APPLICATION FOR RENEWAL OF
CERTIFICATE OF COMPLIANCE NO. 6294
FOR THE MODEL NO. UNC-2901 SHIPPING PACKAGE

COMBUSTION ENGINEERING, INC.
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1. INTRODUCTION

The UNC 2901 container is designed for shipment of uranium dioxide pellets manufactured, inspected and certified in accordance with reactor fuel specifications. It can also be used for the shipment of dry uranium compounds such as uranium dioxide powder and rejected pellets (hard scrap).

The maximum number of containers per shipment shall be limited to:

Fissile Class I	-	None
Fissile Class II	-	Transport index is 2.0 units per container (Maximum 25 containers for total 50 Transport units per shipment).
Fissile Class III	-	Maximum 50 containers

2. PACKAGE DESCRIPTION

The UNC 2901 container consists of a standard 55 gallon steel drum with a 10 3/4" square inner container centered in the drum. The inner container is centered by hardboard support rings. Asbestos, plywood and fiberlite insulation provide thermal protection to the inner container. The inner container closure is fitted with a gasket capable of withstanding temperatures up to at least 500° F.

Details of contruction and assembly are shown on drawings:

D 5007-8086, Rev. 3
D 5008-8192, Rev. 5
B 5007-8112

2. PACKAGE DESCRIPTION (continued)

2.1 Package for Certified Pellets

The uranium dioxide pellet package consists of corrugated, 22 gauge steel trays coated with a thin rubber or similar soft material. The pellets are aligned in the corrugations with one layer of pellets per tray. The trays are stacked together; a sponge rubber (or similar material) and hardboard or plywood cover is placed at the tip and bottom of the stack. This stack is strapped together to form the pellet package.

For handling purposes, the pellet package may be limited in size such that four packages will fit in the inner container. It is possible, however, for some requirements the tray and package dimensions (A and B on Drawing D 5008-8192) may be varied up to the limits of the inner container such that only one or two packages are required.

2.2 Package for Dry Compounds and Reject Pellets

The uranium dioxide powder package consists of modified re-usable metal drums as per Specification MIL D-5044B, Part No. MS 24347-8. Modifications include: (1) increased depth of 13-1/4 inches, (2) a steel ring added to the top lip of the container, and (3) welding the locking lugs in addition to being riveted.

3. CONTENTS OF PACKAGING

3.1 Certified Pellets

A. Maximum Enrichment 4.1%

B. Type Material: Sintered (high fired) uranium dioxide pellets.

C. Maximum quantity per container:

3. CONTENTS OF PACKAGING

3.1 Certified Pellets (continued)

C.

a) Maximum net weight:

Pellets and packaging material (contents of inner container) 427 pounds.

Maximum net weight of pellets: 320 pounds UO_2 up to 3.75 enriched.

240 pounds UO_2 3.75 to 4.1% enriched.

b) Gross Weight

Gross weight of the container as assembled for shipment shall not exceed 655 ± 5 pounds.

3.2 Dry Compounds and Reject Pellets

A. Maximum enrichment 4.1%

B. Type Material: Uranium Dioxide powder or reject pellets.

a) Maximum net weight:

Powder and packaging material (contents of inner container) 229.5 pounds

Maximum net weight of powder: 220 pounds

b) Gross Weight

Gross weight of container as assembled for shipment shall not exceed 457 ± 5 pounds.

4. STRUCTURAL EVALUATION

The container was subjected to the hypothetical accident test condition in accordance with 10CFR71.36 and 49CFR173.398(c). The actual tests and results are discussed in detail in the report "Design and Structural Evaluation of a Low Enriched UO_2 Pellet and Powder Shipping Package, Model UNC 2901", dated April 1970. (Appendix A).

4. STRUCTURAL EVALUATION (continued)

The container was again subjected to a thirty foot drop test while loaded with the powder drums. The actual tests and results are set forth in the supplement to the above referenced report. The supplement is dated November 1970. (Appendix B).

5. CRITICALITY EVALUATION

5.1 Certified Pellets

The complete nuclear criticality analysis of the containers is reported in NED-1154, "Criticality Safety Analysis of UNC Type 2901 Shipping Container for 4.1 w/o U-235 Yankee Rowe Fuel Pellets". (Appendix C)

A. Individual Container
The individual container is safe with maximum water moderation and full water reflection. Reference NED-1154.

B. Array of Containers

a) Normal Transportation
The hypothetical accident test demonstrated that water cannot enter the inner container. Therefore, the pellets remain dry and moderation is only that provided by the packaging materials. A reflected rectangular array of 144 containers (6 x 6 x 4) has a K_{eff} of approximately 0.85. Reference NED-1154. Applying the standard safety factor (5 for Fissile Class II) the allowable number of containers would be:

Fissile Class II	28 containers
Fissile Class III	56 containers

5.1 Certified Pellets (continued)

b) Accident Conditions

The hypothetical accident test demonstrated that:

1) Water cannot enter the inner container.
2) The total container remained intact.
3) The inner container is not deformed.
4) The pellet/tray package remained intact and in its original assembled configuration.

Therefore, moderation is only as provided by the packaging materials and water interspersed between the inner containers. A reflected rectangular array of 50 containers (5 x 5 x 2) has a K_{eff} of approximately 0.96. Reference NED-1154. Applying the standard safety factor (2 for Fissile Class II) the allowable number of containers would be:

Fissile Class II	25
Fissile Class III	50

c) Based on the above the accident condition is the most restrictive and 25 containers could be shipped safely as Fissile Class II and 50 containers as Fissile Class III.

5.2 Dry Compounds and Reject Pellets

Using the zero rod size data in Appendices B and C, DP-1014, the critical bucklings are smaller than for comparable "lumped" systems with rod sizes equal to or greater than 0.1 inches. Also, the critical masses, volumes, cylinder diameters, and slab widths are larger than for lumped systems. This applies to all enrichments up to and including 5.0%. Therefore, the certified pellets are more reactive than the powder and will be the limiting case. Thus the above listed transport indexes will be used.

6. OPERATING PROCEDURES

Specific operating procedures are followed in loading and unloading the UNC-2901 package. Operating personnel complete a packaging check list which includes inspection of structural integrity and proper closure.

7. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Containers will be fabricated only in accordance with approved drawings and specifications. Source inspections will be performed as appropriate at the vendor's facility. Any changes in design which fall outside of the safety envelope specified in this application will be submitted to NRC for approval. Repair and maintenance will also be performed only in accordance with approved drawings and specifications.

APPENDIX A

UNITED NUCLEAR CORPORATION

INTER-OFFICE MEMO

NED-1154

TO R. Kropp AT DATE April 12, 1971

FROM E. Fass AT COPY TO

SUBJECT Criticality Safety Analysis of UNC Type 2901 Shipping Container for 4.1 w/o U^{235} Yankee Rowe Fuel Pellets (2749-521)

1.0 Summary and Conclusions

An analysis has been performed to determine the criticality safety of arrays of UNC Type 2901 shipping containers. Each container was loaded with 240.0 lbs of 4.1 w/o Yankee fuel pellets according the scheme of UNC drawing D-5008-8192 Rev. 3.

Individual containers were found to be safe for all degrees of internal and external flooding.

Under normal transport conditions, i.e., an inner container $H/U^{235} = 110$ provided by packing materials and no water in the outer container, a safe array contains at least 144 containers in a cubic configuration with full water reflection on all sides.

Under accident transport conditions, the most reactive unit for producing the highest array multiplication factor was determined to be a unit with the inner container flooded and the outer container dry. An array of 50 such units in an approximate cubic configuration with full water reflection on all sides was found to be subcritical.

2.0 Description of Containers

The Type 2901 container is a modification of the UNC Type 2900 shipping container. The modification consisted of replacing the inner cylindrical container with a square container with a 10.75" inside side length.

UO_2 pellets are prepared for shipment by placing the pellets into the grooves of corrugated, polyethylene coated, steel trays. The trays are placed one on top of the other until a convenient handling size is reached (10 layers of pellets maximum). The stack of trays is wrapped with a sheet of gum rubber, sandwiched between two 1/2" hard maple boards and taped together. Four such stacks are assembled into one pellet package which will fit into the inner container, any void volume between pellet stacks is filled by further use of hard maple boards.

3.0 Method of Analysis

Reactivity levels for individual containers and infinite arrays were calculated using the DTF code (1). The 16 group Hansen-Roach cross sections(2) were used and linear anisotropic hydrogen scattering was accounted for in the S4 approximation to the transport equation. The calculational model assumed infinitely long cylinders containing homogeneous mixtures of materials (see Table 1).

Reactivity levels for finite reflected arrays were calculated using the KENO (3) multigroup Monte Carlo criticality code. The 16 group Hansen-Roach cross sections were used and P_1 linear anisotropic hydrogen scattering was used, other nuclei were assumed to scatter isotropically in the laboratory system at all energies. The calculational model for KENO assumed homogeneous regions of materials as in the DTF model but the three dimensional geometry more faithfully describes the shipping container (see Figure 1).

The reactivity of the containers is dependent on the moderating ratio and the pellet dimensions because of the U^{238} resonance captures. The homogenization proceedure for the inner container must take account for this effect by an appropriate choice of the U^{238} cross section set. The nominal pellet OD for the Yankee fuel is 0.3105"; the nominal enrichment is 4.0 w/o U^{235} but in the interest of conservatism an upper limit of 4.1 w/o was used in this analysis. A previous analysis of the reactivity levels of Yankee fuel rods in water (4) has given the effective resonance integral and resonance escape probabilities as a function of moderation ratio (see Figure 2). The code used was UNC's LOCALUX-2 (5), an improved version of the LASER (6) code, which calculates resonance data by the method of Strawbridge and Barry (7). The U^{238} cross section set for both DTF and KENO were determined by the effective potential scattering cross section per resonance absorber atom, i. e., $\sigma_p \equiv \Sigma_p / N_A$. It is determined from the resonance data by:

$$p = e^{-N_A I / \xi \Sigma_p}.$$

$$\sigma_p = \Sigma_p / N_A = - \frac{I}{\xi \ln p}$$

The value of $\bar{\xi}$ is not appreciably affected by the presence of heavy nuclei and it was assumed that could be adequately represented by $\bar{\xi}_{H_2O} = 0.95$, a conservative assumption when the U^{238} cross section set is chosen.

The DTF problems were run in order to determine the most reactive unit in an infinite array and then to use that unit in the KENO investigation of finite arrays. In order to represent infinite arrays of containers in DTF, reflection boundary conditions were applied at the outside of the cell. The DTF problems were run for varying amounts of water in the inner and outer container. The minimum H/U^{235} in the inner container is 113 and is provided by the polethylene, rubber, and wood packing materials. The maximum is 205 and is accomplished by flooding of all available void space and absorption of an additional 0.054 gm/cm^3 by the maple boards(8). The hydrogen concentration in the outer container can range from zero to that of full density water depending on the amount of water absorbed in the Fiberlite. It will be seen however, that the addition of water to the Fiberlite always decreases the reactivity of an array an observation which has been made previously (9).

An investigation of the reactivity level of an individual container was made with DTF assuming full water flooding of the Fiberlite and a zero flux boundary condition at the outside wall.

4.0 Nuclear Safety Evaluation-Normal Transport Condition

Under normal transport conditions, an array of shipping containers was evaluated assuming that the nominal O.D. of each container was 22.6" and 144 containers were arranged in a 6 x 6 x 4 rectangular array. The outside of the array was surrounded by a 15cm thick water reflector. The array shape factor i.e., the array height$/\sqrt{\text{base area}}$, was 1.05. The inner container $H/U^{235} = 113$ is provided by hydrogenous packing material and a $\sigma_p = 100b$ was used for the U^{238} cross section set.

KENO was run for this array for a total of 12,000 neutron histories. The first three batches (or 525 neutron histories) were skipped to minimize initial source effects from the calculation. KENO calculated a $k_{eff} = 0.864 \pm 0.007$ for this array.

5.0 Nuclear Safety Evaluation - Accident Conditions

For the KENO investigation of the accident condition, it was assumed that the containers were damaged such that the other mean diameter is reduced for 22.6" to 21.1", this was determined from drop tests of the 2901 shipping container. (10)

The DTF calculations for infinite arrays were performed for various amounts of water in the inner and outer container, the results of these calculations were shown in Table 2 and Figure 3. The O.D. of the shipping container was maintained at 22.6" since the lattice spacing of fissile units does not alter k for an infinite array. The potential scattering cross section per resonance absorber atom was kept at 100 barns throughout the range of flooding of the inner container. Although σ_p increases to 200 barns for full flooding, switching cross section sets leads to a discontunity in the curves, the overestimate of the k_∞ by DTF at full flooding of the inner container by retaining σ_p=100 barns is approximately 5%. Here we are not interested in an exact estimate of k_∞ but only the individual container configuration which gives the highest k_∞ relative to other configurations. From Figure 3 it is seen that the shipping container with the fueled zone flooded and the Fiberlite dry makes the most reactive array unit.

KENO was run for 50 such shipping containers in a 5 x 5 x 2 array giving an array shape factor of 0.67. Each container had an outer mean diameter of 21.1". Figure 1 indicates that the pellet package does not measure up to the full height of the inner container, the void space between the top of the pellet package and inner container lid was assumed to be filled with water. The array was surrounded on all sides by a 15cm thick water reflector. The U^{238} cross section set designated σ_p=200 barns was selected. KENO was again run for 12,000 neutron histories with the first three batches being skipped in averaging keff. The KENO calculated k_{eff} for this array is 0.955 $\pm$ 0.006.

In a previous study of the Yankee Rowe fuel it was found that the maximum critical buckling occurs at an H/U^{235}=240. It is possible that the containers could be loaded with less fuel or have some pellet rows left empty by workmen, etc, such that, under an accident condition, an inner container H/U^{235}=240 could conceivably be achieved. Therefore, as above, a KENO was run for an array of 50 reflected shipping containers, each with an inner container H/U^{235}=240; the calculated keff was 0.939 + 0.006. Evidently, moving to a more optimum H/U^{235} ratio in the inner container shifted the neutron spectrum such that increased absorptions in the container steel walls decreased the finite array keff.

A final DTF calculation was performed to check the reactivity level of an individual container under optimum moderation and reflection conditions. The inner container $H/U^{235} = 240$ was provided by full flooding and decreased fuel loading of that region. The outer container was also flooded to provide full reflection. The infinite cylinder representation of the 2901 had a DTF calculated k = 0.890. For Yankee fuel of 4.1 w/o at an $H/U^{235} = 240$ the neutron migration area found in a previous study (1) is $34 cm^2$. The estimated unit k_{eff}, assuming an axial reflector savings of 6.5cm, is then:

$$k_{eff} = \frac{k}{1 + B_z^2 \ M^2}$$

$$= \frac{0.890}{1+(0.00158)34} = 0.845$$

E. Fass

EF:ah
attachments

REFERENCES

1. Carlson, B. G., et. al., DTF Users Manual, United Nuclear Corporation, UNC Physics Math 3321, Vol. 1 (November 1963); Vol. II (May 1964).

