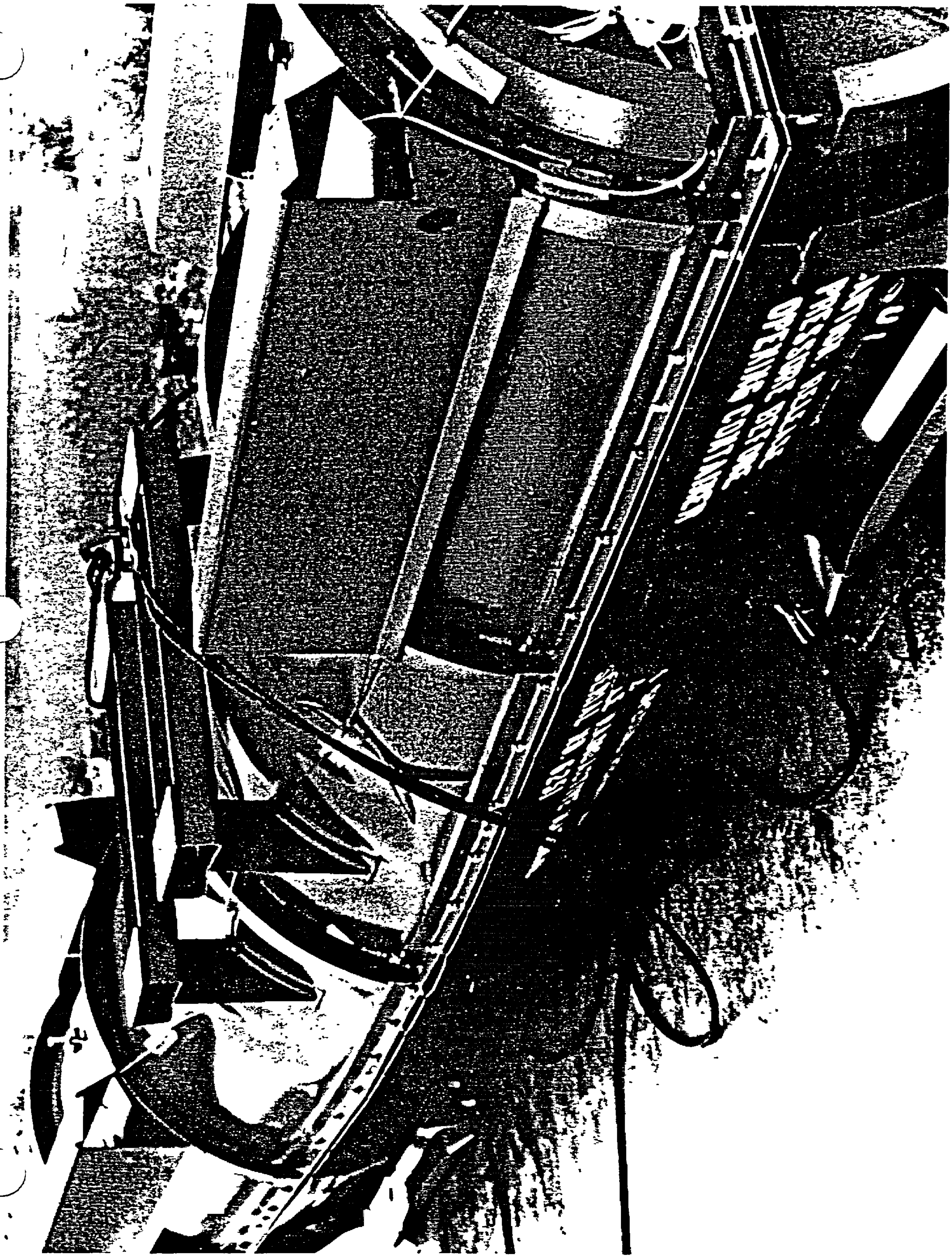




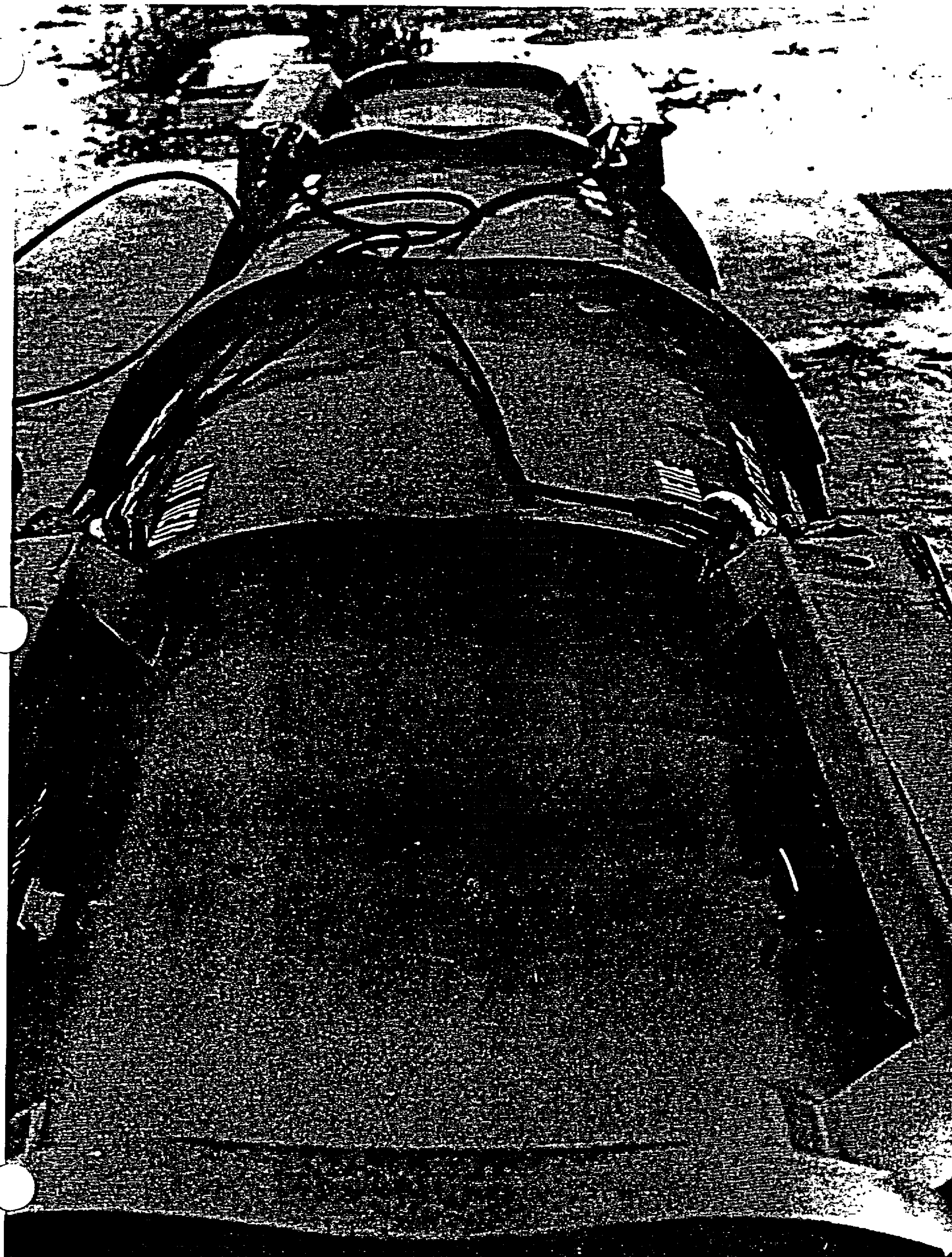









THIS END
FORWARD



VERTICAL DROP TEST

It was hoped that the same container that was used for the horizontal test could also be used for the vertical test. However, due to the assessment made after the horizontal test it was decided to commit a new container to the vertical test. A new container, serial number 6256, was chosen completely at random for this test. The new container was delivered to the test site and the simulated fuel bundles installed. All standard container hardware was used and no extra fuel bundle clamps over and above the standard number were installed since the thrust load would be on the end thrust plate and not on fuel bundle clamps.

After the container was fully loaded and all instrumentation attached, the container was set in a vertical position on its forward end. The container was lifted 30 feet and all rigging and instrumentation checked. By this time, we were running out of daylight, therefore, in order to assure good photographic coverage, the decision was made to postpone the actual drop until the next morning. The container was set back on the test pad in the vertical position overnight.

The following morning, November 1, 1972, the container was lifted to an elevation of 30 feet as measured from the lowest portion of the container and allowed to free fall to the test pad. The container struck perfectly on its end as evidenced by the fact that it remained in the vertical position when it struck the test pad. The container was then lowered from the vertical to the horizontal position and the cover removed for examination. There was a suprisingly small amount of damage from this drop. The outside ring on the container on the impact end snapped off and slight bowing was evident on the outside of the container for approximately 17 inches from the end. On the inside, the 14 bolts attaching the strong back cross beam to the shock mount assembly sheared off and allowed the strong back to shift in the direction of impact. The end of the strong back up to the end thrust plate crumpled. The end thrust plate remained intact and in position. All bolts attaching the end thrust plate to the strong back remained in position, and no failure was observed. The strong back remained in the container and the fuel assemblies remained essentially in perfect position in the strong back.

Attached is a copy of several internal and external measurements taken both before and after the vertical test. Also attached are several sequential photographs taken prior to, during and after the vertical drop. Data strips which show the acceleration of the impact are also attached.

Y DATE SUBJECT CONTAINER DROP TEST SHEET NO. 1 OF 3

CHKD. BY DATE SPACING DIMENSIONS BEFORE JOB NO.

