DNA 2840F

August, 1971

"PROTECTIVE BARRIER SYSTEM FOR MUNITIONS STORAGE"

FINAL REPORT

PARTS I AND II

by

A. J. Palfey

V. L. Hannaford

Defense Nuclear Agency
Washington, D. C. 20305

The Dow Chemical Company
Functional Products And Systems
Midland, Michigan 48640

Contract: DASA01-71-C-0018

Details of illustrations in
this document may be better
studied on microfiche

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PART I

"RESEARCH AND DEVELOPMENT TO SELECT AN OPTIMUM SYSTEM"

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This Effort Supported by Defense Nuclear Agency Under:
NWE D Subtask Code NA 006 Work Unit Code 04

The Dow Chemical Company
Functional Products and Systems
Midland, Michigan 48640

SUMMARY

The Dow Chemical Company of Midland, Michigan, under a Defense Nuclear Agency contract, has developed a sand containment system to replace the stacked sand bag dividing walls currently in use in compartmented storage structures. Protection is provided for high explosive storage against the following propagation modes; fragment initiation, over pressure crushing and translation. Compartments are constructed by abutting short wing walls perpendicular to either one or two sides of a long main wall. The walls of sand measuring 22 inches wide and up to 96 inches in height are contained between two walls of lightweight extruded polystyrene foam boards. All materials of construction are lightweight having virtually no potential for generating undesirable secondary projectiles. The system is designed for shipment to the storage site of a complete prefabricated unit ready for field assembly with minimum hand tools, instructions, or technical supervision. Cost is comparable with conventional sand bag systems and expected life is over 10 years. Reliability of performance is based on over 9 months laboratory testing of full scale sand filled wall sections.

FOREWORD

This final report covers Phase I of a two phase project by The Dow Chemical Company for the development of a protective barrier system for munitions storage. Phase I, under the Defense Nuclear Agency contract DASA01-71-C-0018, 1970 October 20 through 1971, August 31, covers the research and development of a system including laboratory testing of a full scale barrier wall model section. Phase II covers the factory fabrication and field installation of a protective barrier system in a munitions storage magazine at NAD, Earle, New Jersey, with Dow providing fabricated materials and construction supervision.

The final report of the Phase I program is divided into two sections. Part 1 covers the research and development work from which recommendations are made for the Part 2 section covering material specifications, engineering drawings, fabrication, assembly, sand loading, and maintenance procedures.

The DNA Contracting Officer Representative (COR) for this contract is LTC W. D. Nelson, U. S. A. LTC Nelson and Mr. Charles L. Haney, J-4C1 (DNA) established the requirements for this project and gave valuable assistance in guiding the project with their broad knowledge in munitions storage.

In addition the authors wish to acknowledge the technical assistance of Mr. Wm. P. Hovey of The Dow Chemical Company during fabrication, assembly and testing of materials and prototype models, along with the project management assistance furnished by H. S. Smith and B. A. Russell.

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1.0 STATEMENT OF PROBLEM

The construction criteria and design methods for protective structures for high explosive storage is well documented. Most recently, quantitative methods of design for protective structures used in high explosive processing and storage facilities have been described [1]. This document is concerned with the particular portion of the protective structure that is the barrier system made up of compartments within earth-covered concrete magazines or bunkers. The barrier system is designed to protect against or attenuate the donor output to tolerable levels. Thus, the acceptor system, in this case explosives, is protected in the event of an accidental initiation. Protection must be provided against the following propagation modes; fragment initiation, over pressure crushing and translation.

Protective barrier systems constructed of sand bags are very efficient when stacked in a prescribed manner. Sand bags provide protection from impact effects of both blast pressures and primary fragments and do not contribute to the formation of post-failure fragments from the structure itself. The density and particle size of sand is excellent in this regard. Cost and almost universal availability are also in favor of this material.

While stacked sand bag walls provide an effective protective function, on long-term storage, the bags tend to settle or change position for various reasons. The barrier wall can lean or even fall creating a hazardous condition, even causing accidental initiation.

Thus, the problem is to develop an improved barrier system which combines the same protection to the acceptor system as sand bags in the event of an accident, but with long-term storage capability having minimal maintenance and virtually no potential for projectile production. It is believed that composite construction, utilizing the desirable protective properties of sand in combination with plastic materials to retain the sand, is a practical answer to this problem.

2.0 REQUIREMENTS

The significant requirements for the new barrier system design as presented by DNA representative are:

(1). To contain a 22" thick wall of sand.

(2). Sand shall be either wet or dry with grain size not to exceed 1/8".

(3). Be flexible in establishing wall heights up to 8 feet.

(4). Have the flexibility in altering compartment size.

(5). Wall and wall tie material shall have virtually no potential for projectile production.

(6). All raw material shall be commercially available.

(7). Simplicity of fabrication, assembly, loading and maintenance.

(8). The system cost is to be equal to, or less than existing sand bag installations.

(9). Life expectancy of over 10 years.

3.0 RAW MATERIALS SELECTION

Initially the light weight materials w[illegible]inimal potential of secondary fragment production considered were:

(1). Plastic foam
(2). Plastic film
(3). Woven fabrics
(4). Reinforced membranes

Of these materials, lightweight plastic foam is the most rigid and has the greatest potential of meeting the barrier system requirements. In addition to its structural properties, plastic foam is chemically inert, resists rot and fungus and contains no food value; therefore, it does not attract insects or rodents. Also, because of the polymer's moisture resistance and the foam's closed cell structure, these materials will not significantly deteriorate upon long-term exposure in an igloo-type ammunition storage magazine.

4.0 COMMERCIAL PLASTIC FOAMS

The most widely available commercial structural plastic foam materials are:

Foam Type	Available Form
- Extruded Polystyrene	Boards and billets
- Expanded Polystyrene Beads	Molded shapes, boards and billets
- Urethane	Molded shapes, boards and billets

The photos Figures 1,2,3, and 4 show the cell structure of the basic foam types.

4.1 Extruded Polystyrene Foam

Extruded polystyrene foam is produced by the free expansion of a hot mixture of polystyrene, and a blowing agent with additives through a slit orifice to about 40 times its pre-extrusion volume. After cooling, the material is cut to standard board sizes, 16" wide x 108" long in thicknesses up to 6". Densities range from 1.4 to 5 lbs/cu. ft. Of the three foam types listed in paragraph 4.0, extruded polystyrene is structurally stronger than urethane or beads of equivalent density.

4.2 Expanded Polystyrene Bead Foam

Expanded polystyrene bead foam is manufactured by expanding individual beads of polystyrene containing a blowing agent. When placed in a mold and exposed to heat the vapor pressure of the blowing agent causes the beads to expand up to 50 volumes. Densities of large molds or billets, which may be cut to 4 ft x 8 ft board stock, range from 0.5 to 2 lbs/cu. ft. Densities up to 10 lbs cu/ft may be attained with smaller molds. Compared to extruded polystyrene foam, bead foam has lower structural properties and greater susceptibility to moisture because individual beads are not always entirely welded together.

4.3 Urethane Foam

The formation of rigid urethane foams involves the chemical reaction of a polyisocyanate and a polyhydroxyl material under carefully controlled conditions. Production techniques

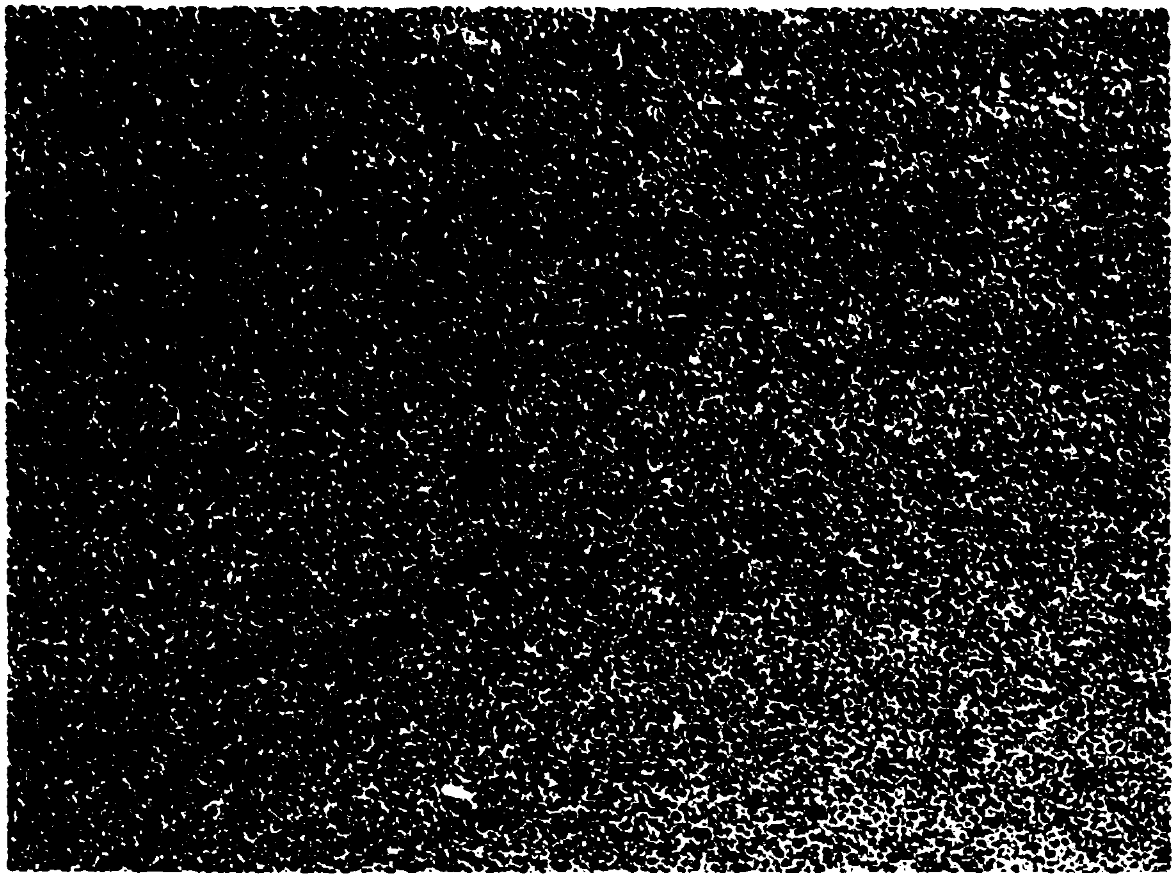


Fig. 1 - Extruded Polystyrene Foam,
Density - 1.9 lbs./cu.ft., Magnification 6X

Fig. 2 - Extruded Polystyrene Foam
Density - 3.5 lbs./cu.ft., Magnification 6X

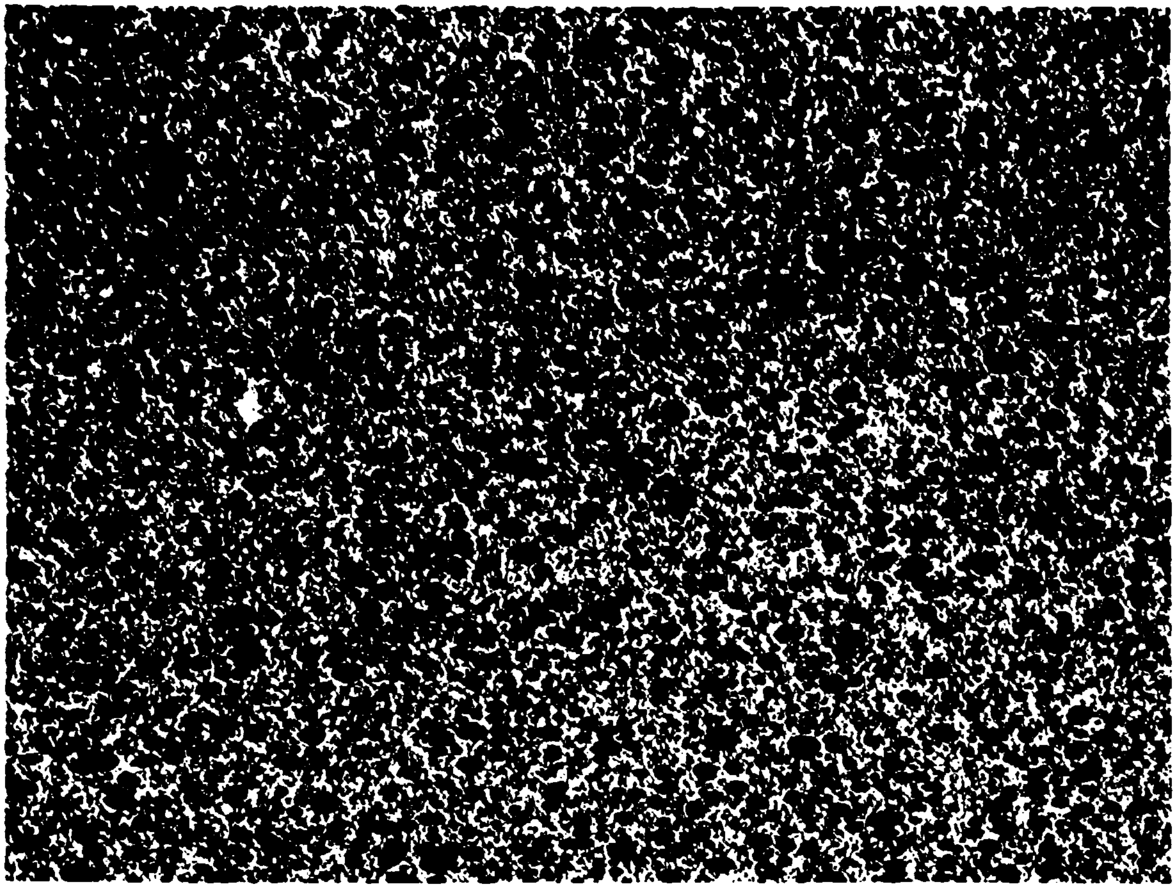


Fig. 3 - Polyurethane Foam, Density - 2.0 lbs./cu.ft., Magnification 6X

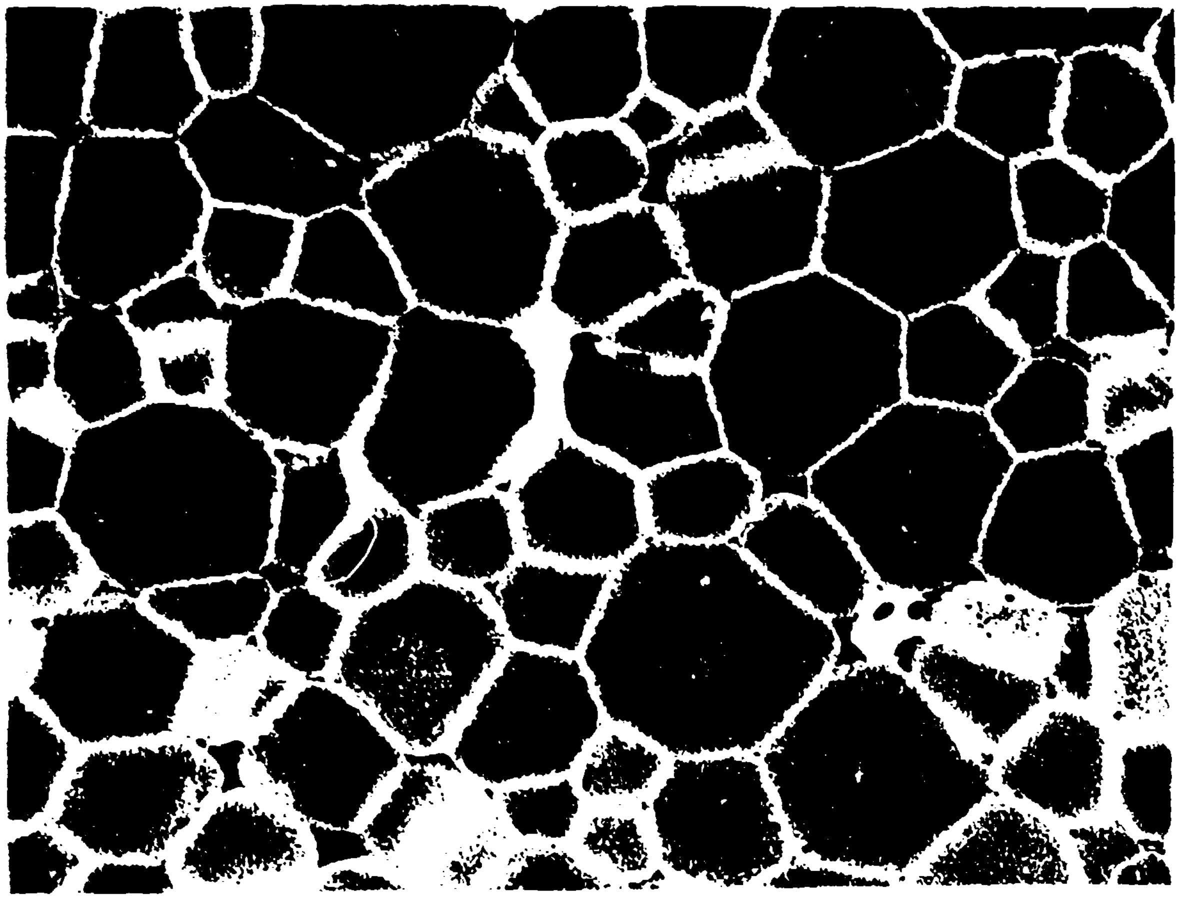


Fig. 4 - Expanded Polystyrene Beads, Density - 1.2 lbs./cu.ft., Magnification 6X

include factory and on-site operations using such procedures as molding pouring, spray, froth, etc. Densities may range from 1 to 25 lb/cu ft. Board or panel stock is commercially manufactured from large foam billets 4 ft wide up to 12 ft in length. At equivalent density, urethane foam structural properties are lower than extruded polystyrene foam.

5.0 PLASTIC FOAM PROPERTIES

Although lightweight plastic foams are noted for their thermal insulating properties, they are utilized extensively in structural applications as load bearing sandwich panel core material, in spiral generated dome buildings and in structural marine applications.

The significant foam property concerned in a sand barrier wall system is the foam's flexural stress properties. The foam becomes stressed by uniformly distributed sand lateral pressures against the foam wall. Typical foam properties and relative costs are tabulated on Figure 5. Relative stress/strain curves for various density foams are plotted on Figure 6. The curves illustrate the characteristics of high density and smaller cell foams to yield considerably without failure, while the lower density and larger cell foams fail quite sharply at less strain. (Note the vertical line at terminal points).

Any of these foams may be considered in a barrier wall design. Thicker walls are required for lower strength foams.

6.0 TYPICAL STEEL-ARCH MAGAZINE LAYOUT

Plan and elevation dimensions of a typical magazine are given on Figure 7. Munitions are stored in compartments

Type	Form	Density lbs./cu.ft.	Flexural Stress psi	Flexural Modulus psi	Compressive Strength psi	Cost Bd/Ft $
ASTM Test			C-203	C-203	D-1621	
Extruded Polystyrene	Boards, Logs	1.8	60	1800	30	.10
	Boards, Logs	3-4.5	90-135	2300-4600	125-175	.23
Expanded Polystyrene Beads	Boards, Panels, Molded Shapes	1-2.0	28	1100-1500	8-12	.08
Urethane	Boards, Panels, Molded S.	1.9	45	1500	25	.15
	Boards, Panels, Molded S.	4.1	90	2000	80	.50

