APPLICATION FOR USE OF THE 51032-2 SHIPPING CONTAINER FOR TRANSPORT OF RADIOACTIVE MATERIALS

B&W FUEL COMPANY

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1.0 GENERAL INFORMATION

1.1 Introduction

This application is for a Certificate of Compliance for shipping container Model 51032-2. The 51032-2 container is similar to the 51032-1 container presently licensed by Siemens, Docket Number 71-6581. Slight variations are present in the separator block design and the 51032-2 shall be licensed to transport BWFC type fuel assemblies that differ in design than those licensed for the 51032-1 packaging.

The Model 51032-2 shipping container is to be used for transporting unirradiated fuel assemblies. The maximum enrichment for any fuel assembly type is 5.0 wt% U-235 and all shipments may be made as Fissile Class I.

1.2 Package Description

As specified in 10 CFR 71.33, the Model 51032-2 shipping container and its contents are described herein. For ready reference, a listing of the safety and licensing related drawings and their current revision number is provided in Section 1.3, Table 1.1.

1.2.1 Packaging

1.2.1.1 Structure

The empty weight of the Model 51032-2 packaging is 4100 ± 100 pounds. Specific materials of construction, weights, dimensions, and fabrication methods of the packaging components are described below.

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 BWFC Drawings 1215935D and 1215929D). The containment vessel is fabricated in two sections: base and cover assemblies (see BWFC Drawings 1215931D and 1215932D). Continuous closure flanges are welded to the base and cover assemblies, and an "O" 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 "O" ring gasket as nuts are tightly seated to 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 stacking brackets are welded to the cover assembly. A steel lifting lug is welded to each set of stacking brackets. These lugs may be used to support the loaded package.

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 14 shock mounts.

The shock-mounted strongback supports and protects the fuel elements. The standard strongback (see BWFC Drawing 1215933D) is designed to securely hold two 11.5 or 13.5 foot long 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 strongback.

Separator blocks are bolted to the strongback channel such that the centerline of the spacer blocks corresponds to the centerline of the strongback channel.

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 BWFC Drawing 1251926C).

Steel end thrust brackets (see BWFC Drawing 1215930D) are bolted to the strongback at both ends of the fuel elements to prevent longitudinal movement. These are adjustable in order to ship fuel assemblies of differing lengths.

When control component assemblies are shipped along with fuel elements, the control assembly is fully inserted into the fuel element and a spacer assembly or filler, is added to the strongback between the control assembly and the end thrust bracket to provide extra longitudinal support. The spacer assembly (see BWFC drawing 1216010D) is composed primarily of 300 series stainless steel and has an adjustable clamp which contacts the end of the control assembly. The clamp, when tightened, holds the control assembly firmly between the fuel element and the end thrust bracket.

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).

There are no <u>materials specifically used as non-fissile neutron absorbers or moderators</u> in this packaging. When control components are shipped with the fuel assemblies, no credit for their poisons was given from a criticality perspective.

1.2.1.2 **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 BWFC Drawing 1215929D). 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. The clamps are designed to clamp against the spacers of PWR fuel elements (see BWFC Drawing 1215926D).

When transporting fuel elements, restraining bars are included in the package. Restraining 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 (see BWFC Drawing 1215934D). The restraining bars are provided for additional restraint in the event of an accident.

Strongback components required for each package vary with the size of the fuel elements shipped.

1. The number of full clamps to be used is dependent upon the number of spacers in the fuel assembly. One full clamp is to be used for each spacer and end fitting The maximum weight supported by each full clamp assembly under hypothetical accident conditions is depicted in the table below.

MODEL 51032-2 PACKAGE
FUEL ASSEMBLY CLAMP REQUIREMENTS

FA Type	FA + CCA Max. Wt. (2 each)	No. Full Clamps Reqd.	Maximum Weight Supported by Each Full Clamp Assy. (lbs)
MK-B	3300 lbs	10	3300 / (3300 + 710) = 82.29% (168,000 / 10) (82.29%) = **13,825**
MK-BW	3016 lbs	10	3016 / (3016 + 710) = 80.94% (168,000 / 10) (82.29%) = **13,599**
C-Y	2510 lbs	9	2510 / (2510 + 710) = 77.95% (168,000 / 9) (77.95%) = **14,551**

2. The number of separator blocks to be utilized is nine (9). See section 2.10 for the 30 foot side drop analysis which determines separator block spacing.

3. The number of restraining bars employed for transporting fuel elements shall be one fewer than the number of fuel element spacers (one between each spacer full clamp).

1.2.1.3 CONTAINMENT VESSEL PENETRATIONS

There are no sampling ports.

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.

There are also four viewports in the container shell through which shock indicating instruments mounted on the strongback may be viewed.

The containment vessel is not required to be pressurized except during leak testing.

1.2.2 **Operational Features**

Not Applicable.

1.2.3 **Contents of Package**

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 content weight for the Model 51032-2 package is 3400 pounds. Fuel assembly parameters are given in Section 6.

1.3 **Associated Drawings**

TABLE 1.1
SUMMARY LISTING OF APPLICABLE LICENSING DRAWINGS

1215926C-01	Shipping Container Detail
1215929D-01	Model 51032-2 Vessel - Isometric
1215930D-01	End Thrust Bracket Shipping Container Detail
1215931D-01	Base Assembly Model 51032-2 Shipping Container
1215932D-01	Cover Assembly Model 51032-2 Shipping Container
1215933D-01	Strongback Assembly Details 51032-2 Container
1215934C-01	Model 51032-2 Details
1215935D-01	Fuel Packaging Model 51032-2 Layout
1216010D-01	Shipping Container Spacer Assembly

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES					
FRACTION: UP TO 6" ±1/64; OVER 6" THRU 24" ±1/32; OVER 24" ±1/16	DWN. BY	L WITT	SHIPPING CONTAINER DETAIL	THIS DRAWING IS THE PROPERTY OF B & W FUEL COMPANY	
DECIMAL: 2-PLACES - .XX ±.02; 3-PLACES - .XXX ±.005	CHKD. BY	BAUCOM			
ANGLE: ±1°	PASSED BY	SHUMAKER			
ANGULAR DIM. FOR CHAM. & C'SINKS ±5°	APPVD. BY	CARR			
FILLET RADII .03 R MAX.	DATE	8/20/92		DO NOT SCALE USE DIMENSIONS ONLY	SCALE NONE
BREAK CORNERS .02 MAX. R OR CHAM.	CONTRACT NO.			DRAWING NO. 1215926 C	REV. NO. 1
ALL MACHINED SURFACES 125/AA FINISH	ME/92-52/1/D4				

FIGURE WITHHELD UNDER 10 CFR 2.390

DWN. BY	L WITT	MODEL 51032-2 VESSEL (ISOMETRIC VIEW)	THIS DRAWING IS THE PROPERTY OF B & W FUEL COMPANY
CHKD. BY	BAUCOM		
PASSED BY	SHUMAKER		
APPVD. BY	CARR		
DATE	9/9/92		DO NOT SCALE USE DIMENSIONS ONLY — SCALE NONE
CONTRACT NO.			DRAWING NO. 1215929 D — REV. NO. 1
ME/92-52/1/D7			

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES

FRACTION:	UP TO 6"	±1/64
	OVER 6" THRU 24"	±1/32
	OVER 24"	±1/16
DECIMAL:	2-PLACES - .XX	±.02
	3-PLACES - .XXX	±.005
ANGLE:	±1°	

ANGULAR DIM. FOR CHAM. & C'SINKS ±5°
FILLET RADII .03 R MAX.
BREAK CORNERS .02 MAX. R OR CHAM.
ALL MACHINED SURFACES 125/AA FINISH

DWN. BY	L WITT
CHD. BY	BAUCOM
PASSED BY	SHUMAKER
APPD. BY	CARR
DATE	8/24/92
CONTRACT NO.	

ME/92-52/1/08

END THRUST BRACKET
SHIPPING CONTAINER
DETAIL

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B & W FUEL COMPANY

DO NOT SCALE USE DIMENSIONS ONLY | SCALE NONE

DRAWING NO. 1215930 D | REV. NO. 1

FIGURE WITHHELD UNDER 10 CFR 2.390

BILL OF MATERIALS

TOLERANCES	DWN. BY	L WITT
FRACTION: UP TO 6" ±1/64	CHKD. BY	BAUCOM
OVER 6" THRU 24" ±1/32	PASSED BY	SHUMAKER
OVER 24" ±1/16	APPVD. BY	CARR
DECIMAL: 2-PLACES - .XX ±.02	DATE	8/26/92
3-PLACES - .XXX ±.005	CONTRACT NO.	
ANGLE: ±1°		
ANGULAR DIM. FOR CHAM. & C'SINKS ±5°		
FILLET RADII .03 R MAX.		
BREAK CORNERS .02 MAX. R OR CHAM.		
ALL MACHINED SURFACES 125/AA FINISH	ME/92-52/1/D9	

BASE ASSEMBLY
MODEL 51032-2
SHIPPING CONTAINER

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B & W FUEL COMPANY

DO NOT SCALE USE DIMENSIONS ONLY | SCALE NONE

DRAWING NO. 1215931 D | REV. NO. 1

FIGURE WITHHELD UNDER 10 CFR 2.390

DWN. BY	L. WITT	COVER ASSEMBLY MODEL 51032-2 SHIPPING CONTAINER	THIS DRAWING IS THE PROPERTY OF B & W FUEL COMPANY
CHKD. BY	BAUCOM		
PASSED BY	SHUMAKER		
APPVD. BY	CARR		
DATE	8/27/92		DO NOT SCALE USE DIMENSIONS ONLY — SCALE NONE
CONTRACT NO.			DRAWING NO. 1215932 D — REV. NO. 1
ME/92-52/1/D10			

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES

FRACTION:	UP TO 6"	±1/64
	OVER 6" THRU 24"	±1/32
	OVER 24"	±1/16
DECIMAL:	2-PLACES - .XX	±.02
	3-PLACES - .XXX	±.005
ANGLE:	±1°	

ANGULAR DIM. FOR CHAM. & C'SINKS ± 5°
FILLET RADII .03 R MAX.
BREAK CORNERS .02 MAX. R OR CHAM.
ALL MACHINED SURFACES 125/AA FINISH

DWN. BY	L WITT
CHKD. BY	BAUCOM
PASSED BY	SHUMAKER
APPD. BY	CARR
DATE	9/1/92
CONTRACT NO.	

ME/92-52/1/D11

STRONGBACK
ASSEMBLY DETAILS
51032-2 CONTAINER

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DO NOT SCALE USE DIMENSIONS ONLY | SCALE NONE

DRAWING NO. 1215933 D | REV. NO. 1

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES
FRACTION: UP TO 6" ±1/64
OVER 6" THRU 24" ±1/32
OVER 24" ±1/16
DECIMAL: 2-PLACES - .XX ±.02
3-PLACES - .XXX .005
ANGLE: ±1°
ANGULAR DIM. FOR CHAM. & C'SINKS ±5°
FILLET RADII .03 R MAX.
BREAK CORNERS .02 MAX. R OR CHAM.
ALL MACHINED SURFACES 125/AA FINISH

DWN. BY	L WITT
CHKD. BY	BAUCOM
PASSED BY	SHUMAKER
APPVD. BY	CARR
DATE	8/21/92
CONTRACT NO.	
	ME/92-52/1/D12

MODEL 51032-2
DETAILS

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DO NOT SCALE USE DIMENSIONS ONLY | SCALE NONE
DRAWING NO. 1215934 C | REV. NO. 1

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES

FRACTION:	UP TO 6"	±1/64
	OVER 6" THRU 24"	±1/32
	OVER 24"	±1/16
DECIMAL:	2-PLACES - .XX	±.02
	3-PLACES - .XXX	±.005
ANGLE:	±1°	

ANGULAR DIM. FOR CHAM. & C'SINKS ±5°
FILLET RADII .03 R MAX.
BREAK CORNERS .02 MAX. R OR CHAM.
ALL MACHINED SURFACES 125/AA FINISH

DWN. BY	L WITT
CHKD. BY	BAUCOM
PASSED BY	SHUMAKER
APPVD. BY	CARR
DATE	9/2/92
CONTRACT NO.	
ME/92-52/1/D13	

FUEL PACKAGING MODEL NO 51032-2 LAYOUT

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DO NOT SCALE USE DIMENSIONS ONLY | SCALE NONE

DRAWING NO. 1215935 D | REV. NO. 1

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES

FRACTION: UP TO 6" ±1/64
OVER 6" THRU 24" ±1/32
OVER 24" ±1/16
DECIMAL: 2-PLACES - .XX ±.02
3-PLACES - .XXX ±.005
ANGLE: ±1°
ANGULAR DIM. FOR CHAM. & C'SINKS ± 5°
FILLET RADII .03 R MAX.
BREAK CORNERS .02 MAX. R OR CHAM.
ALL MACHINED SURFACES 125/AA FINISH

DWN. BY	L WITT
CHKD. BY	A.R. SHUMAKER
PASSED BY	D.D. HELLER
APPVD. BY	T.S. WILKERSON
DATE	10/12/92
CONTRACT NO.	
DWG/ME/92-52/1/D16	

SHIPPING CONTAINER
SPACER ASSEMBLY
(CONCEPT)

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DO NOT SCALE USE DIMENSIONS ONLY | SCALE 1/2

DRAWING NO. 1216010 D | REV. NO. 1

2.0 STRUCTURAL EVALUATION

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
2. Models 927A, 927B, 927C; USNRC Certificate of Compliance No. 6078

2.1 Structural Design

The Model 51032-1 container design is based upon the Model 927C packaging. In all structural and containment respects, however, the Model 51032-1 package equals or exceeds the capabilities of package upon which the design is based.

Model 51032-1 shipping container was subjected to the hypothetical accident test condition in accordance with 10 CFR 71.73 and 49 CFR 173.398 (c). The actual tests and results provided in this section are from the report "Consolidated License Application for Advanced Nuclear Fuels Corporation Model 51032-1 Shipping Container, Docket 71-6581." This report is provided as Appendix A at the end of this document. Appendix A contains the following:

Appendix II -	Structural Analysis of Model 51032-1 Packaging Tie-Down System
Appendix III -	Applied Design Company, IN. Report 2526A
Appendix IV -	30-Foot Drop Test Procedure and Report Packaging Model 51032-1
Appendix V -	Package Component Evaluations
Appendix VI -	Fuel Rod Drop Test

2.2 Weights and Centers of Gravity

The unloaded weight of the Model 51032-2 container is 4100 ± 100 pounds.

The individual major components are as follows:

Outer Shell	2800 pounds
Strongback Assembly	1300 pounds

The center of gravity for each component is approximately the geometric center.

2.3 **Mechanical Properties of Materials**

Not applicable. A testing program was carried out to evaluate package performance in lieu of a complete structural analysis.

2.4 **General Standards for All Packages**

2.4.1 **Minimum Package Size**

The diameter of the package is 43 inches overall. This exceeds the minimum requirement of 4 inches.

2.4.2 **Tamperproof Feature**

Each package will be sealed with Type E tamper-indicating seals. These features prevent inadvertent and undetected opening.

2.4.3 **Positive Closure**

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.

2.4.4 **Chemical and Galvanic Reactions**

The materials from which the packaging is fabricated (steel, rubber padding, and gaskets), along with the contents of the package (Zircaloy 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.

2.5 **Lifting and Tiedown Standards for All Packages**

2.5.1 **Lifting Devices**

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. Details relative to this test are presented in Appendix A. 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.

2.5.2 **Tiedown Devices**

There is no identified system of tie-down devices on the packages. However, a combination of shoring, positioning studs and axial and transverse chokers (chains or straps) are 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 four stacking brackets per package and the analysis in Appendix II of Appendix A shows 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.

2.6 **Normal Conditions of Transport**

The Model 51032-2 container is similar in construction to the Model 51032-1 container. For this reason, no testing has been done specifically for the Model 51032-2 container since the Model 51032-1 container underwent a testing program prior to licensing. This section outlines the evaluation of normal transport conditions for the Model 51032-1 container, and all results are equally applicable to the Model 51032-2 container.

2.6.1 **Heat**

This evaluation is not applicable since the materials of construction of the packaging, the fuel cladding, and the fuel, can be subjected to much more elevated temperatures without significant detrimental effects.

2.6.2 **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.

2.6.3 Reduced External Pressure

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

2.6.4 Increased External Pressure

The materials of construction of the packaging, the fuel cladding, and the fuel, can be subjected to much more elevated pressures without significant detrimental effects. In addition the fuel rods are designed to operate routinely at pressures in excess of 1000 psi.

2.6.5 Vibration

The effects of vibration normally incident from transport were determined to be negligible on a similar package Model 927A. Analysis and road testing of a Model 51032-1 package has demonstrated that no adverse affects occur to the package as a result of normal vibration incident during transportation.

2.6.6 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 containment 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.

2.6.7 Free Drop

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

2.6.8 Corner Drop

Not Applicable. See Appendix A.

2.6.9 Compression

The compression test was not performed. However, it can be demonstrated 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 (2 x 43 x 217 = 18660 pounds) without generating stress in excess of the yield stress of the packaging material. Also, the fact that these packages will be transported by motor vehicles and cargo-only aircraft, coupled with the physical dimensions on the packaging, precludes them from being stacked more that two high during transport.

2.6.10 **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 and Model UNC-2800, see section 2.7.2) 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, could result in penetration into the containment vessel.

2.7 **Hypothetical Accident Conditions**

The Model 51032-2 container is identical in construction to the Model 51032-1 container. For this reason, no testing has been done specifically for the Model 51032-2 container since the Model 51032-1 container underwent a testing program prior to licensing. The results of the hypothetical accident conditions for the Model 51032-1 container were acceptable, and all results are equally applicable to the Model 51032-2 container.

The integrity of the Model 51032-1 packaging has been subjected to hypothetical accident conditions 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 fuel elements weighing no more than 1650 pounds. Fuel assemblies produced by BWFC do not exceed 1650 pounds.

2.7.1 **Free Drop**

Free drop test were performed with similar packages (Model 927A, see reference 2; Model UNC-2800 see reference 1, and Appendix III of Appendix A), 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 A and a summary of those tests is given below.

2.7.1.1 **Horizontal Cover Drop**

A model 51032-1 package was loaded with two simulated 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 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. 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 maintained in the strongback and the minimum 6 inch separation between 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 the top (edge) of the fuel elements and the inner edge of the stiffener rings).

2.7.1.2 **End Drop**

Another Model 51032-1 container was loaded as in the cover drop test, except that the eight restraint 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. See Appendix A)

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 3/4 inch bolts through each side plate and the sides of the strongback). Neither the thrust plate bolts, nor the end thrust plate side plates, nor the end thrust plate itself 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.

2.7.1.2 **75° Cover Corner Drop**

The package used in the End Drop 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 the Corner Drop were the same as for the End Drop (g.w. of 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 on the aft cover at a 75° ± 1° angle. This drop 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 bracket remained secured to the strongback, and the simulated fuel elements were retained within the strongback.

2.7.2 **Puncture**

The puncture test was not performed on the 51032-1 container. However, puncture tests, as specified in 10 CFR §71.73 (c)(2), were performed on two similar packages:

A. Model UNC-2800; USNRC Certificate of Compliance No. 5419.

B. Models 927A, 927B and 927C; USNRC Certificate of Compliance No. 6078.

The 927A container was subjected to the puncture test in accordance with 10 CFR §71.73 (c)(2). The container was loaded with dummy fuel assemblies and allowed to drop freely onto a steel cylinder, 6 inches in diameter by 8 inches high, from a height of 42 inches. This distance is measured from the bottom of the shell to the top of the steel cylinder. The point of impact was approximately midway between the edge of the aft fork lift guide and the edge of the aft container skid.

Following impact, the external birdcage structure of the container sustained no damage as a result of this test. Examination of the inside of the container indicated no damage to the simulated fuel assemblies, no relative movement of the simulated fuel assemblies and no damage to the suspension frame. It is , therefore, concluded that the container satisfactorily passed the puncture test.

The UNC-2800 container was also subjected to the puncture test, in which a container was loaded with dummy fuel assemblies to simulate the weight of actual fuel assemblies. The inner container and the outer container were then sealed in the same manner as for fuel shipments. The loaded package was then dropped 40 inches upon a 6-in. diameter by 8-in. high steel cylinder.

As a result of the puncture test, the package experienced a three inch deflection in the impact area, deforming uniformly up to the central rollover rings. There was no evidence of any damage to the welded joint.

2.7.3 **Thermal**

Under thermal accident conditions (exposure to a thermal radiation environment of 1475°F for 30 minutes), the integrity of all packaging significant to the safety of the container 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.

2.7.4 **Immersion - Fissile Material**

Not Applicable. The container is assumed to fill with water for the criticality analysis. Also, water will not affect the materials of construction of either the package or the fuel.

2.7.5 Immersion - All Packages

Not Applicable. The container is assumed to fill with water for the criticality analysis. Also, water will not affect the materials of construction of either the package or the fuel.

2.7.6 Summary of Damage

After completion of all testing, the Model 51032 Container had provided satisfactory containment of radioactive materials in accordance with 10 CFR 71.

2.8 Special Form

Not Applicable

2.9 Fuel Rods

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 of Appendix A. Although the tests resulted in significant warping and bending of the individual 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.

2.10 30 Foot Side Drop Analysis

A 30 foot side drop analysis concluded that the maximum "clear" spacing between separator blocks, to maintain a 6 inch minimum fuel assembly separation, following a 30 foot drop of the shipping container on its side, is 11.4 inches. That analysis demonstrated conservatively that, as a minimum, 7/8" diameter bolts should be used to withstand the shear of the impact force. It has been determined that 1" bolts will be used. Due to the high deflection, it was also decided that a 3/8" inch rectangular gusset be fillet welded within each separator block, transverse to the length of the rectangular tubing and located lengthwise between bolt locations. This will stiffen the separator block, minimize deformation due to such high impact loads, and most likely eliminate interference of the separator block with the other adjacent fuel assembly.

3.0 **THERMAL EVALUATION**

Not Applicable.

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).

Also, the materials of construction of the packaging, the fuel cladding, and the fuel, can be subjected to much more elevated temperatures without significant detrimental effects.

4.0 CONTAINMENT

4.1 Containment Boundary

4.1.1 Containment Vessel

The containment boundary for radioactive material is the fuel rod cladding. The containment vessel is a Stainless Steel or Zircaloy cladding tube with a cap welded to each end.

4.1.2 Containment Penetrations

None

4.1.3 Seals and Welds

Each fuel rod has an end cap welded to each end and is certified to be leak free before shipment.

4.1.4 Closure

The welds identified in section 4.1.3 perform the function of a closure device.

4.2 Requirements for Normal Conditions of Transport

4.2.1 Containment of Radioactive Material

Not Applicable. The individual fuel rods are certified to be leak free.

4.2.2 Pressurization of Containment Vessel

The fuel rod is pressurized with inert Helium. No additional vapors or gases could form within the containment vessel.

4.2.3 Containment Criterion

Each fuel rod is certified to be leak free before shipment.

4.3 Containment Requirements for Hypothetical Accident Conditions

4.3.1 Fission Gas Products

Not Applicable.

4.3.2 Containment of Radioactive Material

Not Applicable. The individual fuel rods have been tested under hypothetical accident conditions and have been shown to be leak free.

4.3.3 Containment Criterion

Each fuel rod is certified to be leak free before shipment, and testing of individual fuel rods has shown that under hypothetical accident conditions, the rods will remain leak free (see section 2.9).

4.4 Special Requirements

Not Applicable.

5.0 SHIELDING EVALUATION

Not Applicable.

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

6.0 CRITICALITY EVALUATION

References:

1. Siemens Nuclear Power Corporation Consolidated License Application for Model 51032-1 Shipping Container, Rev. 5, 5A, and 5B; and the resulting Certificate of Compliance No. 6581, Revision 21, May 1992.

2. KENO4, An Improved Monte Carlo Criticality Program, NPGD-TM-503, Rev. G, Babcock & Wilcox, Lynchburg, Virginia, September 1987.

3. W. R. Cable, "123 Group Neutron Cross Section Data Generated From ENDF/B-II Data for Use in the XSDRN Discrete Ordinates Spectral Averaging Code," DLC-16, Radiation Shielding Information Center (1971).

4. NITAWL, Nordheim Integral Treatment and Working Library Production, NPGD-TM-505, Rev. 8, Babcock & Wilcox, Lynchburg, Virginia, December 1988.

5. NRC Rules and Regulations, Title 10 - Chapter 1, Code of Federal Regulations, Part 71 - 170, November 30, 1988.

6. BAW-1484-7, "Critical Experiments Supporting Close Proximity Water Storage Of Power Reactor Fuel", DOE Contract EY-77-C-09-1001, Babcock & Wilcox Company, July 1979.

6.1 Discussion and Results

The Model 51032-1 package has been used for shipping finished fuel assemblies since the early 1970's by Siemens Nuclear Power Corporation and its corporate predecessors. This package meets all criticality criteria for Fissile Class I shipments when loaded with the allowable assembly types. The BWFC has performed criticality analyses to demonstrate that the BWFC fresh fuel product line at a maximum enrichment of 5.0 wt%, has at least the same margin to the criticality safety limit of 0.95 as does the Siemens' W15x15 FA design at the same enrichment. The maximum allowed Kg U235/assembly are shown in Table 6.1.

6.2 Package Fuel Loading

The allowable fuel types consist of the BWFC Mk-B 15x15, Mk-BW 15x15, Mk-C 17x17, Mk-BW 17x17 and ConnYank 15x15 fuel assembly designs. The Conn Yankee 15x15 FA was not analyzed because it is essentially the same design as the Mk-BW 15x15 design but with 120 inch active length. The maximum design active fuel length of 144 inches and the maximum anticipated fuel density of 96.3% of theoretical density were used in the analyses. In addition, ambient temperature of 3.98 °C was assumed for water density. The Mk-C 17x17 design was not analyzed because it is very similar to the Mk-BW 17x17 design, a design that is not limiting for criticality safety.

All calculated k-eff data are less than 0.95.

Assemblies are comprised of UO_2 fuel rods with Zircaloy cladding of nominal thickness not less than 0.020 inch or stainless steel cladding of nominal thickness not less than 0.016 inches. Rods containing gadolinia or other neutron absorbers are allowable but not required. The maximum stack length of active fuel is 144 inches and the maximum allowable enrichment at any transverse section along the fuel length is 5.05 wt% including enrichment tolerances. Other limits and controls for these assemblies are listed in Table 6.1.

6.3 Model Specification

6.3.1 Description of Calculational Model

Details of the models are provided in the KENO geometry model sketches and input listings provided in Sections 6.4 and 6.6 respectively.

The Siemens' license upgrade application for the Model 51032-1[1] contained a detailed description of the analyses performed and criticality reactivity results. Both Siemens and BWFC use the KENO code for the reactivity analyses of the shipping container arrays. Siemens used KENO-Va and BWFC used KENO-IV[2]. The major difference in the methods is the use of a 27 group cross section set by Siemens and the use of a 123 group cross section library[3] processed with the NITAWL code[4] by BWFC. The BWFC fuel assembly product line and the Siemens' W15 design parameters used in criticality safety analysis are given in Table 6.1.

BWFC used methods that are essentially the same as those of Siemens. BWFC performed benchmark calculations for the limiting cases provided by Siemens[1] using the Siemens' KENO input listing. A comparison of the BWFC and Siemens reactivity results can be made from the reactivity data given in Table 6.2[1] (note that data in Table 6.2 does not contain a bias). The BWFC results are in close agreement with those of Siemens; being within one standard deviation for the cases with high reactivity, i.e., cases 1 through

5. Therefore, these results verify that consistent modeling practices were maintained between the Siemens and BWFC analyses.

6.3.2 Normal Array Calculation Model

The packages were modeled with the strongback in the normal position and with the two assemblies conservatively positioned directly adjacent to the separator blocks to maintain a minimum 6 inch separation. See Figures 6.2, 6.8 and 6.12. 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. All dimensions and materials relating to the Model 51032-1 container and normal array were taken from the Siemens license application[1].

6.3.3 Damaged Array Calculation Model

The packages were modeled with the strong backs shifted to produce the minimum possible bundle-bundle separations between adjacent packages. This occurs with the strongback shifted alternately 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. See Figure 6.3. Arrays were modeled in a 39.24 inch square-pitch arrangement as infinite arrays. Various volume percent densities of moderation within and between packages were modeled to determine the peak reactivity condition.

An assessment was made of the effect on array reactivity with a triangular pitch. Since the calculations were performed for an infinite array the primary effects to be expected are the relative importance of water location and density. The assessment was done by changing the square array pitch over a narrow range about the minimum array pitch to note the effects of the relative volume ratio change between the container and the array space. The reactivity changes were well within typical 2σ of the accident array cases analyzed. See Figure 6.1. Thus no adjustment to the reactivity results of the square array analyses is required to allow for possible triangular pitch array configurations.

6.4. Criticality Calculation

6.4.1 Geometry Descriptions

The geometry description to model the BWFC fuel assembly designs in the Siemens Model 51032-1 shipping container in both the undamaged (normal) and damaged (accident) array geometries used by Siemens are provided in this section. Geometry layouts within the shipping container, KENO box dimensions and other KENO input are very similar for all of the BWFC designs. The main geometric differences are the number of fuel rods and guide tubes in each fuel assembly design. This data is provided in Figures 6.2 through 6.15 and Table 6.5.

6.4.2 Fuel Loading or Other Contents Loading Optimization

6.4.2.1 Mk-B 15x15 Fuel Assembly Design

The dimensions for location of the two fuel assemblies in the undamaged and damaged container are provided in Figure 6.2 and 6.3. The KENO-IV box orientations within the core boundary are given in Figure 6.4. A note on this Figure describes how to convert from the Normal Array box orientation to that for the Accident Array. The fuel assembly box types are described and dimensioned in Figure 6.5. The dimensions of the remainder of the box types are given in Table 6.5.

Figure 6.6 is a box representation of the fuel assembly separators used in the analyses. Only 5 of the 9 separators were modeled for conservatism. This is a multipurpose sketch. As noted on the sketch, this box type, Type 15, is converted to a second box type, Type 18, by the change of one dimension. The box, Type 15, as drawn represents the vertical segment of the 5 separator plates. When converted to Box Type 18, the box represents the top horizontal segment of the 5 separator plates. No credit is taken for the bottom horizontal segment of the separator plates. This Figure is used for all three BWFC fuel assembly designs, with the only change being the +y dimension of the box to agree with the unit fuel cell dimension of each fuel assembly design.

The axial dimensions of the arrays are given in Figure 6.7. The BWFC active fuel assembly maximum length of 144 inches is located symmetrically within the 196 inch long container. A twenty six (26) inch end reflector is located on each end of the active fuel. For the most reactive array type, the damaged array, this axial centering of the fuel in the container resulted in a higher k_{eff} than location of the fuel at one end of the container.

6.4.2.2 Mk-BW 15x15 Fuel Assembly Design

The same type information described above for the Mk-B 15x15 design is given in Figures 6.8 through 6.11 and Table 6.5 for the Mk-BW 15x15 design.

6.4.2.3 Mk-BW 17x17 Fuel Assembly Design

The same type information described above for the Mk-B 15x15 design is given in Figures 6.12 through 6.15 and Table 6.5 for the Mk-BW 17x17 design.

6.4.3 Criticality Results

KENO-IV calculation results are used to demonstrate compliance with 10 CFR Part 71[5]. All design calculations were based on fuel rods with 144 inch active stack length of UO_2. Fuel pellets with an average UO_2 density of 10.555 g/cc (96.3% TD) enriched to 5.05 wt.% U-235, including enrichment tolerances, were used for all BWFC fuel assembly criticality safety analyses. All packages modeled contained two fuel assemblies spaced six inches edge-to-edge by the minimum allowable number (5) of separator blocks. A 123 group cross section library[3], as processed by NITAWL, was used in all KENO calculations. KENO calculations typically employed 203 generations of 501 neutrons to give a well-converged solution with a relatively small Monte Carlo uncertainty. Calculation results for the allowable contents are grouped together for damaged conditions and undamaged conditions.

6.4.3.1 Damaged Array Calculation Results

Infinite arrays were modeled for three BWFC fuel assembly designs with full density water within packages and for both a dry and full interspersed water density. These designs were the Mk-B 15x15, the Mk-BW 15x15 and Mk-BW 17x17. For all three designs the interspersed environment of full water density was very slightly more reactive than the dry environment, indicating that for full moderation within the container, the interspersed water was not very important. The damaged array maximum reactivity was within 1% Δk for all three BWFC designs, with the Mk-BW 15x15 design being the most reactive. Additional calculations were performed for the Mk-BW 15x15 design for variable water density within and between packages. For the several combinations calculated, the fully moderated container was the most reactive. Therefore, only analyses for damaged arrays with full density water inside and 0% or 100% water density outside (between the damaged array packages) were performed for the remainder of the designs. The reactivity results for the three BWFC fuel assembly designs are provided in Table 6.3. The worst case occured for the Mk-BW 15X15 fuel assembly design which maintained approximately 0.0088 ΔK (0.88%) margin to the 0.95 limit.

6.4.3.2 **Fuel Rod Bow Considerations**

Combustion Engineering performed a 30 foot drop test in which a cask experienced a horizontal side impact[1]. However, the early Combustion Engineering cask design (Model 927A) contained a single stainless steel separator plate that spanned the length of the cask. Combustion Engineering later modified this design (Models 927C and 51032-1) to contain separator blocks that were designed to maintain a minimum 6 inch separation between assemblies. The BWFC Model 51032-2 shipping container contains nine 6 inch wide - 9 inch long separator blocks. Therefore, the direct application of Model 927A drop test results to the BWFC cask design is questionable since the design of the cask internals is significantly different.

Combustion Engineering later gave consideration to the potential for rod bow in the open spaces between the separator blocks after a horizontal side drop. BWFC also evaluated the amount of rod bow that could occur for the BWFC Model 51032-2 cask as a function of separator block spacing. The BWFC Model 51032-2 shipping cask will maintain a separator block spacing that will not exceed 11.4 inches in order that rod bow will be maintained less than 0.648 inches during a horizontal drop accident.

With fuel assemblies assuming a normal configuration within the shipping cask, a 0.648 inch gap is maintained between the separator block and the edge of the fuel assembly to facilitate loading and unloading of the assemblies. This spacing is maintained for the bottom fuel assembly during a horizontal side drop as long as the two 5/8 inch grade 8 carbon steel bolts holding the separator blocks to the strongback or the blocks themselves do not shear or deform during an accident. BWFC performed a structural analysis on the separator blocks assuming the top assembly came loose from the clamps and impacted the separator blocks. The results of this analysis demonstrated that the separator blocks would remain in their original positions during a horizontal side drop accident if two 1 inch diameter bolts were used to secure the separator blocks. Additionally, a gusset plate was added to the separator blocks to prevent deformation. The rod bow in the top fuel assembly caused by the horizontal side drop accident is offset by the gap between the separator blocks and the bottom fuel assembly as long as the longitudinal distance between separator blocks does not exceed 11.4 inches. Therefore, the minimum 6 inch separation between assemblies in a cask, which was assumed for both normal and accident calculations is conservative for criticality calculations.

6.4.3.3 Undamaged (Normal) Array Calculation Results

Infinite arrays were modeled for the three previously identified BWFC fuel assembly designs. They were modeled with a dry environment inside the containers and with interspersed water density conditions outside the casks. Water densities outside the casks were varied over a range of 1% to 100%. For all three designs, the maximum array reactivity occurred at about 2% moderator density. The normal array maximum reactivity was within 1% Δk for all three BWFC designs, with the Mk-B 15x15 design being the most reactive.

All the calculations were performed with a fifty two (52) inch axial dimension void volume being equally divided (26 inches per end reflector) and located at each end of the active fuel. These dimensions result from using a container length of 196 inches. The centering of the active fuel axially is a good approximation. The measured distances of the active fuel stack of a loaded fuel assembly to the ends of the container are about 31 and 41 inches for the container real length of about 216 inches. The reactivity results for the three BWFC fuel assembly designs are provided in Table 6.3.

6.4.3.4 Array Maximum Reactivity Comparison

A summary of the maximum infinite array reactivity calculated for the three BWFC fuel assembly designs and for the Siemens W15 design is given in Table 6.4. These results demonstrate that the BWFC fuel assembly designs have at least the same margin to the criticality safety limit of 0.95 as does the W15 design.

6.5 Critical Benchmark Experiments

6.5.1 Benchmark Experiments and Applicability

Low-enriched UO_2 fuel pins in a water-moderated lattice were used to construct 21 critical experiments that simulated a variety of close-packed LWR fuel storage configurations [6]. The critical assemblies consisted of nine LWR-type fuel assemblies (clusters) grouped in a 3x3 array. Both the spacing and the material between the fuel clusters were varied to provide numerous critical configurations.

The experimental configurations chosen for the benchmark calculations have the following similarities to the cask package configuration:

- low enriched uranium dioxide fuel,
- fissile material size and shape,
- hydrogenous moderation,
- variable spacings between assemblies,
- some configurations contain appropriate materials between assemblies (such as steel).

Thus the critical experiments chosen for the benchmark calculations are directly applicable for this analysis.

6.5.2 Details of Benchmark Calculations

There were three distinct sets of core geometries:

1. Core I - cylindrical critical array of 438 fuel pins, constructed as a base case.

2. Cores II through IX - nine square fuel pin clusters, each 14 pins on a side, arranged in a 3 by 3 array. The fuel clusters were spaced varying distances apart and were vertically aligned by continuous upper and lower grids. In some cases B_4C pins were inserted in the space between the fuel clusters.

3. Cores X through XXI - nine square fuel pin bundles, each 14 pins on a side except that the four corner positions of each fuel assembly were occupied by threaded aluminum rods that positioned the three grid plates and provided the unit assembly framework. The free standing feature was necessary to accommodate the metal isolation sheets used in cores X through XXI. Like cores II through IX, the fuel assemblies were grouped in a 3 by 3 array and spaced varying distances apart.

6.5.3 Results of the Benchmark Calculations

6.5.3.1 Bias For Fully Moderated Casks

BWFC methodology differs from that of Siemens because a non-zero bias was used in the determination of maximum k-effective. Examination of light water reactor critical experiments [6] for low-enriched U^{235} lattices demonstrated an increasing negative bias with increasing separation distances between assemblies. Twenty-one critical light water moderated, low enriched fuel configurations of reference 6 were evaluated using KENOIV with the 123 group cross section library with 160,000 neutron histories. The bias reached a maximum of -0.0145 $\Delta K \pm 0.00411\ \Delta K$ (2σ Unc) with 2.576 inches separating fuel assemblies as shown in Table 6.6. Values in ( ) in Table 6.6 indicate 1σ uncertainty.

Applicable critical experiments in the industry only address separation distances up to 2.576 inches with and without interspersed absorber materials. The separation distance between fuel assemblies in the shipping cask is at least 14 inches with an undamaged fuel configuration (6 inches was actually used in the "nominal" cases for conservatism) and 6 inches during a limiting accident (the minimum distance between assembly pairs in a single cask). Therefore, application of the full -0.0145 ΔK bias is questionable for the fully moderated cask since the neutron spectrums for larger separation distances are decoupled with fully dense water (assemblies appear to be isolated and do not see significant neutron contributions from adjacent assemblies). For critical experiments that represent isolated assemblies the average bias for critical cores I and II is +0.0065 $\Delta K \pm 0.00376\ \Delta K$ (2σ Unc). Critical k-effective for isolated assemblies is therefore conservative by approximately +0.0065 ΔK. Therefore it is reasoned that the negative bias cannot continue to increase with larger separation distances between assemblies. Although the maximum k-effectives calculated by the BWFC might accommodate the -0.0145 $\Delta K \pm 0.00411\ \Delta K$ bias (2σ), it felt that a -0.005 $\Delta K \pm 0.00376\ \Delta K$ bias would be conservative and more reasonable based on fuel assembly separation distances in the range of 6 inches.

To demonstrate that the -0.005 ΔK KENOIV bias is conservative for a 6 inch fuel separation, twelve KENOIV accident cases were performed and each modeled an infinite array of casks. The damaged cask configuration shown in Figure 6.3 was modeled, however, the outer steel shell was removed to allow closer separation distances than are actually possible between casks. A conservative minimum edge-to-edge separation distance of 6 inches (defined by the separator blocks) was maintained between pairs of assemblies in each cask for all of the cases evaluated. The data in Table 6.7 and Figure 6.16 demonstrates the reactivity behavior as cask packages are moved closer together.

For cask fuel edge-to-edge separation distances (the distance between the edge of an assembly in one cask to the edge of an assembly in an adjacent cask) greater than 4.5 inches and up to 10 inches of water or more there is a slight decrease in k-effective due to the presence of increasing amounts of water moderator (see Figure 6.16). The water moderator increases the effective absorption of neutrons by the steel strong back saddle uprights that are positioned adjacent to each assembly. The strong back saddle uprights act as a mild poison for the thermal flux trap between cask packages. For separation distances less than 4.5 inches, k-effective begins to increase rapidly as fast neutrons are able to "see" adjacent fuel assembly pairs and the worth of the thermal flux trap decreases.

These results demonstrate that the thermal neutron spectrums of fuel assembly pairs are essentially decoupled with as little as 4.0 inches of fully dense water in a flux trap (4.0 inches of water plus 0.25 inches of steel * 2 equals 4.5 inch total separation). Since a minimum total separation distance of 6 inches is maintained under all fuel configurations, the application of a +0.0065 $\Delta K \pm$ 0.00376 ΔK bias credit could be argued based on critical experiments. It is possible that Siemens did not apply a bias to their calculations for this reason. However, for conservatism the BWFC will apply an arbitrary bias and uncertainty of -0.005 $\Delta K \pm$ 0.00376 ΔK to all fully dense water moderated cases.

To ensure that removal of the outer steel shell did not significantly effect the k-effective trend, two accident cases were performed with the steel shell modeled (see Table 6.8). One had a fuel edge-to-edge separation distance of 10 inches while the other was performed with 8.655 inches. The results of both cases indicate that k-effective of the casks is increased by approximately 0.003 ΔK relative to the equivalent non-shell cases. The increase in k-effective is due to reflection of neutrons by the outer steel shell.

6.5.3.2 **Interspersed Water Moderator Bias**

Examination of critical experiments indicates that all critical cores were evaluated with a water moderator at 100% density. For low density moderator or fog cases, the bias should be calculated based upon the effective separation distance between assemblies. This would be the equivalent separation distance if there were 100% dense water. For distances up to approximately 36.7 inches (2.567 in/0.07 = 36.7 in.; 7% dense water is typical) separating assemblies the bias would be less than -0.0145 ΔK $\pm$ 0.00411 ΔK. Furthermore, increased neutron leakage at such large distances has not been considered. However, since no specific critical experiments exist for these conditions, use of the maximum calculated bias is conservative and will be applied to all interspersed moderator cases.

6.5.3.3 <u>**Combination Fully Dense Water - Interspersed Moderator Bias**</u>

For accident cases involving a flooded cask surrounded by a fog or mist condition, the flooded cask bias (-0.005 $\Delta K \pm 0.00376\ \Delta K$) was applied since a minimum combined 5.0 inch thickness of fully dense water exists in both casks. The minimum dimension is between the top edges of fuel excluding steel uprights, cask barrel, and intervening mist when the casks are touching each other in the accident configuration.

6.6 <u>**Appendix - KENOIV Input Listings**</u>

The KENO-IV input listings for the case with the highest reactivity for each BWFC fuel assembly design in both Normal and Accident arrays are provided in the Appendix to this chapter. The case input listings are identified by case number (corresponding to the case number given in Table 6.3).

TABLE 6.1
Fuel Assembly Parameters

Category/Parameter	Mk-B 15x15	Mk-BW 15x15	Mk-C 17x17	Mk-BW 17x17	Conn Yankee	W15[c]
Assembly Type	15x15	15x15	17x17	17x17	15x15	15x15
Fuel Rods per Assembly	208	204	264	264	204	204
Nominal Rod Pitch, (nom), in.	.568	.563	.501	.496	.5625	.563
Pellet Diameter, (nom), in.	.3686	.3625	.3240	.3195	.3610	**[d]
Nominal Cladding OD (nom), in.	.430	.422	.379	.374	.422	
Nominal Cladding ID (nom), in.	.377	.370	.332	.326	.368	
Assembly Size (nom), in.[a]	8.520	8.445	8.517	8.432	8.438	8.445
Active Fuel Stack Length, in.	144	144	144	144	120	196
Maximum Assembly wt% U-235[b]	5.05	5.05	5.05	5.05	5.05	5.00
Shipment Fissile Class	1	1	1	1	1	1
Fuel Pellet Density, %TD	96.3	96.3	96.3	96.3	96.3	
Maximum U-235 Loading, kg	24.61	23.34	24.13	23.47	19.29	

[a] The "assembly size" parameter is defined as the product of the rod pitch and the number of rods per edge (e.g., 8.520=15*0.568)

[b] Maximum enrichment includes enrichment tolerance.

[c] Siemens Nuclear Power Corporation Consolidated License Application for Model 51032-1 Shipping Container, Rev 5, 5A and 5B.