2. Hansen, G.E., and Roach, W.H., "Six and Sixteen Group Cross Section for Fast and Intermediate Critical Assemblies", LAMS-2543, Los Alamos Scientific Laboratory (December 1960).

3. Whitesides, G.E., and Cross, N.F., "KENO-A Multigroup Monte Carlo Criticality Program", CTC-5, Union Carbide Corporation, Nuclear Division, Computing Technology Center, Oak Ridge, Tennessee, (September 1969).

4. Fass, E., "Criticality of Yankee Fuel Rods During Pickling and Corrosion", United Nuclear Corporation, UNC Memo NED-1083, (February 1971).

5. Fiscella, J.M., "LOCALUX-2 Program Description - Revision 3 of Physics Math 5201", United Nuclear Corporation, UNC Memo NED-725, (July 1970).

6. Poncelet, C.G., "LASER, a Depletion Program for Lattice Calculations based on MUFT and THERMOS", WCAP-6073, (1966).

7. Strawbridge, L.E., and Barry, R.F., "Criticality Calculations for Uniform Water-Moderated Lattices", Nuclear Science and Engineering, Vol. 23, No. 1 (1965).

8. Strong, Ralph K, editor, Kingzett's Chemical Encyclopedia, Bailliere, Tindall and Cox, London, 8th edition (1952).

9. Fass, E., and Tomonto, J.R., "Criticality Safety Analysis of UNC Type 2901 Shipping Container for UO_2 Pellets", United Nuclear Corporation, UNC Memo NED-550 (April 1970).

10. Personnel Communication with L. Swallow, United Nuclear Corporation, Hemitite Missori, March, 1970.

Table 1
DTF Calculational Model

Region	Material	Outer Radius, cm	Components and Number Density
1	UO_2, steel trays, gum rubber, maple boards, polyethylene	15.405	N_{U235} = 0.00020467 N_{U238} = 0.0047272 N_{Fe} = 0.0054935 N_C = 0.013705 N_H = 0.023207 N_O = 0.012455
	Interspersed water (when present)		N_H, N_O variable, 0.0 to 0.01866 (N_H), 0.009333 (N_O)
2	Steel inner container wall	15.619	N_{Fe} = 0.08359
3	Fiberlite insulating material	28.575	N_{Na} = 0.000026 N_{Al} = 0.000026 N_O = 0.000199 N_{Ca} = 0.000013 N_{Si} = 0.000079
	Interspersed water (when present)		N_H, N_O variable, 0.0 to .06686 (N_H), .03343 (N_O)
4	Steel outer container wall	28.697	N_{Fe} = 0.08359

Table 2

DTF Calculated Multiplication Factors for an Array of 2901 Containers, Each Loaded with 240 lbs of Yankee Rowe Fuel Pellets as a Function of the Amount of Water in the Fuel and Fiberlite Regions

H/U^{235} = 113 in inner container

Outer container H (atoms barr-cm)	k_∞
0.0	1.199
0.003764	1.148
0.007762	1.052
0.01199	0.962

H/U^{235} = 136 in inner container

Outer Container H	k_∞
0.0	1.235
0.003764	1.175

H/U^{235} = 159 in inner container

Outer Container H	k_∞
0.0	1.259
0.003764	1.199
0.007762	1.113
0.01199	1.033

H/U^{235} = 182 in inner container

Outer Container H	k_∞
0.0	1.278
0.003764	1.217

H/U^{235} = 205 in inner container

Outer Container H	k_∞	k_∞ ($\Sigma p/NA = 200$ barns)
0.0	1.290	1.230
0.003764	1.230	1.181
0.007762	1.154	1.109
0.01199	1.089	1.049

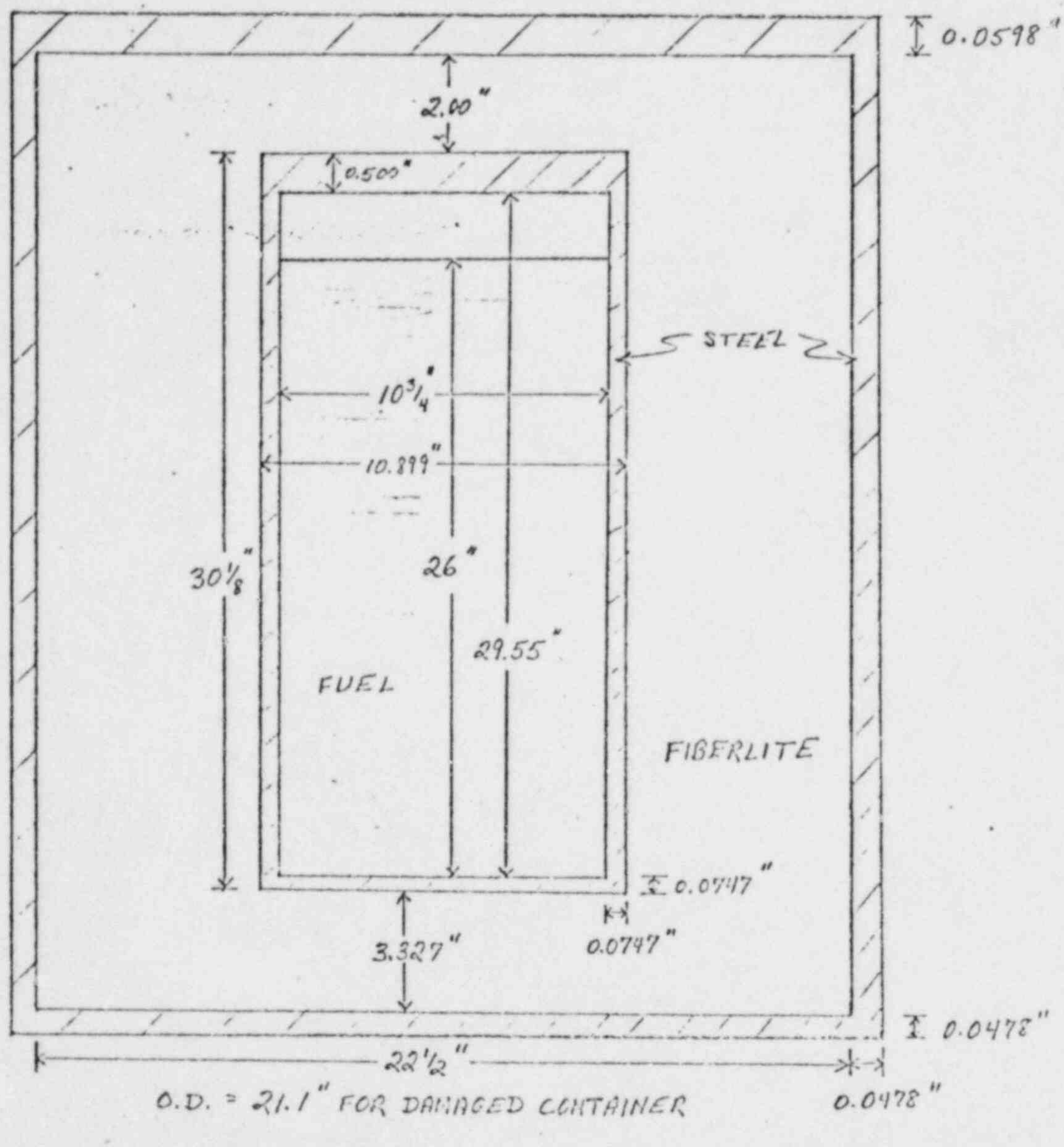


FIGURE 1

The UNC Type 2901 Shipping Container
as Represented in KENO Calculations

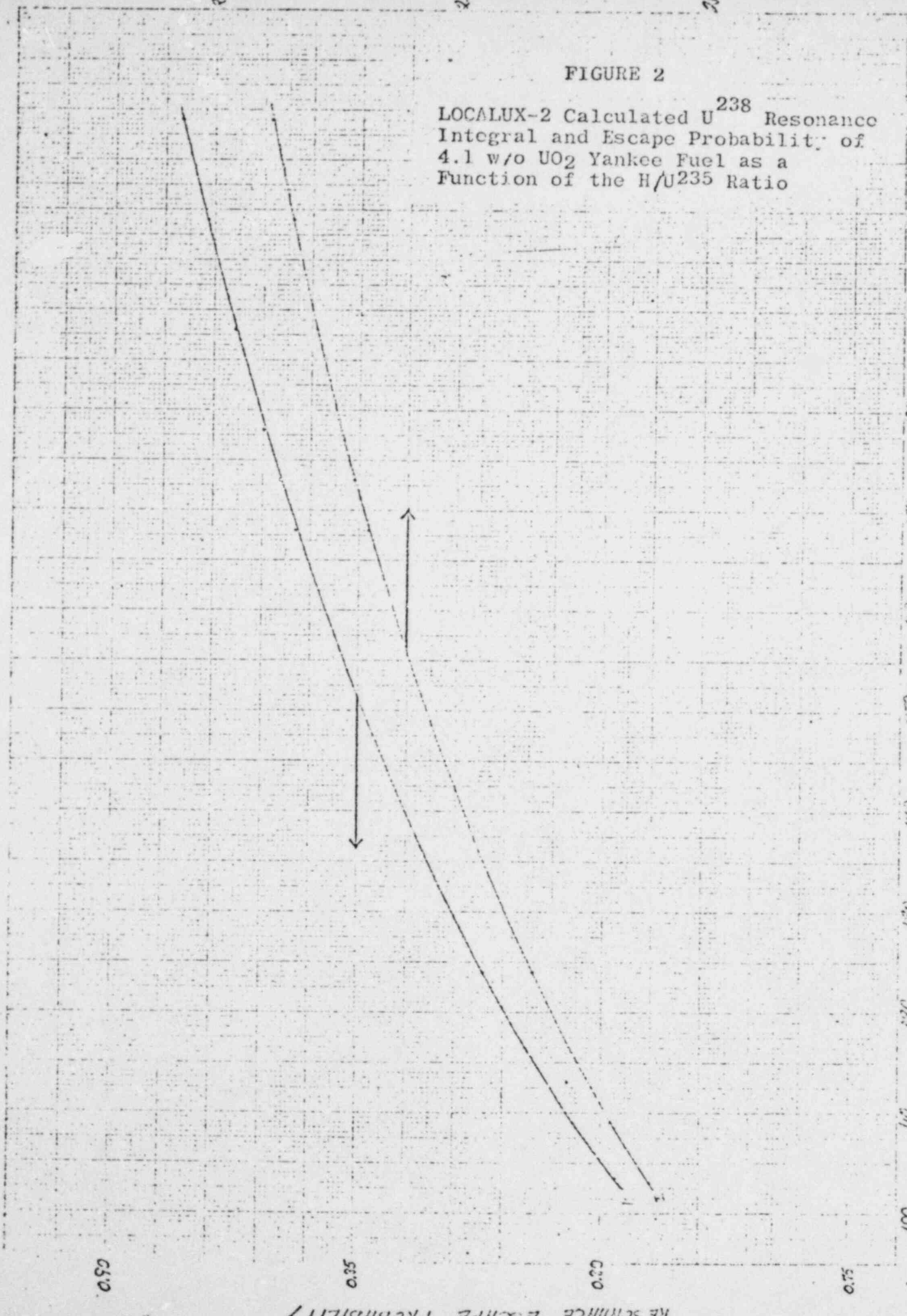


FIGURE 2

LOCALUX-2 Calculated U^{238} Resonance Integral and Escape Probability of 4.1 w/o UO_2 Yankee Fuel as a Function of the H/U^{235} Ratio

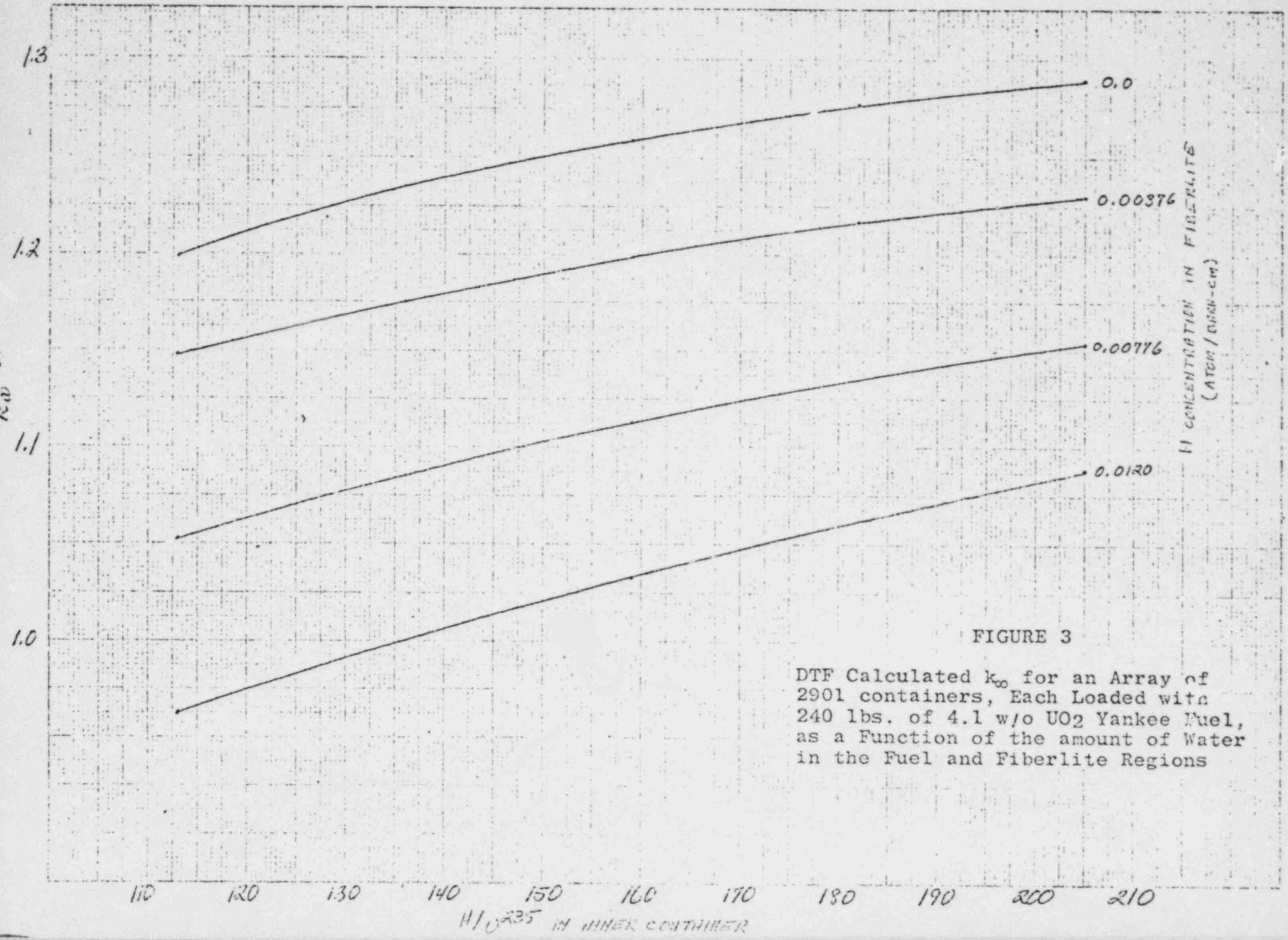


FIGURE 3

DTF Calculated k_∞ for an Array of 2901 containers, Each Loaded with 240 lbs. of 4.1 w/o UO_2 Yankee Fuel, as a Function of the amount of Water in the Fuel and Fiberlite Regions

APPENDIX B

DESIGN AND STRUCTURAL EVALUATION OF A LOW ENRICHED UO_2 PELLET AND POWDER SHIPPING PACKAGE

1.0 SUMMARY

A shipping package was designed for shipment of low enriched UO_2 pellets and powder. The package consisted basically of a square metal inner container supported and insulated inside an $\sim$55 gallon steel outer drum. Pellets were packaged inside the inner container on Polyethylene coated corrugated trays. The shipping package was subjected to a series of drop, fire, and water tests to evaluate its structural stability. The results indicated that a structurally sound, fire-proof, leak resistant package had been developed.