Fig. 5 - Plastic Foam Properties

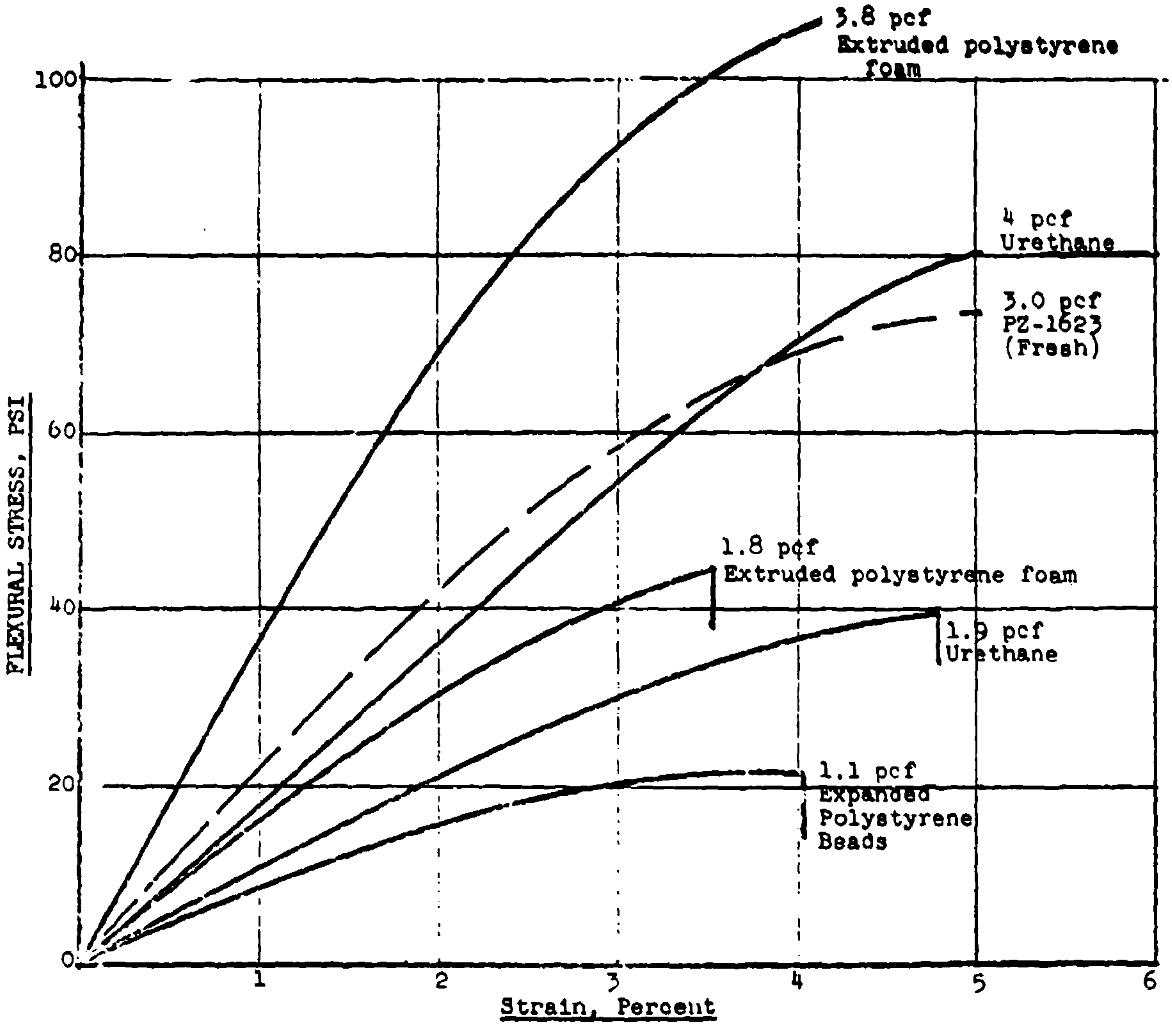


Fig. 6 - Flexural Stress Versus Strain Characteristics of Plastic Foams

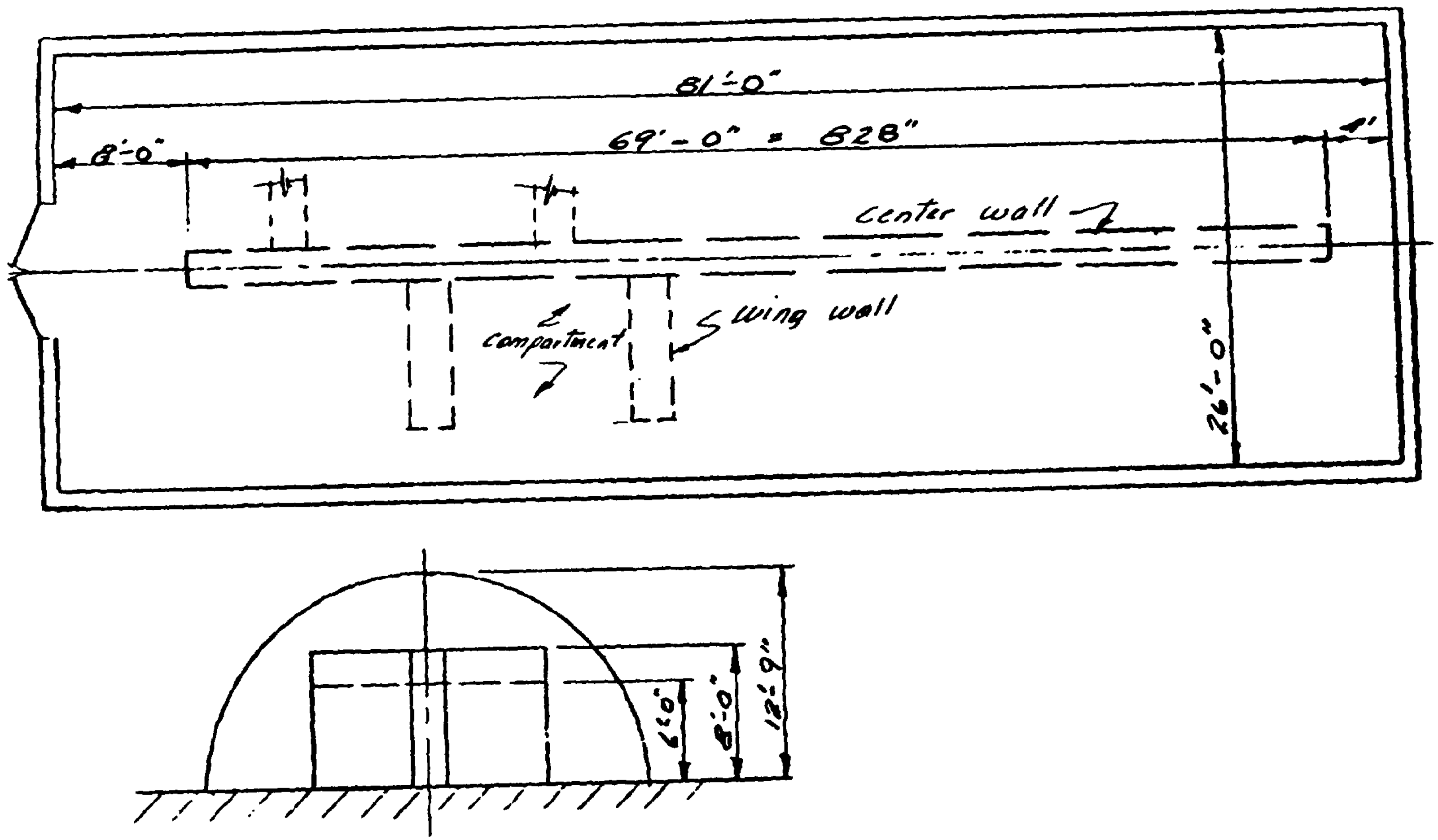


Fig. 7 - Standard Compartmented Magazine

formed by 6 ft wing walls projecting from a long central wall.

7.0 BARRIER WALL CONCEPTS

Commercial fabrication procedures for the three basic foam types determines the design of different systems from these four basic components, namely,

1. Boards
2. Panels
3. Molded Boxes
4. Molded Blocks

7.1 Board System

A board foam system layout is shown in Figure 8. Boards are stacked in courses with splined butt and 90° joints to form box type enclosures to contain a 22 inch wall of sand. Wall to wall ties across the 22 inch width are necessary to retain lateral sand pressure. Wing walls are assembled as separate boxes to provide for flexibility in locating them to form various size compartments.

7.2 Panel System

The panel system, Figure 9, is similar to a board system except the components are larger. Assembly time and the number of joints are reduced. However, larger panels do not provide joints for wall tying and panels must be pierced for tying. Also, panels require sand dumping from greater heights which is undesirable for lightweight wall enclosures.

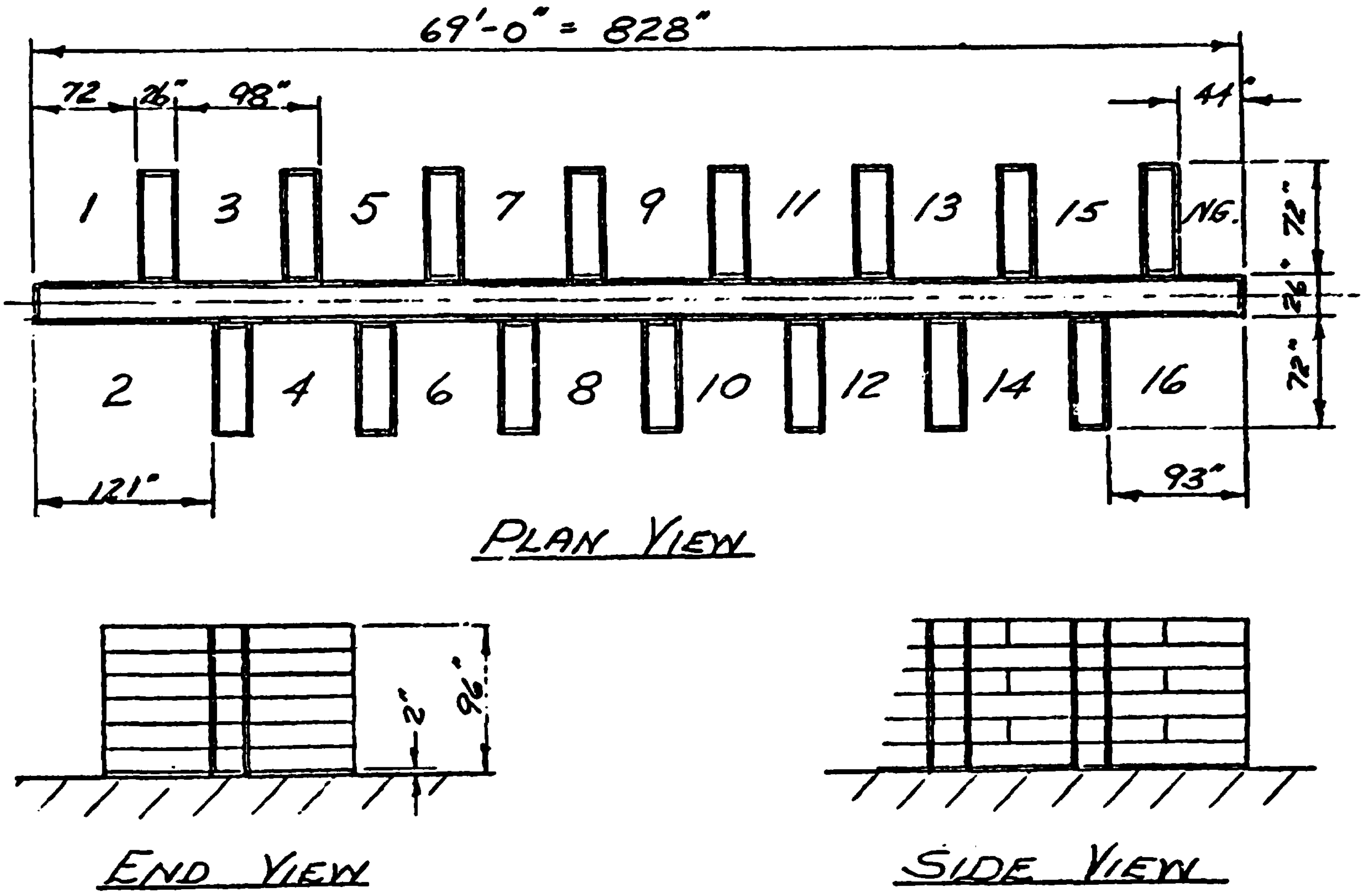


Fig. 8 - Board System for Barrier

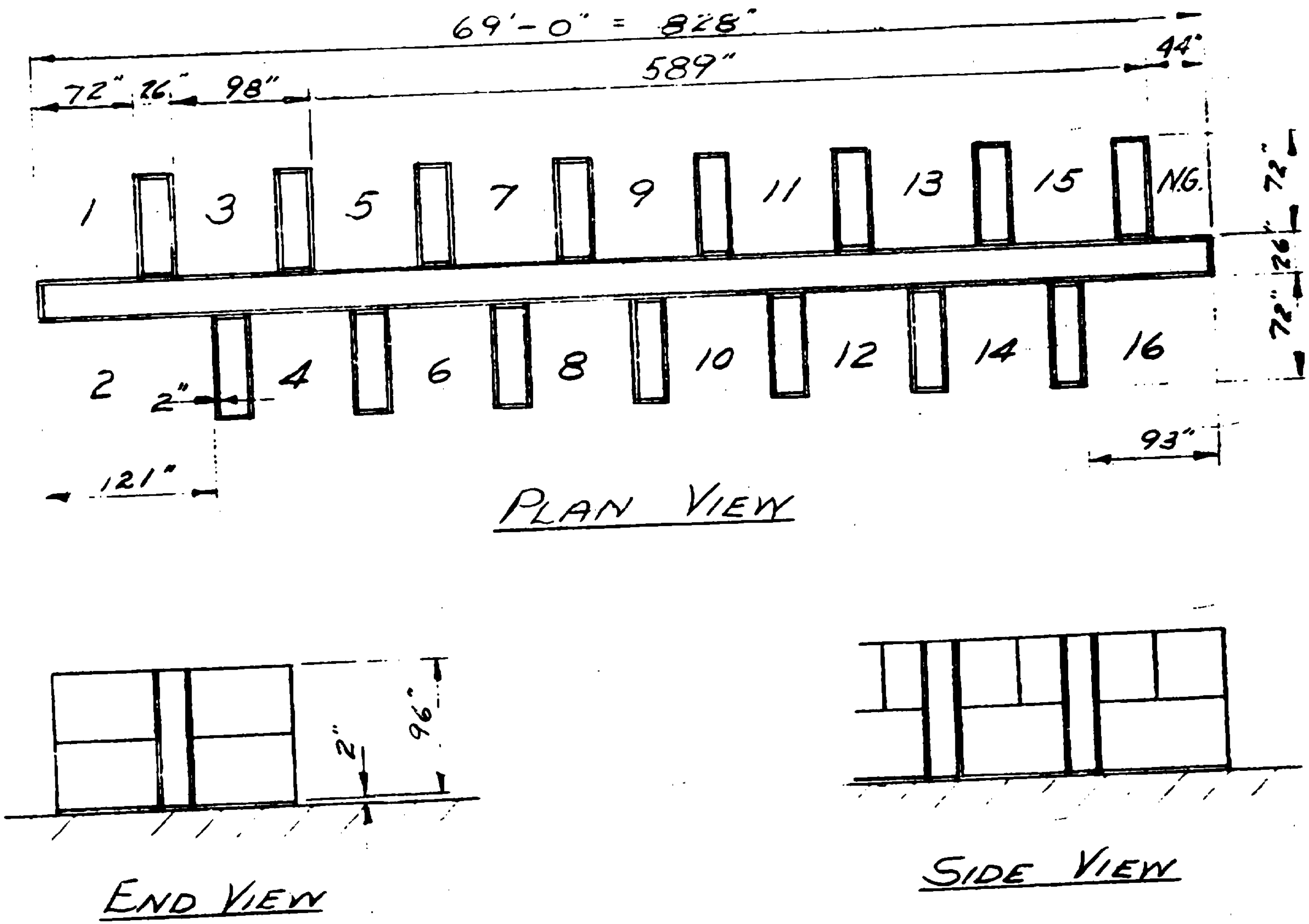


Fig. 9 - Panel System for Barrier

7.3 Box System

The layout of a box system is shown on Figure 10. Molded top opening boxes similar to picnic coolers are stacked and individually filled with sand to form the walls. Lateral wall ties are not required. It is necessary to off-set the box bottoms and ends to maintain the required 22 inch sand barrier without short circuits through the foam. Consequently, barrier walls become about 70 percent thicker. At least 12 different molds would be required for such a system.

7.4 Block System

A barrier system may be built with molded individual solid or hollow core foam blocks as shown on Figure 11. Blocks are adhesively bonded together. Wall to wall ties are required. Greater skill is needed to assemble a system of this kind.

8.0 BASIS FOR STRUCTURAL DESIGN

The most significant structural requirement of the sand containing wall is to resist forces imposed by lateral sand pressure. This lateral pressure must be sustained by the foam wall without excessive deflection or flexural stress failure for a period of over 10 years.

A simplified illustration of vertical and lateral sand pressures against a retaining wall is given on Figure 12. Barkan[2], Schneider[3], and Merriman[4] have developed empirical lateral wall pressure coefficients, k, ranging from 0.4 to 0.5, or, lateral wall pressures equal to 40 to 50 percent of the vertical sand pressure.

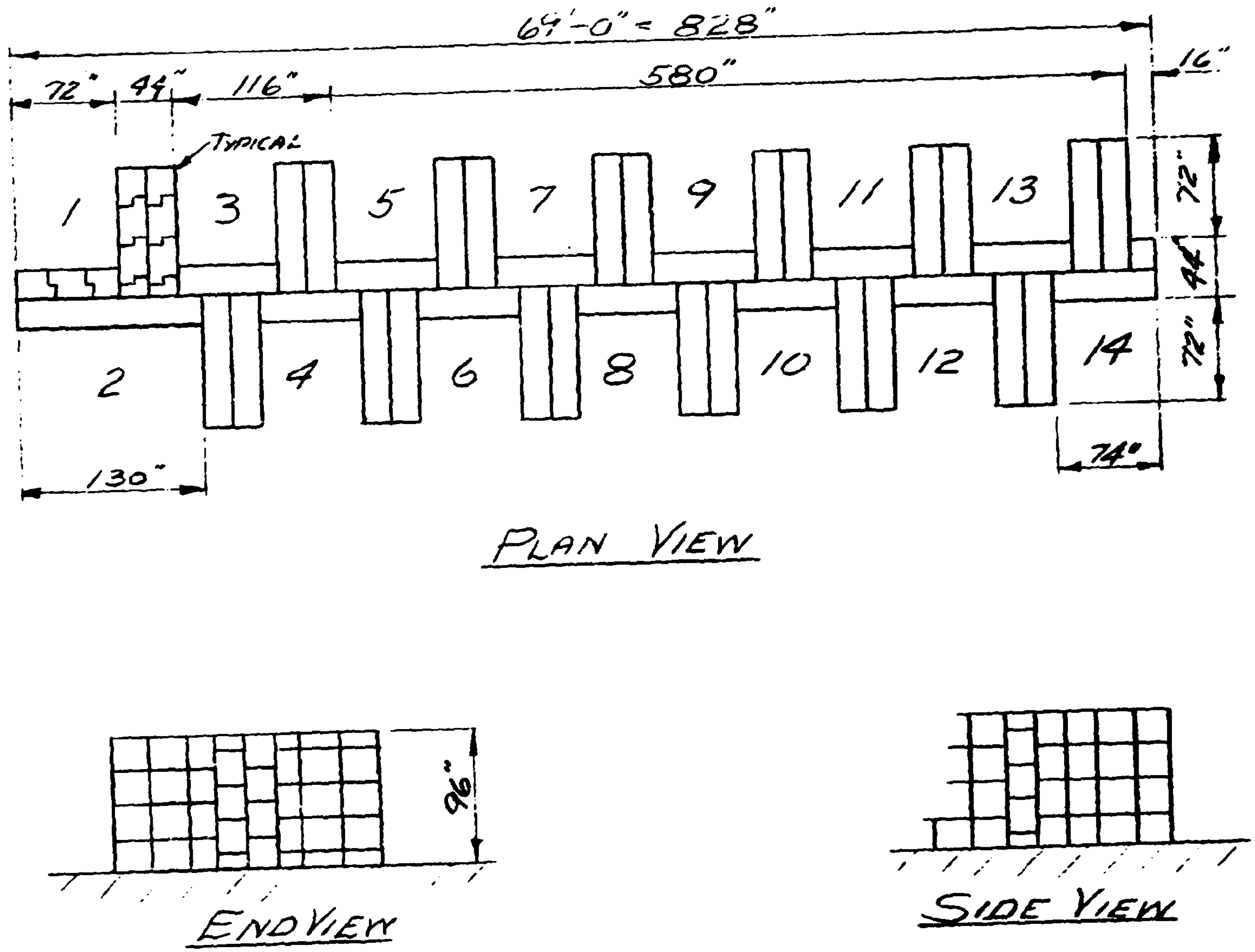


Fig. 10 - Box System for Barrier

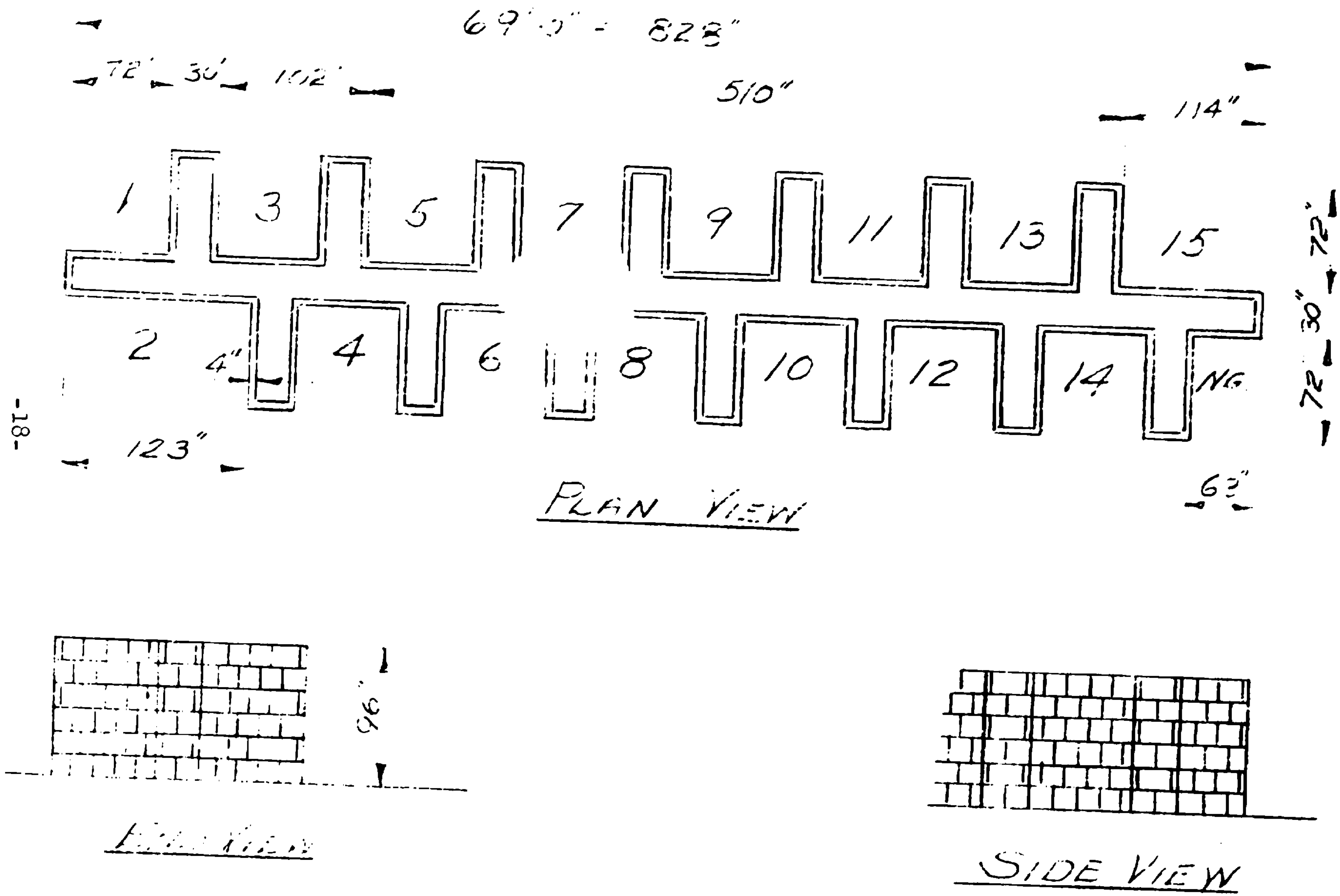
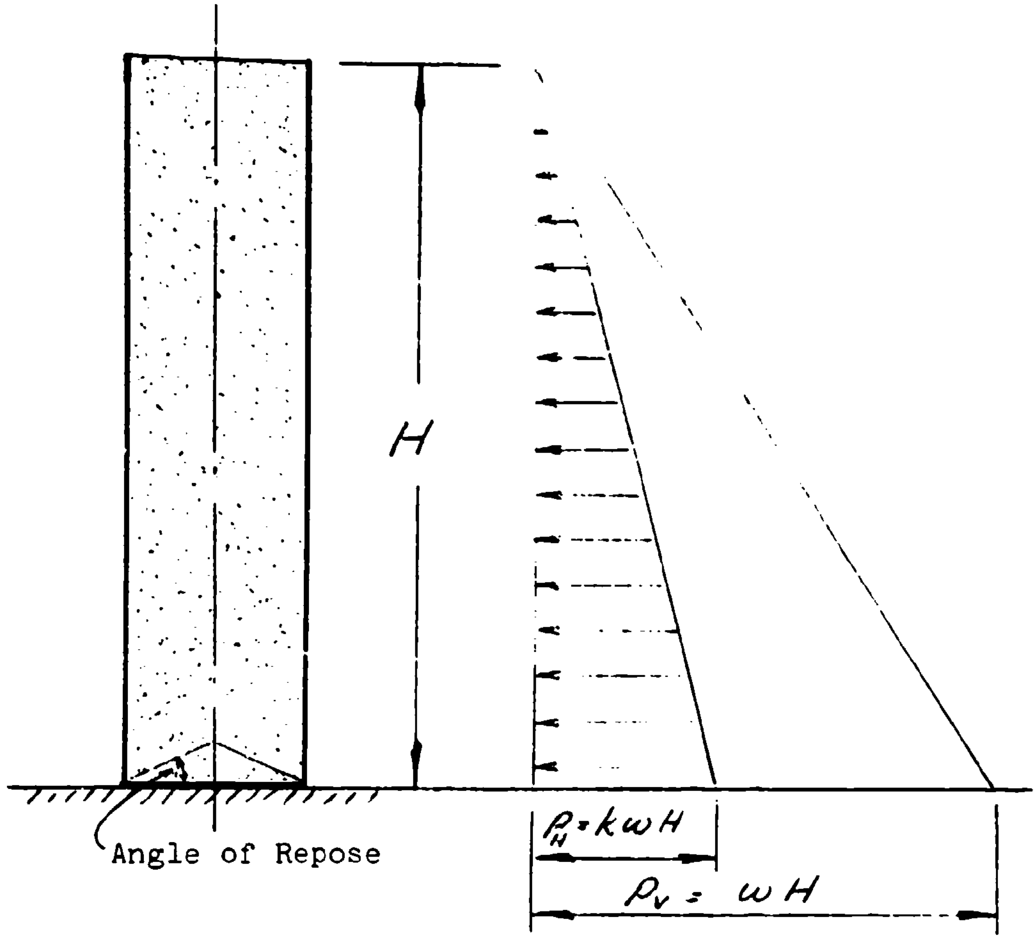


Fig. 11 - Block System for Barrier



P_H = Lateral pressure
P_V = Vertical pressure
w = Unit weight of sand
k = Lateral pressure coefficient, 0.4 to 0.5 and up to 0.8 when tamped in layers.

