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DUAL-PURPOSE WATER CONTAINER

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GARD Final Report 1404 June 1967

REVIEW NOTICE

GENERAL AMERICAN RESEARCH DIVISION

FOREWORD

This report was prepared by the General American Research Division of the General American Transportation Corporation, Niles, Illinois for the Stanford Research Institute, Menlo Park, California under Subcontract B-87008(4949A-55)-US, OCD Work Unit 1433B. The work was monitored by Mr. James F. Halsey of SRI's Civil Defense Technical Office.

The report covers the work performed on the subcontract during the period of April 1966 to June 1967 and describes the design, development, pilot production and testing of a dual-purpose water container for use in Civil Defense shelters.

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ABSTRACT

This report describes the design of a 14 gallon dual-purpose plastic container for storing water in Civil Defense shelters. After the water is consumed, the container can be converted into a commode. The new design overcomes most of the problems experienced with the container now in use, a cylindrical 17-1/2 gallon steel drum with double, 4-mil polyethylene liners. The major problems in using this container are the seepage of water from the liners and rusting of the drum, the heavy weight of the container when filled and the inefficient use of storage space.

The new container is blow-molded out of high density polyethylene and is provided with side frames to allow stacking without compression of the plastic. A total of 150 units were produced and tested to determine the following:

1. Long-term creep of the plastic
2. Chemical compatibility of the plastic with the bleach used to disinfect the water
3. Maximum stacking load
4. Damage when dropped from different heights
5. Failure pressure and location of failure points
6. Effect of freezing.

The results of the tests show that this type of design may be satisfactorily developed for the application.

The container is designed for an estimated life of 15 years when stored under normal conditions.

A draft military specification for the container is included in the report.

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SECTION 1

INTRODUCTION

The water containers furnished at present by the Office of Civil Defense for public fallout shelters consist of 17-1/2 gallon steel drums and double, 4-mil polyethylene liners. Inside dimensions of the drums permitted by the specifications vary from 15-1/4" to 16-1/8" in diameter and 23-3/8" to 21-5/8" in height.

The function of the liners is to contain the water and prevent it from coming in contact with the inside of the drums and causing corrosion. The outer liner is a conventional open-mouth bag with a straight continuous seal at the bottom while the inner one is provided with a spout feature at the top in addition to the continuous seal at the bottom. The liners are made by heat sealing 4-mil seamless low density polyethylene tubing.

The filling instructions require that after the container is filled and a liquid bleach added as a disinfectant, the spout of the inner liner be twisted, doubled back and tied with the plastic wire provided. The top of the outer liner is then gathered and similarly tied, and the drum cover replaced.

Experience with these containers over the past few years has brought out several operational and design problems.[1,2] Briefly, these are:

1. The exterior of the drums rust when stored in high-humidity areas.
2. The inside of the drums rust because of the presence of water between the liner set and the inside wall of the drums. This condition results from one or more of the following:
   (a) Careless handling during the filling operation
   (b) Seepage or capillary action through the tied spout

(c) Leakage through the liners because of pinhole, cut puncture or defective heat seal

3. Liners are susceptible to attack by the bleach (sodium hypochlorite).
4. Height of the drums is excessive when used as a commode.
5. Filled drums are too heavy to be conveniently moved or lifted by two people. Hand-holes or other means for maneuvering the drums are not provided.
6. Storage space is wasted because of the circular cross-section of the drums.
7. Stacking of filled drums is limited to three-high.

To overcome these problems, a new dual-purpose water container was designed. This new design has the following features:

1. The container is blow-molded in one piece out of high density polyethylene and is provided with corrosion-resisting steel frames to give stacking strength. Rusting is thus avoided.
2. Chemical action of the bleach on the plastic is eliminated by using special grades of high density polyethylene.
3. The containers are provided with an integral seat-lid arrangement for easily converting empty containers into commodes. This is accomplished by cutting off the lid with a knife along the groove at the base of the lid. For disposing of used containers, the lid snaps back forming a tight seal. The height of the containers is the same as the height of a standard water closet.
4. Each container is smaller and thus easier to handle. The capacity is 14 gallons and the filled weight, 132 lbs. Hand-holes are provided to further assist in maneuvering the containers.

5. The weight of stacked containers is transmitted to the floor through chromium steel frames -- the plastic container itself is not subjected to any compressive loads.

6. The containers are square in cross-section to save floor space and are designed to be stacked five-high (Figures 1 and 2).

The actual stacking height and floor savings will however depend on the maximum permissible floor loading. For a floor with loading limited to 250 lbs/ft^2*, the amount of water that can be stored on an area equal to that shown in Figure 2 (approximately 4'0" x 2'8") will be as follows:

Container	Stacking of Container	No. of Containers	Total Quantity of Water (gal.)	No. of People Served	Actual Floor Load lbs/ft^2	Area Per Shelter Space ft^2	Volume Ber Shelter Space ft^3
OCD 17-1/2 gallons	Two-High	12	210	60	175.5	0.178	0.704
Dual-Purpose 14 gallons	Three-High	18	252	72	222.7	0.148	0.578

*Maximum value for most building floors.

Figure 1 COMPARISON OF PRESENT AND NEW DESIGN

Figure 2 NEW CONTAINERS STACKED FIVE-HIGH

SECTION 2

DESIGN

2.1 Molding Techniques

Four processes are available for making large hollow items from thermoplastics. These processes are: Blow-molding, Injection molding, Rotational molding and Vacuum forming. A comparison between them is given in Table I.

In blow-molding, a heated hollow thermoplastic tube known as a parison is extruded and confined in a water-cooled mold (Figure 3). Air under pressure is introduced to inflate this parison so that it takes up the shape of the mold and the pressure is maintained while it cools and hardens. The pressure is then removed, the mold opened, and the molded part taken out.

This technique was adopted for making the water containers, based on an evaluation of all the processes, since it has several inherent advantages for forming a large item like the water container. These are:

1. It is very economical for producing one-piece hollow items. Costly cores are not required.
2. There is no need for assembly operations such as adhesive joining of two halves.
3. It is less likely to induce strains that could eventually cause stress cracking.
4. Highly developed, fully automatic molding equipment is available.
5. Wastage of raw materials is negligible. Excess trim from molded items can be readily re-used.

TABLE I

COMPARISON OF MOLDING TECHNIQUES FOR PRODUCING HOLLOW ITEMS

Method	Advantages	Limitations	Cost Factor*
Blow Molding	Can produce hollow items in one piece; no molded-in orientation; can use less heat stable materials.	Wall thickness hard to control; high production runs may favor use of injection molding.	Cost of material, tools and dies, labor, finishing and scrap loss are all low.
Injection Molding	Controlled wall thickness possible; can design complex, intricate shapes; good surface finish.	Not practical for small runs; separate joining operation required; molded-in orientation.	Tool and die costs high; all other costs low.
Rotational Molding	Controlled wall thickness possible; can produce one-piece hollow items.	Only liquid and powdered resins can be used; poor surfaces.	Materials costs medium; all other costs low.
Vacuum Forming	Virtually no limit on wall thickness; can use pre-printed sheet.	Limited to relatively simple shapes; separate joining operation required; can use only materials in sheet form.	Material, finishing, and labor costs are medium; tool and die costs very low.

*These are general statements; costs will vary widely in each specific case.

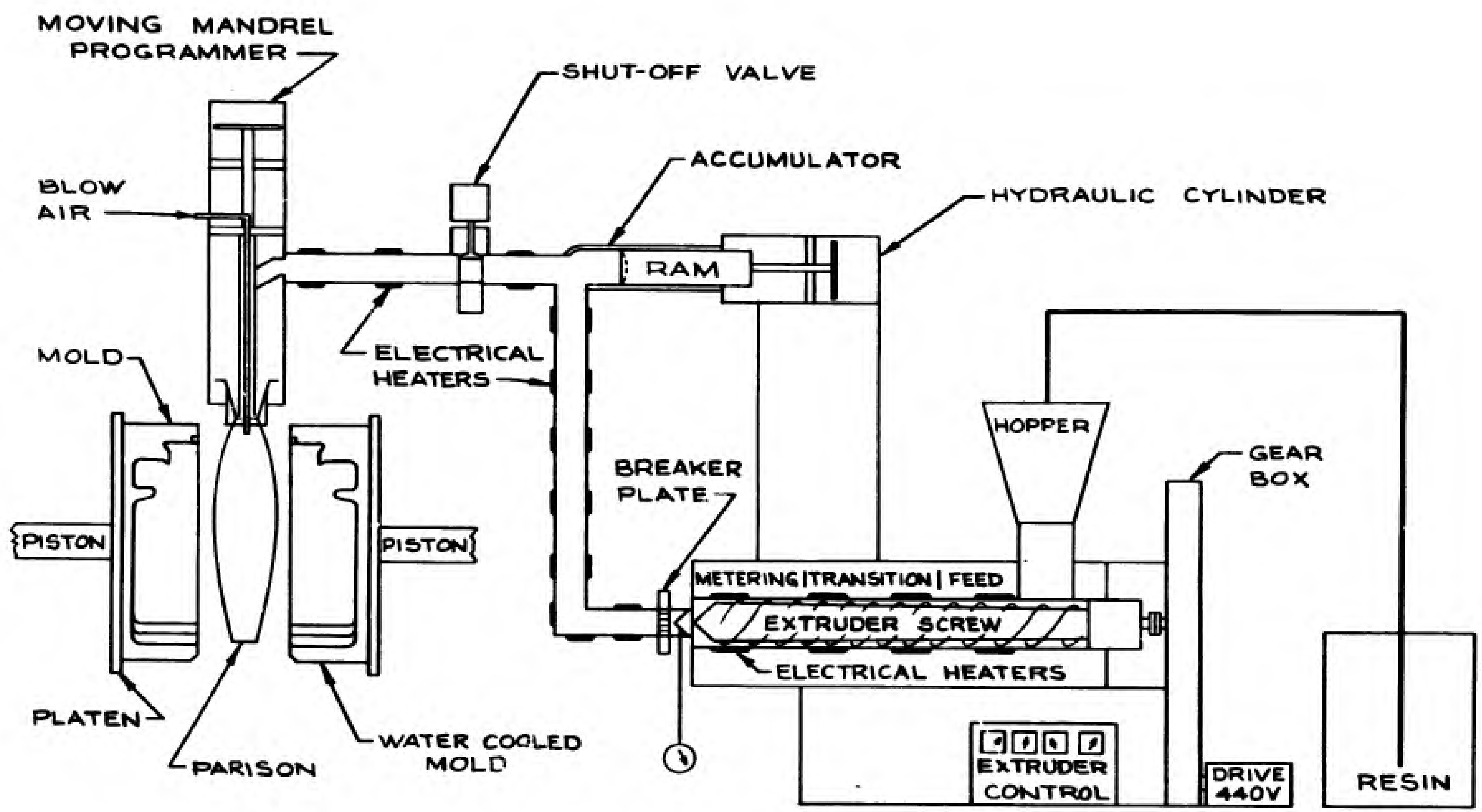

Figure 3 TYPICAL BLOW MOLDING MACHINE

2.2 Material Selection

The water containers are required to have a minimum service life of 15 years when stored under normal conditions. During this period of time, the water must remain in a potable state and the containers must show no signs of deterioration. The containers must also have the strength to be stacked five high when filled with water and not deteriorate if stored outside in the sunlight for a limited time. In addition, the cost must be reasonable.

To meet these different requirements, it was established that the container material must have the following:

1. Food and Drug Administration approval for use in contact with drinking water
2. Low cost
3. High tensile strength
4. High rigidity
5. Low creep
6. High chemical resistance, especially to dilute solutions of sodium hypochlorite
7. Good moldability
8. High impact strength
9. Resistance to ultraviolet degradation
10. Low water absorption
11. Low permeability to water and water vapor
12. Low brittleness temperature.

The properties of some of the more common thermoplastics are given in Table II. From this it can be seen that only high density polyethylene meets the majority of the above requirements.

TABLE II

PROPERTIES OF SOME BLOW MOLDING THERMOPLASTICS

Material	Acetal	Cellulosics		Ethylene Copolymer	Polyethylene		Polypropylene	Modified Polystyrene
		Acetate	Acetate Butyrate		Low Density	High Density		
Cost, $/cu. in.........	0.036	0.018-0.024	0.020-0.030	0.011	0.008	0.010	0.010-0.013	0.011
Mold Shrinkage, in./in.	0.025-0.033	0.003-0.007	0.001-0.009	0.015-0.035	0.010-0.050	0.020-0.050	0.015-0.030	0.002-0.008
Moldability...........	Critical melt point	Excellent	Poor	Excellent	Excellent	Excellent	Excellent	Excellent
Advantages.............	High stiffness; good impact resistance, chemical resistance; instantaneous recovery from deformation and low permeability	High strength, stiffness, surface gloss; good transparency	Same as acetate, but with improved impact resistance; low moisture absorption	Good low temp flexibility, toughness, fatigue resistance; can be blended with other thermoplastics to improve properties	Good flexibility, impact strength, chemical resistance, impermeability; low cost	Good stiffness; high strength, heat distortion temp, impact strength, stress-cracking resistance; chemical resistance	Stiffness; high melting point, gloss; excellent stress-cracking and fatigue resistance; good strength; excellent chemical resistance	Good resistance to staining; low cost
Limitations............	Limited size; high cost; loss of properties when subjected to strong chemicals	Possibility of plasticizer bleeding; non-flexible; high permeability	Possibility of plasticizer bleeding; non-flexible	Low heat distortion point	Low heat distortion temp; poor dimensional stability; low tensile strength	High mold shrinkage	Impact strength is substantially reduced at low temperatures	Low stress-cracking resistance; loss of mechanical strength upon exposure to ultraviolet rays
PHYSICAL PROPERTIES								
Specific Gravity.......	1.41-1.42	1.23-1.31	1.18-1.20	0.931	0.912-0.925	0.940-0.965	0.897-0.910	1.04-1.08
Water Absorption (24 hr), %	0.12	2.1-4	0.9-2.2	0.04	< 0.02	< 0.02	< 0.01	0.03-0.05
MECHANICAL PROPERTIES								
Ten. Str., 1000 psi....	8-10	2.3-8.1	2.6-6.9	0.8-2.0	1.1-2.3	2.5-5.0	4-6	5-9
Elongation, %	12-15	10-70	40-88	300-700	100-600	15-100	200-700	5-75
Impact Str (Izod notched), ft-lb/in....	1.1-1.4	0.5-4.8	0.8-6.3	No break	No break	1-20	1-15	0.25-0.40
Mod of Elast in Tension, 10^5 psi..............	3.7-4.1	0.65-4.0	0.5-2.0	0.46-0.067	0.17-0.35	0.6-1.55	1.4-2.0	3.0-4.5
Mod of Elast in Flex, 10^5 psi..............	3-4.1	0.65-2.6	0.55-1.85	--	12-30	85-150	1.4-1.7	3.5-5.0
Flex Str, 1000 psi.....	12-14	2.2-11.5	1.8-9.3	3.0-3.6	1-2	3-5	6	8.7-14
Softening Temp, F......	185-250	140-220	140-220	190-200	180-212	260	250-320	150-170
Brittleness Temp, F....	--	--	--	-157	-95	-180	-4	--

2.3 Polyethylene

Polyethylene, $(C_2H_4)_n$, is derived from natural gas or petroleum refinery by-products by polymerization of ethylene. The American Society for Testing and Materials classifies it into three types and ten grades depending on the density and the tensile strength, respectively (Table III). For example, Type III has density lying between 0.940 and 0.965 g/cm^3 and is available in three grades with minimum tensile strengths of 2400, 2800, and 3200 lbs/in^2.