2.0 DESCRIPTION OF SHIPPING PACKAGE

Details of the shipping container and pellet package are illustrated on the attached drawings #D-5007-8086, Revision 1 and D-5008-8192, Revision 2. The shipping container is to be identified as a UNC Model 2901.

The basic components of the shipping package are:

1. A 10.75" square inner container with a 1/2" thick flange and cover.

2. Twelve 1/2" diameter bolts securing the cover to the flange.

3. A full-faced 1/8" thick asbestos gasket on the inner container.

4. Three 1-1/2" thick hardboard support rings.

5. Angle iron welded completely around inner container for securing the hardboard.

6. A 1/8" thick asbestos sheet on top and bottom of outer drum.

7. 1" Thick plywood on bottom and 1-1/4" thick plywood on top of drum.

8. Fiberlite insulation, .75#/ft.^{3}, between inner and outer container.

2.0 Description of Shipping Package (continued)

The pellet package consisted of Polyethylene coated corrugated metal trays encased in gum rubber and hardboard as shown on the aforementioned drawings. The pellet loaded trays were held in compression and securely banded to insure no movement of pellets. The exact size and UO_2 capacity is dependent on the pellet diameter. The packaging design allows for one or more individual packages inside the inner container with the overall size not exceeding the 10.75" square.

3.0 STRUCTURAL EVALUATION

3.1 Conditions

The shipping package was subjected to the hypothetical accident conditions of the tests specified in 10 CFR 71.36 and 49 CFR 173.398(c). Tests were conducted at two different loading levels. One package of depleted pellets, assembled as shown on drawing number D-5008-8192 Revision 2, and three lead-filled wood boxes comprised the test load for Test #1. The second test was performed at a greater loading, but with only the lead filled boxes. The weight conditions tested were as follows:

	Test #1	Test #2
Tare Weight (Assembled Container Without Product Packages)	231 Lbs.	228 Lbs.
Net Weight (Pellets & Packaging)	313 "	427 "
Equiv. Pellet Weight	227 "	302 "
Equiv. Pellet Packaging Weight	86 "	125 "
Total Gross Weight	544 Lbs.	655 Lbs.

3.2 Discussion of Results

Pictures of the package in its various stages of assembly and test are included in the Appendix of this report.

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.1 Thirty Foot Drop Test

Conditions - The impact of the 30 foot drop was designed to occur at approximately 45° on the top corner of the drum aligned with a corner of the square inner container. The selected corner for the first test condition was the corner containing the actual pellet package. These conditions were chosen as the most severe for the following reasons:

1. Experience from the same tests performed on other packages indicated that maximum damage occurs from angular impact.

2. Impact on the top end was most likely to break loose the outer drum lid and expose the inner container during the fire and water tests.

3. Impact on the top end subjected the flange of the inner container to the maximum force and the seal on the gasket to the greatest potential for destruction.

4. The weld on the bottom plate was evaluated to be stronger than the parent metal, therefore, the point of failure from dropping on the bottom would have been the sides of the inner container. By dropping on the top corner, the sides were subjected to the same load and equal conditions existed.

5. The corners of the square insert had the least support. Therefore, impact at this point was directly on the weakest member.

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.1 Thirty Foot Drop Test (continued)

6. Striking at an angle caused a greater rebounding effect and a minimum degree of support surface. (i.e., the top corner hit first and then the bottom as opposed to a single flat hit on side or end only.) A flat hit would allow an equal support distribution by the hardboard, plywood, cushioning, etc. and eliminate a greater concentrated force on one point.

7. The pellet package was subjected to brunt of impact from both the initial hit and the weight of the three simulated packages atop it.

Results - The damage to the outer drum for Test #1 (544 lbs.) is depicted in picture 3. The decrease in drum diameter as a result of impact was a maximum of 1-1/2" on the top corner. The small hole just below the lid retainer ring was inflicted by a small bolt which had been tied to a measuring cord used to verify the 30 foot height.

Damage to the plywood and hardboard supports for the inner container was not detrimental. The two 1" thick plywood disks encasing the inner container flange cracked on the corners but remained in position. The bottom hardboard support broke on three corners and the middle hardboard broke on the corner of impact. However, all pieces stayed in place and there was no warpage or shifting of the inner container. (See pictures 11, 13, 14, 17 and 18.) The hardboard supports remained bolted to the angle iron and all welds between the inner container and angle iron were sound. All flange bolts were in tact and securely tightened. There was no deformation of the flanged closure.

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.1 Thirty Foot Drop Test (continued)

The condition of the drum in Test #2 (655 lbs.) is shown in picture 3A. The outer drum deformed ~2" in diameter at the point of contact only, but otherwise showed no significant damage. Since the pellet package proved to uphold its tray-pellet-tray arrangement in the first test, it was not necessary to re-evaluate its stability and, therefore, the load was composed solely of lead-filled boxes.

As was the case for Test #1, a few of the plywood and hardboard supports cracked but no damage occurred to the inner container. (See pictures 5B, 5C, 5D and 5E) All welds and bolts remained in tact and there was no shifting of either the inner container or the supports. The increased loading had no significant effect on the integrity of the inner container following the drop test.

3.2.2 Piston Drop Test

Conditions - For both loading conditions, the drum was dropped 5 ft. on to a 6" diameter x 8" long concrete piston. In Test #1, the point of impact was approximately midway between the center and upper hardboard support. This location was selected to determine if the outer drum would puncture and permit the piston to penetrate to the inner container. For Test #2, the selected impact point was directly on the center hardboard. This condition was evaluated to determine if the direct impact on the hardboard would drive it inward and deform the inner container.

Results - The condition of the outer drum after the piston drop for Tests #1 and #2 is shown in pictures 5 and 5A. In Test #1, a semi-circular hole was punctured through the outer drum in line with a corner of the inner container. No insulation or support material was lost through the hole and no damage was incurred by the inner container.

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.2 Piston Drop (continued)

For Test #2 (Picture 5-A), the piston hit directly on the hardboard and only a small hole, ~1/2" in diameter, was punctured in the outer drum. The hardboard was broken and chipped away for approximately a 3" x 2" area, but not completely through to the inner container (pictures 5C and 5D). The inner container suffered a minor crease ~1/32" high and 3" long at the point where the hardboard was supported against the insert. The inner container suffered no major damage and remained in its original position.

3.2.3 Fire Test

Conditions - The fire test was conducted using diesel fuel fed through piping manifolds placed lengthwise down each side of the shipping package. The flame was directed upward so it engulfed sides, top, and bottom of the package. The location and condition of the package before, during and after the fire test is shown in pictures 6, 7, and 8. The shipping package was placed with the punctured hole facing upward on a grated metal framework ~6" above the ground. The flame temperature as read on an optical pyrometer was in excess of 1650°F throughout the 30 minute test. It is probable that the flame was well above this, as intense black smoke tended to bias the reading low.

The fire test was conducted only for the Test #1 loading condition. Since the extra loading had no significant effect on the package condition after drop and piston testing, the parameters of the fire and water test were identical for both cases. Therefore, the fire and water test results of Test #1 were also applicable for the loading condition of Test #2.

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.3 Fire Test (continued)

Results - Pictures 9-18 illustrate the condition of the shipping package after all the tests were completed. As shown in picture 9, the 1/8" thick asbestos sheet and top 5/8" thick plywood were completely charred. The remaining plywood disks, pictures 10 and 11, were charred only around the edges, from 2-4 inches radially inward for the outermost piece and 3/4" to 1" for the inner disk. The uniform burn completely around the perifery of the plywood indicated an even heat distribution throughout the package. The hardboard was charred slightly as indicated in pictures 12-16, but no substantial loss in strength resulted. Similar results were found on the bottom.

As shown in picture 13, the Fiberlite insulation was charred radially inward from the outer container for approximately 2 inches. However, the insulation in contact with the inner container was unimpaired. The temperatures reached on the inside wall of the inner container are indicated in figure 1, page 9. The temperature template on the underside of the container during the test registered 180°F. A template on the top side during the test showed that portion of the container reached 200°F. (These temperatures verify that the heat was well distributed from top to bottom.) This temperature range had no detrimental effect on the Ethafoam cushioning inside the inner container. Pictures 15 and 16 show the undamaged condition of the cushioning. The asbestos flange gasket and pellet package were undamaged by the fire test; which is very apparent in Picture 15.

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.4 Water Immersion Test

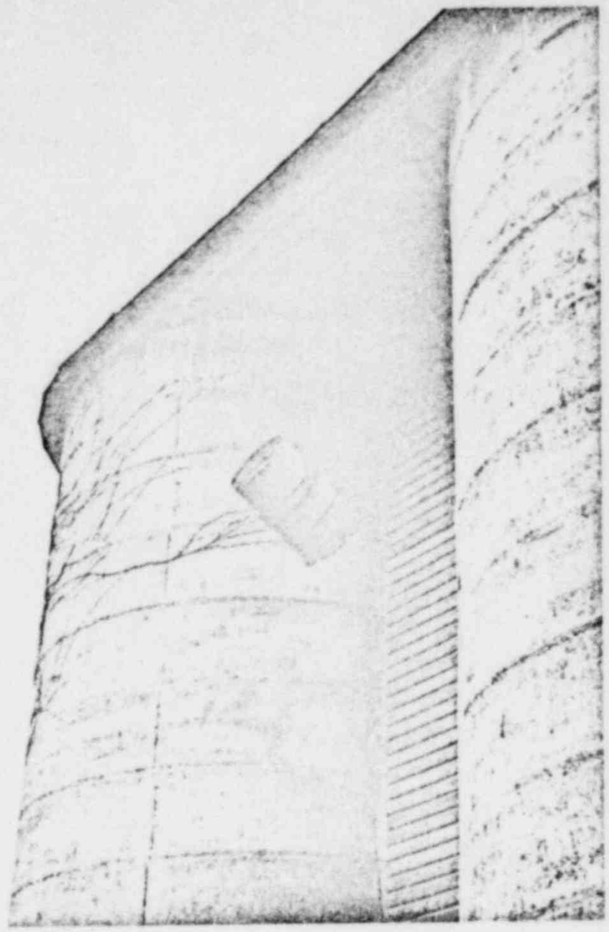
Conditions - The drum was immersed in the horizontal position so that a minimum of three feet of water completely covered the shipping package.

Results - Since the outer container had been punctured in the piston drop, the outer drum was thoroughly flooded. However, the inner container did not show any evidence of leakage after immersion for 8 hours. Some of the Ethafoam cushioning material had been crimped under the asbestos gasket during assembly, but even so, no leakage occurred. Pictures 17 and 18, which were taken immediately after the water test, show no evidence of leakage.

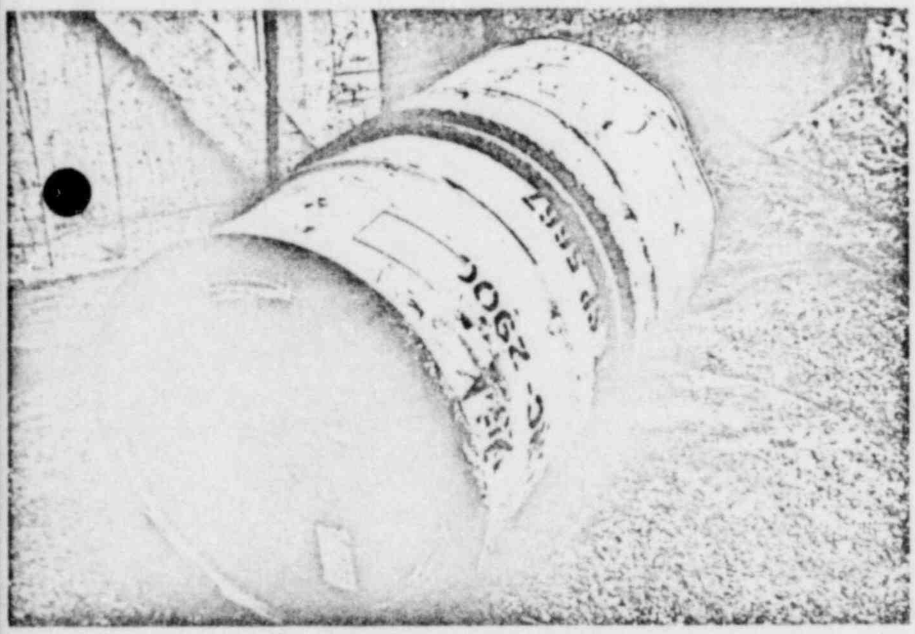
3.2.5 Condition of Pellet Package

The condition of the inner container contents after completion of the tests is shown in pictures 16-22. Although about 25% of the pellets were cracked or broken, (picture 22), the pellet package remained in tact, (Pictures 19 and 20), and less than 1/2% of the pellets became dislodged (picture 21). Picture 19 shows the ends and center of the trays crimped together where the hardboard supports were located. The general condition of the pellet package was "good" with the pellet-tray arrangement remaining unchanged from the original assembled configuration. Picture 23 shows the loaded pellet trays before assembly. Picture 22 shows the same general configuration after completion of the tests. All four packages remained in the exact position in which they were loaded (picture 15) and the inside of the inner container was not damaged in any manner.