Fig. 12 - Sand Pressure Distribution

9.0 LATERAL WALL PRESSURE MEASUREMENTS

Since lateral wall pressure coefficients found in the literature are either based on small laboratory scale models or retaining walls of different configurations, it was decided to measure sand pressured on a full scale model 22 inches wide by 8 feet high.

9.1 Test Wall Sand Properties

The sand selected for this test was kiln dried Lake Michigan Beach Sand. A photomicrograph of this sand is on Figure 13. This is not sharp sand and, being dried, it assumes a minimum angle of repose and therefore will exert the maximum lateral pressure which is desirable for test purposes. The sieve analysis on Figure 14 shows this 101 lbs/cu ft sand will pass through the required number 8 mesh screen.

9.2 Wall Pressure Test

The test model wall, photo Figure 15, is made of rigid aluminum faced STYROFOAM® core sandwich panels 24 inches wide by 8 ft high by 8 ft long. Lateral wall pressure was measured at a location 6 inches from the base, with a 10 inch diameter flexible rubber diaphragm backed with hydraulic fluid connected to a pressure gauge calibrated in lbs/sq in.

As the box was loaded with sand, lateral wall pressures were recorded at various sand heights. Results are plotted on Figure 16. At an assumed lateral wall pressure coefficient of 0.4 the equivalent lateral pressure at the base would be 2.2 psi, however, the maximum pressure

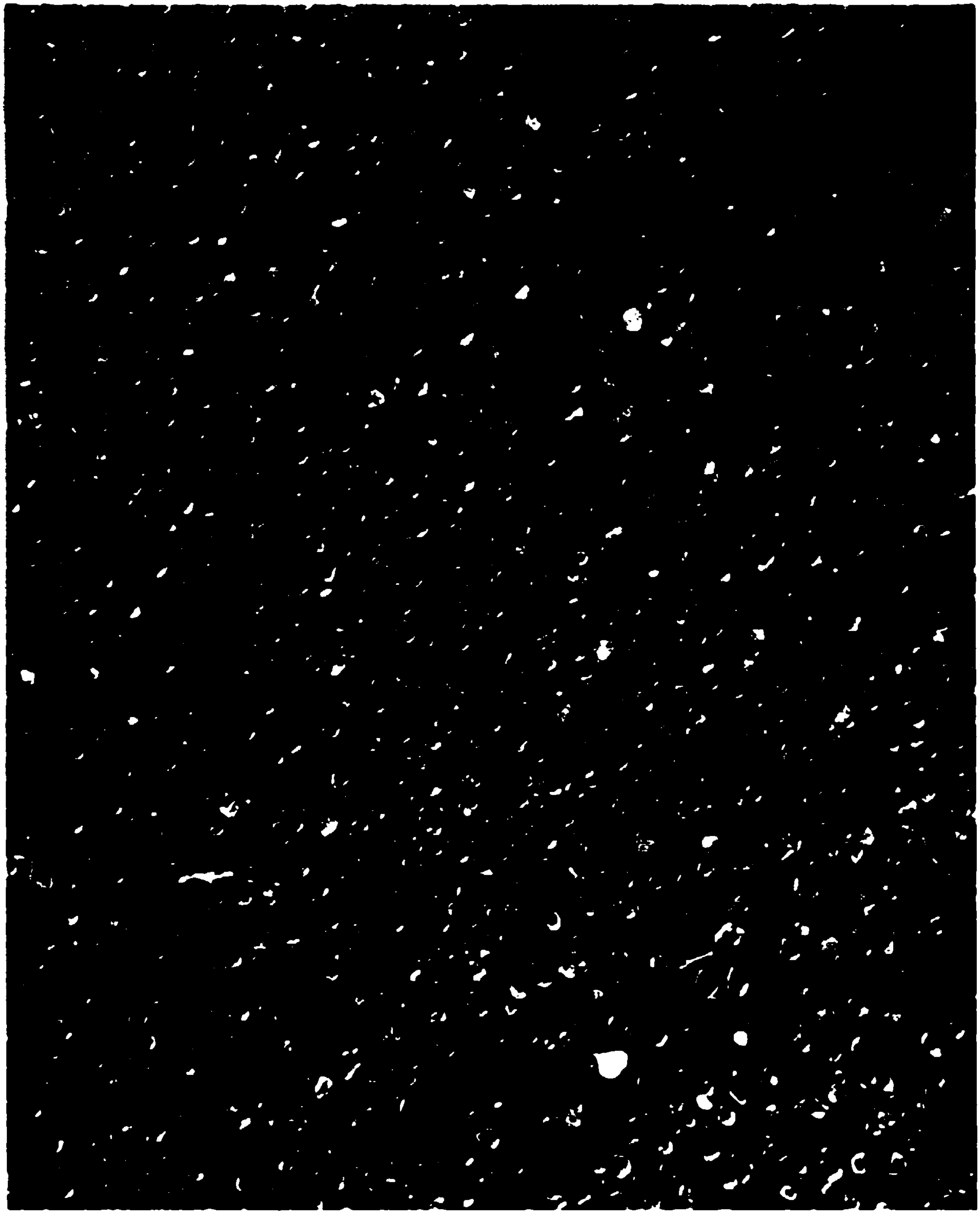


Fig. 13 - Photomicrograph of Sand Used for Test Purposes 10X Photo

SAND ANALYSIS

TYPE Beach Sand

SOURCE Lake Michigan

WET OR DRY Kiln Dried

DATE February 3, 1971

TESTED BY Carrington

ASTM C-144-62T SCREEN TEST (1000 gram Sample)

Screen Numbers	Gross	Tare	Net	% Passing
4	--	--	--	100
8	--	--	--	100
16	223.9	223.8	0.1	100
30	408.2	405.2	2.8	99.6
50	1338.2	443.2	895.0	10.2
100	361.7	257.0	103.7	0.5
200	256.6	254.0	2.6	0.2
Pan	367.9	366.7	1.2	0.0

Dry Sand Weight 101 lbs/cu ft

Wet Sand Weight ______ lbs/cu ft

Fig. 14

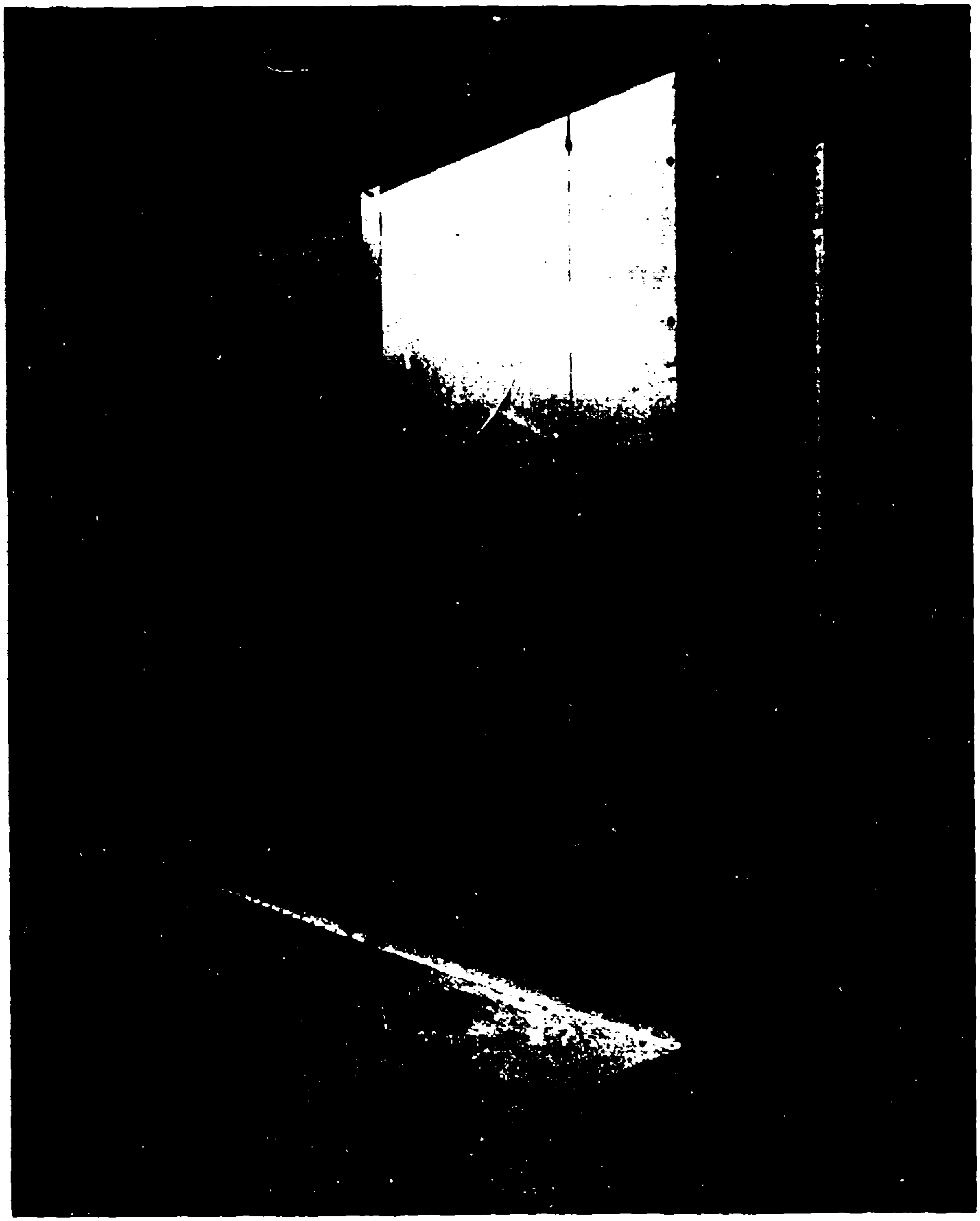


Fig. 15 - 8' High x 8' Long x 24" Wide Test Model to Measure Wall Pressure

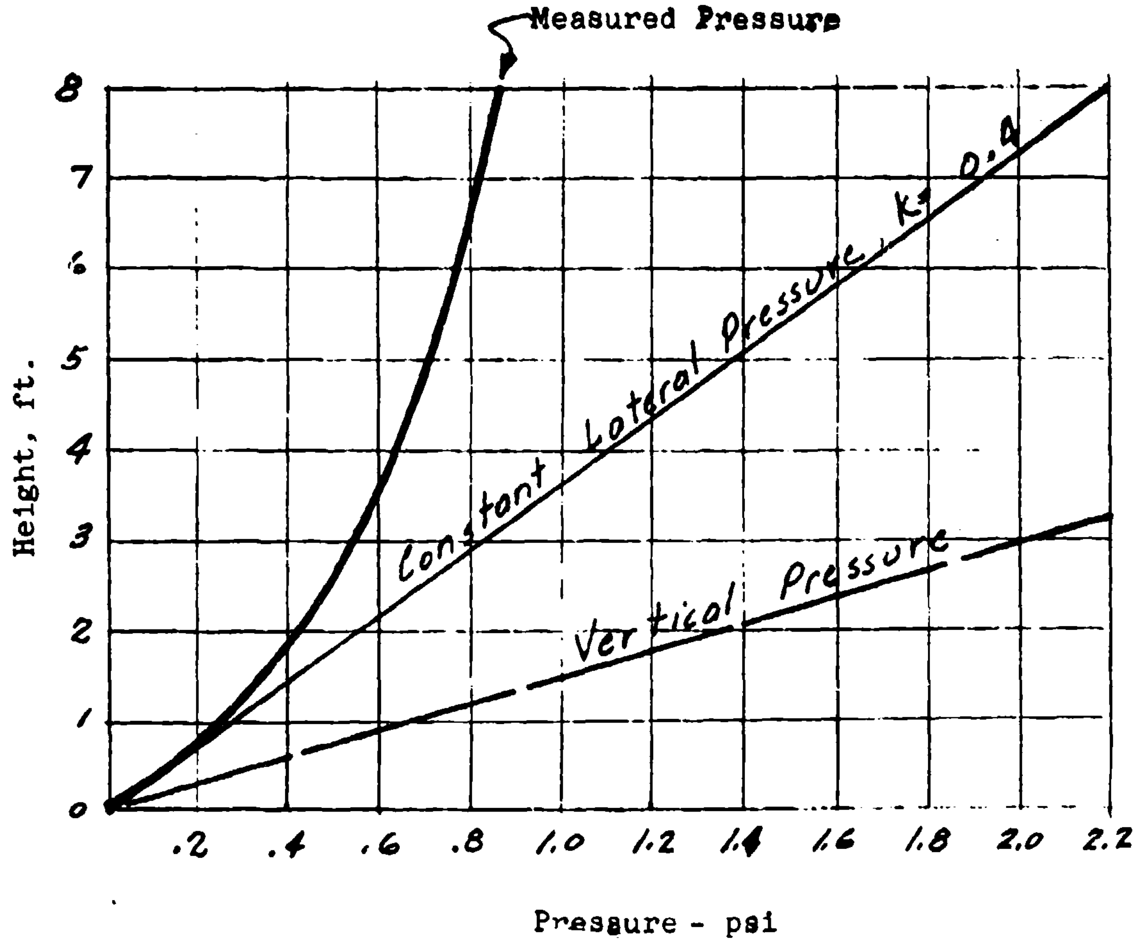


Fig. 16 - Lateral Wall Pressure Measured With a Hydraulic Diaphragm

measured on the filled model was only 0.85 psi. At this point there was no obvious explanation for these lower than predicted pressure measurements.

10.0 METHODS OF REDUCING WALL PRESSURE

It was theorized that the lower than anticipated lateral wall pressure may be due to the narrow 22 inch wall spacing. If this theory is correct, lateral pressure may be further reduced by adding a center partition wall of foam reducing the wall to two 11 inch wall sections.

During this study the thought of horizontal layering was considered. The photo Figure 17 illustrates this concept. In this 6 inch wide by 24 inch long model, 3/4 inch layers of sand are separated with rigid sheets and a column of sand is constructed without the aid of containing walls. If a rigid wall were constructed around this model, the rigid sheets might be replaced by flexible plastic film, and the only lateral wall pressure contribution would result from the lateral sand pressure exerted by the small triangular filled voids at the sheet edges.

This layering theory was demonstrated with two flexible rubber 5 inch diameter cylinders 13 inches high. Each cylinder was rigidly supported while filling with sand. One cylinder was filled with sand separated with discs of 0.004 inch plastic film layers spaced 1.5 inches apart. The second cylinder was filled without layering. When the rigid supports were removed, the layered cylinder of sand did not slump, while the unlayered cylinder slumped to the shape shown on photo Figure 18.

This test model demonstrated the effectiveness of layering in reducing lateral sand wall pressure.

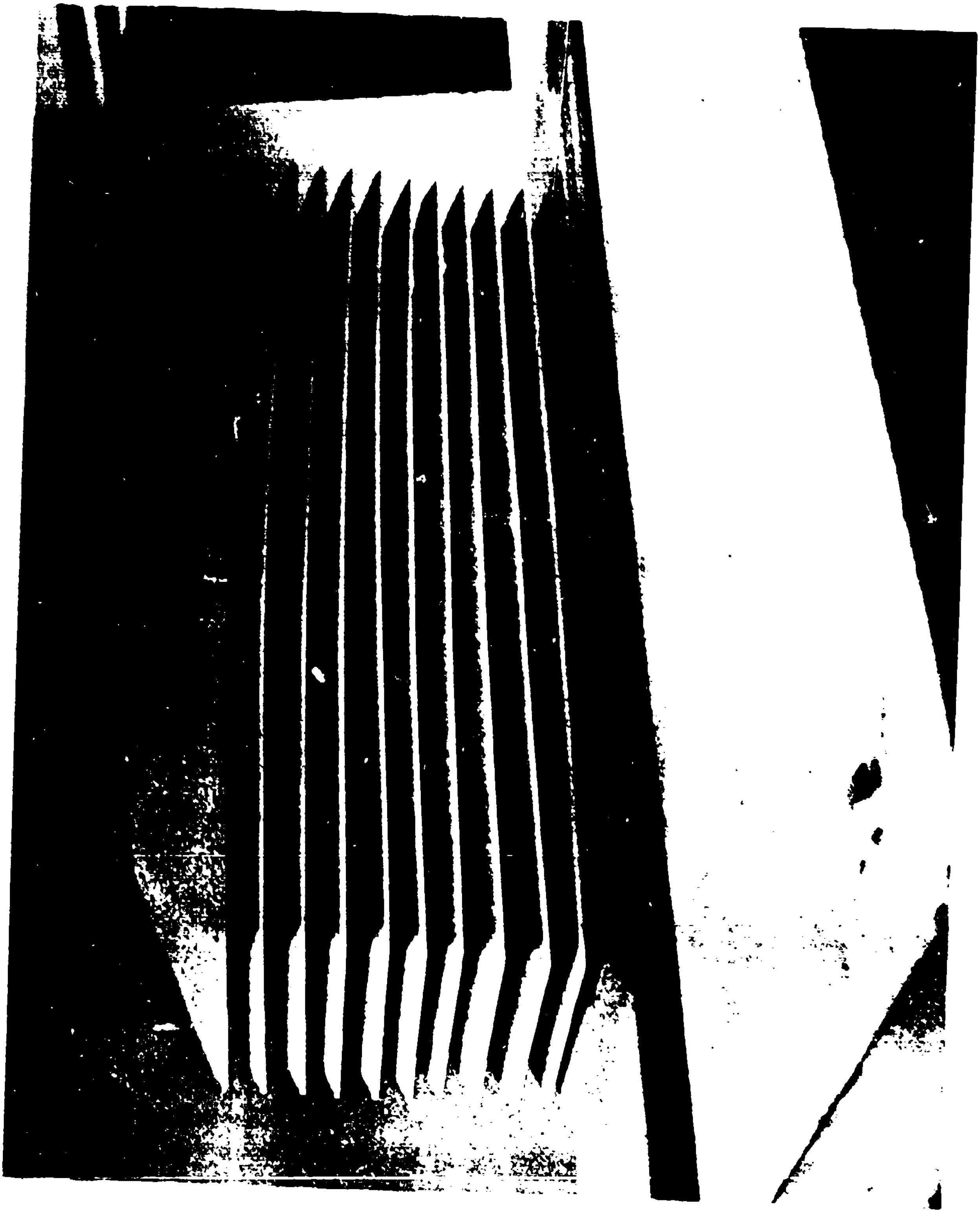


Fig. 17 - Model of Layering Principle

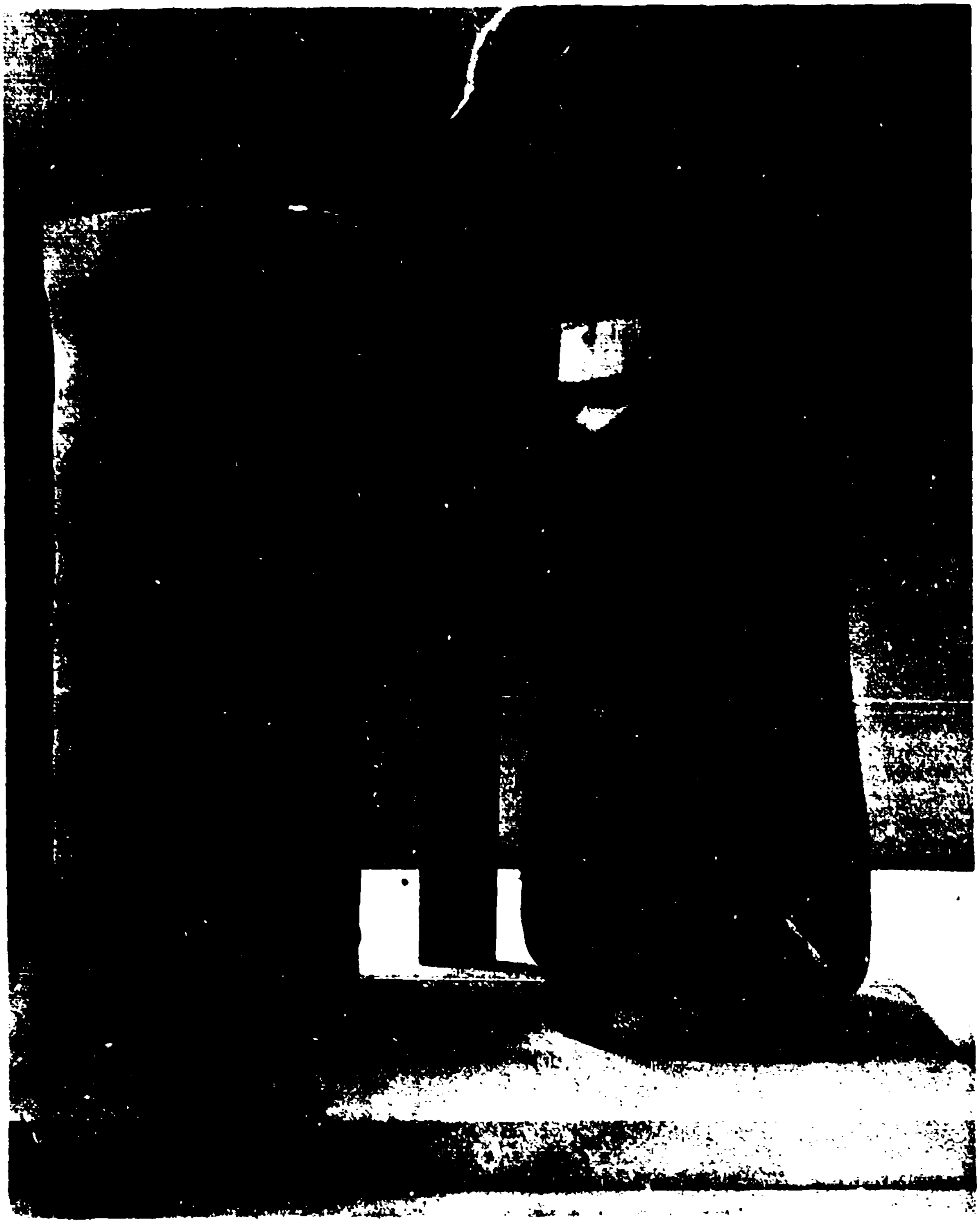


Fig. 18 - Layering Effects on Flexible Rubber Cylinder

11.0 FULL SCALE PLASTIC FOAM WALL MODEL

At this stage of development it was decided to measure the effectiveness of the various concepts with full scale models by measuring lateral wall pressures with a plain wall, with a center dividing wall, and a test of the layering principle.