[d] .364/.370/.410 in., pellet OD/clad ID/clad OD damaged array
.384/.390/.430 in., pellet OD/clad ID/clad OD normal array

TABLE 6.2

Siemens[1] and BWFC Reactivity Comparison
W15x15 Fuel Assembly Design

Case ID	Water Density Within (%)	Water Density Between (%)	Pellet/Clad ID/ Clad OD (inch)	Siemens[1] KENO-Va $k_{eff} \pm \sigma$	BWFC KENO-IV $k_{eff} \pm \sigma$	(Siemens-BWFC) Δk_{max}[a]
	Damaged Package Array					
1	100	0	.364/.370/.410	0.9376 ± 0.0041	0.9388 ± 0.0024	0.0022
2	100	100	.364/.370/.410	0.9376 ± 0.0039	0.9380 ± 0.0025	0.0024
	Undamaged Package Array					
3	0	1	.430	0.8408 ± 0.0016	0.8407 ± 0.0012	0.0009
4	0	4	.430	0.9241 ± 0.0017	0.9253 ± 0.0017	-0.0012
5	0	10	.430	0.8310 ± 0.0019	0.8317 ± 0.0019	-0.0007
6	0	90	.430	0.3841 ± 0.0018	0.3688 ± 0.0015	0.0159
7	0	100	.430	0.3762 ± 0.0017	0.3626 ± 0.0016	0.0138

[a] $k_{max} \equiv k_{eff} + 2\sigma$

TABLE 6.3

Maximum K-effective Including Bias Versus Assembly Type

BWFC MK-B 15X15 Assembly 5.05 wt% U^{235}

	BWFC MK-B 15X15 5.05 wt%U235 Accident Array	Base Keff	Bias	Combined 2*Sigma Unc	Max Keff 0.95 Limit
8	Water Density-100% in/ 100% out	0.92763	+0.005	+0.00653	0.93916
9	Water Density - 100% in/ 0% out	0.92729	+0.005	+0.00651	0.93880
	Normal Array - Dry Internally	Base Keff	Bias	Combined 2*Sigma Unc	Max Keff 0.98 Limit
10	1 Vol % Interspersed Water	0.83745	+0.0145	+0.00501	0.85696
11	2 Vol % Interspersed Water	0.85793	+0.0145	+0.00525	0.87768
12	4 Vol % Interspersed Water	0.84477	+0.0145	+0.00531	0.86458
13	10 Vol % Interspersed Water	0.73744	+0.0145	+0.00557	0.75751
14	20 Vol % Interspersed Water	0.58846	+0.0145	+0.00546	0.60842
15	40 Vol % Interspersed Water	0.45129	+0.0145	+0.00539	0.47118
16	90 Vol % Interspersed Water	0.34159	+0.0145	+0.00505	0.36114
17	100 Vol % Interspersed Water	0.33355	+0.0145	+0.00515	0.35320

$$Kmax = Keff + Bias + 2*((Unc_{BASE})^2 + (Unc_{BIAS})^2)^{1/2}$$

TABLE 6.3 (Continued)

Maximum K-effective Including Bias Versus Assembly Type

BWFC MK-BW 15X15 Assembly 5.05 wt% U^{235}

Case ID	BWFC MK-BW 15X15 5.05 wt%U235 Accident Array	Base Keff	Bias	Combined 2*Sigma Unc	Max Keff 0.95 Limit
18	Water Density-100% in/ 100% out	0.93035	+0.005	+0.00588	0.94123
19	Water Density - 100% in/ 0% out	0.92121	+0.005	+0.00618	0.93239
20	Water Density - 0.2% in/ 0.2% out	0.77550	+0.0145	+0.00462	0.79462
21	Water Density -1.0% in/ 1.0% out	0.83626	+0.0145	+0.00516	0.85592
22	Water Density - 2.0% in/ 2.0% out	0.78510	+0.0145	+0.00540	0.80500
23	Water Density - 10.% in/ 10.% out	0.56538	+0.0145	+0.00575	0.58563
	Normal Array - Dry Internally	Base Keff	Bias	Combined 2*Sigma Unc	Max Keff 0.98 Limit
24	1 Vol % Interspersed Water	0.83111	+0.0145	+0.00486	0.85047
25	2 Vol % Interspersed Water	0.85307	+0.0145	+0.00516	0.87273
26	4 Vol % Interspersed Water	0.83572	+0.0145	+0.00540	0.85562
27	10 Vol% Interspersed Water	0.73310	+0.0145	+0.00557	0.75317
28	20 Vol % Interspersed Water	0.57803	+0.0145	+0.00548	0.59801
29	40 Vol % Interspersed Water	0.44419	+0.0145	+0.00557	0.46426
30	90 Vol % Interspersed Water	0.33626	+0.0145	+0.00506	0.35582
31	100 Vol % Interspersed Water	0.32685	+0.0145	+0.00518	0.34653

$$Kmax = Keff + Bias + 2*((Unc_{BASE})^2 + (Unc_{BIAS})^2)^{1/2}$$

TABLE 6.3 (Continued)

Maximum K-effective Including Bias Versus Assembly Type

BWFC MK-BW 17X17 Assembly 5.05 wt% U^{235}

	BWFC MK-BW 17X17 5.05 wt%U235 Accident Array	Base Keff	Bias	Combined 2*Sigma Unc	Max Keff 0.95 Limit
32	Water Density-100% in/ 100% out	0.92209	+0.005	+0.00621	0.93330
33	Water Density - 100% in/ 0% out	0.91949	+0.005	+0.00621	0.93070
	Normal Array - Dry Internally	Base Keff	Bias	Combined 2*Sigma Unc	Max Keff 0.98 Limit
34	1 Vol % Interspersed Water	0.82925	+0.0145	+0.00487	0.84862
35	2 Vol % Interspersed Water	0.85078	+0.0145	+0.00515	0.87043
36	4 Vol % Interspersed Water	0.83663	+0.0145	+0.00535	0.85648
37	10 Vol % Interspersed Water	0.72976	+0.0145	+0.00575	0.75001
38	20 Vol % Interspersed Water	0.58108	+0.0145	+0.00548	0.60106
39	40 Vol % Interspersed Water	0.44491	+0.0145	+0.00528	0.46469
40	90 Vol % Interspersed Water	0.33796	+0.0145	+0.00510	0.35756
41	100 Vol % Interspersed Water	0.32608	+0.0145	+0.00528	0.34586

$$Kmax = Keff + Bias + 2*((Unc_{BASE})^2 + (Unc_{BIAS})^2)^{1/2}$$

TABLE 6.4

Fuel Assembly Design
Reactivity Comparison

	K_{max} [a]				
FA Design-->	Siemens ANF W15	BWFC ANF W15	BWFC Mk-B 15X15	BWFC Mk-BW 15X15	BWFC Mk-BW 17X17
Array Type					
Accident	.9458	.94356	.93297	.93487	.92703
Normal	.9275	.92873	.86119	.85619	.85388

[a] $K_{max} \equiv K_{eff} + 2\sigma$

TABLE 6.5

BWFC MkBW 15X15 ACCIDENT ARRAY BOX DIMENSIONS

BOX TYPE	+X	-X	+Y	-Y	+Z	-Z	
4	.635	0	.635	0	365.76	0	123Z
5	1.43002	0	.635	0	"	"	"
6	.635	0	1.43002	0			
7	.9525	0	.635	0			
8	13.335	0	1.43002	0			
9	.635	0	9.6647	0			
10	1.43002	0	9.6647	0			
11	.9525	0	9.6647	0			
12	5.0419*	0	0.635	0			
13	5.0419*	0	1.43002	0			
14	5.0419*	0	9.6647	0			
15 & 18	See box breakout for dimensions						
16	13.335	0	.635	0	"	"	"
17	13.335	0	9.6647	0	365.76	0	123Z

* 12x, 13x, and 14x become 2.52095 for the NORMAL array

BWFC MkB 15x15 ACCIDENT ARRAY BOX DIMENSIONS

BOX TYPE	+X	-X	+Y	-Y	+Z	-Z	
4	.635	0	.635	0	365.76	0	123Z
5	1.44272	0	.635	0	"	"	"
6	.635	0	1.44272	0			
7	.9525	0	.635	0			
8	13.335	0	1.44272	0			
9	.635	0	9.4742	0			
10	1.44272	0	9.4742	0			
11	.9525	0	9.4742	0			
12	4.66095*	0	0.635	0			
13	4.66095*	0	1.44272	0			
14	4.66095*	0	9.4742	0			
15 & 18	See box breakout for dimensions						
16	13.335	0	.635	0	"	"	"
17	13.335	0	9.4742	0	365.76	0	123Z

* 12x, 13x, and 14x become 2.33048 for the NORMAL array

BWFC MkBW 17x17 ACCIDENT ARRAY BOX DIMENSIONS

BOX TYPE	+X	-X	+Y	-Y	+Z	-Z	
4	.635	0	.635	0	365.76	0	123Z
5	1.25984	0	.635	0	"	"	"
6	.635	0	1.25984	0			
7	.9525	0	.635	0			
8	13.335	0	1.25984	0			
9	.635	0	9.69772	0			
10	1.25984	0	9.69772	0			
11	.9525	0	9.69772	0			
12	5.10794*	0	0.635	0			
13	5.10794*	0	1.25984	0			
14	5.10794*	0	9.69772	0			
15 & 18	See box breakout for dimensions						
16	13.335	0	.635	0	365.76	0	123Z
17	13.335	0	9.69772	0	365.76	0	123Z

* 12x, 13x, 14x become 2.55397 for the NORMAL Array

TABLE 6.6

KENOIV Bias Versus Separation Distance (in.)

Spacing Between Arrays	Core Configuration	KENOIV Calculated Keffective On IBM R/C 6000	Measured Critical Keffective	Calculated Minus Measured
None	I	1.00447 (0.00181)	1.0002 (0.0005)	+0.00427
	II	1.00892 (0.00168)	1.0001 (0.0005)	+0.00882
0.644	III	0.99937 (0.00149)	1.0000 (0.0006)	-0.00063
	IV	1.00669 (0.00192)	0.9999 (0.0006)	+0.00679
	XI	1.00242 (0.00168)	1.0000 (0.0006)	+0.00242
	XIII	1.01025 (0.00188)	1.0000 (0.0010)	+0.01025
	XIV	1.00405 (0.00181)	1.0001 (0.0010)	+0.00395
	XV	0.99596 (0.00171)	0.9998 (0.0016)	-0.00384
	XVII	1.00015 (0.00188)	1.0000 (0.0010)	+0.00015
	XIX	1.00150 (0.00176)	1.0002 (0.0010)	+0.00130
1.288	V	1.00189 (0.00186)	1.0000 (0.0007)	+0.00189
	VI	1.00929 (0.00187)	1.0097 (0.0012)	-0.00041
	XII	0.99691 (0.00173)	1.0000 (0.0007)	-0.00309
	XVI	0.99193 (0.00200)	1.0001 (0.0019)	-0.00817
	XVIII	0.99139 (0.00179)	1.0002 (0.0011)	-0.00827
	XX	0.99193 (0.00186)	1.0003 (0.0011)	-0.00837
1.932	VII	0.99190 (0.00192)	0.9998 (0.0009)	-0.00790
	VIII	1.01708 (0.00181)	1.0083 (0.0012)	+0.00878
	X	0.99182 (0.00179)	1.0001 (0.0009)	-0.00828
	XXI	0.98954 (0.00159)	0.9997 (0.0015)	-0.01016
2.576	IX	0.98847 (0.00185)	1.0030 (0.0009)	-0.01453

TABLE 6.7

Cask K-effective Versus Separation Distance (in.)

(Without Outer Steel Shell)

Spacing (in.)	Base Keff	2*Sigma Unc	Max Keff	Min Keff
0.000	1.02223	0.00516	1.02739	1.01707
2.000	0.97178	0.00494	0.97672	0.96684
2.600	0.95554	0.00464	0.96018	0.95090
3.345	0.94514	0.00496	0.95010	0.94018
4.000	0.93562	0.00484	0.94046	0.93078
4.500	0.92631	0.00490	0.93121	0.92141
5.000	0.92566	0.00514	0.93069	0.92041
6.000	0.92856	0.00522	0.93378	0.92334
8.655	0.92450	0.00516	0.92966	0.91934
10.000	0.91962	0.00526	0.92488	0.91436
12.000	0.91929	0.00542	0.92471	0.91387

TABLE 6.8

Cask K-effective Versus Separation Distance (in.)

(With Outer Steel Shell)

Spacing	Base Keff	2*Sigma Unc	Max Keff	Min Keff
8.655	0.92763	0.00534	0.93297	0.92229
10.000	0.92230	0.00452	0.92682	0.91778

FIGURE 6.1

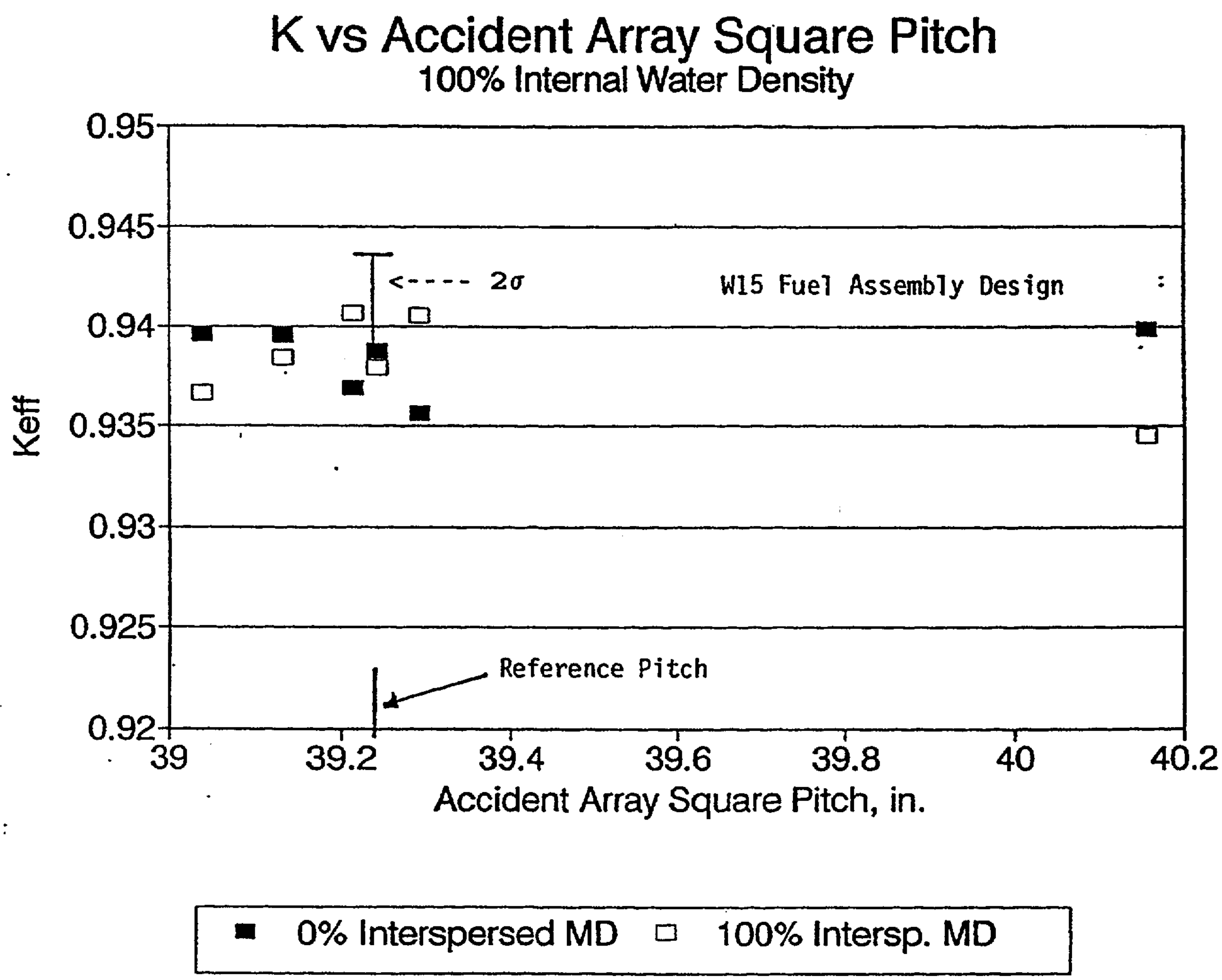

K vs Accident Array Square Pitch
100% Internal Water Density
Keff
0.95
0.945
0.94
0.935
0.93
0.925
0.92
<---- 2σ
W15 Fuel Assembly Design
Reference Pitch
39
39.2
39.4
39.6
39.8
40
40.2
Accident Array Square Pitch, in.
0% Interspersed MD
100% Intersp. MD

FIGURE 6.2

BWFC MkB 15X15 FA Design Normal Array Unit Cell

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 6.3

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 6.4

BWFC MkB 15X15 FA Normal Array Box Orientation

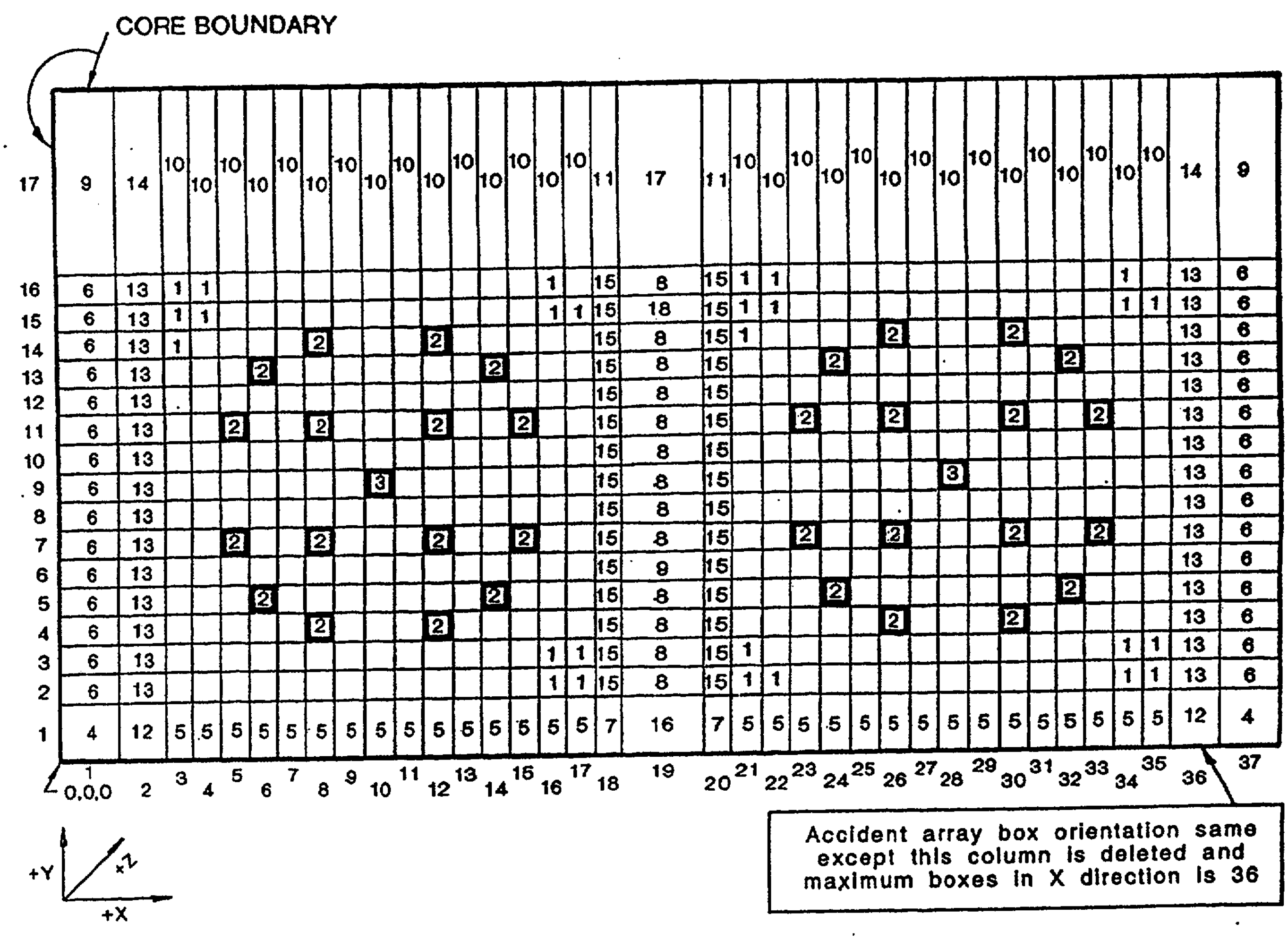


FIGURE 6.5

BWFC MkB 15X15 FA Design KENO Box Types
(All Boxes Have Length of 144 Inches)

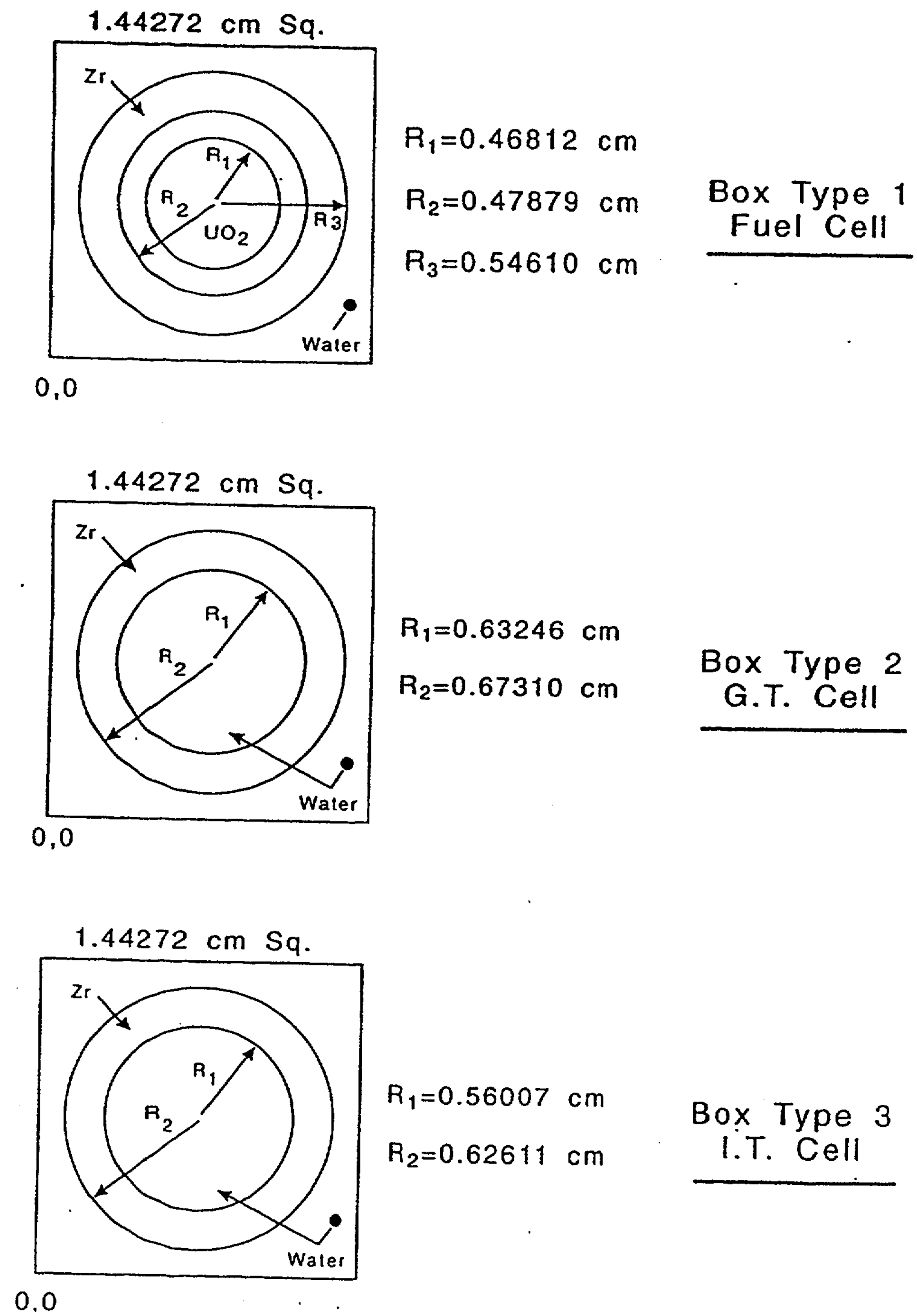


FIGURE 6.6

BWFC MkB 15X15 FA Design KENO Box Types
(All Boxes Have Length of 144 Inches)

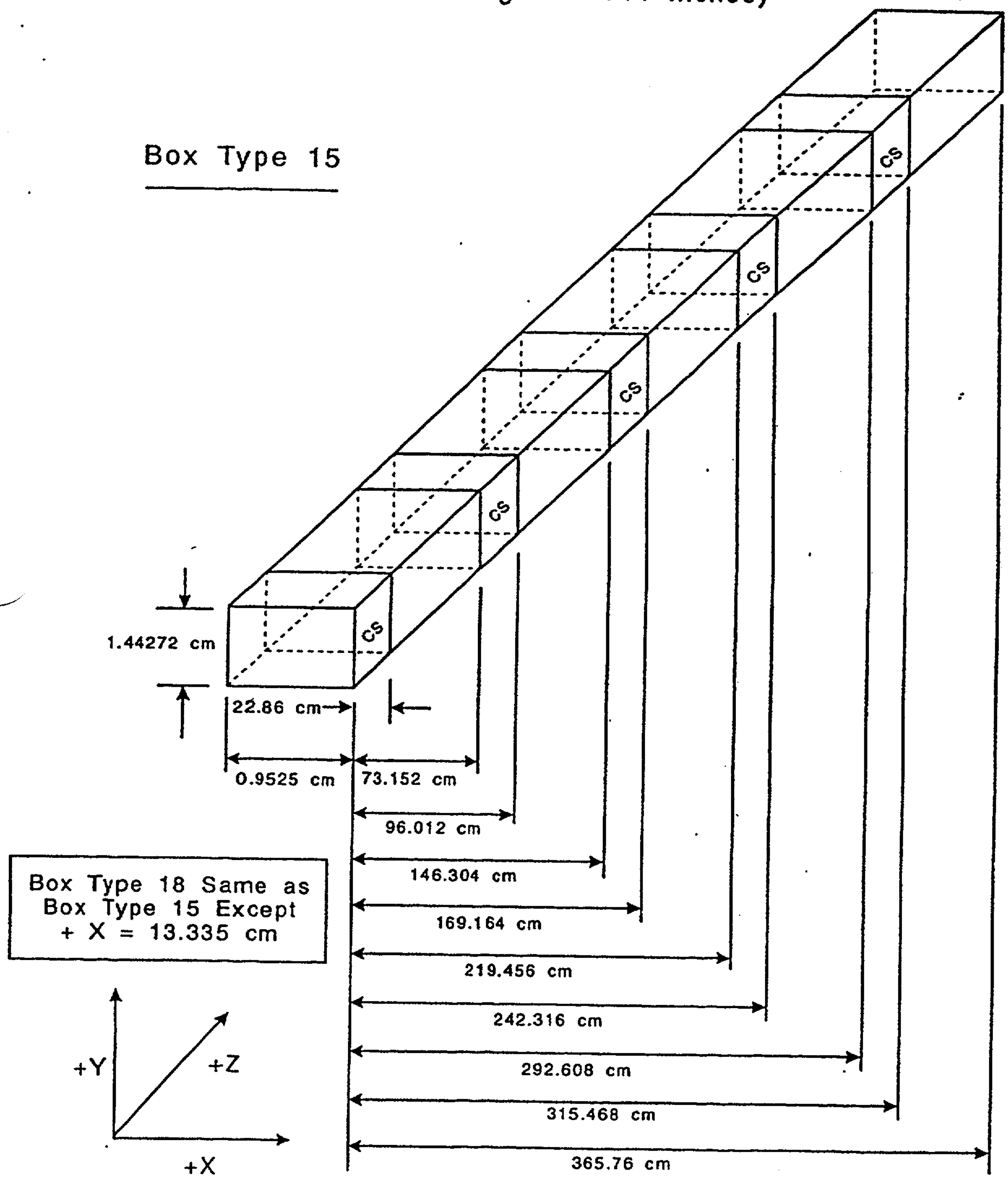


FIGURE 6.7

Z Axis Dimensions

Accident and Normal Array

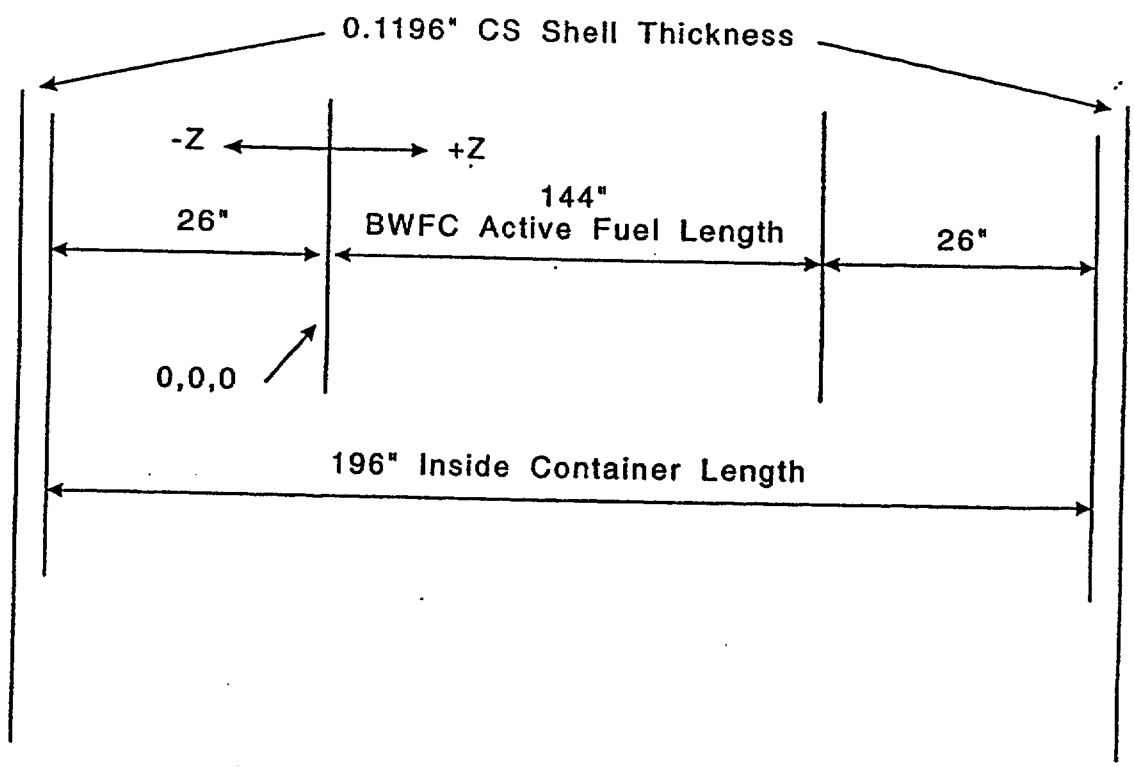


FIGURE 6.8

BWFC MkBW 15X15 FA Design Normal Array Unit Cell

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 6.9

BWFC MkBW 15X15 FA Design Accident Array Unit Cell

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 6.10

BWFC MkBW 15X15 FA Normal Array Box Orientation

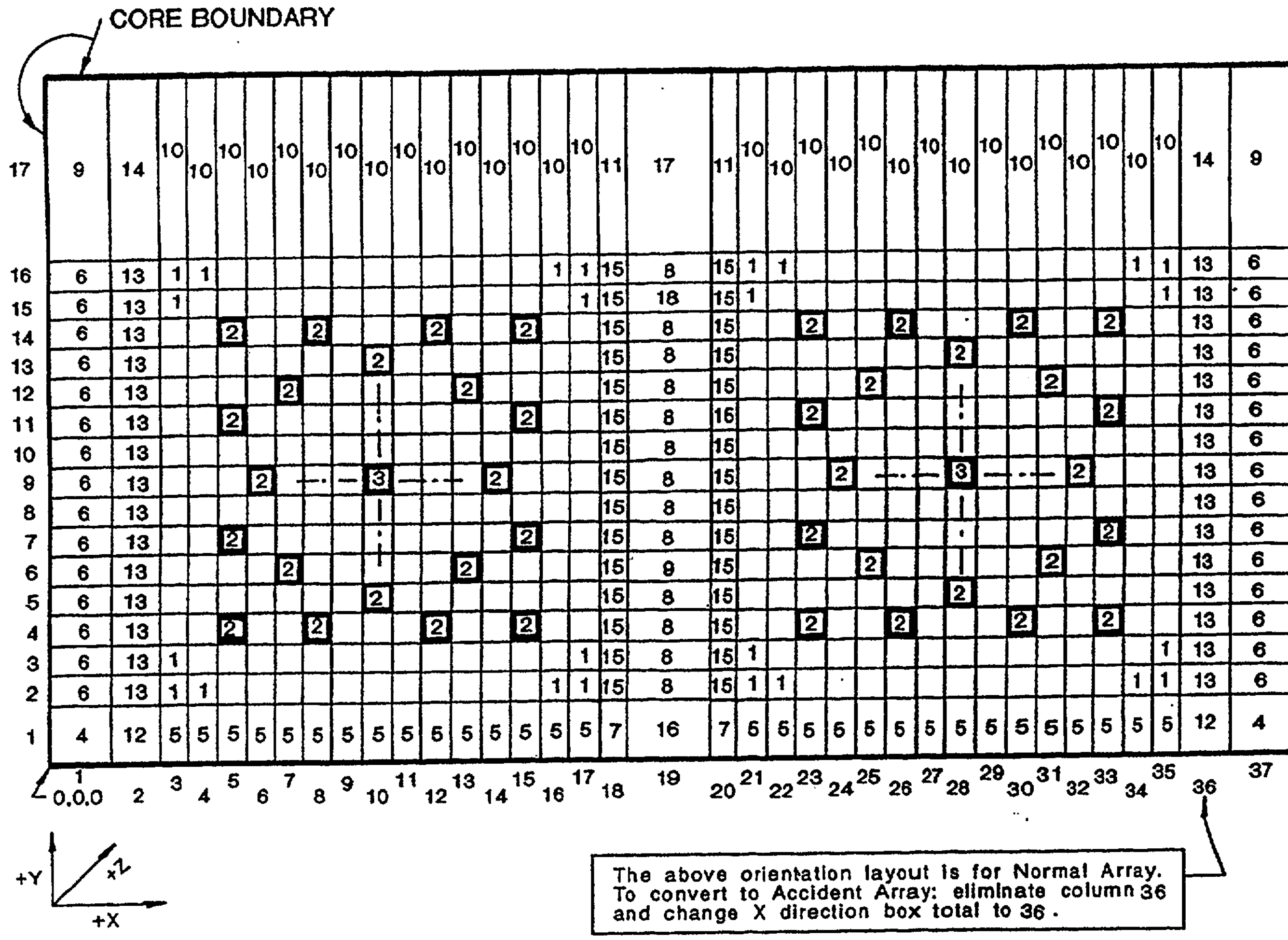
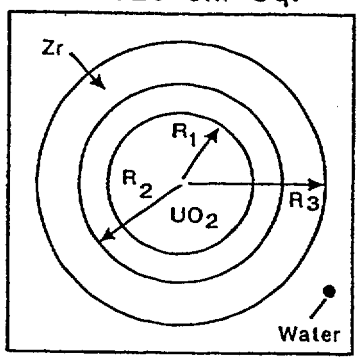


FIGURE 6.11

BWFC MkBW 15X15 FA Design KENO Box Types
(All Boxes Have Length of 144 Inches)

1.430020 cm Sq.



0,0

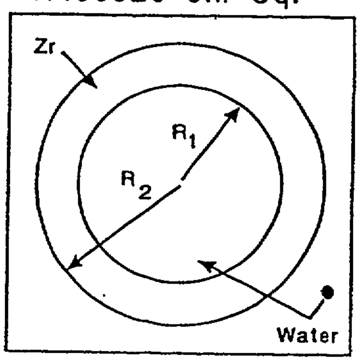
R_1=0.460375 cm

R_2=0.46990 cm

R_3=0.53594 cm

Box Type 1
Fuel Cell

1.430020 cm Sq.



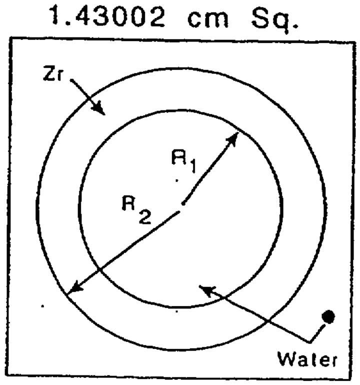
0,0

R_1=0.650240 cm

R_2=0.693420 cm

Box Type 2
G.T. Cell

1.43002 cm Sq.



R_1=0.650240 cm

R_2=0.693420 cm

Box Type 3
I.T. Cell

FIGURE 6.12

BWFC MkBW 17X17 FA Design Normal Array Unit Cell

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 6.13

BWFC MkBW 17X17 FA Design Accident Array Unit Cell

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 6.14

BWFC MkBW 17X17 FA Worst Normal Array Box Orientation

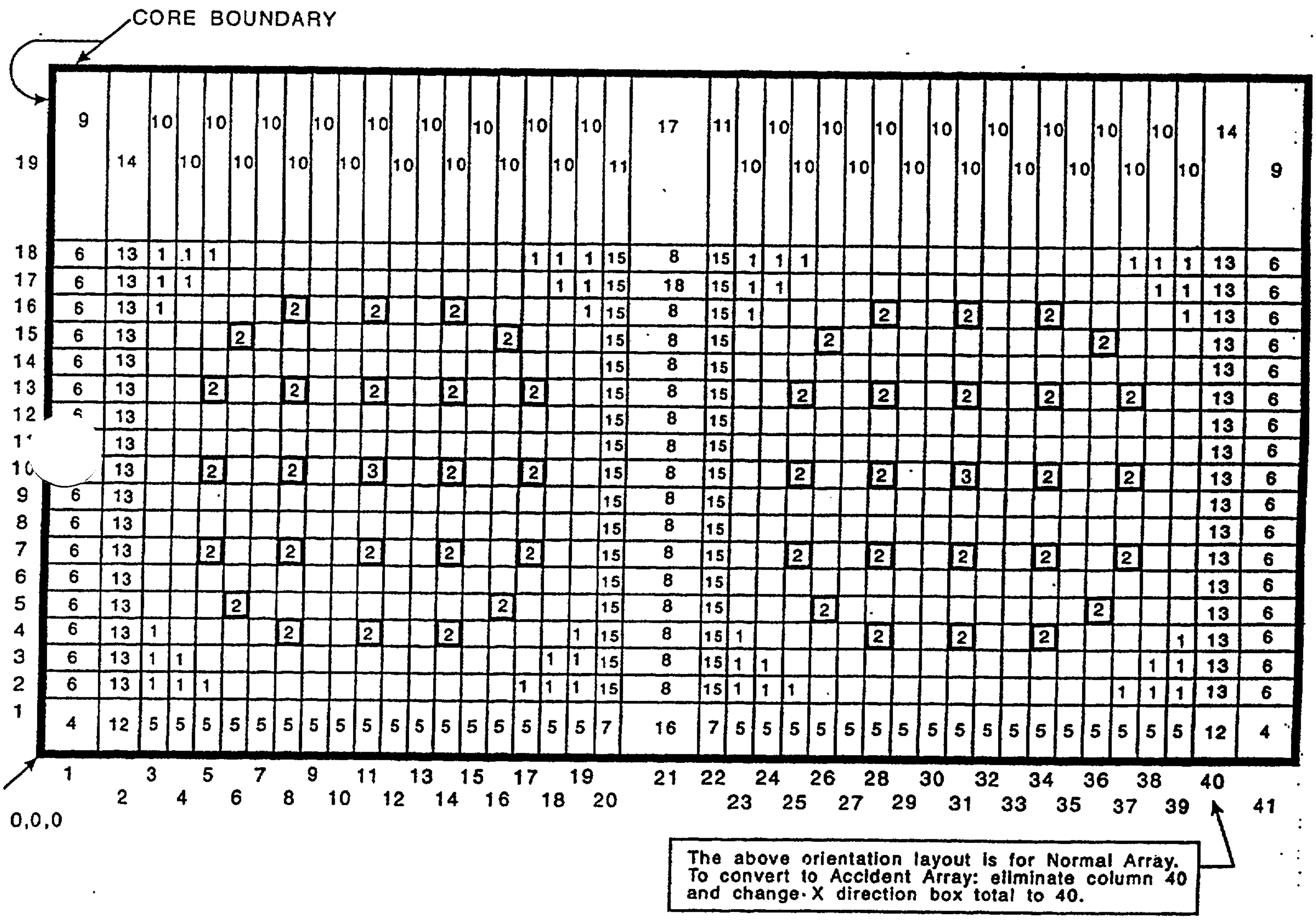
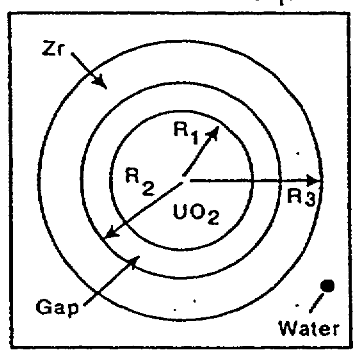


FIGURE 6.15

BWFC MkBW 17X17 FA Design KENO Box Types
(All Boxes Have Length of 144 Inches)

1.25984 cm Sq.



0,0

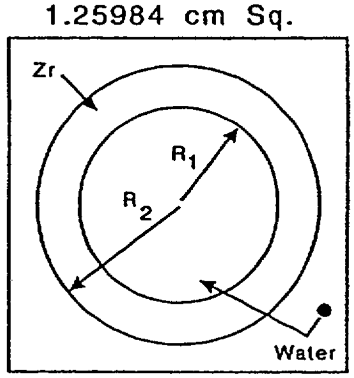
R_1=0.40577 cm

R_2=0.41402 cm

R_3=0.47498 cm

Box Type 1
Fuel Cell

1.25984 cm Sq.



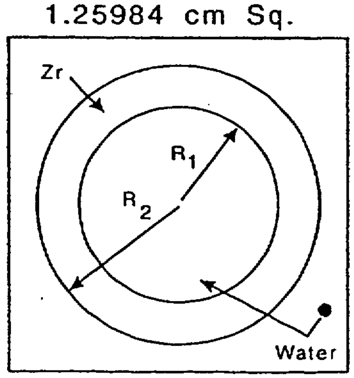
0,0

R_1=0.57150 cm

R_2=0.61214 cm

Box Type 2
G.T. Cell

1.25984 cm Sq.