Physical and Mechanical Properties

The physical and mechanical properties of polyethylene depend on the density and the melt index*. As the density increases, the stiffness, hardness, tensile (yield) strength, barrier properties and chemical resistance increases, while the elongation, impact strength and brittleness temperature decreases (Table IV). On the other hand, as the melt index increases, the tensile (ultimate) strength, elongation, impact strength, creep resistance and melt viscosity decreases, while the brittleness temperature increases (Table V)[3]. Thus the ideal polyethylene for the application is one having a high density and a low melt index. Such a material will have all the desirable properties.

Polyethylenes meeting these requirements are specified in the military specifications for the container (Appendix). The one used for the prototype containers has a density of 0.96 gm/cm^3 (ASTM Type III, Grade 3) and a melt index of 0.3 g/10 min.**

*The melt index is the rate of extrusion, expressed in g/10 min., through an orifice of specified length and diameter, under prescribed conditions of temperature and pressure. The lower the melt index, the higher the viscosity under these conditions. The melt index for polyethylene ranges between 0.1 and 20.0 g/10 min.

**Grade PP60-002, Allied Chemical Corporation.

TABLE III

CLASSIFICATION OF POLYETHYLENE

ASTM Type	ASTM Grade	Tensile Strength Min. (psi)	Ultimate Elongation (%)	Density	Common Designation
I	1	800	50	0.912 to 0.925	Low Density, Regular or High Pressure polyethylene
	2	1200	300		
	3	1500	400		
	4	1800	500		
II	1	1000	50	0.925 to 0.940	Intermediate Density or Medium Density polyethylene
	2	1400	200		
	3	1800	400		
III	1	2400	50	0.940 to 0.965	High Density, Linear or Low Pressure polyethylene
	2	2800	75		
	3	3200	100		

TABLE IV

EFFECT OF DENSITY ON PROPERTIES OF POLYETHYLENE

DENSITY

	LOW ——— Medium ——— HIGH
STIFFNESS	————————→ ——
HARDNESS	————————→ ——
TENSILE (YIELD)	————————→ ——
ELONGATION	—— ←————————
IMPACT STRENGTH	—— ←————————
BARRIER PROPERTIES	————————→ ——
CHEMICAL RESISTANCE	————————→ ——
BRITTLENESS TEMPERATURE	—— ←————————

TABLE V

EFFECT OF MELT INDEX ON PROPERTIES OF POLYETHYLENE

MELT INDEX

	LOW ——— Medium ——— HIGH
TENSILE (ULTIMATE)	—— ←————————
ELONGATION	—— ←————————
IMPACT STRENGTH	—— ←————————
CREEP RESISTANCE	—— ←————————
BRITTLENESS TEMPERATURE	————————→ ——
ENVIRONMENTAL STRESS CRACKING RESISTANCE	—— ←————————
CHEMICAL RESISTANCE	—— ←————————
MELT VISCOSITY	—— ←————————

Effect of UV Light

Polyethylene is a stable polymer and maintains all its properties indefinitely at room temperature in the dark. However, long and continuous exposure to ultraviolet light brings about photochemical degradation due to the breakup of the long polyethylene chains.[4]

To overcome this, either UV stabilizers or pigments are used. Both work by absorbing the harmful UV rays. The UV stabilizers, in general, do not have FDA approval for use in articles in contact with food or drinking water because of their chemical makeup. Pigments, therefore, are used in such cases.

For the water containers, the criterion was established by OCD that it should be possible to store them in sunlight for 5% of their expected service life of 15 years, i.e., 9 months. To obtain this degree of protection, a FDA-approved tan pigment, especially compounded for the application, was used.*

Flame Resistance

Polyethylene is flammable and classified in the slow-burning category by the National Board of Fire Underwriters.[5] Burning rate is approximately 1.0 to 1.5 in./min. However, the kindling temperature is high.

It may be noted in this connection that plastics are used for making gasoline tanks and jerry cans in Canada. These plastics have to pass the Canadian Government flammability test which is as follows: A 1" Bunsen burner flame (approximate temperature, 1000°C) is applied to the tank or can below the liquid level line for 2 minutes. To pass the test, the plastic must not burn. If it does, the flame must extinguish within 5 seconds after the Bunsen burner flame is removed.

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*Pigment Type M710B, Phillips Petroleum Company.

Most high density polyethylenes meet or exceed these requirements. The Allied Chemical Corporation's high density polyethylene, PP60-002, used in the prototype containers, exceeds these requirements.

2.4 Design Details

Container

The design of the container is shown in Figures 4 through 7. The capacity is 14 gallons and the filled weight approximately 125 pounds.*

The 14-gallon size was selected after an analysis of the weight and cost of the different sizes of the container. As the container capacity is increased, the filled weight increases while the cost to store a gallon of water decreases (Table VI). Taking the maximum load which two people can lift conveniently as 125 pounds, the 14-gallon size represents the best compromise between the total weight and cost.

According to present OCD policy, a minimum of 3-1/2 gallons of water must be provided for each shelteree in an identified fallout shelter[6]. On this basis, the 14-gallon size represents a 'four-man-module'. The 'three-man-module' (10-1/2 gallons) was estimated to weigh 24.1% less and cost about 9.1% more per gallon of water stored. This size was rejected due to the higher cost even though the lower weight seemed desirable. The 'five-man-module' (17-1/2 gallons), on the other hand, was estimated to weigh 24.1% more and cost 12.1% less. It was also rejected, in this case because of excessive weight, in spite of the lower cost.

The containers are provided with two hand-holes and an integral seat-lid arrangement. The base is formed in a manner to allow stacking of the containers. A threaded opening is provided at the top for filling. The internal diameter of this opening is greater than 1-9/16" to allow the largest garden hose to be used for filling.

*The actual volume and weight of the prototype containers is 14.69 gallons and 132 pounds, respectively.