Based on the measured maximum lateral pressure of 0.85 psi and theoretical calculations, it was found feasible to construct test models 8 ft high with plastic foam. The system selected as having the greatest potential in complying with the requirements was the board system using 2 inch thick high density extruded polystyrene foam with wall ties on a 16 inch grid.

11.1 Model Design and Fabrication

Standard commercial 16 inch wide by 108 inch boards were selected. The model size was 22 inches wide inside by 96 inches long and a height of six board courses or 96 inches, plus the floor board thickness of 2 inches. A foam spline was used to join all butt and 90 degree corner joints. The nominal spline dimensions were a thickness equivalent to 1/3 the board thickness and a spline depth or height equal to two times the spline thickness.

Conventional wood-working machine tools were used for fabrication. Boards were cut to length with a radial arm saw. A bench saw with dado cutters was used to cut all spline grooves. Splines were also cut on the bench saw. The photo, Figure 19, of a floor board shows all typical spline groove cuts. All fabricated boards and splines for the 8' x 8' model box are shown on the photo, Figure 20.

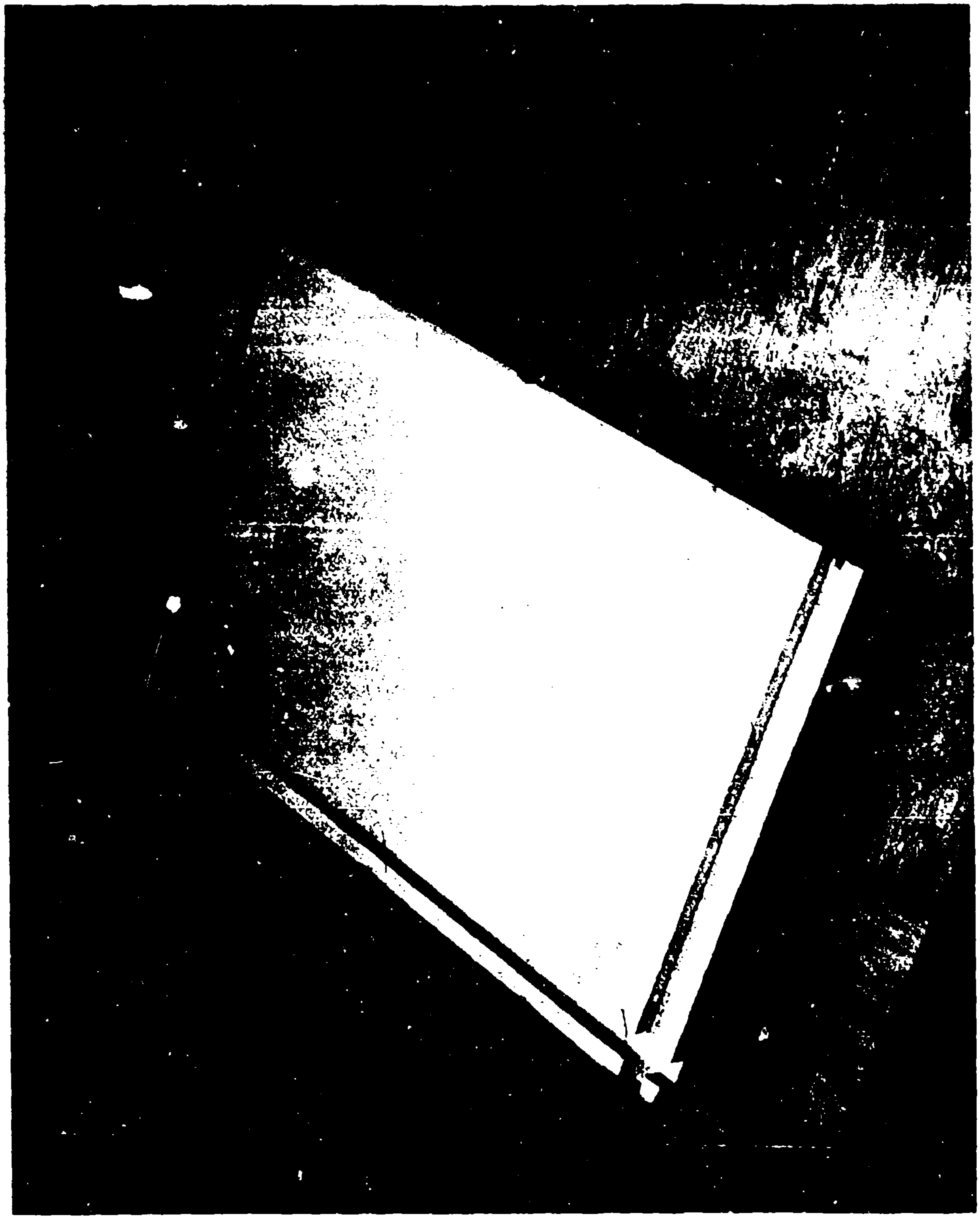


Fig. 19 - Fabricated Fcam Bottom End Board

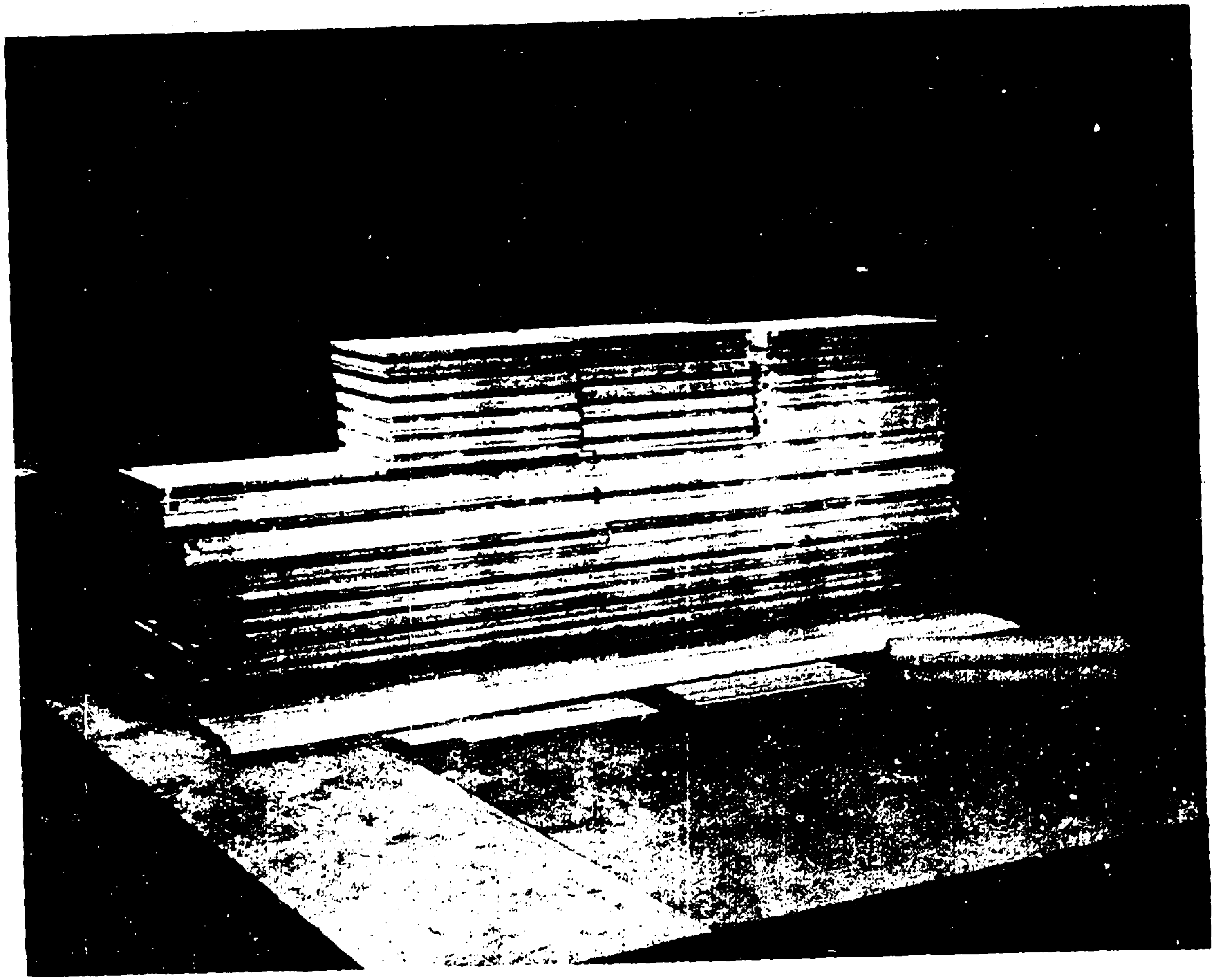


Fig. 20 - Fabricated Boards and Splines for Prototype

11.2 Model Assembly And Sand Filling

The complete assembly of floor boards and one 16 inch high course is shown on Figure 21. The wall ties on 16 inch centers are rigid members used in this test model to restrict wall movement at these points and also to provide for a load dynamometer attachment.

The photo Figure 22 shows two board courses partially filled with sand. The dynamometer is attached to the free end of a rigid wall tie for the purpose of measuring lateral wall pressure over 16 inch x 16 inch area.

Sand filling was done with the aid of a fork lift truck pouring 700 lbs. of sand from a 55 gallon drum as shown on Figure 23.

Sand was unloaded from the box by cutting a ten inch diameter hole at the base of the wall. Sand flowed by gravity into the feed end of a 4 inch diameter commercial grain auger shown on Figure 24. Sand was reloaded into drums at a rate of 300 lbs/min with this 1 HP motor drive arrangement.

11.3 Full Scale Foam Model Test Results

The 8 foot high prototype foam model, Figure 25, is filled with 117 cubic feet of sand. Lateral wall pressure measured with the dynamometer are plotted on Figure 26. Maximum wall pressure at the base was 0.68 psi compared to 0.85 psi measured on the first panel wall model. This pressure difference may be attributed to the difference in wall friction of an aluminum panel surface and a plastic foam wall surface.