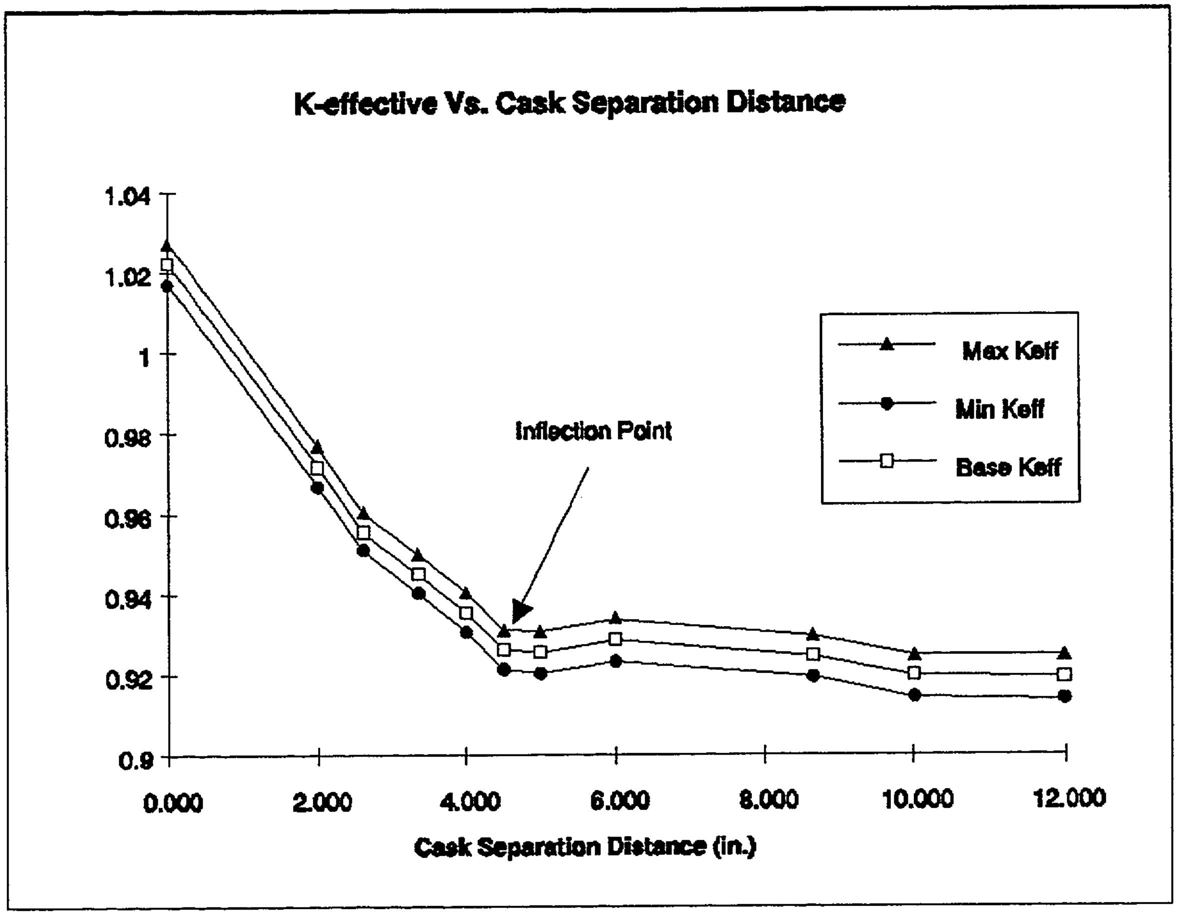
0,0

R_1=0.57150 cm

R_2=0.61214 cm

Box Type 3
I.T. Cell

FIGURE 6.16


K-effective Vs. Cask Separation Distance
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
0.000
2.000
4.000
6.000
8.000
10.000
12.000
Cask Separation Distance (in.)
Max Keff
Min Keff
Base Keff
Inflection Point

APPENDIX 6

KENO INPUT FOR:

Base MkB 15x15 FA ANF Damaged Array
Base MkB 15x15 FA ANF Normal Array
Base MkBW 15x15 FA ANF Damaged Array
Base MkBW 15x15 FA ANF Normal Array
Base MkBW 17x17 FA ANF Damaged Array
Base MkBW 17x17 FA ANF Normal Array

CASE 8

```
Base MkB15x15 FA ANF DAMAGED ARRAY  5.05E 96.3%TD U 100/100% MODDEN
   4000  203 501 0  123  75   8  4  8  47 18 36  17  1  -8
    1  0  2000  00  1  0  0  0  0 00  00  0  0
 -1.0 -1.0 -1.0 -1.0 -1.0  -1.0
  1    -922351  0.00120249
  1     922381  0.02232745
  1      80004  0.04705988
  2     400000  0.04250000
  3      10001  0.06685386
  3      80004  0.03342693
  4      60002  3.921682-3
  4     260001  8.350009-2
BOX TYPE    1
CYLINDER    1  0.46812                                          365.76 -000.00 123Z
CYLINDER    0  0.47879                                          365.76 -000.00 123Z
CYLINDER    2  0.54610                                          365.76 -000.00 123Z
CUBOID      3  0.721360 -0.721360   0.721360 -0.721360 365.76 -000.00 123Z
BOX TYPE    2
CYLINDER    3  0.63246                                          365.76 -000.00 123Z
CYLINDER    2  0.67310                                          365.76 -000.00 123Z
CUBOID      3  0.721360 -0.721360   0.721360 -0.721360 365.76 -000.00 123Z
BOX TYPE    3
CYLINDER    3  0.56007                                          365.76 -000.00 123Z
CYLINDER    2  0.62611                                          365.76 -000.00 123Z
CUBOID      3  0.721360 -0.721360   0.721360 -0.721360 365.76 -000.00 123Z
BOX TYPE    4
CUBOID      4  0.635         0.0    0.635        0.0    365.76 -000.00 123Z
BOX TYPE    5
CUBOID      4  1.44272       0.0    0.635        0.0    365.76 -000.00 123Z
BOX TYPE    6
CUBOID      4  0.635         0.0    1.44272      0.0    365.76 -000.00 123Z
BOX TYPE    7
CUBOID      4  0.9525        0.0    0.635        0.0    365.76 -000.00 123Z
BOX TYPE    8
CUBOID      3  13.335        0.0    1.44272      0.0    365.76 -000.00 123Z
BOX TYPE    9
CUBOID      4  0.635         0.0    9.4742       0.0    365.76 -000.00 123Z
BOX TYPE   10
CUBOID      3  1.44272       0.0    9.4742       0.0    365.76 -000.00 123Z
BOX TYPE   11
CUBOID      3  0.9525        0.0    9.4742       0.0    365.76 -000.00 123Z
BOX TYPE   12
CUBOID      4  4.66095       0.0    0.635        0.0    365.76 -000.00 123Z
BOX TYPE   13
CUBOID      3  4.66095       0.0    1.44272      0.0    365.76 -000.00 123Z
BOX TYPE   14
CUBOID      3  4.66095       0.0    9.4742       0.0    365.76 -000.00 123Z
BOX TYPE   15
CUBOID      4  0.9525        0.0    1.44272      0.0     22.860    0.0  123Z
CUBOID      3  0.9525        0.0    1.44272      0.0     73.152    0.0  123Z
CUBOID      4  0.9525        0.0    1.44272      0.0     96.012    0.0  123Z
CUBOID      3  0.9525        0.0    1.44272      0.0    146.304    0.0  123Z
CUBOID      4  0.9525        0.0    1.44272      0.0    169.164    0.0  123Z
CUBOID      3  0.9525        0.0    1.44272      0.0    219.456    0.0  123Z
CUBOID      4  0.9525        0.0    1.44272      0.0    242.316    0.0  123Z
CUBOID      3  0.9525        0.0    1.44272      0.0    292.608    0.0  123Z
CUBOID      4  0.9525        0.0    1.44272      0.0    315.468    0.0  123Z
CUBOID      3  0.9525        0.0    1.44272      0.0    365.760    0.0  123Z
BOX TYPE   16
CUBOID      4  13.335        0.0     .635        0.0    365.76     0.0  123Z
BOX TYPE   17
CUBOID      3  13.335        0.0    9.4742       0.0    365.76     0.0  123Z
```

```
Base MkB15x15 FA ANF DAMAGED ARRAY  5.05E 96.3%TD U 100/100% MODDEN
BOX TYPE  18
CUBOID       4  13.335        0.0    1.44272    0.0    22.860    0.0  123Z
CUBOID       3  13.335        0.0    1.44272    0.0    73.152    0.0  123Z
CUBOID       4  13.335        0.0    1.44272    0.0    96.012    0.0  123Z
CUBOID       3  13.335        0.0    1.44272    0.0   146.304    0.0  123Z
CUBOID       4  13.335        0.0    1.44272    0.0   169.164    0.0  123Z
CUBOID       3  13.335        0.0    1.44272    0.0   219.456    0.0  123Z
CUBOID       4  13.335        0.0    1.44272    0.0   242.316    0.0  123Z
CUBOID       3  13.335        0.0    1.44272    0.0   292.608    0.0  123Z
CUBOID       4  13.335        0.0    1.44272    0.0   315.468    0.0  123Z
CUBOID       3  13.335        0.0    1.44272    0.0   365.760    0.0  123Z
CORE BDY     0 39.4779  -24.9746   24.6380  -7.1120   365.760  -000.00 123Z
CYLINDER     3 48.2600                                 431.80  - 66.04 123Z
CYLINDER     4 48.5637                                 432.10  - 66.34 123Z
CUBOID       3 49.8348  -49.8348   49.8348  -49.8348   432.10  - 66.34 123Z
  1  3 35 1  2 16  1  1 1 1  0
  2  5  5 1  7 11  4  1 1 1  0
  2  6  6 1  5 13  8  1 1 1  0
  2  8  8 1  4  7  3  1 1 1  0
  2  8  8 1 11 14  3  1 1 1  0
  3 10 10 1  9  9  1  1 1 1  0
  2 12 12 1  4  7  3  1 1 1  0
  2 12 12 1 11 14  3  1 1 1  0
  2 14 14 1  5 13  8  1 1 1  0
  2 15 15 1  7 11  4  1 1 1  0
  2 23 23 1  7 11  4  1 1 1  0
  2 24 24 1  5 13  8  1 1 1  0
  2 26 26 1  4  7  3  1 1 1  0
  2 26 26 1 11 14  3  1 1 1  0
  3 28 28 1  9  9  1  1 1 1  0
  2 30 30 1  4  7  3  1 1 1  0
  2 30 30 1 11 14  3  1 1 1  0
  2 32 32 1  5 13  8  1 1 1  0
  2 33 33 1  7 11  4  1 1 1  0
  4  1  1 1  1  1  1  1 1 1  0
  6  1  1 1  2 16  1  1 1 1  0
 12  2  2 1  1  1  1  1 1 1  0
 13  2  2 1  2 16  1  1 1 1  0
  5  3 17 1  1  1  1  1 1 1  0
  7 18 18 1  1  1  1  1 1 1  0
  7 20 20 1  1  1  1  1 1 1  0
  8 18 20 1  2 17  1  1 1 1  0
  5 21 35 1  1  1  1  1 1 1  0
  4 36 36 1  1  1  1  1 1 1  0
  6 36 36 1  2 16  1  1 1 1  0
  9  1  1 1 17 17  1  1 1 1  0
 14  2  2 1 17 17  1  1 1 1  0
 10  3 17 1 17 17  1  1 1 1  0
 11 18 18 1 17 17  1  1 1 1  0
 11 20 20 1 17 17  1  1 1 1  0
 10 21 35 1 17 17  1  1 1 1  0
  9 36 36 1 17 17  1  1 1 1  0
 15 18 18 1  2 16  1  1 1 1  0
 15 20 20 1  2 16  1  1 1 1  0
 16 19 19 1  1  1  1  1 1 1  0
 17 19 19 1 17 17  1  1 1 1  0
 18 19 19 1 15 15  1  1 1 1  1
END KENO
/EOR
```

CASE 11

```
MkB15x15 FA ANF NORMAL  ARRAY  5.05E 96.3%TD U   0/02 % MODDEN
   4000  203 501 0  123  75   8  4  8  47 18 37  17  1  -8
    1  0  2000  00  1  0  0  0  0 00  00  0  0
 -1.0 -1.0 -1.0 -1.0 -1.0  -1.0
  1     -922351  0.00120249
  1      922381  0.02232745
  1       80004  0.04705988
  2      400000  0.04250000
  3       10001  0.0013370772
  3       80004  0.0006685386
  4       60002  3.921682-3
  4      260001  8.350009-2
BOX TYPE     1
CYLINDER     1  0.46812                                     365.76 -000.00 123Z
CYLINDER     0  0.47879                                     365.76 -000.00 123Z
CYLINDER     2  0.54610                                     365.76 -000.00 123Z
CUBOID       0  0.721360 -0.721360  0.721360 -0.721360 365.76 -000.00 123Z
BOX TYPE     2
CYLINDER     0  0.63246                                     365.76 -000.00 123Z
CYLINDER     2  0.67310                                     365.76 -000.00 123Z
CUBOID       0  0.721360 -0.721360  0.721360 -0.721360 365.76 -000.00 123Z
BOX TYPE     3
CYLINDER     0  0.56007                                     365.76 -000.00 123Z
CYLINDER     2  0.62611                                     365.76 -000.00 123Z
CUBOID       0  0.721360 -0.721360  0.721360 -0.721360 365.76 -000.00 123Z
BOX TYPE     4
CUBOID       4  0.635         0.0     0.635        0.0     365.76 -000.00 123Z
BOX TYPE     5
CUBOID       4  1.44272       0.0     0.635        0.0     365.76 -000.00 123Z
BOX TYPE     6
CUBOID       4  0.635         0.0     1.44272      0.0     365.76 -000.00 123Z
BOX TYPE     7
CUBOID       4  0.9525        0.0     0.635        0.0     365.76 -000.00 123Z
BOX TYPE     8
CUBOID       0  13.335        0.0     1.44272      0.0     365.76 -000.00 123Z
BOX TYPE     9
CUBOID       4  0.635         0.0     9.4742       0.0     365.76 -000.00 123Z
BOX TYPE    10
CUBOID       0  1.44272       0.0     9.4742       0.0     365.76 -000.00 123Z
BOX TYPE    11
CUBOID       0  0.9525        0.0     9.4742       0.0     365.76 -000.00 123Z
BOX TYPE    12
CUBOID       4  2.33040       0.0     0.635        0.0     365.76 -000.00 123Z
BOX TYPE    13
CUBOID       0  2.33040       0.0     1.44272      0.0     365.76 -000.00 123Z
BOX TYPE    14
CUBOID       0  2.33040       0.0     9.4742       0.0     365.76 -000.00 123Z
BOX TYPE    15
CUBOID       4  0.9525        0.0     1.44272      0.0      22.860    0.0   123Z
CUBOID       0  0.9525        0.0     1.44272      0.0      73.152    0.0   123Z
CUBOID       4  0.9525        0.0     1.44272      0.0      96.012    0.0   123Z
CUBOID       0  0.9525        0.0     1.44272      0.0     146.304    0.0   123Z
CUBOID       4  0.9525        0.0     1.44272      0.0     169.164    0.0   123Z
CUBOID       0  0.9525        0.0     1.44272      0.0     219.456    0.0   123Z
CUBOID       4  0.9525        0.0     1.44272      0.0     242.316    0.0   123Z
CUBOID       0  0.9525        0.0     1.44272      0.0     292.608    0.0   123Z
CUBOID       4  0.9525        0.0     1.44272      0.0     315.468    0.0   123Z
CUBOID       0  0.9525        0.0     1.44272      0.0     365.760    0.0   123Z
```

```
MkB15x15 FA ANF NORMAL  ARRAY  5.05E 96.3%TD U   0/02 % MODDEN
BOX TYPE  16
CUBOID       4  13.335       0.0       .635       0.0      365.76     0.0  123Z
BOX TYPE  17
CUBOID       0  13.335       0.0      9.4742      0.0      365.76     0.0  123Z
BOX TYPE  18
CUBOID       4  13.335       0.0      1.44272    0.0      22.860    0.0  123Z
CUBOID       0  13.335       0.0      1.44272    0.0      73.152    0.0  123Z
CUBOID       4  13.335       0.0      1.44272    0.0      96.012    0.0  123Z
CUBOID       0  13.335       0.0      1.44272    0.0     146.304    0.0  123Z
CUBOID       4  13.335       0.0      1.44272    0.0     169.164    0.0  123Z
CUBOID       0  13.335       0.0      1.44272    0.0     219.456    0.0  123Z
CUBOID       4  13.335       0.0      1.44272    0.0     242.316    0.0  123Z
CUBOID       0  13.335       0.0      1.44272    0.0     292.608    0.0  123Z
CUBOID       4  13.335       0.0      1.44272    0.0     315.468    0.0  123Z
CUBOID       0  13.335       0.0      1.44272    0.0     365.760    0.0  123Z
CORE BDY     0 32.22625 -32.22625  20.38980 -11.36015 365.760   -000.00 123Z
CYLINDER     0 48.2600                                  431.80 - 66.04 123Z
CYLINDER     4 48.5637                                  432.10 - 66.34 123Z
CUBOID       3 53.6448   -53.6448   53.6448   -53.6448  432.10 - 66.34 123Z
  1  3 35 1  2 16  1  1 1 1  0
  2  5  5 1  7 11  4  1 1 1  0
  2  6  6 1  5 13  8  1 1 1  0
  2  8  8 1  4  7  3  1 1 1  0
  2  8  8 1 11 14  3  1 1 1  0
  3 10 10 1  9  9  1  1 1 1  0
  2 12 12 1  4  7  3  1 1 1  0
  2 12 12 1 11 14  3  1 1 1  0
  2 14 14 1  5 13  8  1 1 1  0
  2 15 15 1  7 11  4  1 1 1  0
  2 23 23 1  7 11  4  1 1 1  0
  2 24 24 1  5 13  8  1 1 1  0
  2 26 26 1  4  7  3  1 1 1  0
  2 26 26 1 11 14  3  1 1 1  0
  3 28 28 1  9  9  1  1 1 1  0
  2 30 30 1  4  7  3  1 1 1  0
  2 30 30 1 11 14  3  1 1 1  0
  2 32 32 1  5 13  8  1 1 1  0
  2 33 33 1  7 11  4  1 1 1  0
  4  1  1 1  1  1  1  1 1 1  0
  6  1  1 1  2 16  1  1 1 1  0
 12  2  2 1  1  1  1  1 1 1  0
 13  2  2 1  2 16  1  1 1 1  0
  5  3 17 1  1  1  1  1 1 1  0
  7 18 18 1  1  1  1  1 1 1  0
  7 20 20 1  1  1  1  1 1 1  0
  8 18 20 1  2 17  1  1 1 1  0
  5 21 35 1  1  1  1  1 1 1  0
  4 37 37 1  1  1  1  1 1 1  0
  6 37 37 1  2 16  1  1 1 1  0
  9  1  1 1 17 17  1  1 1 1  0
 14  2  2 1 17 17  1  1 1 1  0
 10  3 17 1 17 17  1  1 1 1  0
 11 18 18 1 17 17  1  1 1 1  0
 11 20 20 1 17 17  1  1 1 1  0
 10 21 35 1 17 17  1  1 1 1  0
  9 37 37 1 17 17  1  1 1 1  0
 15 18 18 1  2 16  1  1 1 1  0
 15 20 20 1  2 16  1  1 1 1  0
```

```
MkB15x15 FA ANF NORMAL  ARRAY  5.05E 96.3%TD U   0/02 % MODDEN

 16 19 19 1  1  1  1  1 1 1  0
 17 19 19 1 17 17  1  1 1 1  0
 18 19 19 1 15 15  1  1 1 1  0
 12 36 36 1  1  1  1  1 1 1  0
 13 36 36 1  2 16  1  1 1 1  0
 14 36 36 1 17 17  1  1 1 1  1
END KENO
/EOR
```

CASE 18

```
Base MkBW 15x15 FA ANF DAMAGED ARRAY  5.05E 96.3%TD U 100/100% MODDEN
  4000  203 501 0  123  75   8  4  8  47 18 36  17  1  -8
   1  0  2000  00  1. 0  0  0  0 00  00  0  0
 -1.0 -1.0 -1.0 -1.0 -1.0  -1.0
  1    -922351   0.00120249
  1     922381   0.02232745
  1      80004   0.04705988
  2     400000   0.04250000
  3      10001   0.06685386
  3      80004   0.03342693
  4      60002   3.921682-3
  4     260001   8.350009-2
BOX TYPE   1
CYLINDER    1  0.460375                                    365.76 -000.00 123Z
CYLINDER    0  0.46990                                     365.76 -000.00 123Z
CYLINDER    2  0.53594                                     365.76 -000.00 123Z
CUBOID      3  0.71501   -0.71501    0.71501   -0.71501    365.76 -000.00 123Z
BOX TYPE   2
CYLINDER    3  0.65024                                     365.76 -000.00 123Z
CYLINDER    2  0.69342                                     365.76 -000.00 123Z
CUBOID      3  0.71501   -0.71501    0.71501   -0.71501    365.76 -000.00 123Z
BOX TYPE   3
CYLINDER    3  0.65024                                     365.76 -000.00 123Z
CYLINDER    2  0.69342                                     365.76 -000.00 123Z
CUBOID      3  0.71501   -0.71501    0.71501   -0.71501    365.76 -000.00 123Z
BOX TYPE   4
CUBOID      4  0.635         0.0     0.635        0.0      365.76 -000.00 123Z
BOX TYPE   5
CUBOID      4  1.43002       0.0     0.635        0.0      365.76 -000.00 123Z
BOX TYPE   6
CUBOID      4  0.635         0.0     1.43002      0.0      365.76 -000.00 123Z
BOX TYPE   7
CUBOID      4  0.9525        0.0     0.635        0.0      365.76 -000.00 123Z
BOX TYPE   8
CUBOID      3  13.335        0.0     1.43002      0.0      365.76 -000.00 123Z
BOX TYPE   9
CUBOID      4  0.635         0.0     9.6647       0.0      365.76 -000.00 123Z
BOX TYPE  10
CUBOID      3  1.43002       0.0     9.6647       0.0      365.76 -000.00 123Z
BOX TYPE  11
CUBOID      3  0.9525        0.0     9.6647       0.0      365.76 -000.00 123Z
BOX TYPE  12
CUBOID      4  5.0419       0.0     0.635        0.0      365.76 -000.00 123Z
BOX TYPE  13
CUBOID      3  5.0419       0.0     1.43002      0.0      365.76 -000.00 123Z
BOX TYPE  14
CUBOID      3  5.0419       0.0     9.6647       0.0      365.76 -000.00 123Z
BOX TYPE  15
CUBOID      4  0.9525        0.0     1.43002      0.0      22.860     0.0  123Z
CUBOID      3  0.9525        0.0     1.43002      0.0      73.152     0.0  123Z
CUBOID      4  0.9525        0.0     1.43002      0.0      96.012     0.0  123Z
CUBOID      3  0.9525        0.0     1.43002      0.0     146.304     0.0  123Z
CUBOID      4  0.9525        0.0     1.43002      0.0     169.164     0.0  123Z
CUBOID      3  0.9525        0.0     1.43002      0.0     219.456     0.0  123Z
CUBOID      4  0.9525        0.0     1.43002      0.0     242.316     0.0  123Z
CUBOID      3  0.9525        0.0     1.43002      0.0     292.608     0.0  123Z
CUBOID      4  0.9525        0.0     1.43002      0.0     315.468     0.0  123Z
CUBOID      3  0.9525        0.0     1.43002      0.0     365.760     0.0  123Z
BOX TYPE  16
CUBOID      4  13.335        0.0      .635        0.0      365.76      0.0  123Z
```

```
Base MkBW 15x15 FA ANF DAMAGED ARRAY  5.05E 96.3%TD U 100/100% MODDEN

BOX TYPE  17
CUBOID       3  13.335       0.0      9.6647      0.0    365.76      0.0  123Z
BOX TYPE  18
CUBOID       4  13.335       0.0      1.43002     0.0     22.860     0.0  123Z
CUBOID       3  13.335       0.0      1.43002     0.0     73.152     0.0  123Z
CUBOID       4  13.335       0.0      1.43002     0.0     96.012     0.0  123Z
CUBOID       3  13.335       0.0      1.43002     0.0    146.304     0.0  123Z
CUBOID       4  13.335       0.0      1.43002     0.0    169.164     0.0  123Z
CUBOID       3  13.335       0.0      1.43002     0.0    219.456     0.0  123Z
CUBOID       4  13.335       0.0      1.43002     0.0    242.316     0.0  123Z
CUBOID       3  13.335       0.0      1.43002     0.0    292.608     0.0  123Z
CUBOID       4  13.335       0.0      1.43002     0.0    315.468     0.0  123Z
CUBOID       3  13.335       0.0      1.43002     0.0    365.760     0.0  123Z
CORE BDY     0 39.4779   -24.9746    24.6380   -7.1120   365.760  -000.00 123Z
CYLINDER     3 48.2600                                    431.80  - 66.04 123Z
CYLINDER     4 48.5637                                    432.10  - 66.34 123Z
CUBOID       3 49.8348   -49.8348    49.8348  -49.8348   432.10  - 66.34 123Z
   1  3 35 1  2 16  1  1 1 1  0
   2  5  5 1  4  7  3  1 1 1  0
   2  5  5 1 11 14  3  1 1 1  0
   2  6  6 1  9  9  1  1 1 1  0
   2  7  7 1  6 12  6  1 1 1  0
   2  8  8 1  4 14 10  1 1 1  0
   2 10 10 1  5 13  8  1 1 1  0
   3 10 10 1  9  9  1  1 1 1  0
   2 12 12 1  4 14 10  1 1 1  0
   2 13 13 1  6 12  6  1 1 1  0
   2 14 14 1  9  9  1  1 1 1  0
   2 15 15 1  4  7  3  1 1 1  0
   2 15 15 1 11 14  3  1 1 1  0
   2 23 23 1  4  7  3  1 1 1  0
   2 23 23 1 11 14  3  1 1 1  0
   2 24 24 1  9  9  1  1 1 1  0
   2 25 25 1  6 12  6  1 1 1  0
   2 26 26 1  4 14 10  1 1 1  0
   2 28 28 1  5 13  8  1 1 1  0
   3 28 28 1  9  9  1  1 1 1  0
   2 30 30 1  4 14 10  1 1 1  0
   2 31 31 1  6 12  6  1 1 1  0
   2 32 32 1  9  9  1  1 1 1  0
   2 33 33 1  4  7  3  1 1 1  0
   2 33 33 1 11 14  3  1 1 1  0
   4  1  1 1  1  1  1  1 1 1  0
   6  1  1 1  2 16  1  1 1 1  0
  12  2  2 1  1  1  1  1 1 1  0
  13  2  2 1  2 16  1  1 1 1  0
   5  3 17 1  1  1  1  1 1 1  0
   7 18 18 1  1  1  1  1 1 1  0
   7 20 20 1  1  1  1  1 1 1  0
   8 18 20 1  2 17  1  1 1 1  0
   5 21 35 1  1  1  1  1 1 1  0
   4 36 36 1  1  1  1  1 1 1  0
   6 36 36 1  2 16  1  1 1 1  0
   9  1  1 1 17 17  1  1 1 1  0
  14  2  2 1 17 17  1  1 1 1  0
  10  3 17 1 17 17  1  1 1 1  0
  11 18 18 1 17 17  1  1 1 1  0
  11 20 20 1 17 17  1  1 1 1  0
  10 21 35 1 17 17  1  1 1 1  0
```

```
Base MkBW 15x15 FA ANF DAMAGED ARRAY  5.05E 96.3%TD U 100/100% MODDEN

  9 36 36 1 17 17  1  1 1 1  0
 15 18 18 1  2 16  1  1 1 1  0
 15 20 20 1  2 16  1  1 1 1  0
 16 19 19 1  1  1  1  1 1 1  0
 17 19 19 1 17 17  1  1 1 1  0
 18 19 19 1 15 15  1  1 1 1  1
 END KENO
 /EOR
```

CASE 25

```
MkBW 15x15 FA ANF NORMAL ARRAY 5.05E 96.3%TD U 0%IN/  2% OUT MODDEN
   4000  203 501 0  123  75   8  4  8  47 18 37  17  1  -8
    1  0  2000  00  1  0  0  0  0 00  00  0  0
 -1.0 -1.0 -1.0 -1.0 -1.0  -1.0
  1     -922351  0.00120249
  1      922381  0.02232745
  1       80004  0.04705988
  2      400000  0.04250000
  3       10001  0.0013370772
  3       80004  0.0006685386
  4       60002  3.921682-3
  4      260001  8.350009-2
BOX TYPE    1
CYLINDER    1  0.460375                                          365.76 -000.00 123Z
CYLINDER    0  0.46990                                           365.76 -000.00 123Z
CYLINDER    2  0.53594                                           365.76 -000.00 123Z
CUBOID      0  0.71501  -0.71501    0.71501   -0.71501           365.76 -000.00 123Z
BOX TYPE    2
CYLINDER    0  0.65024                                           365.76 -000.00 123Z
CYLINDER    2  0.69342                                           365.76 -000.00 123Z
CUBOID      0  0.71501  -0.71501    0.71501   -0.71501           365.76 -000.00 123Z
BOX TYPE    3
CYLINDER    0  0.65024                                           365.76 -000.00 123Z
CYLINDER    2  0.69342                                           365.76 -000.00 123Z
CUBOID      0  0.71501  -0.71501    0.71501   -0.71501           365.76 -000.00 123Z
BOX TYPE    4
CUBOID      4  0.635        0.0     0.635        0.0             365.76 -000.00 123Z
BOX TYPE    5
CUBOID      4  1.43002      0.0     0.635        0.0             365.76 -000.00 123Z
BOX TYPE    6
CUBOID      4  0.635        0.0     1.43002      0.0             365.76 -000.00 123Z
BOX TYPE    7
CUBOID      4  0.9525       0.0     0.635        0.0             365.76 -000.00 123Z
BOX TYPE    8
CUBOID      0  13.335       0.0     1.43002      0.0             365.76 -000.00 123Z
BOX TYPE    9
CUBOID      4  0.635        0.0     9.6647       0.0             365.76 -000.00 123Z
BOX TYPE   10
CUBOID      0  1.43002      0.0     9.6647       0.0             365.76 -000.00 123Z
BOX TYPE   11
CUBOID      0  0.9525       0.0     9.6647       0.0             365.76 -000.00 123Z
BOX TYPE   12
CUBOID      4  2.52095      0.0     0.635        0.0             365.76 -000.00 123Z
BOX TYPE   13
CUBOID      0  2.52095      0.0     1.43002      0.0             365.76 -000.00 123Z
BOX TYPE   14
CUBOID      0  2.52095      0.0     9.6647       0.0             365.76 -000.00 123Z
BOX TYPE   15
CUBOID      4  0.9525       0.0     1.43002      0.0              22.860    0.0   123Z
CUBOID      0  0.9525       0.0     1.43002      0.0              73.152    0.0   123Z
CUBOID      4  0.9525       0.0     1.43002      0.0              96.012    0.0   123Z
CUBOID      0  0.9525       0.0     1.43002      0.0             146.304    0.0   123Z
CUBOID      4  0.9525       0.0     1.43002      0.0             169.164    0.0   123Z
CUBOID      0  0.9525       0.0     1.43002      0.0             219.456    0.0   123Z
CUBOID      4  0.9525       0.0     1.43002      0.0             242.316    0.0   123Z
CUBOID      0  0.9525       0.0     1.43002      0.0             292.608    0.0   123Z
CUBOID      4  0.9525       0.0     1.43002      0.0             315.468    0.0   123Z
CUBOID      0  0.9525       0.0     1.43002      0.0             365.760    0.0   123Z
BOX TYPE   16
CUBOID      4  13.335       0.0      .635        0.0             365.76     0.0   123Z
```

```
MkBW 15x15 FA ANF NORMAL ARRAY 5.05E 96.3%TD U 0%IN/  2% OUT MODDEN
BOX TYPE   17
CUBOID       0  13.335        0.0      9.6647      0.0     365.76     0.0  123Z
BOX TYPE   18
CUBOID       4  13.335        0.0      1.43002   0.0      22.860   0.0  123Z
CUBOID       0  13.335        0.0      1.43002   0.0      73.152   0.0  123Z
CUBOID       4  13.335        0.0      1.43002   0.0      96.012   0.0  123Z
CUBOID       0  13.335        0.0      1.43002   0.0     146.304   0.0  123Z
CUBOID       4  13.335        0.0      1.43002   0.0     169.164   0.0  123Z
CUBOID       0  13.335        0.0      1.43002   0.0     219.456   0.0  123Z
CUBOID       4  13.335        0.0      1.43002   0.0     242.316   0.0  123Z
CUBOID       0  13.335        0.0      1.43002   0.0     292.608   0.0  123Z
CUBOID       4  13.335        0.0      1.43002   0.0     315.468   0.0  123Z
CUBOID       0  13.335        0.0      1.43002   0.0     365.760   0.0  123Z
CORE BDY     0 32.22625 -32.22625  20.38980 -11.36015 365.760   -000.00 123Z
CYLINDER     0 48.2600                                  431.80 - 66.04 123Z
CYLINDER     4 48.5637                                  432.10 - 66.34 123Z
CUBOID       3 53.6448   -53.6448   53.6448   -53.6448  432.10 - 66.34 123Z
  1  3 35 1  2 16  1  1 1 1  0
  2  5  5 1  4  7  3  1 1 1  0
  2  5  5 1 11 14  3  1 1 1  0
  2  6  6 1  9  9  1  1 1 1  0
  2  7  7 1  6 12  6  1 1 1  0
  2  8  8 1  4 14 10  1 1 1  0
  2 10 10 1  5 13  8  1 1 1  0
  3 10 10 1  9  9  1  1 1 1  0
  2 12 12 1  4 14 10  1 1 1  0
  2 13 13 1  6 12  6  1 1 1  0
  2 14 14 1  9  9  1  1 1 1  0
  2 15 15 1  4  7  3  1 1 1  0
  2 15 15 1 11 14  3  1 1 1  0
  2 23 23 1  4  7  3  1 1 1  0
  2 23 23 1 11 14  3  1 1 1  0
  2 24 24 1  9  9  1  1 1 1  0
  2 25 25 1  6 12  6  1 1 1  0
  2 26 26 1  4 14 10  1 1 1  0
  2 28 28 1  5 13  8  1 1 1  0
  3 28 28 1  9  9  1  1 1 1  0
  2 30 30 1  4 14 10  1 1 1  0
  2 31 31 1  6 12  6  1 1 1  0
  2 32 32 1  9  9  1  1 1 1  0
  2 33 33 1  4  7  3  1 1 1  0
  2 33 33 1 11 14  3  1 1 1  0
  4  1  1 1  1  1  1  1 1 1  0
  6  1  1 1  2 16  1  1 1 1  0
 12  2  2 1  1  1  1  1 1 1  0
 13  2  2 1  2 16  1  1 1 1  0
  5  3 17 1  1  1  1  1 1 1  0
  7 18 18 1  1  1  1  1 1 1  0
  7 20 20 1  1  1  1  1 1 1  0
  8 18 20 1  2 17  1  1 1 1  0
  5 21 35 1  1  1  1  1 1 1  0
 12 36 36 1  1  1  1  1 1 1  0
 13 36 36 1  2 16  1  1 1 1  0
 14 36 36 1 17 17  1  1 1 1  0
  4 37 37 1  1  1  1  1 1 1  0
  6 37 37 1  2 16  1  1 1 1  0
  9  1  1 1 17 17  1  1 1 1  0
 14  2  2 1 17 17  1  1 1 1  0
 10  3 17 1 17 17  1  1 1 1  0
 11 18 18 1 17 17  1  1 1 1  0
```

```
MkBW 15x15 FA ANF NORMAL ARRAY 5.05E 96.3%TD U 0%IN/  2% OUT MODDEN

 11 20 20 1 17 17  1  1 1 1  0
 10 21 35 1 17 17  1  1 1 1  0
  9 37 37 1 17 17  1  1 1 1  0
 15 18 18 1  2 16  1  1 1 1  0
 15 20 20 1  2 16  1  1 1 1  0
 16 19 19 1  1  1  1  1 1 1  0
 17 19 19 1 17 17  1  1 1 1  0
 18 19 19 1 15 15  1  1 1 1  1
END KENO
/EOR
```

CASE 32

```
Base MkBW 17x17 FA ANF DAMAGED ARRAY  5.05E 96.3%TD U 100/100% MODDEN
   4000  203 501 0  123  75   8  4  8  47 18 40  19  1  -8
    1  0  2000  00  1  0  0  0  0 00  00  0  0
 -1.0 -1.0 -1.0 -1.0 -1.0  -1.0
  1     -922351  0.00120249
  1      922381  0.02232745
  1       80004  0.04705988
  2      400000  0.04250000
  3       10001  0.06685386
  3       80004  0.03342693
  4       60002  3.921682-3
  4      260001  8.350009-2
BOX TYPE    1
CYLINDER    1  0.40577                                   365.76 -000.00 123Z
CYLINDER    0  0.41402                                   365.76 -000.00 123Z
CYLINDER    2  0.47498                                   365.76 -000.00 123Z
CUBOID      3  0.62992  -0.62992   0.62992  -0.62992     365.76 -000.00 123Z
BOX TYPE    2
CYLINDER    3  0.57150                                   365.76 -000.00 123Z
CYLINDER    2  0.61214                                   365.76 -000.00 123Z
CUBOID      3  0.62992  -0.62992   0.62992  -0.62992     365.76 -000.00 123Z
BOX TYPE    3
CYLINDER    3  0.57150                                   365.76 -000.00 123Z
CYLINDER    2  0.61214                                   365.76 -000.00 123Z
CUBOID      3  0.62992  -0.62992   0.62992  -0.62992     365.76 -000.00 123Z
BOX TYPE    4
CUBOID      4  0.635       0.0     0.635       0.0       365.76 -000.00 123Z
BOX TYPE    5
CUBOID      4  1.25984     0.0     0.635       0.0       365.76 -000.00 123Z
BOX TYPE    6
CUBOID      4  0.635       0.0     1.25984     0.0       365.76 -000.00 123Z
BOX TYPE    7
CUBOID      4  0.9525      0.0     0.635       0.0       365.76 -000.00 123Z
BOX TYPE    8
CUBOID      3  13.335      0.0     1.25984     0.0       365.76 -000.00 123Z
BOX TYPE    9
CUBOID      4  0.635       0.0     9.69772     0.0       365.76 -000.00 123Z
BOX TYPE   10
CUBOID      3  1.25984     0.0     9.69772     0.0       365.76 -000.00 123Z
BOX TYPE   11
CUBOID      3  0.9525      0.0     9.69772     0.0       365.76 -000.00 123Z
BOX TYPE   12
CUBOID      4  5.10794     0.0     0.635       0.0       365.76 -000.00 123Z
BOX TYPE   13
CUBOID      3  5.10794     0.0     1.25984     0.0       365.76 -000.00 123Z
BOX TYPE   14
CUBOID      3  5.10794     0.0     9.69772     0.0       365.76 -000.00 123Z
BOX TYPE   15
CUBOID      4  0.9525      0.0     1.25984     0.0       22.860    0.0  123Z
CUBOID      3  0.9525      0.0     1.25984     0.0       73.152    0.0  123Z
CUBOID      4  0.9525      0.0     1.25984     0.0       96.012    0.0  123Z
CUBOID      3  0.9525      0.0     1.25984     0.0      146.304    0.0  123Z
CUBOID      4  0.9525      0.0     1.25984     0.0      169.164    0.0  123Z
CUBOID      3  0.9525      0.0     1.25984     0.0      219.456    0.0  123Z
CUBOID      4  0.9525      0.0     1.25984     0.0      242.316    0.0  123Z
CUBOID      3  0.9525      0.0     1.25984     0.0      292.608    0.0  123Z
CUBOID      4  0.9525      0.0     1.25984     0.0      315.468    0.0  123Z
CUBOID      3  0.9525      0.0     1.25984     0.0      365.760    0.0  123Z
BOX TYPE   16
CUBOID      4  13.335      0.0      .635       0.0      365.76     0.0  123Z
```

```
Base MkBW 17x17 FA ANF DAMAGED ARRAY  5.05E 96.3%TD U 100/100% MODDEN
BOX TYPE  17
CUBOID      3  13.335      0.0     9.69772      0.0    365.76     0.0  123Z
BOX TYPE  18
CUBOID      4  13.335      0.0     1.25984    0.0     22.860    0.0  123Z
CUBOID      3  13.335      0.0     1.25984    0.0     73.152    0.0  123Z
CUBOID      4  13.335      0.0     1.25984    0.0     96.012    0.0  123Z
CUBOID      3  13.335      0.0     1.25984    0.0    146.304    0.0  123Z
CUBOID      4  13.335      0.0     1.25984    0.0    169.164    0.0  123Z
CUBOID      3  13.335      0.0     1.25984    0.0    219.456    0.0  123Z
CUBOID      4  13.335      0.0     1.25984    0.0    242.316    0.0  123Z
CUBOID      3  13.335      0.0     1.25984    0.0    292.608    0.0  123Z
CUBOID      4  13.335      0.0     1.25984    0.0    315.468    0.0  123Z
CUBOID      3  13.335      0.0     1.25984    0.0    365.760    0.0  123Z
CORE BDY    0 39.4779  -24.9746   24.6380  -7.1120  365.760  -000.00 123Z
CYLINDER    3 48.2600                                431.80  - 66.04 123Z
CYLINDER    4 48.5637                                432.10  - 66.34 123Z
CUBOID      3 49.8348  -49.8348   49.8348  -49.8348  432.10  - 66.34 123Z
   1  3 39 1  2 18  1  1 1 1  0
   2  5  5 1  7 13  3  1 1 1  0
   2  6  6 1  5 15 10  1 1 1  0
   2  8  8 1  4 16  3  1 1 1  0
   2 11 11 1  4 16  3  1 1 1  0
   2 14 14 1  4 16  3  1 1 1  0
   2 16 16 1  5 15 10  1 1 1  0
   2 17 17 1  7 13  3  1 1 1  0
   3 11 11 1 10 10  1  1 1 1  0
   2 25 25 1  7 13  3  1 1 1  0
   2 26 26 1  5 15 10  1 1 1  0
   2 28 28 1  4 16  3  1 1 1  0
   2 31 31 1  4 16  3  1 1 1  0
   2 34 34 1  4 16  3  1 1 1  0
   2 36 36 1  5 15 10  1 1 1  0
   2 37 37 1  7 13  3  1 1 1  0
   3 31 31 1 10 10  1  1 1 1  0
   4  1  1 1  1  1  1  1 1 1  0
   6  1  1 1  2 18  1  1 1 1  0
  12  2  2 1  1  1  1  1 1 1  0
  13  2  2 1  2 18  1  1 1 1  0
   5  3 19 1  1  1  1  1 1 1  0
   7 20 20 1  1  1  1  1 1 1  0
   7 22 22 1  1  1  1  1 1 1  0
   8 21 21 1  2 18  1  1 1 1  0
   5 23 39 1  1  1  1  1 1 1  0
   4 40 40 1  1  1  1  1 1 1  0
   6 40 40 1  2 18  1  1 1 1  0
   9  1  1 1 19 19  1  1 1 1  0
  14  2  2 1 19 19  1  1 1 1  0
  10  3 19 1 19 19  1  1 1 1  0
  11 20 20 1 19 19  1  1 1 1  0
  11 22 22 1 19 19  1  1 1 1  0
  10 23 39 1 19 19  1  1 1 1  0
   9 40 40 1 19 19  1  1 1 1  0
  15 20 20 1  2 18  1  1 1 1  0
  15 22 22 1  2 18  1  1 1 1  0
  16 21 21 1  1  1  1  1 1 1  0
  17 21 21 1 19 19  1  1 1 1  0
  18 21 21 1 17 17  1  1 1 1  1
END KENO
/EOR
```

CASE 35

```
MkBW 17x17 FA ANF NORMAL  ARRAY  5.05E 96.3%TD U   0/ 2% MODDEN
   4000  203 501 0  123  75   8  4  8  47 18 41  19  1  -8
    1  0  2000  00  1  0  0  0  0 00  00  0  0
 -1.0 -1.0 -1.0 -1.0 -1.0  -1.0
   1    -922351  0.00120249
   1     922381  0.02232745
   1      80004  0.04705988
   2     400000  0.04250000
   3      10001  0.0013370772
   3      80004  0.0006685386
   4      60002  3.921682-3
   4     260001  8.350009-2
BOX TYPE   1
CYLINDER   1  0.40577                                     365.76 -000.00 123Z
CYLINDER   0  0.41402                                     365.76 -000.00 123Z
CYLINDER   2  0.47498                                     365.76 -000.00 123Z
CUBOID     0  0.62992  -0.62992    0.62992   -0.62992    365.76 -000.00 123Z
BOX TYPE   2
CYLINDER   0  0.57150                                     365.76 -000.00 123Z
CYLINDER   2  0.61214                                     365.76 -000.00 123Z
CUBOID     0  0.62992  -0.62992    0.62992   -0.62992    365.76 -000.00 123Z
BOX TYPE   3
CYLINDER   0  0.57150                                     365.76 -000.00 123Z
CYLINDER   2  0.61214                                     365.76 -000.00 123Z
CUBOID     0  0.62992  -0.62992    0.62992   -0.62992    365.76 -000.00 123Z
BOX TYPE   4
CUBOID     4  0.635        0.0     0.635        0.0      365.76 -000.00 123Z
BOX TYPE   5
CUBOID     4  1.25984      0.0     0.635        0.0      365.76 -000.00 123Z
BOX TYPE   6
CUBOID     4  0.635        0.0     1.25984      0.0      365.76 -000.00 123Z
BOX TYPE   7
CUBOID     4  0.9525       0.0     0.635        0.0      365.76 -000.00 123Z
BOX TYPE   8
CUBOID     0  13.335       0.0     1.25984      0.0      365.76 -000.00 123Z
BOX TYPE   9
CUBOID     4  0.635        0.0     9.69772      0.0      365.76 -000.00 123Z
BOX TYPE  10
CUBOID     0  1.25984      0.0     9.69772      0.0      365.76 -000.00 123Z
BOX TYPE  11
CUBOID     0  0.9525       0.0     9.69772      0.0      365.76 -000.00 123Z
BOX TYPE  12
CUBOID     4  2.55397      0.0     0.635        0.0      365.76 -000.00 123Z
BOX TYPE  13
CUBOID     0  2.55397      0.0     1.25984      0.0      365.76 -000.00 123Z
BOX TYPE  14
CUBOID     0  2.55397      0.0     9.69772      0.0      365.76 -000.00 123Z
BOX TYPE  15
CUBOID     4  0.9525       0.0     1.25984      0.0      22.860    0.0   123Z
CUBOID     0  0.9525       0.0     1.25984      0.0      73.152    0.0   123Z
CUBOID     4  0.9525       0.0     1.25984      0.0      96.012    0.0   123Z
CUBOID     0  0.9525       0.0     1.25984      0.0     146.304    0.0   123Z
CUBOID     4  0.9525       0.0     1.25984      0.0     169.164    0.0   123Z
CUBOID     0  0.9525       0.0     1.25984      0.0     219.456    0.0   123Z
CUBOID     4  0.9525       0.0     1.25984      0.0     242.316    0.0   123Z
CUBOID     0  0.9525       0.0     1.25984      0.0     292.608    0.0   123Z
CUBOID     4  0.9525       0.0     1.25984      0.0     315.468    0.0   123Z
CUBOID     0  0.9525       0.0     1.25984      0.0     365.760    0.0   123Z
BOX TYPE  16
CUBOID     4  13.335       0.0      .635        0.0     365.76     0.0   123Z
```

```
MkBW 17x17 FA ANF NORMAL  ARRAY  5.05E 96.3%TD U   0/ 2% MODDEN
BOX TYPE  17
CUBOID      0  13.335       0.0     9.69772     0.0    365.76      0.0  123Z
BOX TYPE  18
CUBOID      4  13.335       0.0     1.25984   0.0     22.860    0.0  123Z
CUBOID      0  13.335       0.0     1.25984   0.0     73.152    0.0  123Z
CUBOID      4  13.335       0.0     1.25984   0.0     96.012    0.0  123Z
CUBOID      0  13.335       0.0     1.25984   0.0    146.304    0.0  123Z
CUBOID      4  13.335       0.0     1.25984   0.0    169.164    0.0  123Z
CUBOID      0  13.335       0.0     1.25984   0.0    219.456    0.0  123Z
CUBOID      4  13.335       0.0     1.25984   0.0    242.316    0.0  123Z
CUBOID      0  13.335       0.0     1.25984   0.0    292.608    0.0  123Z
CUBOID      4  13.335       0.0     1.25984   0.0    315.468    0.0  123Z
CUBOID      0  13.335       0.0     1.25984   0.0    365.760    0.0  123Z
CORE BDY    0 32.22625 -32.22625  20.38980 -11.36015 365.760  -000.00 123Z
CYLINDER    0 48.2600                                 431.80 - 66.04 123Z
CYLINDER    4 48.5637                                 432.10 - 66.34 123Z
CUBOID      3 53.6448   -53.6448   53.6448   -53.6448  432.10 - 66.34 123Z
  1  3 39 1  2 18  1  1 1 1  0
  2  5  5 1  7 13  3  1 1 1  0
  2  6  6 1  5 15 10  1 1 1  0
  2  8  8 1  4 16  3  1 1 1  0
  2 11 11 1  4 16  3  1 1 1  0
  2 14 14 1  4 16  3  1 1 1  0
  2 16 16 1  5 15 10  1 1 1  0
  2 17 17 1  7 13  3  1 1 1  0
  3 11 11 1 10 10  1  1 1 1  0
  2 25 25 1  7 13  3  1 1 1  0
  2 26 26 1  5 15 10  1 1 1  0
  2 28 28 1  4 16  3  1 1 1  0
  2 31 31 1  4 16  3  1 1 1  0
  2 34 34 1  4 16  3  1 1 1  0
  2 36 36 1  5 15 10  1 1 1  0
  2 37 37 1  7 13  3  1 1 1  0
  3 31 31 1 10 10  1  1 1 1  0
  4  1  1 1  1  1  1  1 1 1  0
  6  1  1 1  2 18  1  1 1 1  0
 12  2  2 1  1  1  1  1 1 1  0
 13  2  2 1  2 18  1  1 1 1  0
  5  3 19 1  1  1  1  1 1 1  0
  7 20 20 1  1  1  1  1 1 1  0
  7 22 22 1  1  1  1  1 1 1  0
  8 21 21 1  2 18  1  1 1 1  0
  5 23 39 1  1  1  1  1 1 1  0
 12 40 40 1  1  1  1  1 1 1  0
  4 41 41 1  1  1  1  1 1 1  0
  6 41 41 1  2 18  1  1 1 1  0
  9  1  1 1 19 19  1  1 1 1  0
 14  2  2 1 19 19  1  1 1 1  0
 10  3 19 1 19 19  1  1 1 1  0
 11 20 20 1 19 19  1  1 1 1  0
 11 22 22 1 19 19  1  1 1 1  0
 10 23 39 1 19 19  1  1 1 1  0
 14 40 40 1 19 19  1  1 1 1  0
  9 41 41 1 19 19  1  1 1 1  0
 13 40 40 1  2 18  1  1 1 1  0
 15 20 20 1  2 18  1  1 1 1  0
 15 22 22 1  2 18  1  1 1 1  0
 16 21 21 1  1  1  1  1 1 1  0
 17 21 21 1 19 19  1  1 1 1  0
 18 21 21 1 17 17  1  1 1 1  1
END KENO
```

7.0 OPERATING PROCEDURES

7.1 Procedures for Loading Package

7.1.1 Inspection Prior to Loading

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 is has not been significantly damaged (no cracks, punctures, holes, or broken welds). Any welding required shall be per approved procedures.

