Test Report No. 2312B
on the
Applied Design Company Model 927A
Metal Shipping and Storage Container
for
Combustion Engineering, Inc.
Fuel Bundle Assembly

APPLIED DESIGN COMPANY, INC.
Tonawanda, New York 14150

February 7, 1969

Reference B

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Applied Design Company Model 927A
Metal Shipping and Storage Container
for
Combustion Engineering, Inc.
Fuel Bundle Assembly

The Applied Design Company Model 927A Container employs a special cradle assembly utilizing elastomeric shock mounts to isolate and protect the Combustion Engineering Inc. Fuel Bundle Assembly during conditions of normal shipping and handling as well as some likely abuse or accident. The container also protects the contents from possible damage due to the atmosphere.

The work involved in the design, fabrication and testing of the container is covered by Combustion Engineering, Inc. Purchase Order No. 9801668.

The qualification testing was accomplished in accordance with Test Report No. 2312A Qualification Test Procedure for the Applied Design Company Model 927A Metal Shipping and Storage Container for Combustion Engineering, Inc. Fuel Bundle Assembly.

It is the purpose of this report to summarize the results of the tests performed on the container with two simulated fuel bundle assemblies installed within. The simulated fuel bundles were furnished by Combustion Engineering, Inc. The actual fuel bundle assembles are identified on Combustion Engineering, Inc. Drawing No. CND-SE-2813.

1. Summary and Conclusions

A. The dummy fuel bundle assemblies were installed in the strongback and the strongback with assembled units satisfactorily lowered into the shipping position.

B. The container satisfactorily protected the packaged items during the shipping test of the container under conditions normally encountered in shipments by common carrier.

C. Prior to the rough handling tests the container successfully passed the leak test.

D. The container successfully passed the rough handling tests. The fuel bundles and suspension frame satisfactorily withstood these tests. The maximum accelerations imposed on the simulated

fuel bundle during these tests are as follows:

Edgewise - Fore End Drop	50 g's Vertical
Cornerwise - Aft End Drop	40 g's Vertical
Flatwise Drop	32 g's Vertical
Roll-over (side to base)	14 g's Lateral
Impact (Fore End)	20 g's Longitudinal

E. The container successfully passed the static load and handling tests.

F. The container satisfactorily passed the pinnacle test and two of the 30-foot free fall drop tests as described in the United States Atomic Energy Commission's Rules and Regulations, Title 10 - Atomic Energy Part 71.

G. It is the conclusion of this report that the Model 927A Metal Shipping and Storage Container is capable of protecting the Combustion Engineering, Inc. Fuel Bundle Assemblies from damage due to shipping and rough handling and that it meets the test requirements of Combustion Engineering, Inc. Specification MFG-03-01.

It is further concluded that the container satisfies the test requirements of the United States Atomic Energy Commission's Rules and Regulations Title 10, Atomic Energy Part 71 by retaining the two fuel bundles within the strongback, with the Boral Plate remaining in place and continuing to completely separate the two units. Further, the strongback, with fuel bundles installed, were contained within the container structure.

II. Discussion

The container was subjected to the tests of paragraph 5.0 of the Qualification Test Procedure as tabulated below:

Test No.	Test Procedure Paragraph No.	Date of Test	Title of Test	Location of Test
1	5.1	12-3 to 12-4-68	Install Dummy Units	Combustion Eng. Hartford, Conn.
2	5.2	12-3 to 12-4-68	Loading Test, Ship Container to Applied Design	Combustion Eng. Hartford, Conn.
3	5.3	1-2-69	Leak Test	Applied Design N.Tonawanda, NY

Test No.	Test Procedure Paragraph No.	Date of Test	Title of Test	Location of Test
4	5.4.1	1-2-69 1-3-69	Edgewise Drop Test	Applied Design N.Tonawanda, N.Y.
5	5.4.2	1-3-69	Cornerwise Drop Test	Applied Design N.Tonawanda, N Y.
6	5.4.3	1-3-69	Flatwise Drop Test	Applied Design N.Tonawanda, N.Y.
7	5.4.3	1-3-69	Roll-over Test	Applied Design N.Tonawanda, N.Y.
8	5.4.4	1-3-69	Impact Test	Applied Design N.Tonawanda, N.Y.
9	5.4.4	1-8-69	Impact Test	Applied Design N.Tonawanda, N.Y.
10	5.5	1-4-69	Stacking Test	Applied Design N.Tonawanda, N.Y.
11	5.6	1-8-69	Hoisting Test	Brace-Mueller-Huntley, Inc. Tonawanda, N Y.
12	5.7	1-8-69	Lifting Test	Brace-Mueller-Huntley, Inc. Tonawanda, N. Y.
13	5.8	1-8-69	Towing Test	Brace-Mueller-Huntley, Inc. Tonawanda, N. Y.
14	5.9	12-5-68	Shipping Test	Combustion Eng. to Applied Design
15	5.10	1-8-69	Pinnacle Test	Applied Design N.Tonawanda, N. Y.
16	5.11	1-9-69	30 Foot Drop Tests	Louis Levin & Co. Tonawanda, N. Y.

The following personnel were in attendance for the listed tests:

Mr. Edward Petras, Combustion Engineering, Inc., Hartford, Conn., all tests

Mr. J. B. Aikman, Senior Project Engineer, Applied Design Company, Tests 1,2,4-8, 10

Mr. W. F. Schreiber, Project Engineer, Applied Design Company, Tests 9-13, 15, 16

Mr. J. Kovacs, Project Engineer, Applied Design Company, Tests 4-10, 15, 16

Mr. H. Arsenault, Quality Control Manager, Applied Design Company, Test 3

The discussion is divided as follows: A. Container Description and Weights Employed; B. Test Equipment; C. Installation Test; D. Shipping Test; E. Leak Test; F. Rough Handling Tests; G. Static Load and Handling Tests; and H. United States Atomic Energy Commission Prescribed Tests.

A. Container Description and Weights Employed

The container is of the horizontal circular style with a horizontal bolted closure flange and rubber 'O' ring gasket for sealing. The container is constructed of steel and is defined on Applied Design Company Drawing No. 927A1. The overall dimensions of the container are 45-7/8 inches high, 43-1/4 inches wide and 188-1/4 inches long.

The forward end of the container is identified by the end containing the nameplate. Left and right sides of the container are identified as those sides to the viewers left and right when standing at the aft end of the container and looking forward.

One simulated fuel bundle, located on the right side of the container, was fabricated from steel plates. The other fuel bundle utilized construction similar to an actual unit.

The weights employed during the tests are summarized as follows:

Container Weight	3285-pounds
Two simulated Fuel Bundles and Boral Plate	2835-pounds
Total	6120-pounds

The weight of the container was obtained by weighing on a certified scale. The weight of the simulated fuel bundles was obtained from Drawing No. CND-SE-2813. The weight of the boral plate is estimated.

The condition of the container prior to the leak test is shown in photographs No. 1 through 5. The photographs and description are contained in Table I.

B. Test Equipment

1. The test equipment employed during the performance of the

rough handling tests is listed as follows:

a) Accelerometer
The Statham Accelerometers employed have the following characteristics:
Three non-bonded strain gauge type
Range: Plus or minus 50 g's
Natural Frequency: 550 cps
Damping: 0.6 to 0.8
Response: Flat to approx. 440 cps.

b) Recorder
A Brush Development Company Recorder Model 8000-99 Ser. No. 125, was employed to record the accelerations. A calibrated resistor is utilized to check the equipment before each test to assure accuracy. The wiring is completely shielded and the system is grounded to the chassis to eliminate pickup of stray voltages.

The equipment employed in the testing is periodically calibrated in accordance with established procedures to insure its proper functioning.

C. Installation

Following a simple procedure, the strongback was prepared for the fuel bundles and raised to the vertical position. The two simulated fuel bundles were installed and clamped into place. The strongback with fuel bundles was lowered and bolted into its normal shipping position. This test satisfactorily demonstrated that the strongback provided adequate support to the fuel bundles during the operation of the strongback.