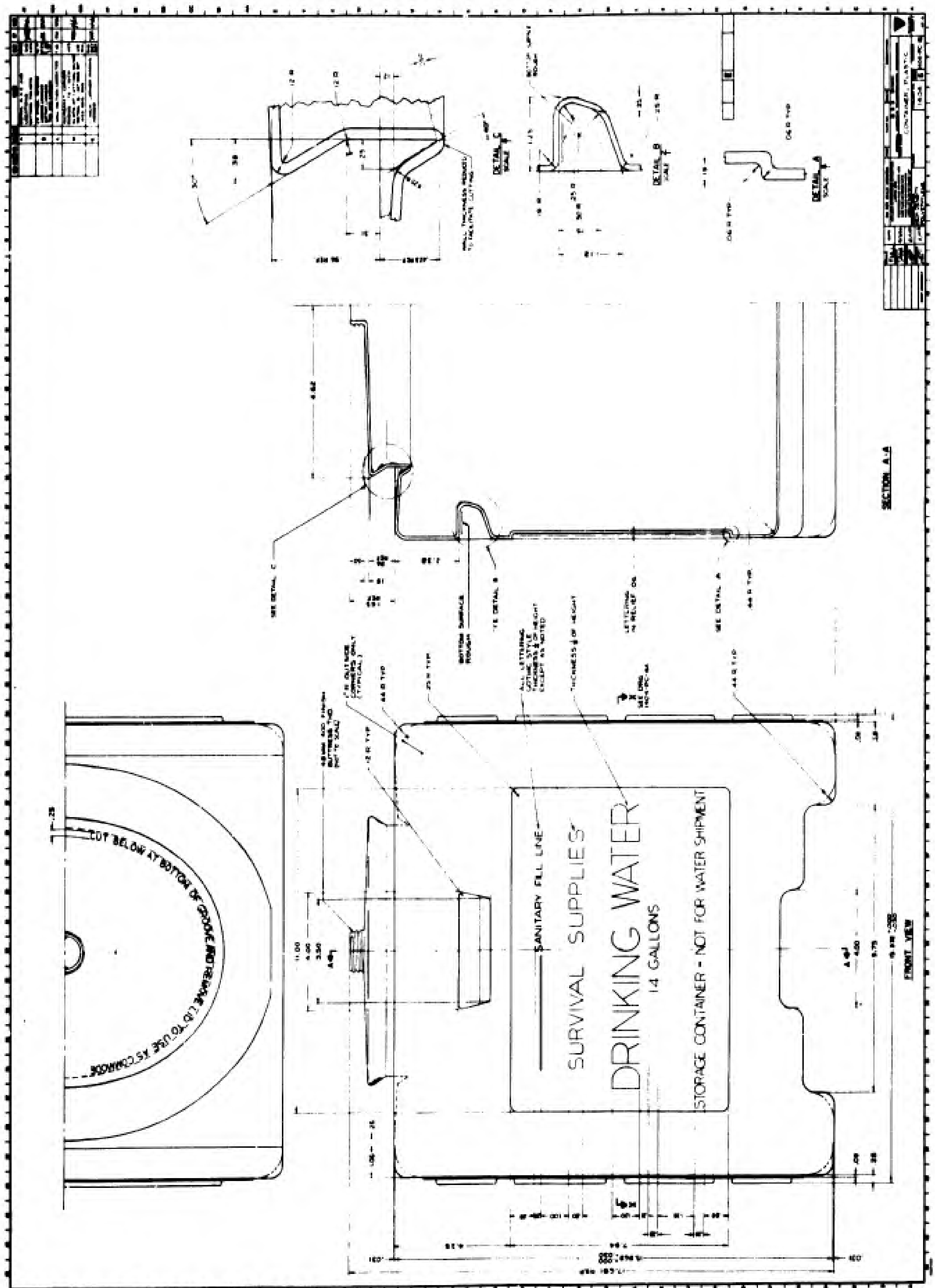

Figure 4 CONTAINER, FRONT VIEW

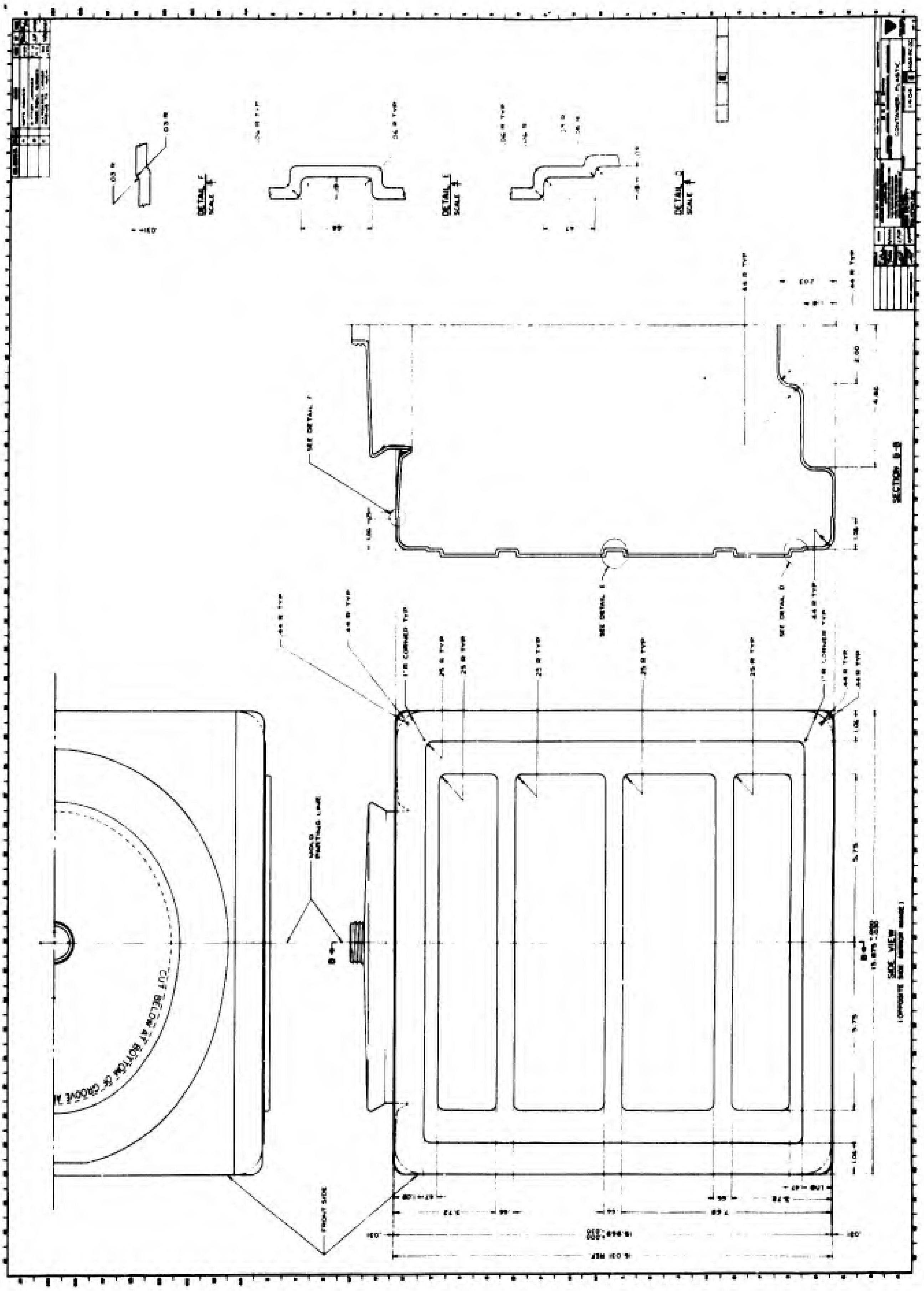

Figure 5 CONTAINER, SIDE VIEW

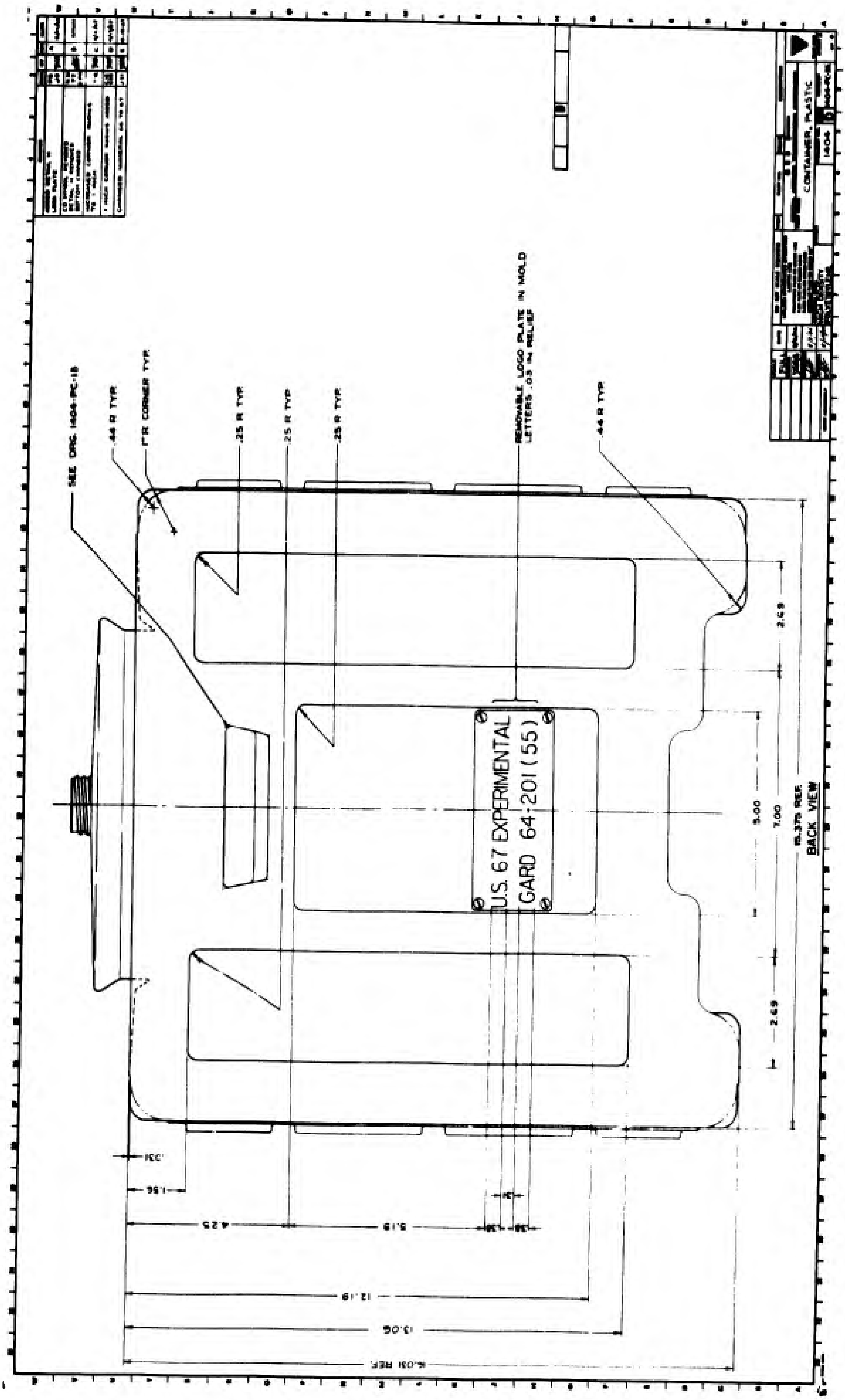

Figure 6 CONTAINER, BACK VIEW

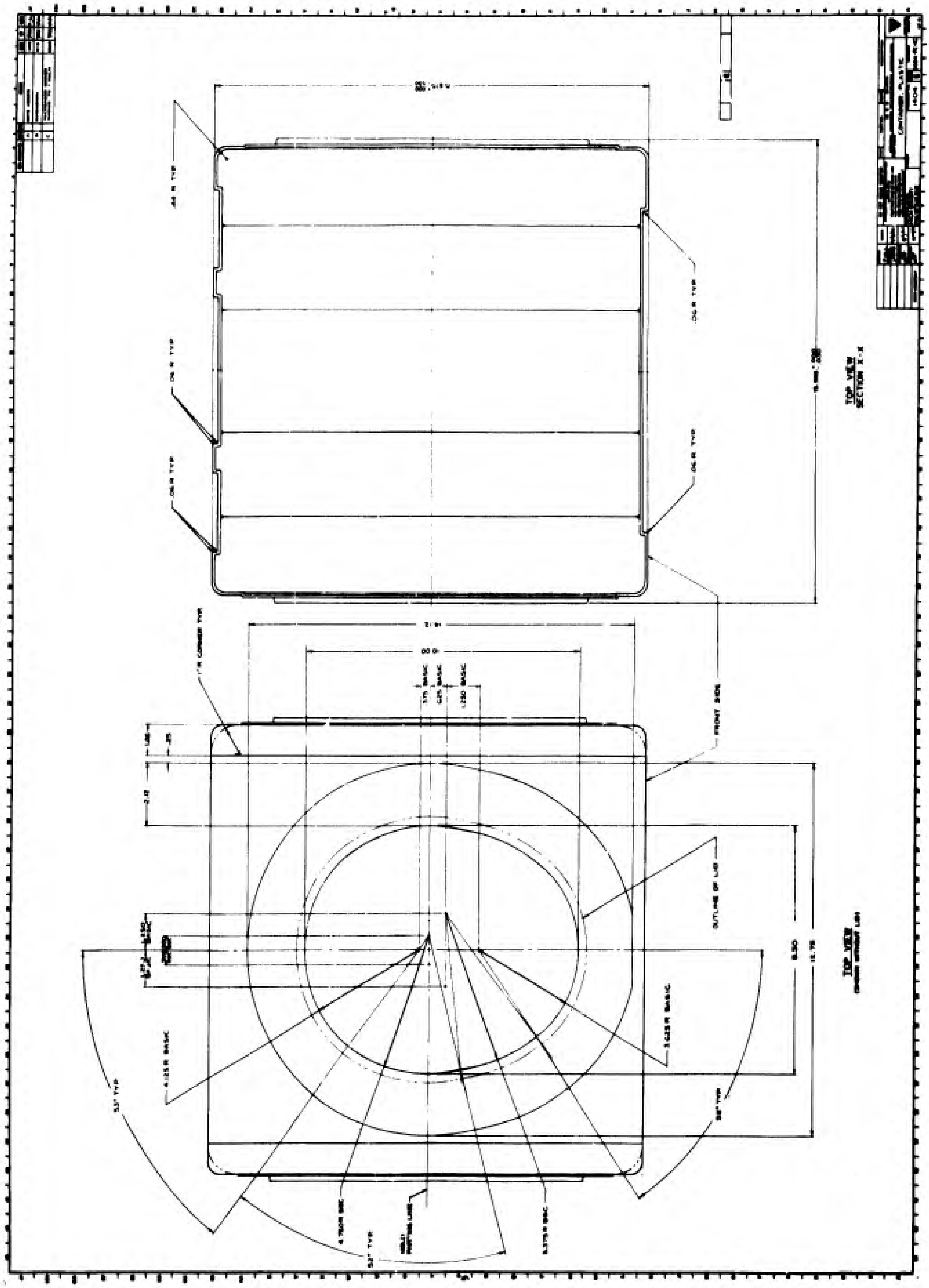

Figure 7 CONTAINER, TOP VIEW

TABLE VI

ESTIMATED FILLED WEIGHT AND COST OF CONTAINERS VERSUS CAPACITY

Capacity (gallons)	Width x Depth[1] (16" height)	Weight (lbs.)					Cost ($)[4]					
		Plastic[2]	Metal Frame[3]	Empty Container	Water	Filled Container	Plastic	Molding of Plastic	Metal Frame	Assembly of Metal Frame + Banding	Completed Container	Cost per gallons of stored water
(g)		(a)	(b)	(a+b)	(c)	(a+b+c)	(A)	(B)	(C)	(D)	(A+B+C+D)	(A+B+C+D)/g
10	13 x 13	3.9	3.3	7.2	83.5	90.7	$0.87	$1.23	$1.86	$0.10	$4.07	$0.41
10.5	13-1/4 x 13-1/4	4.0	3.4	7.4	87.6	95.0	0.89	1.27	1.86	0.10	4.12	0.39
12	14-1/8 x 14-1/8	4.3	3.5	7.8	100.2	108.0	0.96	1.39	1.89	0.10	4.34	0.36
14	15-1/4 x 15-1/4	4.7	3.7	8.4	116.8	125.2	1.05	1.55	1.94	0.10	4.64	0.33
16	16-1/4 x 16-1/4	5.1	3.8	8.9	133.5	142.4	1.13	1.72	1.97	0.10	4.92	0.31
17.5	16-7/8 x 16-7/8	5.4	3.9	9.3	146.1	155.4	1.20	1.84	1.97	0.10	5.11	0.29
18	17-1/8 x 17-1/8	5.5	4.0	9.5	150.2	159.7	1.22	1.88	2.00	0.10	5.20	0.28

[1] Outside dimensions. (Wall thickness of .095 taken into account.)

[2] Plastic: Polyethylene, cost 22-1/4¢/lb

[3] Metal: Allegheny Ludlum MF-1, density .276 lbs /in^3, cost 25-3/4¢/lb

[4] Based on production of 10,000 units. Cost of mold or stamping dies not included.

The "sanitary fill" line was placed at the maximum practical operating level and the volume corresponding to this is about 65% of the total volume of the container.

Cover

The cover for the threaded opening at the top of the container is of molded phenolic. It has a 48 mm internal thread of 400 finish (i.e., 10 mm deep) and can be either of G.C.M.I. (Glass Container Manufacturers Institute) or buttress profile.

The inside of the cover is provided with a liner which consists of a .0015" high density polyethylene film coated to paper and laminated to pulpboard. The polyethylene is FDA approved for use in contact with drinking water.

Frame

The containers are required to be strong enough to allow stacking up to five high, if necessary, to conserve space in a shelter, provided the floor loading will permit this. This means that the total load on the bottom container will be approximately 500 lbs. To transmit this load to the floor and relieve the plastic container from carrying any compressive load, two side frames are provided for each container (Figure 8).

The frames are made of corrosion-resistant 11% chromium alloy, developed originally for automotive mufflers by the Allegheny Ludlum Steel Corporation. This alloy, designated MF-1, is relatively inexpensive with a base price approximately 1/2 to 1/3 that of the common stainless steels such as Type 302 or Type 316.

The corrosion resistance of MF-1 is entirely satisfactory for the application. When plain carbon or low alloy steels corrode, the moisture in the atmosphere tends to accelerate the attack by acting as an electrolyte.

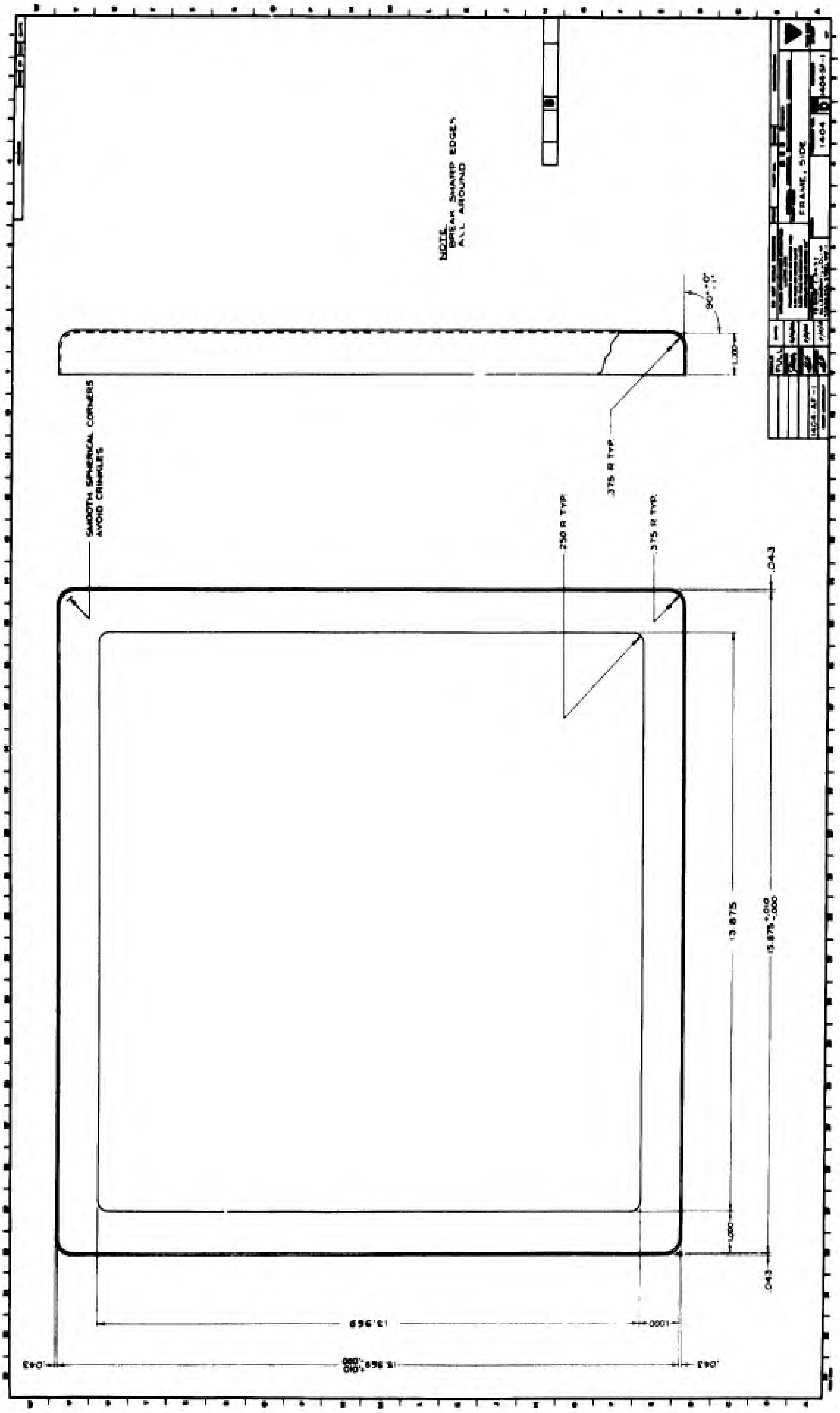

Figure 8 FRAME, SIDE

The rust which forms is loose, porous and non-protective. Moisture penetrates this rust causing further attack beneath. Eventually the loose rust falls off and the steel rapidly thins until failure. In contrast, MF-1 does not form a heavy loose rust scale and even after many years, there is no detectable loss of thickness.

Muffler steel Type 100 (also designated stainless steel Type 409) developed by the U. S. Steel Corporation for automotive applications has properties similar to MF-1 and should prove similarly suitable for the application. The nominal composition and mechanical properties of these two steels are given in Table VII.

Strapping

The side frames are held on to the containers by means of nylon strapping joined by crimp type seals (Figure 9).

The nylon strapping is the strongest of the nonmetallic types available. For the 1/2" x .015" size used, the breaking strength is approximately 475 pounds and the elongation at break about 15%. The strength of the crimp joint is greater than 225 pounds.*

The strapping is stretched up to 7% when applied to an item. The practical result of this is that it tends to stay tight even if the item settles, shrinks or compresses. This is particularly important in the case of the container since the container plastic gradually shrinks for some time following molding and tends to creep slightly when under a continuous load.

The strapping is resistant to moisture, oil, greases, most organic solvents and fungi. It is unaffected by continuous exposure in air to temperatures up to 150°F. Extremely cold weather causes it to stiffen somewhat but does not affect its strength adversely. It, however, shows a slight loss in strength after about a year's exposure to direct sunlight.

*Dymax Strapping Class 502, Seal Model 50AD, Signode Corporation.

TABLE VII

NOMINAL COMPOSITION AND MECHANICAL PROPERTIES OF CHROMIUM STEELS

	NOMINAL COMPOSITION					MECHANICAL PROPERTIES @ 80°F			
	C	Cr	Ni	Ti	Fe	Yield Strength psi	Tensile Strength psi	Elongation in 2"	Hardness, R_B
MF-1*	0.045	11.00	0.20	0.50	Bal.	34500	65000	32.5%	72
Muffler Steel Type 100** (Stainless Steel, Type 409)	0.080	10.50 to 11.75	0.50	0.40 to 0.65	Bal.	37500	64000	30.0%	68 to 75

*Allegheny Ludlum Steel Corporation.