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 is properly oriented within the container shell).

5. Visually inspect the shock mounts to assure that they are free of defects, 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.

7.1.2 Generalized Loading Procedure

The procedure to be used to load fuel elements into the Model 51032-2 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 end fittings 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 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 nuts and washers that secure the strongback to the shock mounts bolts.

8. Attach a crane hook to the U-bolt on the upper end of the strong-back. Elevate the strongback until it is in the vertical position.

9. Install the two strut-type stabilizer braces to the strongback, making sure these braces are adequately secured and ball lock pins or bolts and nuts are in place.

10. Install lower fuel element support plates on 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.

14. Supporting the strongback with a crane, remove the ball lock pins from stabilizer braces.

15. Remove 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. The half clamps shall 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 and set, as necessary.

20. Inspect the inside of the container to assure that there are no loose articles within the container. Verify that the polyethylene surrounding the fuel elements is open on the ends.

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. (The loaded container weighs up to 7500 pounds.)

27. Stack packages two high (no higher), and secure them to the transport vehicle. Do not bolt packages together.

7.2 <u>Generalized Unloading Procedure</u>

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 BWFC promptly of any damage and await BWFC instructions for unloading. Inspect accelerometers through the viewports and record condition.

3. If the containers are not damaged, remove them from the transport vehicle using a forklift or crane with adequate capacity. (The loaded containers weigh up to 7500 pounds.)

4. Place the containers in the unloading area and await approval by BWFC before opening the containers.

5. After receiving approval from BWFC to open the containers, remove the security seals and record the numbers of the seals.

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 full clamps and install half clamps in locations where half clamps were replaced by full clamps during loading.

10. Free the strongback from the container by removing the hex nuts and washers 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 strut-type stabilizer braces to the strongback, making sure these braces are adequately secured with ball-lock pins or bolts and nuts.

12. Elevate the strongback to the vertical position.

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 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. Inspect fuel elements for any damage.

16. Lower strongback and reassemble containers for return shipment to original shipper.

7.3 **Preparation of Empty Package for Transport**

Packages to be shipped empty are to be surveyed and shipped in accordance with 49 CFR 173.427 "Empty Radioactive Material Packaging."

7.4 **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 Virginia scales. If an overweight condition is found, return to B&W Fuel Company to shift 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 loading.

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 the Shipping Company dispatcher at least every 6 hours during the trip.

8. Promptly notify the Shipping Company dispatcher on duty in the event of a breakdown. In the event of an accident or other emergency, notify the following promptly.[1]

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

9. In case of a significant accident, also notify the United States Department of Energy Regional Coordinating Office. When notifying this agency, they should be advised that the shipment is low enriched (< 6.0%) unirradiated nuclear reactor fuel elements. Also, inform them of the extent of damage as it pertains to the shipping containers. An Emergency Procedure is included with the driver's package.

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

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

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

8.1.1 Visual Inspection

Each package shall be inspected and released for use. The following items are included in such inspections:

1. Visually inspect the shipping container to assure there are no significant material defects (no cracks, punctures, holes, or broken welds).

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 is free of significant material defects (no broken welds, no broken nor bent members).

5. Visually inspect the shock mounts to assure that there are proper numbers and 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 working condition.

8.1.2 Structural and Pressure Tests

Before acceptance, each container will be subjected to the standard routine maintenance program for structural members outlined in Section 8.2.1.

8.1.3 Leak Tests

Before acceptance, each container will be subjected to the standard routine maintenance program for leak testing outlined in section 8.2.1.

8.1.4 Component Tests

8.1.4.1 Valves, Rupture Discs, and Fluid Transport Devices

Not Applicable.

8.1.4.2 **Gaskets**

Gaskets material durometer is verified to be acceptable prior to use.

8.1.5 **Tests for Shielding Integrity**

Not Applicable.

8.1.6 **Thermal Acceptance Tests**

Not Applicable.

8.2 **Maintenance Program**

8.2.1 **Structural and Pressure Tests**

A structural inspection is performed on all fuel assembly shipping containers before each use by BWFC as follows:

1. Visually inspect for broken welds.
2. Examine fasteners (bolts, washers and nuts) for worn, stripped, or missing parts. Replace if necessary, using approved parts.
3. Check "T" bolt slots for visual discrepancies.
4. Look for loose, damaged or missing rubber pads on all required surfaces. Replace or repair if needed. Remove all ink identification markings from rubber pad.
5. Visually inspect shock mounts. If signs of deterioration are evident or if date embossed shows expiration of life expectancy, replace shock mount.
6. Check all shock indicators (accelerometers) for proper installation, calibrations and correct setting.
7. Visually inspect container outer shell for damage (dents, cracks, tears, etc.).
8. Check humidity indicator for blue color and replace desiccant if required. Check plexiglas cover on humidity indicator by touching.
9. Verify that all container markings (labels, stencils) are in place and are legible. Correct as necessary.

10. Utilizing crane hoist and wire rope slings, position the lid directly over bottom half of shipping container. Lower lid slowly locating on guide pins and seat. Make sure O-ring is positioned properly prior to tightening fasteners and that there are no obstructions that will damage seal.

11. Insert T-head bolts and tighten lid to assure seal. Use an alternating, random tightening sequence, torque to a maximum of 600 in. lbs.

8.2.2 Leak Tests

A leak test is to be performed on all fuel assembly shipping containers annually, as follows:

1. Pressurize the sealed container to 5 ± 1 psi of dry air. Record initial pressure applied to container.

2. After a minimum of one hour, record pressure and determine if loss of container pressure is evident.

3. Release pressure back down to zero.

If container pressure has dropped below 4 psi after one hour, replace closure gasket.

8.2.3 Subsystem Maintenance

Not Applicable.

8.2.4 Valves, Rupture Discs, and Gaskets on Containment Vessel

Before each use, visually inspect O-ring gasket for signs of deterioration. Replace as necessary. As a minimum, gasket is to be replaced once annually.

Check air filling valve and air pressure gauge for correct operation and replace if necessary. Ensure hole cover is in place.

8.2.5 Shielding

Not Applicable.

8.2.6 Thermal

Not Applicable.

APPENDIX A

TEST REPORT FROM CONSOLIDATED LICENSE APPLICATION FOR ADVANCED NUCLEAR FUELS CORPORATION MODEL 51032-1 SHIPPING CONTAINER, DOCKET 71-6581

CONTENTS:

THE CALCULATION SHEETS, PHOTOGRAPHS AND DRAWINGS CONTAINED WITHIN THIS APPENDIX WERE DIFFICULT TO REPRODUCE. THE QUALITY AND LEGIBILITY IS SUBSTANDARD IN SOME CASES. THE ORIGINALS ARE CONTAINED IN THE TEST REPORT FROM CONSOLIDATED LICENSE APPLICATION FOR ADVANCED NUCLEAR FUELS CORPORATION MODEL 51032-1 SHIPPING CONTAINER, DOCKET 71-6581 LOCATED IN THE NRC PUBLIC DOCUMENT ROOM.

APPENDIX II

STRUCTURAL ANALYSIS OF MODEL 51032-1

PACKAGING TIE-DOWN SYSTEM

STRUCTURAL ANALYSIS OF MODEL 51032-1 PACKAGING TIE-DOWN SYSTEM

PURPOSE

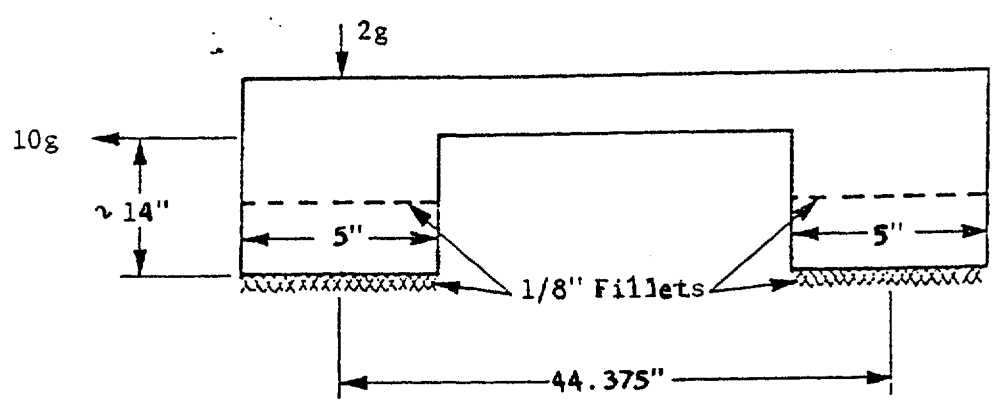
Assure that the Model 51032-1 packaging stacking brackets have adequate structural integrity for use in a tie-down system.

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.

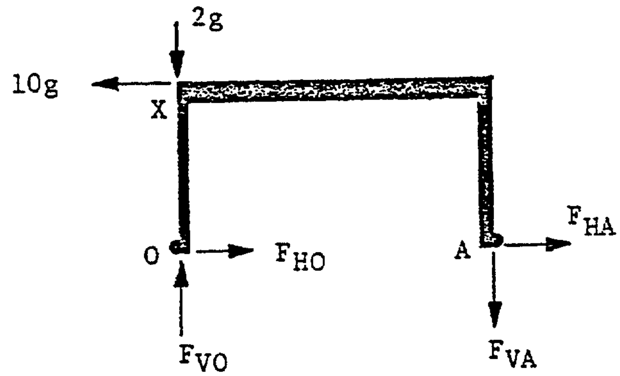
ASSUMPTIONS

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 low:



where:  = sign convention,

$\Sigma F_X = 0,$

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

$\Sigma F_Y = 0,$

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

$\Sigma M_O = 0,$

$F_{VA} = 23{,}346.5$ 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.)

S = 43,163 psi.

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

where: S_s = shear stress (psi)

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

S_s = 41,867 psi.

Applying the maximum shear stress theory:

$\tau = [(S_s)^2 + (S/2)^2]^{1/2}$, (3)

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

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_{oy}-min. = 0.6 (42,000) = 25,200 psi.

<u>Conclusion</u>

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

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

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[1]Churchill & Austin, <u>Weld Design</u>, Prentice Hall

APPENDIX III

APPLIED DESIGN COMPANY, IN.

REPORTS 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

Jersey Nuclear Company Purchase Order No. R085 is dated July 8, 1971 and is placed on Applied Design Company. This purchase order covers the sign, 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 quirements 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 each mount is shown in the calculations in Appendix I.

The strongback structure is identical to the Model 927 C 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 on 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, though 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 sideways 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.
2465 SHERIDAN DRIVE
TONAWANDA, NEW YORK

III-5

CALCULATION SHEET

XN-52, Rev. 1

PAGE 1

JOB/EST. No. 2526-1

DATE 8-31-71

TITLE Appendix I to Engineering Analysis for Jersey Nuclear Company

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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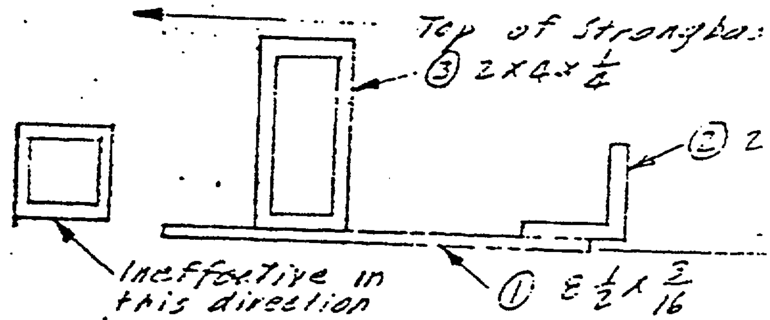
CAL

JOB / EST. No. 2526-1

TITLE Appendix I to Engineering
Analysis for Jersey Nuclear C

Compare Thrust Bracke

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.
Σ	5.28		6.89	11.58	5.72

$$\bar{x} = \frac{\Sigma Ax}{\Sigma A} = \frac{6.89}{5.28} = 1.3 \text{ IN.}$$

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

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

$$= 8.36 \text{ IN.}^4$$

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

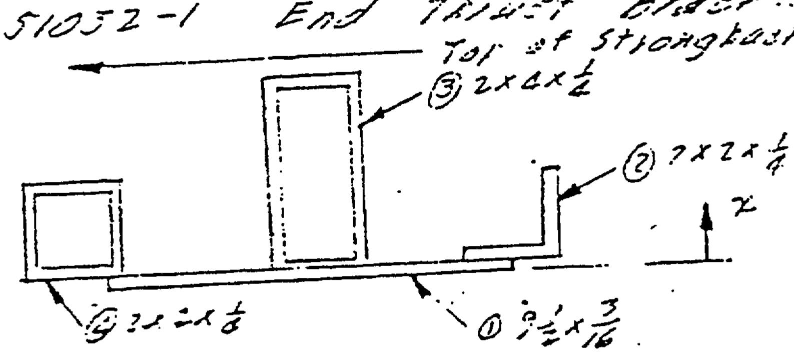
JOB/EST. No. 2526-1

DATE 8-31-71

TITLE Appendix I to Engineering Analysis for Jersey Nuclear Company

BY WJS

Model 51032-1 End Thrust Brackets



Elem	A	x	Ax	Ax^2	$A\bar{I}_x$
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

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

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

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

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

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

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

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

CALCULATION SHEET

JOB / EST. No. 2526-1

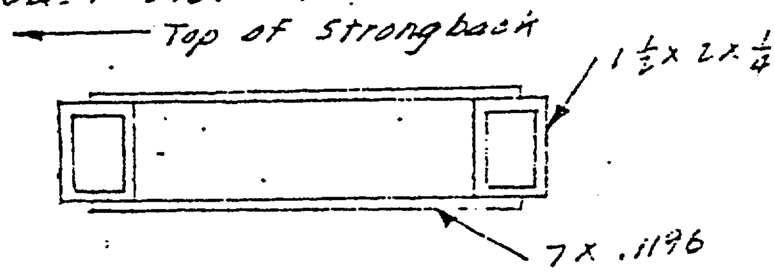
PAGE 4

TITLE Appendix I to Engineering Analysis for Jersey Nuclear Company

DATE 8-31-71

BY WJG

Model 51032-1 Center Thrust Bracket



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

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

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

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

$$\text{Increase} = \frac{3.36 - 2.9}{2.9} \times 100 = \underline{16}\,\%$$

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 ________ 9/27/72

Instrumentation ________ 9-27-72

Structural G. R. ________ 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-20801. 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 ncrete 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 holds 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 butt welded together, with skip welds, to form a pad 20' x 8' ½". The plate shall be anchored to the concrete pad using 3/4" Philips "Red Head" bolts on 4' centers around the outside edge.

MULATED 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 preferably three, separate ops: (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 ccelerometers. The Jersey Nuclear Mobile Instrumentation to obtain time ersus 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 1000Hz. The crystal accelerometers are PCB Piezontronics Inc., Model 302A.=, and have amounted resonant frequency in excess of 30,000 Hz, with a usable frequency response form 1 Hz to 5000 Hz. The range of the accelerometers vary from $\pm$ 200g to $\pm$ 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 d 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 form 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. <u>VERTICAL POSITION TEST</u>

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 the forward end of the strongback inside the container and two on the ...er 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 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 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 ...rified that all interested parties are present, the container shall be ...oisted 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 e 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 containers. 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 strongback 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 guide lines shall be attached to adequately control the sway of the suspended load.

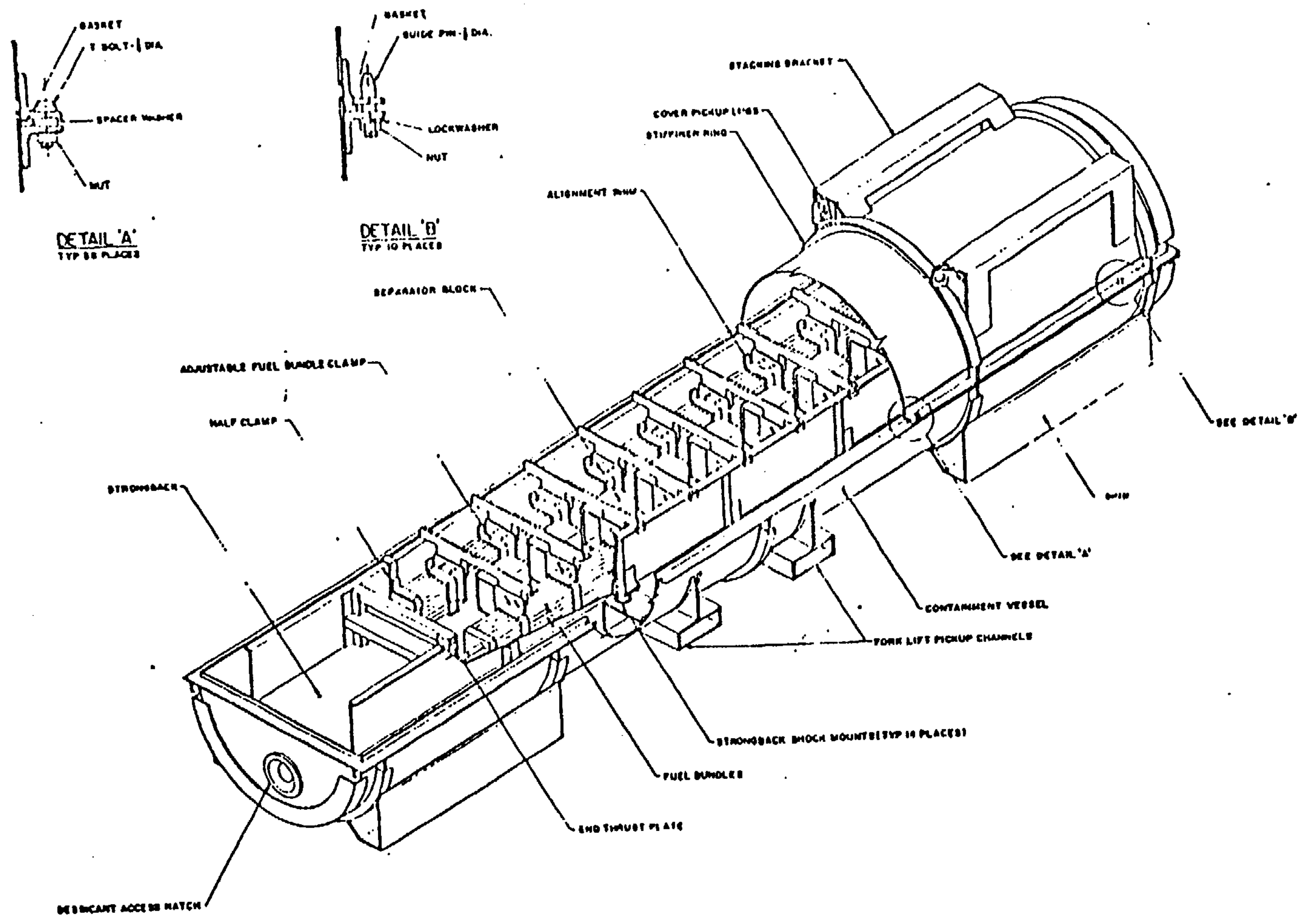
Upon a signal from the test director the quick release devise shall be -tuated and the load allowed to fall onto the steel pad.

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 form the accelerometers.

TEST REPORTS

At the conclusion of the two, and possibly three, drop test, 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. e test report shall include the following lists of photographs.

1. Dummy 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

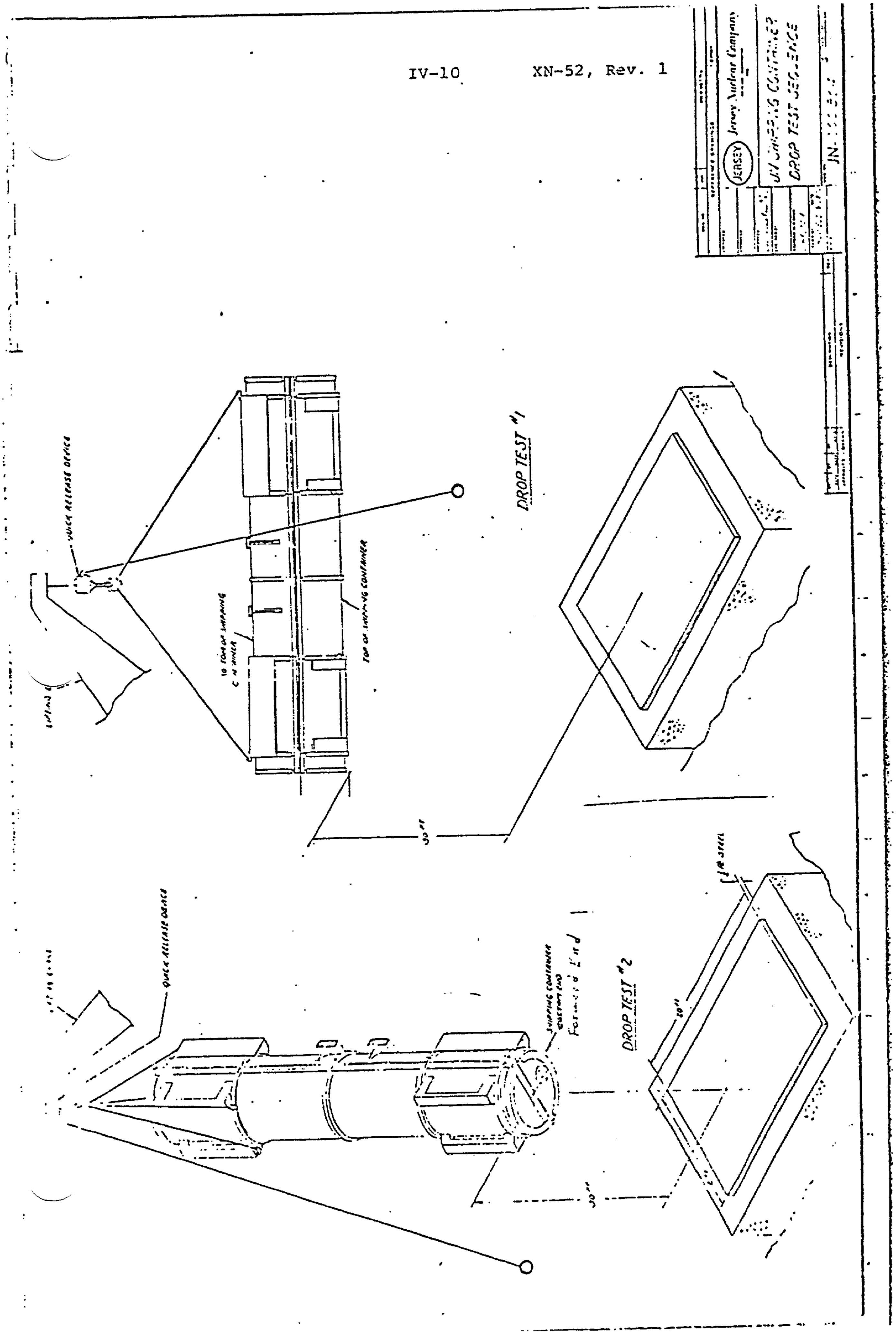


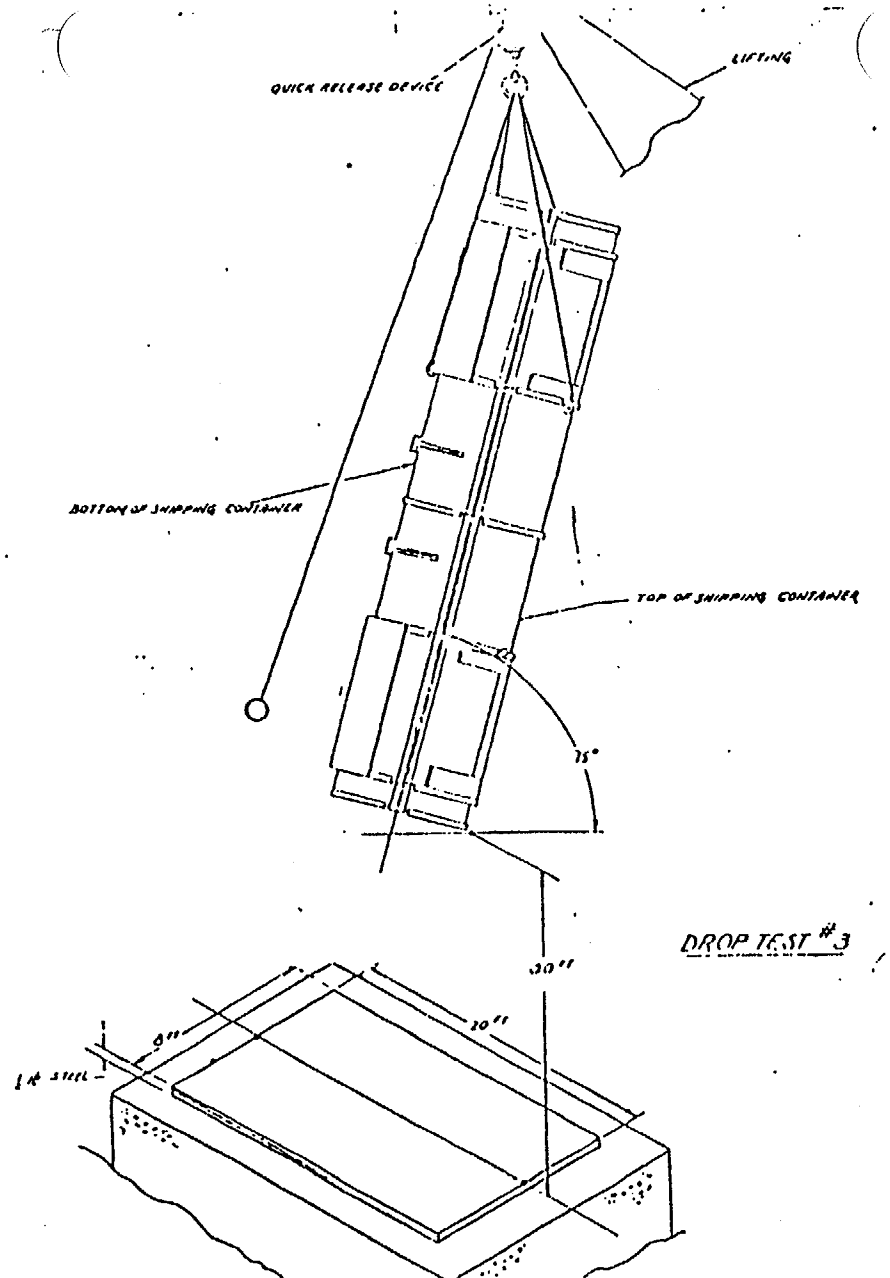
JERSEY Jersey Nuclear Company

FUEL PACKAGING MODEL

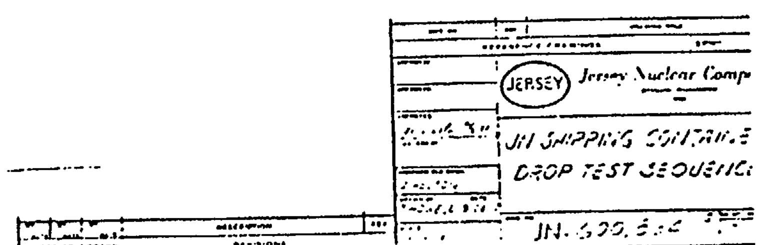
N9 51032-1 ISOMETRIC

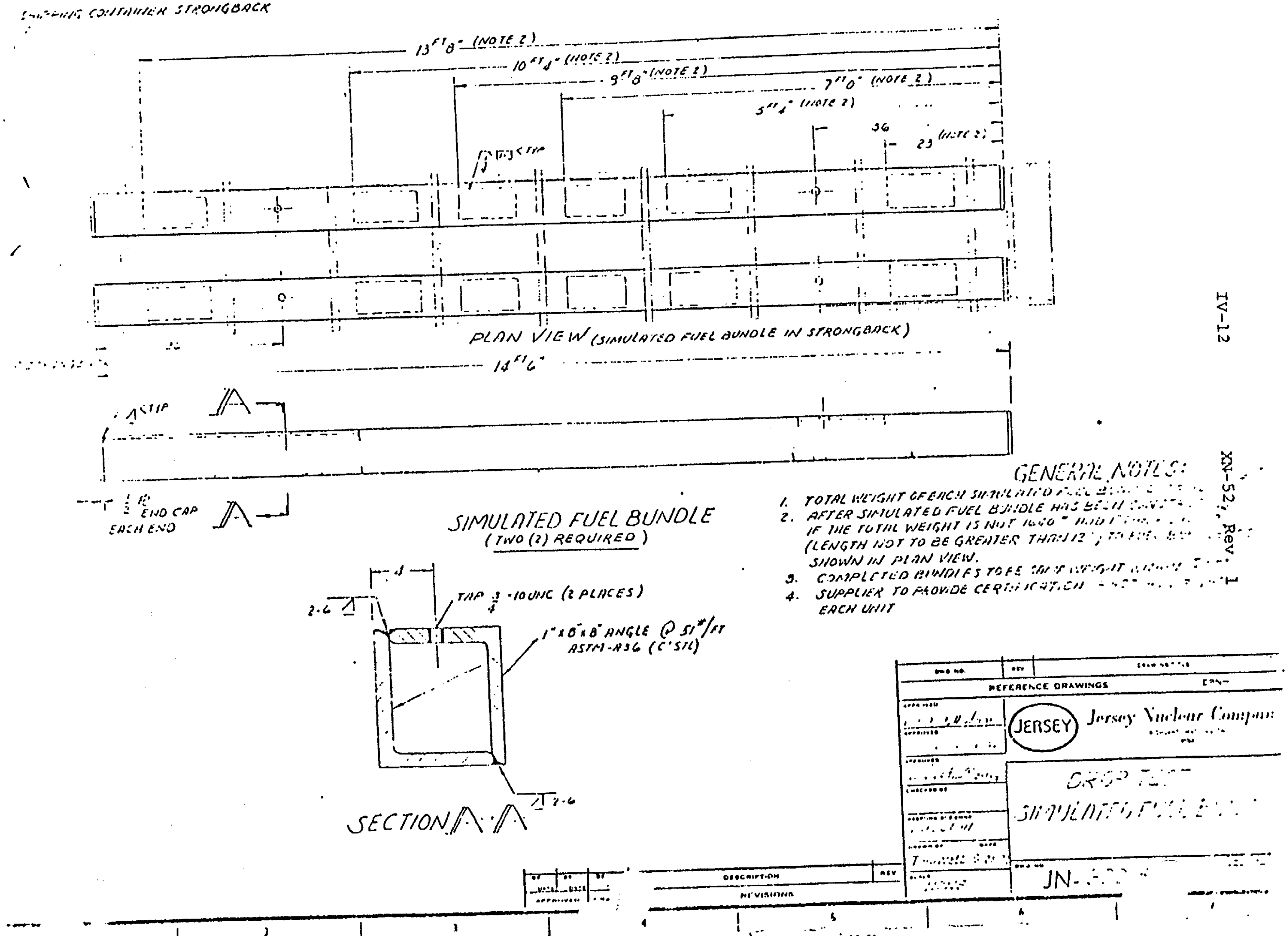
JN-250001

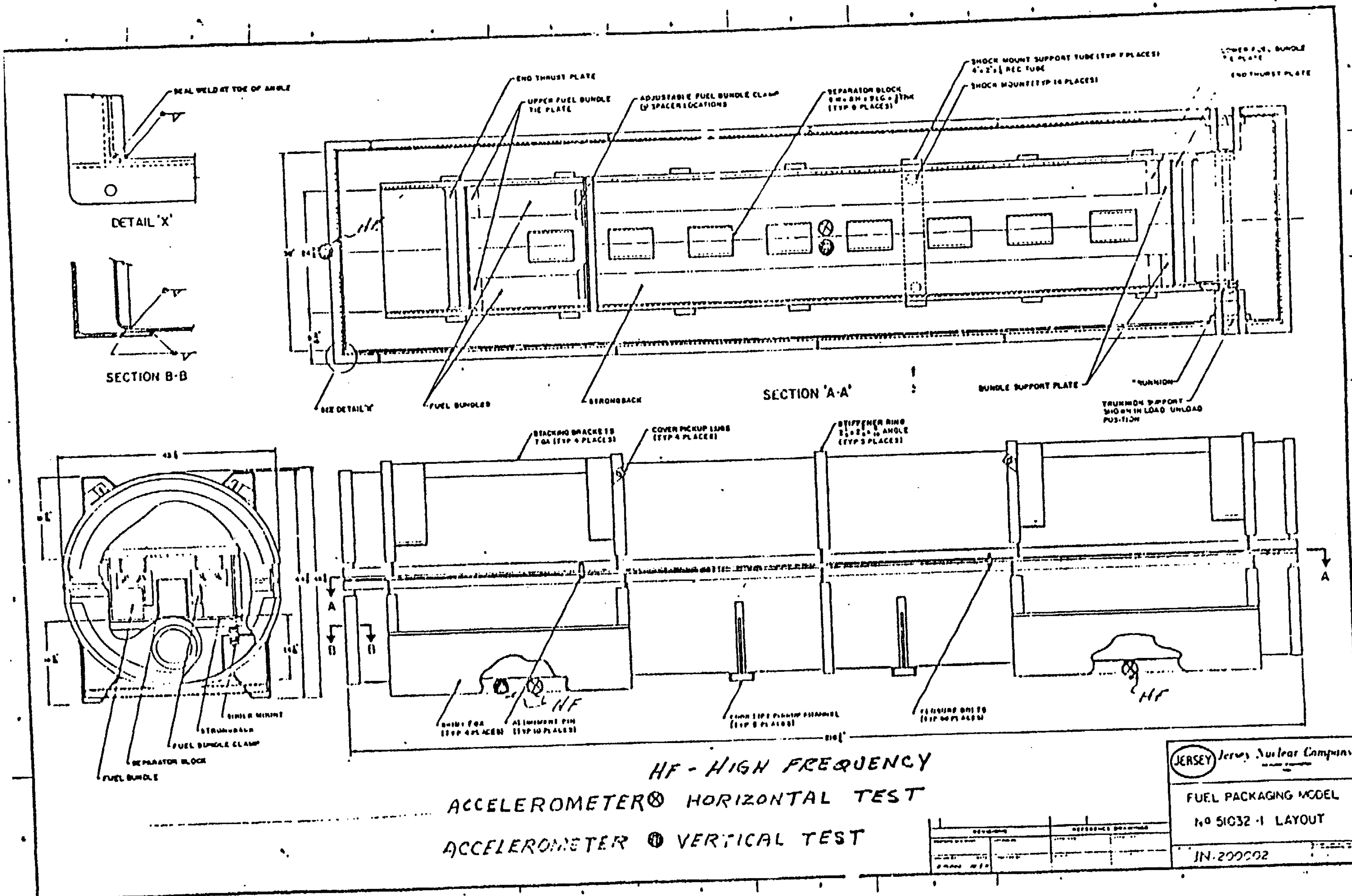

Jersey Nuclear Company
DROP TEST SEQUENCE
DROP TEST #1
DROP TEST #2
TOP OF SHIPPING CONTAINER
QUICK RELEASE DEVICE
SHIPPING CONTAINER
30"
20"


LIFTING
QUICK RELEASE DEVICE
BOTTOM OF SHIPPING CONTAINER
TOP OF SHIPPING CONTAINER
75°
30"
20"
8"
1" STEEL

DROP TEST #3


JERSEY
Jersey Nuclear Comp
JN SHIPPING CONTAINE
DROP TEST SEQUENC
JN.


SHIPPING CONTAINER STRONGBACK
13 FT 8" (NOTE 2)
10 FT 4" (NOTE 2)
9 FT 8" (NOTE 2)
7 FT 0" (NOTE 2)
5 FT 4" (NOTE 2)
36
23 (NOTE 2)
PLAN VIEW (SIMULATED FUEL BUNDLE IN STRONGBACK)
14 FT 6"
A
1/2 R END CAP EACH END
SIMULATED FUEL BUNDLE
(TWO (2) REQUIRED)
8
TAP 3/4 -10UNC (2 PLACES)
1" x 8" x 8" ANGLE @ 51#/FT
ASTM-A36 (C'STL)
2-6
SECTION A-A
GENERAL NOTES:
1. TOTAL WEIGHT OF EACH SIMULATED FUEL BUNDLE
2. AFTER SIMULATED FUEL BUNDLE HAS BEEN
IF THE TOTAL WEIGHT IS NOT
(LENGTH NOT TO BE GREATER THAN
SHOWN IN PLAN VIEW.
3. COMPLETED BUNDLES TO BE
4. SUPPLIER TO PROVIDE CERTIFICATION
EACH UNIT
REFERENCE DRAWINGS
JERSEY
Jersey Nuclear Company
DROP TEST
SIMULATED FUEL B
DESCRIPTION
REVISIONS
JN-


SEAL WELD AT TOE OF ANGLE
DETAIL 'X'
SECTION B-B
END THRUST PLATE
UPPER FUEL BUNDLE TIE PLATE
ADJUSTABLE FUEL BUNDLE CLAMP
SEPARATOR BLOCK
SHOCK MOUNT SUPPORT TUBE
BUNDLE SUPPORT PLATE
TRUNNION
TRUNNION SUPPORT SHOWN IN LOAD UNLOAD POSITION
SEE DETAIL 'X'
FUEL BUNDLES
STRONGBACK
SECTION 'A-A'
STACKING BRACKETS
COVER PICKUP LUGS (TYP 4 PLACES)
STIFFENER RING
ALIGNMENT PIN
FUEL BUNDLE
SEPARATOR BLOCK
FUEL BUNDLE CLAMP
STRONGBACK
HF
HF - HIGH FREQUENCY
ACCELEROMETER ⊗ HORIZONTAL TEST
ACCELEROMETER VERTICAL TEST
JERSEY Jersey Nuclear Company
FUEL PACKAGING MODEL
No 51032-1 LAYOUT

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 . 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 was no signs of concrete cracking or spilling 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 undle weighted 1,653 ± 2 pounds. The bundles were fabricated in fuel compliance with reference drawing.

Memo from Jersey Nuclear Company

I have surveyed the proposed drop site and have evaluated the adequacy 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.

F ICATION

STEEL SUPPLIES

Metalfab Inc. Steel

ERECTION

CRANE SERVICE

• • • TELEPHONE 967-2946 • • •

5302 W. VanGiesen • Richland, Wash. 99352

"Quality Products Built With Pride"

October 4, 1972

RECEIVED
OCT 11 1972
J.W. 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 Gans
President

Larry J. Hunt
Witness

C. M. Gibson
Witness

HORIZONTAL DROP TEST

The simulated fuel bundles were installed in shipping container number ¬1. The container was selected completely at random by the test director ,m 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 remained.

Interior examination revealed that the strong back remained totally inside the container and that the fuel element remained totally inside the strong back. Almost all for the fuel bundle clamps showed pronounced 'ing; however, only one clamp came completely loose. Most of the bolts .aching 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.

SUBJECT Container Drop Test — SHEET NO. 1. OF 3.

Spacing Dimensions Before and After Each Drop

Horizontal Test

DATE

D. BY DATE

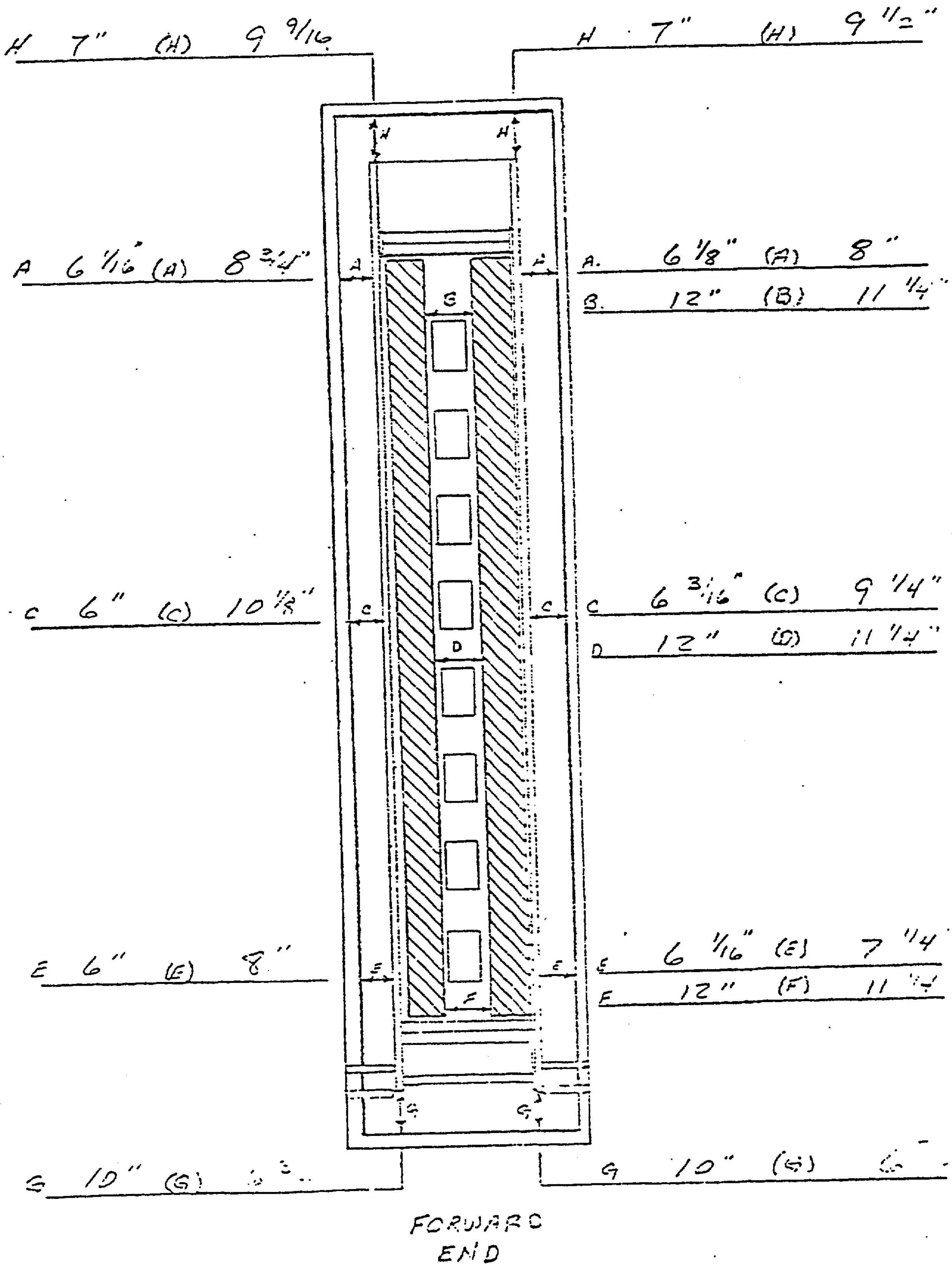
JOB NO.