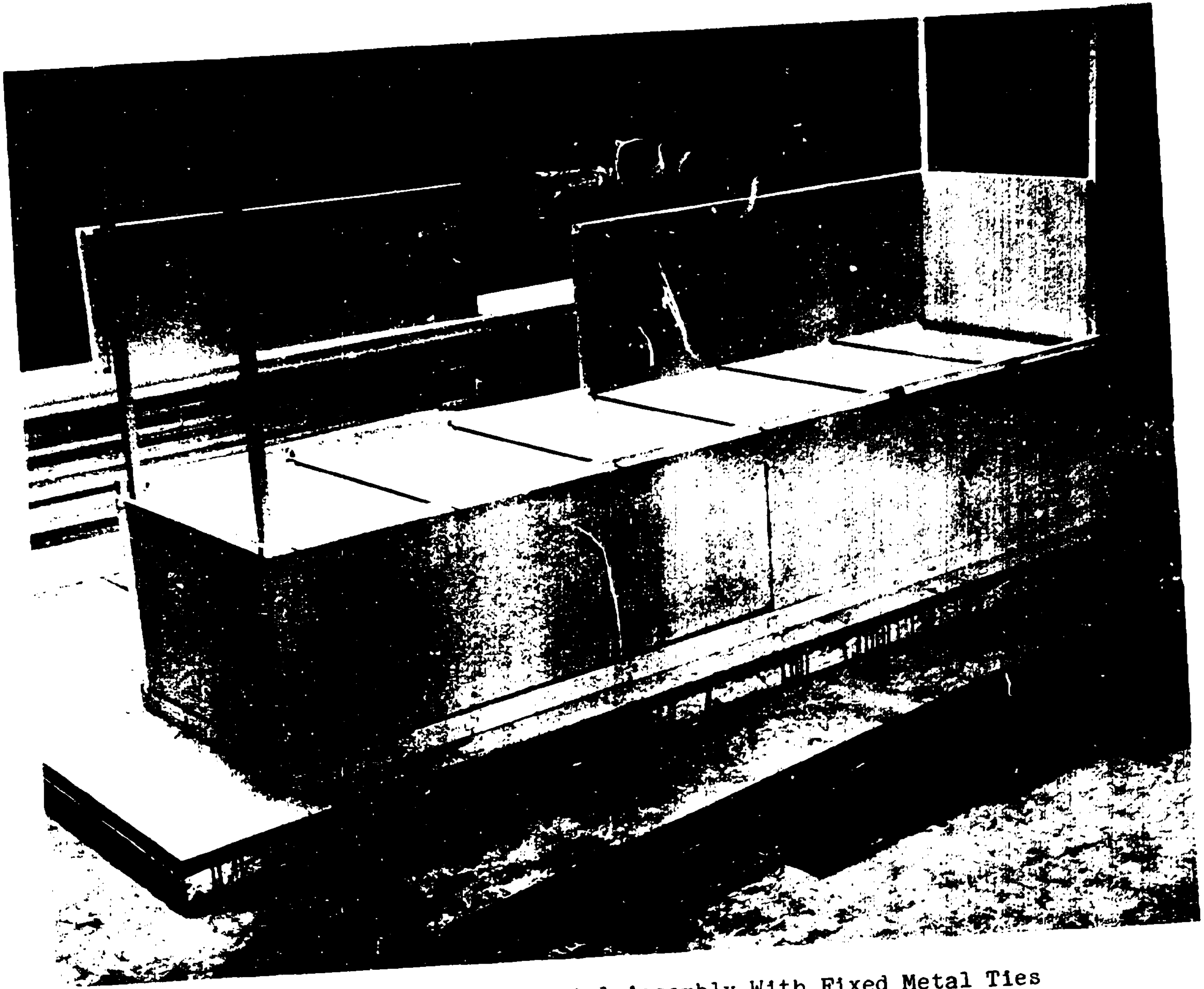


Fig. 21 - Prototype Partial Assembly With Fixed Metal Ties

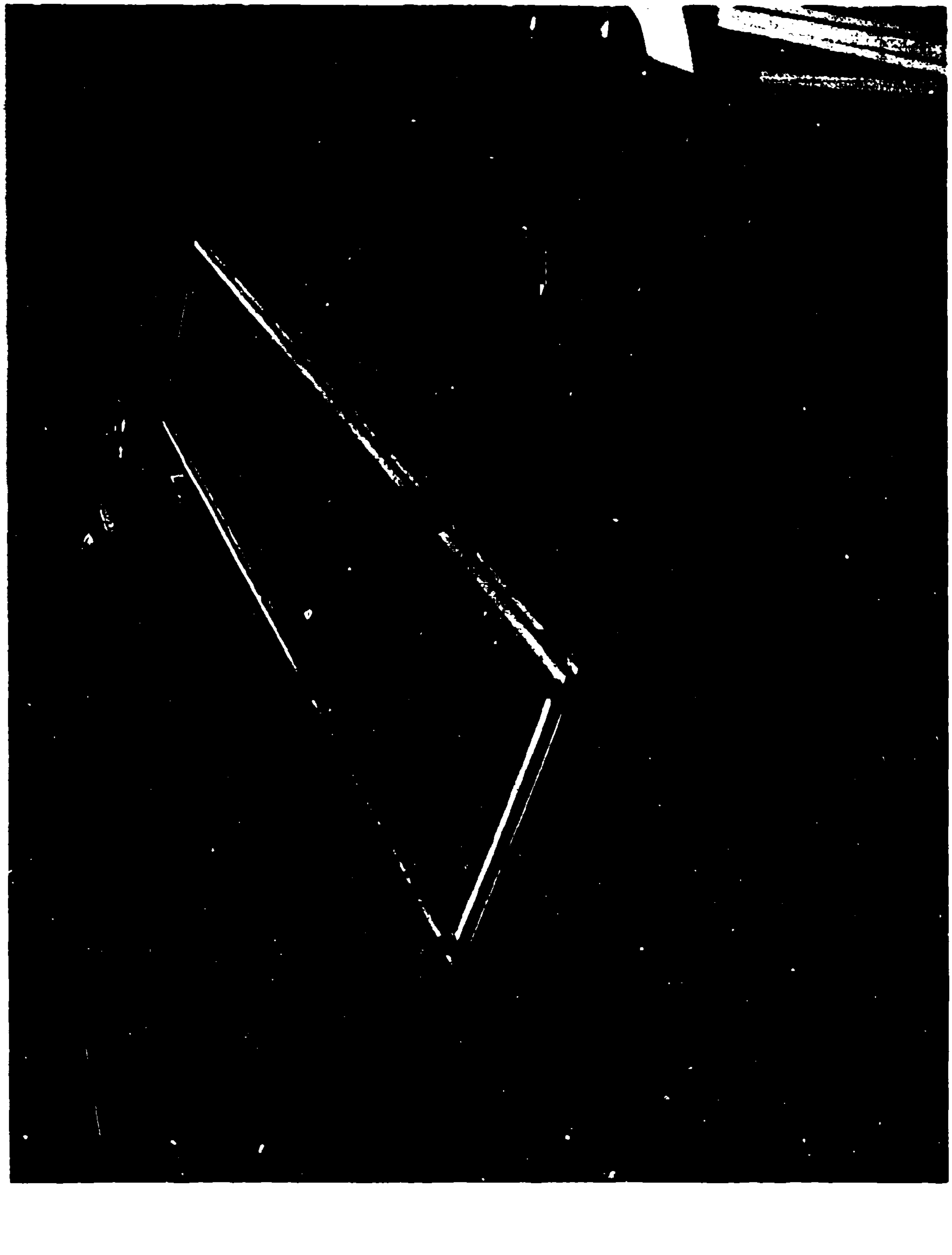


Fig. 22 - Partially Loaded Prototype With Dynamometer

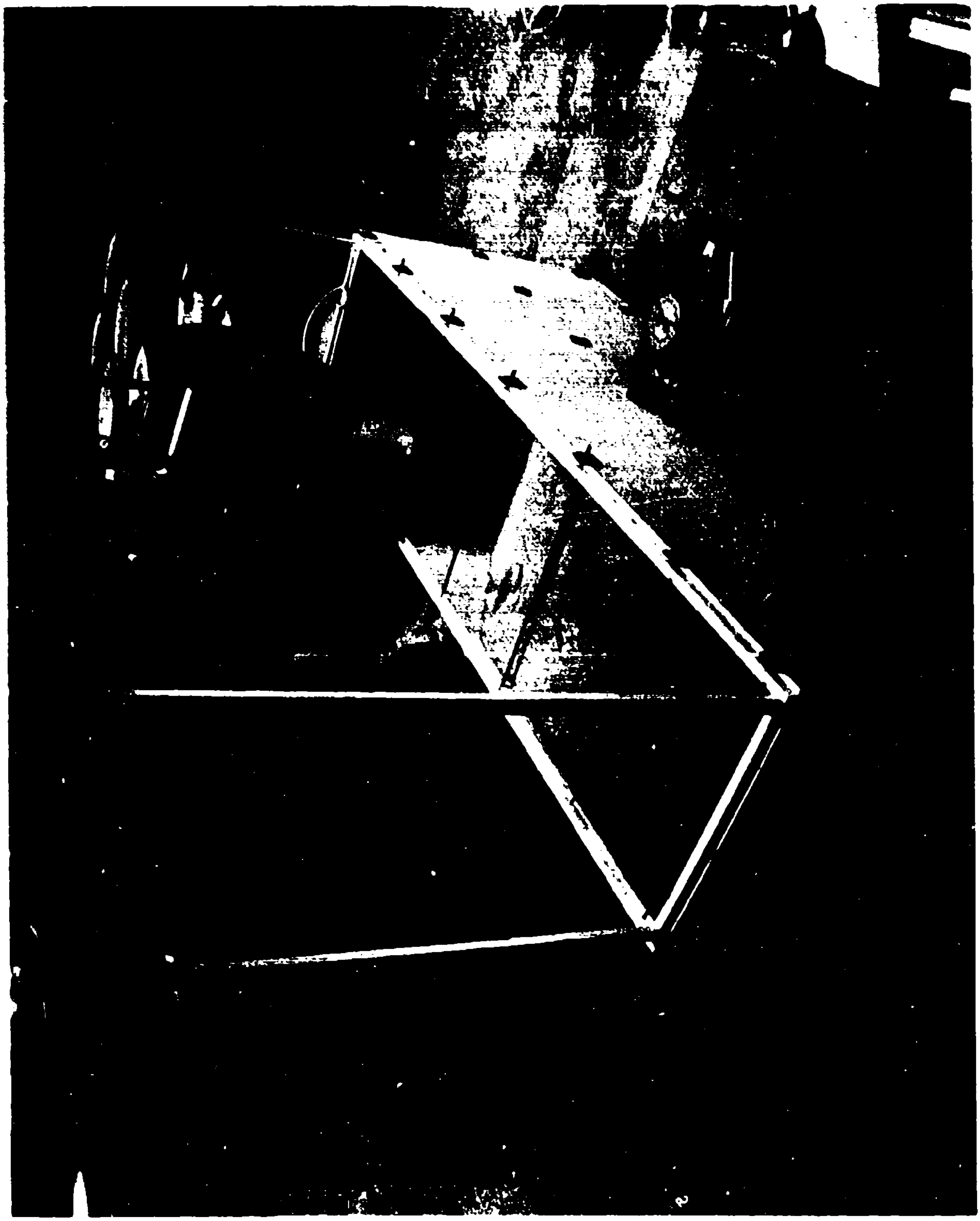


Fig. 23 - Sand Loading Method

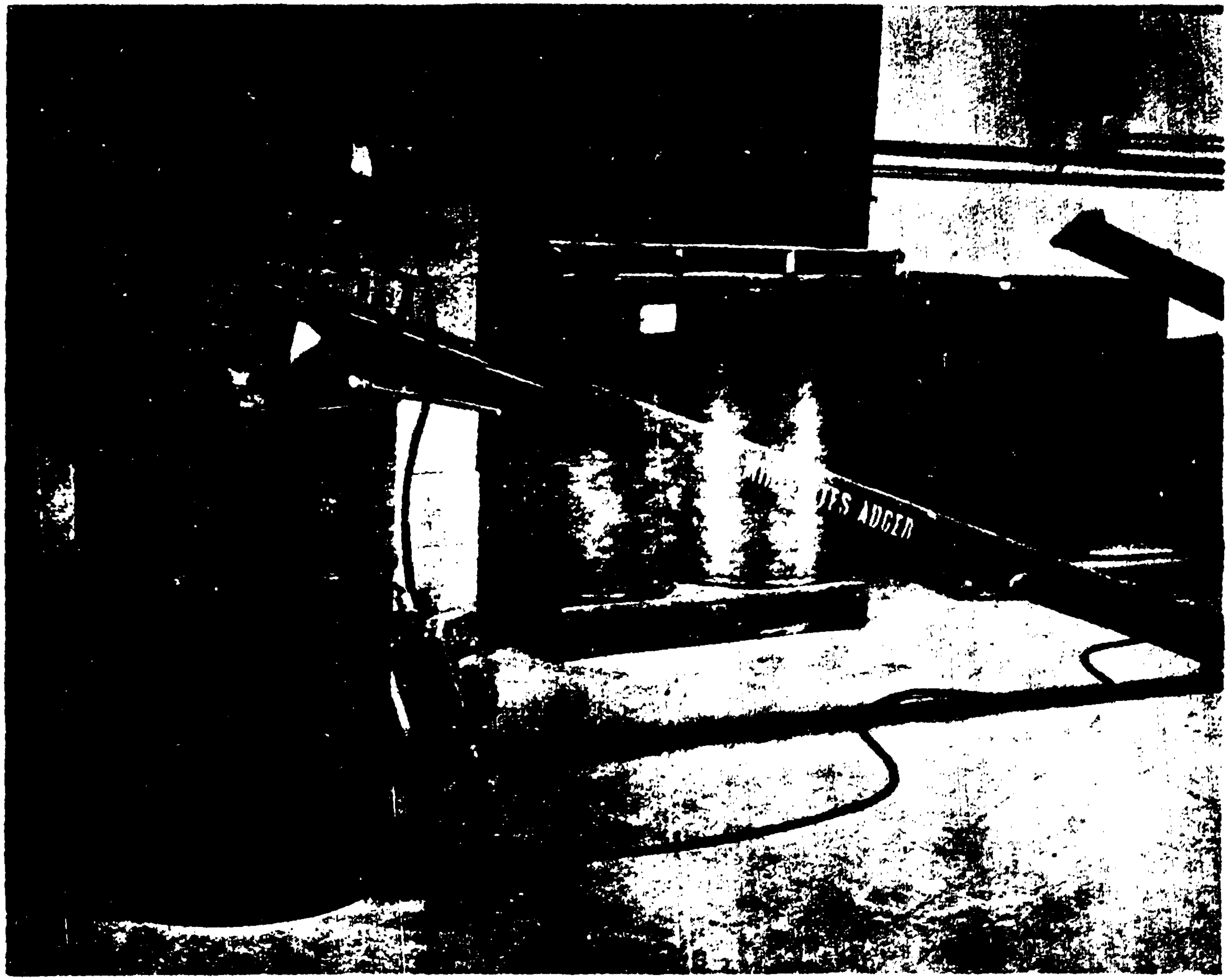


Fig. 24 - Sand Conveying A

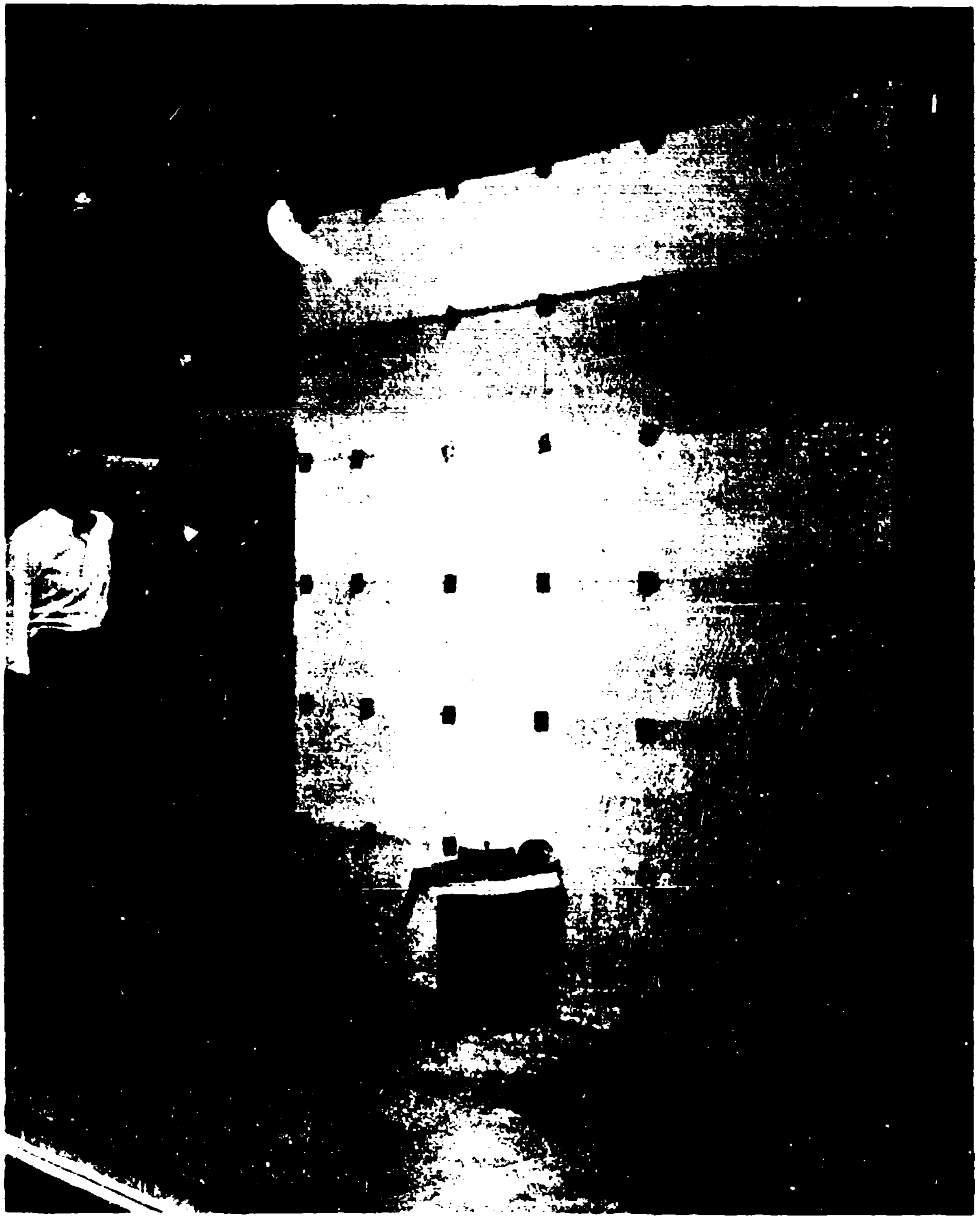
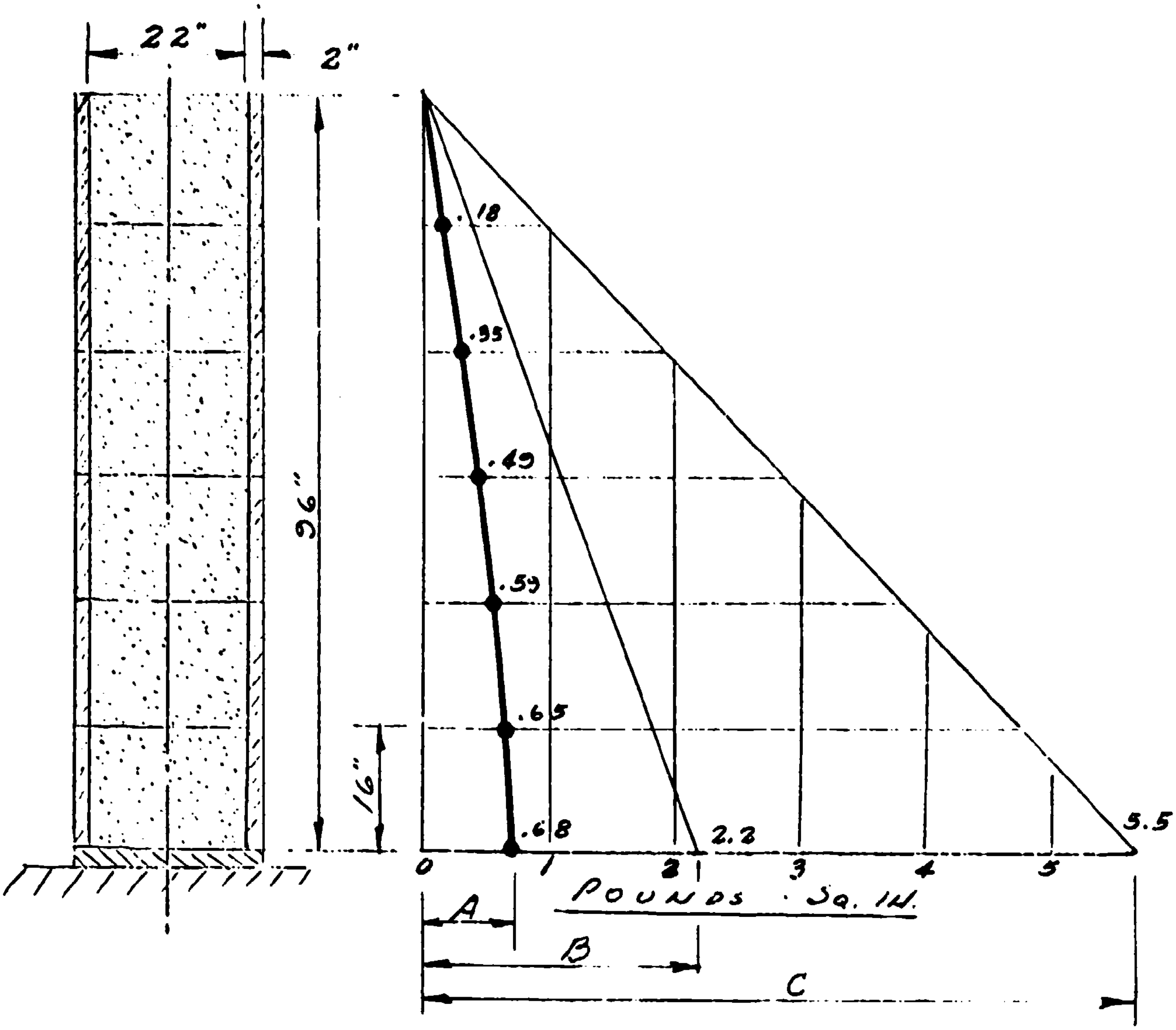


Fig. 25 - Completed Prototype No. 1 - 8' High
With 117 cu. ft. of Sand



A = Measured lateral wall pressure.

C = Theoretical sand pressure on the supporting base without sidewall friction.

$$C = \frac{(8\ ft.)(100\ \#/ft^3)}{144} = 5.5\ psi$$

B = Theoretical lateral wall pressure with k = 0.4

$$B = kC = (0.4)(5.5) = 2.2\ psi$$

Fig. 26 - Measured Lateral Wall Pressure

12.0 VERTICAL SAND LOADS CARRIED BY THE WALL

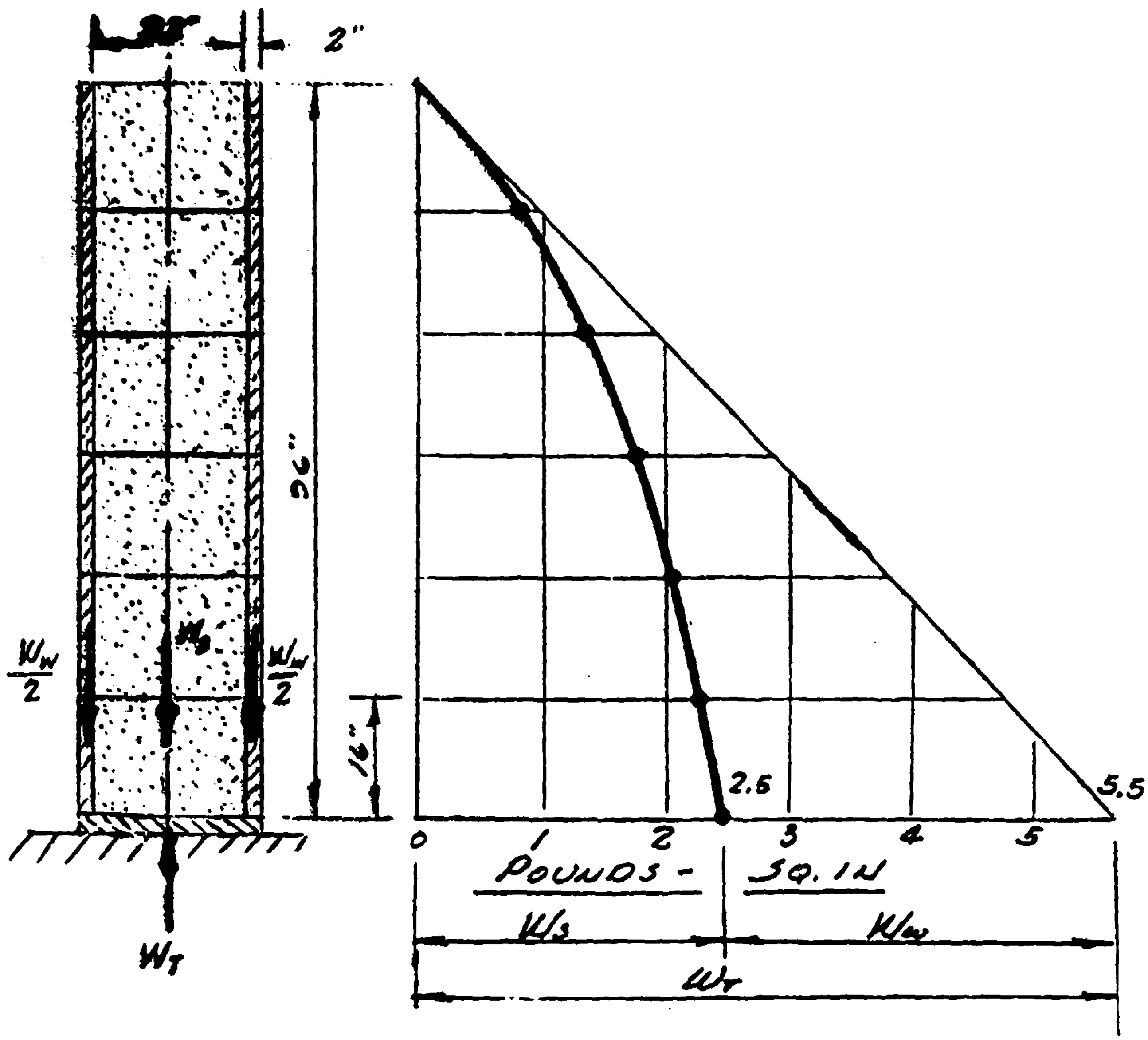
Since lateral wall loads are a function of vertical sand loads, and since there was evidence that a large portion of vertical sands loads are being transferred to the walls, it was decided to define the extent of these forces by testing. Hydraulic rubber bladders were located at 16 inch vertical intervals starting at the base. The hydraulic fluid was connected to an external pressure gauge calibrated in psi. The measured pressures are plotted on Figure 27. The measured vertical sand load per foot of wall length, for the 22 inch width, was 660 lbs of the actual sand weight of 1460 lbs for this area. Therefore, the difference of 800 lbs is carried by the two walls, and maximum lateral wall pressures are based on 660 lbs maximum vertical sand load at the base rather than 1460 lbs.

13.0 WALL PRESSURE REDUCING CONCEPTS

Maximum lateral pressure must be known to determine the foam wall thickness and also the extent of wall tying required. Since foam boards are 16 inches wide, wall tie spacing on a 16" x 16" grid was selected. Maximum wall pressures were measured over a 16 x 16 area between the first two board courses with the dynamometer connected to the free end of a rigid wall tie.

An eight foot high test wall was loaded three times to measure maximum loads of three different pressure reducing concepts. Results plotted on Figure 28 give loads of 165, 140 and 125 lbs for a plain wall, a center dividing wall and layering on 4 inch centers, respectively.

The most significant lateral wall pressure reduction is due to wall friction rather than layering or the center dividing wall. It is expected the reduction of lateral sand pressure by



W_S = Sand pressure measured on base

W_S = (2.5 psi) (22" x 12") = 660 lbs./ft.

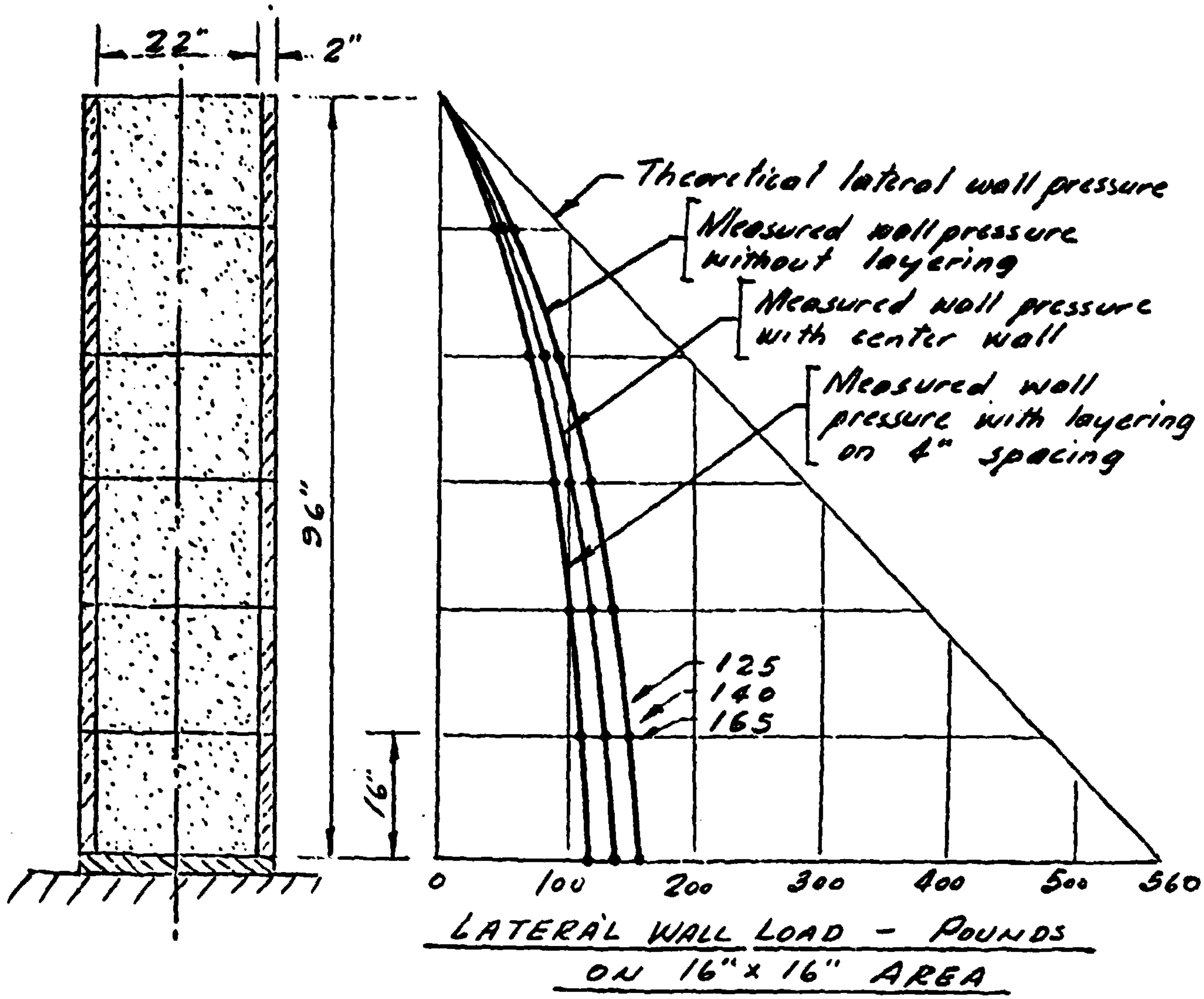
W_T = Total weight of sand

W_T = (5.5 psi) (22" x 12") = 1460 lbs./ft.

$W_W = W_T - W_S$ = 1460 − 660

W_W = 800 lbs.

Fig. 27 - Vertical Sand And Wall Loads



Lateral wall pressure $W_L = wkA$

$$W_L = (5.5\,psi)(0.4)(16" \times 16")$$

$$W_L = 560\ lbs.$$

Fig. 28 - Lateral Wall Pressure on 16" x 16" Area

layering does not permit transfer of vertical sand loads to the wall, therefore, there is incompatability of the two systems. The slight reduction in lateral pressure by layering or a center wall does not justify the material and installation cost of these concepts, therefore, a plain wall is recommended.