D. Shipping Test

The container was subjected to the Shipping Test of Paragraph 5.9 of the Qualification Test Procedure.

Clay was placed between the suspension frame and the container shell to determine the maximum deflections experienced during shipping of the container from Combustion Engineering, Inc. to Applied Design Company. It is estimated that the distance travelled is in the range of 400-450 miles, thus considerably exceeding the specification requirements of not less than 200 miles.

The deflections measured are tabulated in Table II. In addition, the calculated accelerations imposed as a result of these deflections are recorded in this table.

E. Leak Test

The container was subjected to the leak test in accordance with Paragraph 5.3 of the Qualification Test Procedure, Test Report No. 2312A, prior to the rough handling tests. The container was pressurized to 5.55 psi gage. At the end of 1 hour there was no loss in gage pressure. It is concluded that the container satisfactorily passed the requirements of this test.

F. Rough Handling Tests

The container with two simulated fuel bundle assemblies installed was subjected to the following rough handling tests in accordance with Test Report No. 2312A Qualification Test Procedure:

Para. 5.4.1 Edgewise Drop Test
Para. 5.4.2 Cornerwise Drop Test
Para. 5.4.3 Flatwise Drop Test
Para. 5.4.3 Roll-over Test
Para. 5.4.4 Impact Test

During these tests three accelerometers were employed to record the accelerations imposed on the simulated load. One accelerometer was mounted at the top fore end, one at the top center and one at the top aft end of the simulated load which utilized steel plate construction. In general, all accelerometers were mounted to measure acceleration in the direction of the drop or impact. Details of accelerometer orientation for each test are given in Table III.

The maximum accelerations imposed on the simulated fuel bundle during each of the above rough handling tests are as follows:

Edgewise - Fore End Drop - 50 g's Vertical
Cornerwise - Aft End Drop- 40 g's Vertical
Flatwise Drop - 32 g's Vertical
Rollover (side to base) - 14 g's Lateral
Impact (Fore end) - 20 g's Longitudinal

Accelerations recorded during these rough handling tests are listed in Table III.

Prints of accelerations-vs-time traces representative of the various tests conducted are attached to this report as Figures No. 1 through No. 7. These figures are labeled to indicate the type of test and calibration of the coordinates.

Examination of the dummy fuel bundles and container upon completion of the tests showed that they were in good condition.

G. Static Load and Handling Tests

In order to assure the structural strength of the container under normal usage, the following performance tests were conducted:

1. Stacking Test

The container was subjected to the stacking test in accordance with Paragraph 5.5 of the Qualification Test Procedure.

A weight of 12,000 pounds simulating the stacking of two containers, was placed on the stacking brackets of the container and allowed to rest for over 2 minutes. No yielding was observed. It is concluded that the container satisfactorily passed the requirements of this test.

2. Hoisting Test

The container was subjected to the hoisting test, Paragraph 5.6 of the Qualification Test Procedure. The container was lifted free of the floor by each of its lifting eyes, individually, and held for at least 2 minutes. No yielding was observed and it is concluded that the container satisfactorily passed the requirements of this test.

3. Lifting Test

The container was subjected to the lifting test, Paragraph 5.7 of the Qualification Test Procedure. The container was transported a minimum of 100 feet by a fork lift truck. No problems with stability of the container on the forks nor evidence of the forks causing any deformation of the container were noted. It is concluded that the container satisfactorily passed the requirements of this test.

4. Towing Test

The container was subjected to the towing test of Paragraph 5.8 of the Qualification Test Procedure. The container was towed a minimum of 50 feet by means of each set of towing eyes. No problems were encountered in towing the container and no evidence of deformation of the container was noted. It is concluded that the container satisfactorily passed the requirements of the test.

H. United States Atomic Energy Commission Prescribed Tests

In order to assure the structural strength and reliability of the

container under extreme accident conditions, the following tests of the United States Atomic Energy Commissions Rules and Regulations Title 10 - Atomic Energy Part 71 were conducted:

1. Pinnacle Test

The container was subjected to the pinnacle test in accordance with Paragraph 5.10 of the Qualification Test Procedure. The container was 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.

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 loads, no relative movement of the simulated loads and no damage to the suspension frame. It is, therefore, concluded that the container satisfactorily passed the pinnacle test.

2. 30-Foot Drop Tests

The container was subjected to two 30-foot drops. The first drop was made with the longitudinal axis of the container at an agle of approximately 30° to the horizontal. The angle was such that the aft end of the container struck first, the container then rotating so that the bottom of the fore and skids hit the concrete slab. The container cover was removed at the test site after the 30° angle, 30-foot drop and the container visually inspected. The simulated fuel bundles were retained in the container cradle assembly and little relative movement of one fuel bundle with respect to the other was noted. The most notable deformation as a result of this test was in the skid brackets. See photographs No. 6 through No. 17 for various views of the container during and after this test.

The second 30-foot drop was made with the container oriented such that the left side closure flange struck the concrete slab. The simulated load utilizing tubular construction was nearest the ground. Upon impact the container remained stable on its side without any rotation about its axis.

After the 30-foot side drop, the container was inspected as above. Although the simulated fuel bundles had shifted sidewise from their original mounting positions the fuel bundles did not come loose and were contained in the container shell after testing. The most notable deformation in the container shell is at the forward right closure flange. Refer to photographs No. 18 through No. 30 for various views of the container during and after this test.

It is concluded that the container satisfies the test requirements by retaining the two fuel bundles within the strongback with the Boral Plate remaining in place and continuing to completely separate the two units. Further, the strongback with fuel bundles installed were contained within the container structure.

Conducted by
J. B. Aikman
Senior Project Engineer

Written by
J. Kovacs
Project Engineer

Approved by
H. E. Johnson
General Manager

Applied Design Company, Inc.
Tonawanda, New York 14150
February 7, 1969

TABLE I

Photographs
of the
Applied Design Company Model 927A Container
at
Various Stages of the Test Program

A. Photographs Subsequent to Shipping Test and Prior to Rough Handling Tests.

Photograph No.	Description
1	Cover Removed Fuel Bundles, Aft End
2	Cover Removed Fuel Bundles, Fore End
3	Cover Removed Aft End, Strongback
4	Cover Removed Aft End, Partial Side View of Strongback
5	Complete Assembly Aft End, 3/4 Side View

B. Photographs Illustrating the 30-Foot Free Fall Drop Test and Results - 30 Degrees to Horizontal.

Photograph No.	Description
6	Container Underside, Aft End Down Container Being Raised for 30° Angle, 30-Foot Drop.
7	Container Raised 30-Feet at 30° Just Prior to Release.
8	Container at Instant of Impact after 30°, 30-Foot Drop.
9	Container After 30°, 30-Foot Drop Fore End View