XN-52, Rev. 1

IV-20

A - BEFORE TEST

(A) - AFTER TEST



DATE .... SUBJECT Container Drop Test SHEET NO. 6 OF —

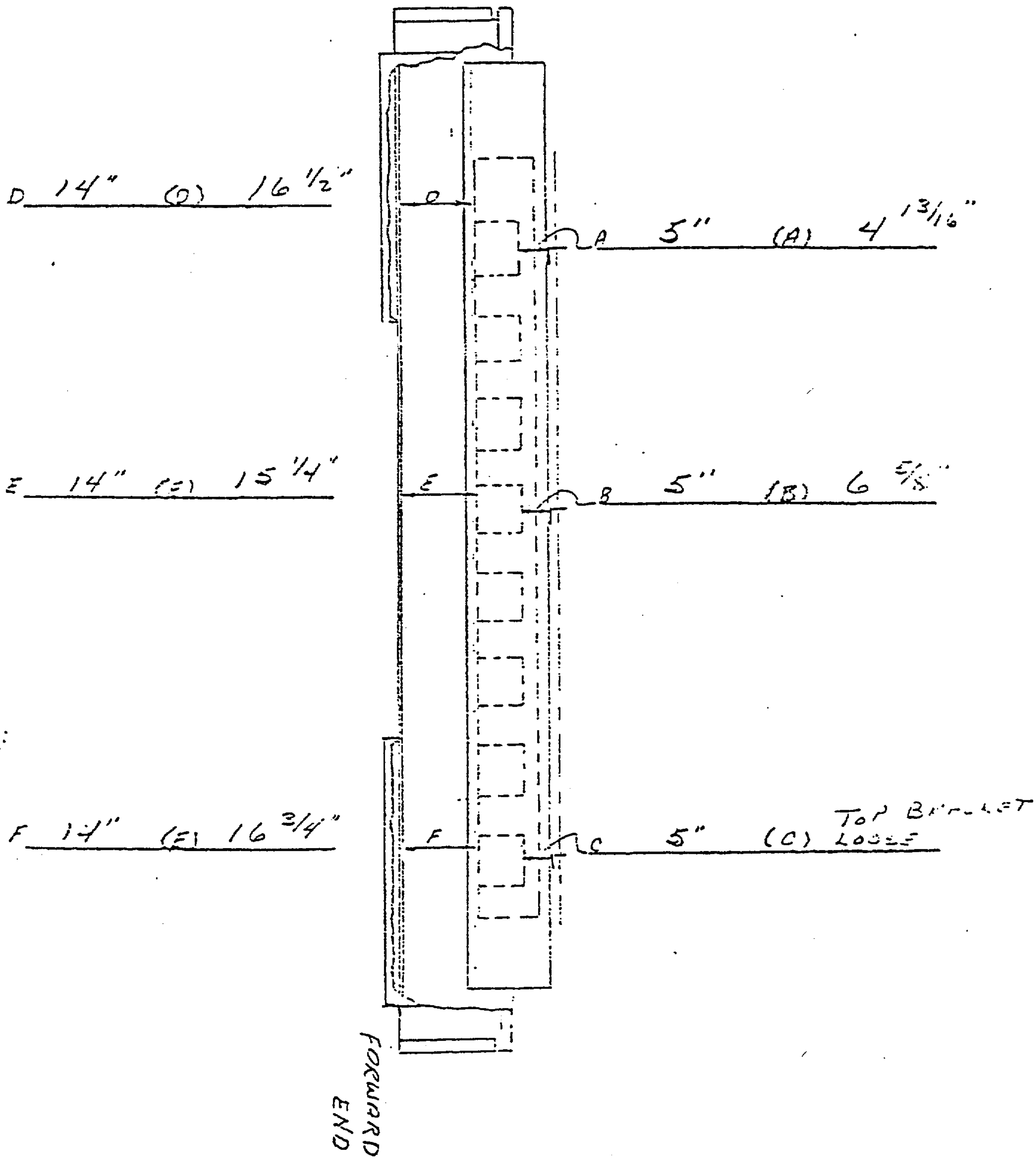
BY .... DATE .... Spacing Dimensions Before JOB NO. ....

And After Each Drop.

Horizontal Test

XN-52, Rev. 1

IV-21



DATE

B DATE

SUBJECT Container Drop Test
Outer Dimensions Before
and After Each Drop
Horizontal Test

SHEET NO. 3 OF 3

JOB NO.

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

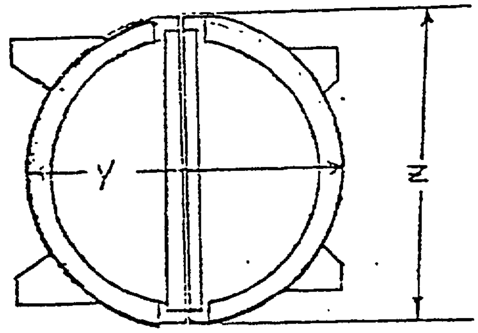
Y 40 1/8"

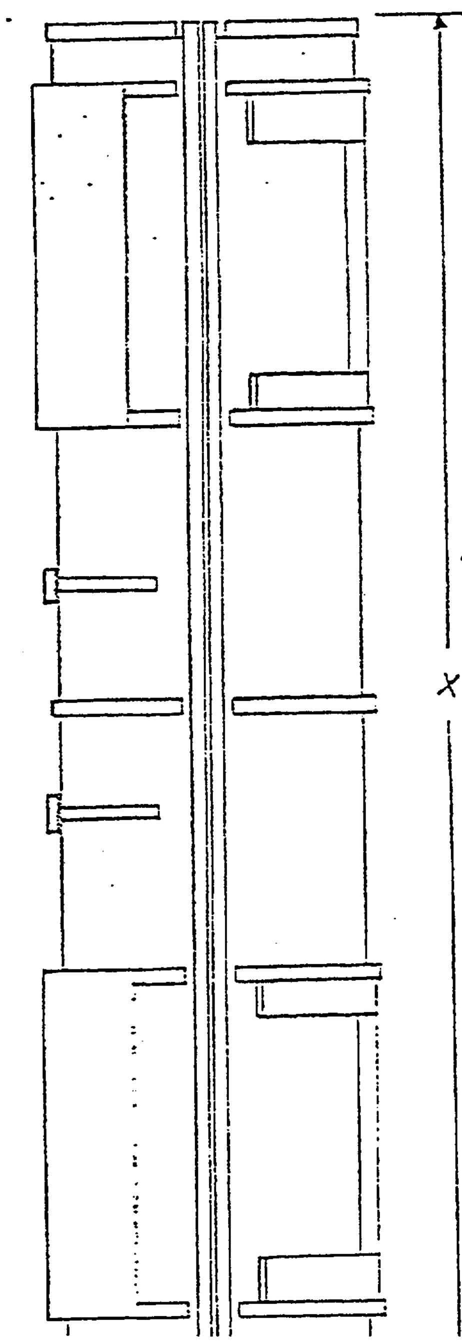
Z 41 7/8"

REAR END

Y 40 1/4"

Z 41 7/8"





(X) DIMENSIONS (after test)

(TOP) 17' 11 7/8"

(BOTTOM) 17' 10 5/8"

(RIGHT) 17' 11 1/8"

(LEFT) 17' 11 1/2"

"X" DIMENSIONS (before test)

TOP 18' 1 1/2"

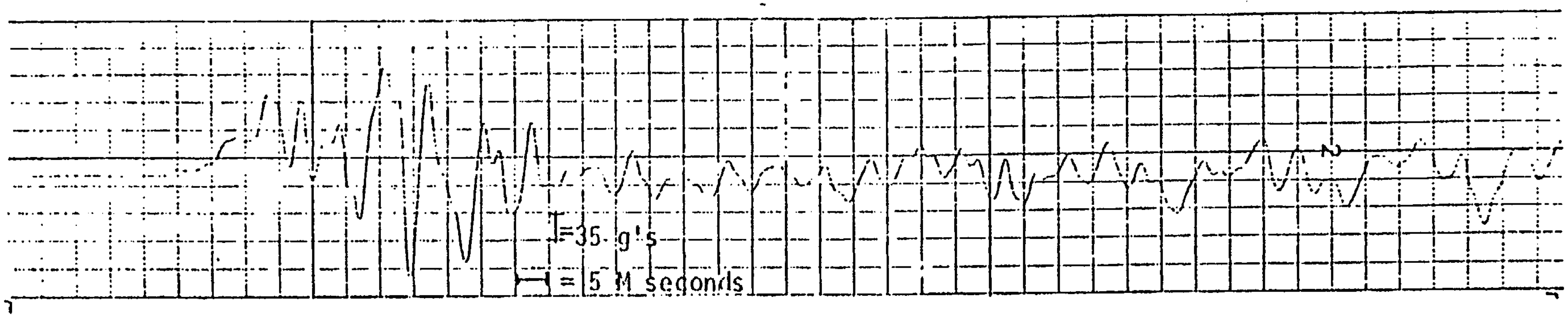
BOTTOM 18' 5/8"

RIGHT SIDE 17' 11 1/8"

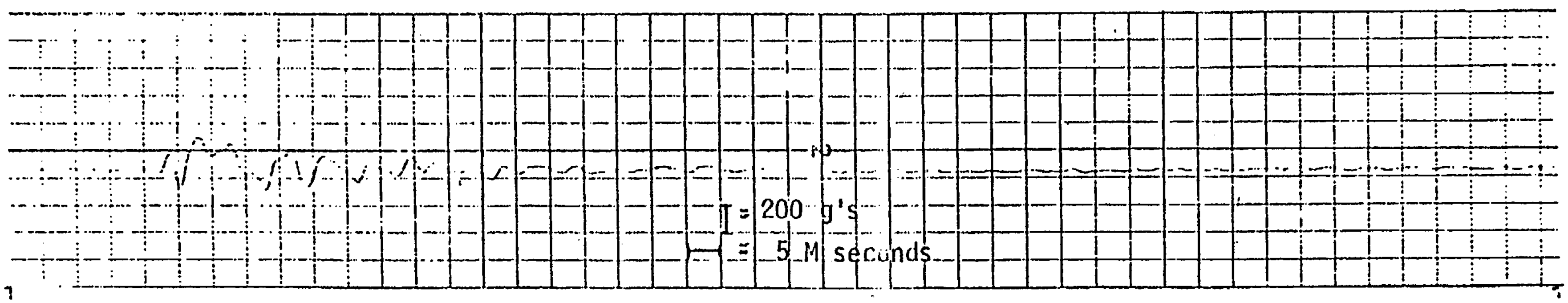
LEFT SIDE 17' 11 1/4"

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

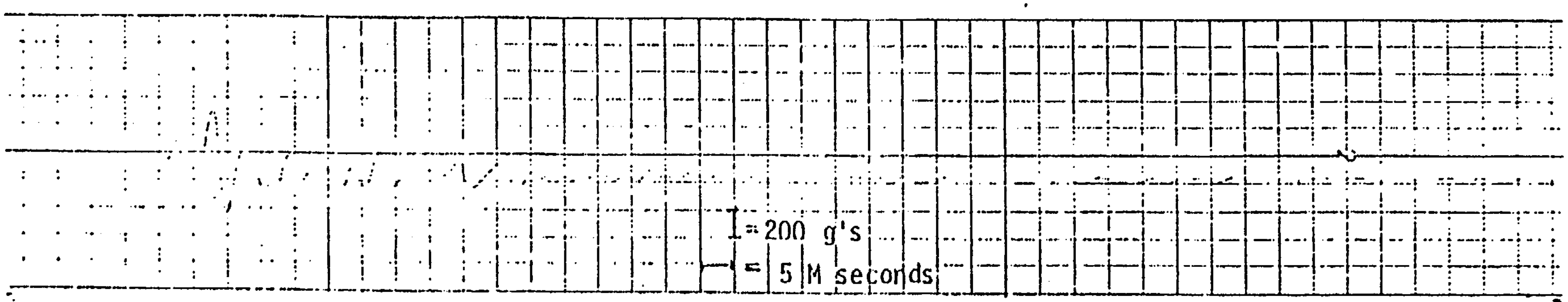
TEST NO. 1 - HORIZONTAL COVER DROP



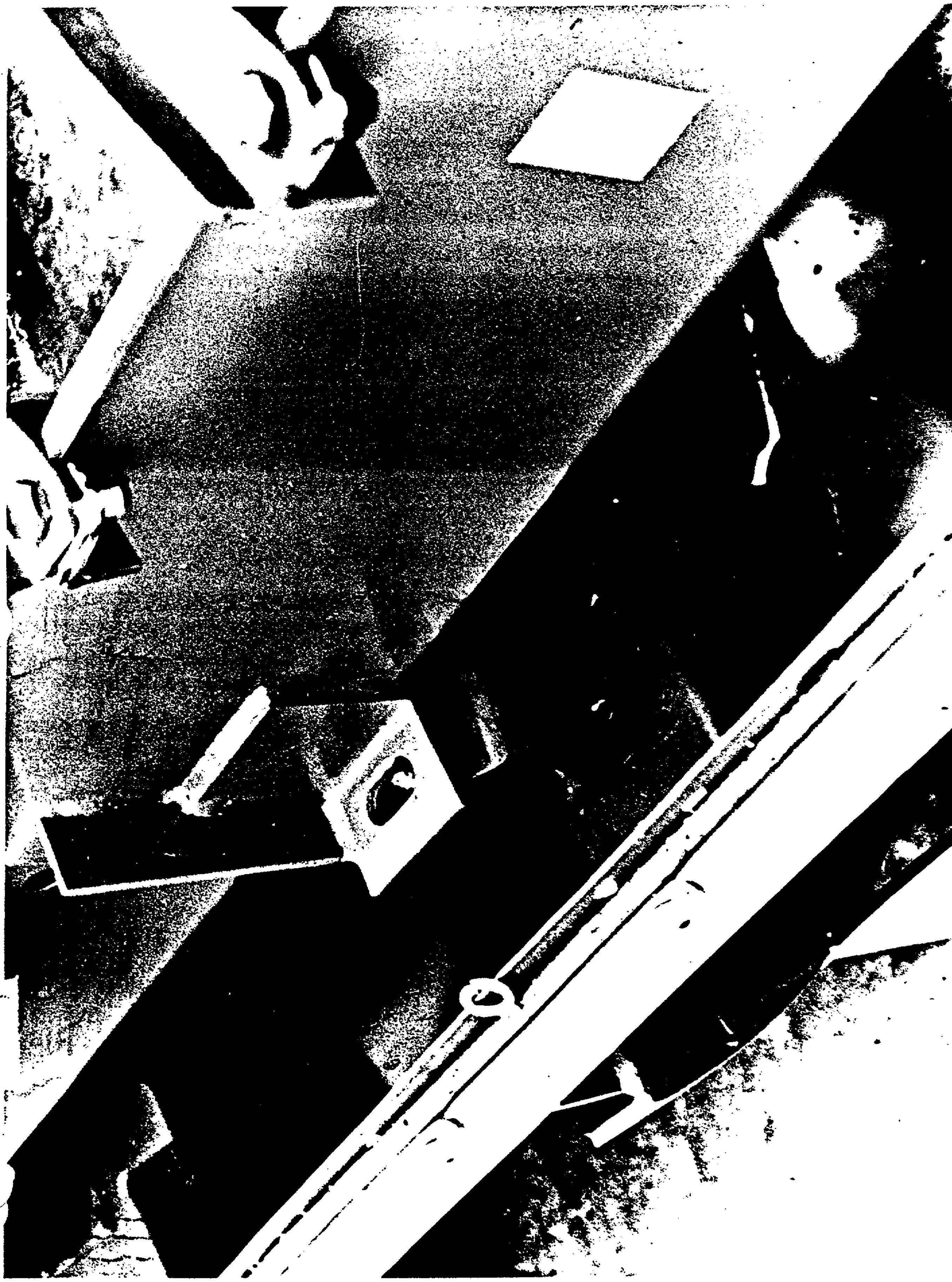
STRONGBACK

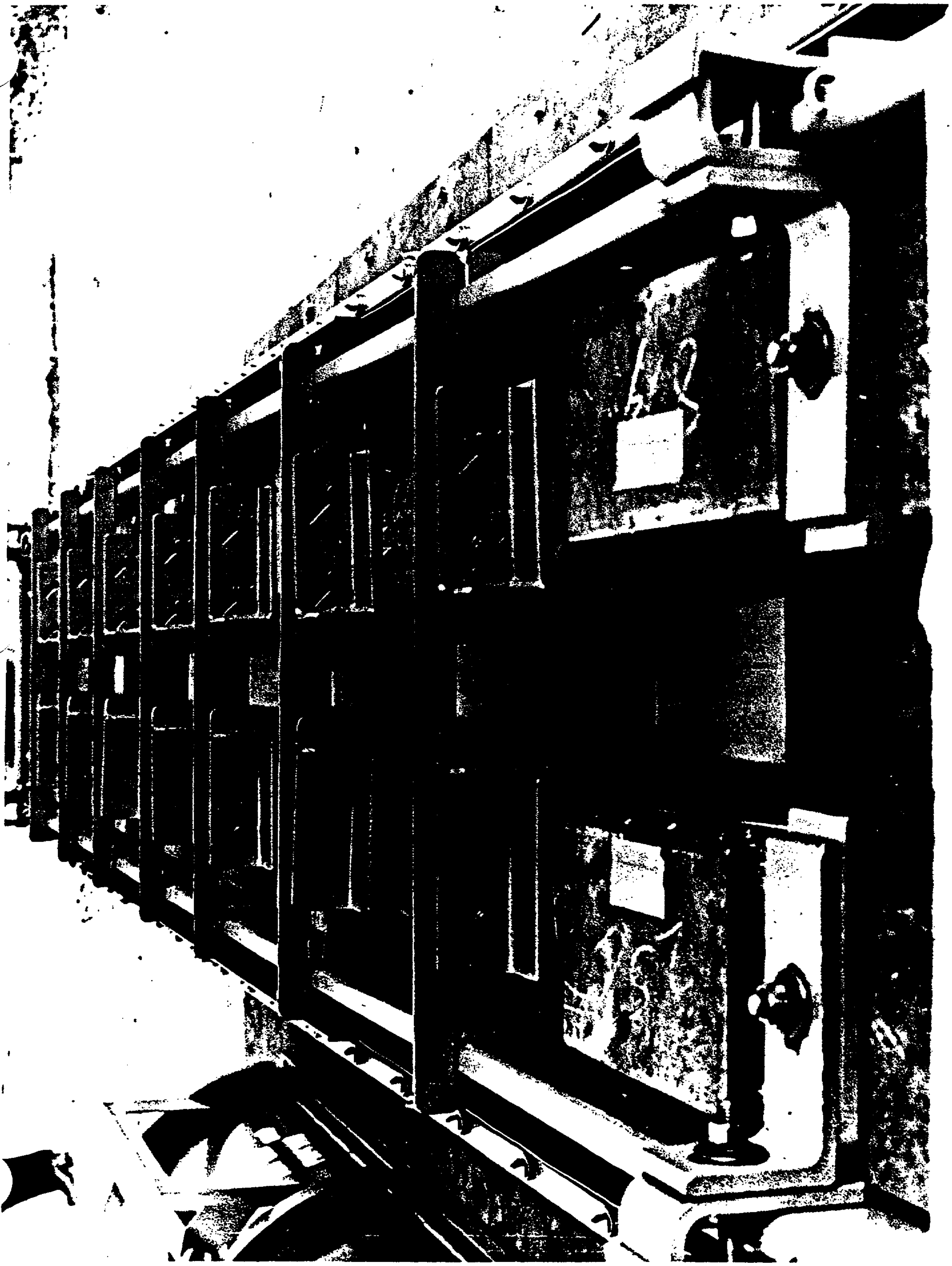


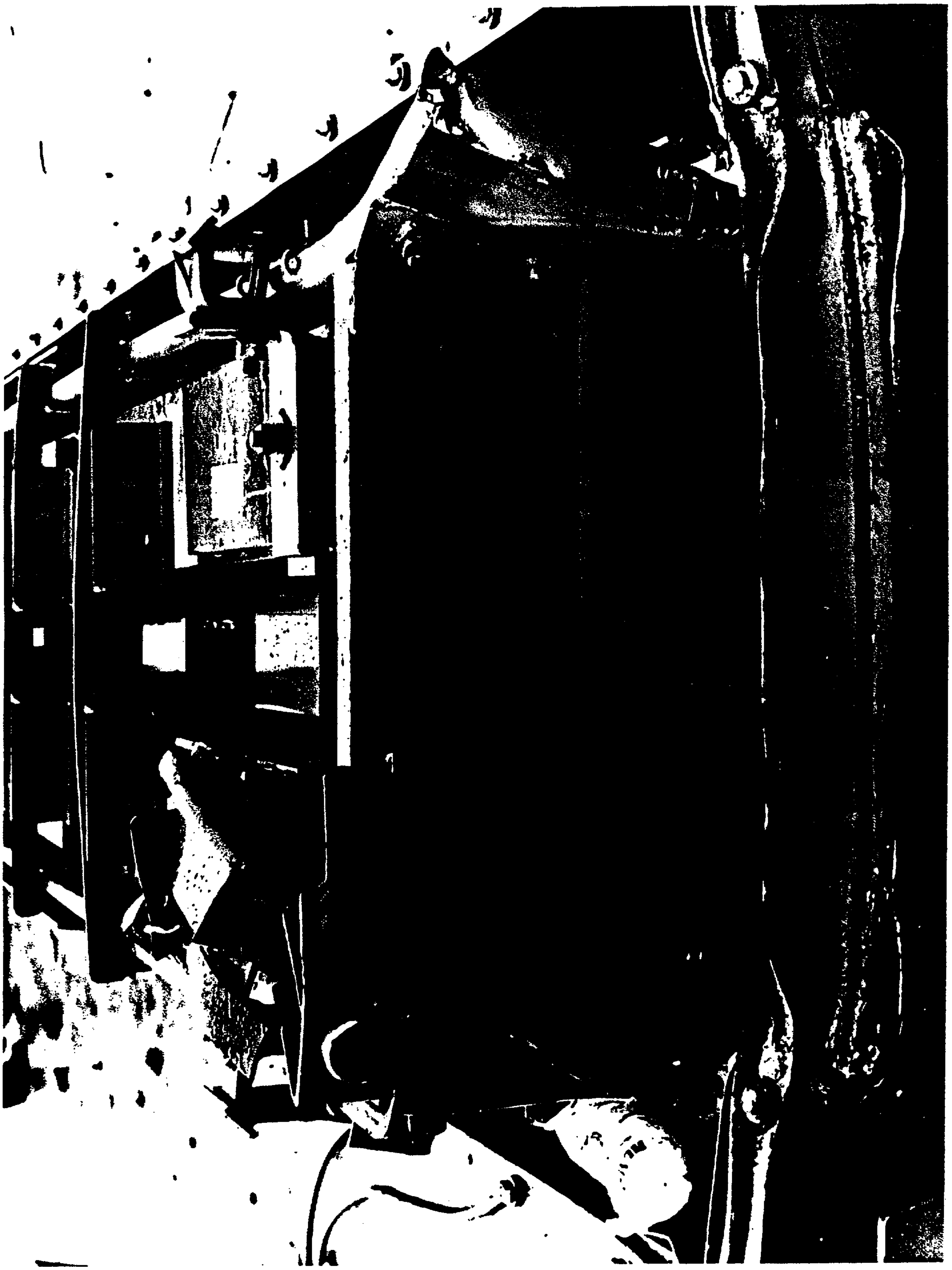
CONTAINER SHELL (EAST END)

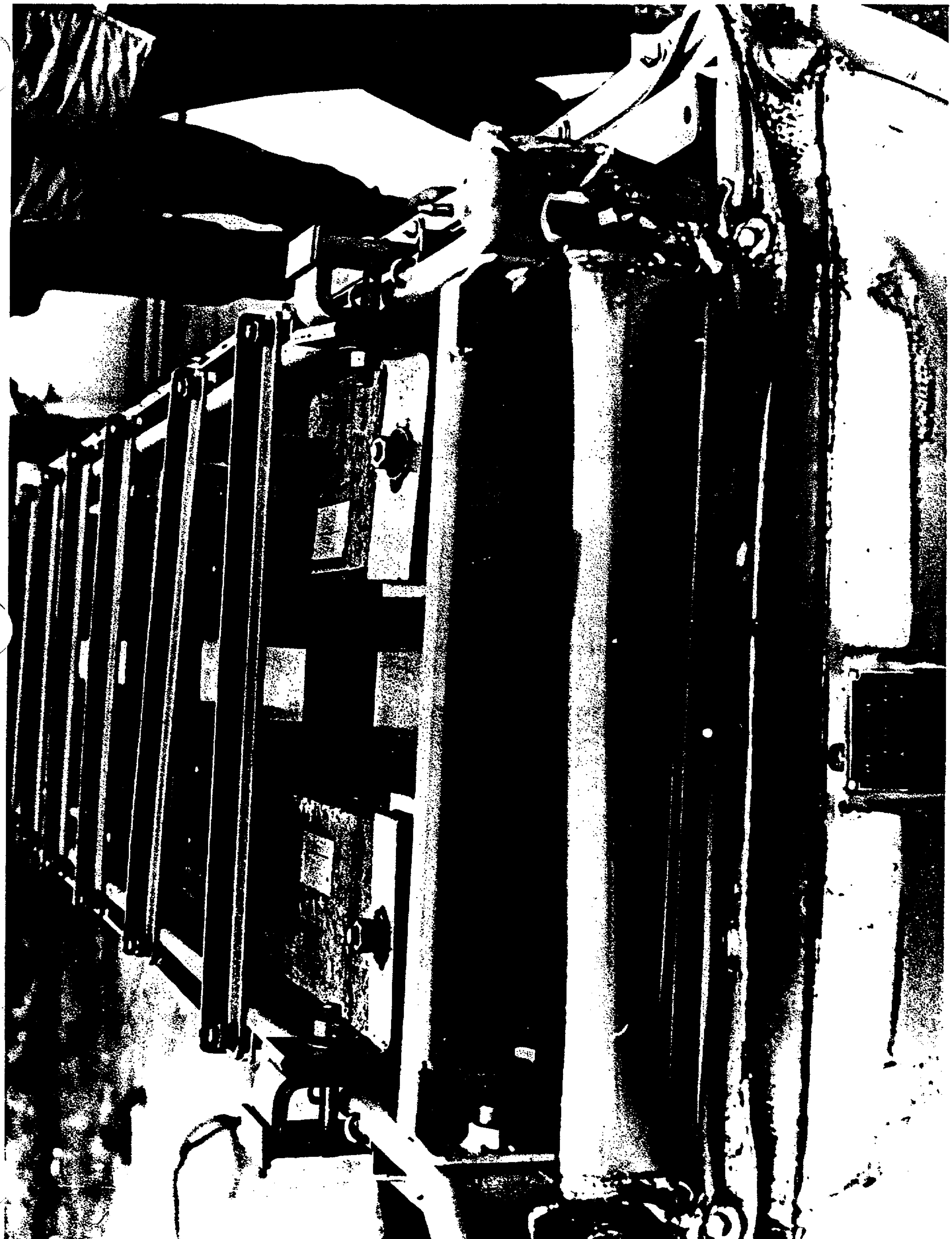


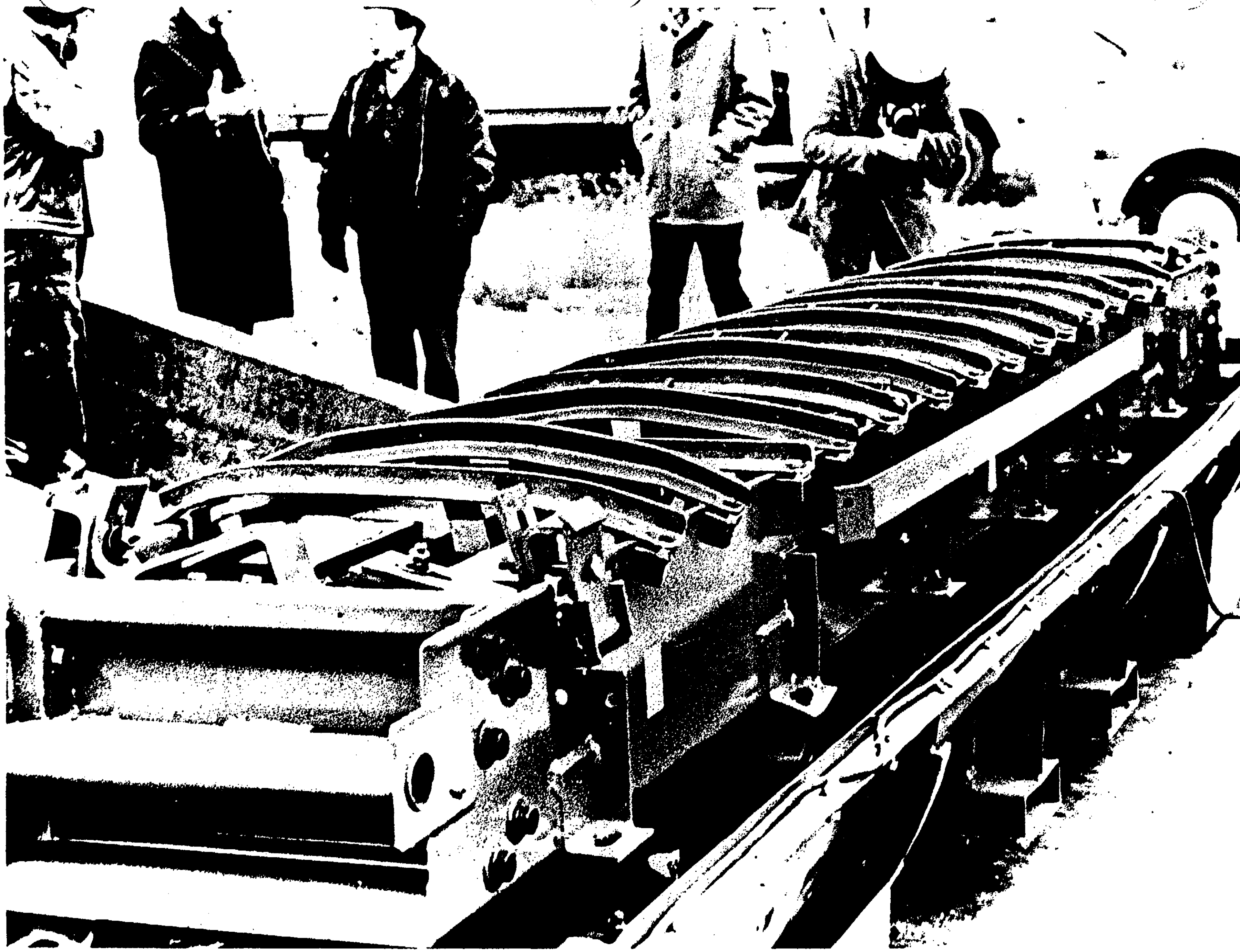
CONTAINER SHELL (WEST END)