**U. S. Steel Corporation.

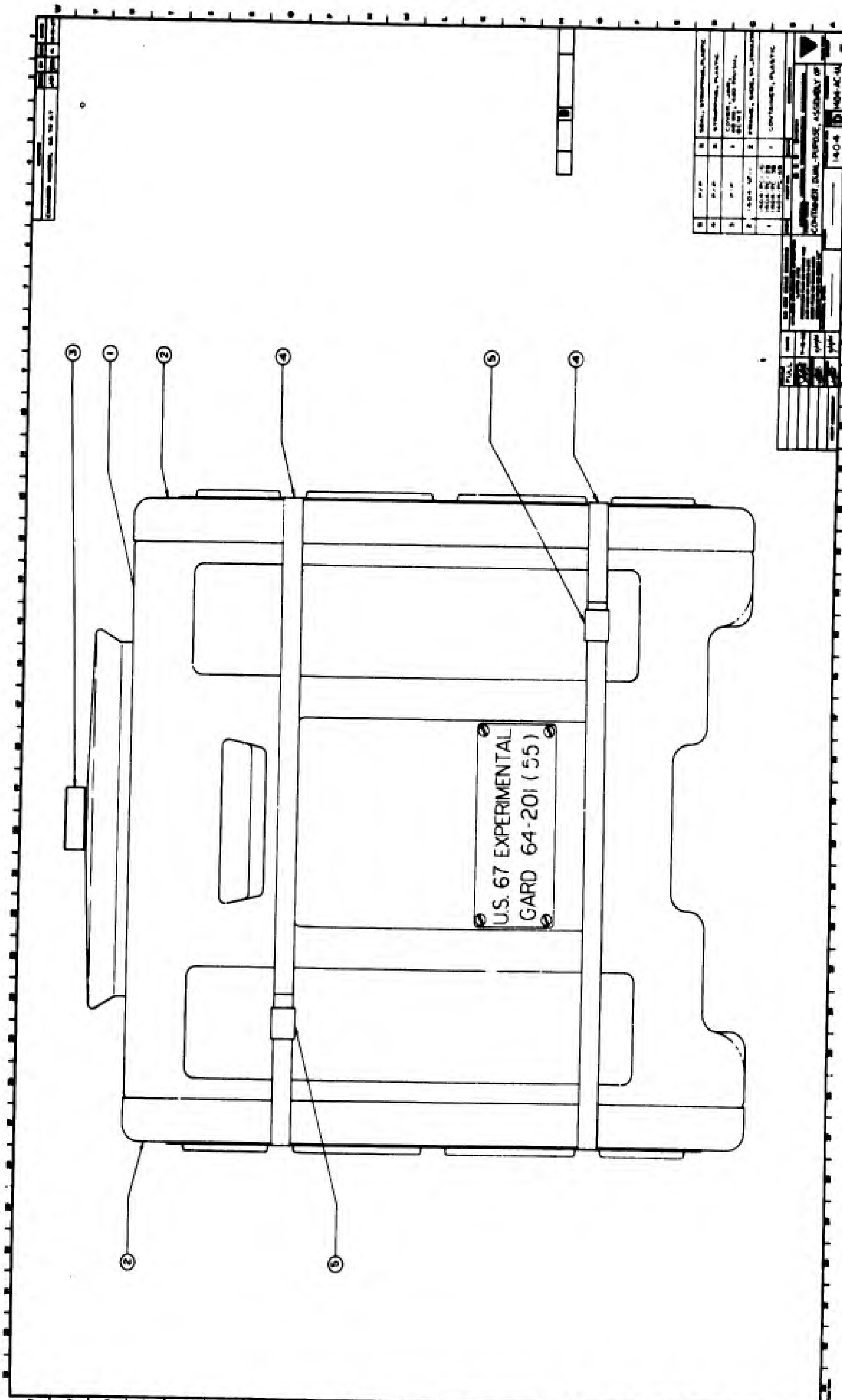

Figure 9 CONTAINER, ASSEMBLY

The crimp seals for the strapping are available in either galvanized steel or stainless steel Type 430. The corrosion resistance of the latter is adequate for all possible storage conditions for the container. The seals can be applied manually or by automatic power-driven equipment.

2.5 Comparison of Cost of Present and New Containers

The 1962 cost of the present steel container in production lots greater than 100,000 units was as follows[7]:

		$/Each
1.	Steel Drum, 17-1/2 gallons	1.90
2.	Polyethylene double liners (4 mil)	0.30
3.	Plastic toilet seat*	0.03
	Total	2.23

The estimated cost of the new design in lots of 10,000 units is $4.64 (Table VI). The higher cost is more than offset by the many advantages of the new design over the present one.

*Allocated cost.

SECTION 3

TESTING

3.1 Creep and Creep Rupture of Containers with Frames

Creep is the time-dependent strain in a material caused by stress. If the creep is large and allowed to continue, it will ultimately result in failure or 'creep rupture'.

Virtually all solid materials creep to some degree when subjected to stress. In the case of polyethylene, this is particularly important since polyethylene has no creep limit, i.e., there is no stress value below which creep is absent.

The creep rate and hence the time to rupture (which may be minutes or years) is affected by the following:

1. Material properties
2. Temperature
3. Stress intensity
4. Stress-temperature history.

In the case of plastics, the creep is basically due to the slipping of the molecules over one another.

In the container, the creep is almost entirely due to the hydrostatic force exerted by the water. The stacked weight of other containers, if any, play no part since the weight is transmitted to the floor through the frames and does not affect the plastic.

To determine the creep in the container at the end of 15 years and hence the likelihood of creep rupture, two approaches were taken. One was to calculate the hydrostatic stresses in the container and from this to estimate the probable creep by using published data on the long-term behavior of polyethylenes under load. The other was to measure experimentally the creep at selected points in the container, say for 1000 hours, and then to extrapolate this to give the creep at the end of 15 years.

The experimental verification of the calculated results was considered necessary since published data on the long-term behavior of polyethylenes are scarce and not very reliable. This is partly due to the fact that polyethylenes have existed commercially for less than 15 years and partly because they are seldom used as structural members where creep is important.

Calculated Creep in Containers

Assuming the container to be a 16" cube, the pressure exerted by the 16 inches of water in the container will be:

$$p = h \times 0.0361 \qquad (1\text{" of water} = 0.0361 \text{ psi})$$

$$= 16 \times 0.0361$$

$$= 0.58 \text{ psi}$$

For a wall 0.080" thick with an E of 1.55×10^5 psi, the maximum stress will be:

$$s = \frac{pd}{t}$$

$$= \frac{0.58 \times 11.3}{0.080} \qquad \left(d = \frac{1}{2}\sqrt{16^2 + 16^2} = 11.3"\right)$$

$$= 82 \text{ psi}$$

and the maximum extension in each wall will be:

$$\delta \ell = \frac{s}{E}\ell$$

$$= \frac{82 \times 16}{1.55 \times 10^5}$$

$$= 0.0085"$$

Using published data on high density polyethylenes, the 82 psi stress will result in a creep of less than 0.5% in 15 years*.

*Consultant's Report, Broutman, L. J., "Design and Long-Term Performance of Plastic Container", August 1966.

The yield tensile strength and ultimate elongation for the polyethylene used in making the prototype containers is 4500 psi and 40%, respectively, (Table VIII). In comparison, the 82 psi stress due to the water and the 0.5% creep are extremely small. The design is therefore safe for the application.

Experimental Determination of Creep

The creep was determined at three locations on the container over a period of 1000 hours by means of metal foil gages. The setup is shown in Figure 10 and the location of the gages in Figures 11, 12 and 13*. At each location, two gages were used -- one in the vertical direction and one in the horizontal. A temperature compensating gage, forming one arm of the full bridge measuring circuit, was mounted on an unstressed container.

The spcts for mounting the gages were found by filling a container with water and observing the points where the sides tended to bulge the most. These points were then selected for the strain measurements.

The gages were bonded to the container with a thin layer of low-creep epoxy cement and coated with a water-proof varnish. The cement was allowed to cure for 72 hours before commencing the test. The container was then filled with water at room temperature and strain readings taken every 0.1 hour for the first hour and then every hour for 10 hours. Beyond this, readings were taken once every 24 hours.

The results of the test are shown in Figure 14. The values of strain changes with time are plotted on semi-log graph and the curves extrapolated to indicate the probable creep at the end of 15 years (1.314×10^5 hours).

*Strain Gages: Constantan foil with epoxy backing, Type C40-131, Budd Co.
Strain Indicator: Model 120, Baldwin-Lima-Hamilton Corporation.
Switching and Balancing Unit: Model 225, Baldwin-Lima-Hamilton Corporation.

TABLE VIII

PROPERTIES OF HIGH DENSITY POLYETHYLENE USED IN MAKING THE PROTOTYPE CONTAINERS*

Properties	Value	ASTM Method
Melt Index, Nominal, gms/10 min.	0.3	D1238-62T
Density, Nominal, gms/cc	0.96	D1505-60T
Yield Tensile Strength (20"/min), psi	4,500	D638-61T
Ultimate Elongation (20"/min), %	40	D638-61T
Hardness, Shore D	70	D1706-61
Impact Strength, ft-lb/in	12	D256-56
Stiffness in Flexure, psi	130,000	D747-61T
Tensile Modulus of Elasticity, psi	155,000	D638-61T
Deformation Temperature (66 psi), °F	175	D648-56
Vicat Softening Point, °F	260	D1525-58T
Brittleness Temperature, °F	< -106	D746-57T

*Grade PP60-002, Allied Chemical Corporation.

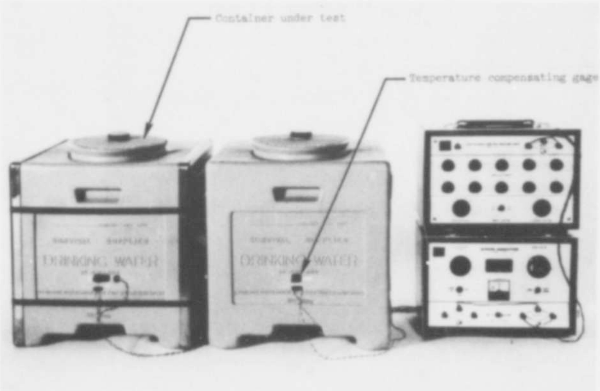

Figure 10 SETUP FOR DETERMINING STRAIN

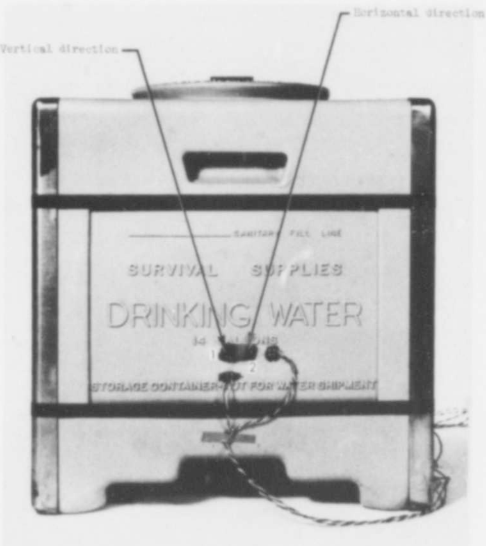

Figure 11 LOCATION OF STRAIN GAGES ON FRONT OF CONTAINER

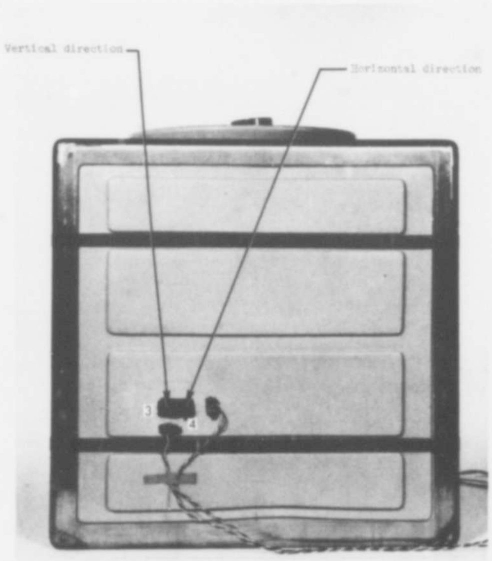

Figure 12 LOCATION OF STRAIN GAGES ON SIDE OF CONTAINER

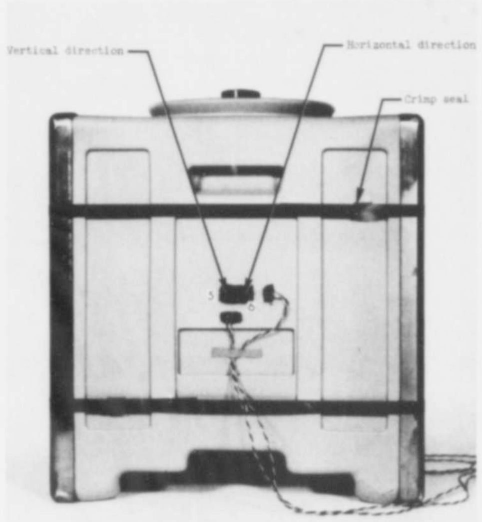

Figure 13 LOCATION OF STRAIN GAGES ON BACK OF CONTAINER

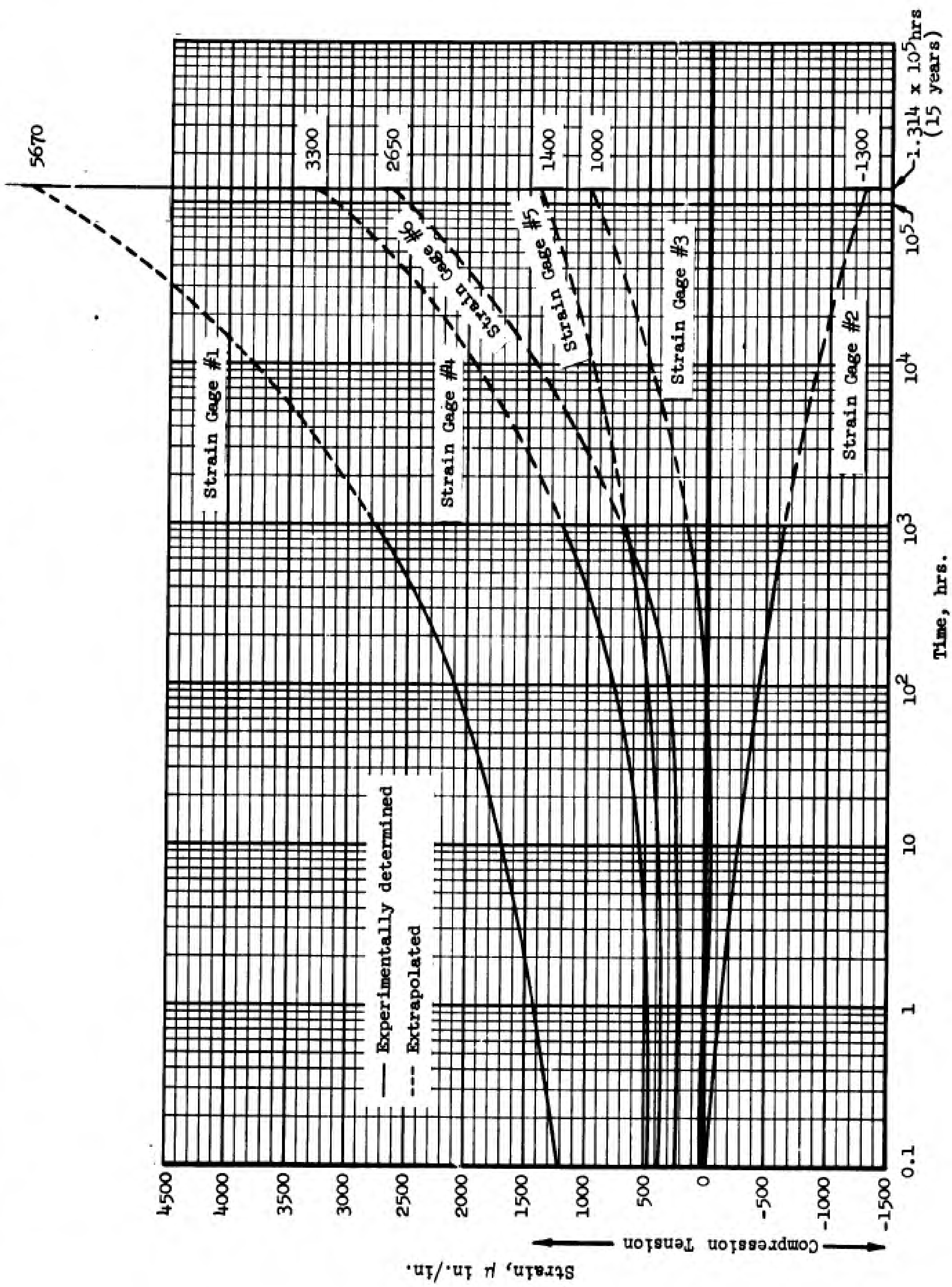

Figure 14 CREEP IN PLASTIC CONTAINER WITH TIME

The maximum creep was observed for Strain Gage #1 (vertical direction, front of container) and the extrapolated value for 15 years for this is 5670 μin./in., i.e., 0.567% .

This is in good agreement with the calculated value and confirms that the container is adequately designed for the application.