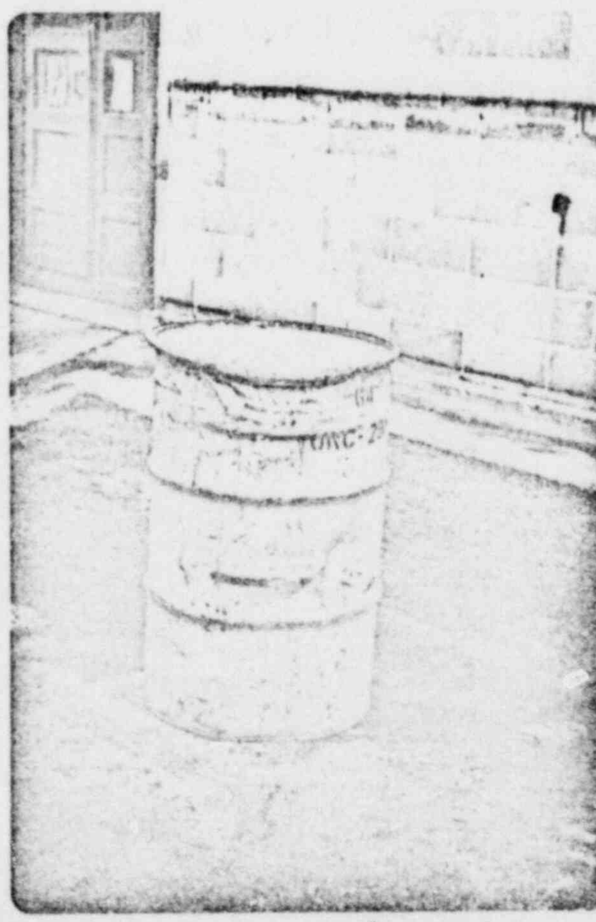
PICTURE 1 — ASSEMBLY OF SHIPPING PACKAGE FOR TEST #1



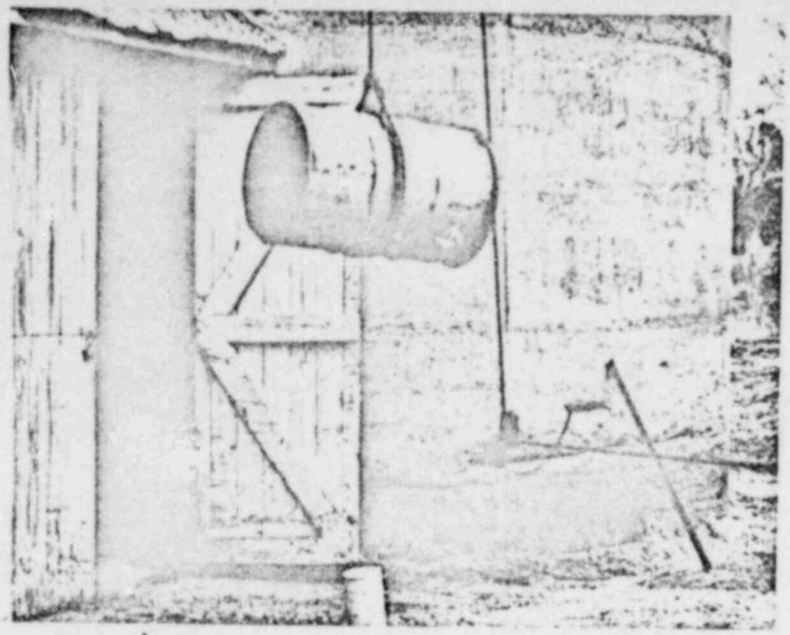
PICTURE 2 — SHIPPING PACKAGE IN UPPER POSITION FOR 30' DROP TEST.



PICTURE 3 — CONDITION OF OUTER DRUM AFTER 30' DROP TEST — (TEST #1)



PICTURE-3A — CONDITION OF OUTER DRUM AFTER 30' DROP TEST - (TEST #2) →

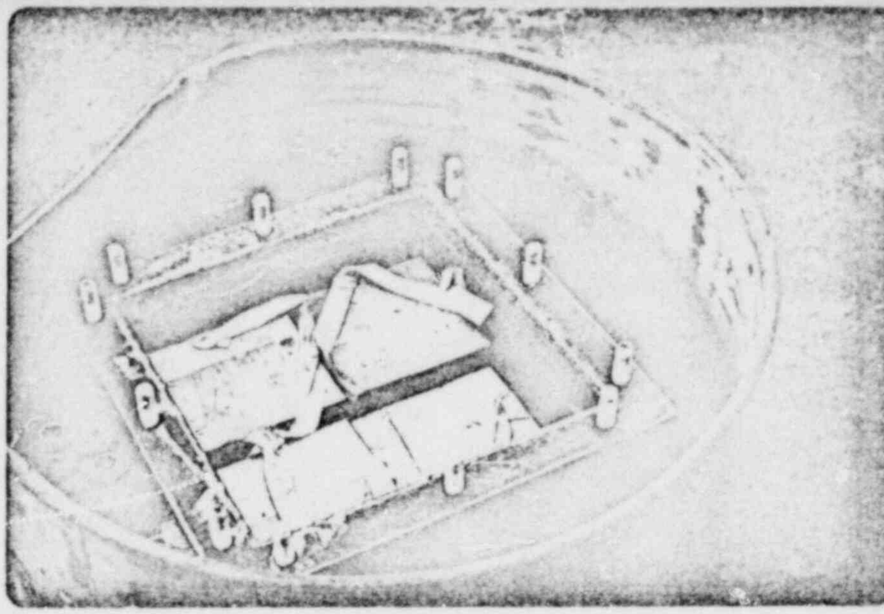


PICTURE-4 — SHIPPING PACKAGE IN UPPER POSITION FOR PISTON DROP

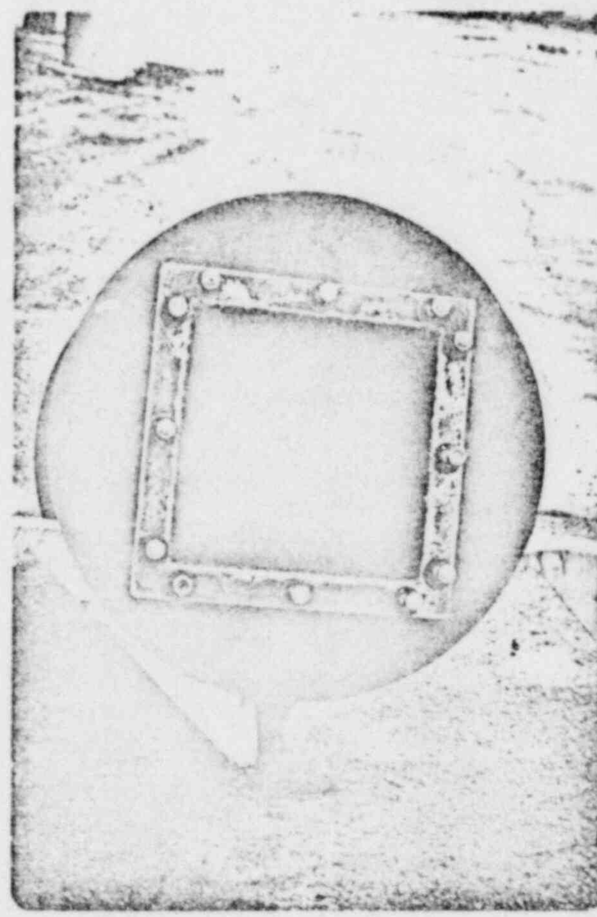
PICTURE-5 — CONDITION OF DRUM AFTER PISTON DROP — (TEST #1)

PICTURE-5A — CONDITION OF DRUM AFTER 30' DROP + PISTON DROP — (TEST #2)

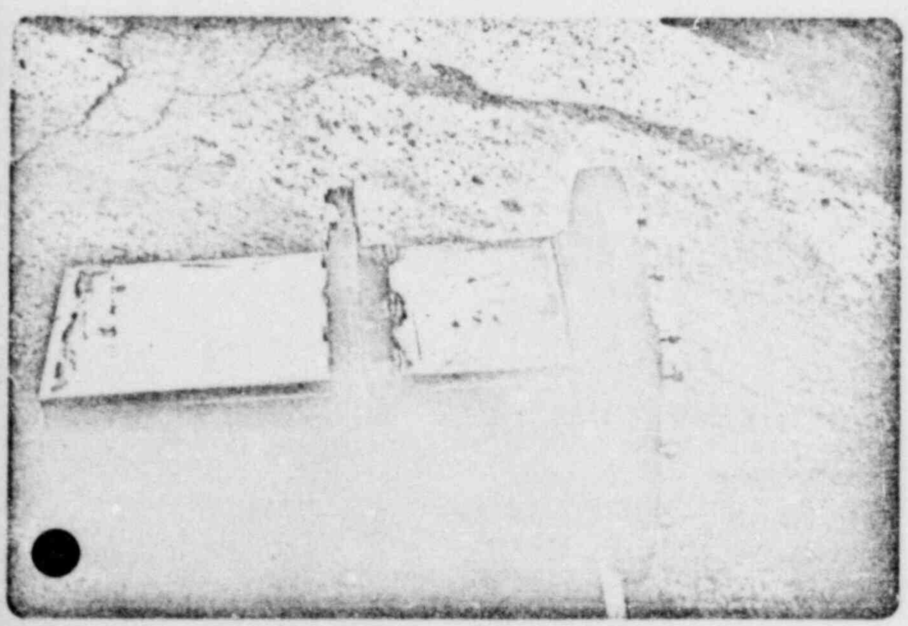
PICTURE-5B – CONDITION OF FLANGE–AFTER 30' DROP & PISTON TEST – (TEST #2)



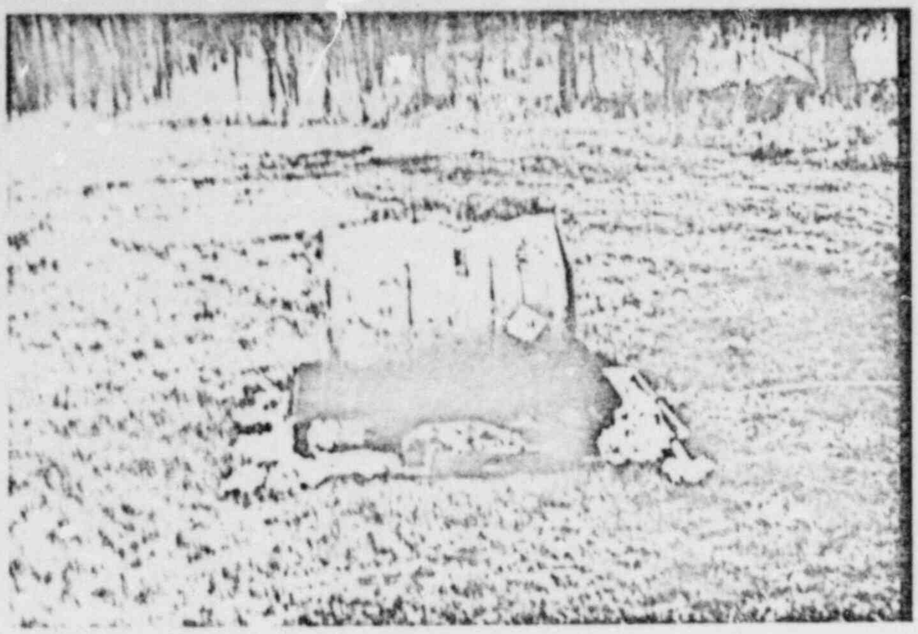
PICTURE-5C – CONDITION OF INNER CONTAINER & HARDBOARD AFTER 30' DROP & PISTON TEST – (TEST #2)



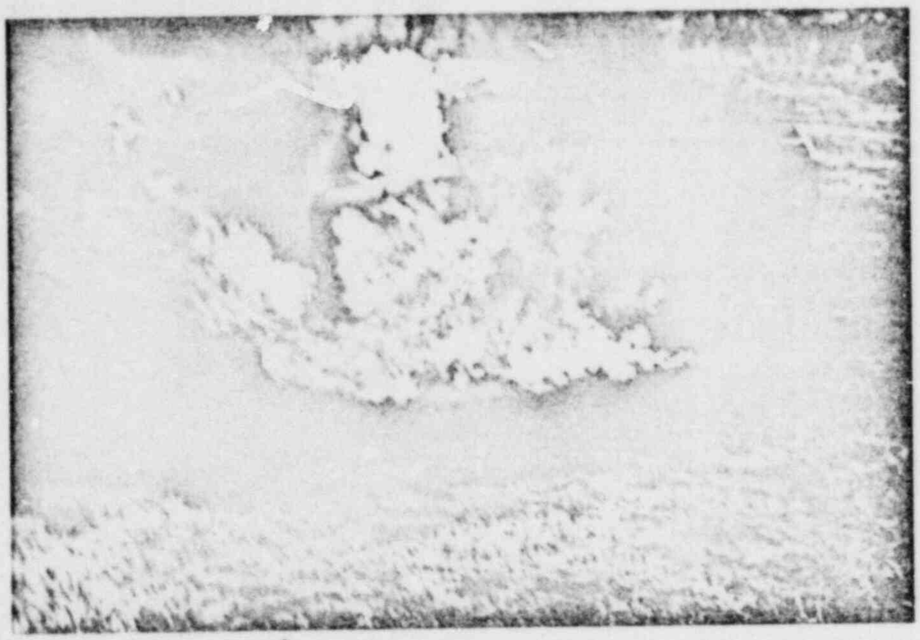
PICTURE-5E – VIEW INSIDE INNER CONTAINER AFTER 30' DROP & PISTON TEST – (TEST #2)



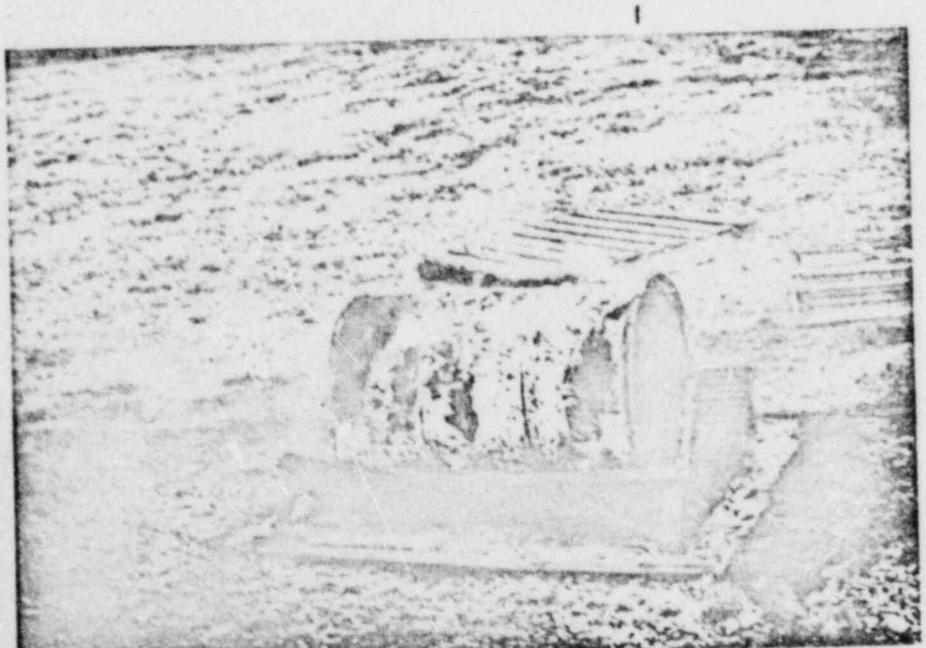
PICTURE-5D – CONDITION OF INNER CONTAINER AFTER 30' DROP & PISTON TEST – (TEST #2)



PICTURE - 6 — SHIPPING PACKAGE IN POSITION FOR FIRE TEST.