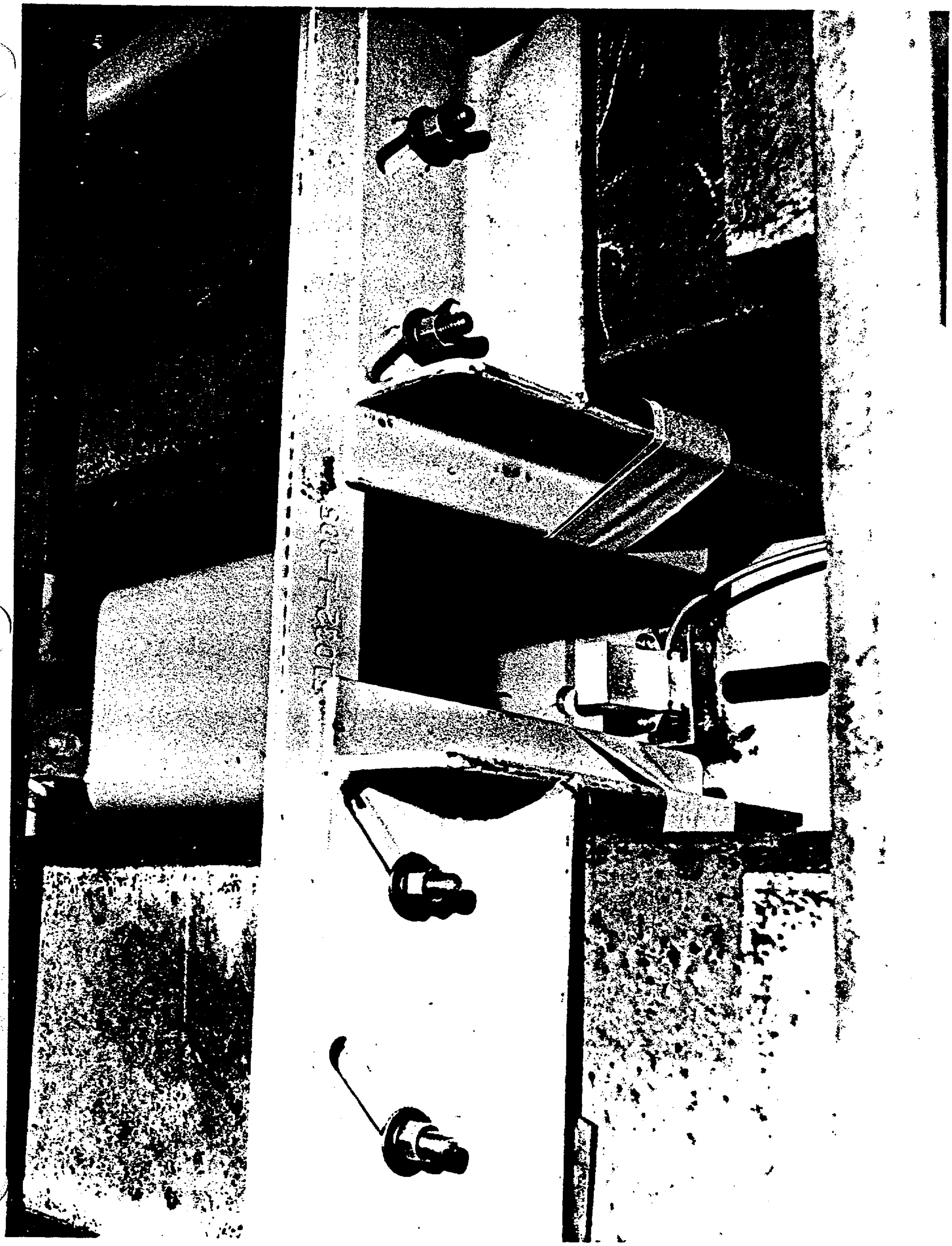


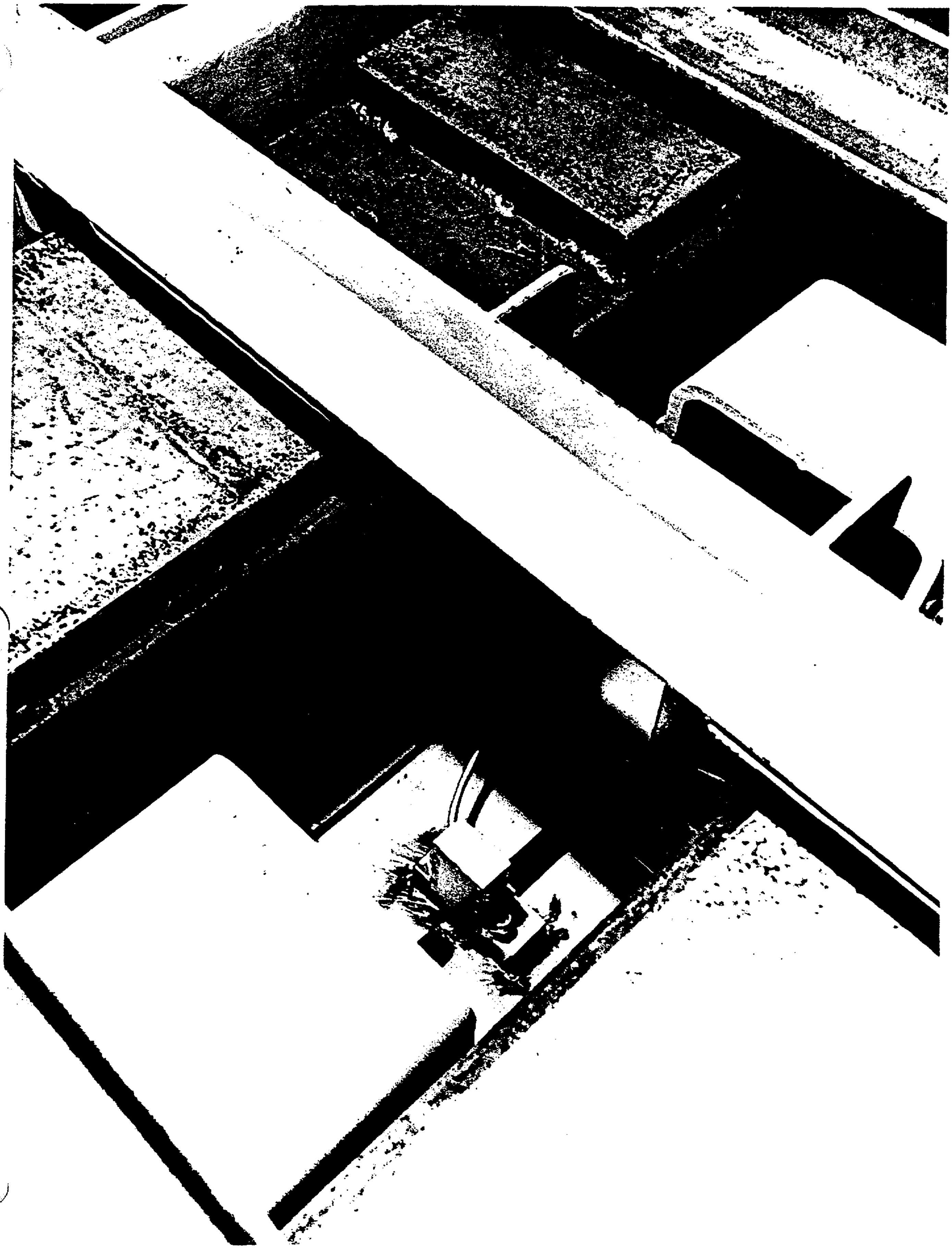


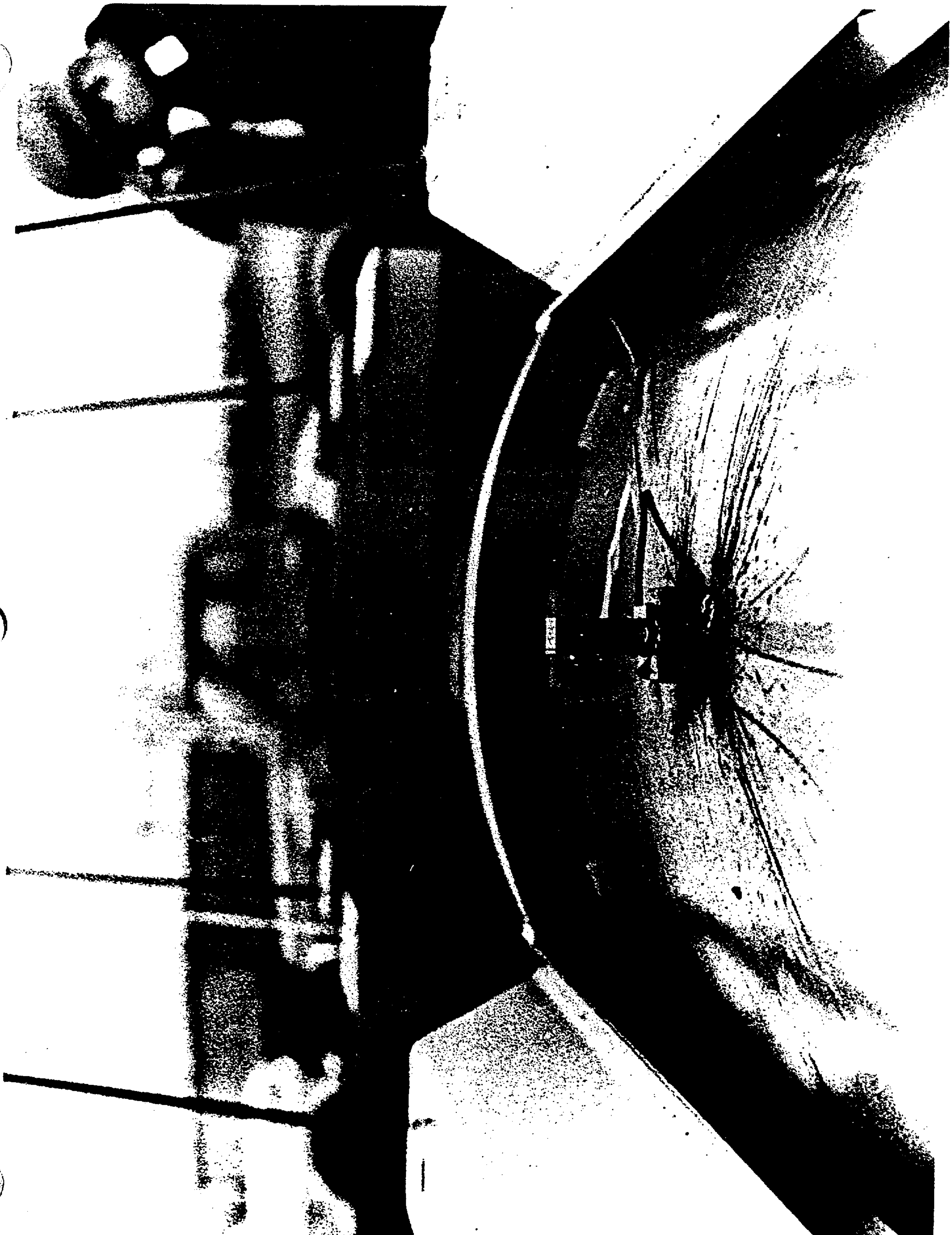


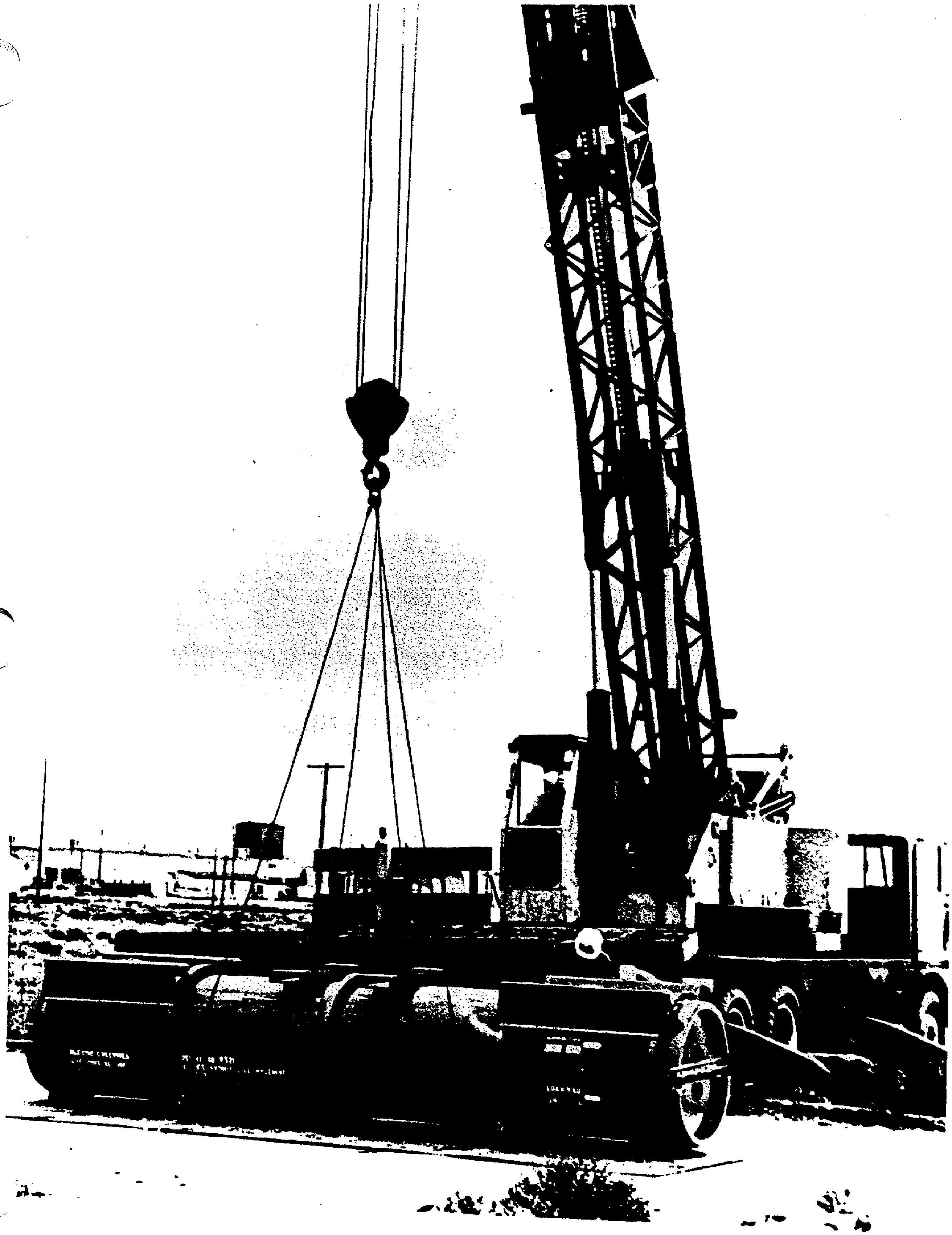


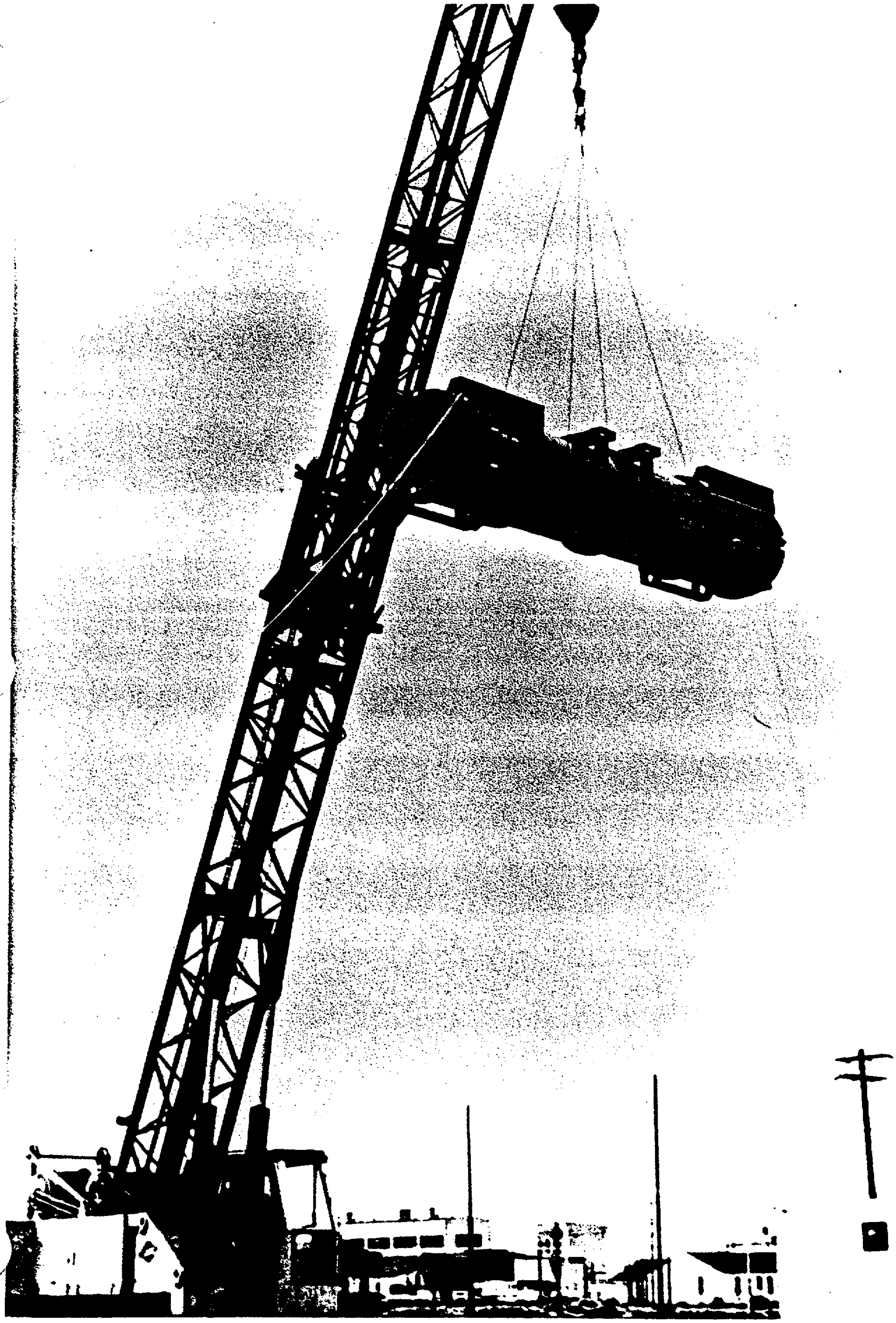


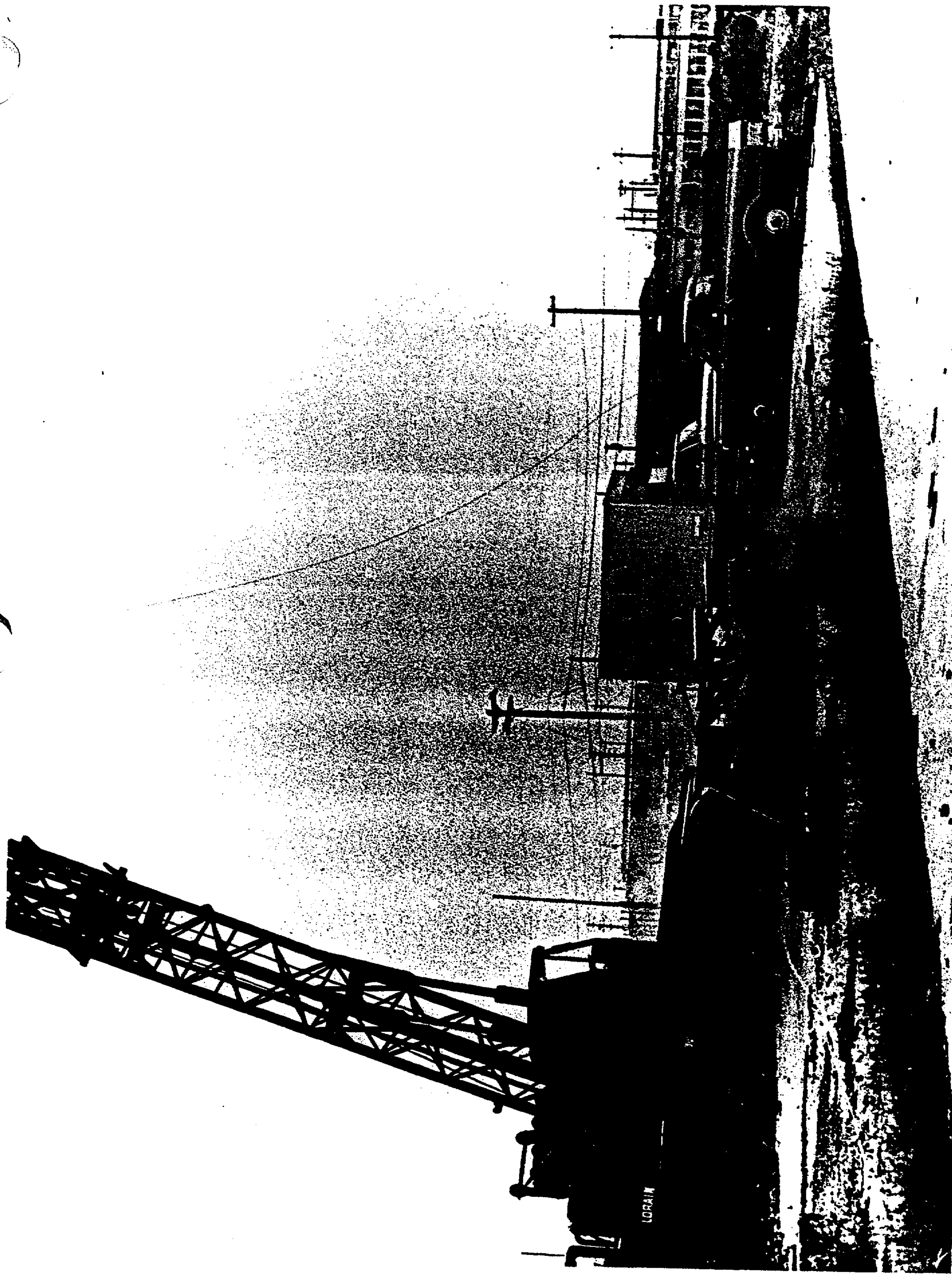








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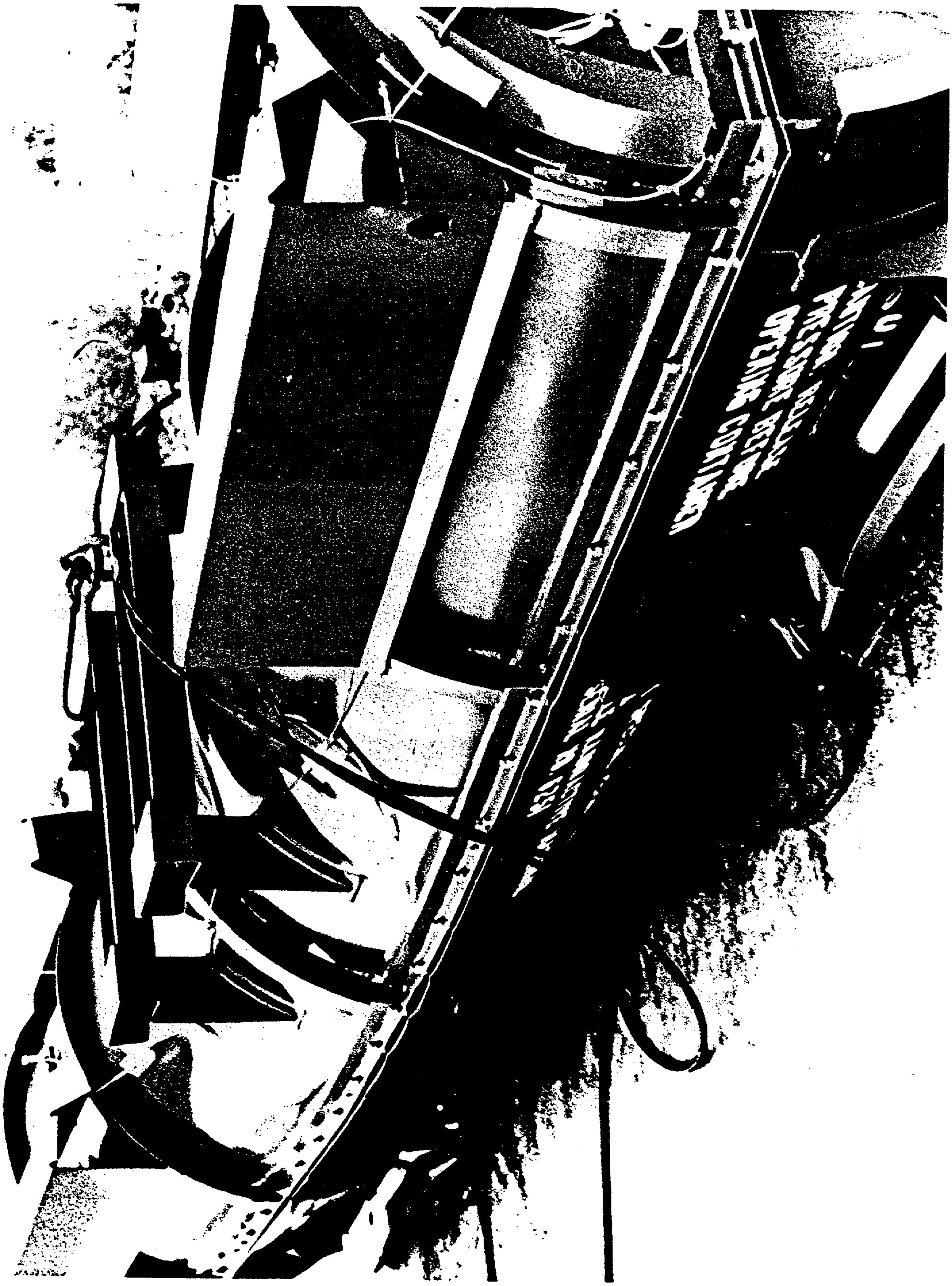
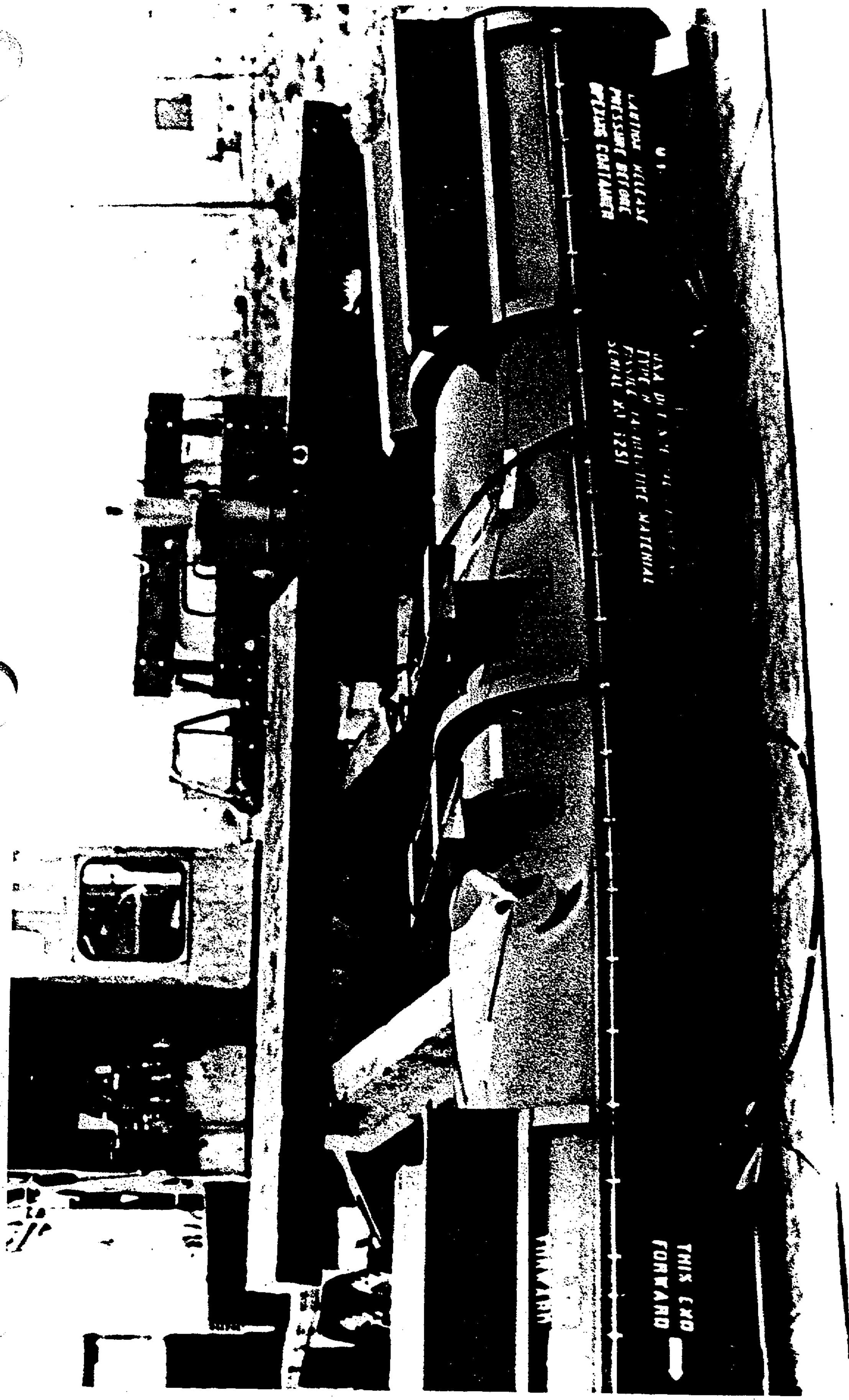
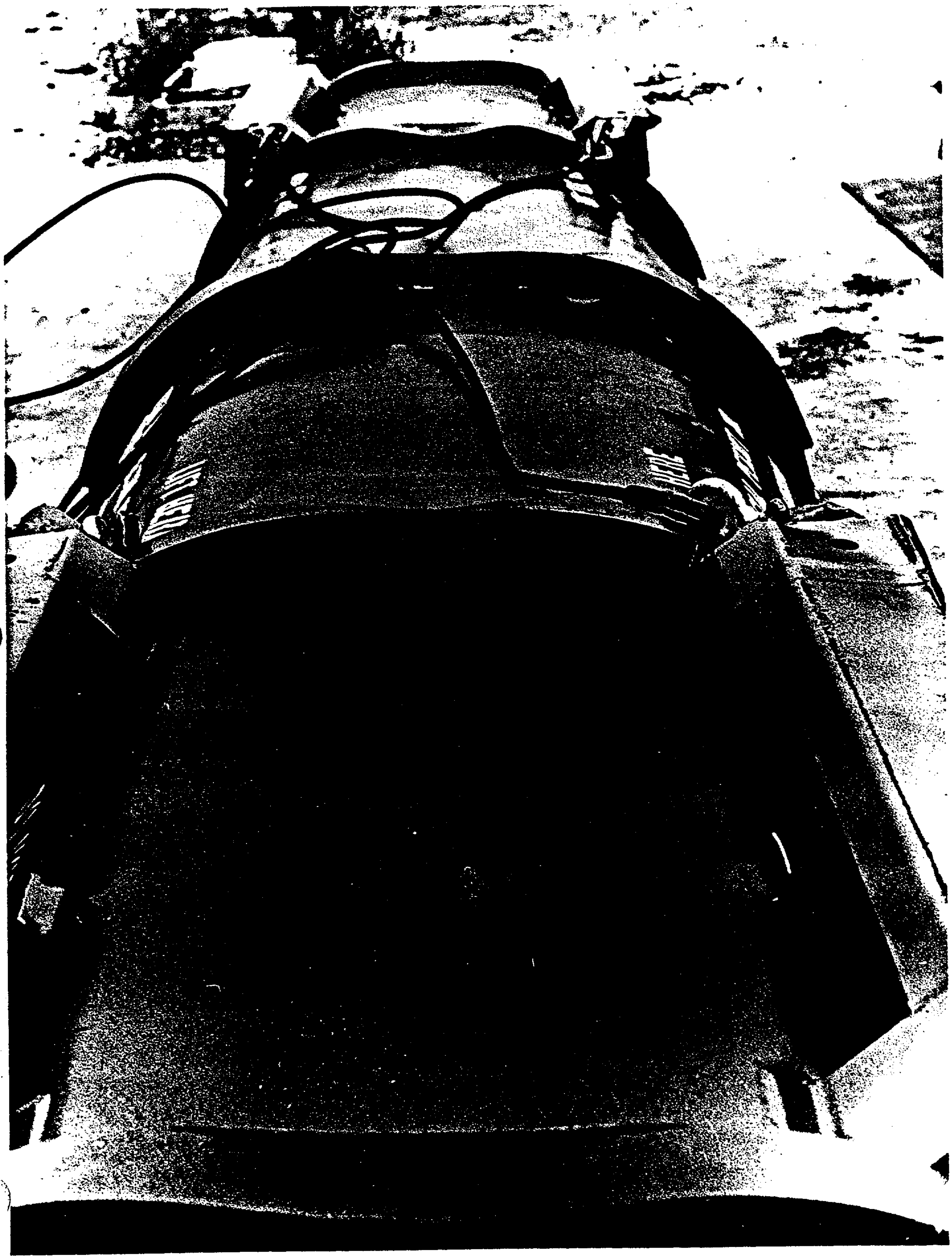
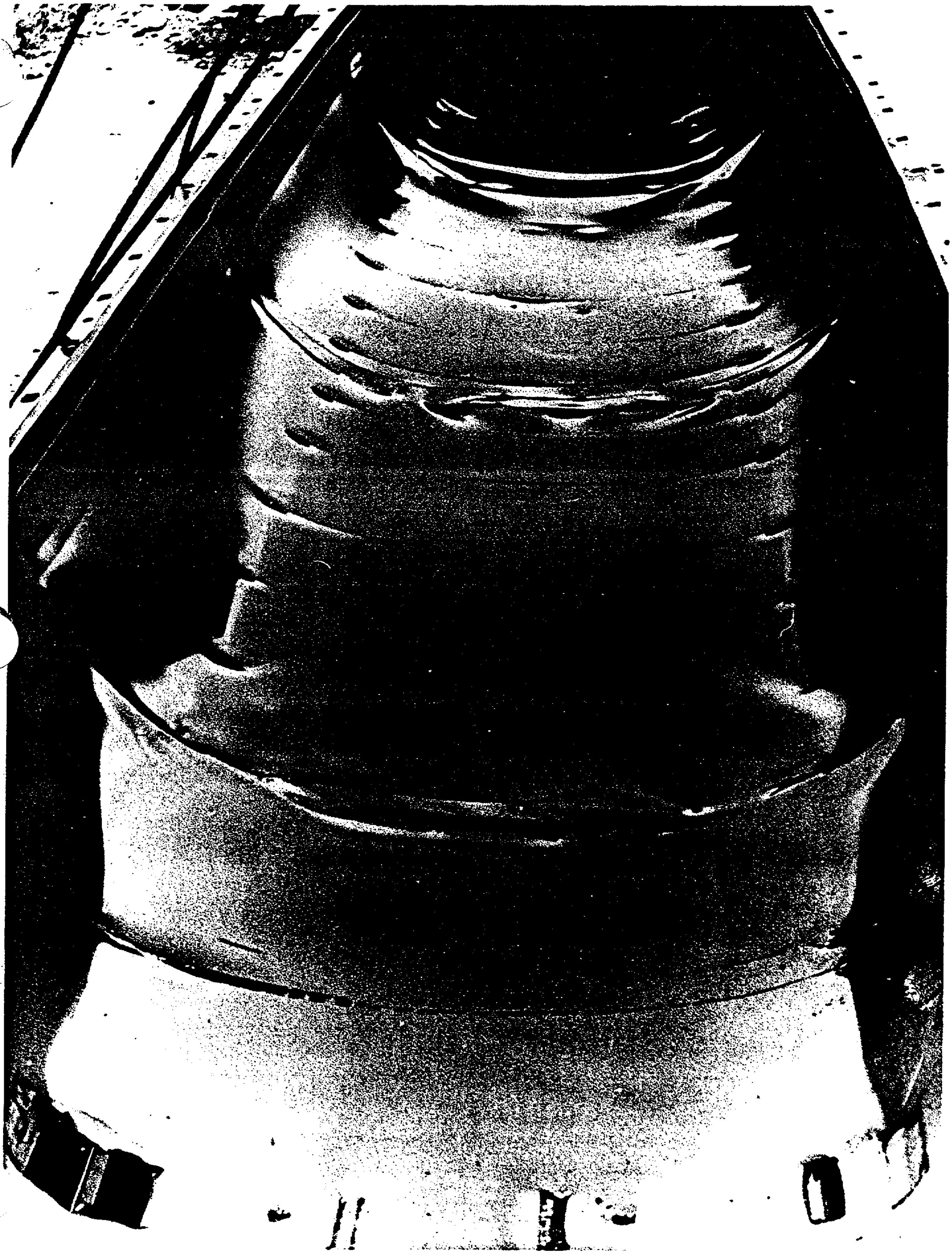



THIS END
FORWARD





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 ntainer 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 form the vertical to the horizontal position and the cover removed for examination. There was a surprisingly small amount of damage form 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 to shift in the direction of impact. The end of the strong back up to the end thrust plate crumpled. The end thrust plat remained intact and in position. All bolts attaching the end thrust plat to the strong back mained 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.

B .... DATE .... SUBJECT Container Drop Test SHEET NO. 1 OF 3

CHKD. BY .... DATE .... Spacing Dimensions Before and After Each Drop JOB NO. ....

Vertical Test

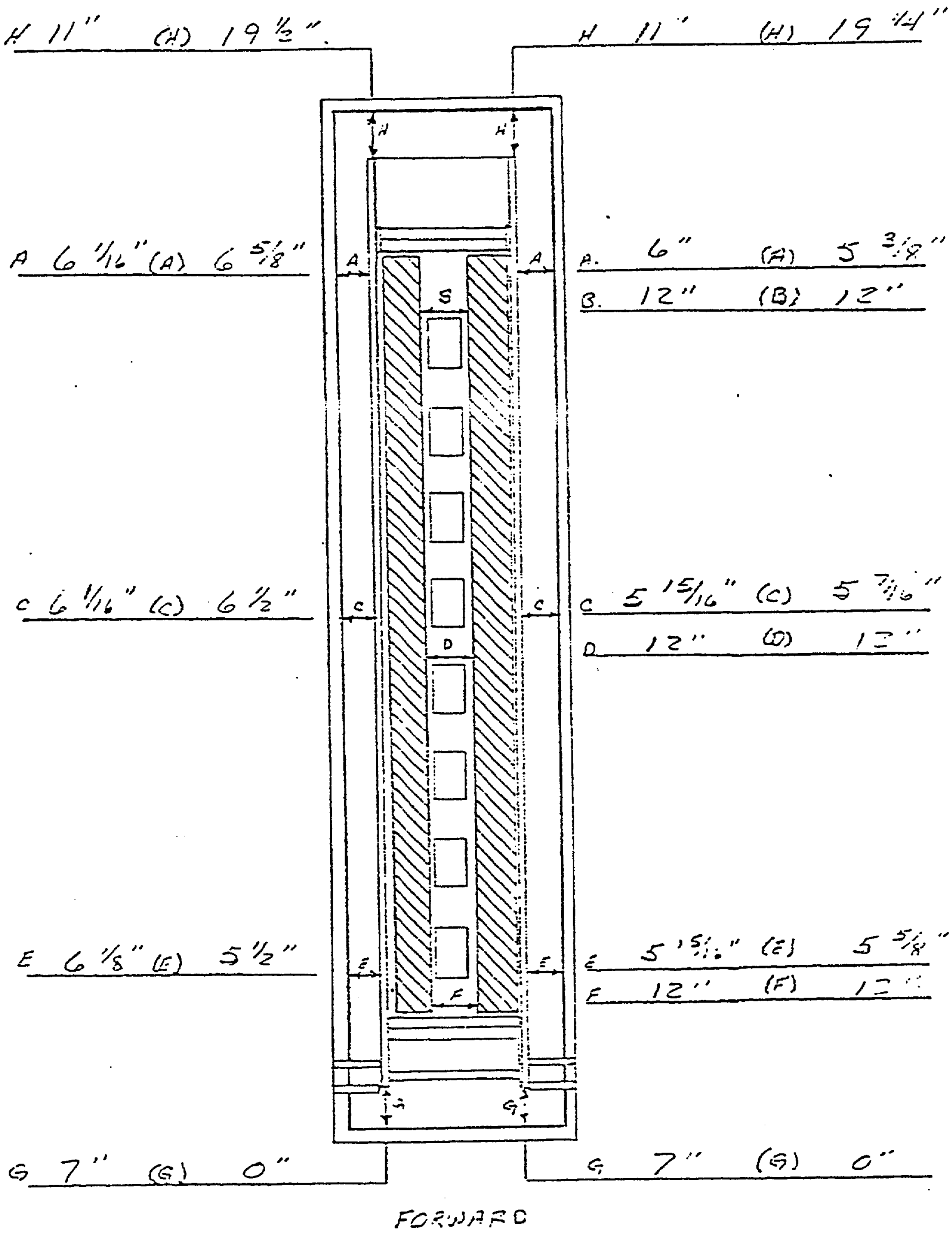
XN-52, Rev. 1

IV-43

ntainer # 6256

A - Before Test

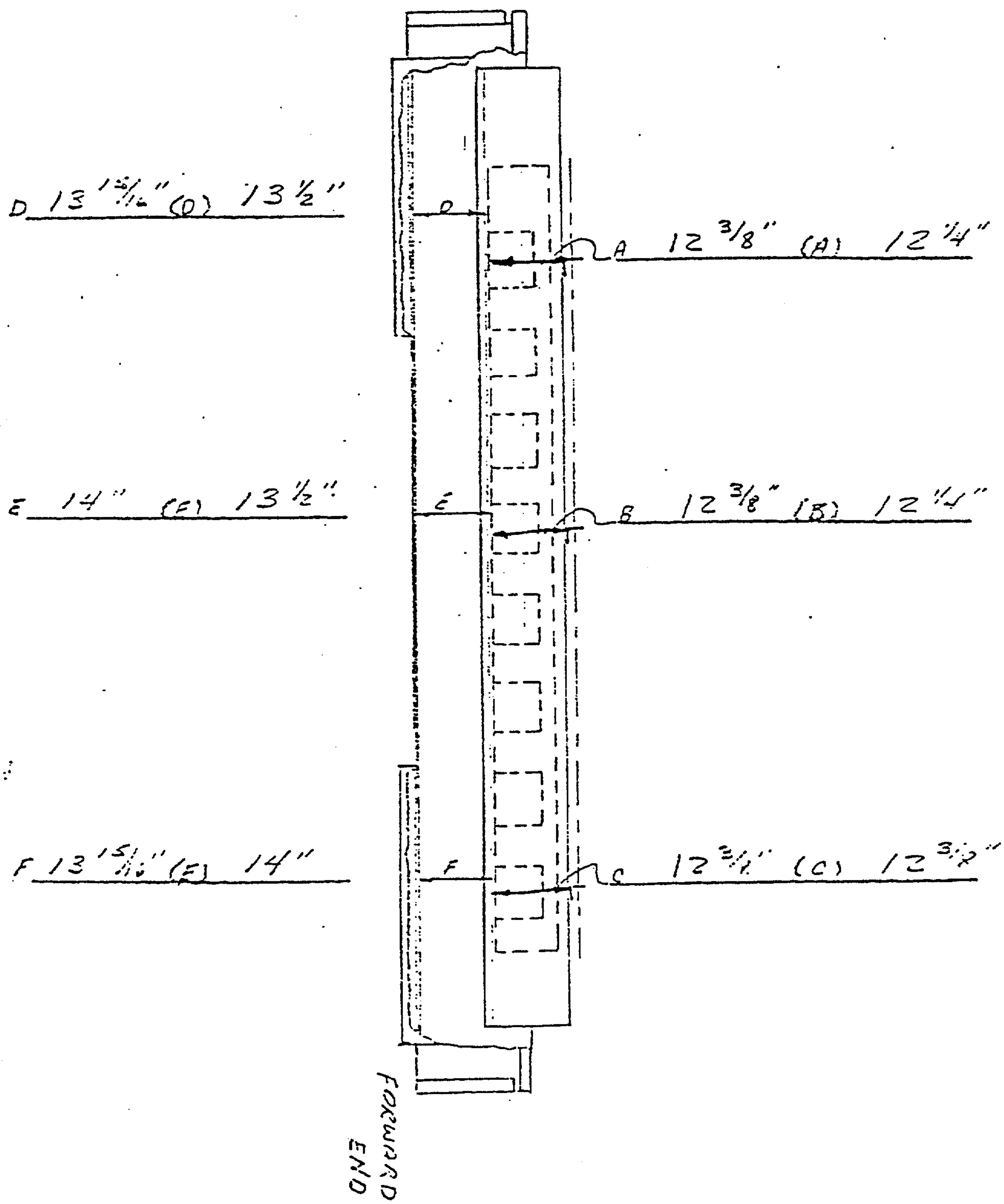
(A) - After Test



SUBJECT Container Drop Test
Spacing Dimensions Before
and After Each Drop

SHEET NO. 2 OF 3
JOB NO.

VERTICAL TEST



DATE

CK. BY DATE

SUBJECT CONTAINER DROP TEST
OUTER DIMENSIONS BEFORE
AND AFTER EACH DROP
VERTICAL TEST

SHEET NO. — OF —

JOB NO.

XN-52, Rev. 1

IV-45

AFTER TEST

FORWARD END

(Y) RING CAME OFF

(Z) 42"

REAR END

(Y) 40 3/16"

(Z) 42"

BEFORE TEST

FORWARD END

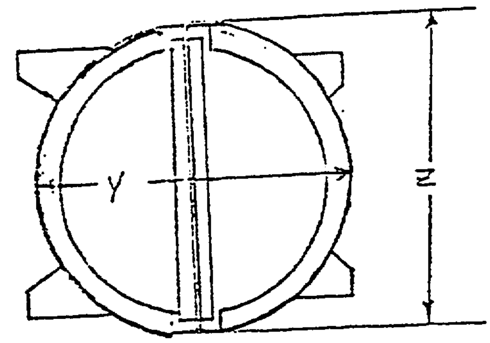
Y 40 1/8"

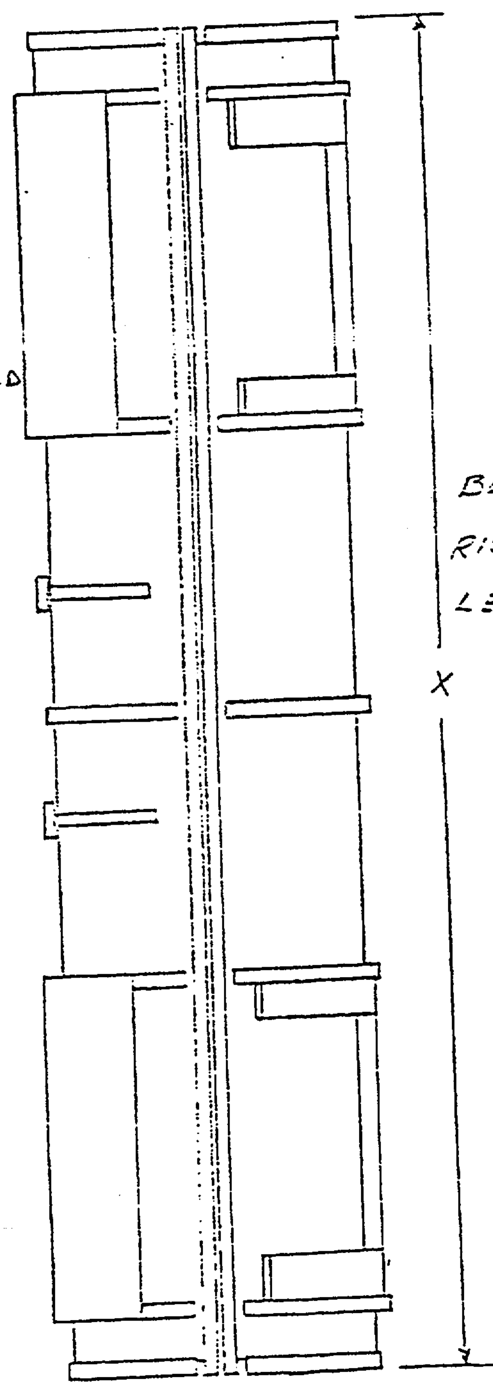
Z 42"

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"

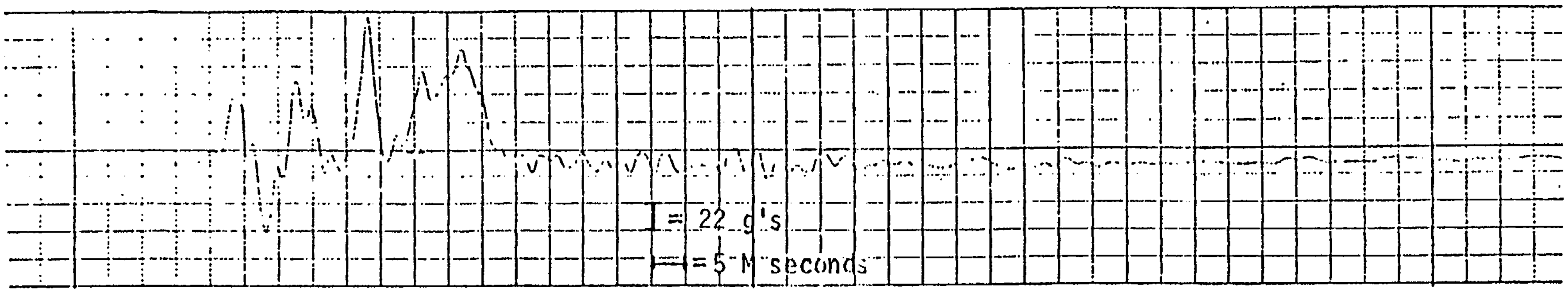
BOTTOM 18'-1/2"

RIGHT SIDE 17'-11 1/8"

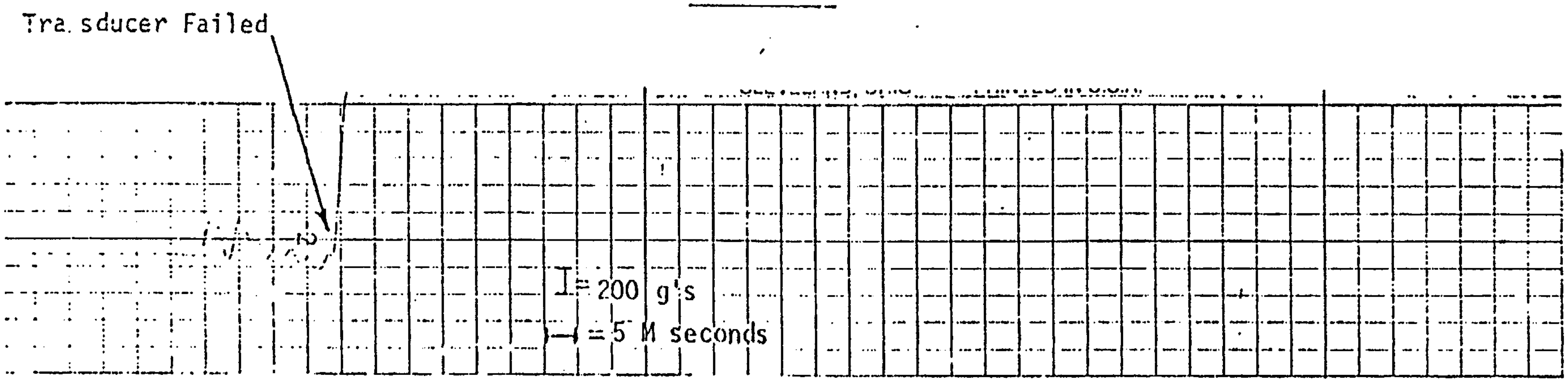
LEFT SIDE 17'-11 1/8"