AND AFTER EACH DROP

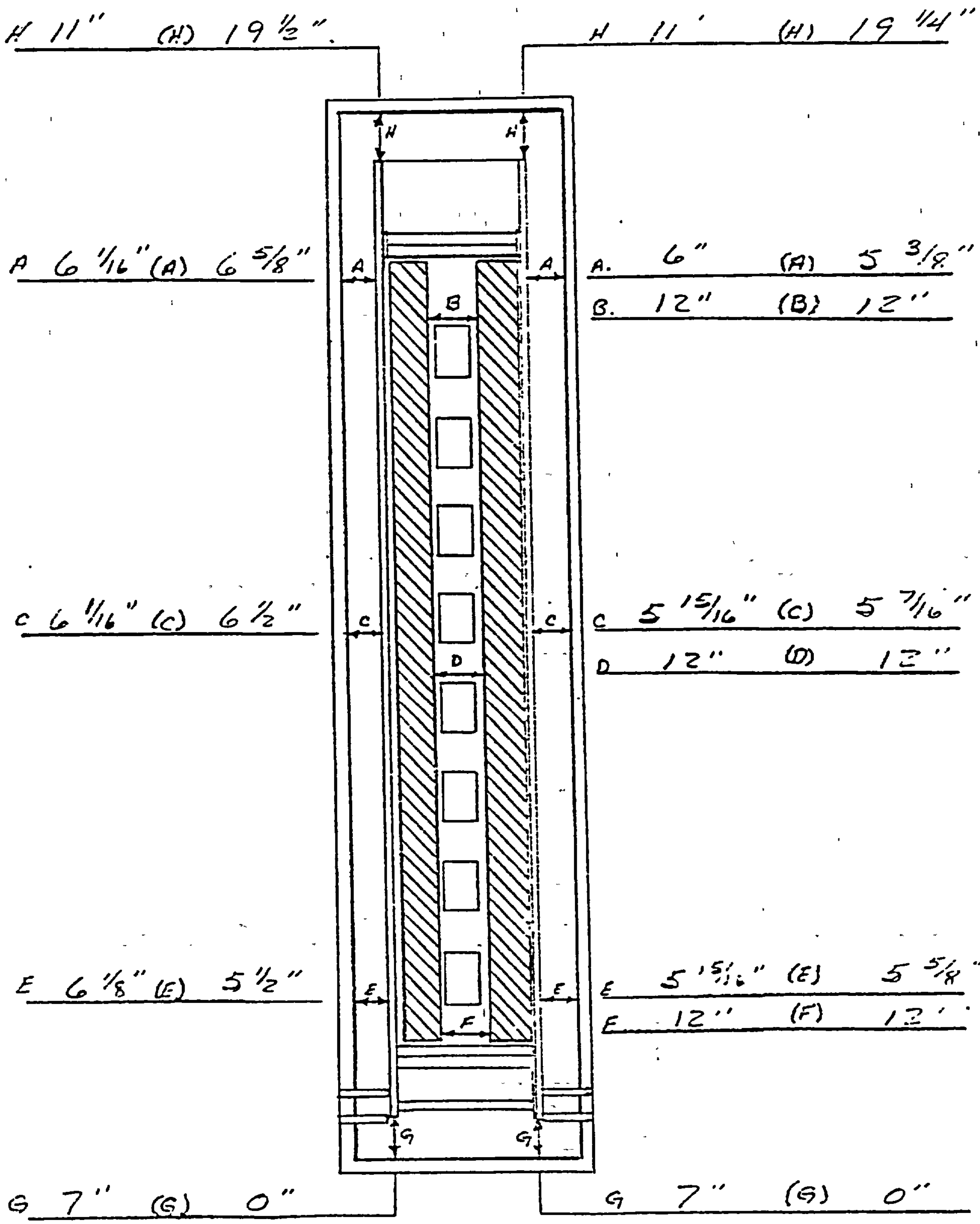
VERTICAL TEST

XN-52, Rev. 1

UNIT # 6256

A - BEFORE TEST

(A) - AFTER TEST

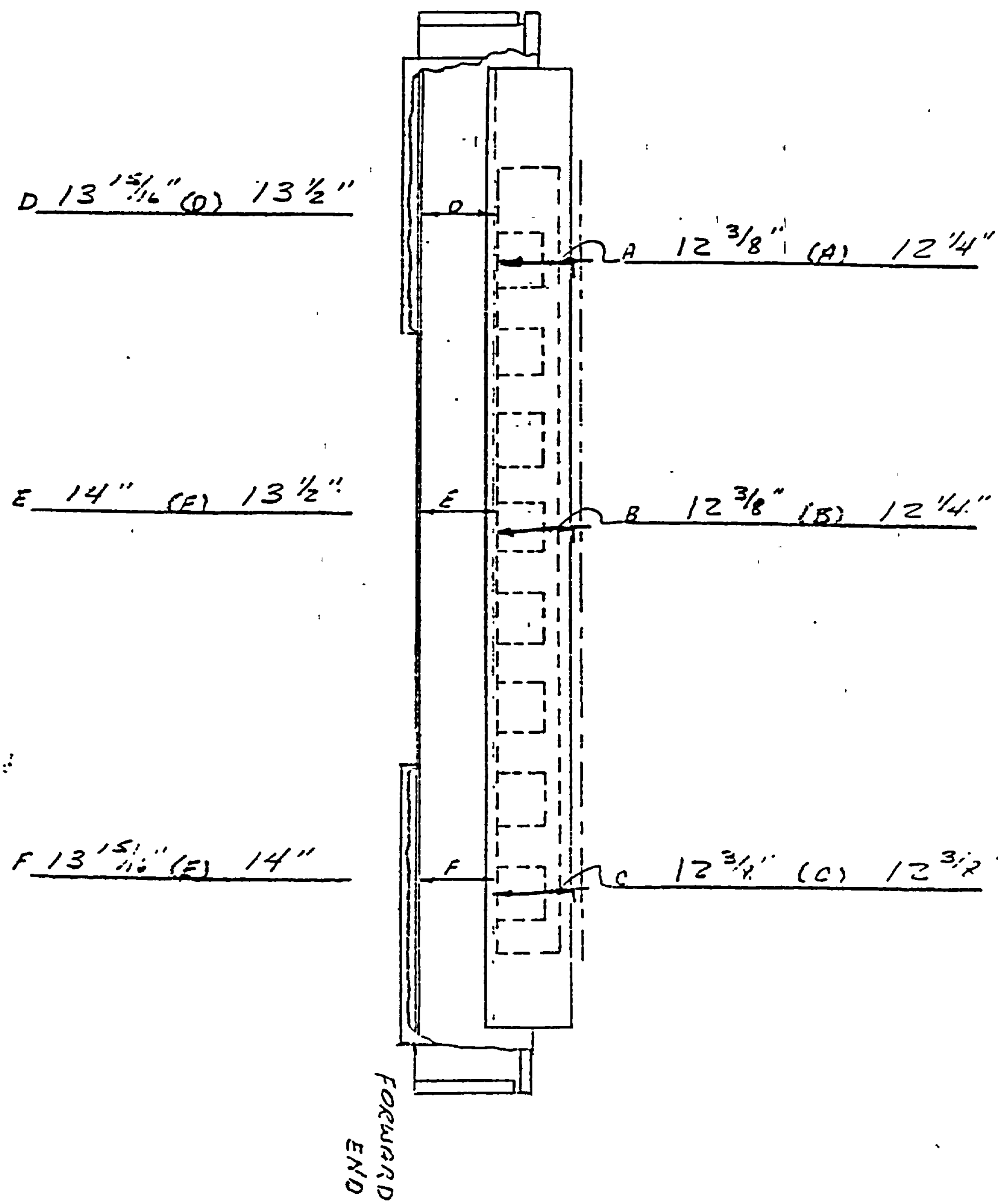


FORWARD END

DATE ……
D. BY DATE ……

SUBJECT Container Drop Test SHEET NO. 2 OF
Spacing Dimensions Before JOB NO.
And After Each Drop

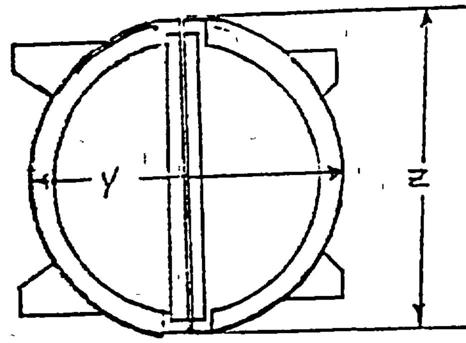
Vertical Test



AFTER TEST

FORWARD END
(Y) Ring Came Off
(Z) 42"

REAR END
(Y) 40 3/16"
(Z) 42"

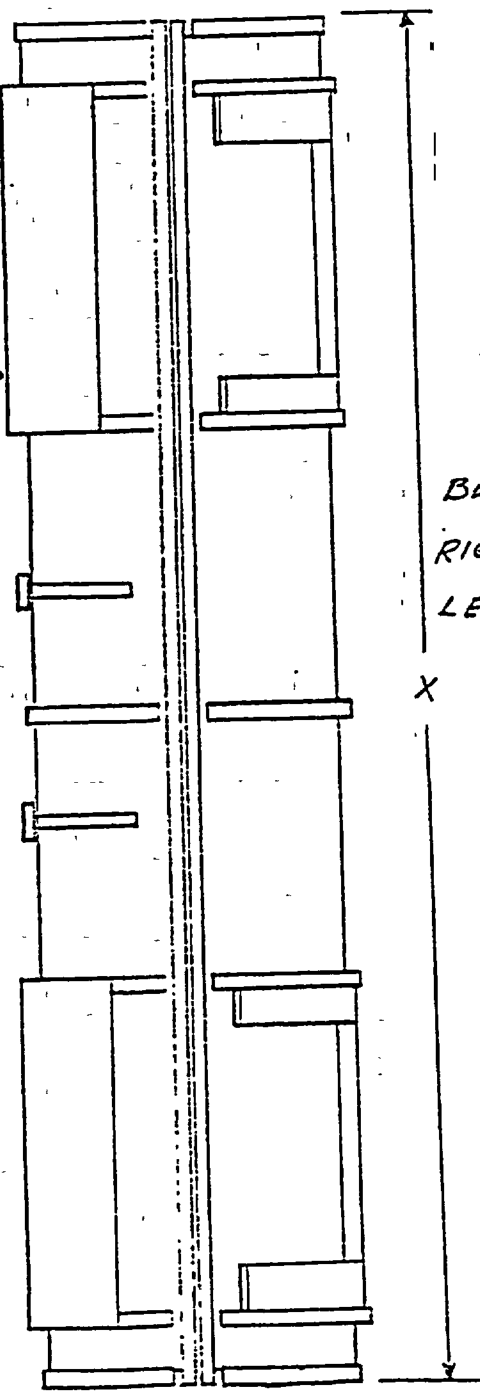


BEFORE TEST

FORWARD END
Y 40 1/8"
Z 42"