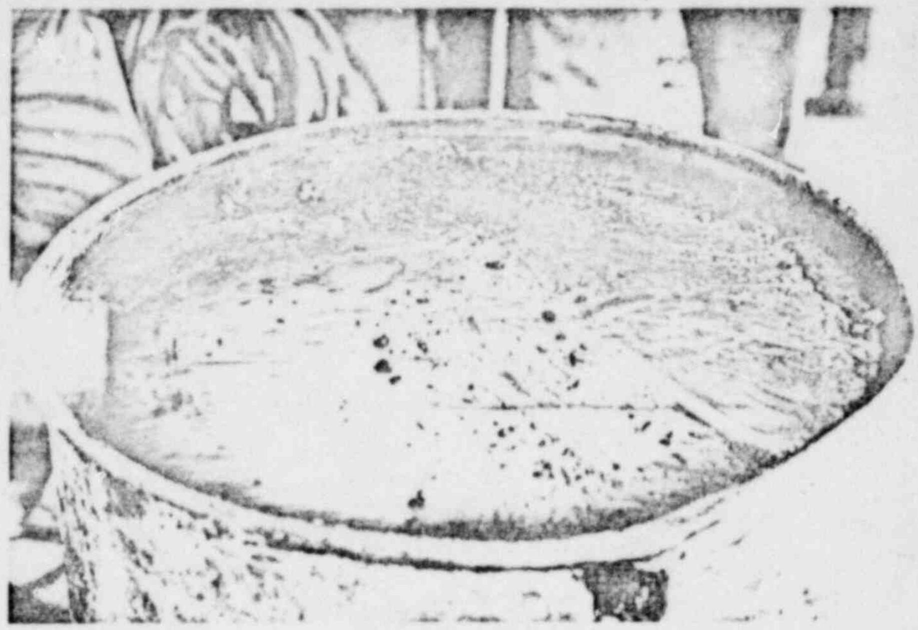


PICTURE - 7 — SHIPPING PACKAGE ENGULFED IN FLAMES DURING FIRE TEST.



PICTURE - 8 — CONDITION OF OUTER DRUM AFTER FIRE TEST.

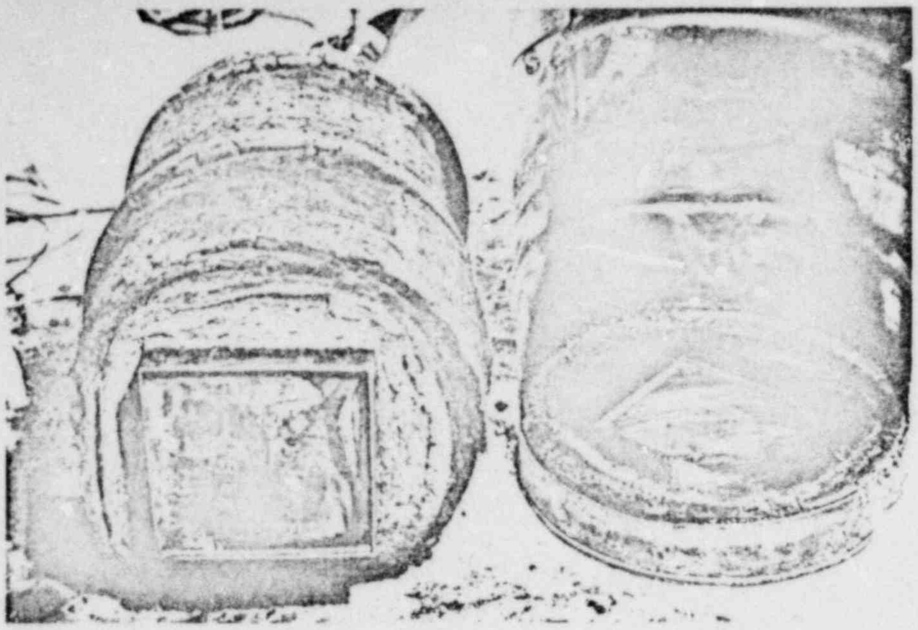
PICTURE-9 — CONDITION OF ASBESTOS AND TOP PLYWOOD SHEET AFTER FIRE & WATER TEST.



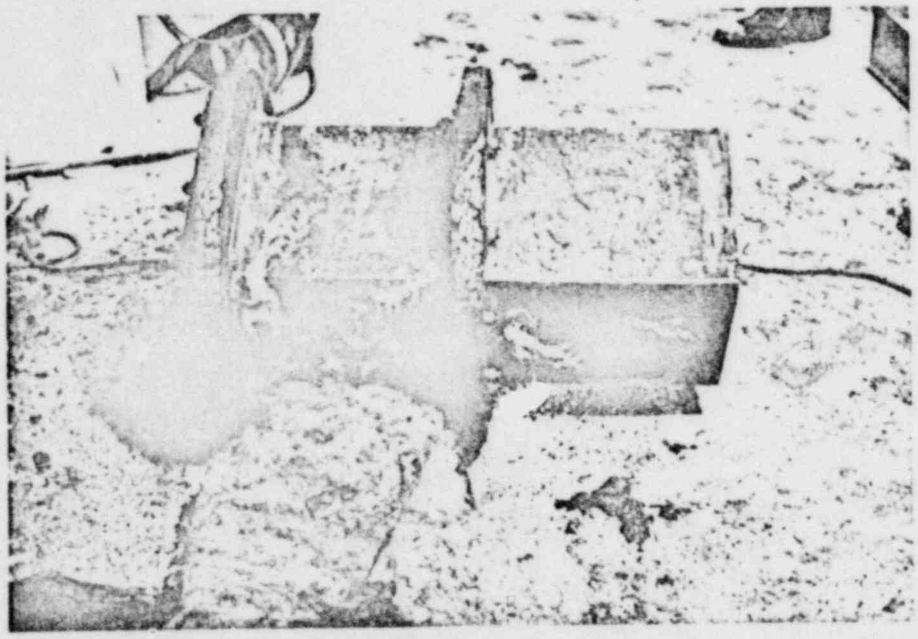
PICTURE-10 — CONDITION OF 2ND PLYWOOD SHEET AFTER FIRE & WATER TEST.

PICTURE-11 — CONDITION OF FLANGE COVER & PLYWOOD DISK AROUND FLANGE AFTER FIRE & WATER TEST.

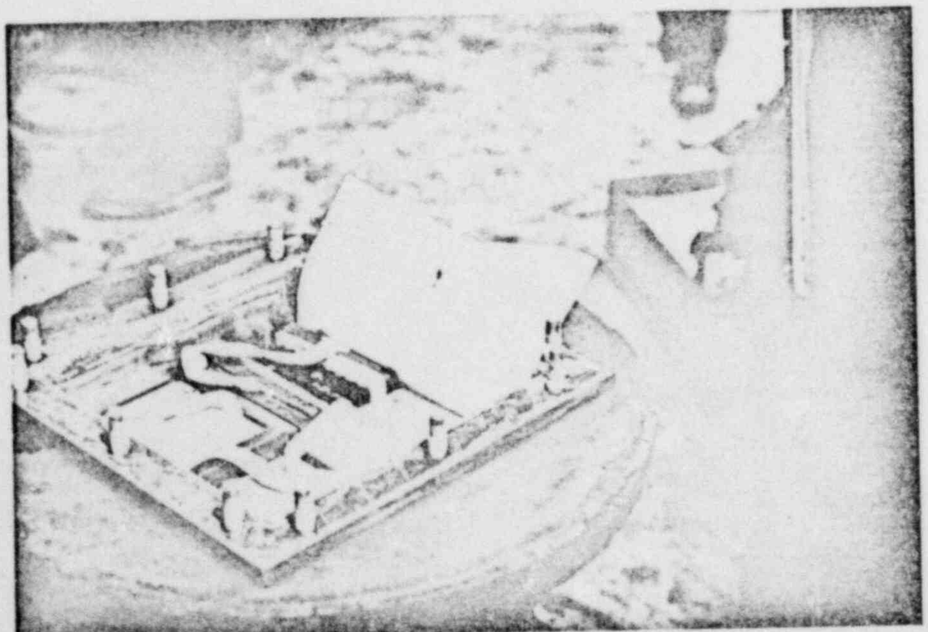
PICTURE-12 — CUT-OUT VIEW OF INSULATION & HARDBOARD AFTER FIRE & WATER TEST.



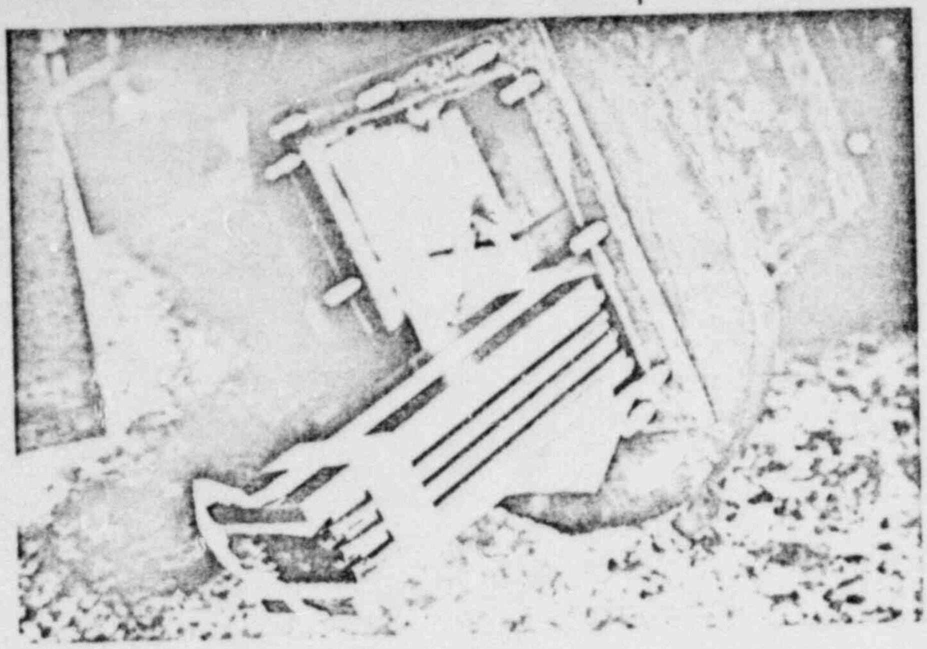
PICTURE-13 —— CONDITION OF BOTTOM OF INNER & OUTER CONTAINERS AFT COMPLETION OF ALL TESTS.



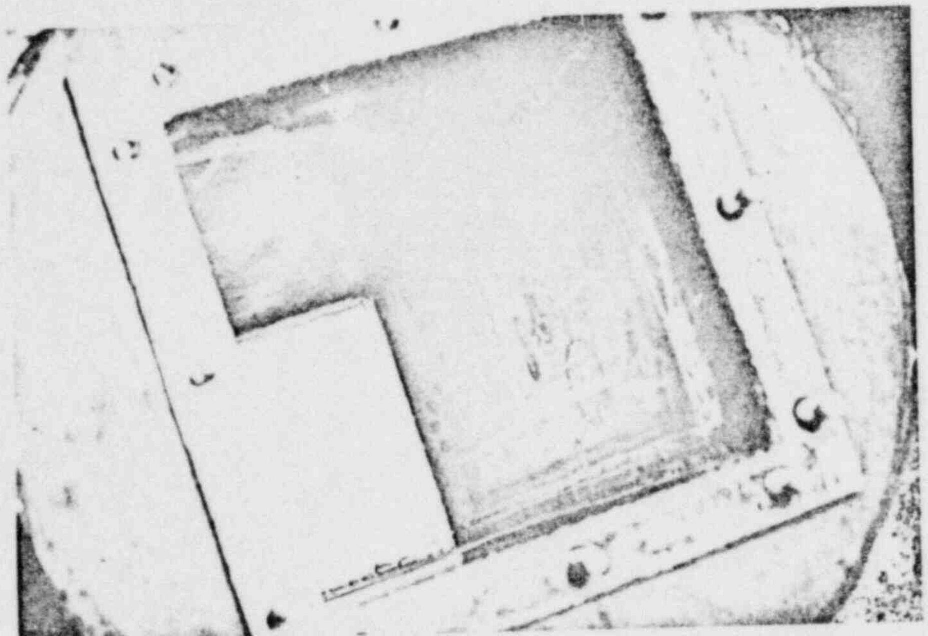
PICTURE-14 —— VIEW OF INNER CONTAINER WITH INSULATION REMOVED AFTER COMPL OF ALL TESTS



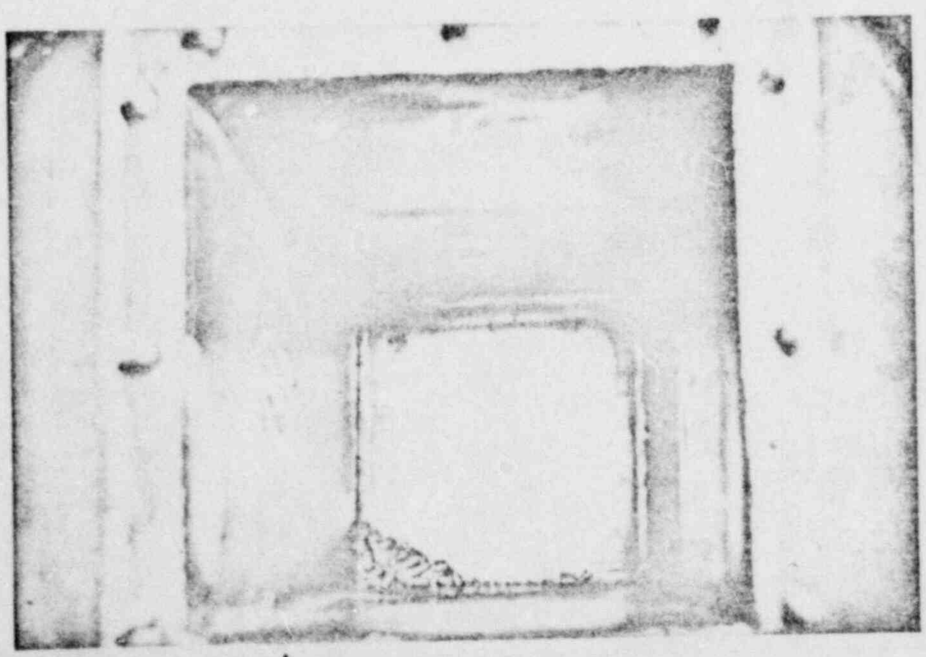
PICTURE-15 —— CONDITION OF PELLET PACKAGES & CUSHIONING MATERIAL AFTER COMPLETION OF ALL TESTS



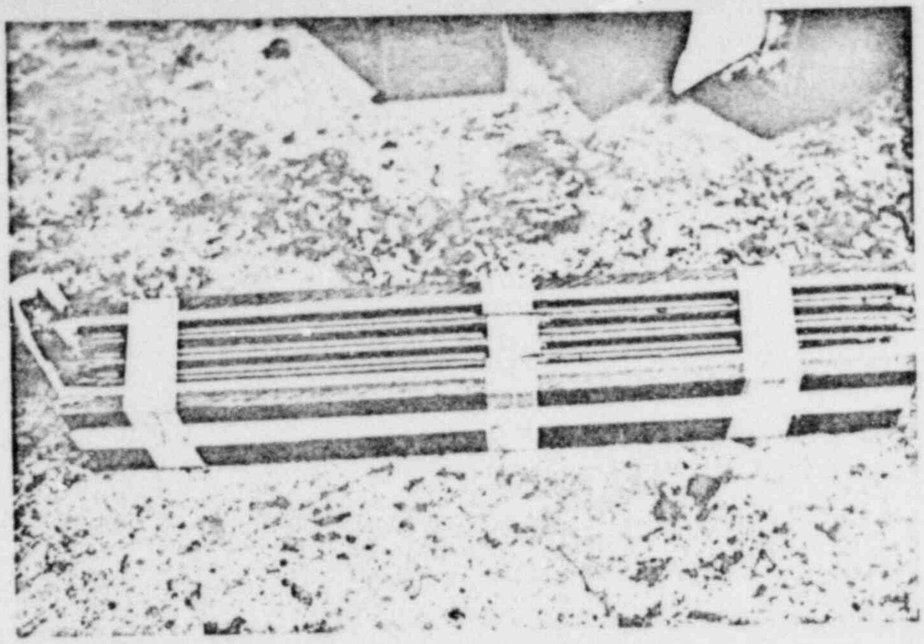
PICTURE-16 — REMOVAL OF PELLET PACKAGE AFTER COMPLE OF TESTS.