3.2 Chemical Compatibility of Plastic with Sodium Hypochlorite

Present OCD policy requires that one to two teaspoons of household liquid bleach such as Clorox (active ingredient 5.25% sodium hypochlorite; 94.75% inert ingredient) be added to each 17-1/2 gallon water drum when they are filled[6]. This is to keep the bacterial count down and prevent the growth of fungi and algae.

The sodium hypochlorite (NaOCl), however, attacks some polyethylenes, breaking up the long polyethylene chains and forming compounds having the organic radical CO. This reaction, the rate of which depends on the concentration of the sodium hypochlorite, results in the polyethylene becoming brittle and eventually disintegrating.

To insure that the polyethylene used in the prototype containers is immune to such an attack, an accelerated test was undertaken. This accelerated test is based on the reasonably accurate rule-of-thumb that the rate of chemical reaction doubles with every 10°C rise in temperature[8]. Assuming that room temperature is 28°C, a test conducted at 88°C for six weeks will then simulate a test conducted for 7.11 years at room temperature. This is derived as follows:

Test Temperature	Equivalent weeks at 28°C for a 1-week test at the test temperature
28°C	1
38°C	2
48°C	4
58°C	8
68°C	16
78°C	32
88°C	64

Thus the equivalent weeks at 28°C for a test of 2, 4 and 6 weeks duration at the test temperature of 88°C will be:

2 x 64 = 128 weeks = 2.46 years,

4 x 64 = 256 weeks = 4.92 years, and

6 x 64 = 384 weeks = 7.11 years, respectively.

In the test, samples of the polyethylene (2-1/2 x 1-15/16 x .015) were kept in different solutions of Clorox and water at 88°C, and examined for possible attack after 2, 4 and 6 weeks. The solutions used were 0, 1/2, 1, 2, 3 and 4 teaspoons of Clorox in 17-1/2 gallons of water. The samples in the pure water were intended as controls while those in the 4-teaspoon solution were intended for determining the possible effects on the plastic of twice the maximum recommended concentration of Clorox.

A double beam infrared spectrophotometer was used to observe changes in the samples (Figure 15).* The carbonyl radical (CO) which is formed as a result of the chemical reaction between sodium hypochlorite and polyethylene gives a strong absorption band at 5.8 microns and can be easily detected by this instrument.

*Model IR5, Range 2 to 16 microns, Beckman Instruments, Inc.

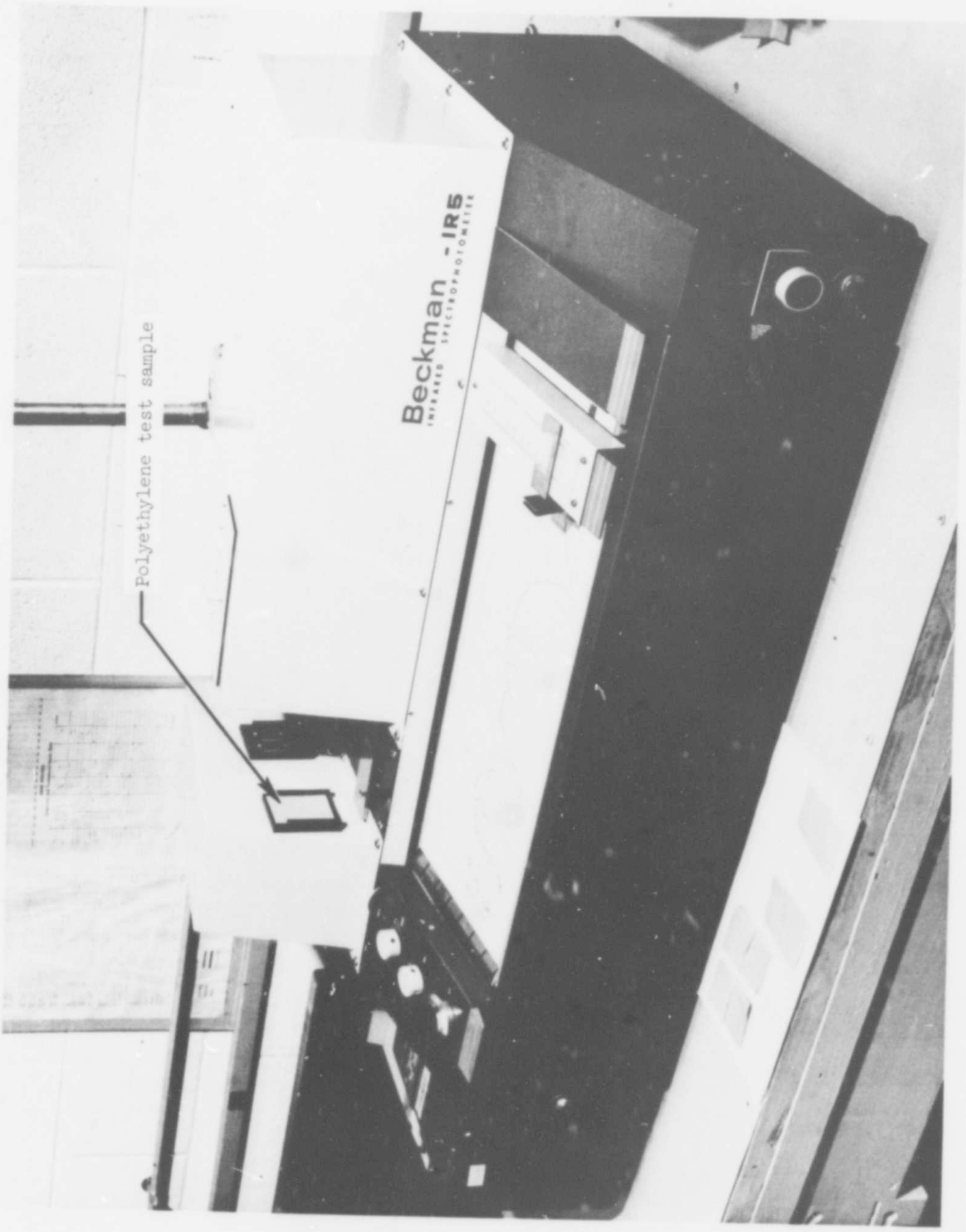

Figure 15 INFRARED SPECTROPHOTOMETER

The curves of transmittance versus wavelength for a sample before test and after the 6-week test in the 4-teaspoon solution are given in Figure 16. From this it can be seen that the two spectra are practically identical and that no absorption band is present at 5.8 microns after the test. This means that the material should be chemically unaffected after 7.11 years in a solution twice as concentrated as the maximum recommended. It can therefore be safely concluded that the chemical resistance of the material to sodium hypochlorite in the concentration normally recommended by OCD is adequate for the application.

In addition to the above, samples of low density polyethylene from drum liners used at present and which are known to be attacked by sodium hypochlorite, were also tested. Before the test, their spectra showed no absorption bands at 5.8 microns. After the test of 6 weeks in the 4-teaspoon Clorox solution, the spectra showed strong absorption bands at 5.8 microns. This confirmed the reliability of the test procedures.

3.3 Compressive Strength of Containers

Compression tests were run on containers with and without frames to determine their compressive strengths (Figure 17).

In the case of container with frames, the load was applied along the top of the frames to simulate the weight of stacked containers (Figure 18). The load was gradually increased and at about 3500 pounds a slight buckling of the frame sides was noticed. The load was increased further and at 6000 pounds the test was discontinued.

The strapping was intact at the end of the test. The only damage suffered by the frames was a slight bending in and outwards at the corners (Figures 19 and 20). The container was still usable.

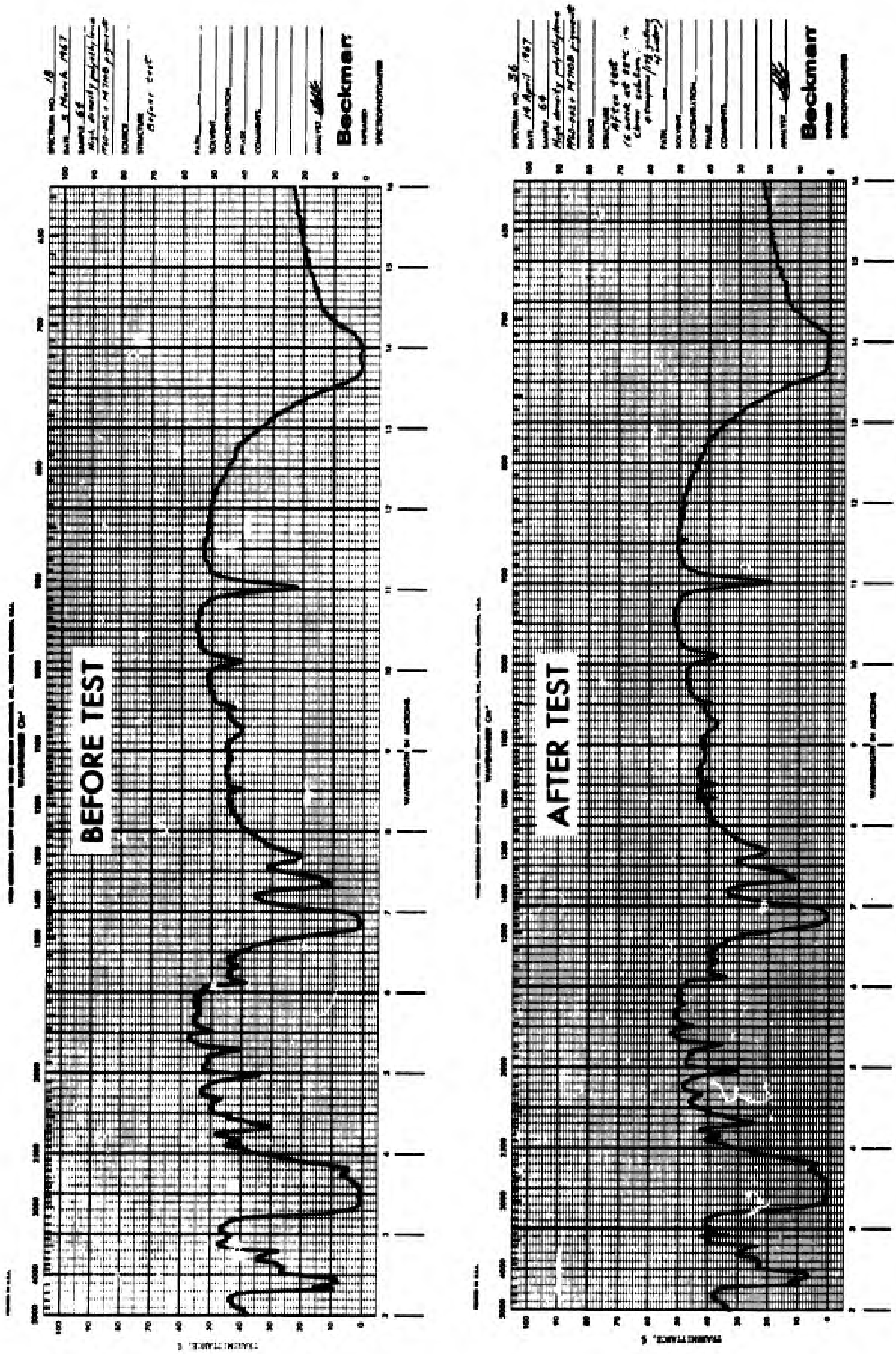

Figure 16 HIGH DENSITY POLYETHYLENE SPECTRA, BEFORE AND AFTER CHEMICAL COMPATIBILITY TEST

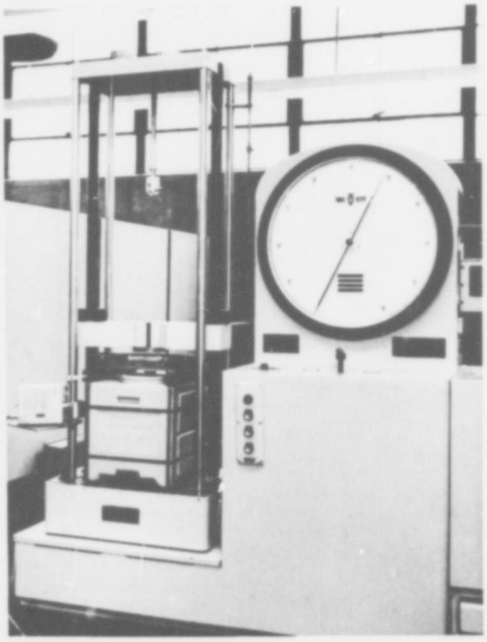

Figure 17 SETUP FOR COMPRESSION TEST OF CONTAINER

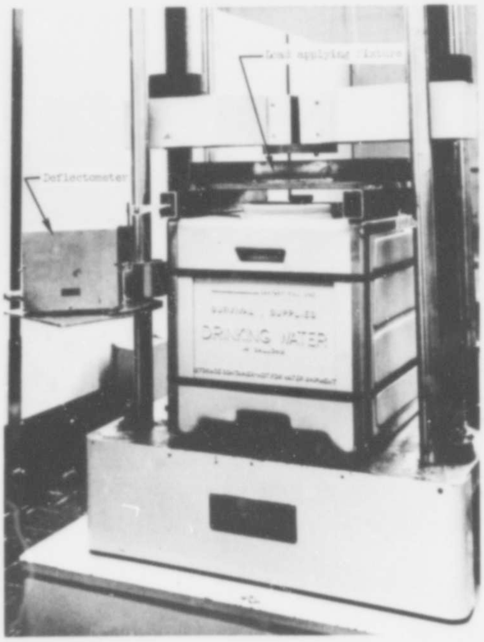

Figure 18 METHOD OF APPLICATION OF LOAD ON CONTAINER WITH FRAMES

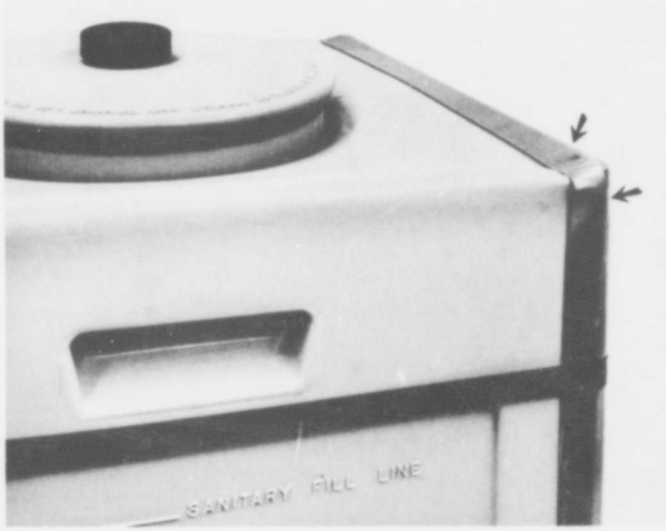

Figure 19 DAMAGE TO FRAME AFTER 6000 LBS. COMPRESSION TEST

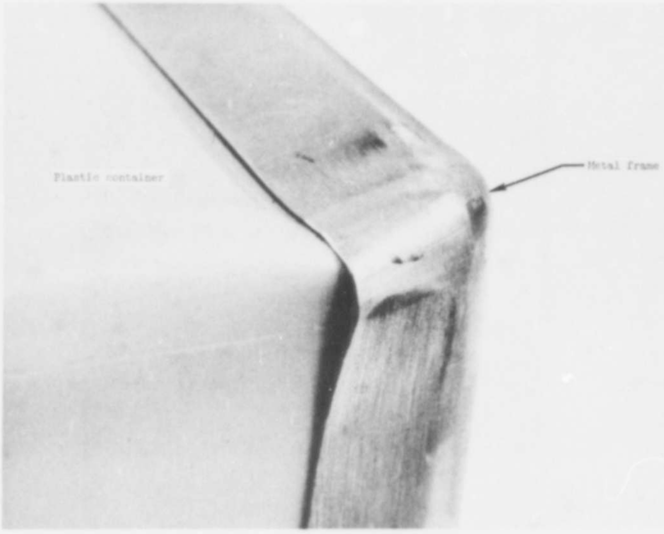

Figure 20 CORNER OF FRAME AFTER 6000 LBS. COMPRESSION TEST

As pointed out earlier, the maximum possible stacked load on a container when in use is 500 pounds. The frames are therefore more than adequate for the application. In fact production frames could be made thinner, say 20 gage, instead of the 19 gage of the prototypes and these would be cheaper and still have adequate strength.