REAR END
Y 40 3/16"
Z 42"

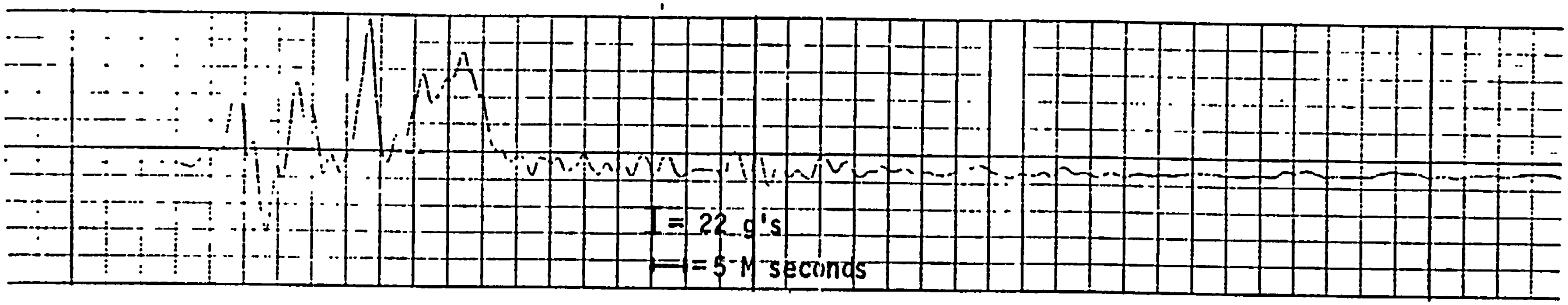
(X) DIMENSIONS
NO RING ON FORWARD END.
(TOP) 17'-10 1/2"
(BOTTOM)
(RIGHT) 17'-10 1/2"
(LEFT) 17'-9 3/8"



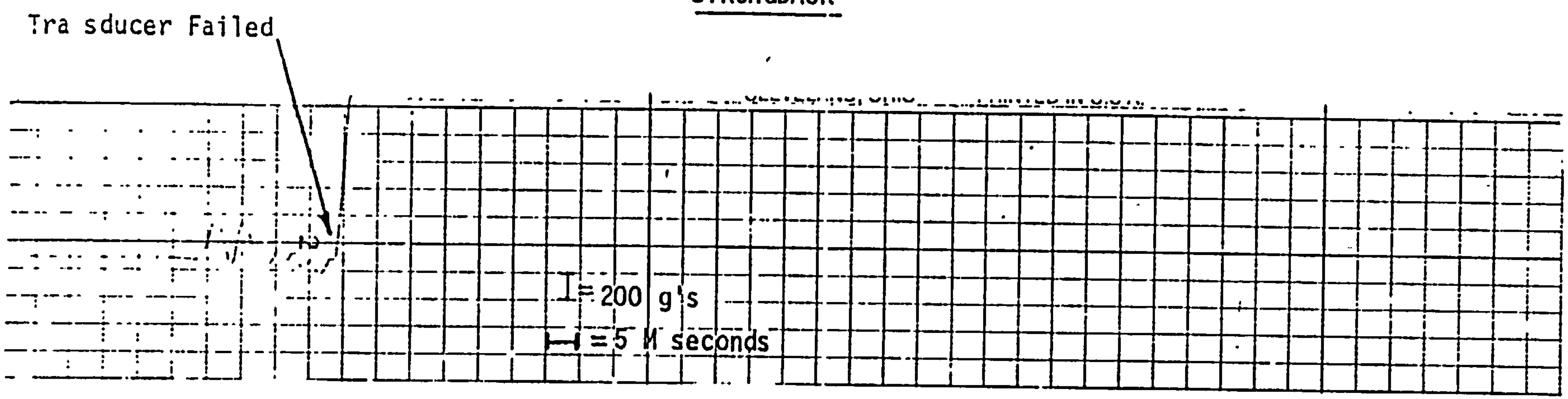
"X" DIMENSIONS
TOP 18'- 1/2"
BOTTOM 18'- 1/2"
RIGHT SIDE 17'-11 1/8"
LEFT SIDE 17'-11 1/8"