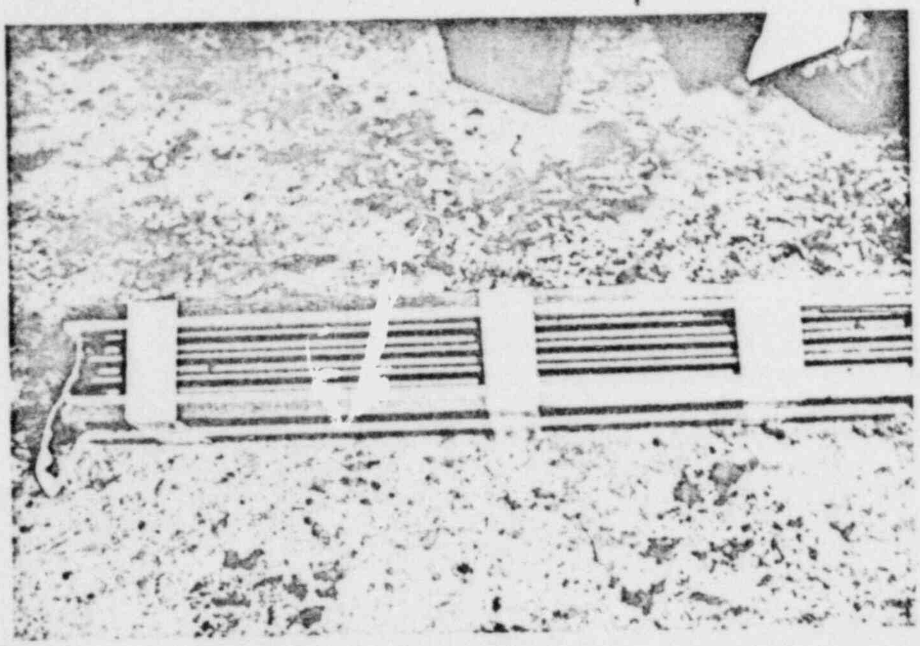
PICTURE-17 — CONDITION OF INNER CONTAINER AFTER COMPLETION OF TESTS.



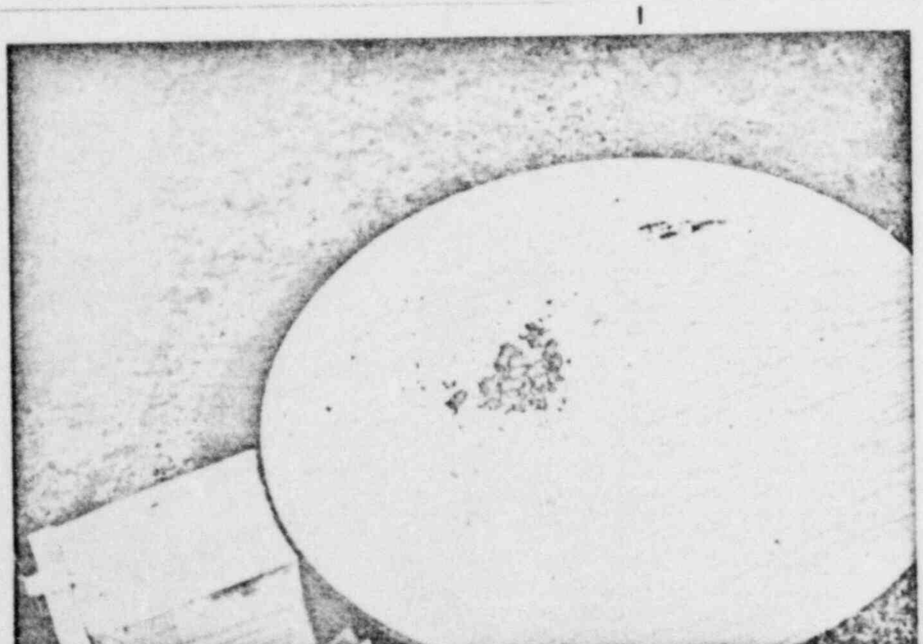
PICTURE-18 — INNER CONTAINER & BROKEN PELLETS AFTER COMPLE OF TESTS.



PICTURE-19 — SIDE OF PELLET PACKAGE FACING CONTAINER WALL DURING TEST.

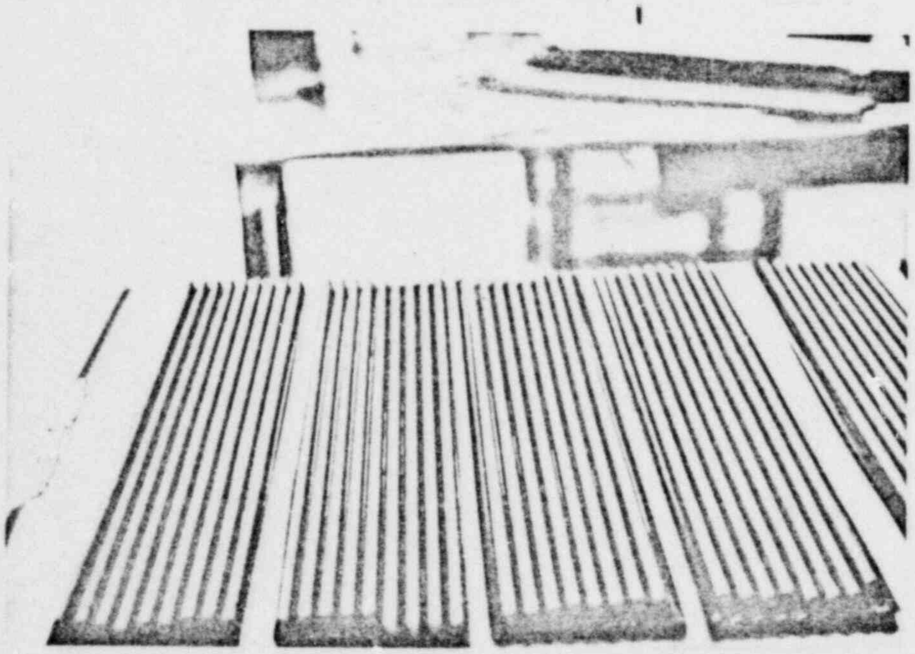


PICTURE-20 — SIDE OF PELLET PACKAGE FACING OTHER PACKAGE DURING TEST.



PICTURE-21 — AMOUNT OF PELLETS DISLODGED IN TEST.

PICTURE-22 — TOP ROW OF DISASSEMBLED PACKAGE AFTER TEST.



PICTURE-23 — LOADED PELLET TRAYS AS ASSEMBLED. BEFORE TESTING.

APPENDIX C

EVALUATION OF UO_2 POWDER DRUMS

FOR USE IN MODEL UNC 2901 SHIPPING PACKAGE

1.0 SUMMARY

A metal drum and inner cushions were designed for the shipment of low enriched UO_2 powder in the Model UNC 2901 shipping container. The drums were filled with the maximum test weight and packaged inside the shipping container. The shipping container was subjected to a 30 foot drop test to evaluate the structural stability of the UO_2 powder drum. The results indicated that the powder drum was structurally sound for UO_2 powder shipments.

2.0 DESCRIPTION OF UO_2 POWDER DRUMS & INNER CUSHION

Details of the UO_2 powder shipping container assembly are illustrated on the attached drawing, #A-5007-2011. MIL specifications of the drum and drawing #A-5007-8111 of the inner cushion are shown in the Appendix.

The basic components of the shipping assembly are:

1. Two (2) re-usable metal shipping drums as per Specification MIL D-5044B, Part No. MS 24347-8. The drum was modified in the following manner to meet UNC requirements.

    a. The inside depth was increased to 13-1/4 inches.

    b. A steel ring was added to the top lip of the container.

    c. The locking lugs were welded in addition to being rivited.

2. Three (3) 10-3/4 inches square x 1 inch thick Ethafoam.

3. Two (2) inner cushions of large bead Polystyrene.

3.0 STRUCTURAL EVALUATION

3.1 Conditions

The shipping package was subjected to one of the hypothetical accident conditions of the tests specified in 10 CFR 71.36 and 49 CFR 173.398 (c). This test was the 30 foot drop test. Original testing performed for the pellet shipment has demonstrated structural integrity of the inner and outer container including the ability to prevent water in-leakage. The net weight of the contents in that test was 427 pounds. Since the net weight of contents for UO_2 powder is only 229.5 pounds, the original fire test, water test and "piston" drop test is applicable to this requirement; current testing was performed to demonstrate the ability of the powder drum to retain its contents.

One test was conducted. The 2901 container was assembled with two UO_2 powder drums. Each was filled with 110 pounds of lead shot and sand. The weight conditions were as follows:

Tare Weight (Assembled Container without Product Package)	227.5 pounds
Net Weight (Sand, Lead Shot, Drums & Packaging)	229.5 pounds
Equivalent Powder Weight	220.0 pounds
Equivalent Drum & Cushion Weight	9.5 pounds
Total Gross Weight	457.0 pounds

3.2 Discussion of Results

Photographs of the shipping drum and cushioning in its various stages of assembly are included in the Appendix of this report.

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.1 Thirty Foot Drop Test

Conditions - The impact of the 30 foot drop test was designed to occur at approximately 45° on the top corner of the drum aligned with the side of the square inner container. The lugs of the powder drums were centered on that side of the inner container. The conditions were chosen as the most severe conditions for the following reasons:

1. Experience from the same test performed on other packages indicated that maximum damage occurs from angular impact.

2. The lugs on the locking ring were indicated to be the weakest structural point of the powder drum.

3. Striking at an angle caused a greater rebounding effect and a minimum degree of support surface (i.e. the top corner hit first and then the bottom as opposed to a single flat hit on side or end only). A flat hit would allow an equal support distribution by the cushions and metal drums and eliminate a greater concentrated force on one point.

4. The top powder drum was subjected to the brunt of impact from both the initial hit and the weight of the second drum.

Results - The decrease in drum diameter as a result of impact was a maximum of 1-3/4 inches on the top corner. The drum, drum lid and the locking ring remained intact. No significant damage to the plywood discs was noted. All flange bolts were intact and securely fastened. There was no deformation of the flanged closure.

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.1 Thirty Foot Drop Test (continued)

Results (continued)
The top & center 1 inch thick Ethafoam cushions were completely severed by the impact of the powder drums. Both of the polystyrene cushions were broken into two pieces. Deformation of the cushion was not severe and both powder drums were securely in place.

The locking ring and top flange of both powder drums were deformed. The bottom of the top powder drum was also badly deformed by the impact ot the bottom powder drum. Although the drums were deformed, the locking rings and lid remained in place. There was no leakage noted at the drum lid or bottom seam.

APPENDIX

1. UO_2 Powder Shipping Container Assembly - A-5007-2011
2. UO_2 Powder Drum Specifications - MIL D-6055
3. Insert Pail Cushion - A-5007-8111
4. Photographs

MATERIAL FOR COMPLETE ASSEMBLY

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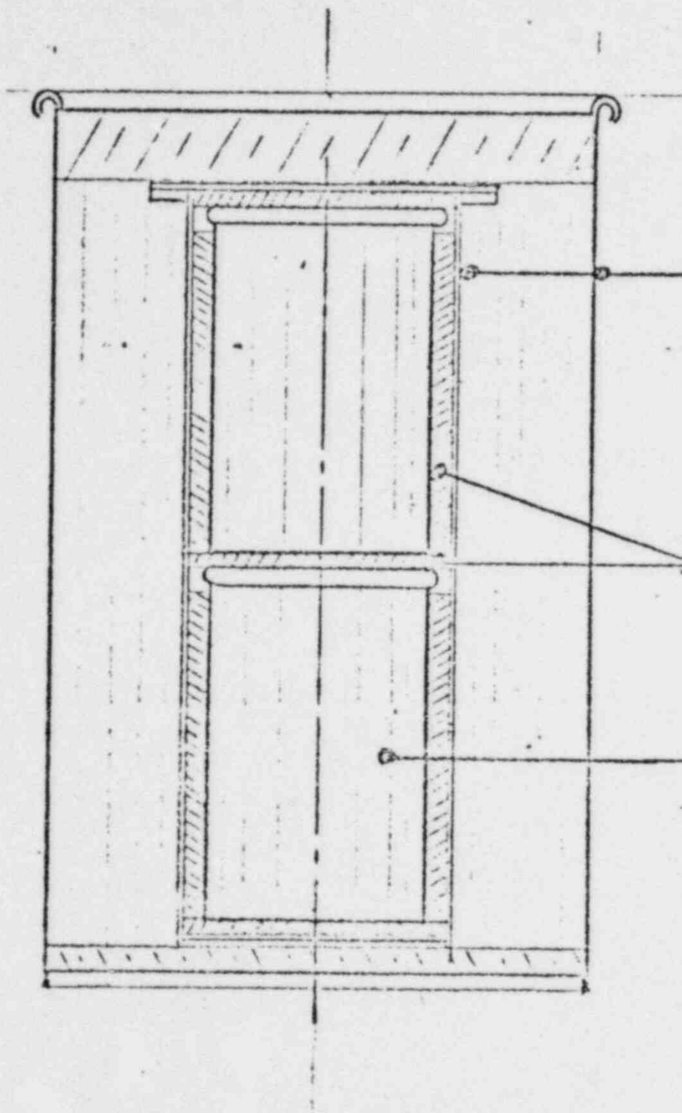