TABLE I - Continued

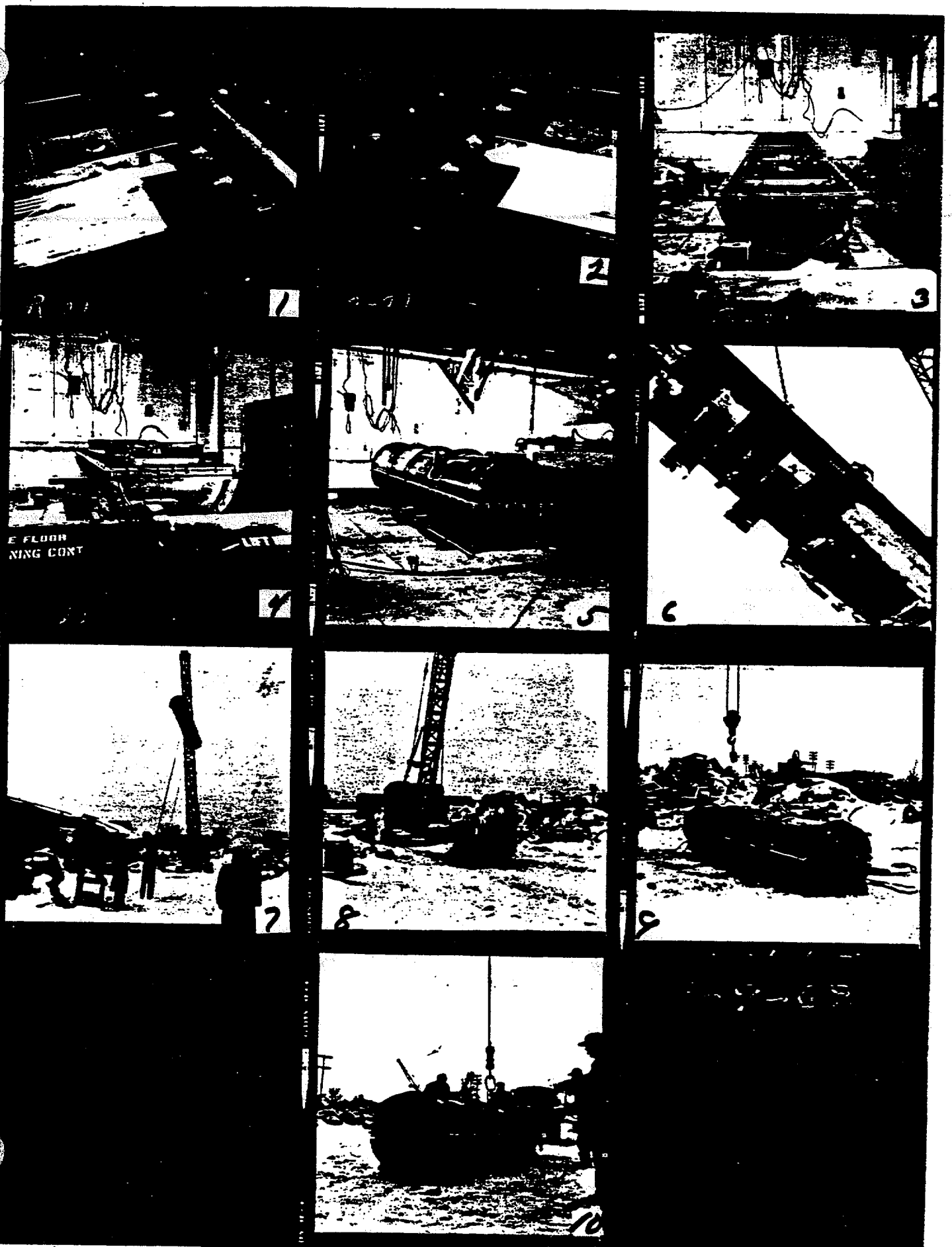
Photograph No.	Description
10	Container After 30 , 30-Foot Drop Aft End View.
11	Container After 30 , 30-Foot Drop Fore End View.
12	Container After 30 , 30-Foot Drop Bottom View.
13	Container After 30 , 30-Foot Drop Cover Removed Fuel Bundles, Fore End.
14	Container After 30 , 30-Foot Drop Cover Removed Fuel Bundles, Fore End.
15	Container after 30 , 30-Foot Drop Cover Removed Fuel Bundles, Aft End.
16	Container After 30 , 30-Foot Drop Cover Removed Left Side View
17	Container After 30 , 30-Foot Drop Cover Removed Fore, Left Side View.

C. Photographs Illustrating the 30-Foot Free Fall Drop Test and Results - To Left Side Closure Flange.

Photograph No.	Description
18	Container Raised 30-Feet Just Prior to Release Left Side Down.
19	Container at Instant of Impact after 30-Foot Side Drop.
20	Container after 30-Foot Side Drop Fore End View

TABLE I - Contained

Photograph No.	Description
21	Container After 30-Foot Side Drop Aft End View.
22	Container After 30-Foot Side Drop Fore Right Side View.
23	Container After 30-Foot Side Drop Aft Left Side View.
24	Container After 30-Foot Side Drop Cover Removed Aft Left Side View.
25	Container After 30-Foot Side Drop Cover Removed Aft End View.
26	Container After 30-Foot Side Drop Cover Removed Right Side View.
27	Container After 30-Foot Side Drop Cover Removed Fuel Bundles, Fore End View.
28	Container After 30-Foot Side Drop Cover Removed Fuel Bundles, Aft End View.
29	Container After 30-Foot Side Drop Cover Removed Fuel Bundles, Aft End View.
30	Container After 30-Foot Side Drop Cover Removed Fuel Bundles, Fore End View.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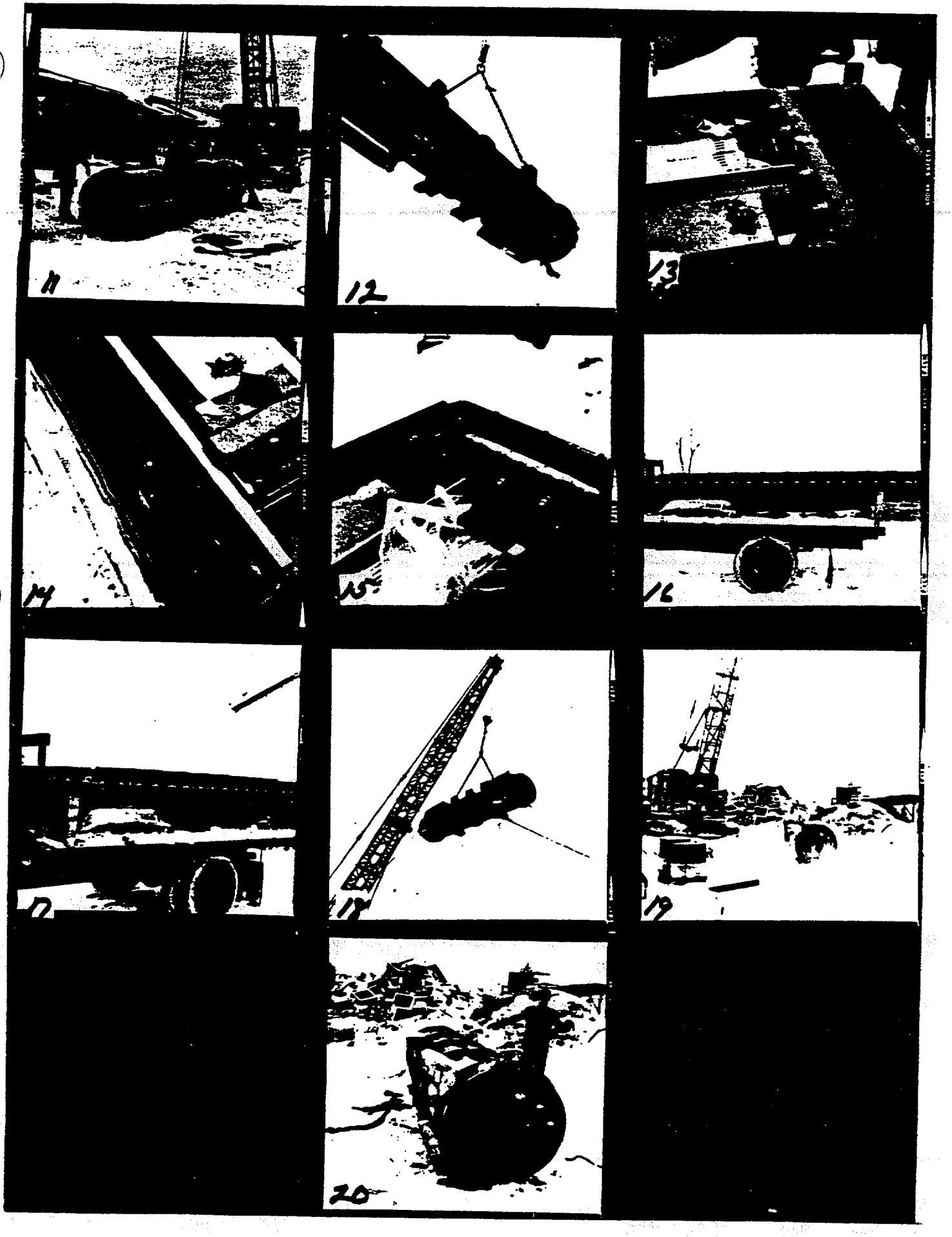
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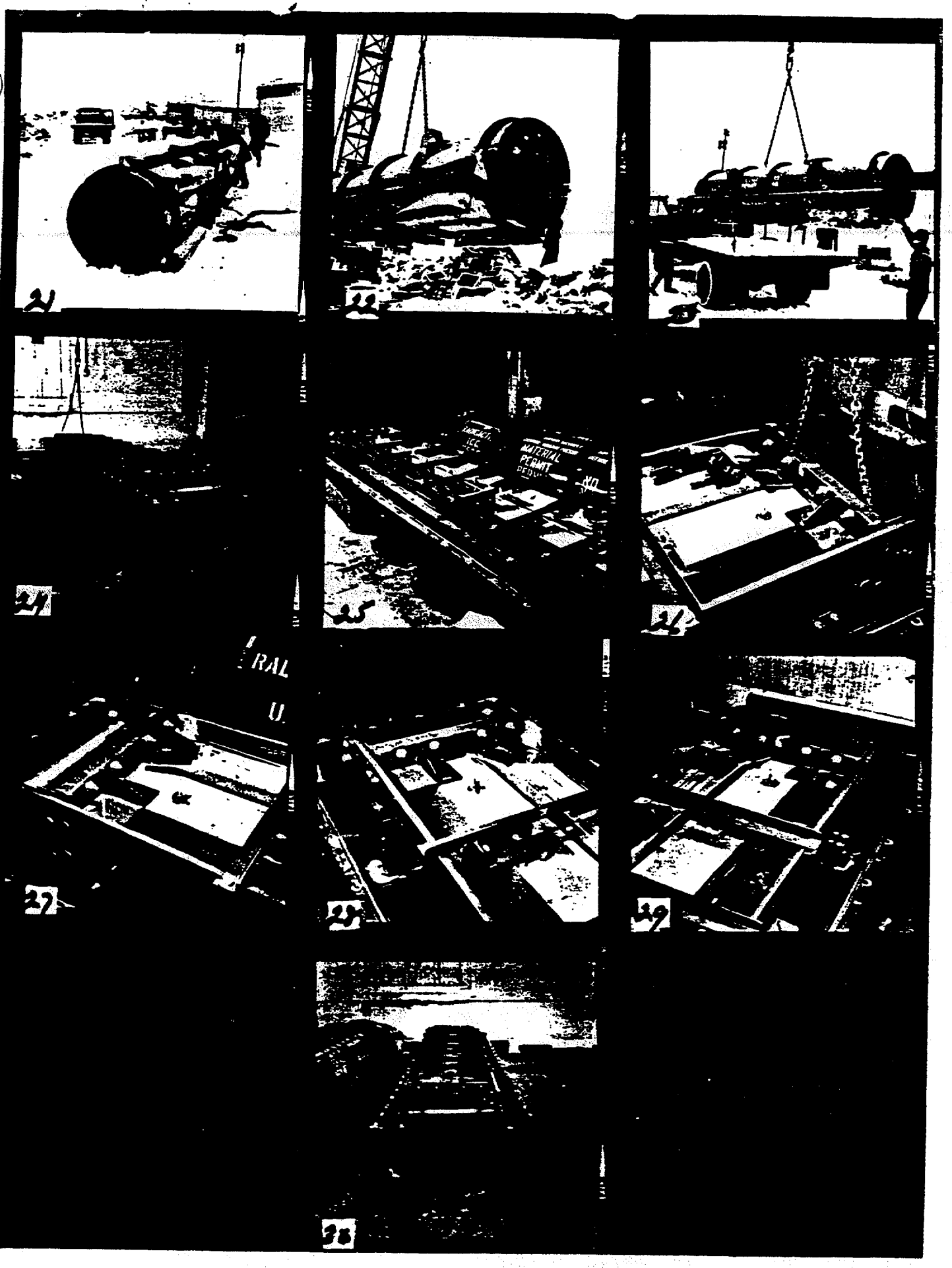
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MATERIAL
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TABLE II