JERSEY NUCLEAR SHIPPING CONTAINER - 30 FOOT DROP TEST

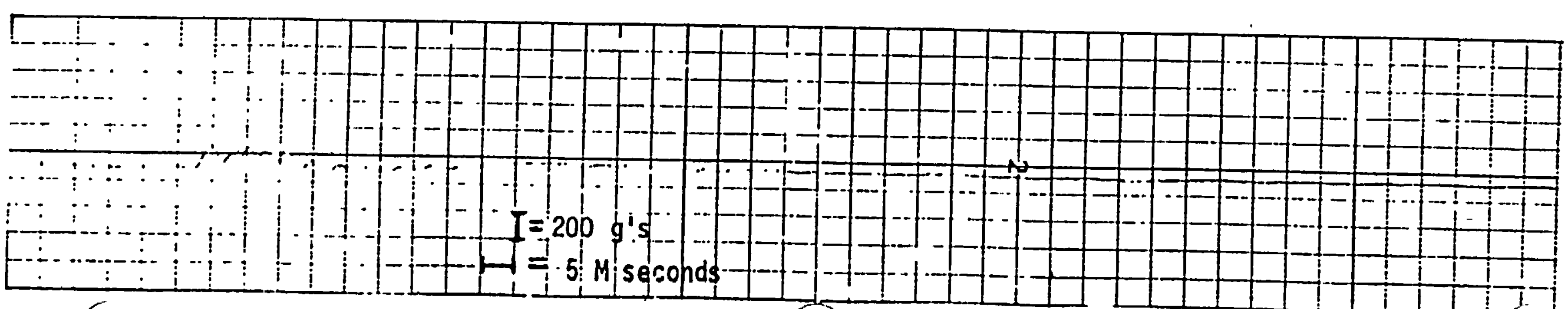
TEST NO. 2 - VERTICAL END DROP



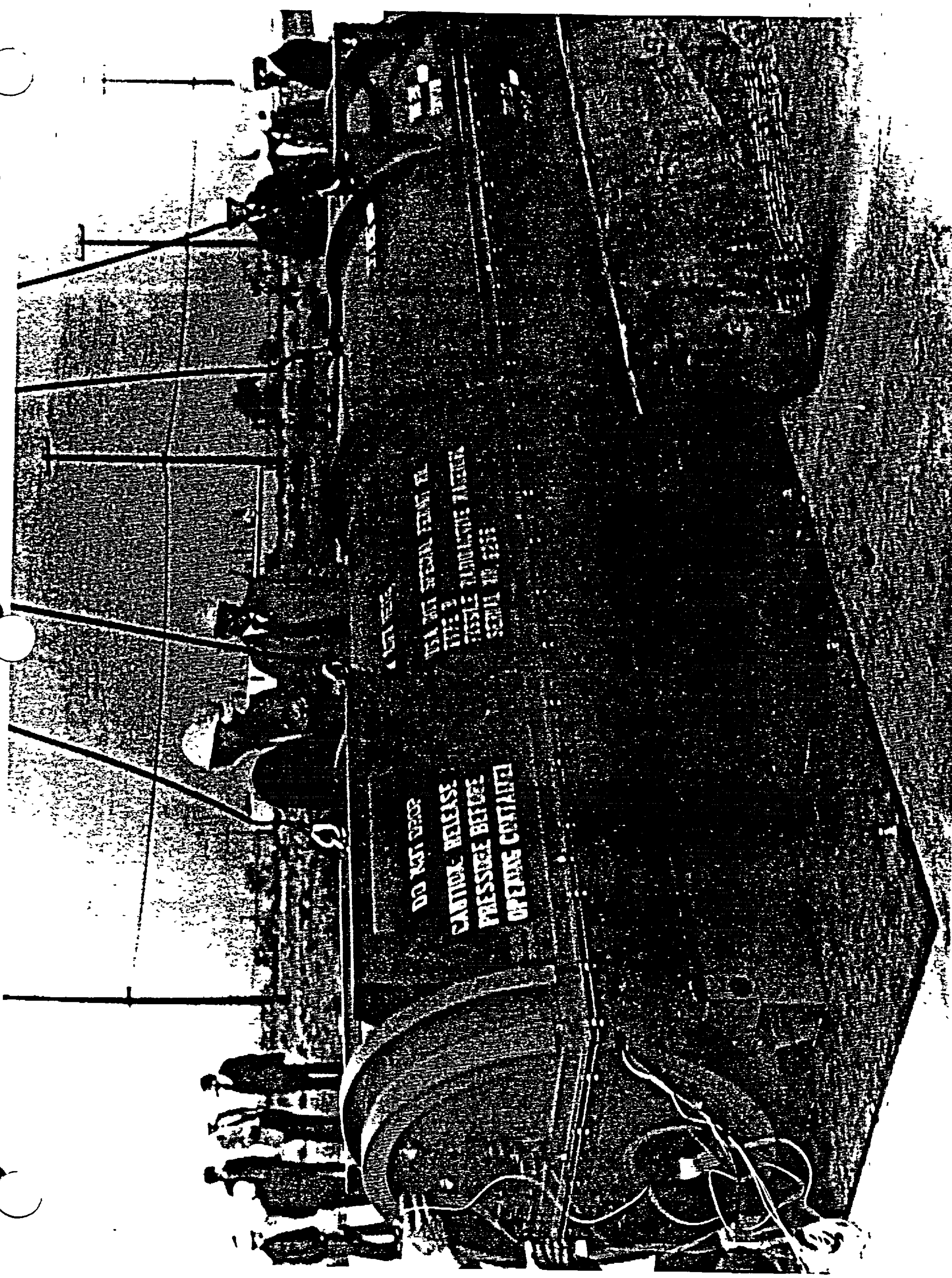
STRONGBACK

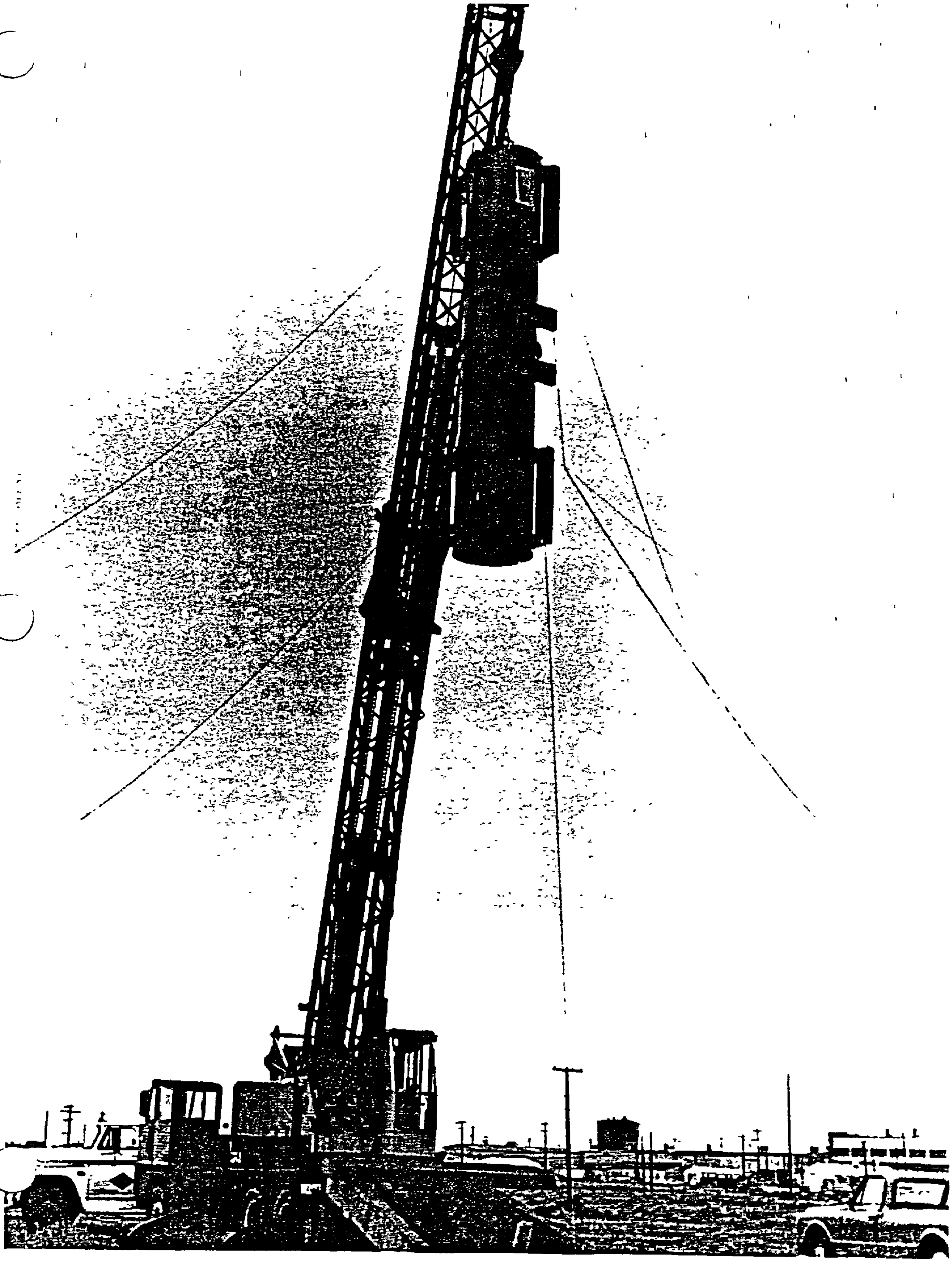


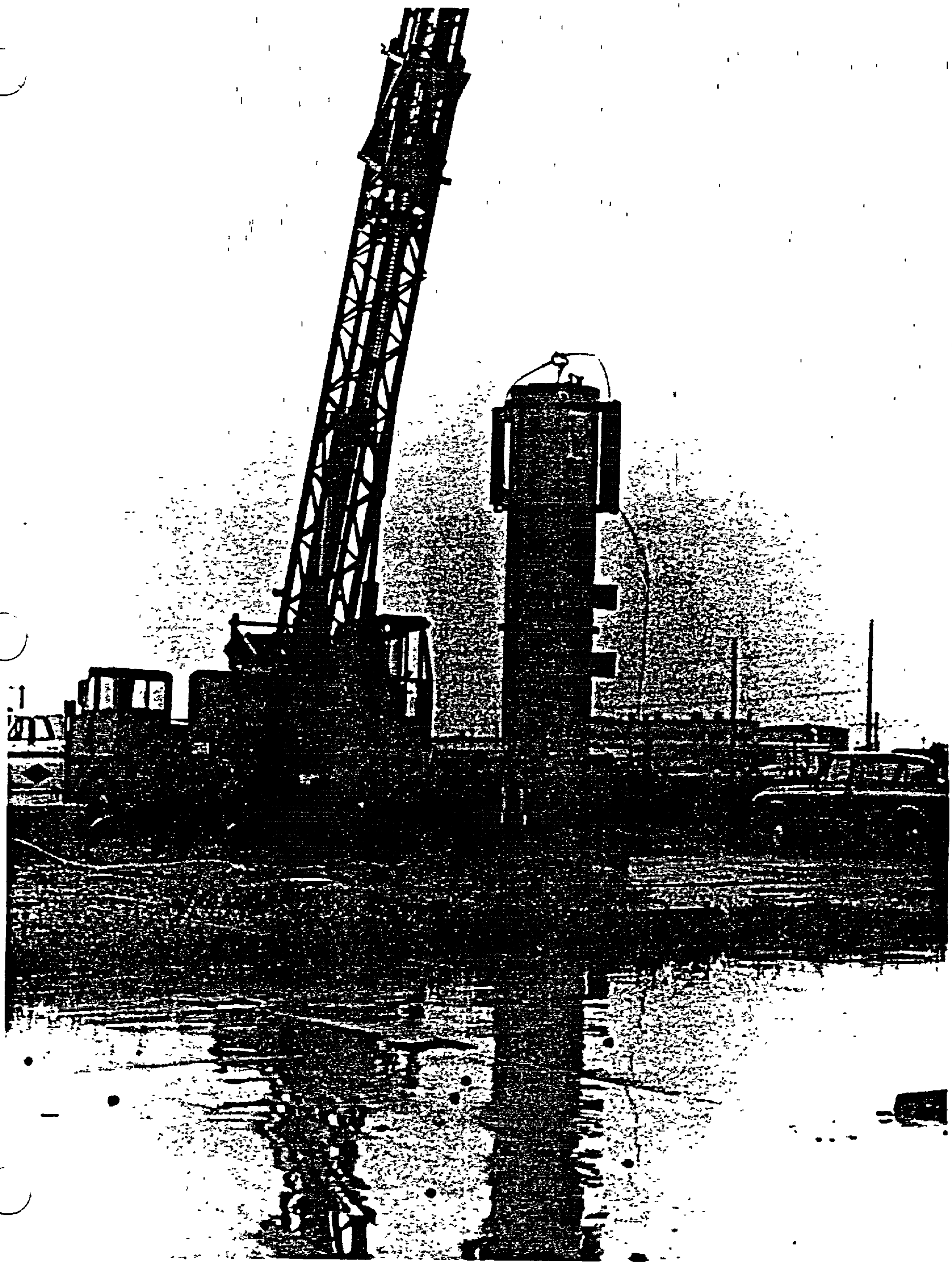
CONTAINER REAR CLOSURE PLATE

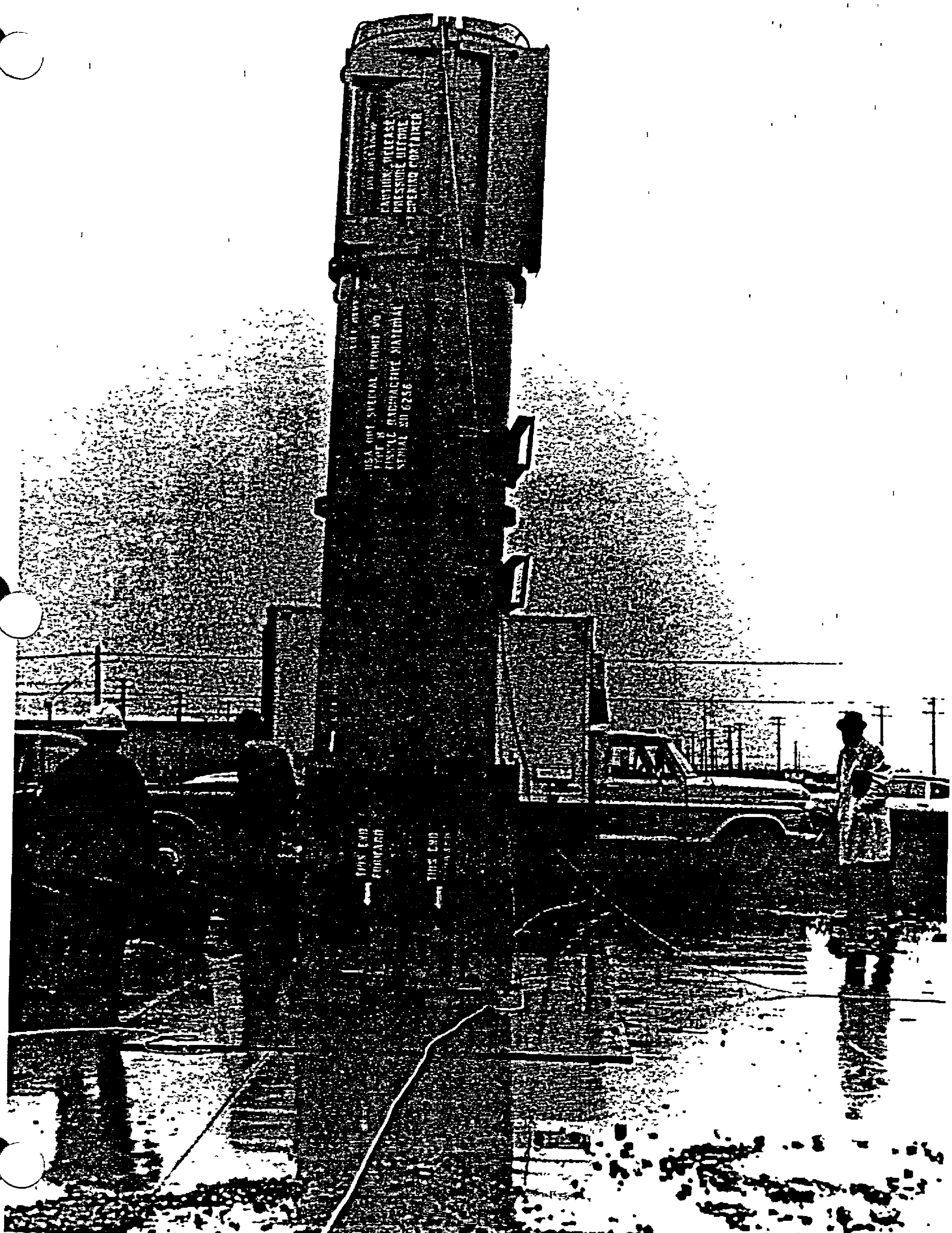


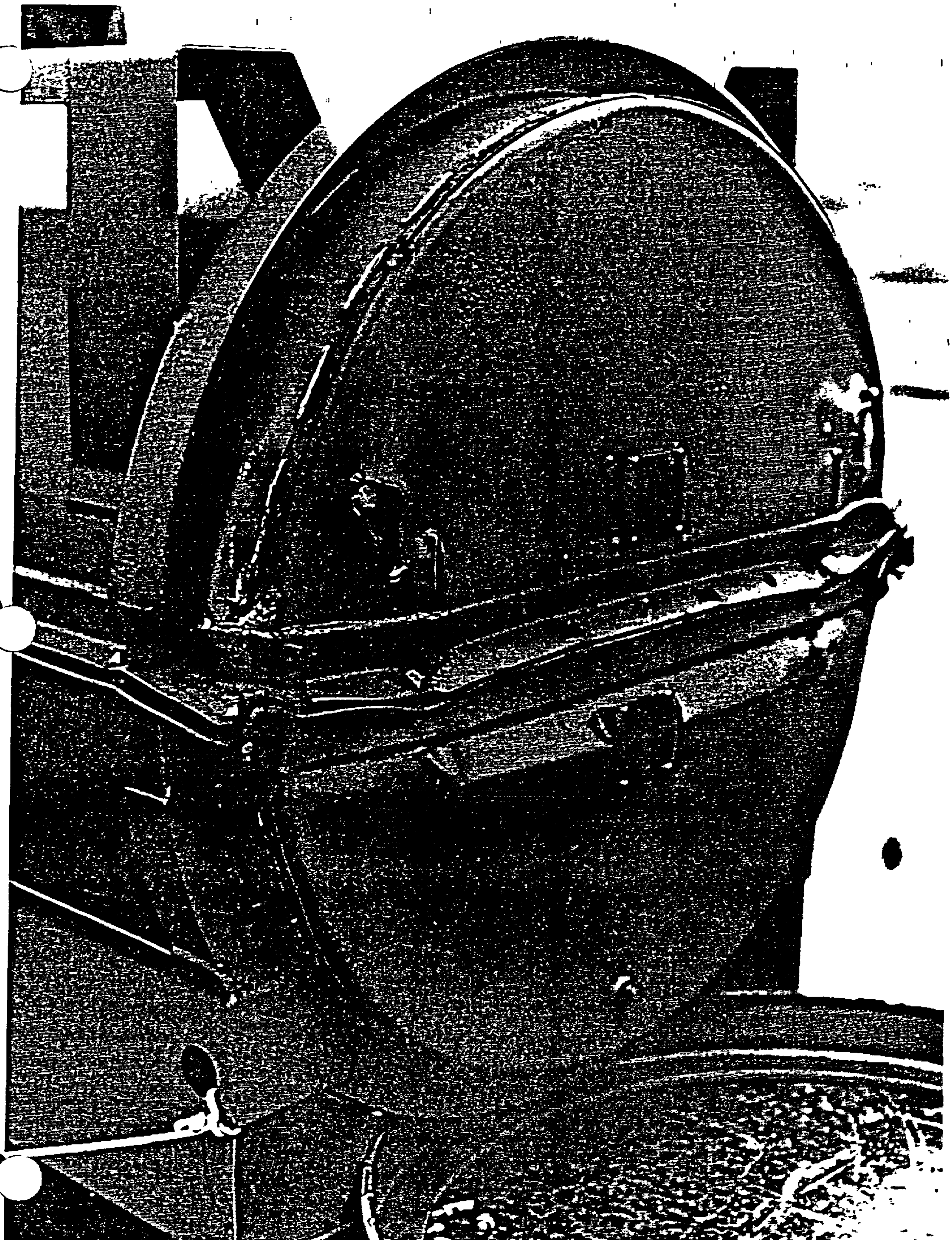
CONTAINER SHELL FLANGE

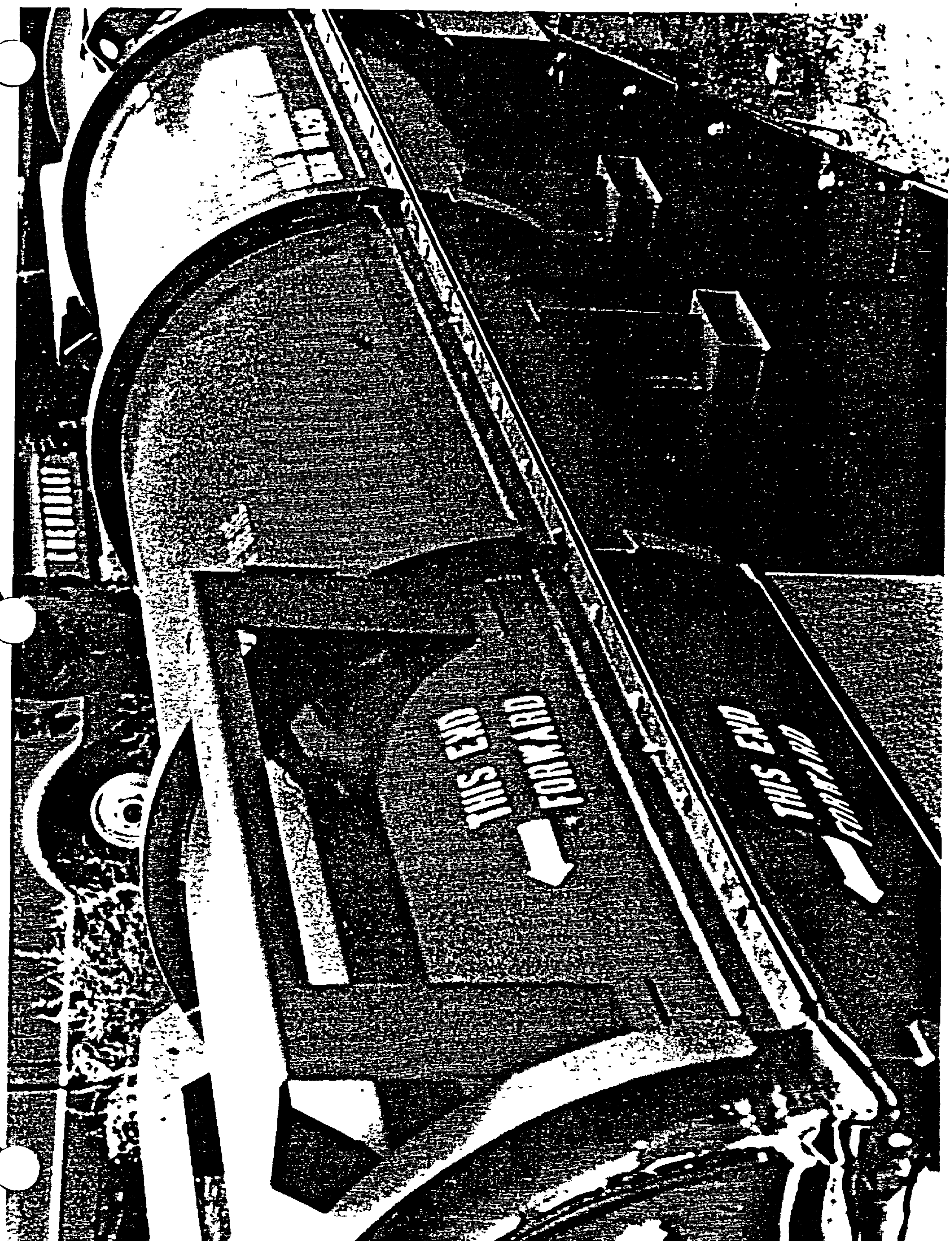

DO NOT DROP
CAUTION- RELEASE
PRESSURE BEFORE
OPENING CONTAINER

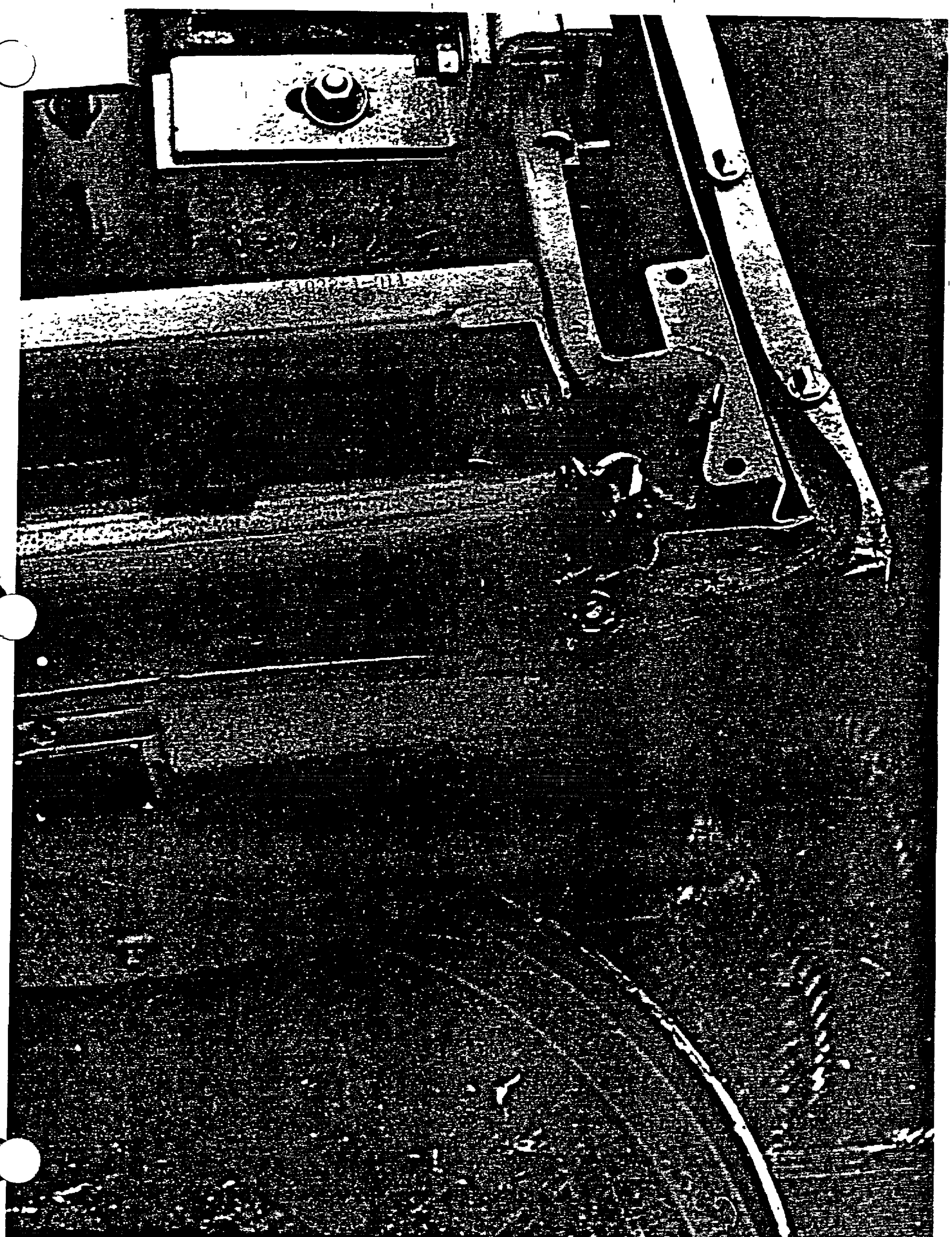


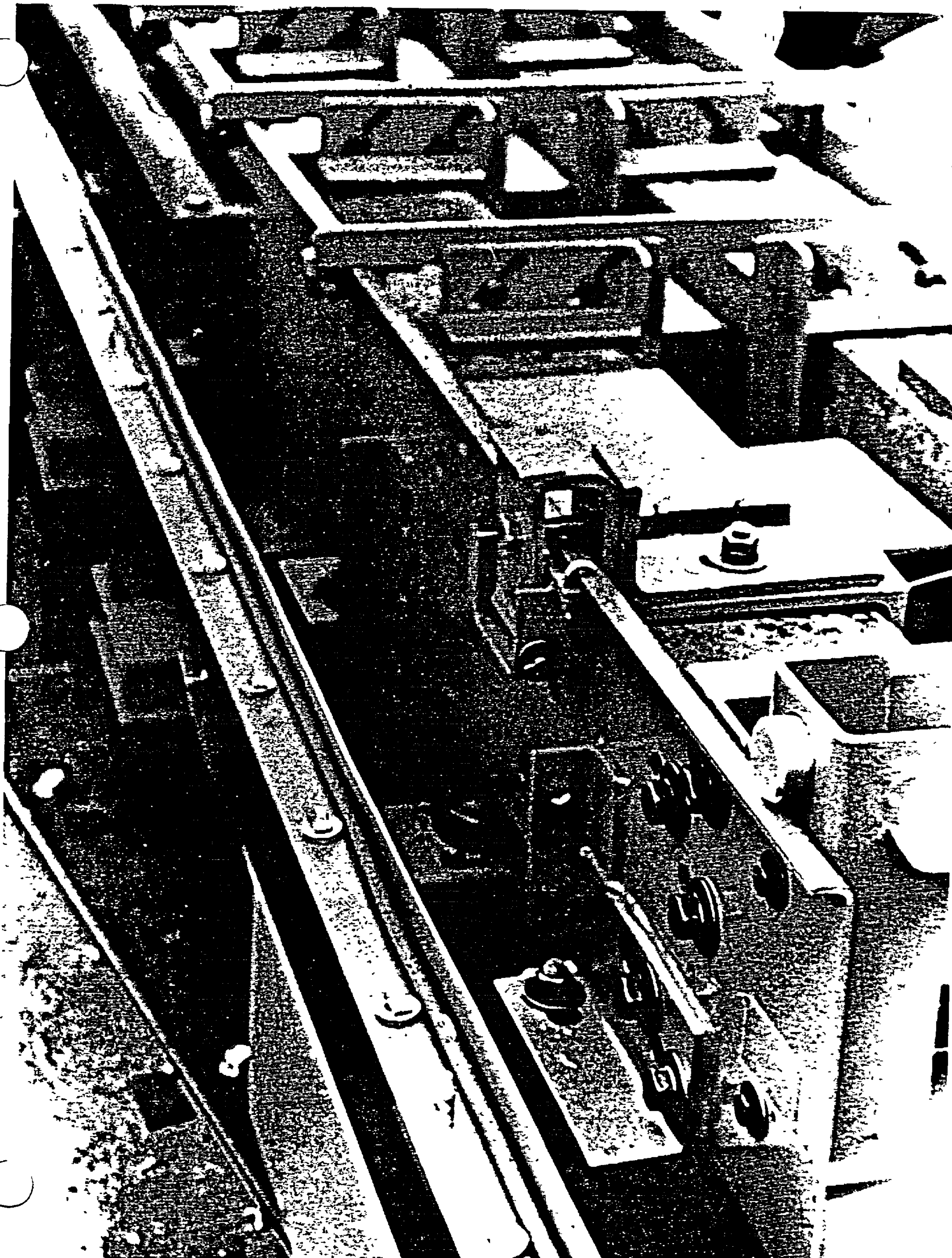


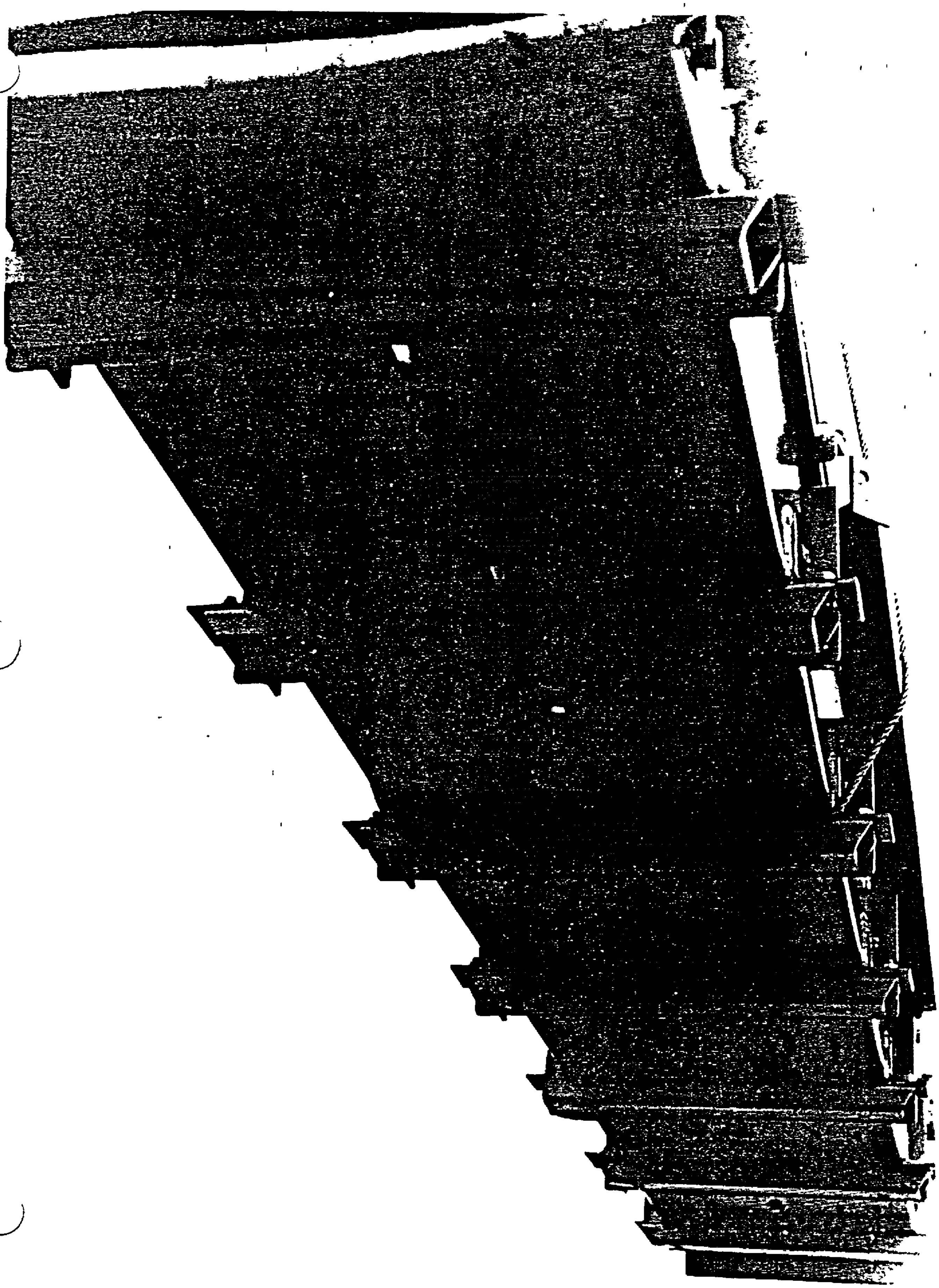

CAUTION: RELEASE
PRESSURE BEFORE
OPENING CONTAINER
USA DOT SPECIAL PERMIT NO
TYPE B
FISSILE RADIOACTIVE MATERIAL
SERIAL NO 0256
THIS END
FORWARD
THIS END