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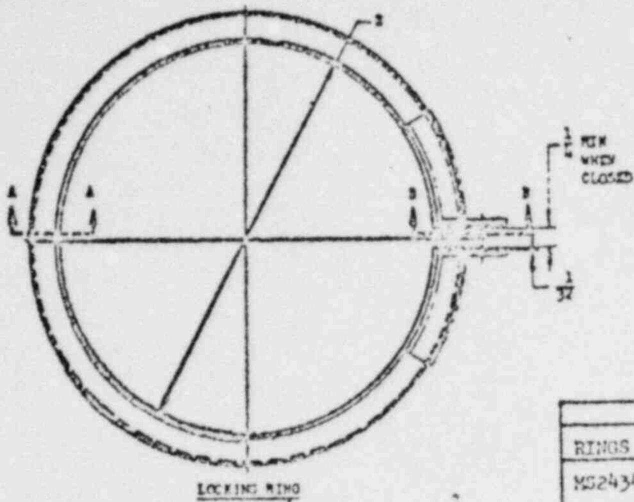
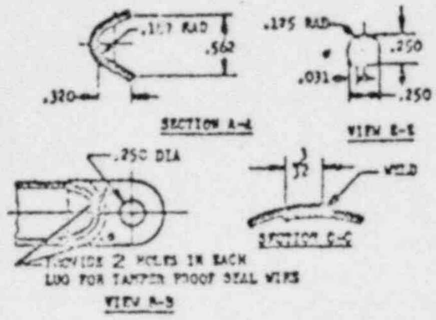
TOLERANCES
UNLESS OTHERWISE SPECIFIED
FRACTIONAL ±
DECIMAL ±
ANGULAR ±
FINISH SYMBOL ASA ST'D

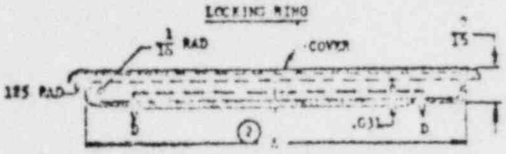
UNITED NUCLEAR CORPORATION
FUELS DIVISION
HEMATITE MISSOURI

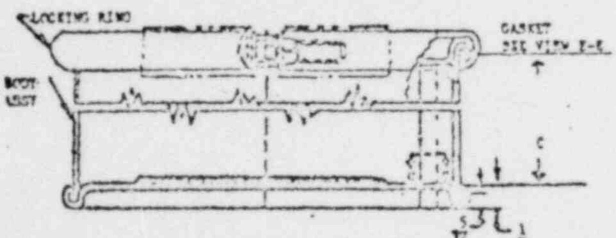
UNC-2901 ; UO_2 POWDER SHIPPING CONTAINER ASSEMBLY

SCALE ~	DWN. BY VAL	APP'D.		REV.
DATE 9-29-70	CHK'D BY L. Deve	APP'D.	A-5007-2011	









TYPE I

SPARE PARTS					
RINGS	EA.	COVERS	EA.	GASKETS	EA.
MS24347-61 (5")	.24	MS24347-41	.22	MS24347-81	.10
MS24347-62 (6½")	.26	MS24347-42	.24	MS24347-82	.12
MS24347-63 (8½")	.30	MS24347-43	.28	MS24347-83	.14

CLOSURE BOLT, ROUND SLOTTED HEAD
1/4-20 X 1 1/4, WITH HEXNUT, CAD PLATED .04 PER SET

				QUANTITY - PRICES PER SHIPMENT							
SIZE NO.	DRUM ASSEMBLY	DIA. -A*	INSIDE DEPTH -C-	1 TO 11	12 TO 99	100 TO 499	500 TO 2499	2500 AND OVER	UNITS PER CTN	WT. PER CTN.	
1	MS24347-1	5.00"	4.50"	1.52	1.38	1.22	1.10	1.05	24	27	
2	MS24347-2	5.00"	8.50"	1.70	1.56	1.37	1.24	1.18	12	20	
3	MS24347-3	6.50"	4.50"	1.64	1.50	1.33	1.20	1.14	12	22	
4	MS24347-4	6.50"	6.75"	1.76	1.62	1.43	1.30	1.24	12	25	
5	MS24347-5	6.50"	8.50"	1.88	1.74	1.55	1.40	1.30	12	31	
6	MS24347-6	8.50"	6.00"	2.00	1.87	1.74	1.60	1.52	12	36	
7	MS24347-7	8.50"	7.50"	2.10	1.98	1.88	1.74	1.64	12	42	
8	MS24347-8	8.50"	9.00"	2.16	2.04	1.94	1.80	1.74	12	46	

INSIDE PACKING HEIGHT WITH COVER IN PLACE IS 1/4" LESS THAN INSIDE DEPTH -C-.

MATERIAL: STEEL, COLD ROLLED SPEC QQ-S-698.
BODY, BOTTOM & COVER: ITEM 1 & 2 26 GAUGE ALL OTHERS 24 GAUGE.
LOCKING RINGS 20 GAUGE AND LUGS 14 GAUGE.
GASKET, SYNTHETIC RUBBER WEATHER RESISTANT, SHORE HARDNESS 60.

ABOVE PRICES BASED UPON DELIVERY QUANTITY PER ITEM.

PACKAGING CHARGE FOR NON STANDARD CARTON - $2.00.

Minimum Order: $5.00

Terms ½% 10: Net 30 F.O.B. St. Louis

PROCUREMENT SPECIFICATION MIL-D-6055	DRUM Metal Reusable Interior and Exterior Shipping and Storage	MILITARY STANDARD MS24347
No. 3169	MIRAX CHEMICAL PRODUCTS CORPORATION Metal Container Division 4999 FYLER AVENUE ST. LOUIS, MISSOURI 63139	SUPERSEDES: AN8029
March 1, 1969		

MATERIAL FOR COMPLETE ASSEMBLY

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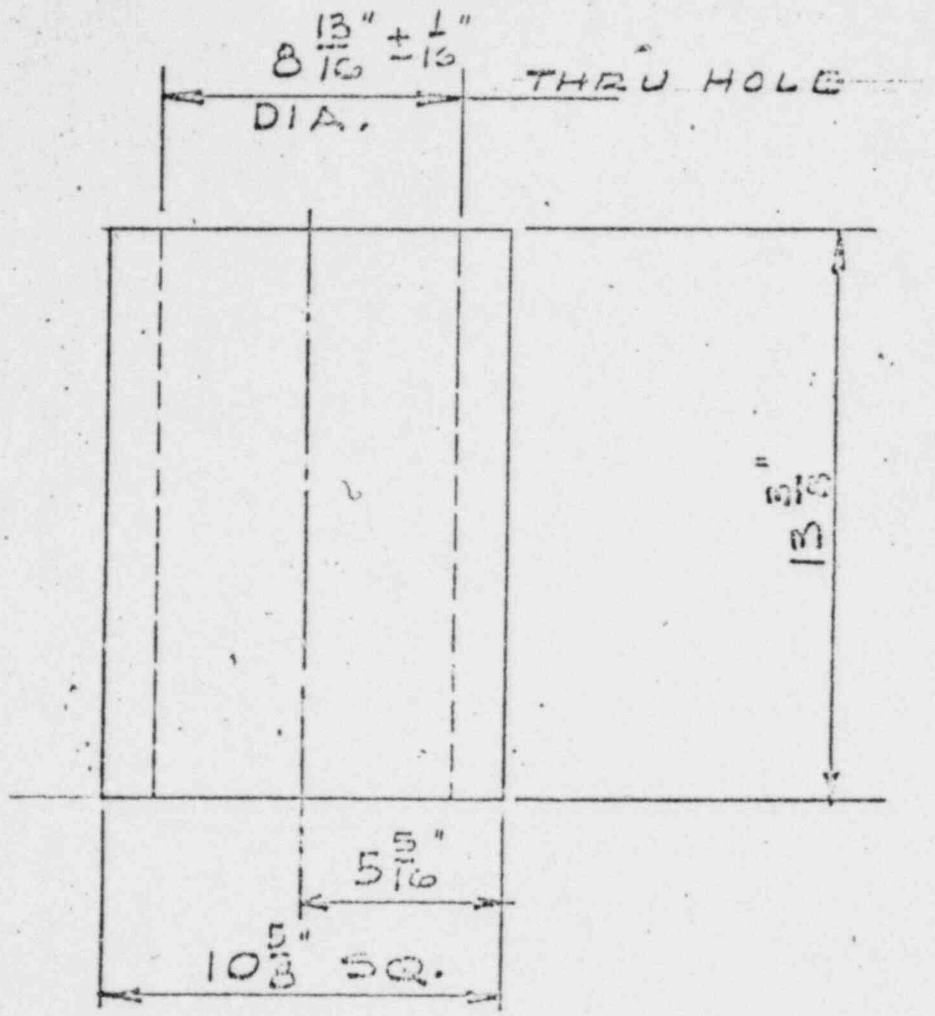


MATL:

LARGE BEAD "POLYSTYRENE".
"DOW CHEM. CO" TYRILL FOAM OR EQUAL.

REV.	BY	DATE	APP'D.	DATE	JOB NO.	DESCRIPTION	W. O. NO.

TOLERANCES
UNLESS OTHERWISE SPECIFIED
FRACTIONAL ± 1/16"
DECIMAL ± —
ANGULAR ± —
FINISH SYMBOL ASA ST'D

UNITED NUCLEAR CORPORATION
FUELS DIVISION
HEMATITE MISSOURI

INSERT PAIL CUSHION FOR
2901 POWDER SHIPPING DRUM

SCALE —
DATE 11-17-70
DWN. BY VAL
CHK'D BY
APP'D.
APP'D.
A-5007-8111
REV.

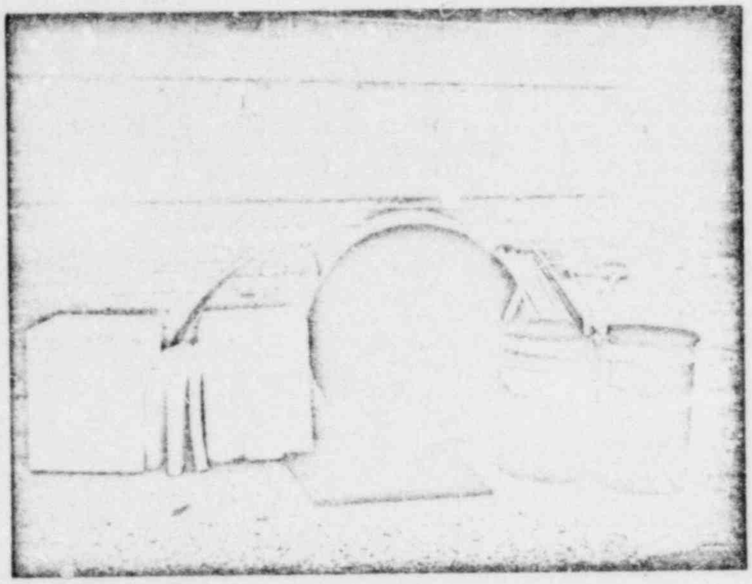


Photo 1

Shipping Drum & Components for Powder Drum Assembly

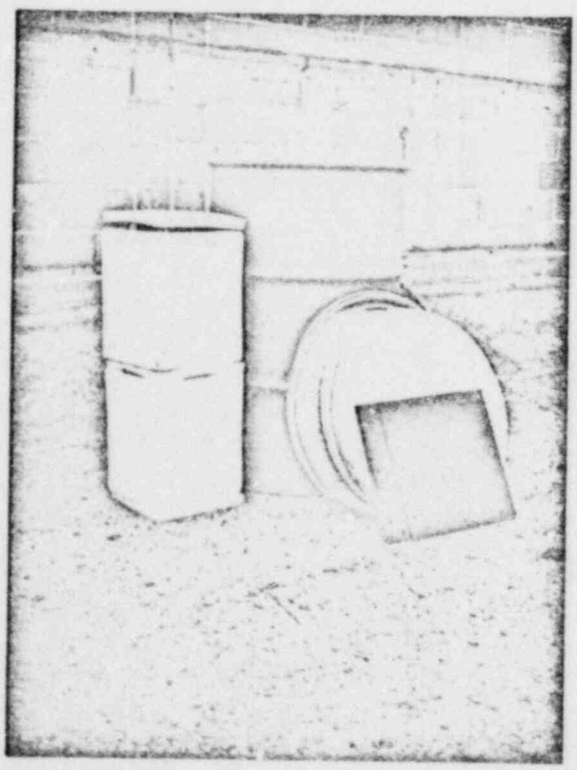


Photo 2

Powder Drum Assembly as It will Fit Into 2901

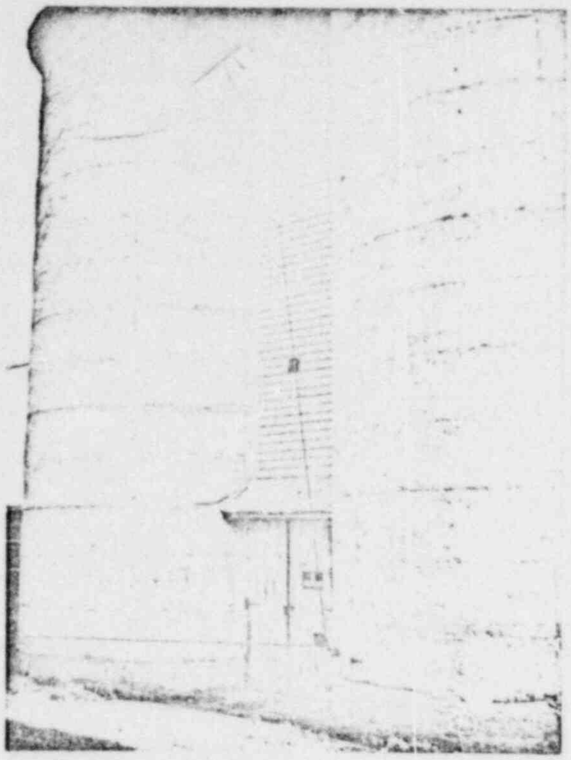


Photo 3

Shipping Package in Position for 30 Foot Drop Test.