Test Data and Results
Obtained During Shipping Test
of
Applied Design Company Model 927A Container

Point of Measurement	Maximum Deflection of Suspension Frame Inches	Calculated Acceleration g's
1. Fore End Shock Mount	0.165	2.05
2. Center Shock Mount	0.116	1.28
3. Aft End Shock Mount	0.164	2.05

The calculated g's represent the loads imposed on the dummy units in the same relative locations as the indicated shock mounts.

TABLE III

Acceleration Test Data
Obtained in the Test
of
Applied Design Company Model 927A Container

Title of Test	Drop Height Inches	Acceleration - g's Accelerometer No. 1	No. 2	No. 3	Remarks
Paragraph 5.4.1	12	5	15	23	All Readings
Edgewise Drop	24	7	23	35	Vertical
Force End	30	11	30	50	
Paragraph 5.4.1	12	20	10	6	Accel. Mounted
Edgewise Drop	24	33	20	11	Top of Steel
Aft End	30	43	25	13	Plate Dummy as. Follows: No. 1 Aft No. 2 Center No. 3 Fore
Paragraph 5.4.2	12	18	10	5	Same as 5.4.1
Cornerwise Drop	24	35	20	5	
Aft End	30	40	20	6	
Paragraph 5.4.2	12	7	4	12	Same as 5.4.1
Corner Wise	24	10	10	18	
Fore End	30	11	22	38	
Paragraph 5.4.3 Flatwise Drop	18	22	32	32	Same as 5.4.1
Paragraph 5.4.3					No. 2 Changed
Roll-Over (Base to Side)		3	7	3	to Read Lateral
Roll-Over (Side to Top)		7	3	8	Otherwise Same
Roll-Over (Top to Side)		3	6	3	as 5.4.1
Roll-Over (Side to Base)		6	14	8	
Paragraph 5.4.4					
Impact (Aft)	18	10	14	6	Same as 5.4.1
Impact (Fore)	18	10	20	2	Except: No. 1 Long No. 2 Long No. 3 Vert