JERSEY NUCLEAR SHIPPING CONT - 30 FOOT DROP TEST

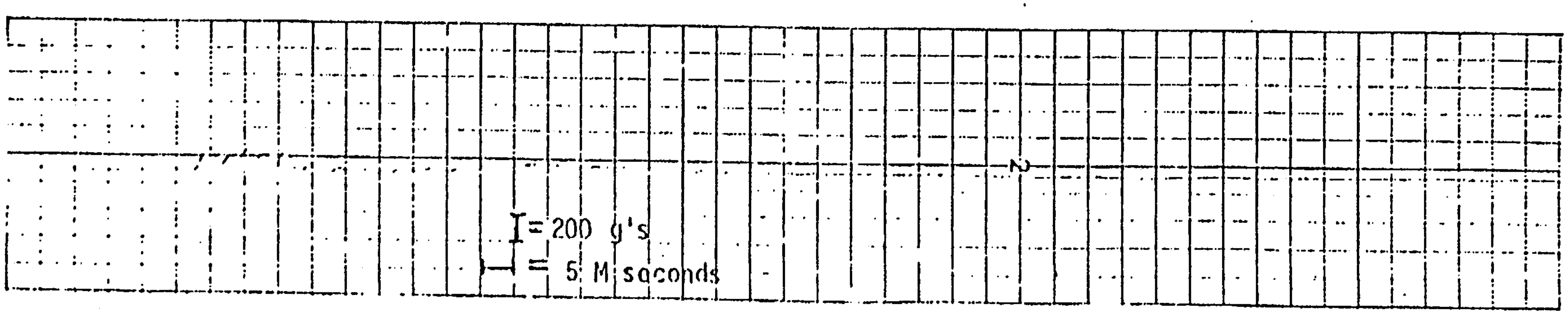
TEST NO. 2 - VERTICAL END DROP



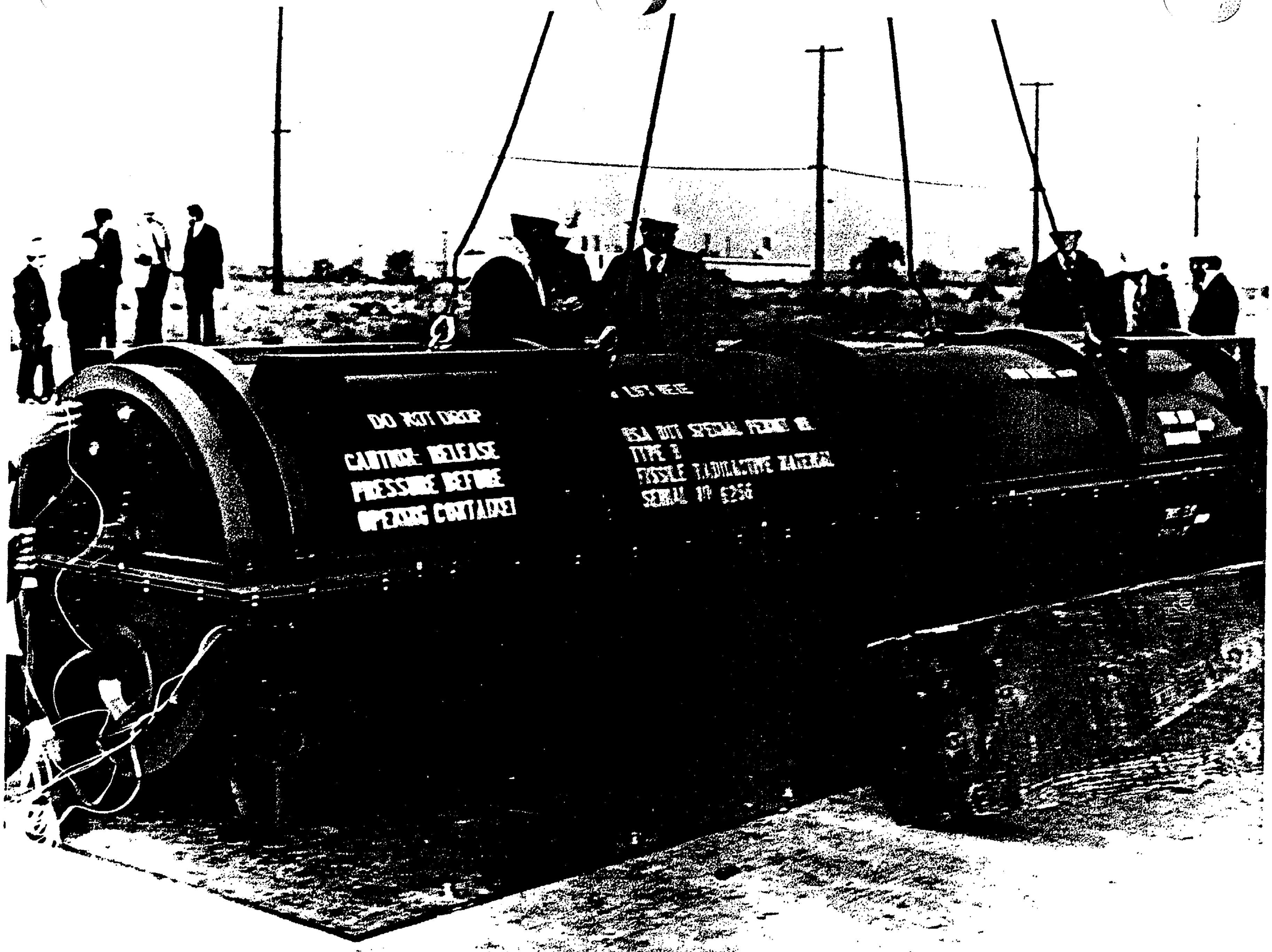
STRONGBACK

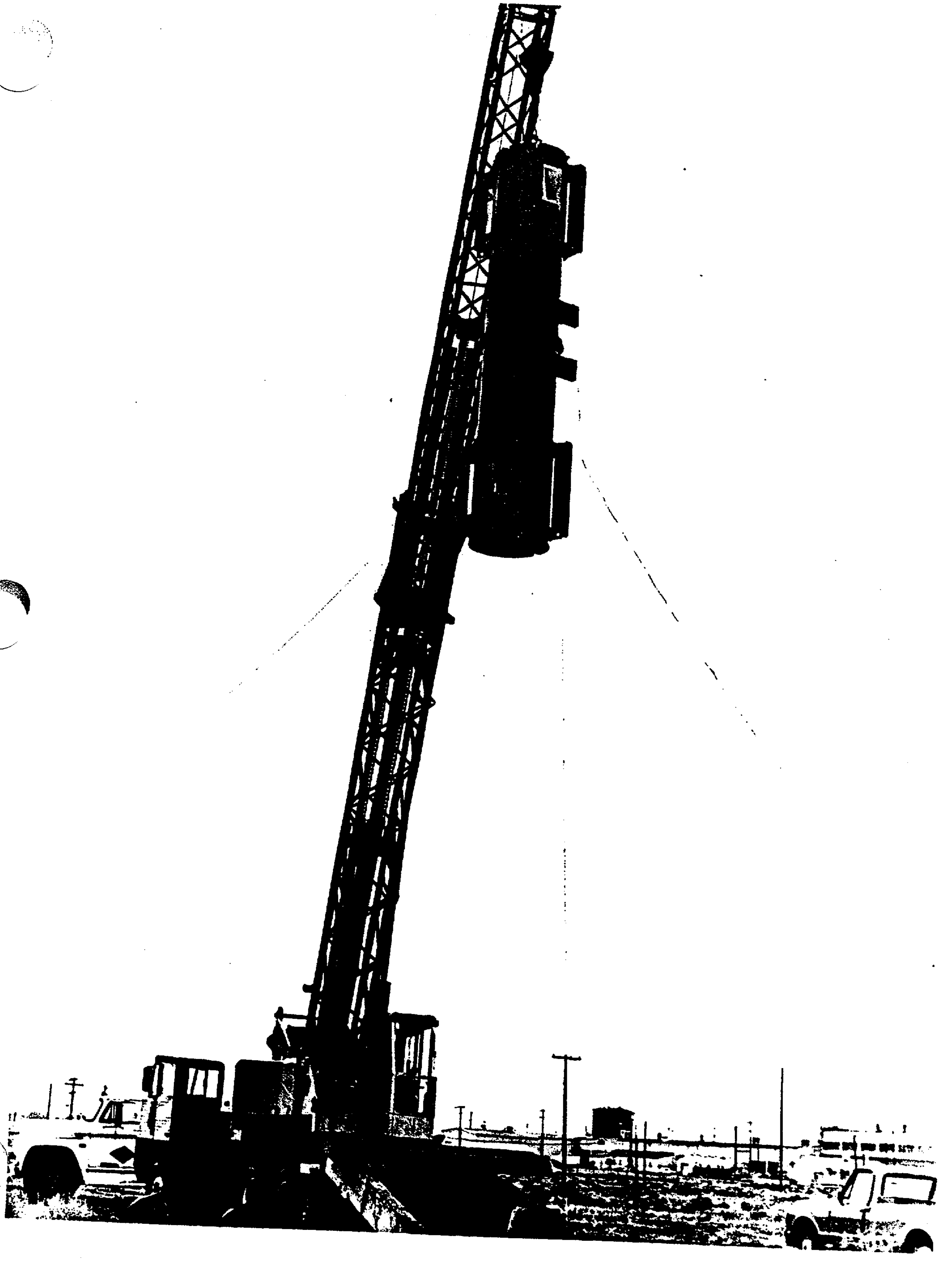


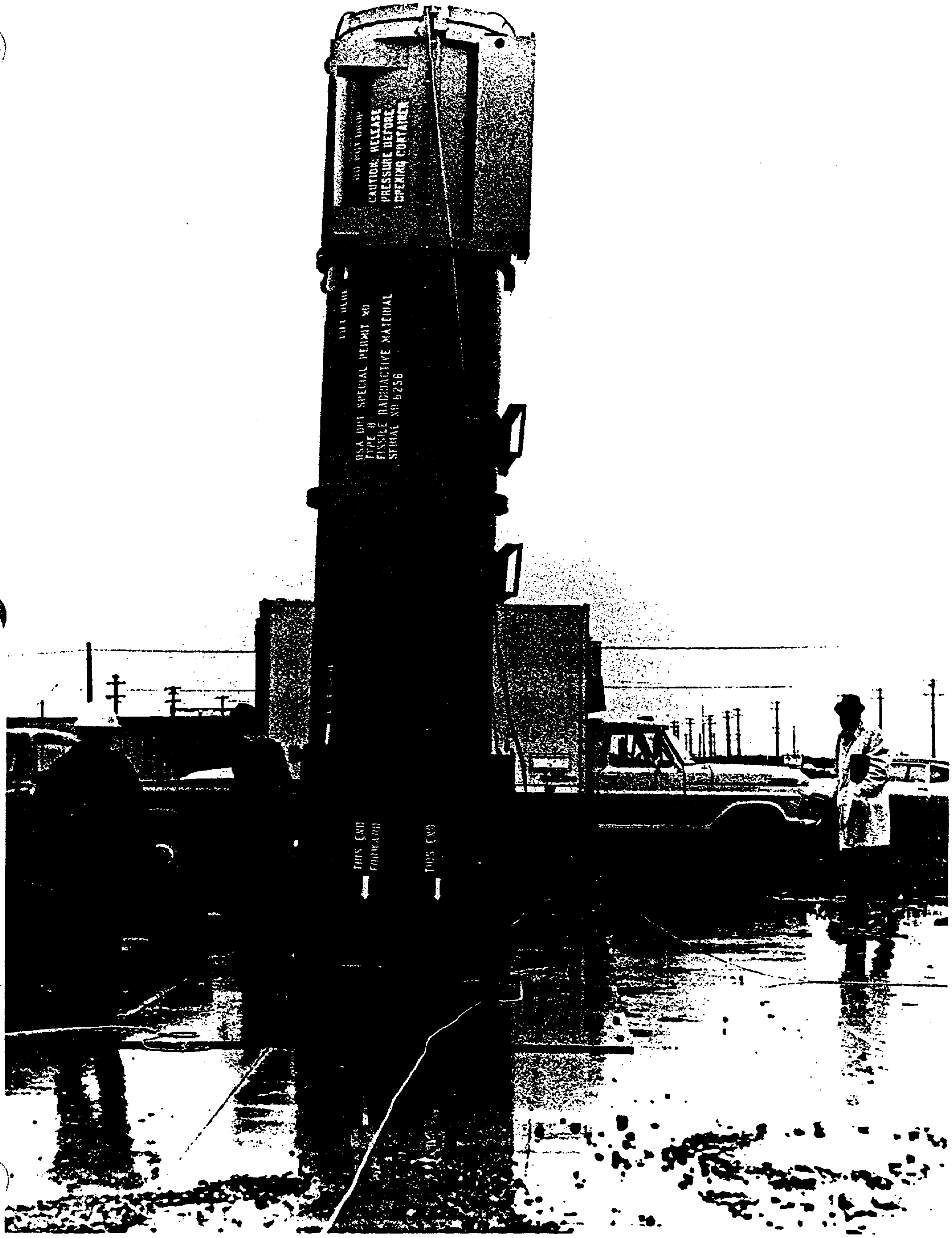
CONTAINER REAR CLOSURE PLATE

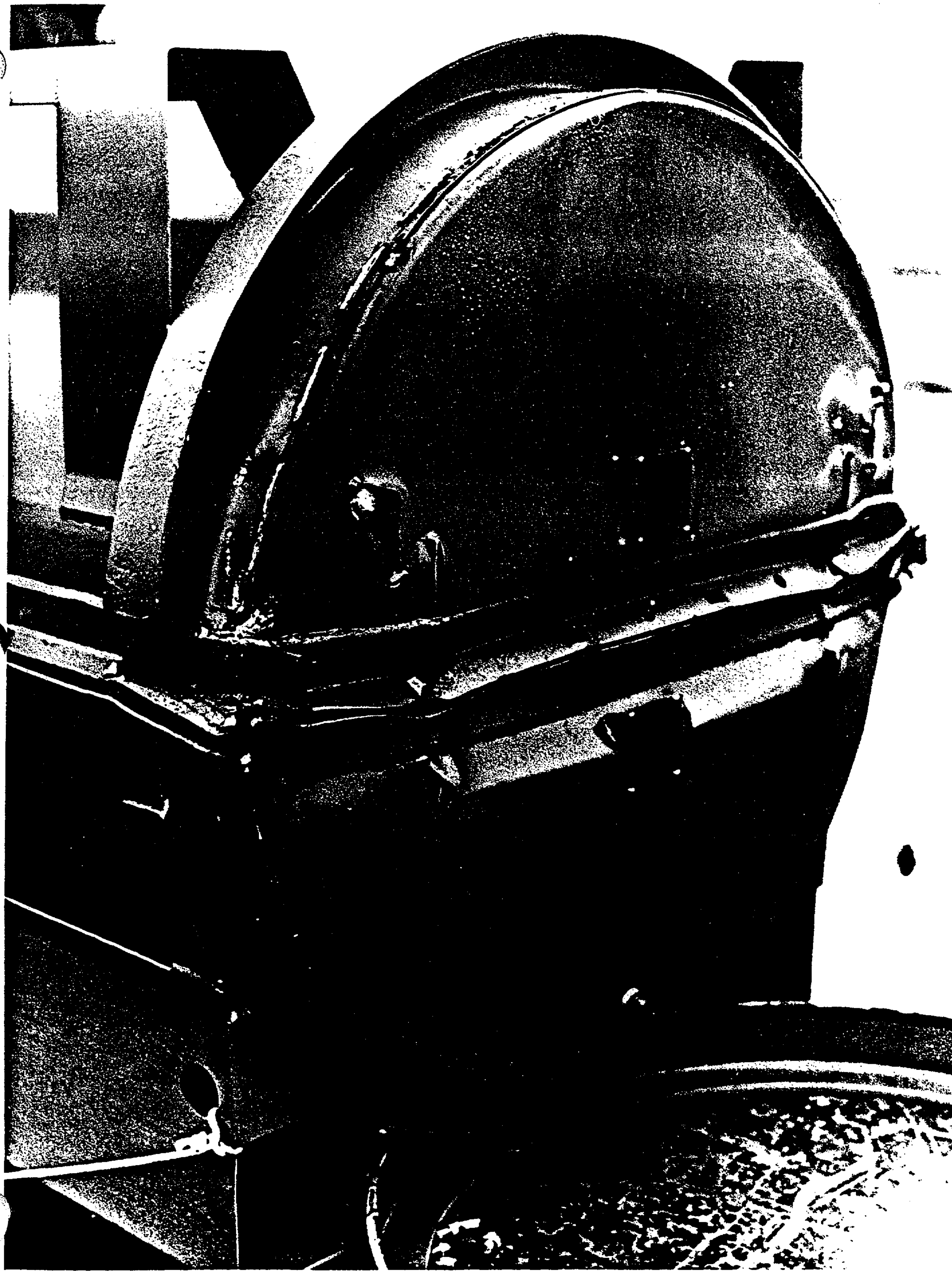


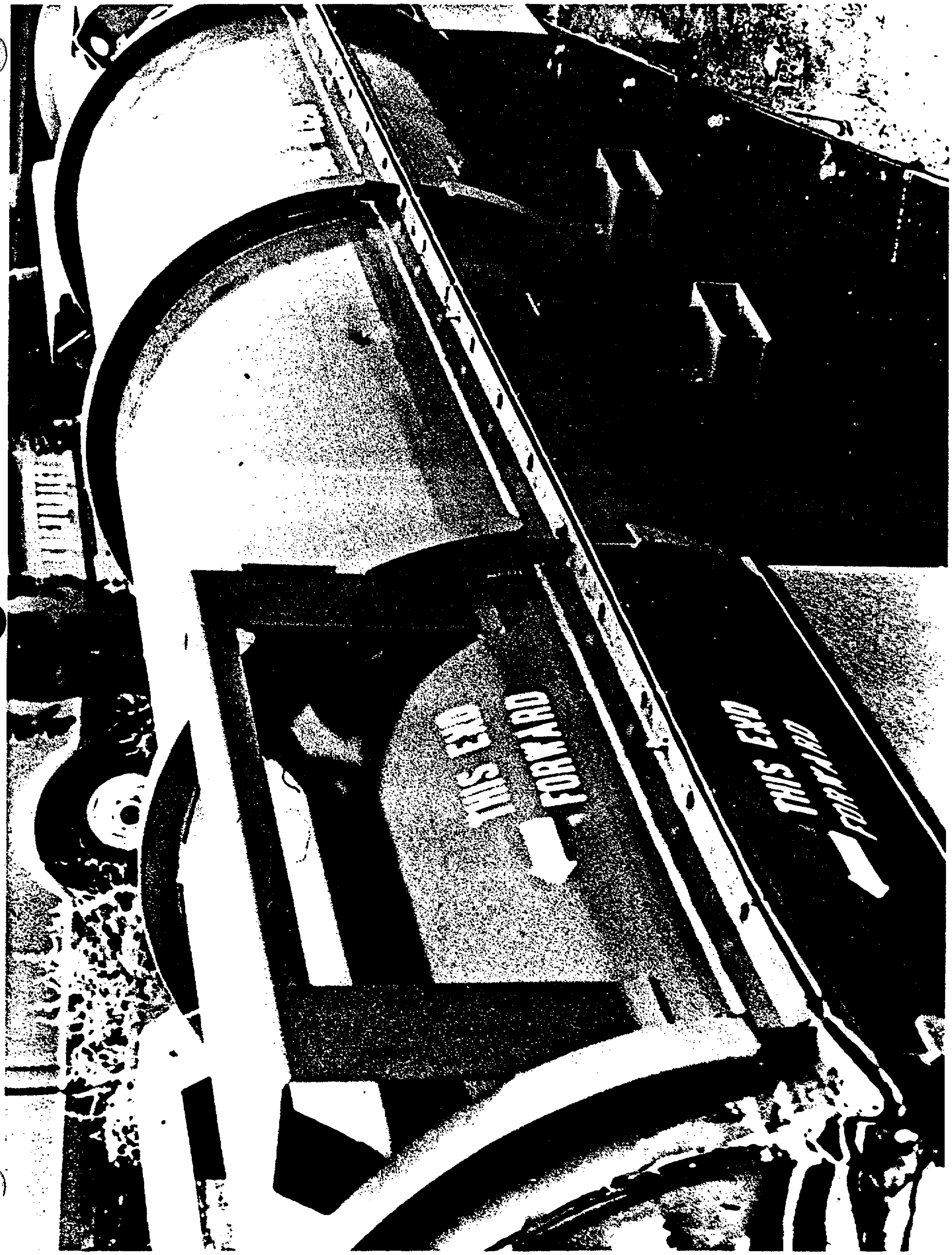
CONTAINER SHELL RE FLANGE

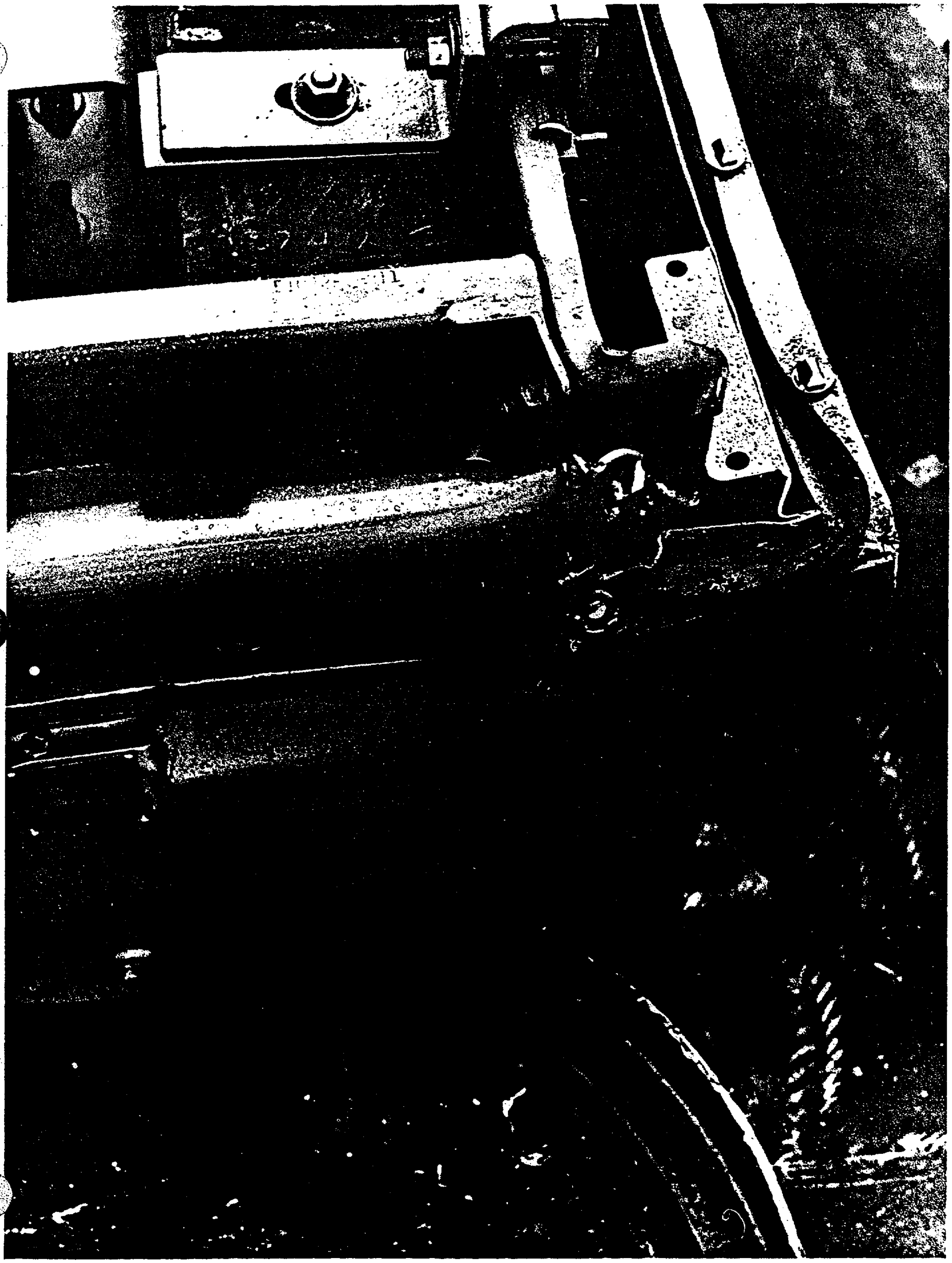

DO NOT DROP
CAUTION RELEASE
PRESSURE BEFORE
TYPE B

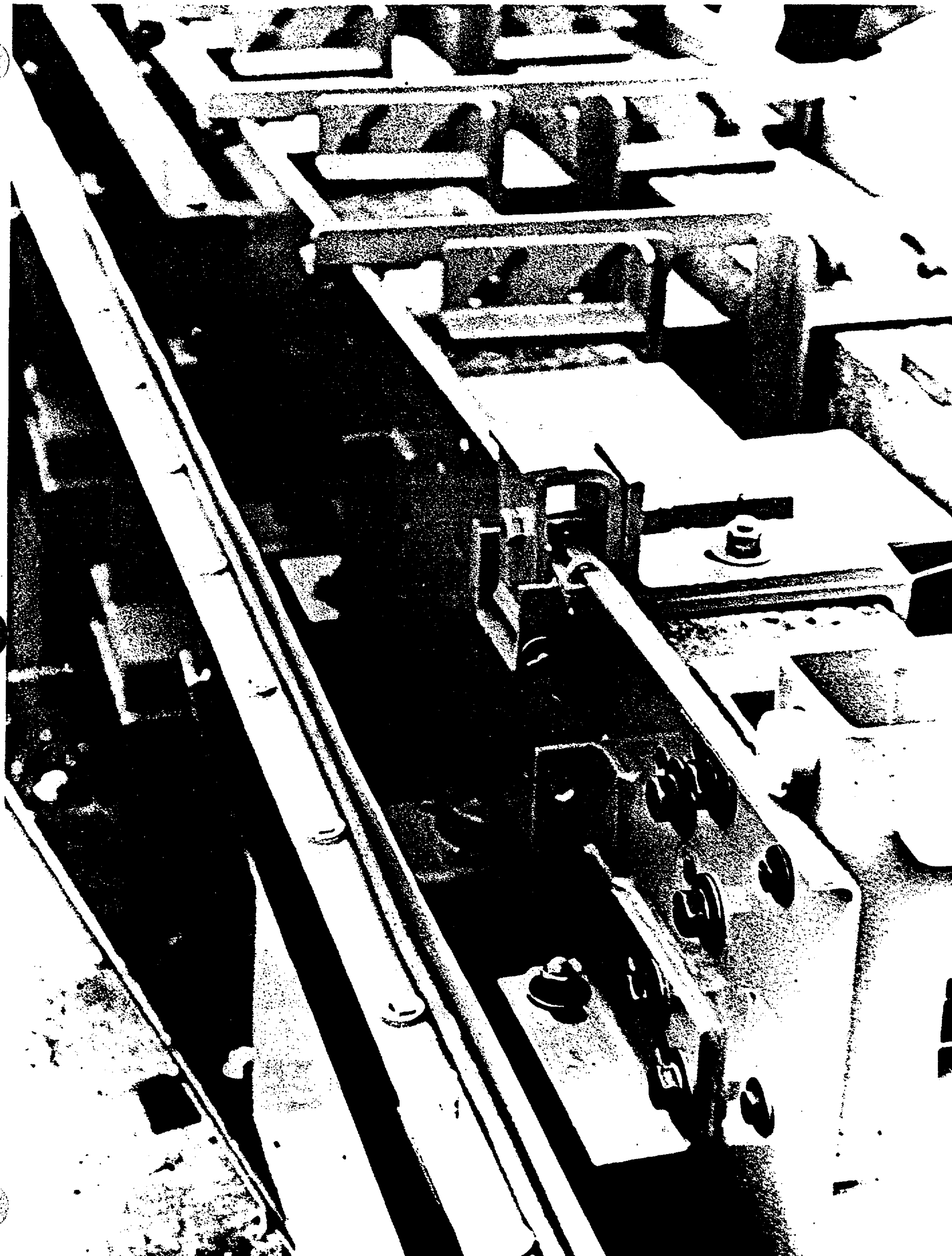


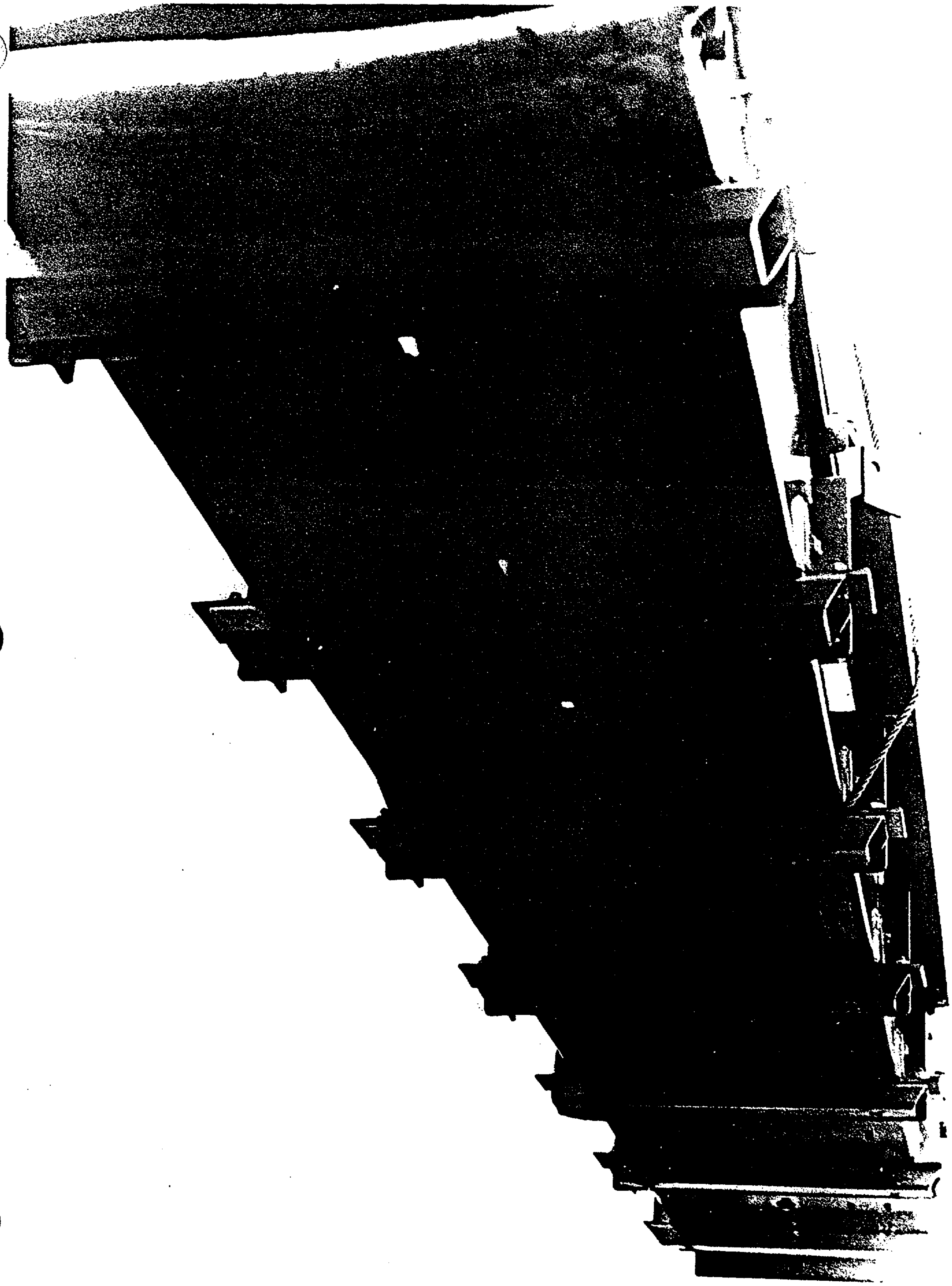

CAUTION: RELEASE
PRESSURE BEFORE
OPENING CONTAINER
USA DOT SPECIAL PERMIT NO
TYPE B
FISSILE RADIOACTIVE MATERIAL
SERIAL NO 6256
THIS END
FORWARD
THIS END

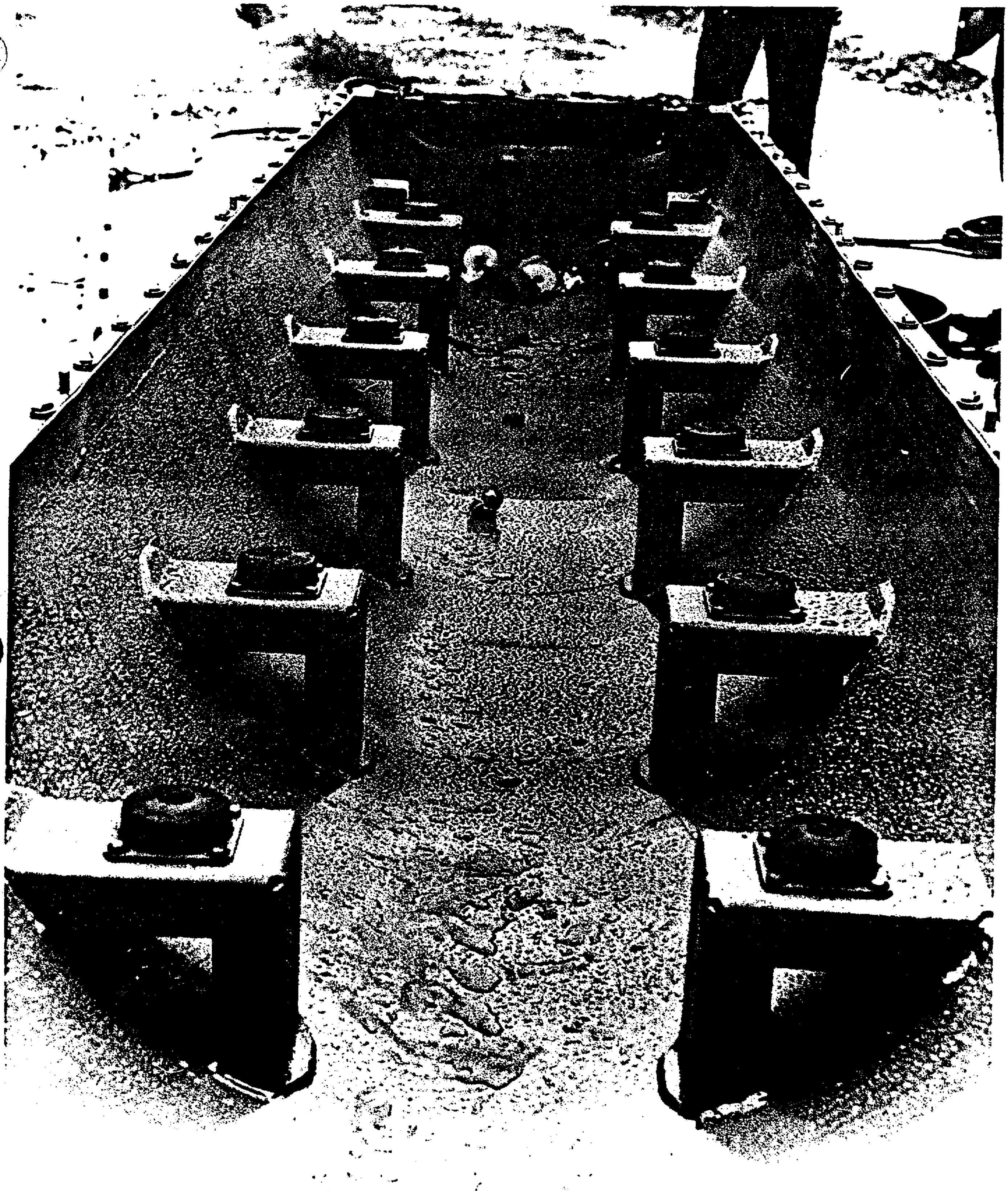



THIS END FORWARD
THIS END FORWARD









75° DROP TEST

As 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.

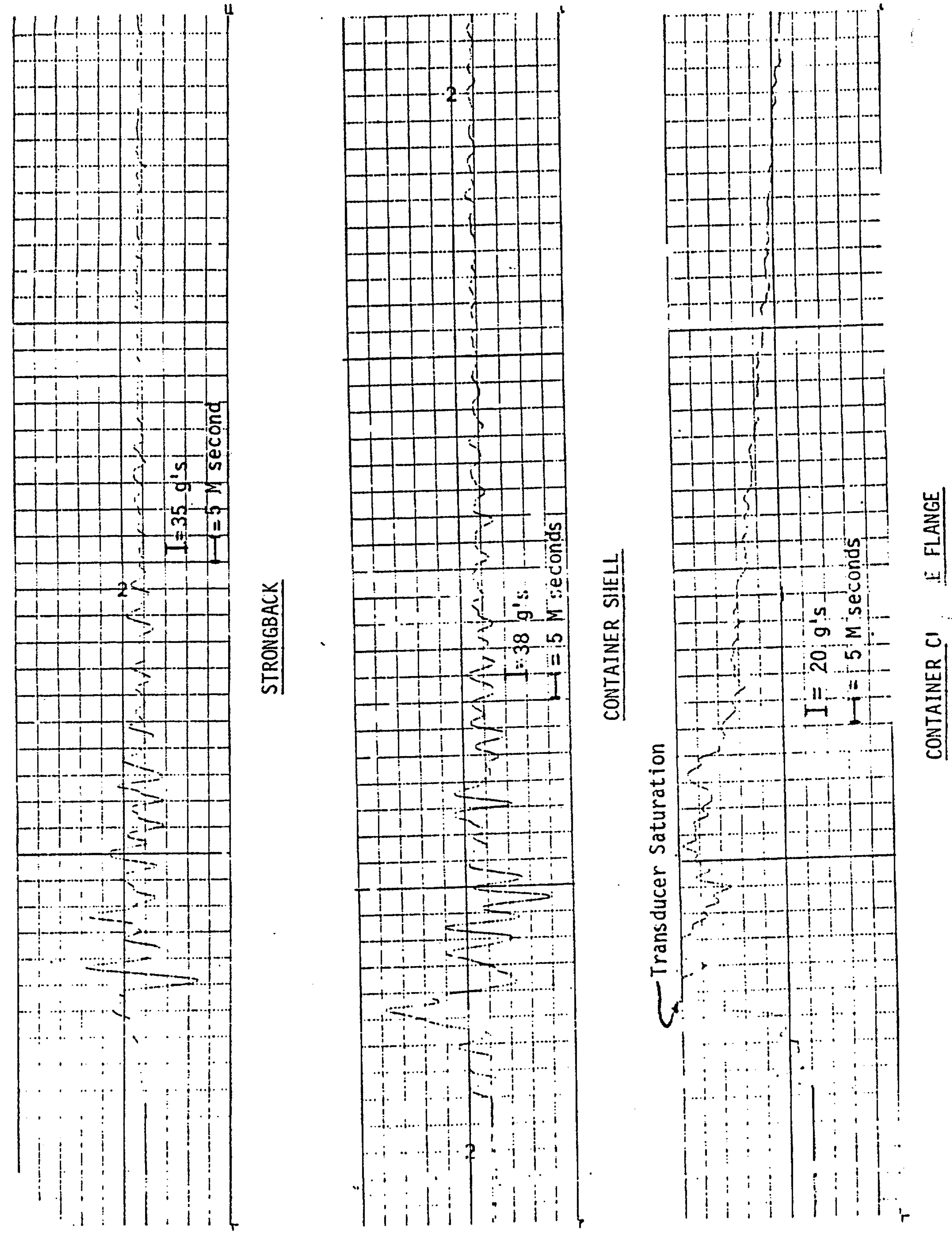
After the above work was completed, the simulated fuel bundles were re-installed and the container closed. Due to the damage on the forward end (from the vertical drop) the decision was made to make the 75° drop on the rear end top cover. The container was rigged, in accordance with the test procedure, in such a way that it would strike the ground 75° from the 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.

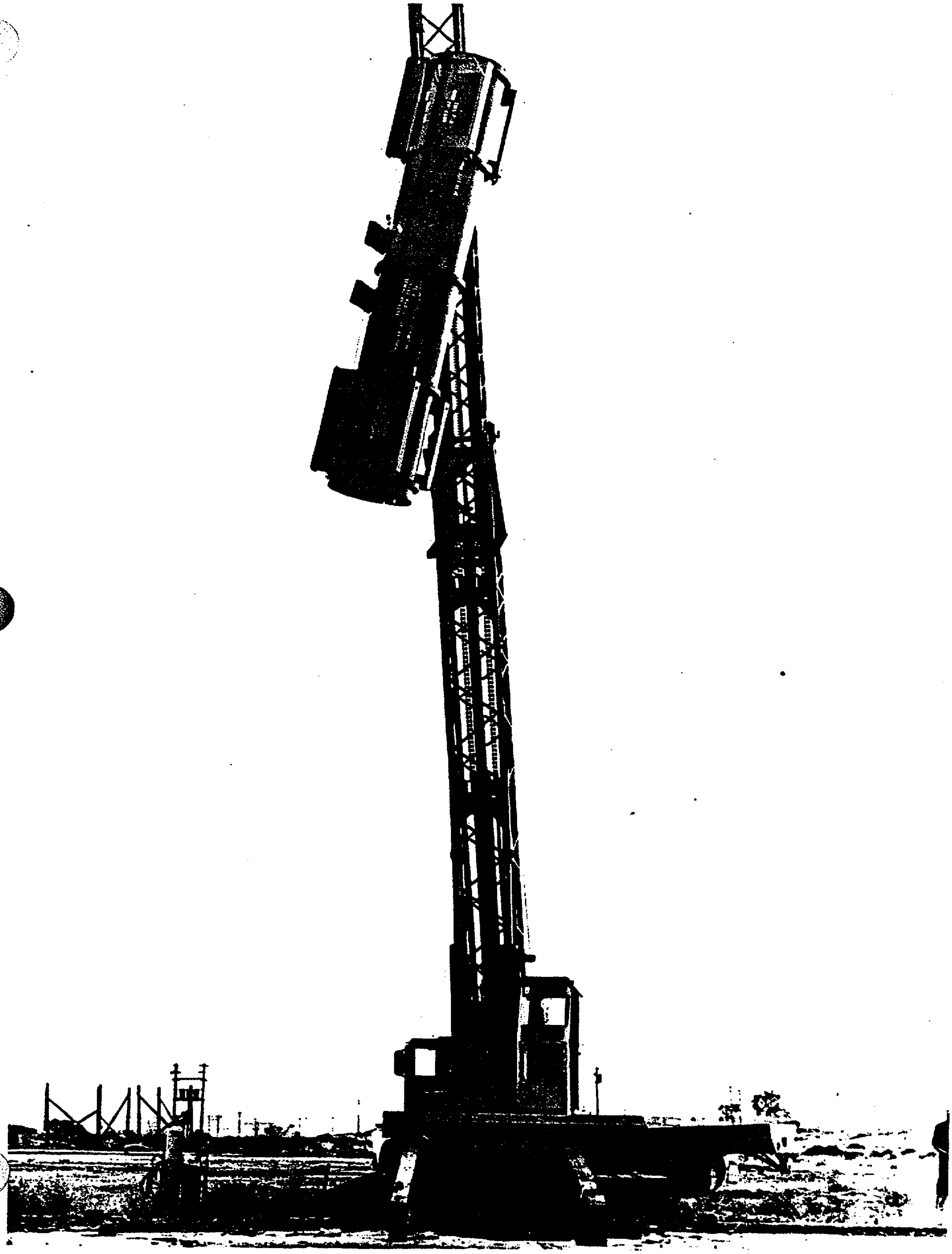
The conclusions of this test indicate that the top closure bolts remained in good condition, the cover remained in position, the strong back remained in the container and that the fuel assemblies maintained their separation within the strong back.

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 CON... NER - 30 FOOT DROP TEST

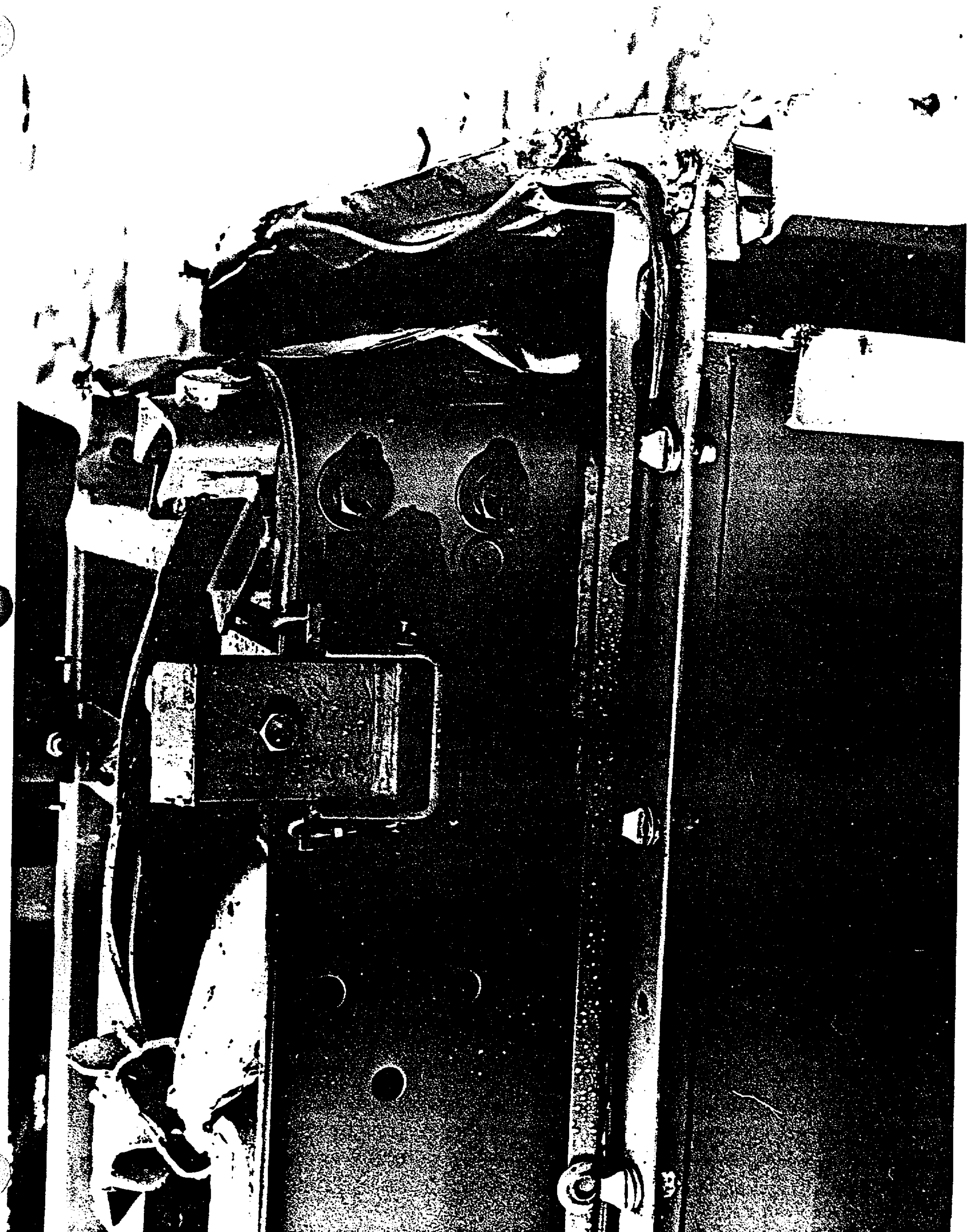
TEST NO. 3 75° COVER DROP






DO NOT DROP
CAUTION: RELEA
PRESSURE BEFO
OPENING CONTAI


THIS END
FORWARD
THIS END
FORWARD



APPENDIX V

PACKAGE COMPONENT EVALUATIONS

APPENDIX V

PACKAGE COMPONENT EVALUATIONS

The Model 51032-1a package includes design changes to assure that the main shock mount bolts yield and dissipate energy in any drop configuration, except for a drop in the normal upright configuration which is the least subject to failure potential. Clearances between the assembled strongback and the containment vessel are about two and one-half inches and may limit the combined distortion of bolts, full-clamps and shock mounts. The static tensile test results in shock mount bolt failure at about 1.7 inches of bolt distortion, which is sufficient for the desired energy dissipation. When the bolts are loaded transverse to the shock mount, the net distortion at failure, included bolt and mount, it about 3.2 inches in static tests.

To assure that the distortion occurs in the shock mount bolts, other bolts which could fail and relive the stress on the shock mounts have been strengthened. These have also been tested statically to verify that their strength exceeds that of the shock mount bolts.

Full-clamp assemblies consist of 2-1/2 x 2-1/2 x 1/2 inch angle bars which span the strongback, clamping to its lip, and sliding clamps which bolt to the angle bars and hold the fuel elements in the corners of the strongback (see Figure 2.17). These full-clamps were strengthened, by about a factor of three, relative to the drop-tested package to assure that they retain the fuel elements within the strongback during the time required to distort and fail the shock mount bolts. In the drop-tested package, abrupt failure of the shock mount bolts protected the full clamps until they impacted the cover. To assure this same failure mode in the Model 51032-1a container, even though dynamic loads could result in shock mount bolt failures before the clamp distortion is excessive even if the clamp were the weak link statically, static tests were made to show that the full clamps are, in fact, stronger than the shock mount bolts.

The separator blocks and their attaching bolts have been strengthened to provide at least 23% more strength than those in the Model 51032-1 packages. This increased strength, when eight separator blocks are employed with Type AA fuel elements, assures that the strength of the separator blocks per unit weight of the contents is equivalent to the Model 51032-1 package. To obtain the increased strength, a gusset plate has been added to the block and the carbon steel bolts have been replaced by grade 8 bolts, which have a shear strength of 90,000 psi as compared to 38,400 psi for the previously used bolts. New washers have also been provided to prevent the bolts from tearing out of the strongback.

Aluminum honeycomb energy absorbing material has been added at the strongback ends to absorb energy in the end-drop configuration. The purchase order specified that the strength shall be between 1200 and 1500 psi. The manufacturer has provided test data on the actual material which gave an average strength of 1310 psi up to 80% compression.

The influence of dynamic loading conditions on component performance is discussed in Section V.6.

V.1 Shock Mount and Bolt Response in End-Drop Configurations

Two different static tests of the shock mount and stainless steel bolt behavior have been conducted for designs similar to the one selected. The first was with a stock 304 SS 5/8 inch diameter bolt with on undercut. The second was with a 304 SS 3/4 inch diameter bolt undercut to 0.6 inch diameter over a 4 inch length to improve the tensile properties for the cover-drop accident. The loading for both test was prototypical for an end-drop. The head-end of the bolt was forced to move in a straight line perpendicular to the bolt axis. This shear loading leads to distortion of the shock mount and bending of the bolt. The mid-section tends to be supported by the shock mount and the most severe stresses are at the two ends.

The first test was carried to bolt failure when the head end had been moved 3.255 inches and the loading was 24,000 pounds. Failure occurred at the nut end in a thread root. The second test was taken to the 30,000 pound limit of the testing machine when the deflection was 2.6 inches. There was no indication of approach to the failure and it was predicted that the ultimate joint strength would again be determined by the thread-root strength which scales up to 35,000 lb based upon the experience with the 5/8 inch bolt. The expected bolt head movement at failure would have been equal to the 3.25 inches in the first test, or greater if the reduced section were to develop significant elongation.

To provide greater assurance that the shock mount bolt is the weakest link in a cover-drop, the undercut diameter was reduced to 0.43 inches.