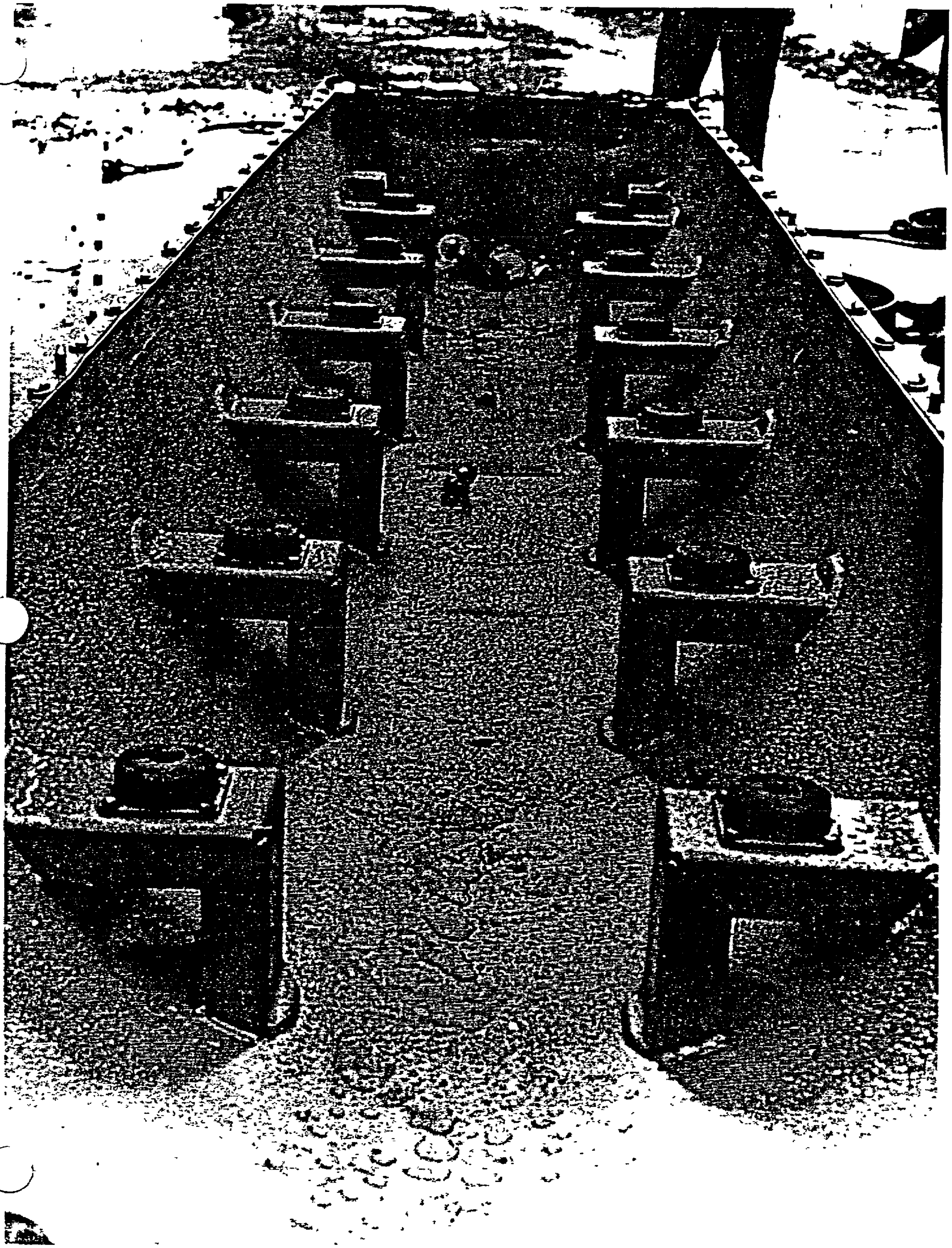



THIS END
FORWARD
THIS END
FORWARD









75° DROP TEST

As a result of the second container (one used for vertical test) coming through the test in fairly good condition, it was decided to proceed with the third test - i.e. the 75° drop, using this container. The only refurbishment required was the replacement of the fourteen bolts connecting the shock mount assembly to the strong back cross beam, replacement of one slightly bent shock mount assembly and straightening the flange between the top and bottom sections of the container on the forward end.

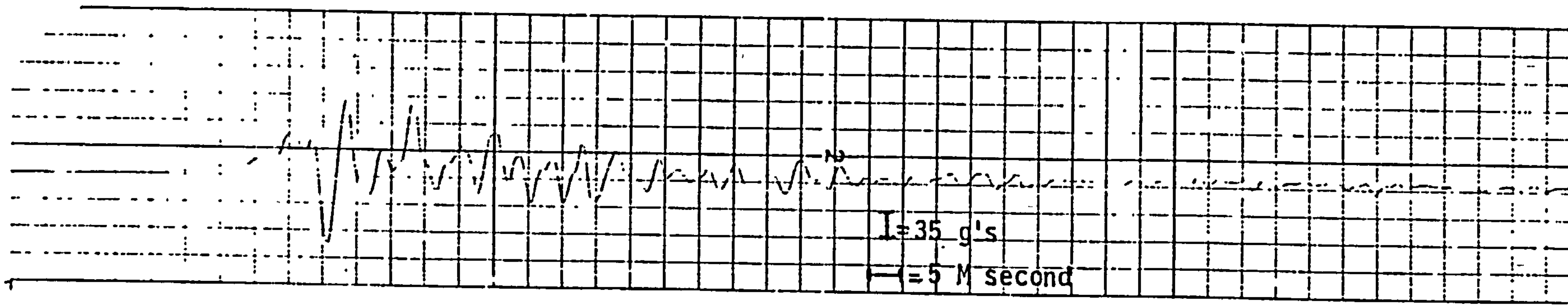
After the above work was completed, the simulated fuel bundles were re-installed and the container closed. Due to the damage on the forward end (from the vertical drop) the decision