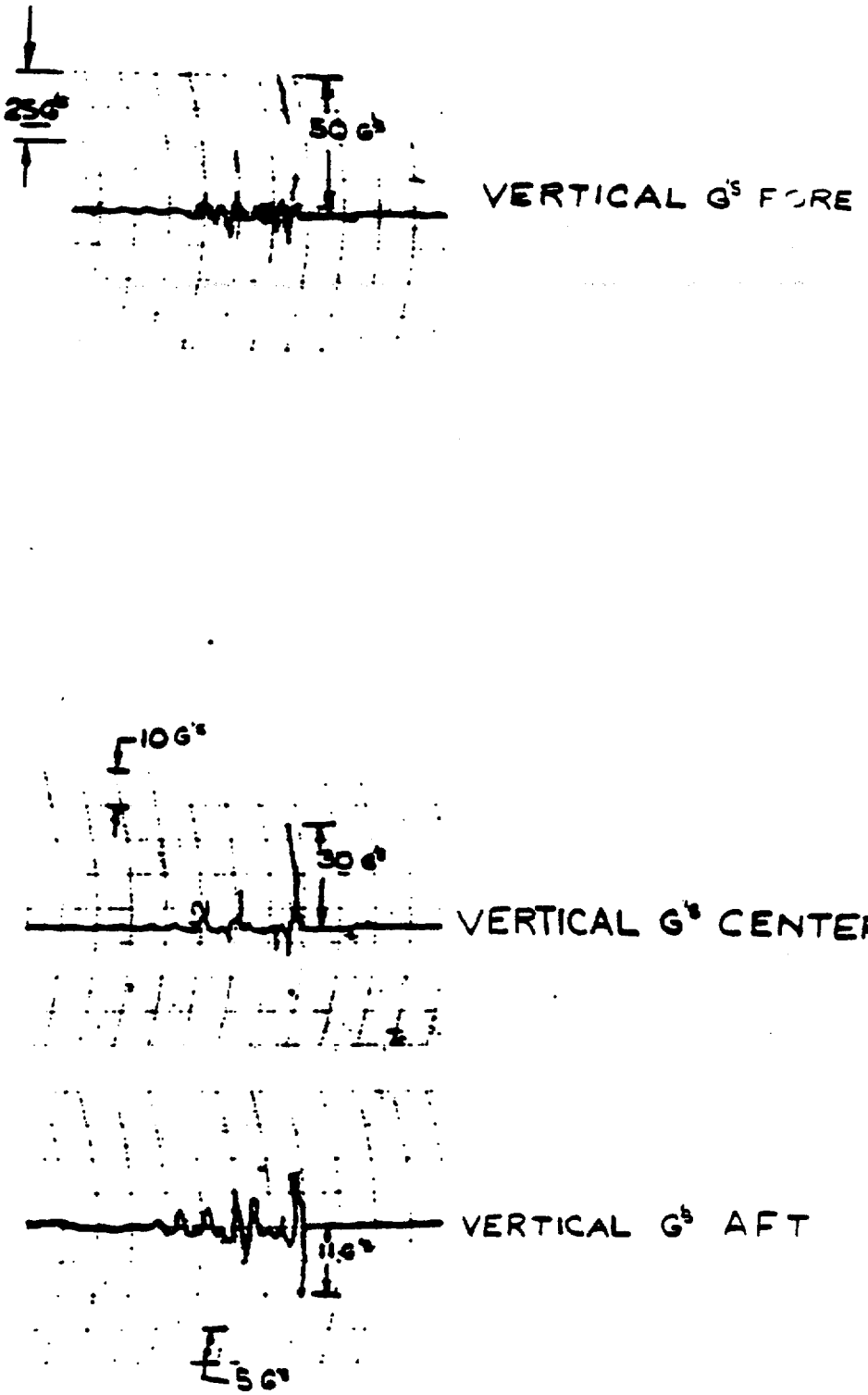
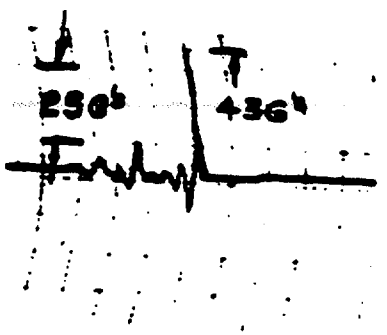
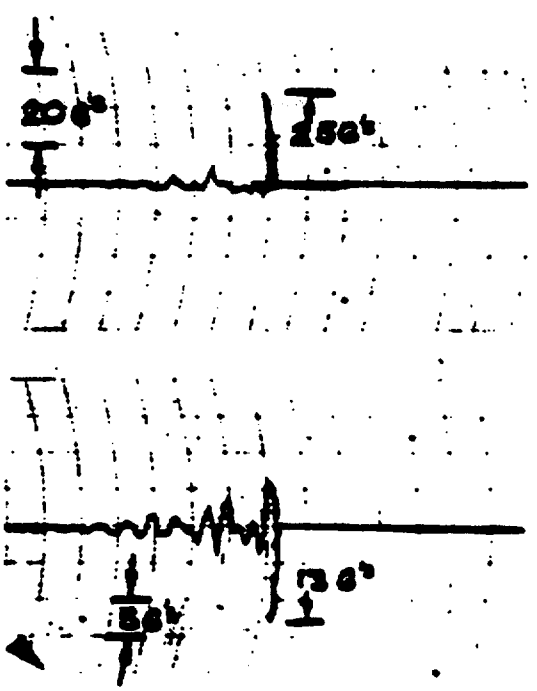