The results of the tests on containers without frames or strapping are summarized in Table IX.

3.4 Drop Tests

The object of drop tests is to determine how much abuse a product can undertake before damage. Both filled and empty containers were drop-tested to determine their susceptibility to damage. In one series of tests, the containers were oriented to land flat on one of the sides on a concrete floor and in another, on one of the corners. The results are given in Table X.

From the tests it can be concluded that filled containers are much more susceptible to damage than empty ones (Figures 21 and 22). A filled container will be damaged and will leak if dropped from a height of 1 foot on its corner or about 3 feet on its side. An empty container, on the other hand, will not be damaged and will not leak when filled with water after a test, even if dropped from a height of 5 feet on its corner or side.

3.5 Pressure Tests

Containers with frames and without frames were both pressurized with air to determine the pressures to failure and the mode and location of failure.

The failure pressure was found to be a function of time. A higher pressure will cause rupture in a shorter time than a lower one. For a short duration test (less than 5 minutes), the failure pressure was 30 psi for both. For the container without frames, the failure took place at the back near the top

TABLE IX

COMPRESSION TESTS ON CONTAINER

Test No.	Container	Point of Application of Load	Result
1	Complete with frame and strapping	Along top of frames	Slight buckling of frames at 3500 lbs. Test discontinued at 6000 lbs. No failure. Plastic strapping intact at 6000 lbs.
2	Without frame or strapping	At center of lid	Deflection of center 1.150" at 280 lbs. No failure.
3	"	Along top side edges	Container yielded at 780 lbs.
4	"	Along entire top perimeter	Container yielded at 980 lbs.

TABLE X

DROP TESTS ON CONTAINER*

(A) Drop tests with container filled with water.

Drop Height**	Effect of dropping container on:	
	Side	Corner
1 foot	No damage. No water leakage.	Frame slightly damaged. Corner cracked. Water leakage.
2 feet	No damage. No water leakage.	Frame slightly damaged. Corner cracked. Water leakage.
3 feet	Corners and top at base of lid cracked. Water leakage.	Frame damaged. Corners and top at base of lid cracked. Water leakage.
5 feet	Frame damaged. Corners and top at base of lid split. Water leakage.	Frame severely damaged. Corners and top at base of lid split. Water leakage.

(B) Drop tests with container empty.

5 feet	No damage. No leakage when filled with water after test.	Frame slightly damaged. No leakage when filled with water after test.

*Complete with frame and strapping.

**On concrete floor.

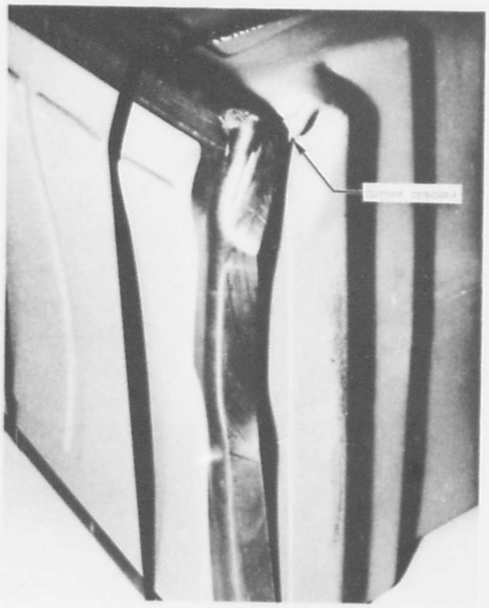

Figure 21 DAMAGE TO FILLED CONTAINER DROPPED ON CORNER FROM 3 FEET

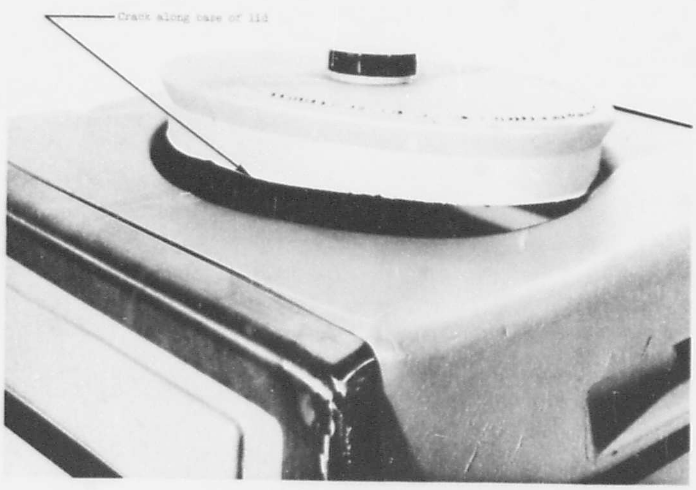

Figure 22 DAMAGE TO FILLED CONTAINER DROPPED ON SIDE FROM 5 FEET

(Figures 23 and 24). For the container with the frames, the failure took place at the base of the lid (Figures 25 and 26).

The failures were the results of the gradual stretching of the plastic and were not catastrophic.

3.6 Cutting of Container Lid

To convert a container into a commode, the lid has to be cut off. A suitable tool for this will have to be provided.

A number of knives were tested for this purpose (Figure 27). A serrated blade .032" thick with 18 teeth per inch was found to be the best.

To start the cut, an initial puncture must be made in the plastic. If the end of the knife is pointed, it could be used for this purpose. As an alternative, an awl may be employed.

3.7 Freeze Test

During storage it is quite possible for the containers to be subjected to freezing temperatures. To determine the effect of this a container was filled with water and frozen solid by leaving outdoors during sub-zero weather. After 48 hours it was taken indoors and allowed to thaw.

Examination disclosed no cracks and no leakage of water. Thus occasional freezing will have no effect on the container. However, repeated freezing and thawing may have a detrimental effect and should be further investigated.

3.8 Stability of Stacked Containers

Containers were filled with water, stacked five high, and their stability evaluated by rocking from side to side. It was found to be satisfactory.

3.9 Human Factor Tests

Human factor tests are planned for the containers under the scope of the prime contract, OCD-PS-66-9, Work Unit 1522A, "Specialized Occupancy Tests

Figure 23 CONTAINER WITHOUT FRAME AT 30 PSI PRESSURE

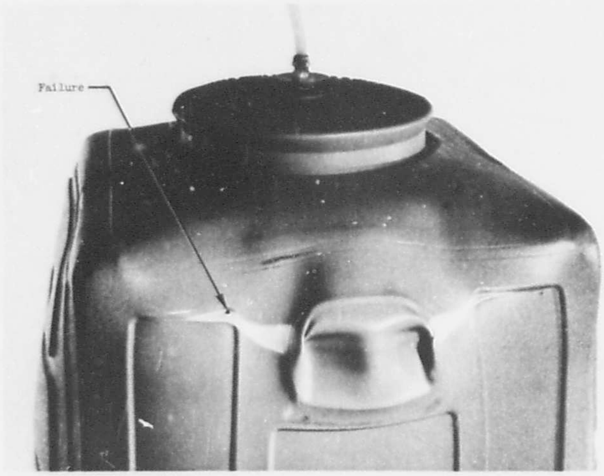

Figure 24 FAILURE OF CONTAINER WITHOUT FRAME AT 30 PSI PRESSURE

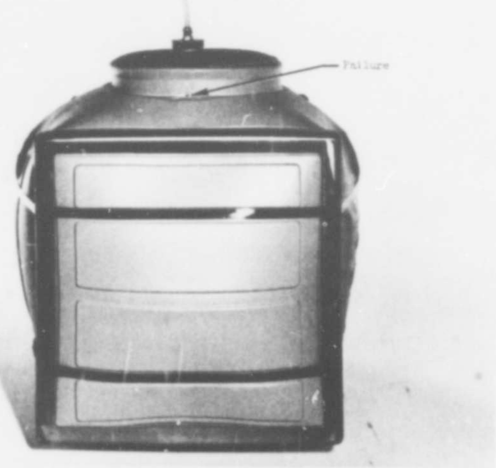

Figure 25 CONTAINER WITH FRAME AT 30 PSI PRESSURE

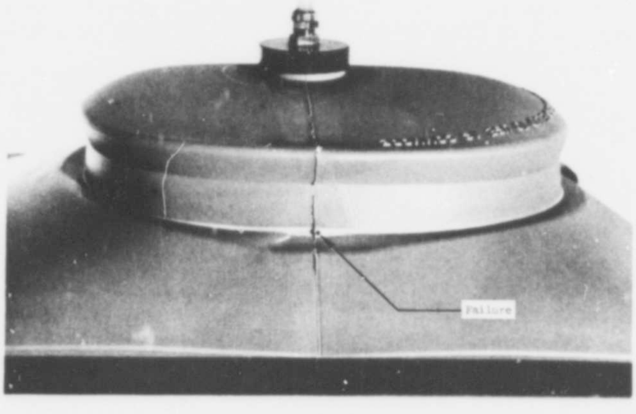

Figure 26 FAILURE OF CONTAINER WITH FRAME AT 30 PSI PRESSURE

Figure 27 KNIVES EVALUATED FOR CUTTING LID

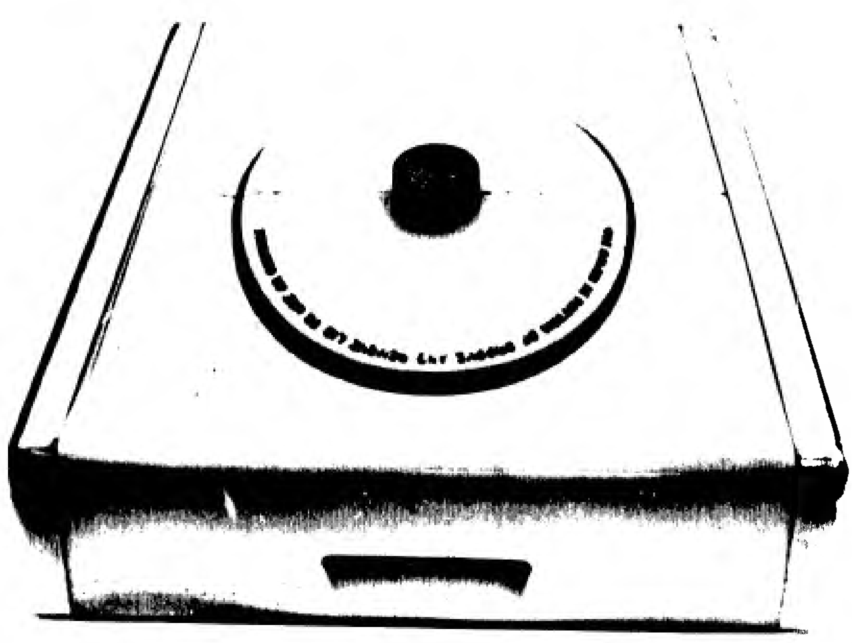

Figure 28 CONTAINER WITH LID IN PLACE AFTER CUTTING

of Shelter Environmental Conditions - Physical and Behavioral".

The tests will cover the following:

1. Recognition of the dual functions of the container by the shelterees
2. Ease of portability
3. Adequacy of molded instructions
4. Methods for water removal
5. Conversion to a commode
6. Use under actual occupancy conditions.

The results will be reported in the final report of the above contract.

RECOMMENDATIONS

The 14 gallon dual-purpose container is estimated to cost $4.64 in lots of 10,000 pieces. Of this, $1.94 or nearly 42% is for the metal frames. Thus the frames represent a substantial portion of the total cost.

Preliminary estimates show that this frame cost could be reduced significantly by using glass fiber reinforced polyethylene instead of chromium steel. The overall container cost could be reduced as a result by at least 15%. Such a frame could be injection molded and placed directly in the blow mold and the container molded over it. At the high temperatures in the mold, the frame and the container would bond readily forming a monolithic unit, eliminating the need for the plastic strapping and the seals (Figure 29).

The tensile strength of high density polyethylene triples at certain glass fiber concentrations with a corresponding increase in creep strength. Thus the long-term strength requirements of the container can be met with frames of this material.

It is strongly recommended that this design approach be investigated further and an 'all-plastic' container produced and tested before large volume production of this type of container is undertaken.

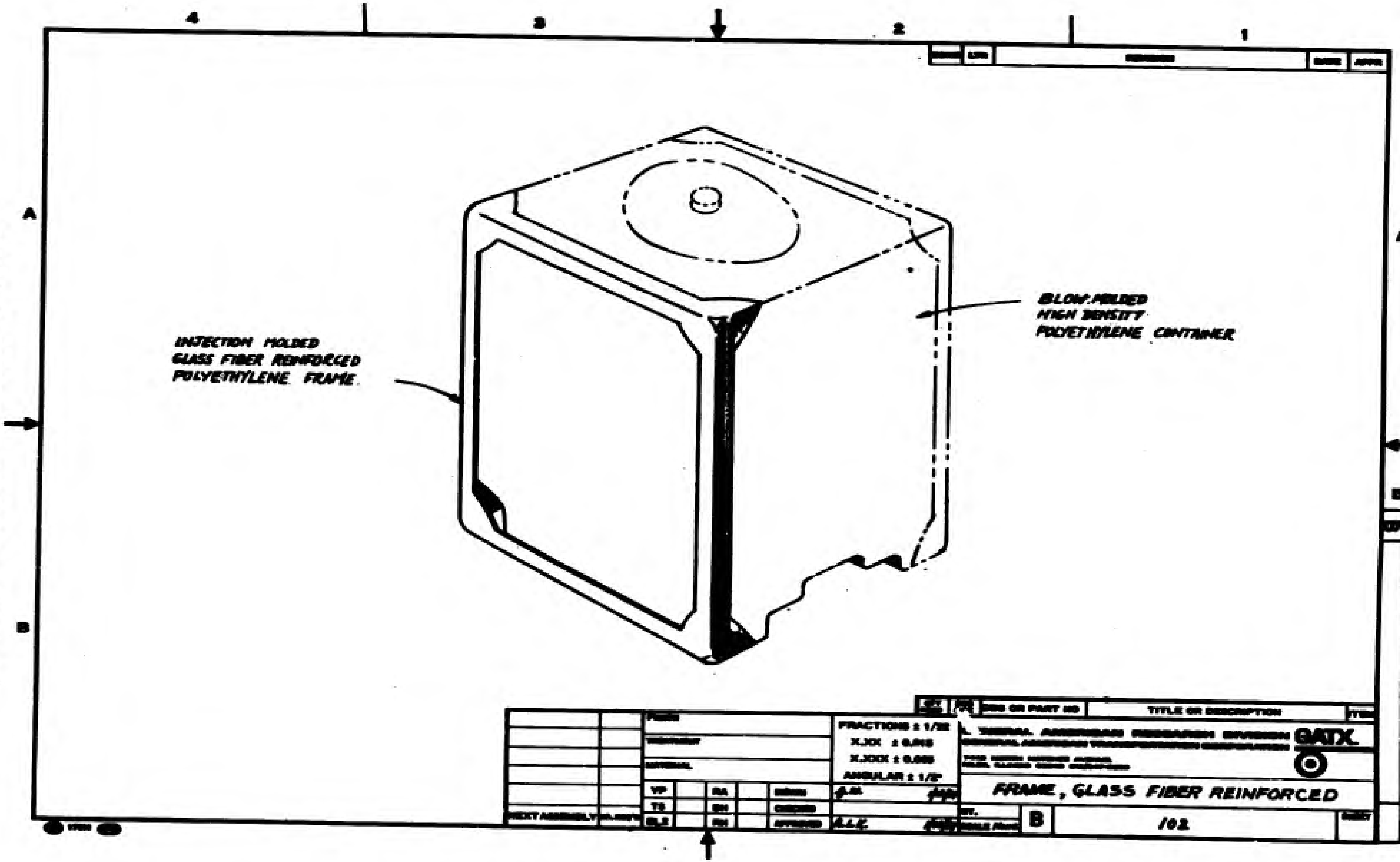

Figure 29 PROPOSED GLASS FIBER REINFORCED POLYETHYLENE FRAME

REFERENCES

1. Bulletin, U. S. Civil Defense Council, May 1967, p. 2.

2. "Guidance on Water Containers Stored in Public Fallout Shelters", Federal Civil Defense Guide, Part D, Chap. 2, Appendix 1, Annex 1, December, 1965.