This reduces the tensile strength for 1/2 the 0.6 inch diameter strength. Since the strength in the transverse loading in end drops was not limited by the undercut to 0.6 inch, the reduction to 0.43 inch will not reduce the strength by as much as a factor of 2. Furthermore, the bolt head movement will be enhanced since the undercut section must certainly elongate at the reduced strength. It is conservative, therefore, to assume that the load at failure will be at least 16,500 lb, the head movement at failure at least 3.2 inches and the energy absorption at least 1/2 that of the extrapolated energy absorption obtained in the second test.

The force-deflection curve for the second test with the undercut 3/4 inch diameter bolt is shown in Figure V.1, with the extrapolation beyond the test machine limit shown as a dotted line. In this test, the mount was fastened with the four 3/8 inch bolts used to fasten the mount to the shipping container. The test determined, as desired, that these bolts provide a stronger link than the stainless steel shock mount bolts.

V.2 Shock Mount Bolt Response in a Cover Drop

In a cover drop the shock mount bolts are in tension and the shock mount itself is put in compression. In static tests the mount is not expected to provide significant energy dissipation and was not included in the tests. The bolts, however, yield plastically and have been tested in the Tinium-Olsen machine.

A standard Type 304L SS bolt, machined down to 0.6 inch diameter over a four inch length, was tested to failure. The test gave a 42 percent elongation at a failure tensile strength of 27,000 pounds. The average energy dissipation was 25,000 in -lbs. per inch of deformation of the 0.6 inch diameter portion of the bolt length. This provides 48,000 ft. -lbs. of energy absorption in the set of 14 shock mount bolts. The stress-strain curve for this bolt is given in Figure V.2.

The bolts actually used in the shock mount are undercut to 0.43 inch diameter over a four inch length. The expected elongation at failure is the same as in the test and the energy absorption is 24,000 ft. -lbs.

In a similar test of 5.8 inch low carbon steel bolts used in the Model 51032-1 package, the shock mount bolt energy absorption capability was found to be less than 4,000 ft. -lbs. for all 14 bolts. Thus, the Model 51032-1a package with 14 shock mounts dissipates at least an additional 20,000 ft. -lbs. in bolt distortion.

V.3 Combined Energy Dissipation of the Shock Mount Bolts, Aluminum Honeycomb, Strongback Extension, and Fuel Element Nozzles in End Drops

Test described in Section V.1 on the shock mounts define the energy dissipation in those assemblies. At the strongback ends, aluminum honeycomb has been added which has a compressive strength (1310 psi) and area designed to absorb at minimum of 129,000 ft. -lbs. of energy. As the strongback and its contents move toward the container end, this material compresses and dissipates energy while the shock mount bolts are deformed.

As designed, there is a one-half inch clearance between the honeycomb and the containment vessel. When the container impacts the ground, the end may be pushed in sufficiently close this gap. In drop tests of the Model 51032-1 package, the end did not appear to be pushed in any more than that.

The performance of the honeycomb is not sensitive to this uncertainty and is described here assuming that the gap is closed only by relative motion between strongback and container.

The two ends of the shipping package differ in honeycomb absorber design because at the fuel element nozzle end the nozzle projects two inches into the honeycomb. The honeycomb is cut back in that area and additionally cut back to facilitate assembly. The design is shown in Figure 2.20. As the strongback and fuel elements move forward, the nozzle impales into the honeycomb and it is assumed that the honeycomb area interior to the nozzle is unavailable for energy dissipation. Crushing of the raised section of honeycomb material begins when the 1/2 inch clearance gap is closed. The area of the raised section if 135 in^2 and begins crushing first. With the exception of the nozzle area, the depressed section begins to compress when the strongback has moved an additional 2.25 inches toward the container end. The depressed area crushed in 77 in^2. The honeycomb thickness if 7.75 inches in the raised area and 5.625 inches in the depressed area.

The manufacturer has provided test data on the production run for the honeycomb which shows that the honeycomb will crush 80% with an average force of 1310 psi. The energy absorption capability is therefore:

$$E = 1301 \times 0.8 \times \{7.75 \times 135 + 5.625 \times 77\} = 1{,}550{,}000 \text{ in-lbs.}$$

$$E = 120{,}000 \text{ ft-lb}$$

There is a 2.5 inch extension of the sides at the strongback beyond the thrust plate. This will strike the container end 1 inch before the honeycomb is fully compressed. The crushing strength is calculated to be 225,000 lb and it can, therefore, add 19,000 ft-lb of energy dissipation. The fuel element nozzle would strike the end 1/2 inch before the honeycomb is fully compressed, although the energy balance indicates that the strongback would be stopped before that point. If not, the combined crushing strength of the two nozzles is 500,000 pounds of force and could add 20,000 foot pounds of energy dissipation in 1/2 inch of crushing.

The combined stopping force versus relative strongback container displacement due to shock mount bolts, honeycomb, strongback extension and fuel elements nozzles is presented in Figure V.3. In this figure the sloping lines show the increase in stopping force as the bolts and shock mounts yield. The step down at 3.25 inches is due to the failure of the bolts. The first step up at 0.5 inch occurs at gap closure as the raised section of honeycomb begins to crush. The second step up at 2.75 inches occurs as the depressed section of honeycomb begins to crush. The third step up at 5.75 inches is where the strongback extension begins crushing and the final step at 6.25 inches results when the fuel element nozzles begin to crush. The arrow at 6.2 inches, however, indicates that the kinetic energy is dissipated at that point and the last step due to crushing of the nozzles should not occur.

The situation at the other end of the container is much more simple. The full 300 in^2 of the honeycomb area crushes uniformly and has a restraining force of 400,000 lb. Complete compression from 8.25 inch thickness to 1.65 inch thickness could absorb 220,000 ft-lb of energy. Since the shock mounts provide 30,000 ft-lbs and the total needed is only 159,000 ft-lbs, the honeycomb will only crush 4 inches. The strongback will not reach the container end and will not crush.

V.4 Integrity of the Full Clamps

A lower limit for the strength of the full clamps was determined by loading one in a nea prototypical manner on the Tinius-Olsen testing machine. Preliminary tests demonstrated that small design changes would greatly improve the performance and, therefore, part no. 5 of Figure 2.17 was replaced by a similar part 3.4 inch thick and 2 1/2 x 4 inches. This provides 4 inches of bearing length on the lip of the strongback. The bolts for the sliding clamp have been replaced by similar but high-strength grade 8 bolts with 150,000 psi ultimate strength. In the final test the 2 1/2 x 2 1/2 inch angle bar began yielding at 17,000 pounds force and was bent 1 inch at 23,000 pounds force. At that point there was some slippage in the test jog linkage and the bolts, part 10 of Figure 2.17 appeared near to failure. The test was run with a weaker SAE grade 2 bolt rather than the specified grade 8. Because the test had demonstrated sufficient strength the test was terminated prior to failure. The total deflection of the beam resulting from combined beam bending, bolt distortion, clam distortion, and strongback lip distortion was 2.3 inches. The distortion at 23,000 lb would have been less and the strength higher with the high-strength bolt.

The test also determined that the sliding clamp is self-locking under the applied loads and will not slip.

There are nine full clamps in the Model 51032-1a shipping package with the Type AA fuel elements. These provide a total restraining force in excess of 207,000 pounds of force (9 x 23,000). This is sufficiently larger than the 180,000 pound strength of the 14 shock-mount bolts and assures that the shock-mount bolts would elongate to failure and prevent failure of the full clamps in a 30 ft drop on the cover.

Tests conducted on the aluminum clamp assemblies shown in Figure 2.18, result in a deflection of 0.257 inch at 10,000 pounds force. For BWR fuel elements this indicates smaller deflections, at equivalent "g" loadings, than were obtained in the drop tested Model 51032-1 package. The force deflection curve is shown in Figure V.4.

V.5 Integrity of the Separator Blocks

The Model 51032-1a package separator blocks have been tested on the Tinius-Olsen compression machine. The test established that buckling strength of the gusset plate was greater than the 30,000 pound limit of the machine. The plate did not buckle and there was no significant block deformation. Without the gusset plate, significant deformation occurs at 16,000 pounds force. The attachment of the separator blocks to the strongback was also strengthened. Notably, Grade 8 bolts with a shear strength of 90,000 psi are used instead of carbon steel bolts with a shear strength of 38,400 psi and 3/8 inch thick washers are added in place of 1/8 inch thick washers to distribute the load over a larger area of the strongback channel.

V.6 The Influence of Dynamic Loading on Component Performance

Steel shows some increase in tensile strength under impact loading*[2]. The ductility under some loading conditions increases and for other conditions decreases. The increases in strength are mainly in the range of ten percent to twenty percent. Davies and Magee studied a wide range of materials, including Types 302 and 310 stainless steel, at room temperature and found "no significant change in tensile ductility over the investigated strain rate range", which included the range of interest for the impact loadings in container drop tests. Type 310 stainless steel showed a small increase in strength with higher strain rate, while for Type 302 the strength was independent of strain rate. At elevated temperatures, Steichen found an increasing trend in ductility in Types 304 and 316 stainless steel towards the upper end of the strain rate range, which did not quite reach the range of interest for this application.

Relative to the performance evaluation of the Model 51032-1a packaging, it is only important that the dynamic effects do not alter the designed bolt deformation mode, (i.e., that the stainless steel shock mount bolts deform while the high-strength carbon steel bolts do not fail). Available data supports this result. With respect to energy dissipation in the stainless steel bolt distortion, the data suggests a small increase in energy dissipation capability under impact loads.

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[2]See, for example, R. G. Davies and C. L. Magee , Journal of Eng. Mat. and Tech., April 1975, pages 151-155, and J. M. Steichen, High Strain Rate Mechanical Properties of Types 304 and 316 Stainless Steel, HEDL-TME-71-164, November 1971.

FIGURE V.1

SHOCK MOUNT LOADING CHARACTERISTICS

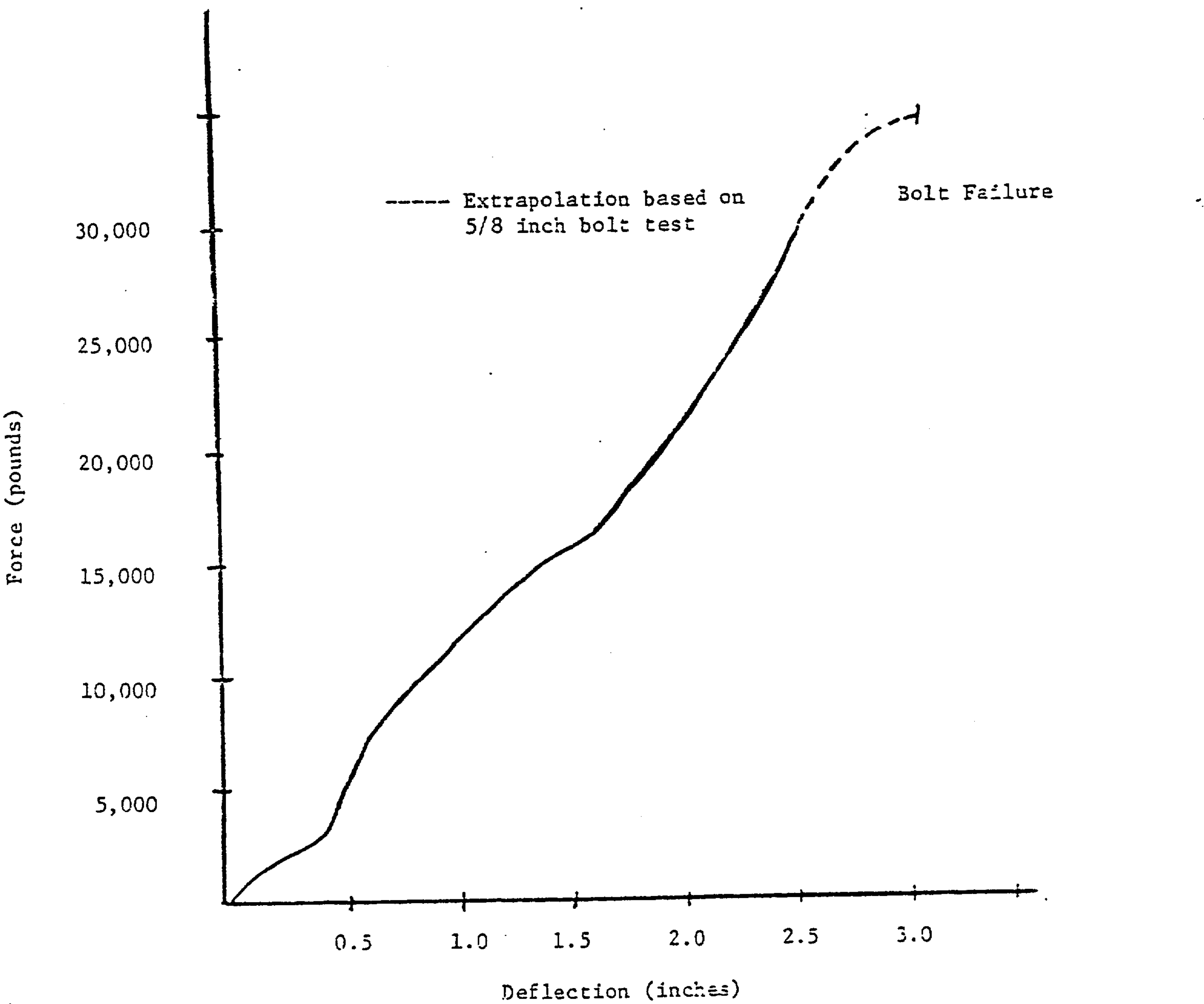


FIGURE V.2

SHOCK MOUNT BOLT TENSILE STRESS-STRAIN CURVE

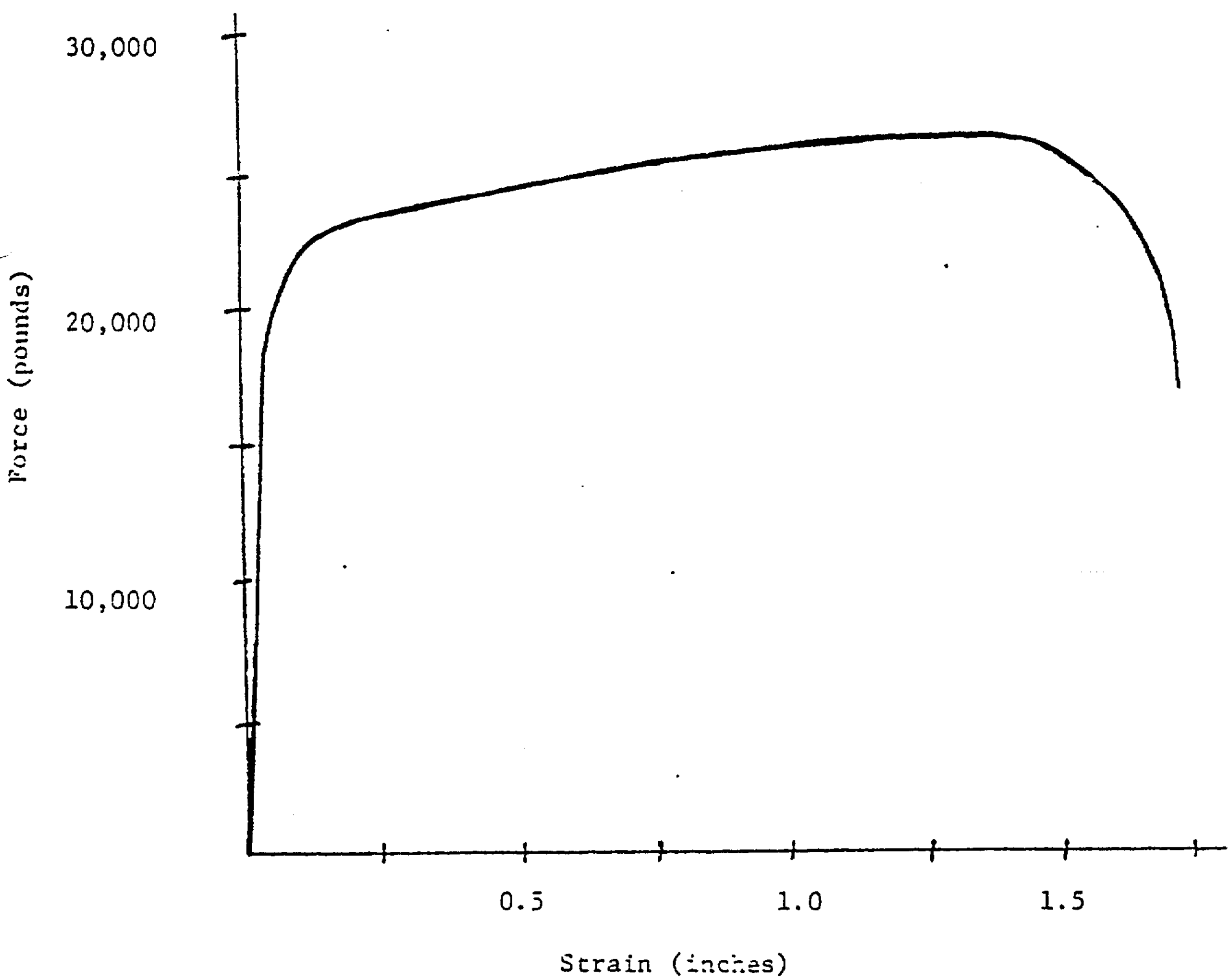
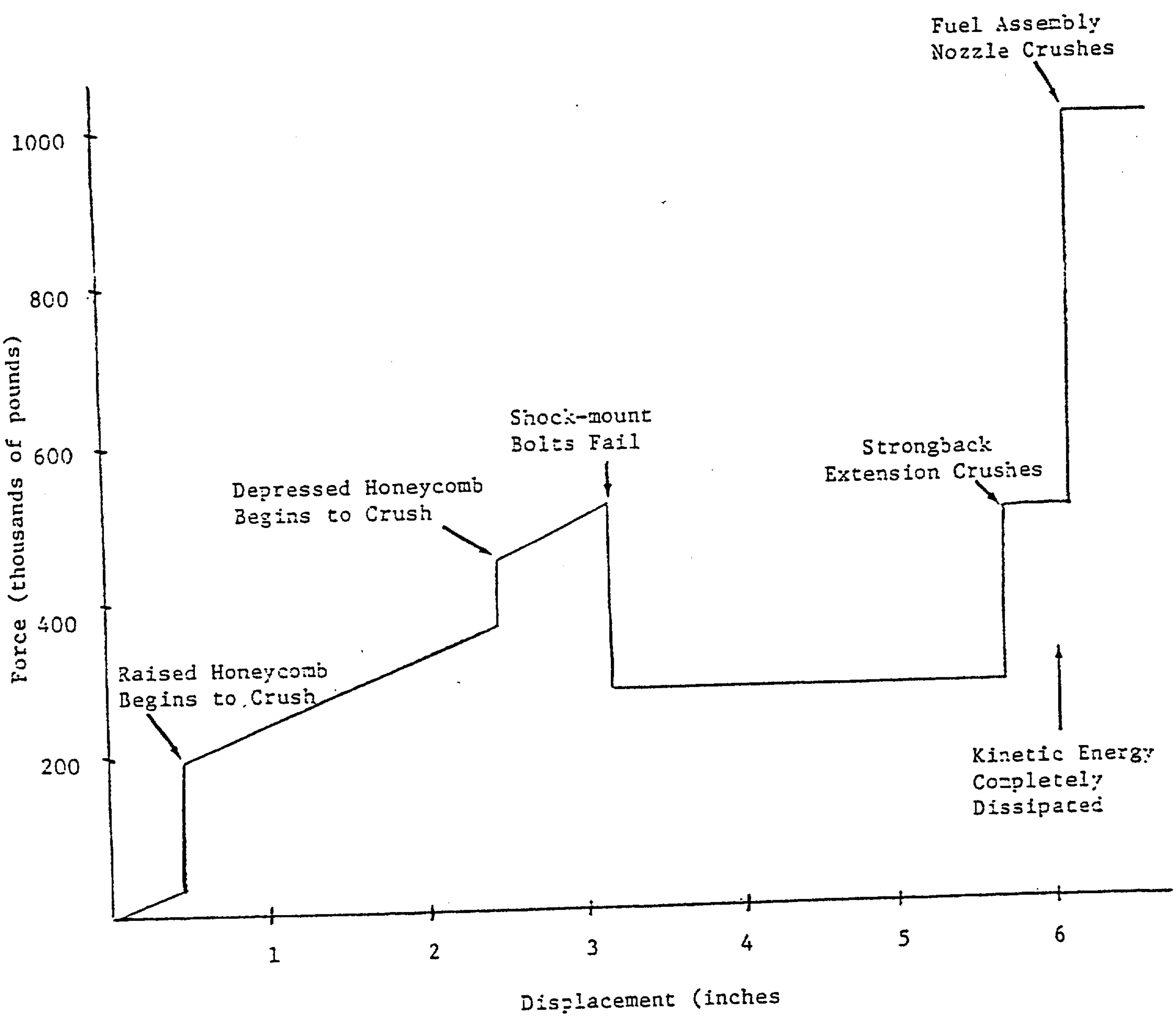


FIGURE V.3

LOADED STRONGBACK STOPPING FORCE IN AN END DROP



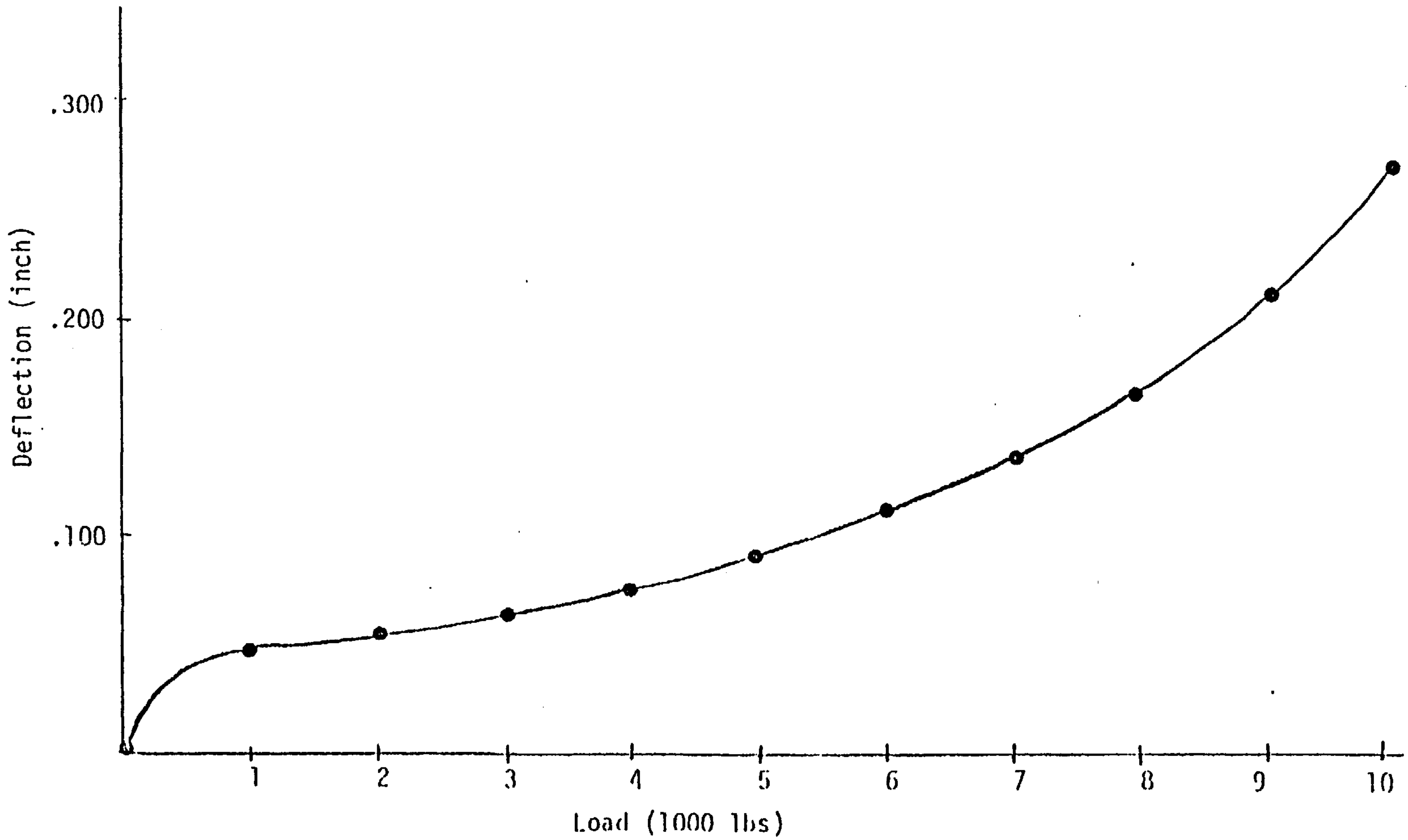


Figure V.4

Force Deflection Curve For
Model 51032-1a Aluminum Clamp Assembly

APPENDIX VI

FUEL ROD DROP TEST REPORT

FUEL ROD DROP TEST

GENERAL

Of interest to persons involved with the shipment of fuel assemblies is the degree of containment and protection provided by the fuel rods themselves. To get a feel for containment and protection provided it was decided to subject individual fuel rods to the hypothetical accident conditions detailed in Appendix B of 10CFR71.

This test consisted of subjecting three fuel rods to the specified 30 ft. drop test. Test conditions, methods, procedures and results are discussed below.

FUEL ROD DESCRIPTION

The three fuel rods used in this test were earlier fabricated and employed for certain quality control examinations. As such, one rod had been autoclaved, and two of the rods had small holes drilled through the cladding near the plugs; one rod had a single 0.016 inch hold, and the other rod had a 0.125 inch hole. Upon completion of the quality control examinations, these fuel rods were to be scrapped; instead, they were turned over to Nuclear Safety for the subject test. The physical characteristics of the fuel rods are defined below:

Overall Length:	158.148 inches (nominal);
Fuel Length:	144 inch (nominal);
Fuel:	Sintered depleted UO_2 pellets;
Cladding:	36.5 (nominal) mil zircaloy-^{2};
Tube O.D.:	0.570 inches (nominal).

All three fuel rods had been fabricated in accordance with standard process specifications, and contained the standard internal hardware components, and, as such, were prototypical of rods which will make up typical fuel assemblies.

TEST CONDITIONS

Since the fuel rods contained depleted uranium, each rod was Individually encased in a thin polyethylene tube, which as taped to the two end plugs with masking tape. This was done to provide secondary containment in the event of rod rupture as a results of the impact.

The rods were dropped (by hand) from a height of two feet above the parapet of the UO^2 building to the concrete pad (8 inches thick) at the south side of the building, thus constituting a 30 foot drop to an unyielding surface.

METHODS AND PROCEDURES

The three fuel rods (individually encased in thin polyethylene tubing) were held, one at a time, out over the edge of the building such that the lowest part of the rods were 30 feet above the concrete pad -- and released (see photo No. 1)

ROD NO. 1 (45° L Drop)

This fuel rod was not autoclaved and had a 0.016 inch hold drilled in the plenum region (upper end). The rod was held at 45° angle with the lower end 30 ft. above the concrete pad, and dropped such that the lower end plug (no plenum spring) was the first part of the fuel rod to make contact with the pad.

ROD NO. 2 (Flat Drop)

This fuel rod was not autoclaved an had a 0.125 inch hold drilled in the plenum region (upper end). The rod was held horizontal 30 ft. above the concrete pad and dropped; the fuel rod was in this same position when it made contact with the pad.

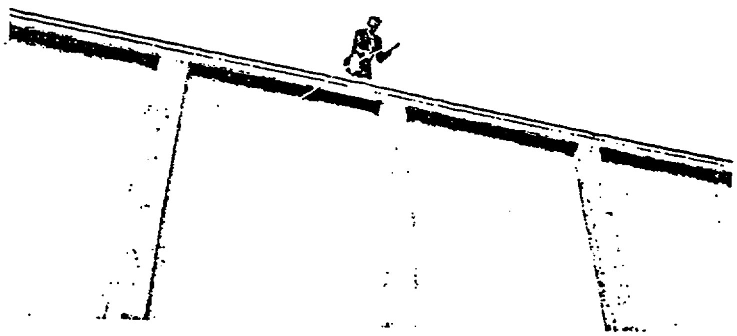
ROD NO. 3 (Straight Drop)

This fuel rod had been autoclaved in accordance with standard process specifications; no holes had been drilled in this rod. This rod was held vertical with the lower end 30 ft. above the concrete pad, and dropped such that the lower end plug (no plenum spring) was the first part of the fuel rod to make contact with the pad.

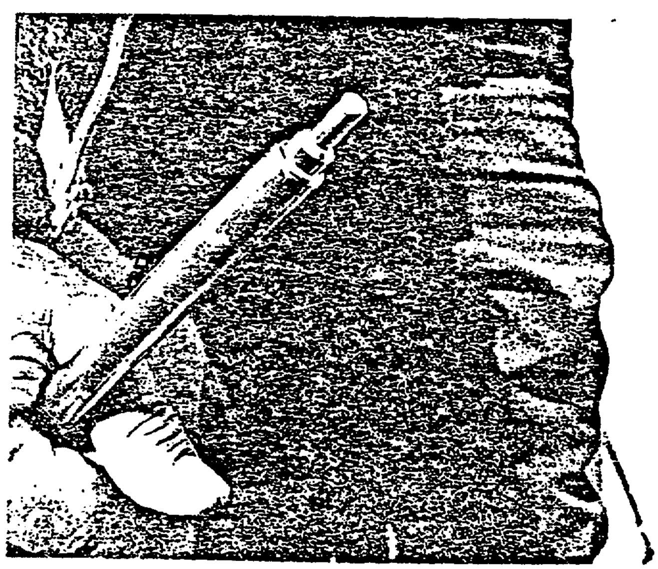
RESULTS

Each fuel rod, after being subjected to the afore described tests, was inspected for damage and release of radioactive material. In no case was there any release of radioactive material (as determined by surveys with alpha sensitive instruments), nor were there any cracks in either the tubing or the welds detected.

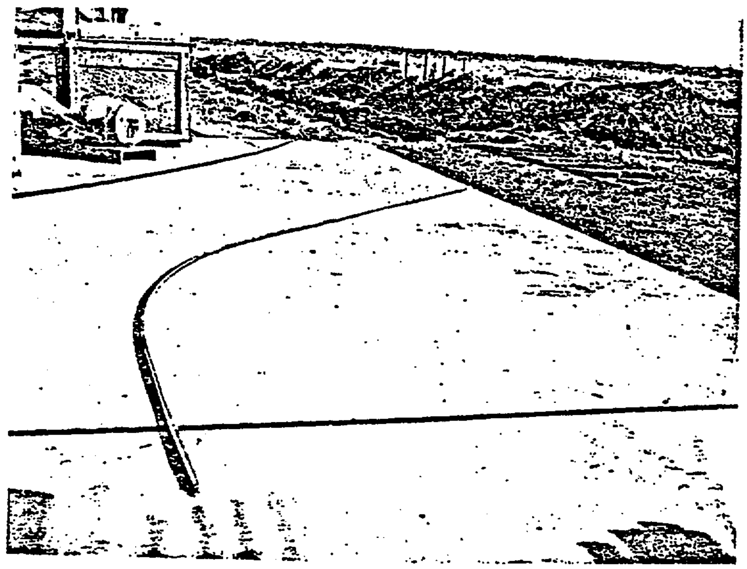
Photographs were taken of the fuel rods subjected to these drop tests; these appear, along with brief discussions, on the following pages.



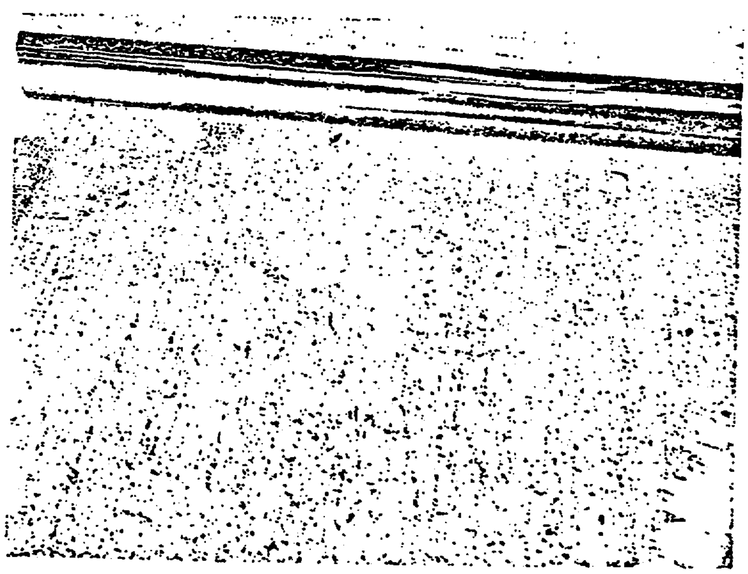
Preparation for dropping fuel rods from the roof of the UO_2 building to the concrete pad at the south end of the building.



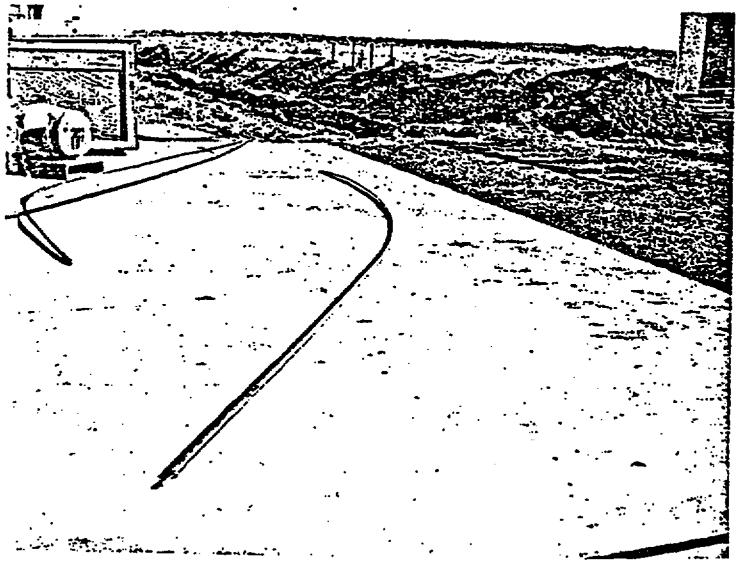
Rod No. 1: This photo shows the lower end plug and weld region of the fuel rod dropped at a 45° angle. The tip of the lower end plug was deformed.



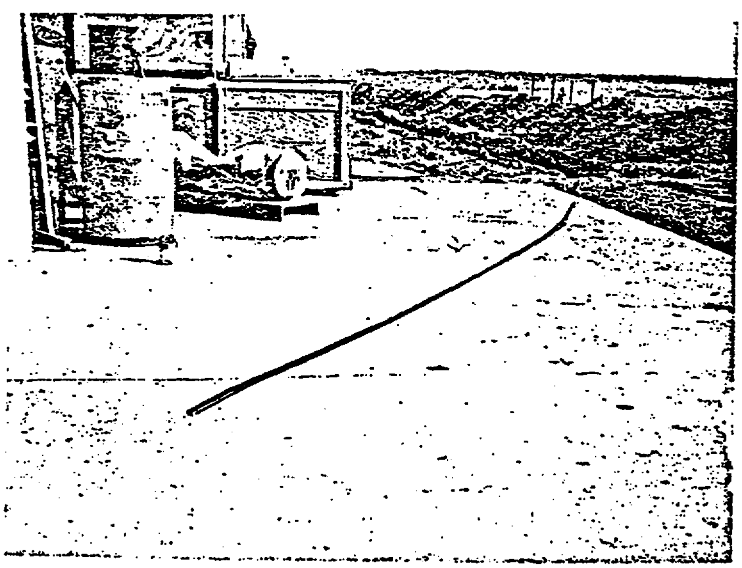
Rod No. 1: This photo shows the warp developed in the fuel rod dropped at a 45° angle.



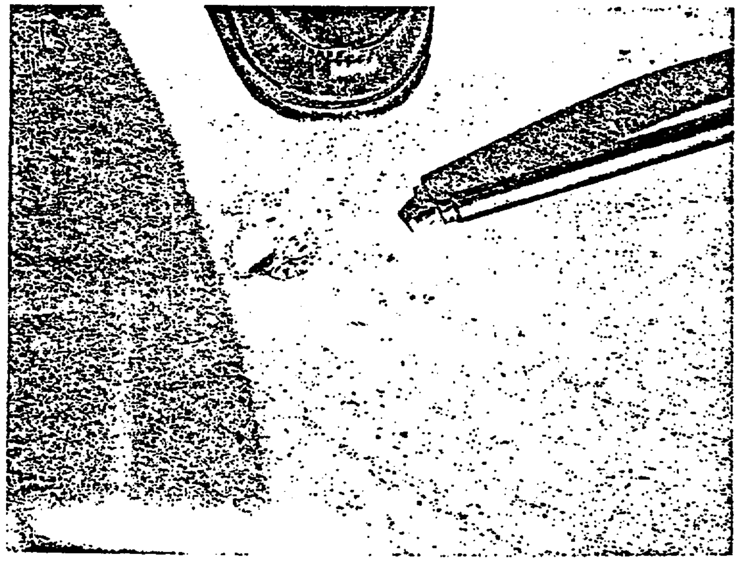
Rod No. 2: This photo shows abrasion of the rod surface of the fuel rod dropped in the horizontal (flat) position.



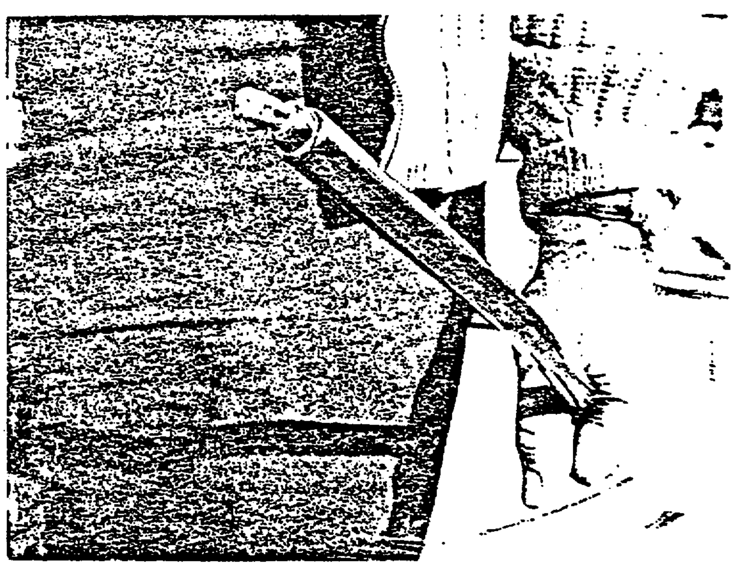
Rod No. 2: This photo shows the warp developed in the fuel rod dropped in the horizontal (flat) position.



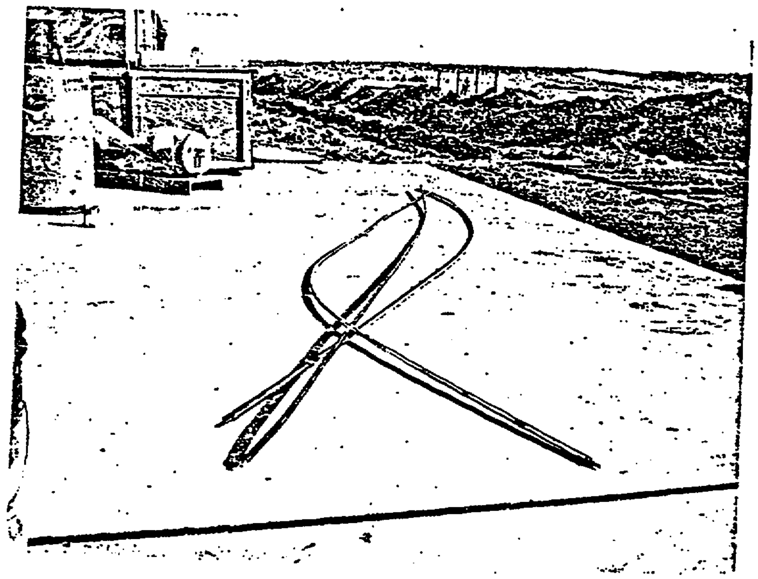
Rod No. 3: This photo shows the warp developed in the fuel rod dropped in the vertical (straight) position.



Rod No. 3: This photo shows the damage done to the concrete pad, and the lower end plug, caused by the fuel rod dropped in the vertical (straight) position.



Rod No. 3: This photo shows the lower end plug and weld region of the fuel rod dropped in the vertical (straight) position.



Rod Nos. 1, 2 & 3: This photo shows all three fuel rods together -- depicting the relative warps developed as the results of the individual drop tests.

SECOND FUEL ROD DROP TEST

GENERAL

Additional information was desired on the degree of containment of radioactive materials and environmental protection afforded by the fuel rods themselves during the transport of nuclear fuel assemblies. The object of this test was to determine the upper range of probable damage that could be expected as a result of impact with an internal component of the packaging.

This test consisted of dropping (individually) three loaded fuel rods 30 feet onto a 4" x 4" x 3/8" steel angle positioned on a concrete pad. Test conditions, methods, procedures and results are discussed below.

FUEL ROD DESCRIPTION

The test rods are those described in the Fuel Rod Description in JN-55. These same rods were previously subjected to various 30 foot drop test as described in JN-55.

TEST CONDITIONS

As stated above, the test rods had been used in previous tests, and, as such, exhibited bends and warps prior to being subjected to the following tests. However, none of the rods exhibited any cracks or other enclosure failure (as described in the Results section of JN-55).

Since the fuel rods contain depleted uranium each rod was individually encased in a thin polyethylene tube, which was taped to the two end plugs with masking tape. This was done to provide secondary containment in the event of rod rupture as a result of the impact.

The rods were hand-dropped (see Photo No. 1 of JN-55) from a height of two feet above the parapet for the UO_2 building onto a 4" x 4" x 3/8" steel angle set on a concrete pad 30 feet below.

RESULTS

Following the completion of the drops, the three rods were positioned upon the steel angle (Photo No. 1) to show how many they struck the angle and the pad, and to show the deformation inflicted. The deformations inflicted by these drops are not truly depicted in Photo No. 1 as all of the rods exhibited deformations as the result of previous drop test (reference JN-55).

Photo No. 2 shows the points (arrows) of impact of each of the fuel rods upon the steel angle.

Photo No. 3 shows the overall warping and bending of the fuel rods resulting from the combined tests. The arrows located the points of impact with the steel angle in the most recent tests.

Each fuel rod, after being subjected to the above described tests, was inspected for damage and surveyed for release of radioactive material. In no case was there any release of radioactive material (as determined by surveys with alpha sensitive instruments), nor were there any cracks detected in either the tubing or the welds.

PHOTO NO. 1

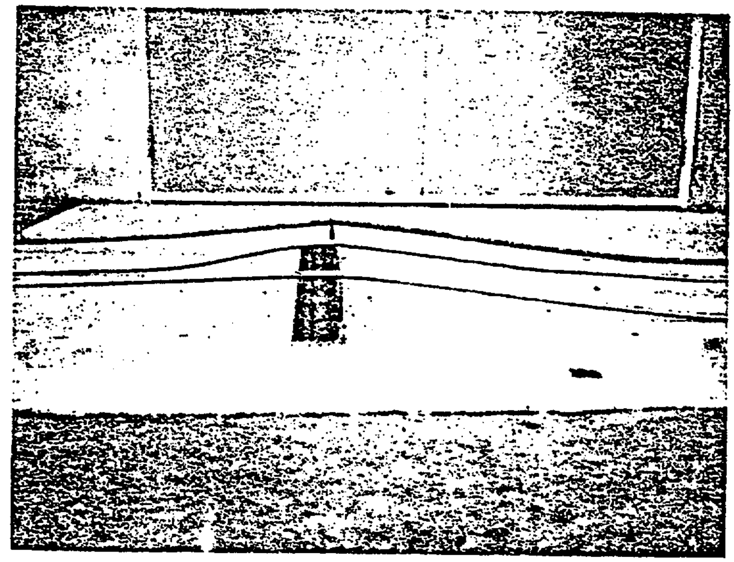


PHOTO NO. 2

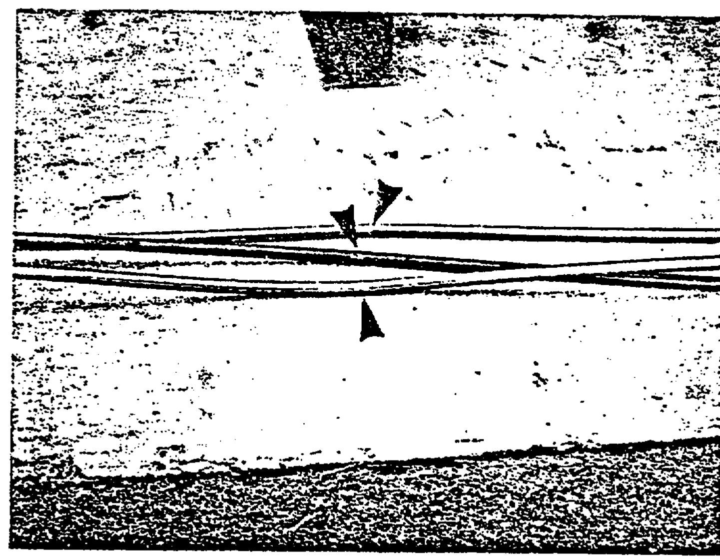


PHOTO NO. 3