FIG 1
ACCELERATION VS. TIME TRACE
30 INCH EDGEWISE DROP
FORE END FALLING
DATE TESTED 1-3-69
MODEL 927A CONTAINER



VERTICAL G'S AFT



VERTICAL G'S CENTER

VERTICAL G'S FORE

FIG 2
ACCELERATION VS. TIME TRACE
30 INCH EDGEWISE DROP
AFT END FALLING
DATE TESTED 1-3-69
MODEL 927A CONTAINER

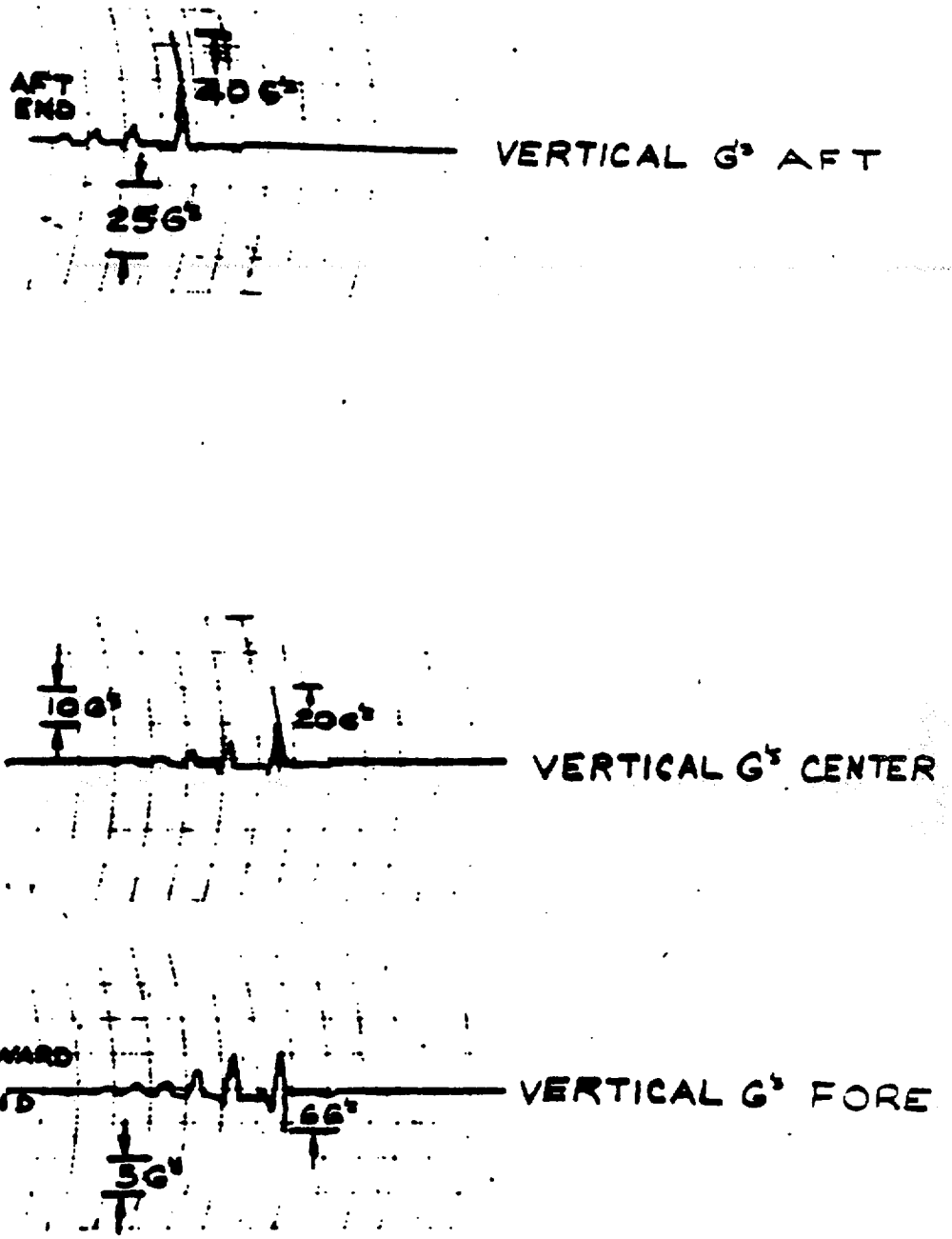


FIG - 3

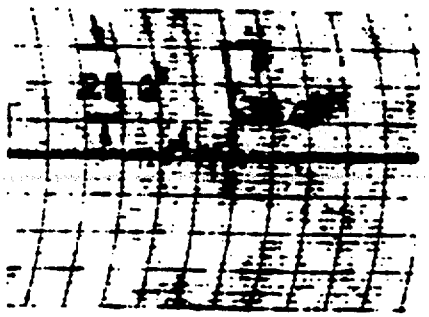
ACCELERATION VS. TIME TRACE

30 INCH CORNERWISE DROP

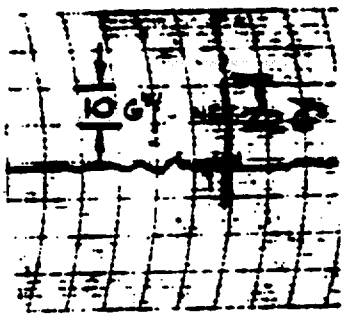
AFT END FALLING

DATE TESTED 1-3-69

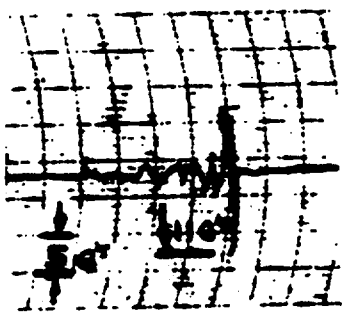
MODEL 927A CONTAINER



VERTICAL G'S FORE



VERTICAL G'S CENTER



VERTICAL G'S AFT

FIG 4
ACCELERATION VS. TIME TRACE
30 INCH CORNERWISE DROP
FORE END FALLING
DATE TESTED 1-3-69
MODEL 927 A CONTAINER

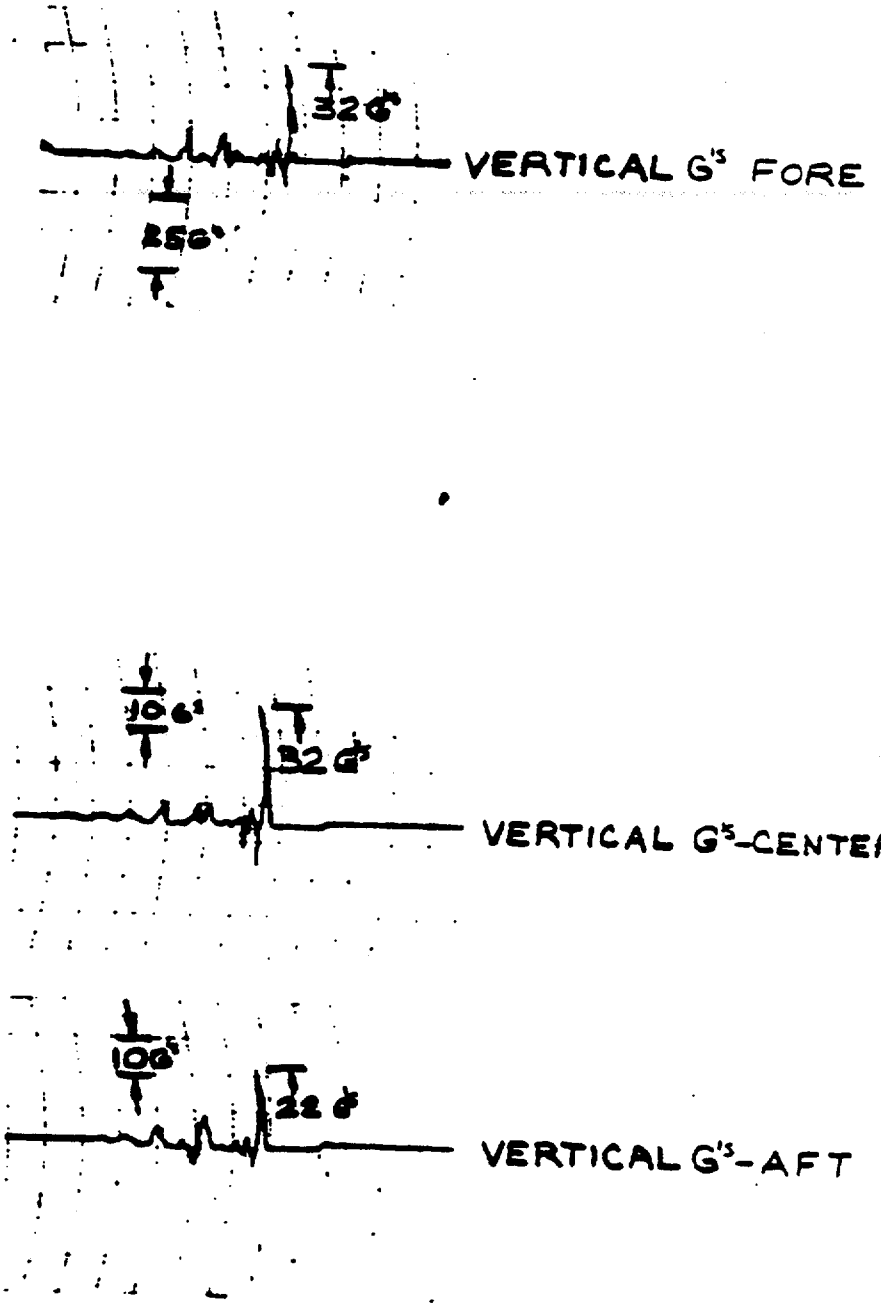
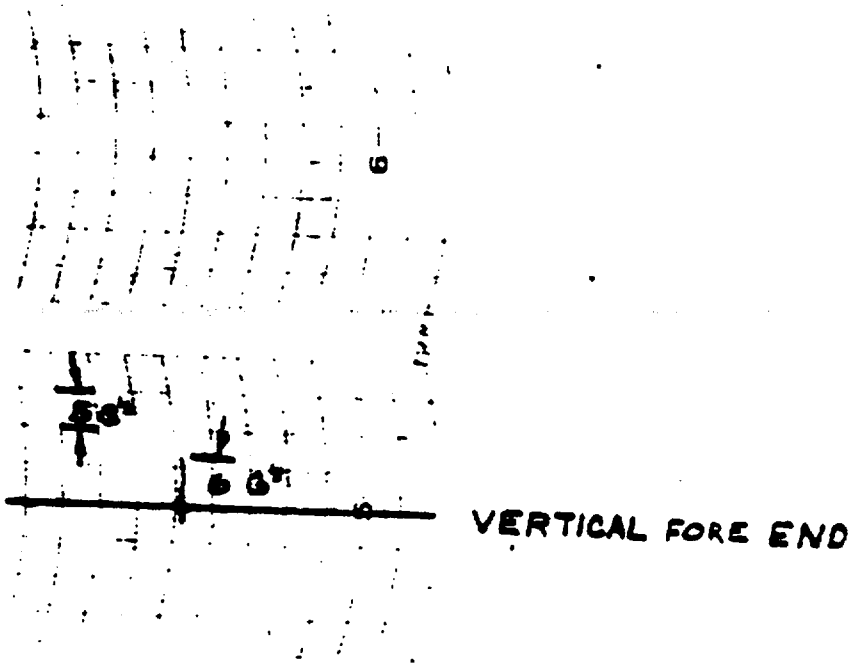