was made to make the 75° drop on the rear end top cover. The container was rigged, in accordance with the test procedure, in such a way that it would strike the ground 75° from horizontal. The container was lifted and by actual measurement of the angle, it turned out to be 76°. It was felt that this was sufficiently close to the required angle to proceed. The container was lifted 30 feet off the test pad as measured from the lowest portion of the container and allowed to free fall to the test pad. The top cover was bent extensively on the impact end and three of the cover bolts sheared directly under the impact area. No other bolts were sheared and the cover remained securely fastened. After external observations were made the top cover was removed. The interior examination revealed that end thrust plate remained in good condition and that the bolts between the strong back and the strong back cross beam had sheared. When these bolts sheared, it allowed the strong back to shift toward the impact end.

The conclusions of this test indicate that the top closure bolts remained in good condition, the cover remained in position, the strong back remained in the container and that the fuel assemblies maintained their separation within the strong back.

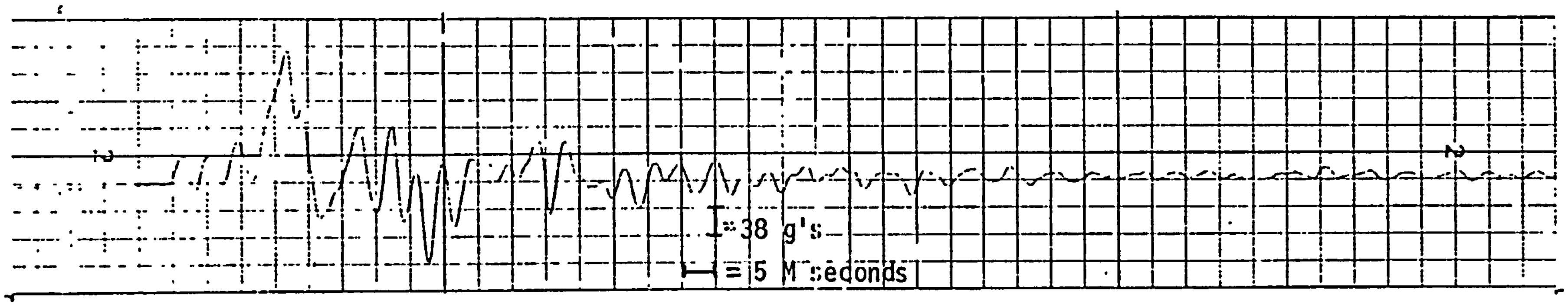
Since this test was only to demonstrate the integrity of the cover, no internal or external measurements were taken either prior to or after the test. Attached are several sequential photographs taken prior to, during and after the test. Data strips which show the acceleration of the impact are also attached.