14.0 LONG TERM LOADING CHARACTERISTICS

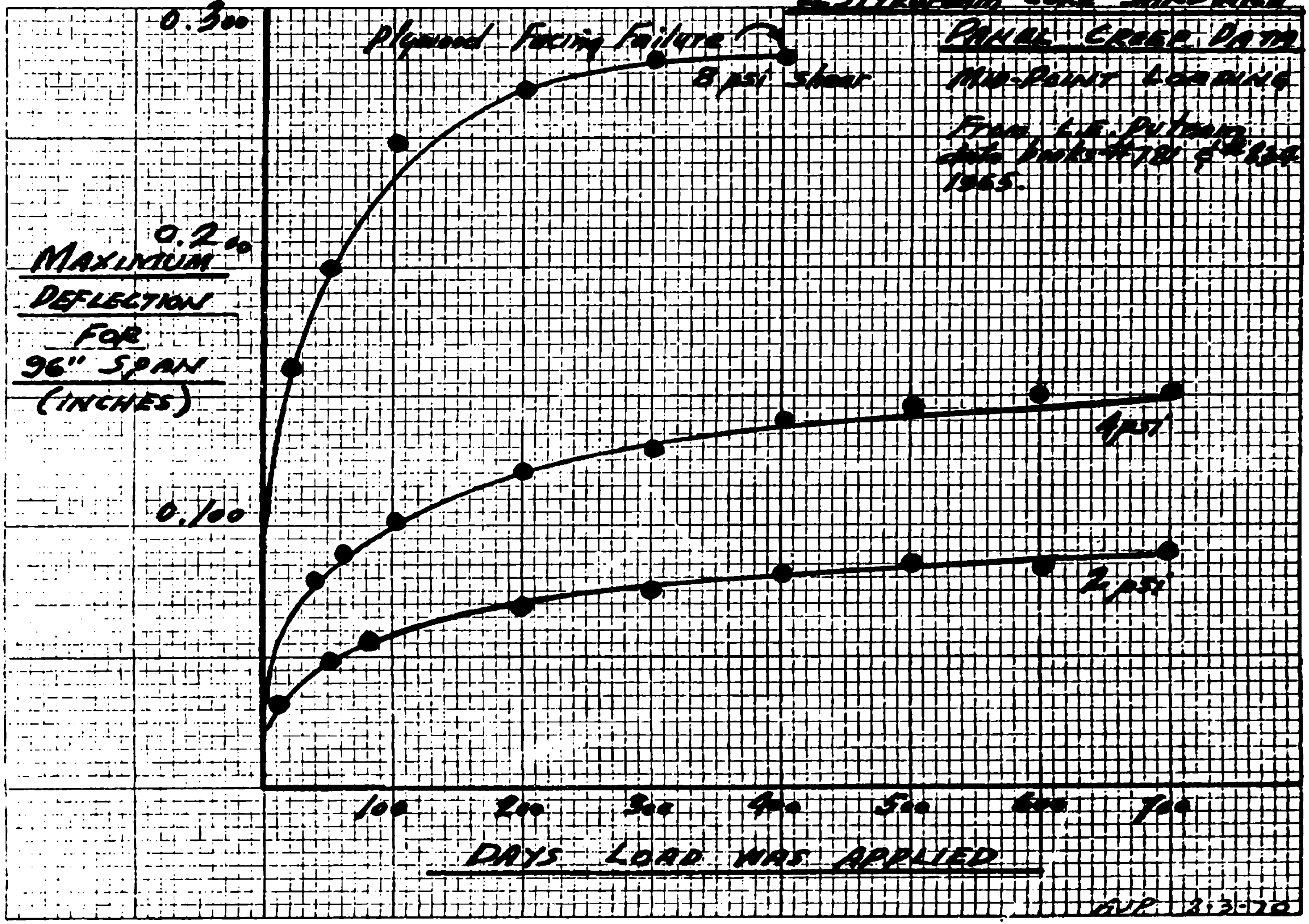
The long term loading characteristics of the foam wall should determine selection of a safe flexural stress value. Long term creep tests of plastic foams loaded in a similar manner have not been made. Long term creep of extruded polystyrene foam core sandwich panels have been tested with results plotted on Figure 29. The ultimate shear stress of this foam material is 30 psi. Although foam creep has been reduced to a negligible value of 8 psi after one year loading, the commercial limits on panel core shear stress has been established at 4 psi, for a safety factor of about 8.

15.0 FLEXURAL CREEP OF FOAM MODEL

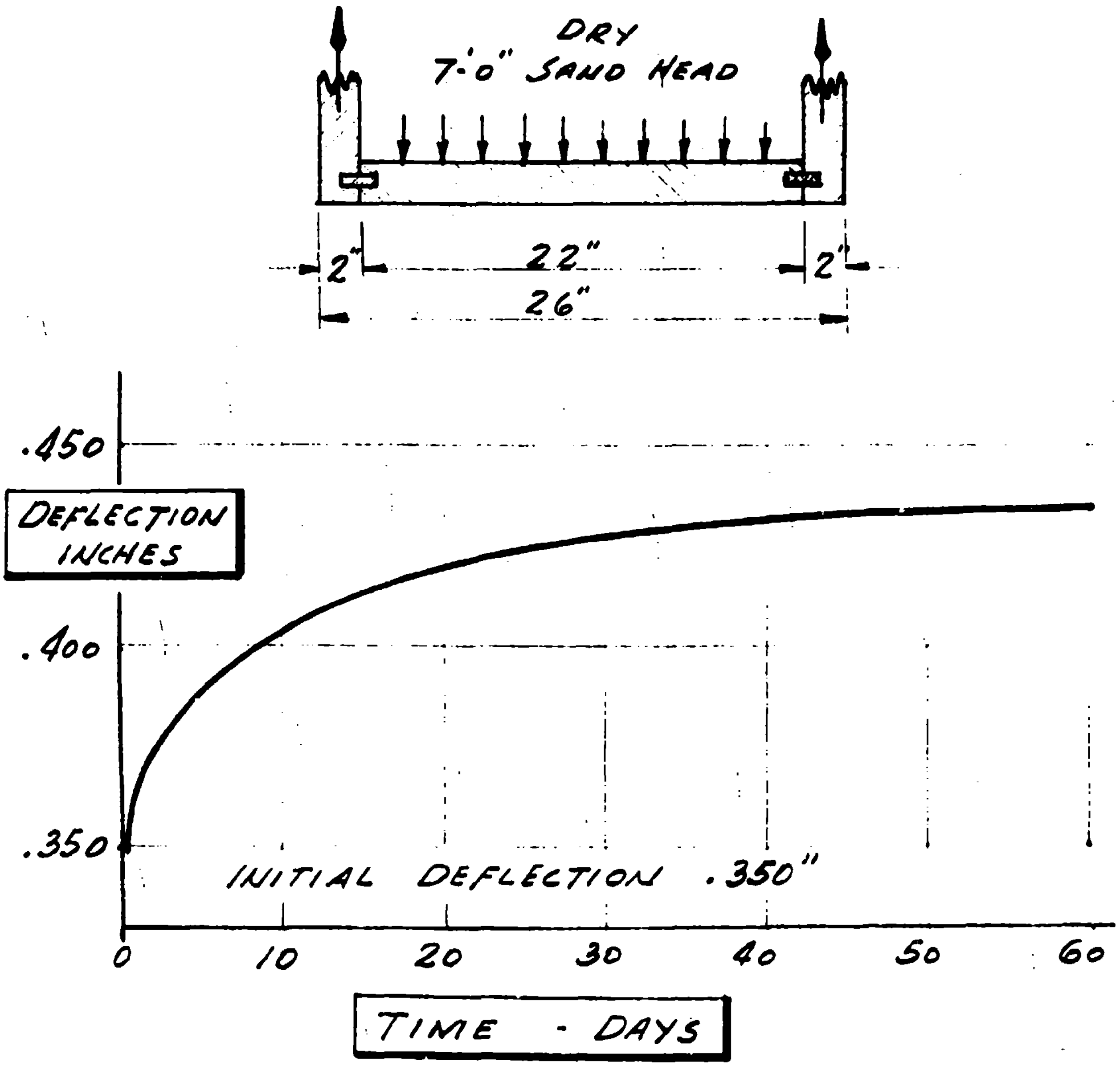
Flexural creep was measured at a point of maximum deflection on an end wall 16 inches from the base. The initial deflection of the 2 inch thick wall on a 22 inch span was 0.350 inches. The change in deflection was plotted, Figure 30, until the 60th day when creep became negligible. Flexural creep in this test leveled off in much shorter time than the 300 days measured on the sandwich panel test. It is possible the sand does not exert constant lateral wall pressure and this pressure is reduced with time.

16.0 FOAM MODEL OBSERVATIONS

The model was assembled and filled vertically plumb and square without the aid of a level or square. The wall assumes this



4" STYROFOAM CORE SANDWICH
PANEL CREEP DATA
MID-POINT LOADING
From L.E. Putnam data books #781 & #839 1965.
Plywood Facing Failure
8 psi Shear
4 psi
2 psi
0.300
0.200
0.100
MAXIMUM DEFLECTION FOR 96" SPAN (INCHES)
100
200
300
400
500
600
700
DAYS LOAD WAS APPLIED
GVP 2-3-70



END WALL CREEP

Fig. [illegible]

position with spliced 2 inch thick walls provided boards and splices are cut square. Care was taken to prevent excessive force of sand against one wall while loading. Attempts were made to drop sand vertically between walls.

There was no sand leakage of the filled wall. The combination of a 2 inch thick wall and spliced butt and 90 degree corners design prevents sand leakage without the aid of auxiliary sealing.

The effects of frictional forces on the foam wall was noted by the tightening of all horizontal joints, with the tighter joints starting from the bottom.

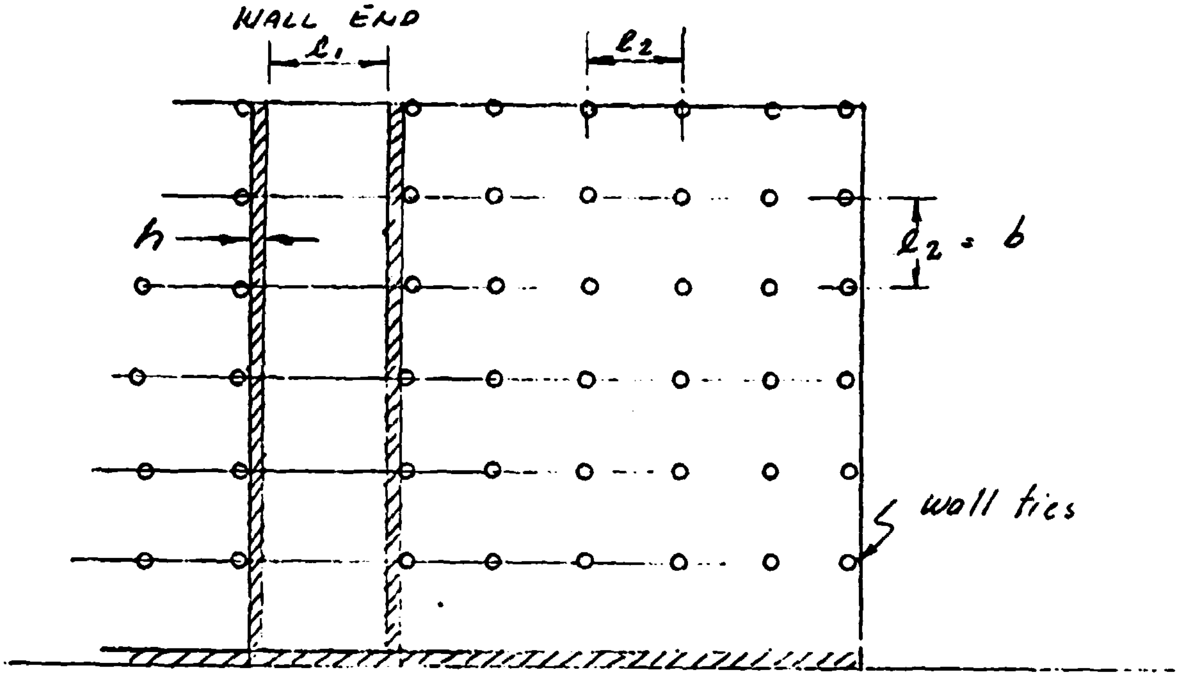
17.0 CALCULATIONS

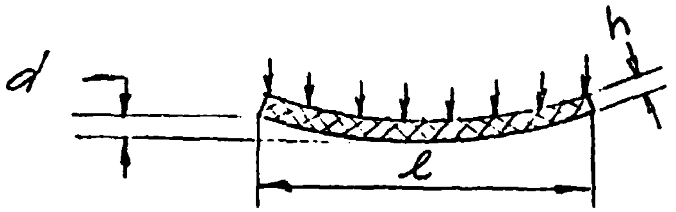
17.1 Wall Stiffness

The foam wall stiffness between wall ties may be calculated using simple beam equations given on Figure 31. More exact calculations are made using Timoshenko's[7] plate theory whereby the foam wall between ties is treated as a plate elastically supported at the edges with rigid corner supports. The simple beam theory is 10 percent more conservative and will be used in this report.

17.2 Wall Thickness

Generally the wall thickness will be determined by the maximum fiber stress rather than maximum deflection. A wall thickness versus foam flexural stress selection chart for various wall heights and wall tie spacing is plotted on Figure 32. The important criteria in determining wall thickness is the correct selection of a design safety factor for foam flexural stress. For example, if a safety factor of 3 were selected for an 85





$c = \frac{h}{2}$

* deflection, $d = \frac{5w\ell^4}{384EI}$, $I = \frac{bh^3}{12}$

E = Flexural Modulus

max. Fiber Stress, $S = \frac{Mc}{I}$ $\quad M = \frac{w\ell^2}{8}$

For square ties $S = \frac{3w\ell}{4h^2}$

* Calculated as a simple beam. For more accurate calculations refer to Timoshenko's "Theory of Plates and Shells" pp. 218 - 220

Fig. 31 - Wall Strength Calculations

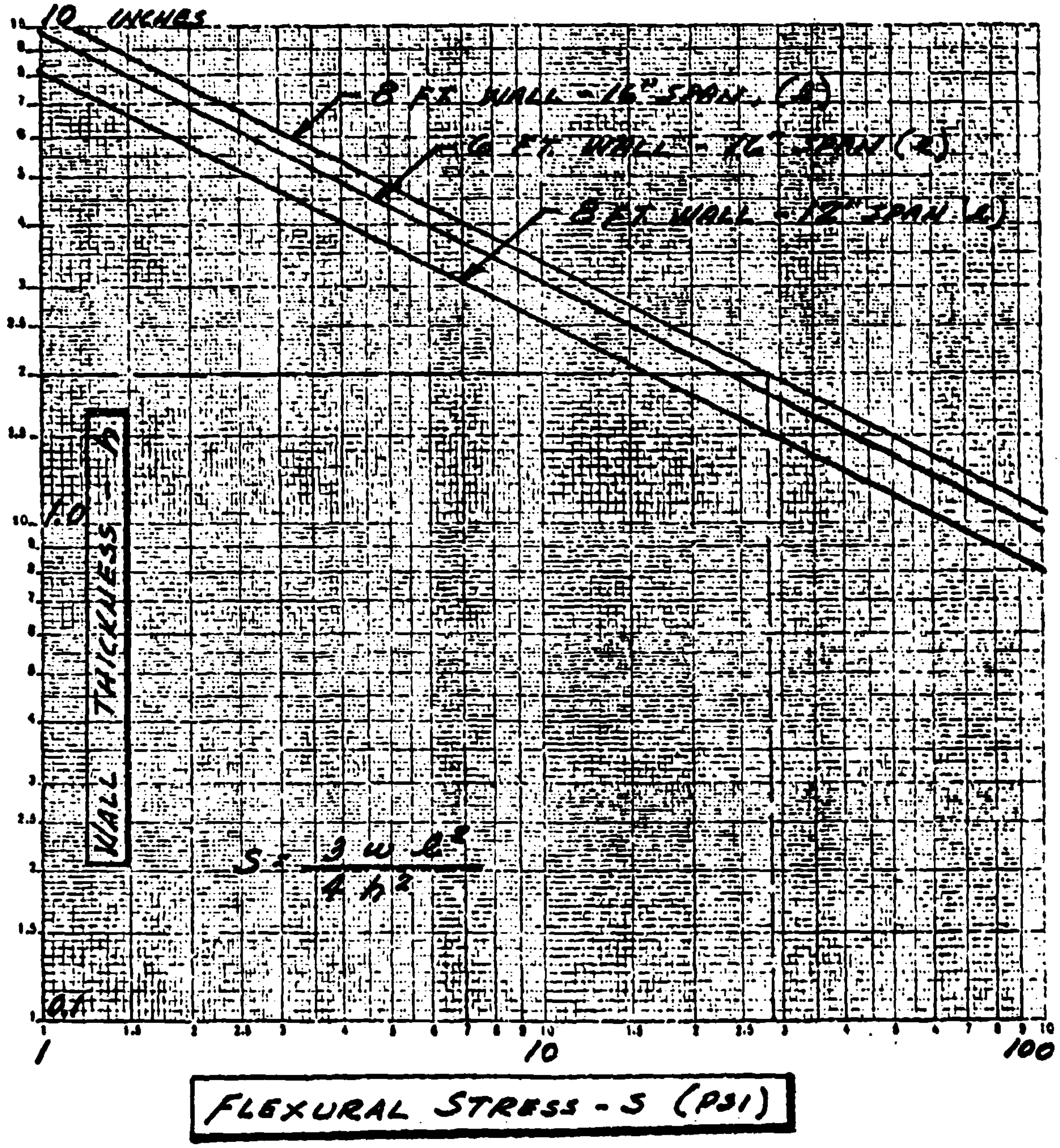


Fig. 32 - Wall Thickness Versus Flexural Stress For Various Sand Heads

psi flexural stress foam, for a limiting stress of 28.5 psi, a 2 inch thick wall is required to contain an 8 foot head of sand with wall ties on 16 inch centers. Using a safety factor of 6, or 14 psi stress, a 3 inch wall is needed.

18.0 WALL TIES

18.1 Requirements

Wall ties must be made of lightweight material incapable of becoming secondary missiles. Ties on a 16 inch by 16 inch grid, must sustain a maximum load of 165 lbs for several years, therefore, the material should have low elongation and creep characteristics. Since ties pass through 22 inches of sand, the material should be relatively inert to moisture or other contaminants which may be found in the sand.

18.2 Prototype Band Ties

Prototype wall ties were made from adhesive backed glass fiber tape one inch wide, Minnesota Mining and Mfg. Co., Type 891. Endless bands 84 inches long were made with the tape in two long lap plies with adhesive sides face to face. Ties were assembled in the walls by making 1/32 inch vertical saw cuts down to one inch below the spline groove. Cuts were spaced on 16 inch centers with alignment to cuts on opposite walls. The nominal 84 inch long bands were assembled in four slots thus forming a horizontal rectangle 16" x 22" x 16" x 22" as illustrated on Figure 33. Bands were made one inch undersize to allow for foam compression at the slots when loaded with sand. A completed model 8 feet high by 8 feet long, loaded with

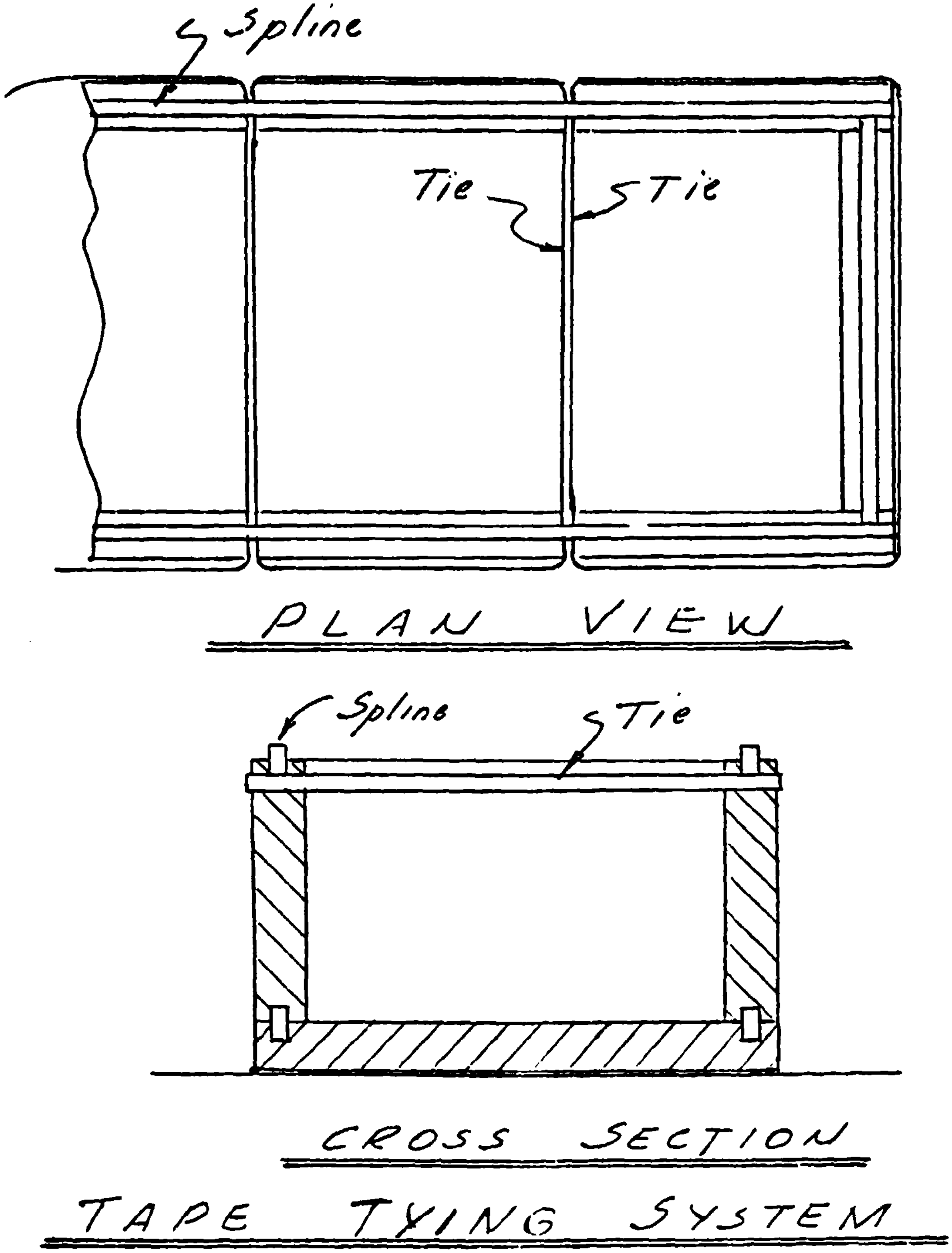

Spline
Tie
Tie
PLAN VIEW
Spline
Tie
CROSS SECTION
TAPE TYING SYSTEM

Fig. 3

sand, using this wall tying system is shown on Figure 34. This model remained assembled for one week before disassembling.