FIG-5
ACCELERATION VS. TIME TRACE
18 INCH FLATWISE DROP
DATE TESTED 1-3-69
MODEL 927A CONTAINER



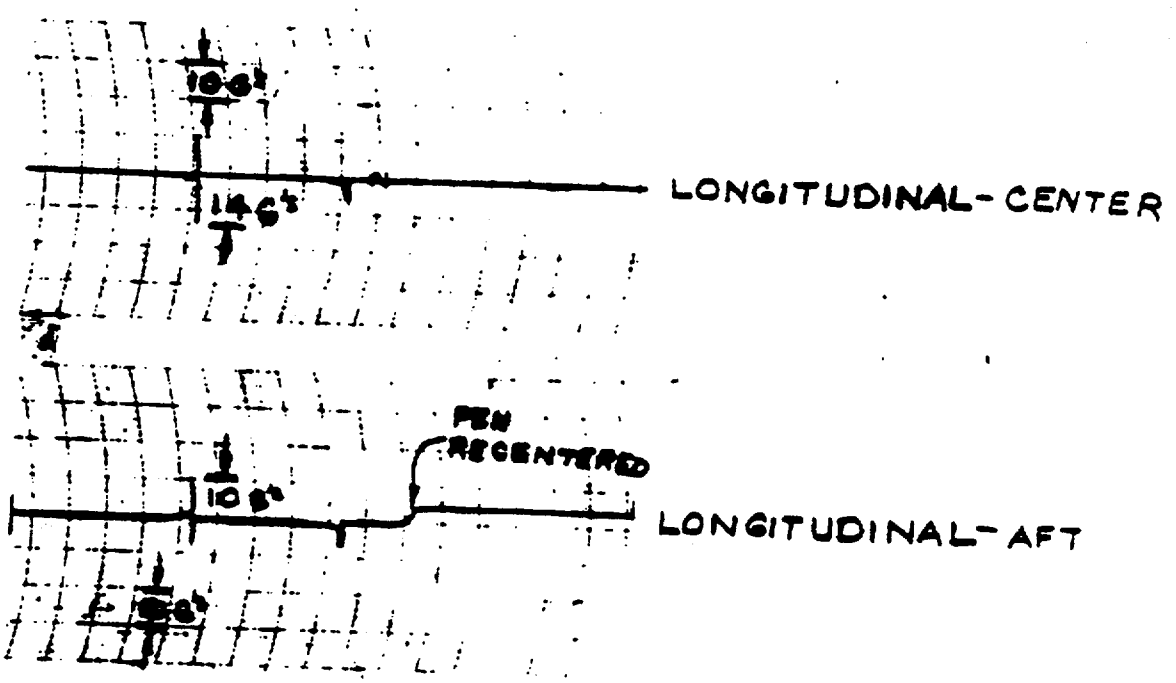


FIG - 6
ACCELERATION VS. TIME TRACE
IMPACT - AFT END
DATE TESTED 1-8-69
MODEL 927 A CONTAINER

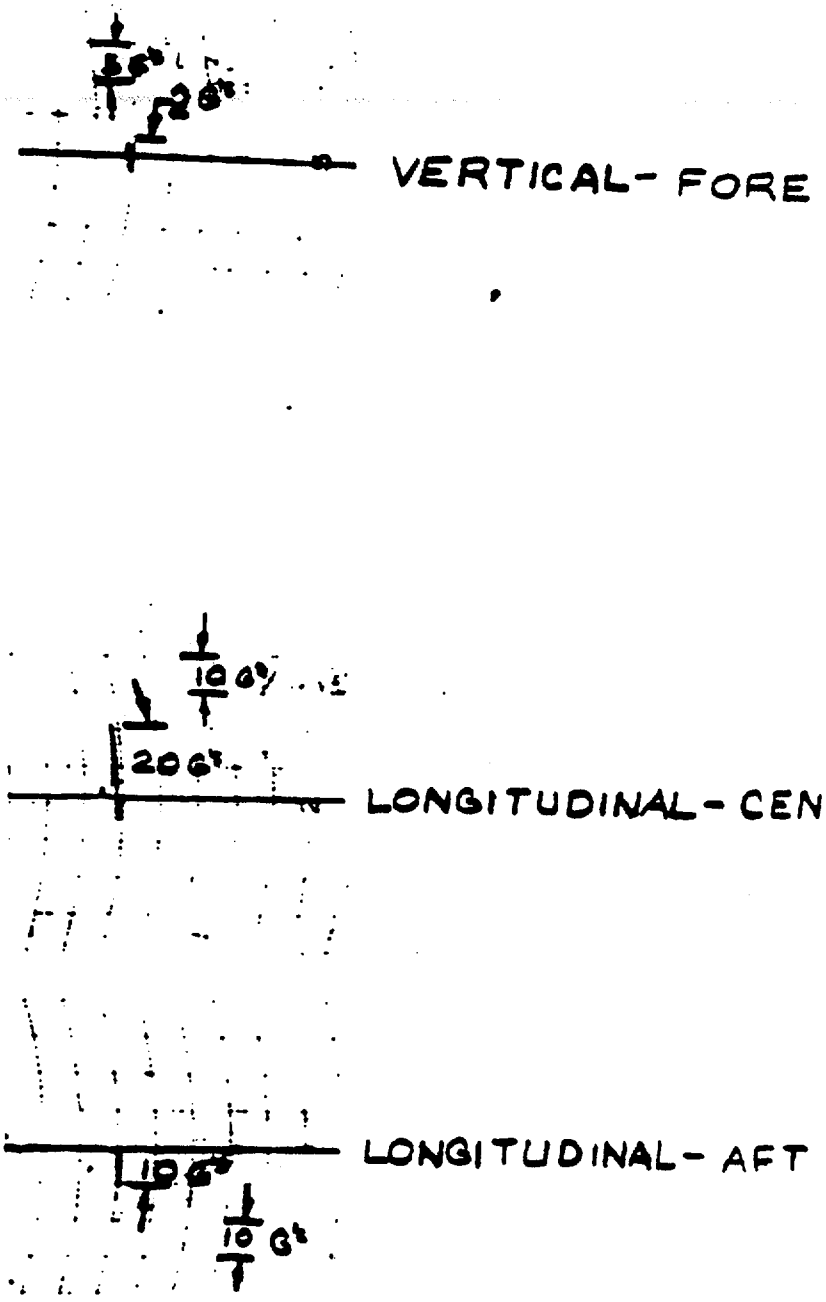
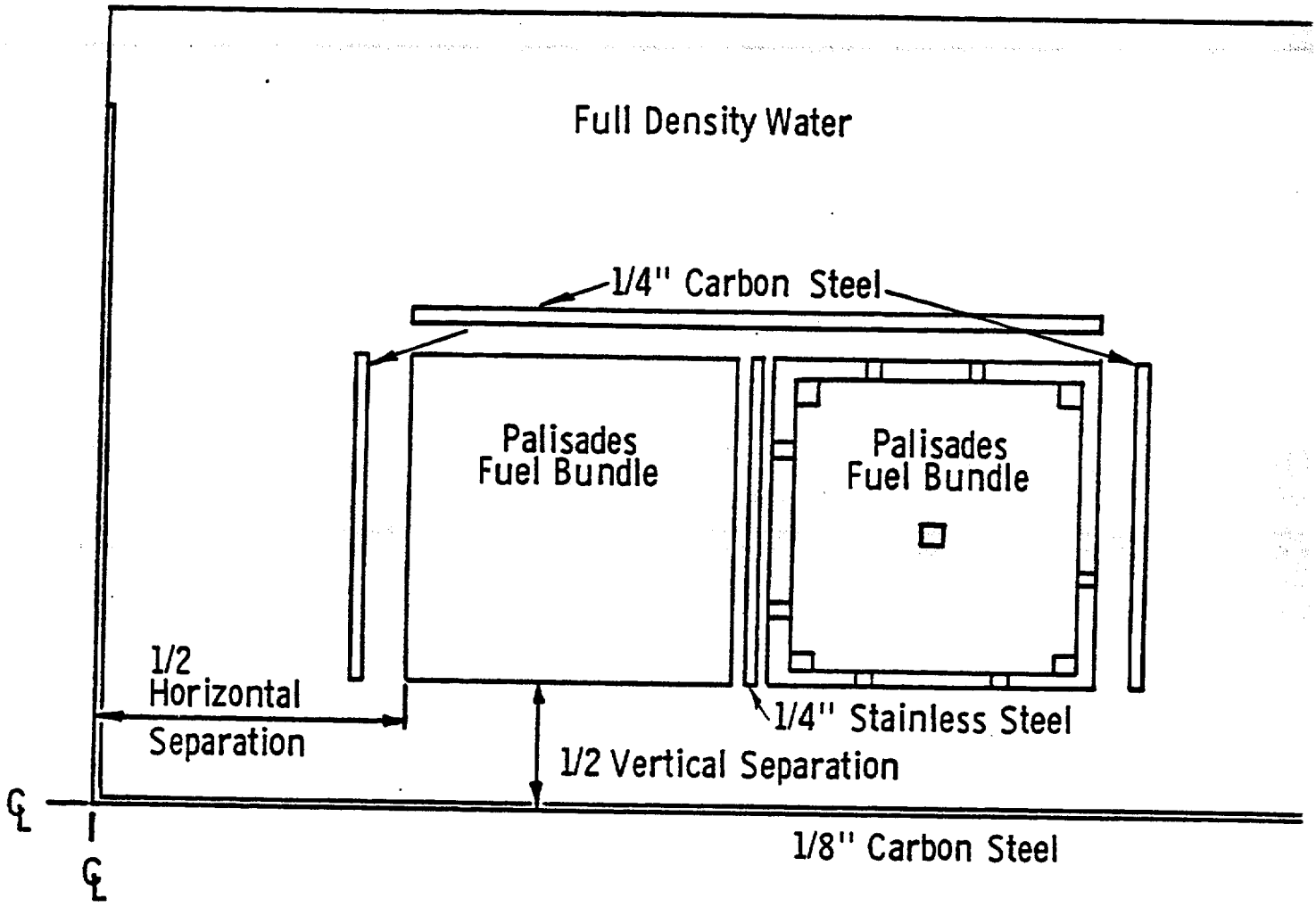