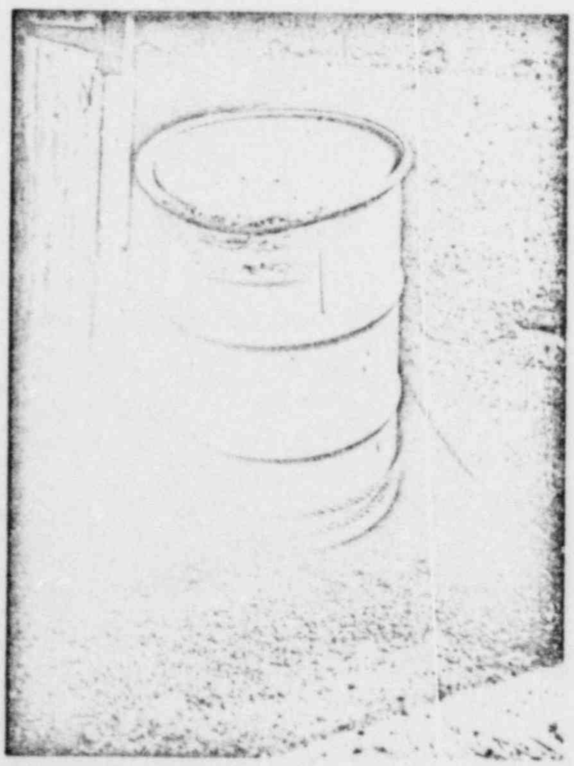


Photo 4

Condition of Drum After 30 Foot Drop Test

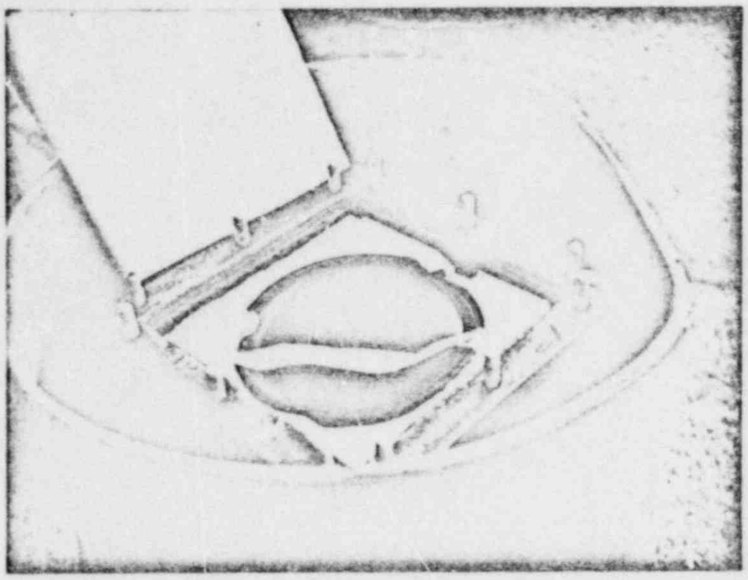


Photo 5

Inner Package After 30' Drop Test

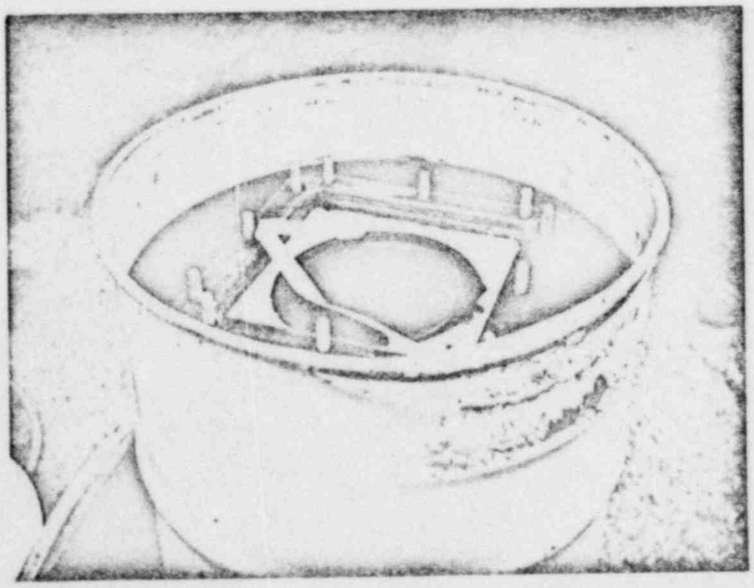


Photo 6

Inner Package And Drum After 30' Drop Test

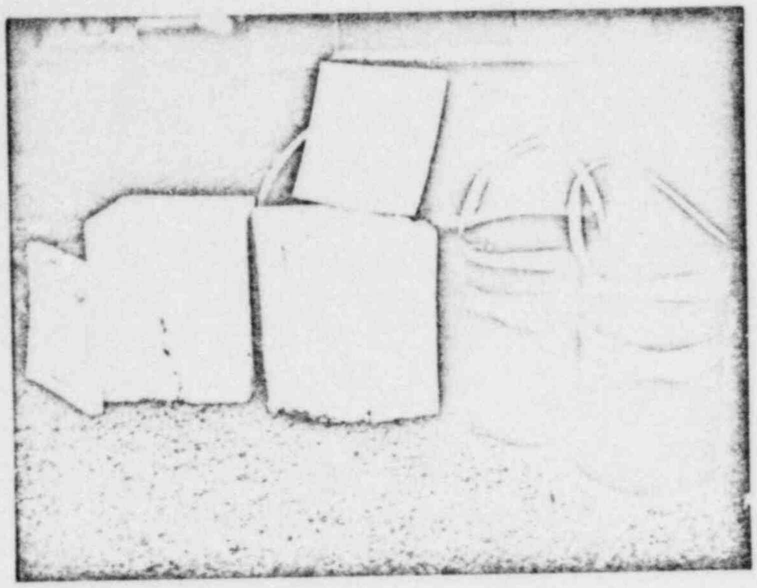


Photo 7

Condition of Ethafoam Cushions, Polystyrene Cushions & Powder Drums After 30' Drop Test

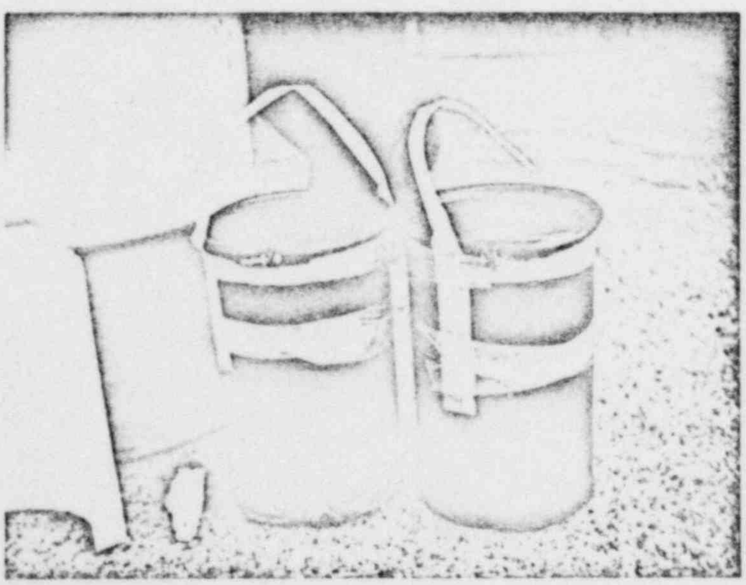


Photo 8

Condition of Powder Drums After 30' Drop Test. Drum on Left was on Top.

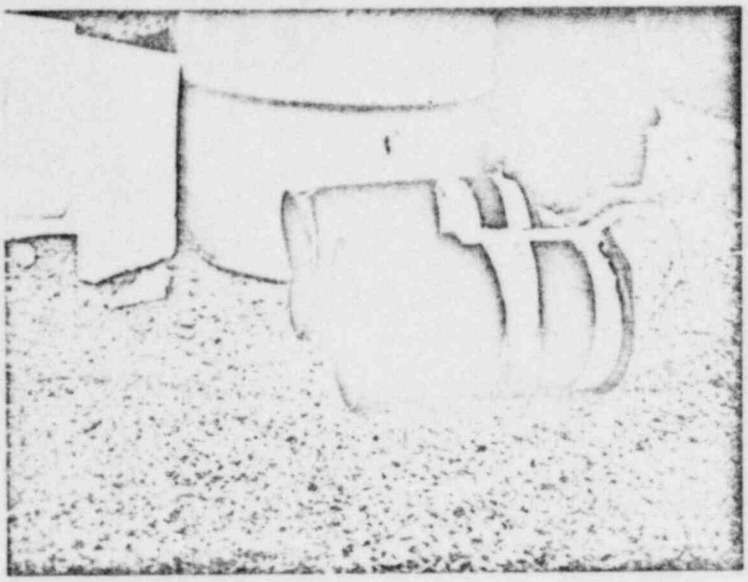


Photo 9

Condition of Powder Drums After 30' Drop Test. Drum in Foreground was on Bottom.

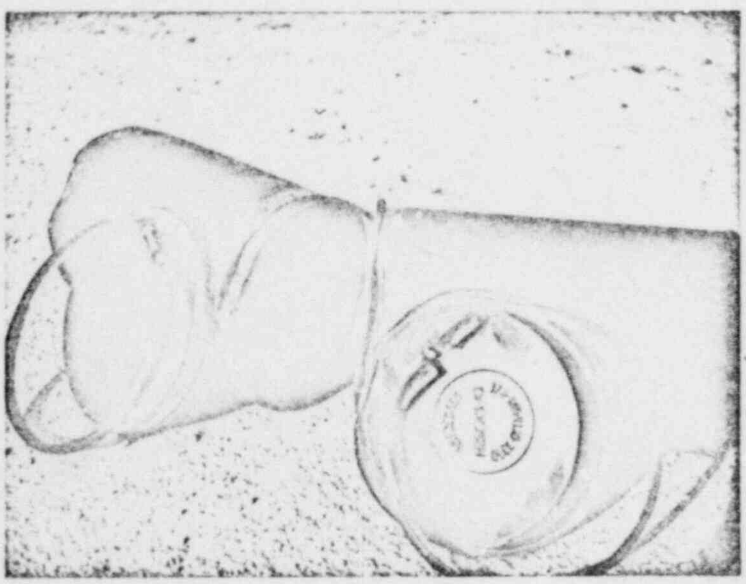
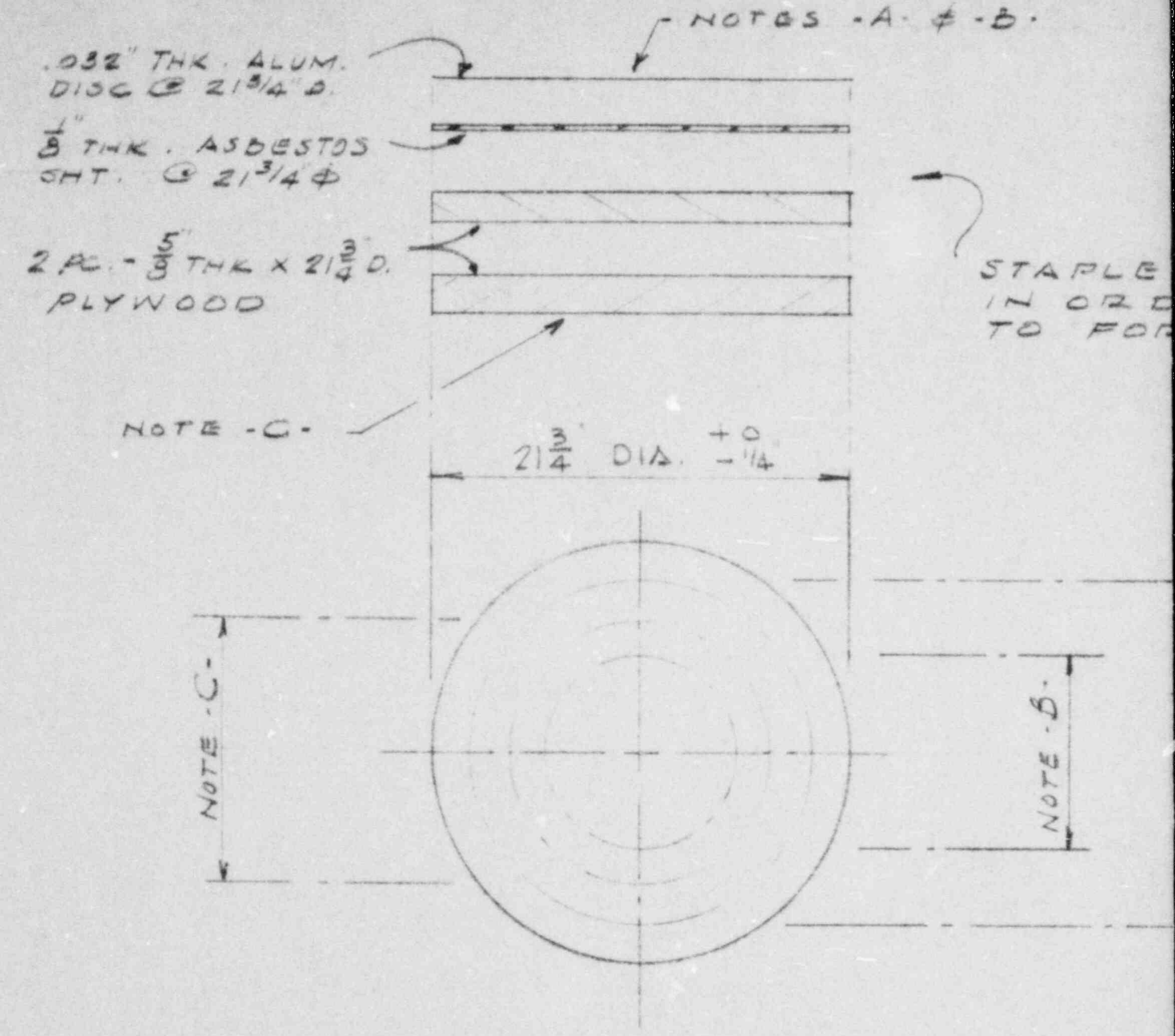


Photo 10

Condition of Powder Drums After 30' Drop Test. Drum on Left was on Top.

16649



NOTE A.. USING A 18" CIRCLE, PLACE ON 4" CTRS. 1 3/16" LG. STAPLES

NOTE B.. USING A 10" CIRCLE, PLACE ON 3" CTRS. 1 3/16" LG. STAPLES

NOTE C.. USING A 14" CIRCLE PLACE 4 @ 90° . 1 3/16" LG. STAPLES.

MATERIAL FOR COMPLETE ASSEMBLY

ITEM NO.	PART DESCRIPTION	NO. REQ'D	SOURCE

TOGETHER
ER SHOWN
M A UNIT.

NOTE ·A·

REV.	BY	DATE	APP'D.	DATE	JOB NO.	DESCRIPTION	W. O. NO.

TOLERANCES
UNLESS OTHERWISE SPECIFIED
FRACTIONAL ± 1/8
DECIMAL ±
ANGULAR ±
FINISH SYMBOL ASA ST'D

COMBUSTION ENGINEERING, INC.
POWER SYSTEMS
HEMATITE MISSOURI

SUGGESTED ASSEMBLY
OF 2901 PLYWOOD INSERT

SCALE 1½"=1'-0" DWN. BY YAL APP'D. [signature]
DATE 11-24-70 CHK'D BY RAA APP'D.

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