3. Modern Plastics Encyclopedia 1967, Vol. 44, No. 1A, p. 236.

4. Martinovich, R. J., "Factors Affecting UV Degradation in Polyolefin Resins", Technical Information Bulletin #18, Phillips Petroleum Company, February 1964.

5. Plastics Reference Issue, Vol. 38, No. 14, Machine Design, 16 June 1966, p. 79.

6. "Fallout Shelter Water Requirements", Federal Civil Defense Guide, Part D, Chap. 2, Appendix 4, July 1965.

7. Annual Statistical Report, Fiscal Year 1966, Department of Defense, Office of Civil Defense, p. 30.

8. Perry, J. H., Chemical Engineers' Handbook, Third Edition, p. 323.

APPENDIX

DRAFT MILITARY SPECIFICATION FOR CONTAINER

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LIMITED COORDINATION

MILITARY SPECIFICATION

CONTAINER, WATER, DUAL-PURPOSE, 14 GALLONS (CIVIL DEFENSE)

This limited coordination military specification has been prepared by the Office of Civil Defense based upon currently available technical information, but it has not been approved for promulgation as a coordinated military specification. It is subject to modification. However, pending its promulgation as a coordinated military specification, it may be used in procurement.

1. SCOPE AND CLASSIFICATION

1.1 Scope. This specification covers the fabrication, assembly, testing and packaging of one type of 14 gallon dual-purpose water container.

2. APPLICABLE SPECIFICATIONS, STANDARDS, DRAWINGS AND OTHER PUBLICATIONS

2.1 Specifications and standards. The following specifications and standards of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

Specifications

<u>Federal</u>

PPP-B-636	Box, Fiberboard

Standards

<u>Military</u>

MIL-STD-105	Sampling Procedure and Tables for Inspection by Attributes
MIL-STD-109	Inspection Terms and Definitions
MIL-STD-129	Marking for Shipment and Storage

(Copies of specifications and standards required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

2.2 Drawings

1404-AC-1S	Container, Dual-Purpose, Assembly of
1404-PC-1E	Container, Plastic
1404-PC-2C	Container, Plastic
1404-PC-3CS	Container, Plastic
1404-PC-4C	Container, Plastic
1404-SF-1	Frame, Side

(Copies of drawings required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

2.3 Other Publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

American Society for Testing and Materials (ASTM)

A 370-64	Standard Methods and Definitions for Mechanical Testing of Steel Products
D 790-63	Standard Method of Test for Flexural Properties of Plastics
D 883-64bT	Tentative nomenclature Relating to Plastics
D 1248-63T	Tentative specification for Polyethylene Molding and Extrusion Material
D 1505-63T	Tentative Method of Test for Density of Plastics by the Density-Gradient Technique

(Copies may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

Food and Drug Administration (FDA)

Food Additives Regulation, Subpart F, Section 121.2501

(Copy may be obtained from the Food and Drug Administration, Department of Health, Education, and Welfare, Washington, D. C. 20204)

3. REQUIREMENTS

3.1 Plastic Container

3.1.1 Material. The plastic container shall be blow-molded out of first quality high-density polyethylene conforming to Type III, Grade 3, Class A or B of ASTM D 1248-63T (see 6.3). The density shall be within a range of .950 and .965 g per cu cm when tested in accordance with ASTM D 1505-63T. The flexural modulus shall equal or exceed 195,000 psi when tested in accordance with ASTM D 790-63. The resin shall meet the requirements of section 121.2501, Subpart F, Food Additives Regulation issued by the Food and Drug Administration for materials in contact with drinking water, and shall contain only FDA approved anti-oxidants to provide the aging characteristics necessary for a 15-year service life. The contractor shall furnish written certification that these requirements are met.

3.1.2 Construction. The container shall be constructed to be completely leakproof to water. The surface shall be free from pinholes, cracks, blisters, fish eyes, nicks, cuts, or other imperfections which will impair their leakproofness. The definition of these terms shall be as per ASTM D 883-64bT. The fit between the threads on the neck and the cover (see 3.3) shall be tight to prevent water leakage. The wall thickness shall be a nominal .080" and shall not be less than 0.60" at any point except at the bottom of the groove (inner edge of the seat). The thickness at this point shall not be less than .045". The dimensions of the container shall be within the tolerance specified on the drawings, and shall be checked at least 48 hours after molding. The capacity shall not be less than 14.0 gallons.

3.1.3 Markings. The front and top of the container shall have embossed lettering as shown in Figure 1. The back of the container shall have the information shown in Figure 2. The lettering style shall be Gothic.

3.2 Side Frame

3.2.1 Material. The side frames shall be fabricated out of corrosion resistance stainless steel having at least 10% Chromium (see 6.4). The stainless steel shall be unaffected by storage in a high humidity atmosphere or in contact with natural water. The mechanical properties of the steel shall be as follows:

Yield Strength (.2% offset):	32,000 psi (min.)
Ultimate Tensile Strength:	62,000 psi (min.)
Test Temperature:	80°F

The Yield and Ultimate Tensile Strengths shall be determined as per paragraph 13(b) and 14 respectively of ASTM A 370-64. The contractor shall furnish written certification that these requirements are met.

3.2.2 Construction. The frame shall be constructed to be free from wrinkles at the corners and all edges shall be broken. The nominal thickness of the frame shall be .0375" (20 gage) and the thickness at any point shall not be less than .030".

3.3 Cover

3.3.1 Material. The cover shall be of molded phenolic and shall be provided with a liner to ensure a leakproof closure. The liner shall consist of a .0015" high-density polyethylene film coated on paper and laminated to pulpboard. The polyethylene film shall be of a grade approved by the Food and Drug Administration for use in contact with drinking water. The contractor shall furnish written certification that this requirement is met.

3.3.2 Construction. The cover shall have internal threads. These threads shall be 48 mm, 400 finish G.C.M.I. (Glass Container Manufacturers Institute) or buttress. The threads shall have a smooth finish and shall form a leakproof closure with the container.

3.4 Strapping. The strapping for retaining the side frames to the container shall be of high strength plastic such as nylon or polypropylene. The width of the strapping shall be .500" ± .010" and the tensile strength shall be greater than 425 lbs. The strapping shall be smooth, abrasion resisting and shall be unaffected by high humidity or water.

3.5 Seals for Strapping. The seals for joining the ends of the strapping shall be of the metal crimp type and shall be of stainless steel Type 430 or equivalent. The seals shall be less than 1-1/4 inch long and the strength of the crimp joint shall be greater than 225 lbs.

3.6 Assembly. The two side frames shall be assembled to the container with two strappings (see Figure 3). The strapping shall be crimp sealed at the back of the container with the seal lying over the depressions in the container as shown. A tensile force of 45 ± 5 lbs shall be applied to the strapping during assembly.

3.7 Workmanship. Workmanship shall be in accordance with the highest grade of commercial industry practice. The containers shall be supplied clean and free of contamination.

3.8 Preproduction Sample. When specified in the contract or order (see 6.2) before production is commenced, a sample container shall be submitted or made available to the contracting officer or his authorized representative for approval in accordance with 4.2. The approval of the preproduction sample authorizes the commencement of production, but does not relieve the supplier of responsibility for compliance with all applicable provisions of this specification. The preproduction sample shall be manufactured in the same facilities to be used for the manufacture of the production items.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection Responsibility. The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the Government. Inspection records of the examination and tests shall be kept complete and available to the Government as specified in the contract or order. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Preproduction Sample Inspection. When a preproduction sample is required, it shall be examined as per 4.4.2 and tested as per 4.4.3.1 and 4.4.3.2 at contractor's expense. The sample shall be approved if the examination and tests are passed successfully.

4.3 Definitions. All inspection terms used herein shall be as defined in MIL-STD-109.

4.3.1 Lot. A lot shall consist of one day's production or all container assemblies offered for acceptance at one time.

4.4 Quality Conformance Inspection

4.4.1 Sampling

4.4.1.1 Sampling for Examination. Sampling for examination shall be in accordance with MIL-STD-105, at inspection level II. The AQL shall be 1.5 percent defective for major defects.

4.4.1.2 Sampling for Tests

4.4.1.2.1 Sampling for Test 1. Sampling for Test 1 shall be in accordance with MIL-STD-105, at inspection level I. The AQL shall be 1.5 percent defective.

4.4.1.2.2 Sampling for Test 2. Sampling for Test 2 shall be in accordance with MIL-STD-105, at inspection level S-1. The AQL shall be 1.5 percent defective.

4.4.2 Examination. Each unit selected in accordance with 4.4.1.1 shall be examined for defects listed in Table I. Any sample having one or more defects shall be considered defective.

Table I

Classification of Defects

Category	Defects
Critical	None defined.
Major	
101	Container not as specified.
102	Container surface defective (pinholes, cracks, blisters, fish eyes, nicks, cuts or other imperfections).
103	Container not clean (grease, dirt or other foreign matter present).
104	Frame not as specified.
105	Frame edges not broken.
106	Cover not as specified.
107	Cover loose on container.
108	Cover too tight on container.
109	Cover liner not as specified.
110	Cover liner missing.
111	Strapping not as specified.
112	Strapping loose.
113	Strapping too tight (container distorted).

114	Strapping missing.
115	Strapping seal not as specified.
116	Strapping seal not crimped as specified
117	Strapping seal not located at position specified.

<u>Minor</u> None defined.

4.4.3 Tests

4.4.3.1 Test 1. Each unit selected in accordance with 4.4.1.2.1 shall be tested for leakage as follows. The container shall be filled with drinking quality water up to the sanitary fill line and the cover tightened with a torque of 25 ± 1 inch-lbs. After an interval of not less than 5 minutes the container shall be examined for leakage. The container shall then be inverted (cover down) and again examined after an interval of not less than 5 minutes. Any sample showing water leakage shall be considered defective. Samples so tested shall not be considered part of the procurement unless thoroughly cleaned and dried.

4.4.3.2 Test 2. Each unit selected in accordance with 4.4.1.2.2 shall be tested for wall thickness as follows. The side frames and the cover shall be removed and the container sectioned along an axial plane passing through two corners. A hacksaw or a band saw shall be used for this purpose. The wall thickness of any one of the halves shall then be measured with a micrometer. The wall thickness at any point, except at the bottom of the groove (inner edge of the seat), shall not be less than .060". The thickness at the bottom of the groove shall not be less than .045". Any sample having wall thickness less than these values shall be considered defective. Sample so tested shall not be considered part of the procurement.

4.4.4 Inspection of Preparation for Delivery. The packaging, packing and marking shall be inspected to determine compliance with the requirements of Section 5 of this specification.

5. PREPARATION FOR DELIVERY

5.1 Packing. Each container shall be placed in a type RSC, single wall corrugated fiberboard box, 200 pound bursting strength, in conformance with specification PPP-B-636, Box, Fiberboard. Corrugated fiberboard pads, as stipulated in Figure 4, shall be placed on top of the unit. Inside dimensions of the box shall be 16-1/8 inches by 16-1/8 inches by 17-1/2 inches.

5.2 Marking. Marking shall be in accordance with MIL-STD-129, Marking for Shipment and Storage.

6. NOTES

6.1 Intended Use. The dual-purpose water containers are intended for use in identified fallout shelters for storing drinking water. After the water is consumed the containers shall be converted into chemical toilets by cutting off the top as specified. The cut-off portion forms a tight fitting lid for ease in disposing of the containers.

6.2 Ordering Data. Procurement documents shall specify the following:
(a) Title, number and date of this document.
(b) Number of container assemblies required.
(c) Preproduction sample, if required.

6.3 High-density Polyethylenes. The following high-density polyethylenes are believed to be suitable for blow-molding containers acceptable under this specification:

Manufacturer	Manufacturers Designation
Allied Chemical Corp.	PP60-002, 6-34B
E. I. duPont de Nemours & Co., Inc.	Alathon 7516
Phillips Petroleum Co.	6003
Sinclair-Koppers Co.	Super Dylan 7004
Union Carbide Corp.	DMDA-4300
National Distillers & Chemical Corp.	U.S.I. LB 830

6.4 Stainless steels. The following stainless steels are believed to be suitable for fabricating side frames acceptable under this specification:

Manufacturer	Manufacturers Designation
Allegheny Ludlum Steel Corp.	MF-1
All	Type 302, 304, 409, 410 or 430.

6.5 Deviations. To ensure a minimum of leakage of drinking water in the Civil Defense shelter program, no deviation from this specification shall be permitted. Should there be a need for changes in the requirements set forth herein, the changes shall be made by amending this document.

Notice. When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

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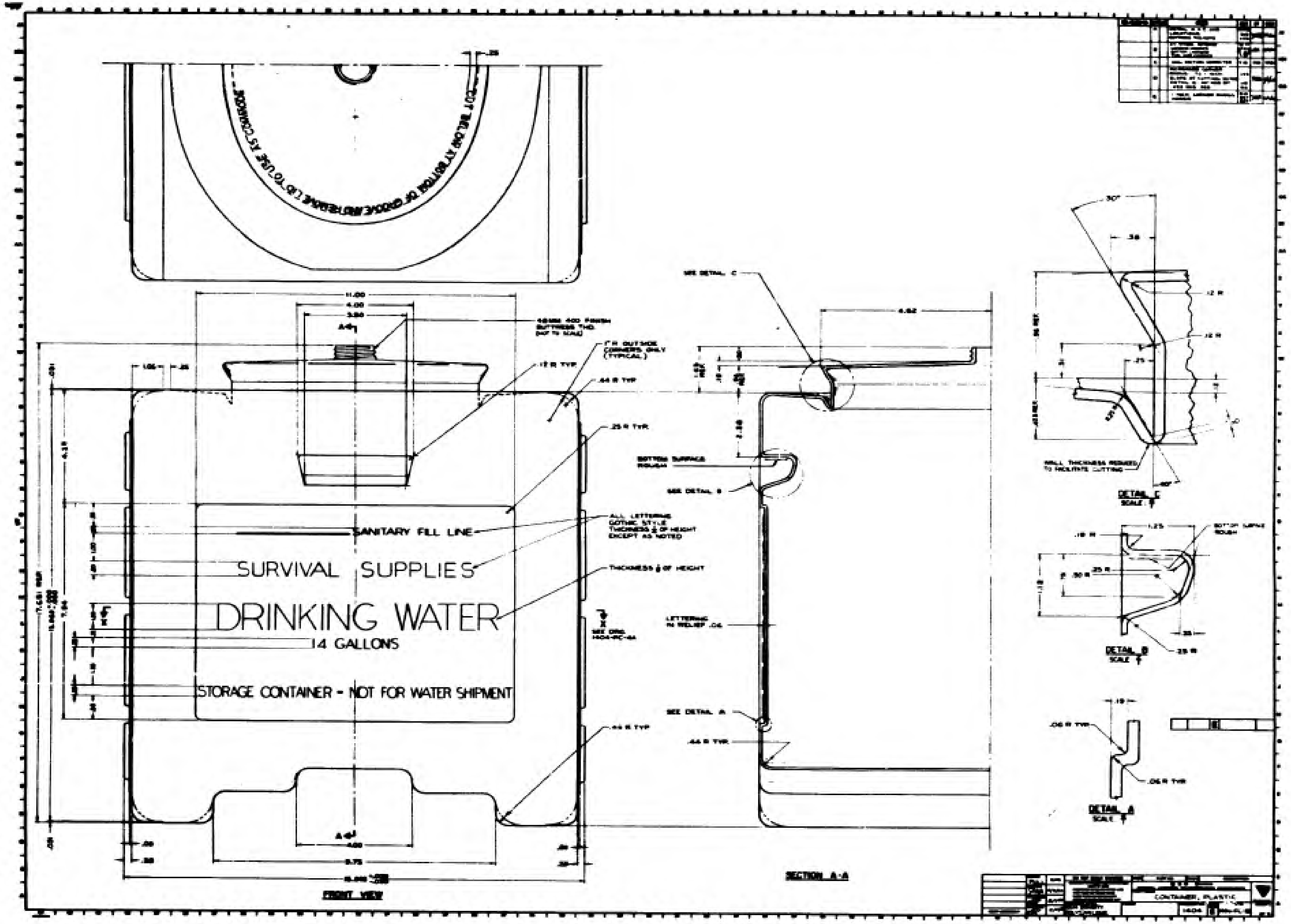