FIG 7
ACCELERATION VS. TIME TRACE
IMPACT - FORE END
DATE TESTED 1-8-69
MODEL 927A CONTAINER



REPRESENTATION OF DAMAGED SHIPPING CONTAINERS WITH PALISADES BUNDLES

Figure XII

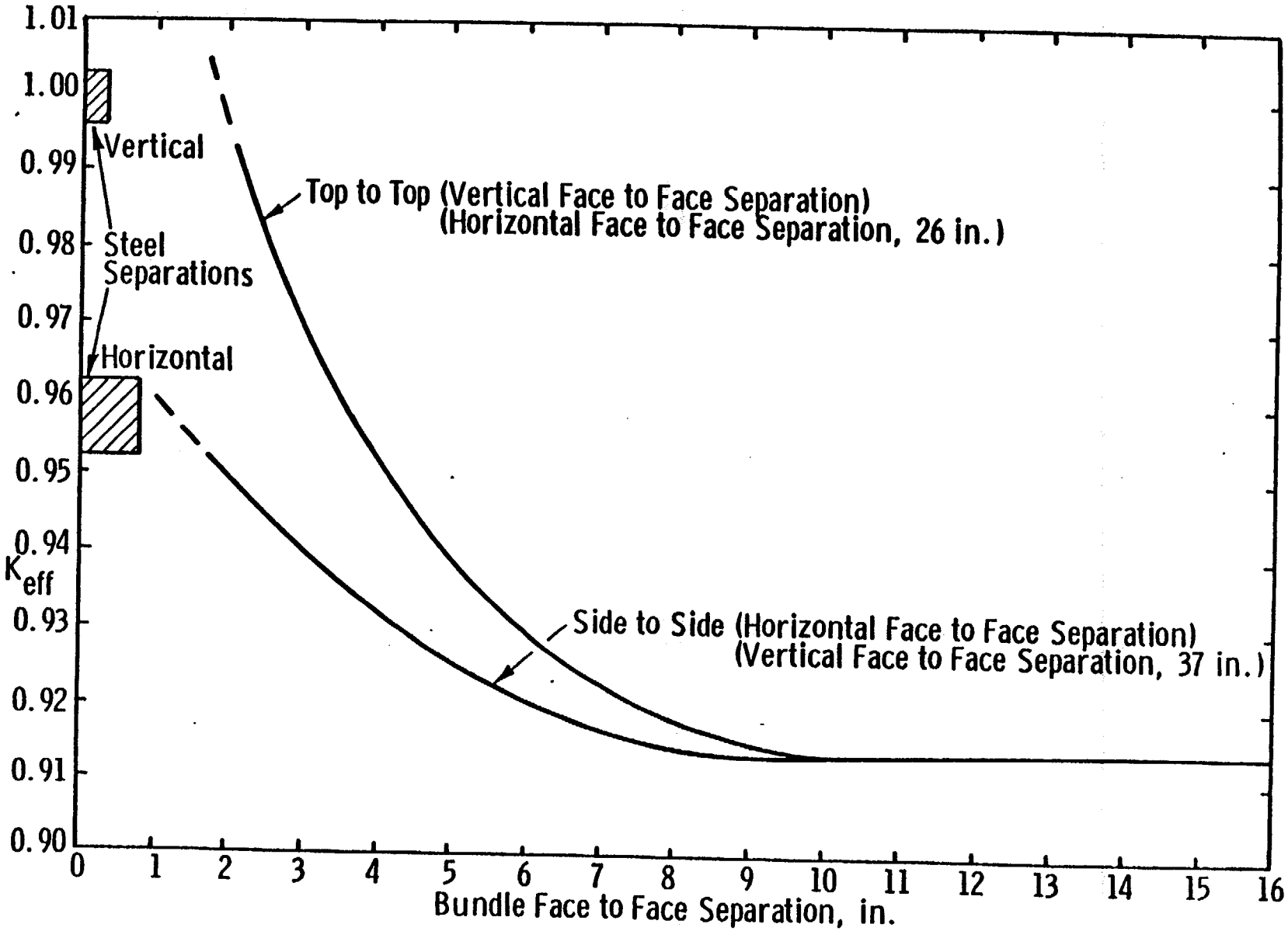


Figure XIII

ACCIDENT CONDITIONS FOR EIGHT SHIPPING CONTAINERS
FULLY FLOODED AT VARIOUS SEPARATIONS OF PALISADES BUNDLES

REFERENCE C

E X H I B I T P

Nuclear Safety Calculations for Fuel Bundle Shipping Containers Under Accident Conditions

Summary and Conclusions

Calculations were performed to determine the nuclear safety of the shipping containers under two accident conditions. The calculation was performed assuming that each of the shipping containers housed two of the most reactive Palisades Fuel Bundles separated by a 1/4 inch thick stainless steel plate. For a top-to-top collapse with twelve inches of water separating the faces of the assemblies the k_{eff} would be 0.914. In the second case the side to side assembly separation was six inches and yielded a k_{eff} of 0.920. In each case it was assumed that the separation in the other direction was at least twelve inches of water. Calculations were also made for varying vertical separations holding the pre-collapse horizontal separation, and for varying horizontal separations holding the vertical separation at the pre-collapse figure.

The case of no damage to the containers under a wide range of moderating conditions has previously been shown to be safe from a criticality viewpoint.

Description

Eight shipping containers each have an effective diameter of about 43 inches and contain two Palisades fuel assemblies each of which have 164 fuel rods of 3.2 w/o U^{235} enrichment and 48 fuel rods of 2.54 w/o U^{235} enrichment. The two fuel assemblies rest side by side on a 1/4 inch steel plate and are separated from each other by a distance of 29/32 inches containing a 1/4 inch stainless steel plate. At the side of the two assemblies is a steel strong-back edge 1/4 inch thick. These containers are arranged in a two by two by two cubic array on the shipping truck.

Representation

The representation is as shown in Figure XII. Full density water one foot thick surrounds the exterior of this infinite length two by two shipping cask array and completely floods the interior including the fuel. While varying the separation in the vertical direction the horizontal separation is set at 26 inches, when varying the separation in the horizontal direction the vertical separation is set at 37 inches.

Results

The resulting k_{eff} as a function of separation are shown in Figure XIII and indicate that for the assumed minimum horizontal separation of six inches with the vertical separation twelve inches or greater the maximum k_{eff} is 0.920.

APPENDIX C

"APPENDIX P-1"
APPLICATION FOR LICENSING OF COMBUSTION ENGINNERING
MODEL 51032-1 SHIPPING CONTAINER, DOCKET 71-6581

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 COMBUSTION ENGINEERING, INC. MODEL 927A SHIPPING CONTAINER, DOCKET 71-6078 LOCATED IN THE NRC PUBLIC DOCUMENT ROOM.