JERSEY NUCLEAR SHIPPING CONTAINER - 30 FOOT DROP TEST

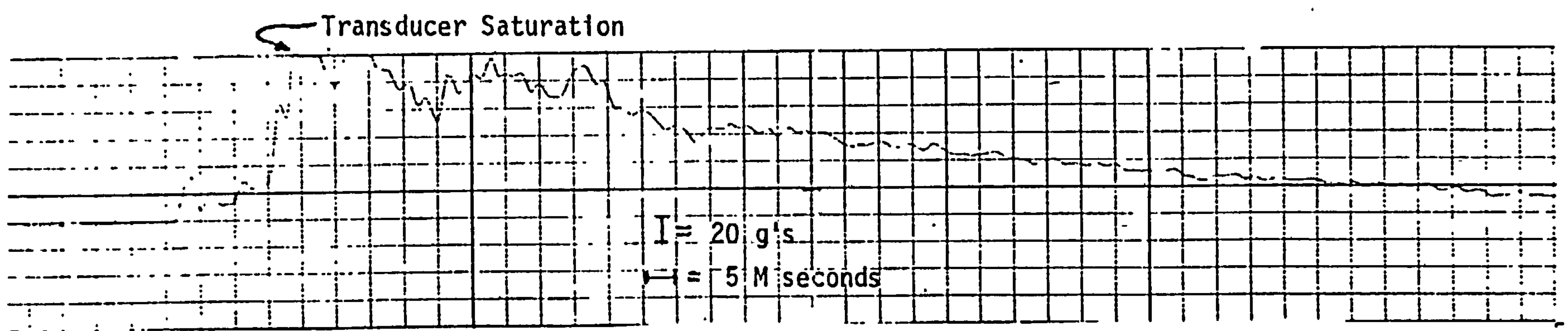
TEST NO. 3 75° COVER DROP



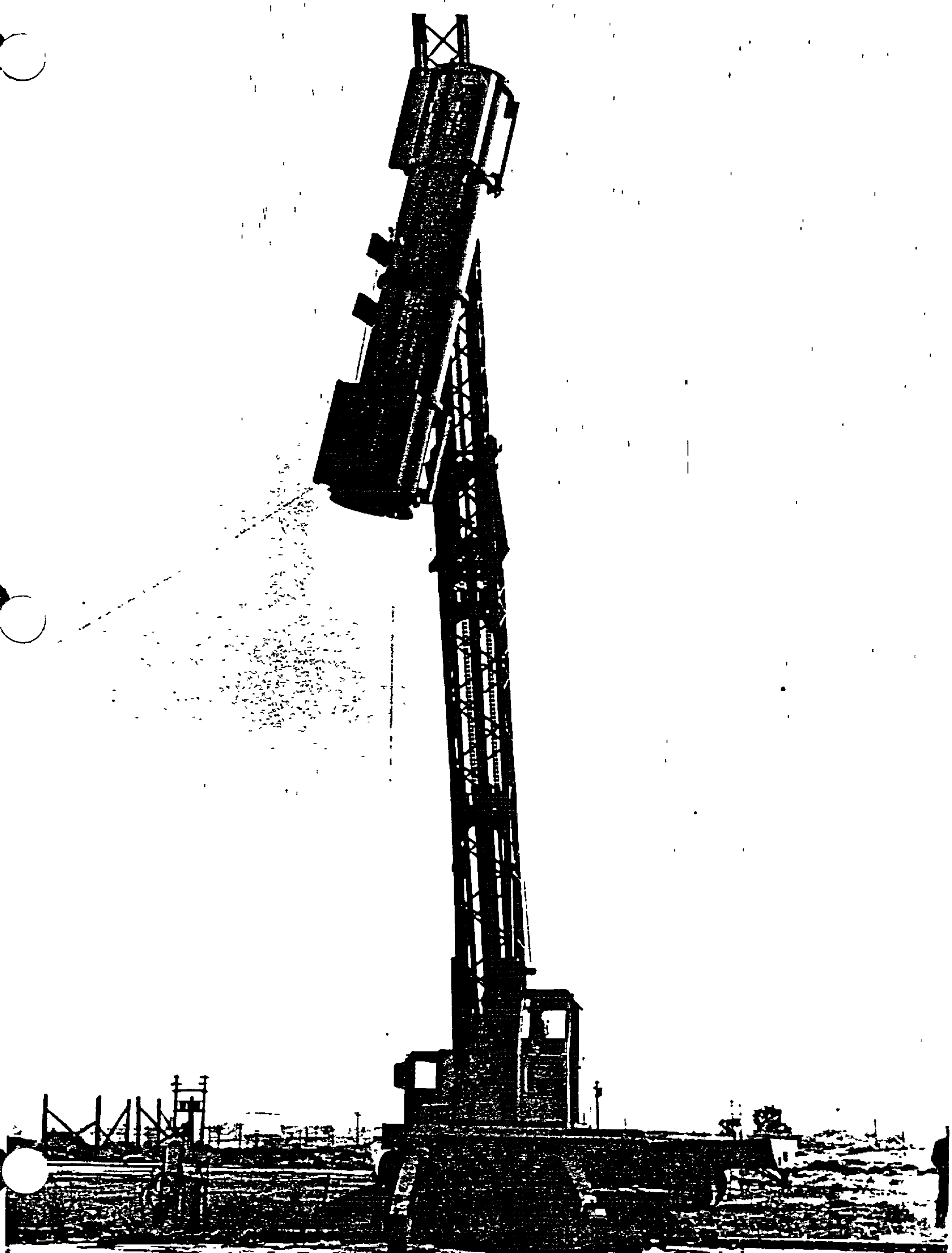
STRONGBACK

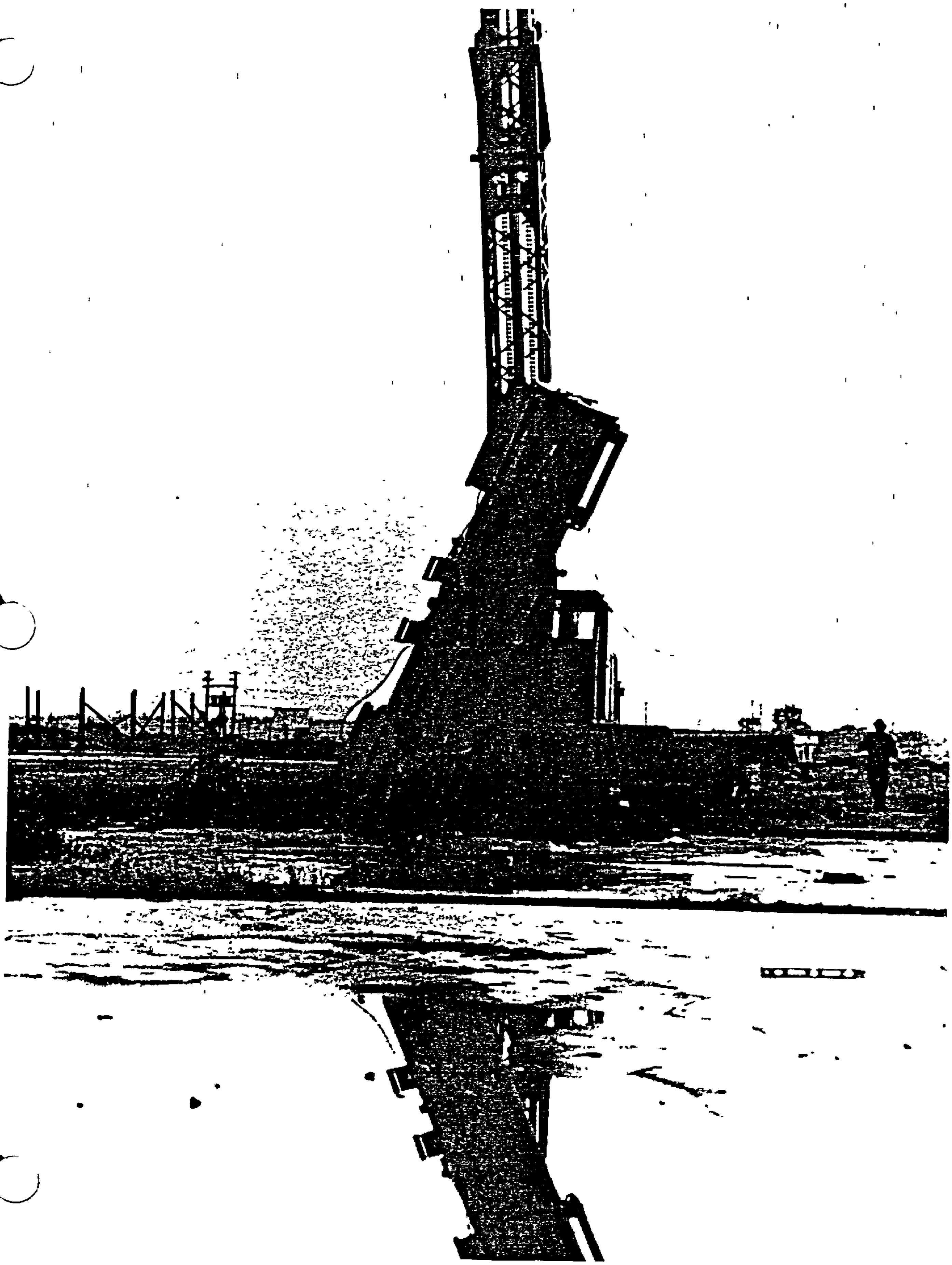


CONTAINER SHELL



CONTAINER C[illegible] FLANGE






DO NOT DROP
CAUTION: RELEASE
PRESSURE BEFORE
OPENING CONTAINE


THIS END
FORWARD
THIS END
FORWARD