Figure 1 CONTAINER, FRONT VIEW

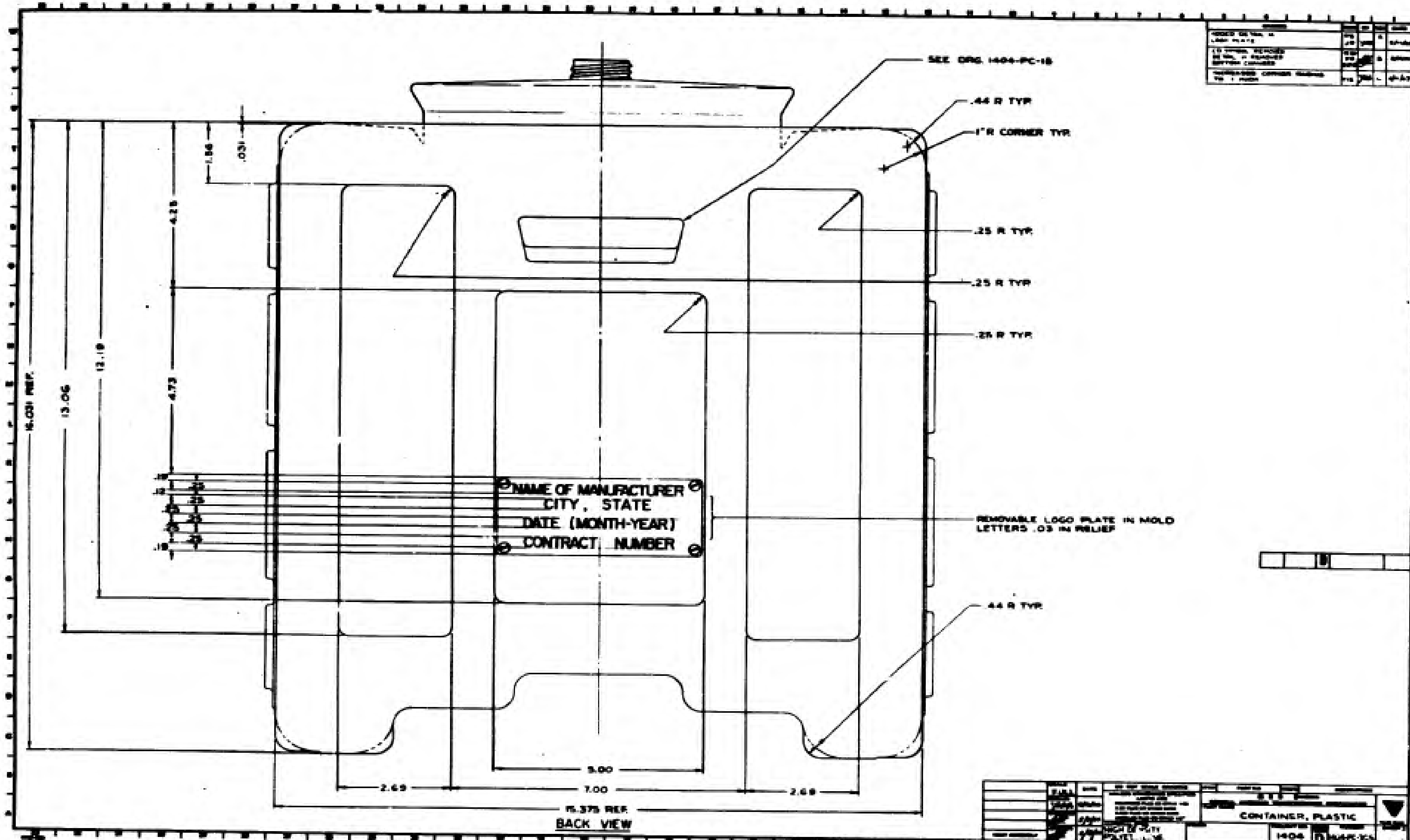

Figure 2 CONTAINER, BACK VIEW

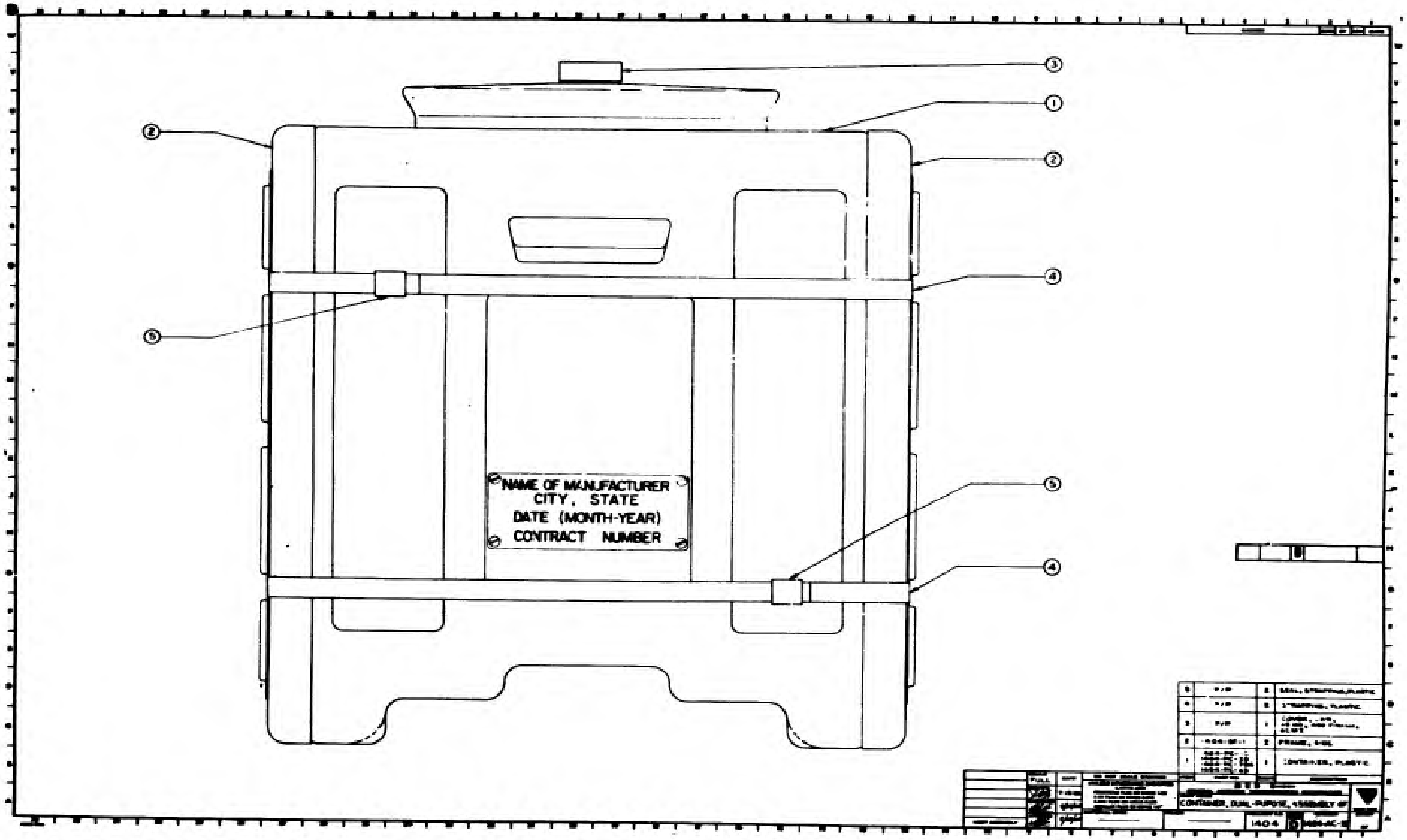

Figure 3 CONTAINER ASSEMBLY, BACK VIEW

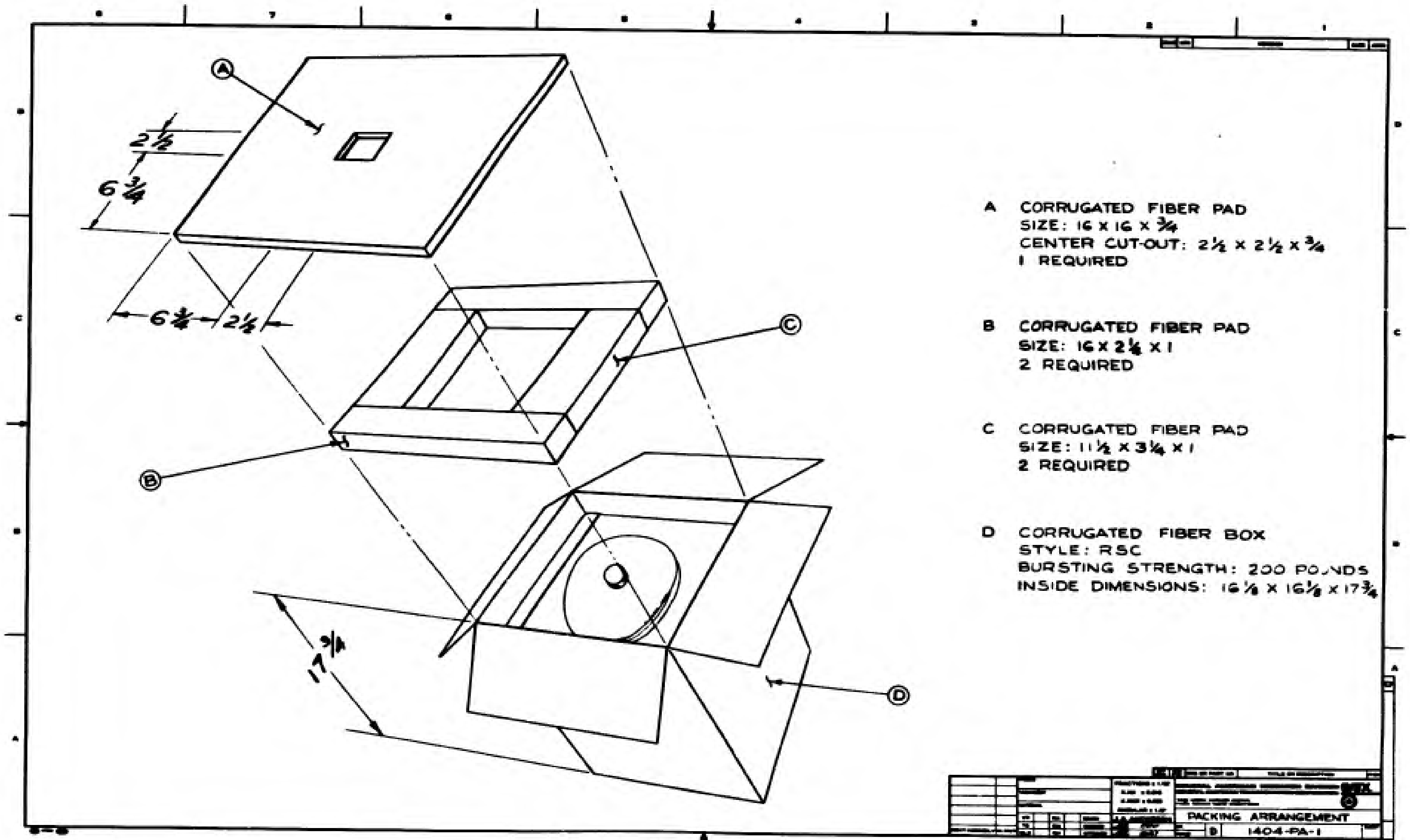

Figure 4 PACKING ARRANGEMENT

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13. ABSTRACT

A 14-gallon, dual-purpose polyethylene container was developed for storing water in fallout shelters. After the water is consumed, the container can be converted into a commode. Tests on prototype containers show the design to be satisfactory.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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SUMMARY
OF
RESEARCH REPORT

DUAL-PURPOSE WATER CONTAINER

A. L. Kapil

GARD Final Report June 1967

REVIEW NOTICE

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

GENERAL AMERICAN RESEARCH DIVISION

SUMMARY OF REPORT

The containers furnished at present by the Office of Civil Defense for storing water in public fallout shelters consist of 17-1/2 gallon steel drums with double 4-mil polyethylene liners. Inside dimensions of the drums permitted by the specifications vary from 15-1/4" to 16-1/8" in diameter and 23-3/8" to 21-5/8" in height.

Experience with these containers over the past few years has brought out several operational and design problems. Briefly, these are:

1. The exterior of the drums rust when stored in high-humidity areas.
2. The inside of the drums rust because of the presence of water between the liner and the inside wall of the drums. This condition results from one or more of the following:
   (a) Careless handling during the filling operation
   (b) Seepage or capillary action through the tied spout of the inner liner bag
   (c) Leakage through the liners because of pinhole, cut, puncture or defective heat seal.
3. Liners are susceptible to attack by the bleach (sodium hypochlorite) which is added to the water as a disinfectant.
4. Height of the drums is excessive when used as a commode.
5. Filled drums are too heavy to be conveniently moved or lifted by two people. Hand-holes or other means for maneuvering the drums are not provided.
6. Storage space is wasted because of the circular cross-section of the drums.
7. Stacking of filled drums is limited to three-high.

To overcome these problems, a new dual-purpose water container was designed. This new design has the following features:

1. The container is blow-molded in one piece out of high density polyethylene and is provided with corrosion-resisting steel frames to give stacking strength. Rusting is thus avoided.
2. Chemical action of the bleach on the plastic is eliminated by using special grades of high density polyethylene.
3. The containers are provided with an integral seat-lid arrangement for easily converting empty containers into commodes. This is accomplished by cutting off the lid with a knife along the groove at the base of the lid. For disposing of used containers, the lid snaps back forming a tight seal. The height of the containers is the same as the height of a standard water closet.
4. Each container is smaller and thus easier to handle. The capacity is 14 gallons and the filled weight, 132 lbs. Hand-holes are provided to further assist in maneuvering the containers.
5. The weight of stacked containers is transmitted to the floor through chromium steel frames -- the plastic container itself is not subjected to any compressive loads.
6. The containers are square in cross-section to save floor space and are designed to be stacked five-high (Figures 1 and 2).

A total of 150 units were produced and tested to determine the following:

1. Long-term creep of the plastic
2. Chemical compatibility of the plastic with the bleach
3. Maximum stacking load

4. Damage when dropped from different heights

5. Failure pressure and location of failure points

6. Effect of freezing.

The results of the tests show that this design may be satisfactorily developed for the application.

The container is designed for an estimated life of 15 years when stored under normal conditions.

A draft military specification for the container is included in the report.