18.3 Fabric/Spline Ties

A second wall tying system was conceived and tested. Strips of open mesh, 4 x 4 x 5 x 5, glass fiber fabric 4 inches wide was adhesively bonded to the centerline of wall splines as sketched on Figure 35. The tensile strength of this fabric ranged from 200 to 300 lbs per inch width, or 800 to 1200 lbs for a 4 inch tie. Fabric/spline wall tie assemblies were tensile tested. Failures occurred in stripping the adhesive bonded fabric from the spline at 350 lbs for a 1 inch x 2 inch spline in a 3 inch thick wall, indicating satisfactory performance.

19.0 COMPARTMENTED TEST STRUCTURE NO. 1

19.1 Description

A full size prototype compartmented structure section was assembled in the final phase of this program. The center wall was 26'-8" long with five wing walls 6 feet long, two on one side and three on the other as sketched on Figure 36. The center wall, as well as three wing walls were fabricated from 2 inch thick foam boards. Two wing walls were made from 3 inch boards. Both wet and dry sand was to be loaded to compare loading and lateral pressure effects. Walls were tied with fabric/spline ties.

19.2 Assembly And Loading

The walls were assembled on a relatively flat concrete

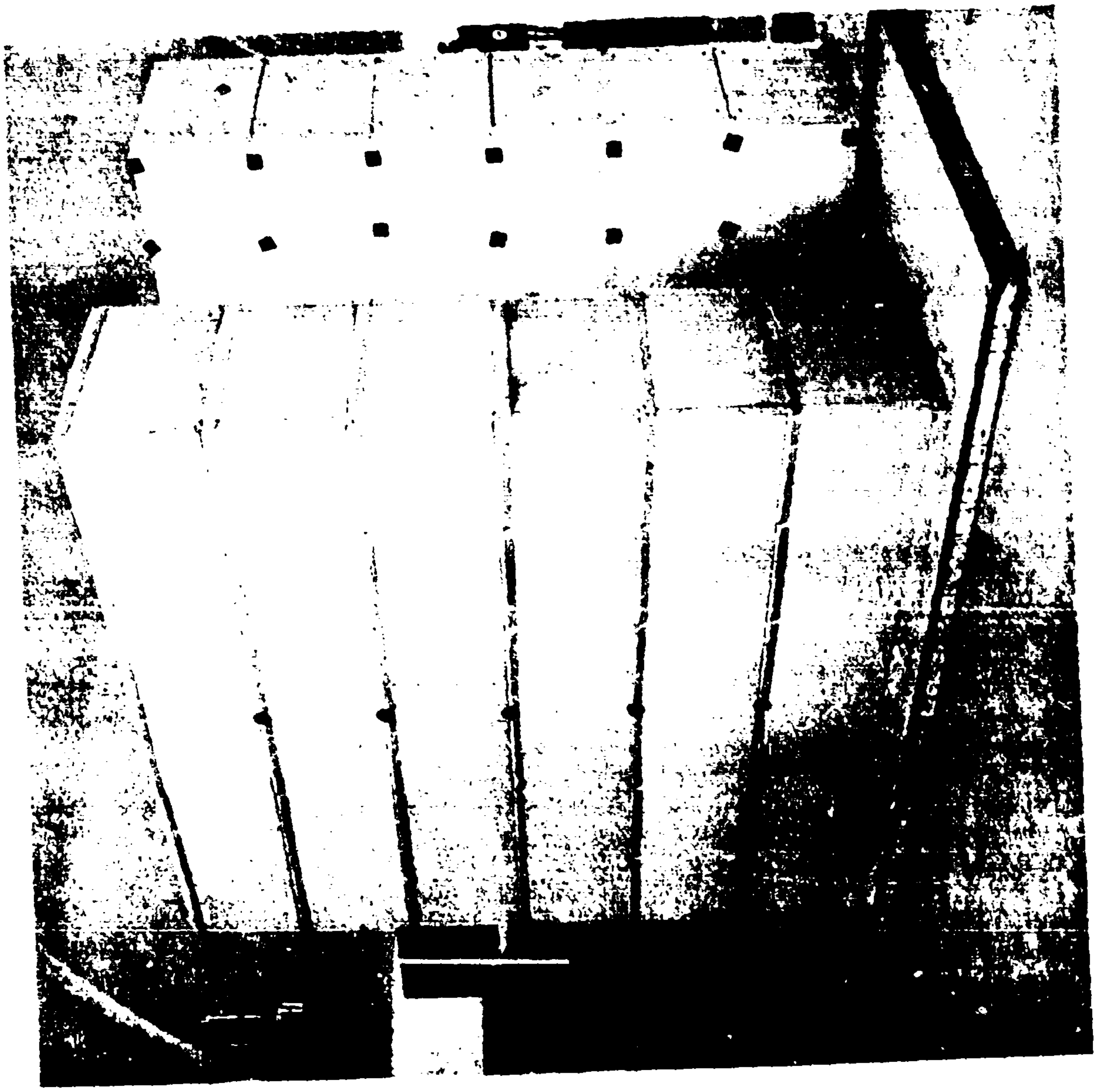


Fig. 34 - Completed Prototype No. 2 With Taped Wall Ties

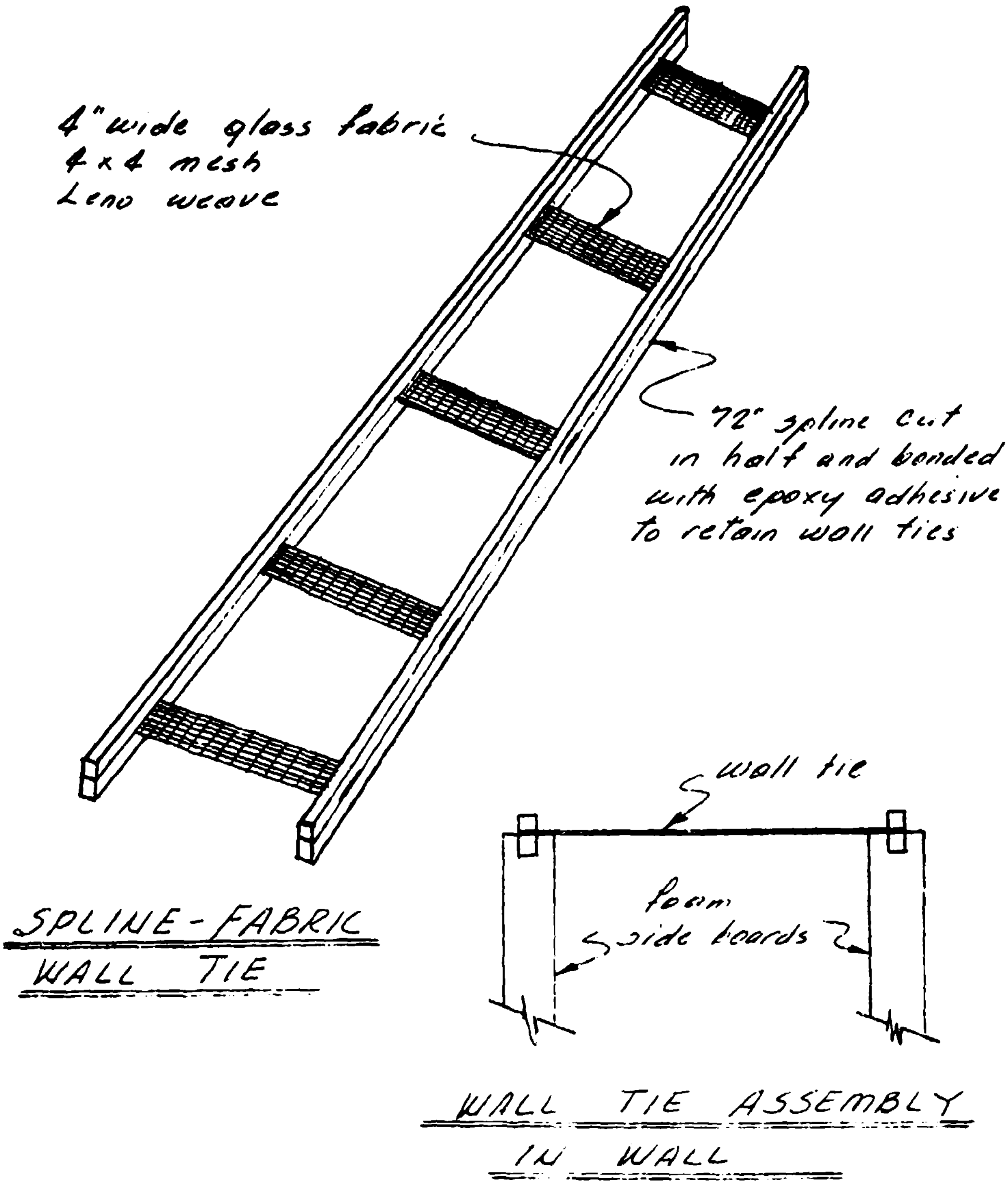
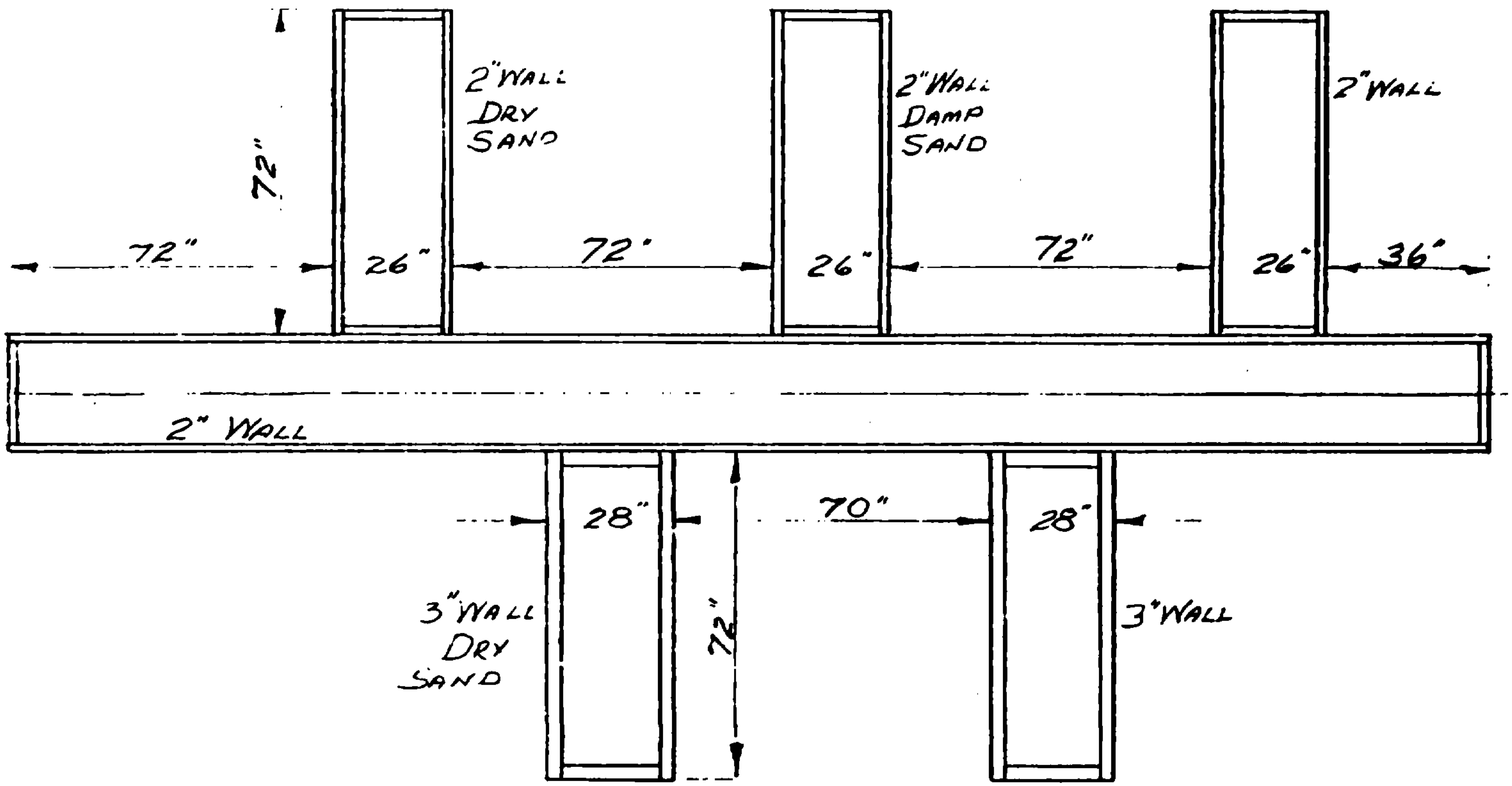


Fig. 35 - Spline/Fabric Wall Tie Details



CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY [signature]	DATE 3/19/71	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY [signature]	DATE 3/19/71		JOB NUMBER PY1578
CHECKED BY	DATE	PROTOTYPE TEST SECTION	DRAWING NUMBER PY1578-1D
APPROVED BY	DATE		

Fig. 36

floor. The center and wing wall location were marked with chalk line. Assembly and loading started from the center wall far end as shown on the photo, Figure 37. Sand was loaded with a one-half yard bucket mechanical front end loader shown at wet and dry sand piles, Figure 38. Other photos, Figures 39 and 40 show various stages of assembly.

19.3 Wall Failure

The center wall 26'-8" long, with closed ends was loaded with dry sand to a 5 board height of 80 inches. After one hour the entire center wall, with the exception of the end, collapsed.

19.4 Review of Failure

Initial failure occurred in the spline wall ties in the adhesive bonded joints. Several splines were checked and found bonded with insufficient adhesive. Although there was no one present when the wall collapsed, it appeared the initial failure occurred near the center of the wall. The far end remained standing as shown in the photo, Figure 41. Also, note that failure of this type wall occurs initially at the base where wall pressure is maximum. As a result the sand and broken wall pieces drop straight down forming a pyramid-like pile.

The conclusions derived from this test disclose the unreliability of an adhesively bonded system where only one improperty fabricated spline/tie can be the cause of an entire wall failure.

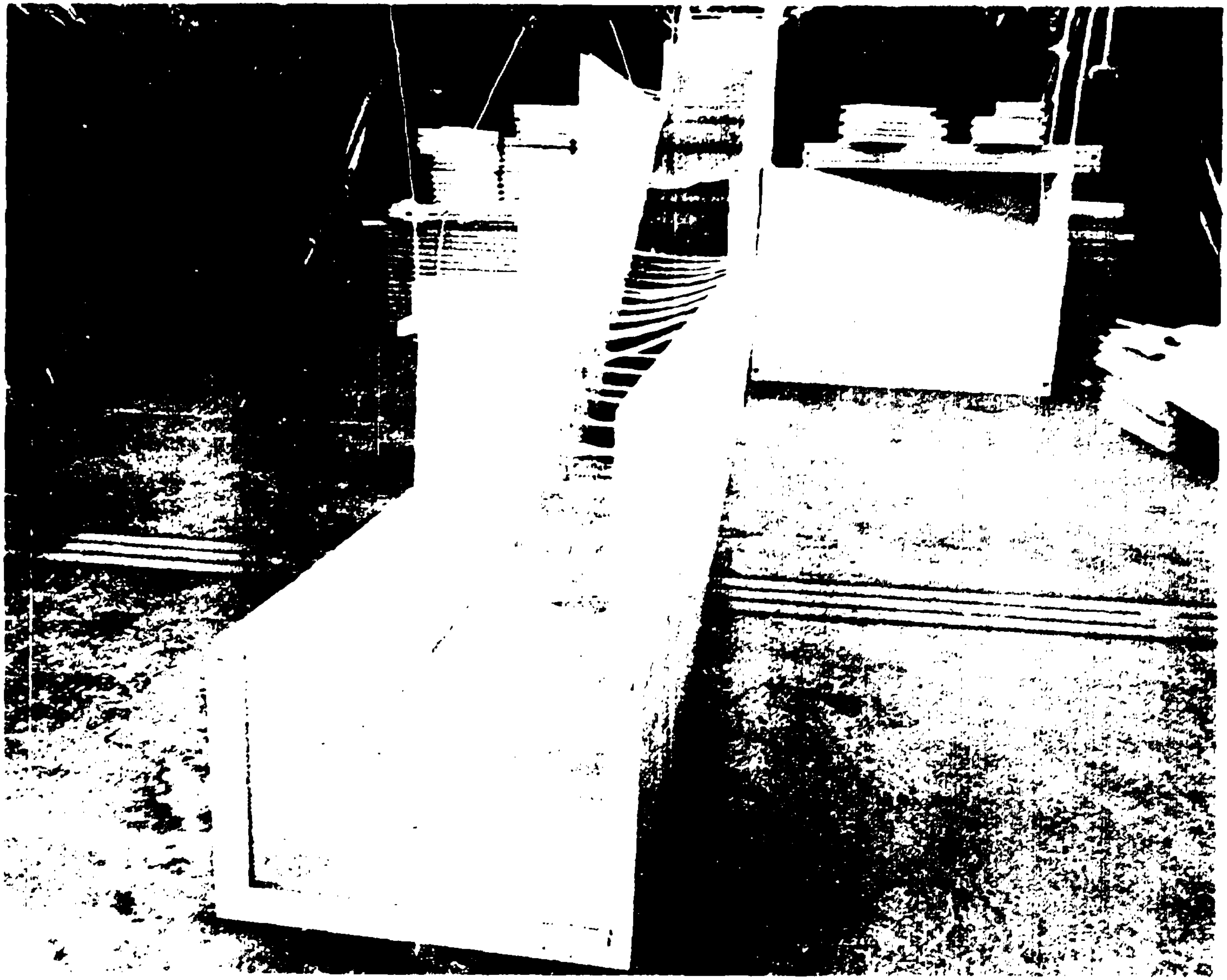


Fig. 37 - Partial Loaded Center Wall

Fig. 30 - Mechanical Loader - Wet and Dry Sand Piles

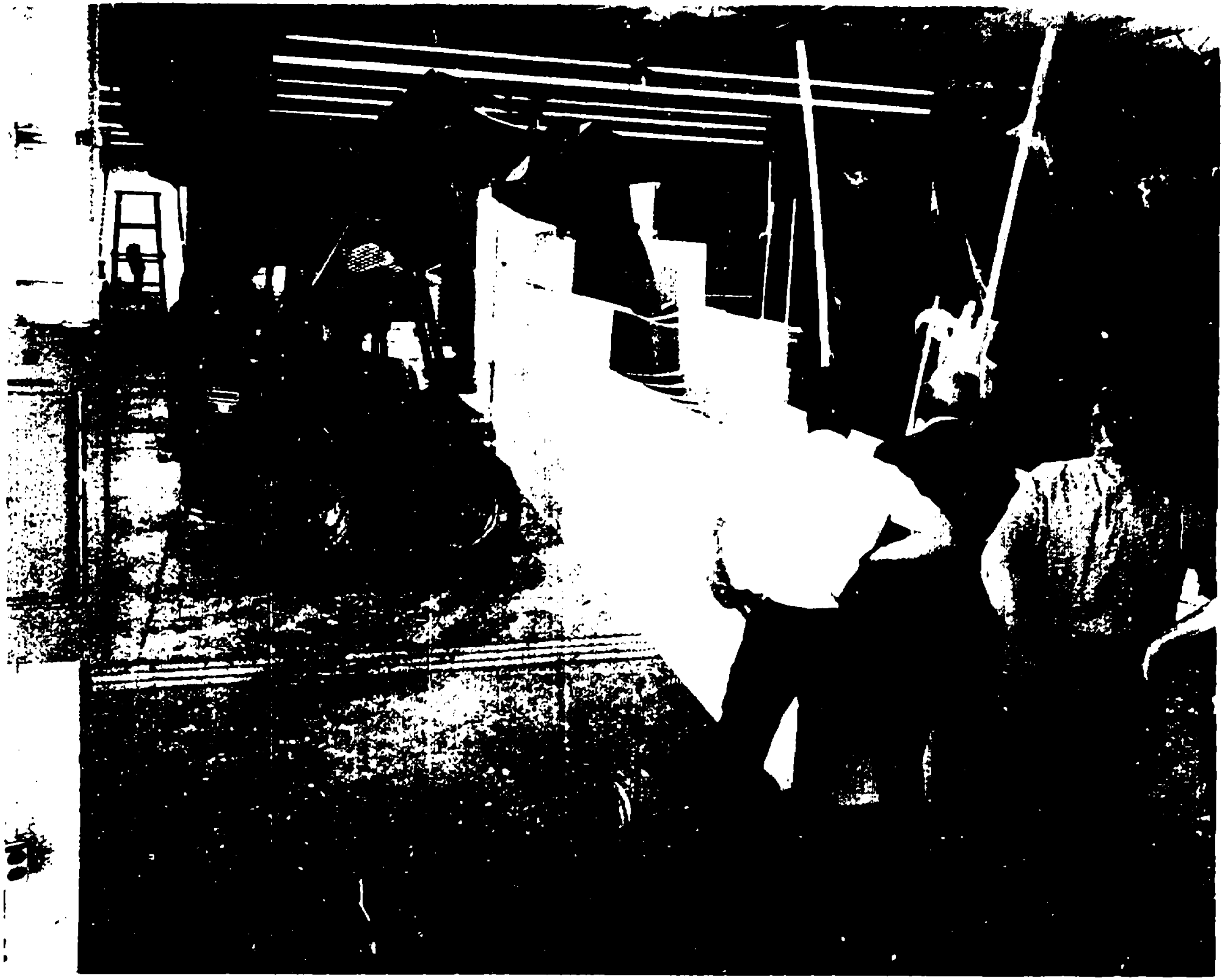
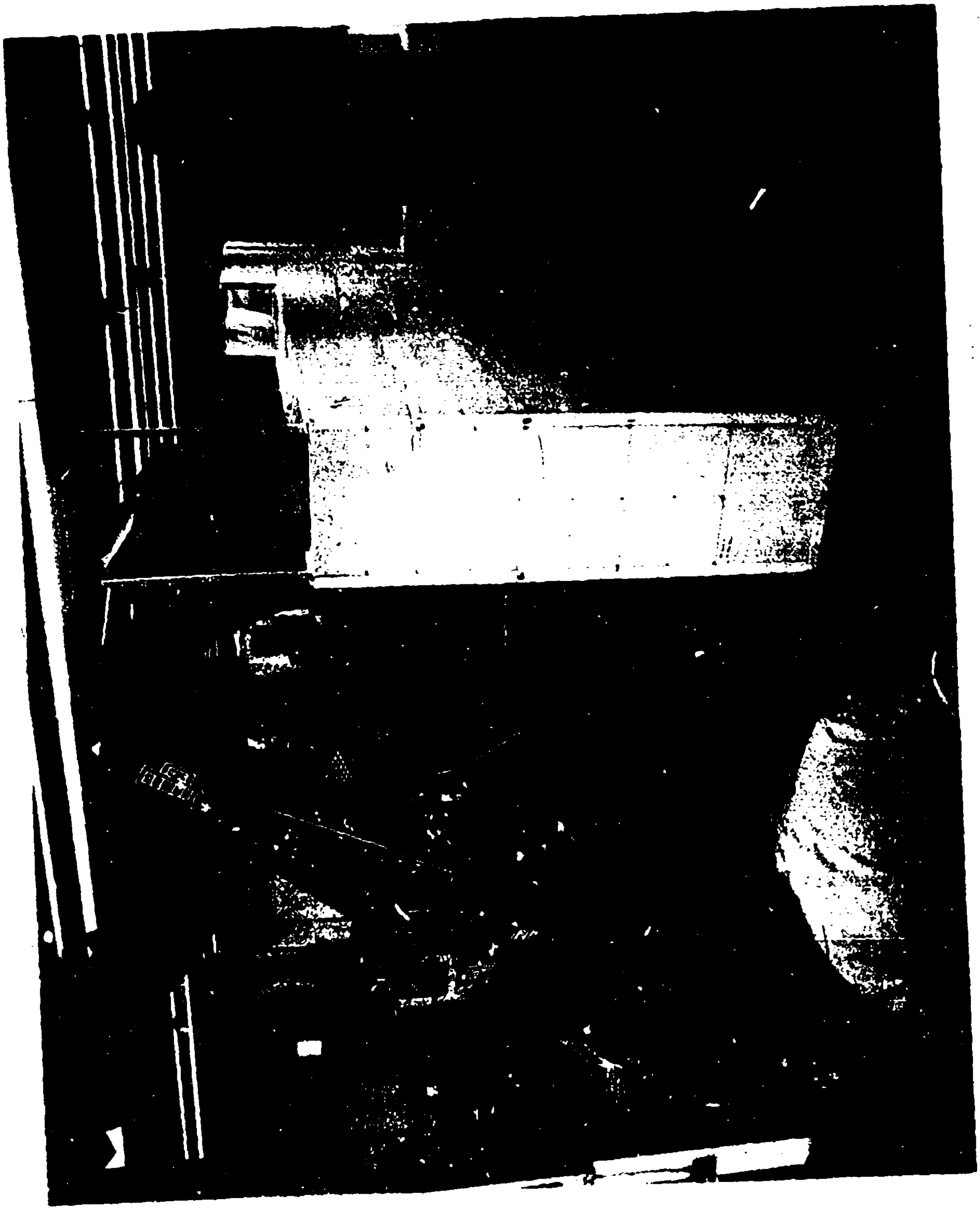


Fig. 39 - Center Wall Loading



Partially Loaded Center Wall

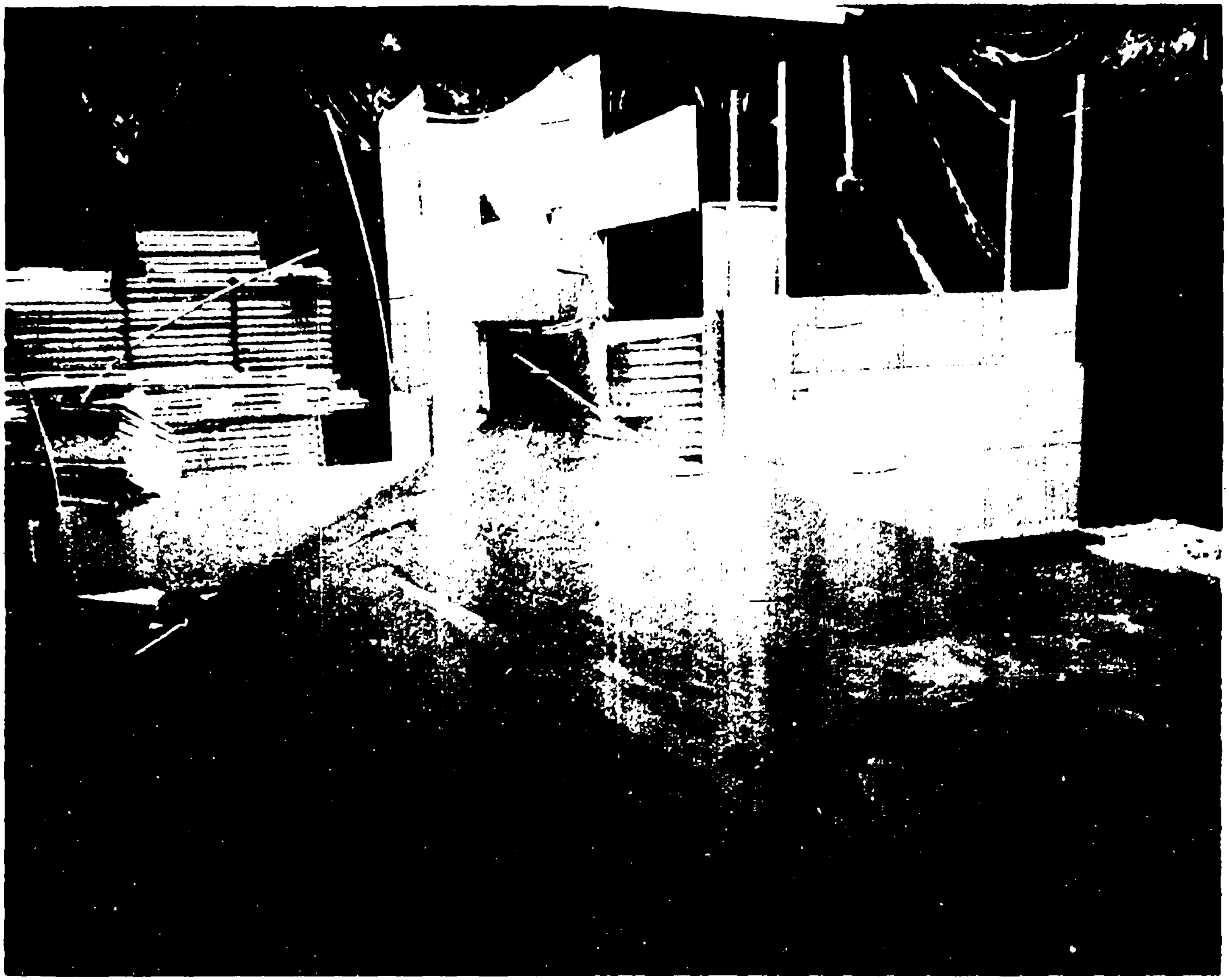


Fig. [illegible] - Coll[illegible] Center Wall

The sand used in this test was kiln dried and was still warm when loaded. Sand temperature was measured in subsequent loadings and found to be 210°F. At this temperature the epoxy adhesive and the polystyrene foam become quite soft. This condition also contributed to wall failure.

The unused spline/fabric splines were inspected and those with the most deficient adhesive bonds were selected and tested. Loaded in tension, two of the specimens failed at 130 and 140 lb loads, which is below the required 165 lbs maximum wall load.

20.0 COMPARTMENTED TEST STRUCTURE NO. 2

20.1 Description

A second test structure was assembled following the original plan of testing several variables which includes;

(1). Center wall - 26'-8" long, 3" thick boards, dry sand, tied with bands.

(2). Wing wall - 6 feet long, 3" boards, dry sand, tied with glass fabric/spline ties.

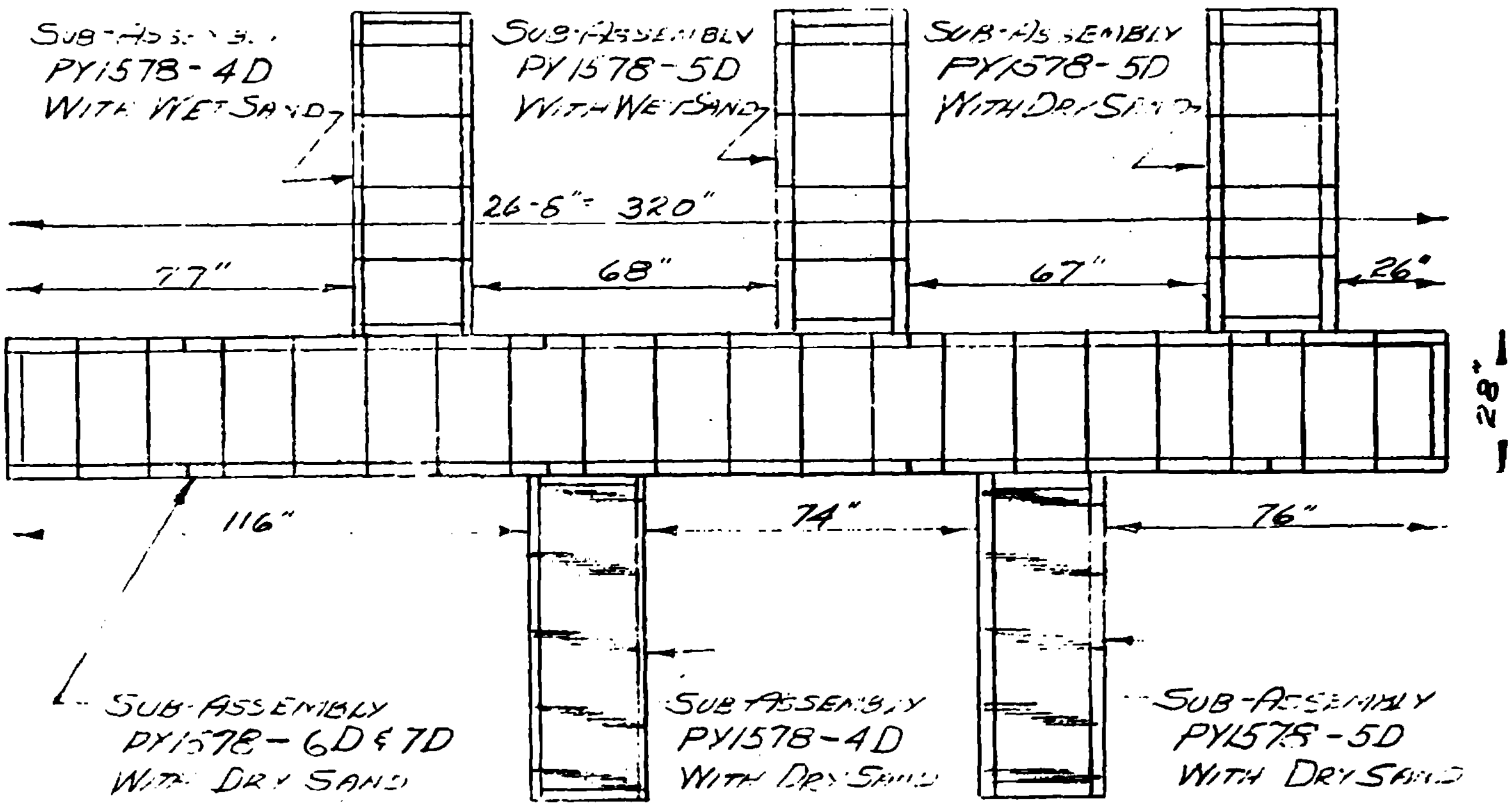
(3). Wing wall - 2" boards, wet sand, tied with bands.

(4). Wing wall - 3" boards, wet sand, tied with bands.

(5). Wing wall - 3" boards, dry sand, tied with bands.

(6). Wing wall - 2" boards, dry sand, tied with glass fabric/spline ties.

The sketch, Figure [illegible], shows a layout of this test structure. Detailed drawings and parts lists for this section plus the recommended system are included in Part II of this report.



CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY	DATE 4/7/71		JOB NUMBER PY1578
CHECKED BY	DATE	ASSEMBLY PROTOTYPE TEST SECTION No. 2	DRAWING NUMBER PY1578-3D
APPROVED BY	DATE 4/24/71		

Fig. 42

20.2 Wall Tie Fabrication

20.2.1 Fabric/Spline Ties

Ties with better adhesive bonds for both 2 inch and 3 inch walls were selected from those fabricated for the No. 1 structure. These ties were used in the assembly of two wing walls - one 2 inch and one 3 inch.

20.2.2 Band Ties

One-inch wide, two-ply, glass-fiber tape bands used were similar to those used on the earlier test wall structure. Test jigs, Figure 43 were made to test the band elongation and wall board corner compression to determine allowances to be made in band lengths. The full size 16 inch grid bands were made 1.5 inches undersize and the 8 inch end bands were made one inch undersize.

Two test rigs with full 170 lb loads, one on a band assembled to a wall board specimen, the other a glass band only, remained loaded to check longer term creep properties.

20.3 Assembly And Loading

The 3 inch board center wall (26'-8" long) with band ties was loaded first, with dry sand. Since band ties were made undersize, this caused the walls to bow inwardly a maximum of 1/2 inch before loading with sand. The photo Figure 44 shows a wall tie being assembled.

Sand was again loaded with a one-half yard mechanical loader. A partially assembled wall is shown in the photo, Figure 45.

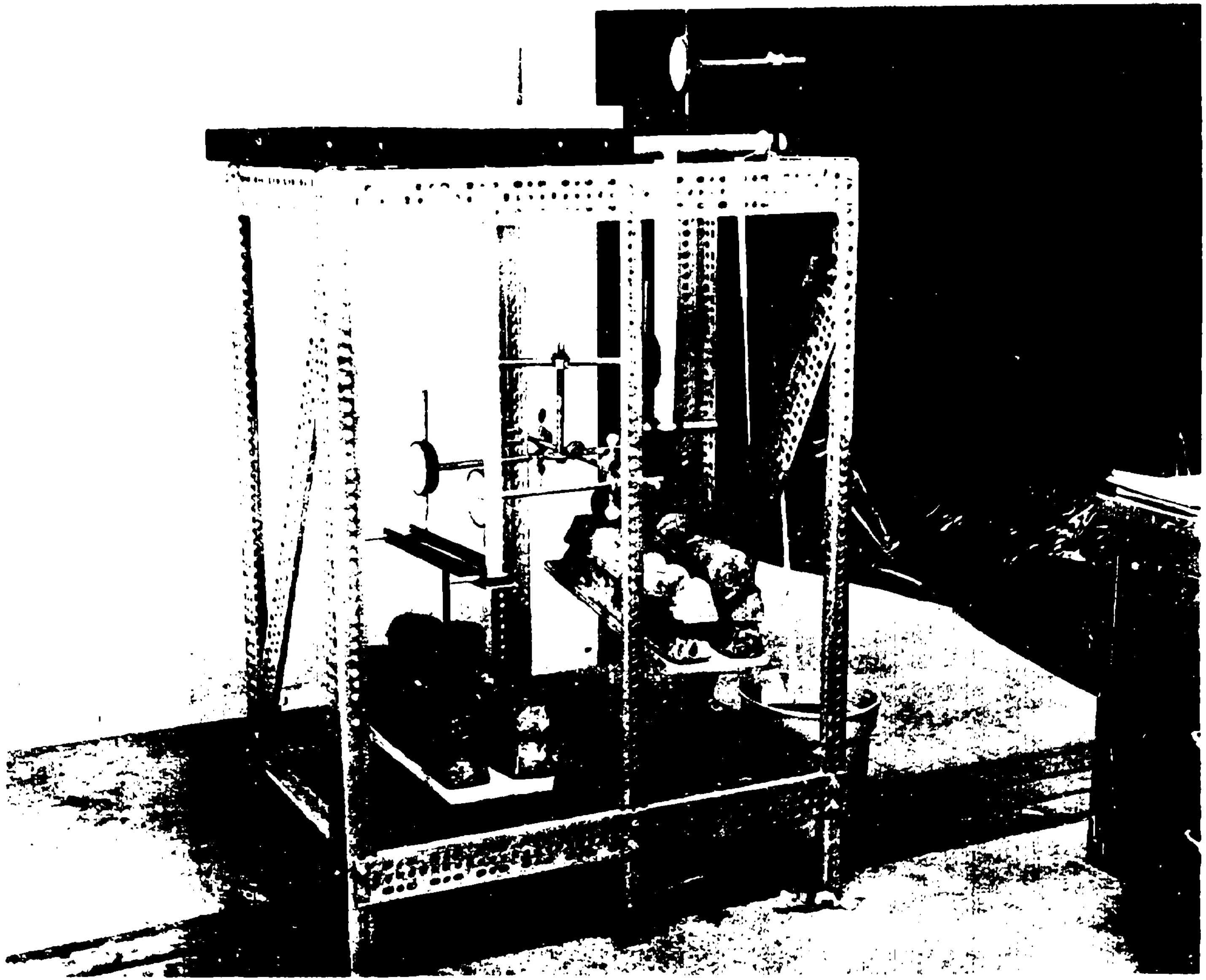


Fig. 43 - Tape Wall Tie Tensile Test Apparatus

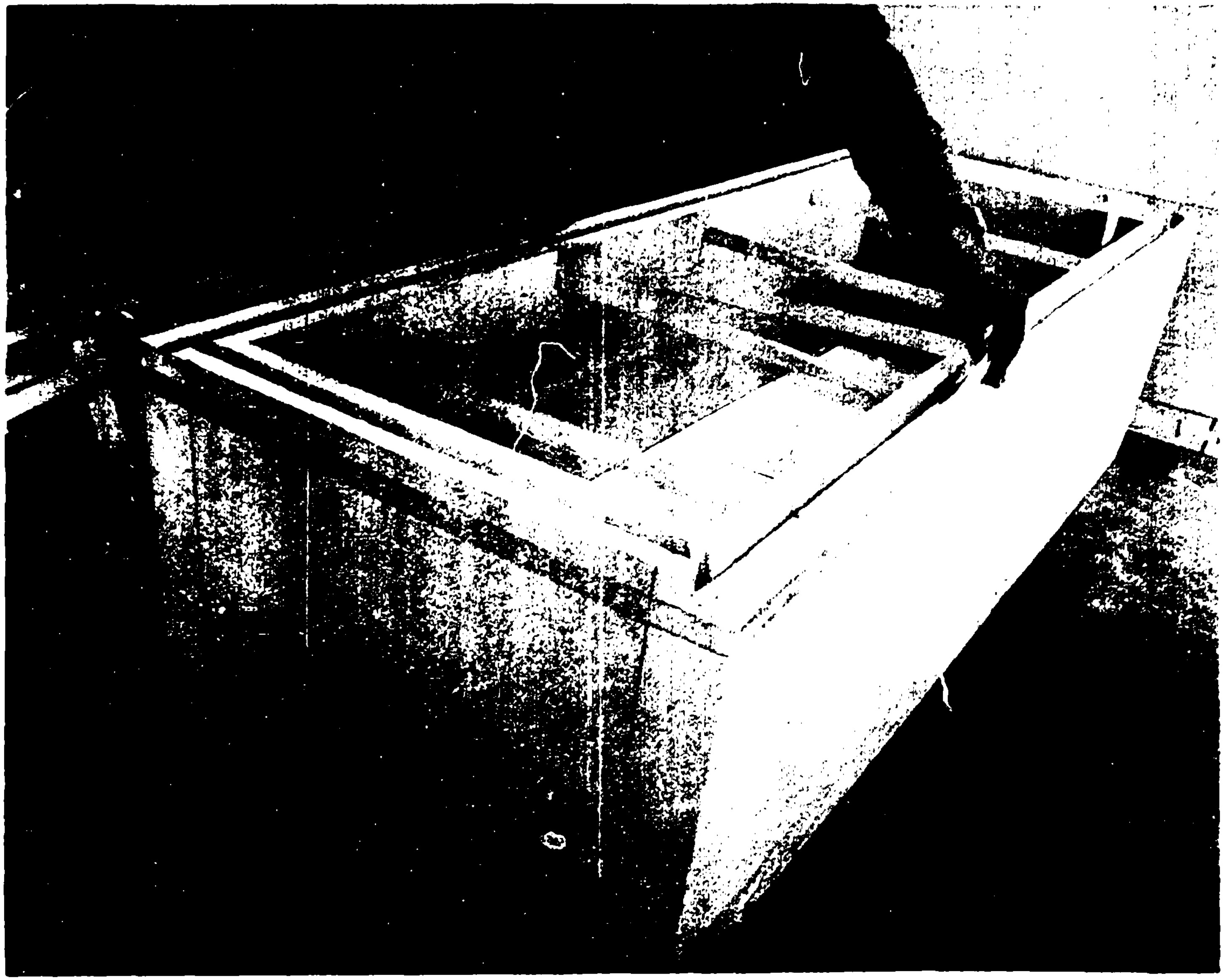


Fig. 44 - Assembly of a Tape Wall Tie

Fig. 45 - Partially Assembled Center Wall

The kiln dried sand arrived at the test site at 250°F. One-half yard was loaded into the foam wall without damage before spreading the sand to cool. Sand was loaded at about 160°F.

Since wet sand does not pour, the effects of loading wet sand from some height was questionable. This was tested by dropping wet sand from a height of 5 feet. No problems were encountered.

The wet sand consistency is illustrated in the photo, Fig. 46, of the loader in position for unloading. A sieve analysis and other properties of the wet sand used are given on Figure 47.

20.4 Observations

The 8-foot high by 26'-8" center wall was loaded without aid of a level. After filling, the maximum void space between center wall and wing wall was 1/2 inch of the top. The remaining four wing walls made full height contact with the center wall. Since sand loading can force the wall out of plumb, it is recommended a level or plumb line be used.

The wet sand exerts less lateral wall pressure than the dry sand, when gravity loading without tamping. When pressure was exerted on the sand, for example, forcing sand into corners in the end walls, the 2-inch walls were deflected outwardly more than by normal loading.

Earlier tests indicated the lateral wall pressure developed by the sand is reduced with time. This was verified by running Jenike-Johanson Inc., Flow Factor Tests[7] to determine the change in angle of friction for the wet and dry sand used. The graphs on Figure 48 illustrates the test results.

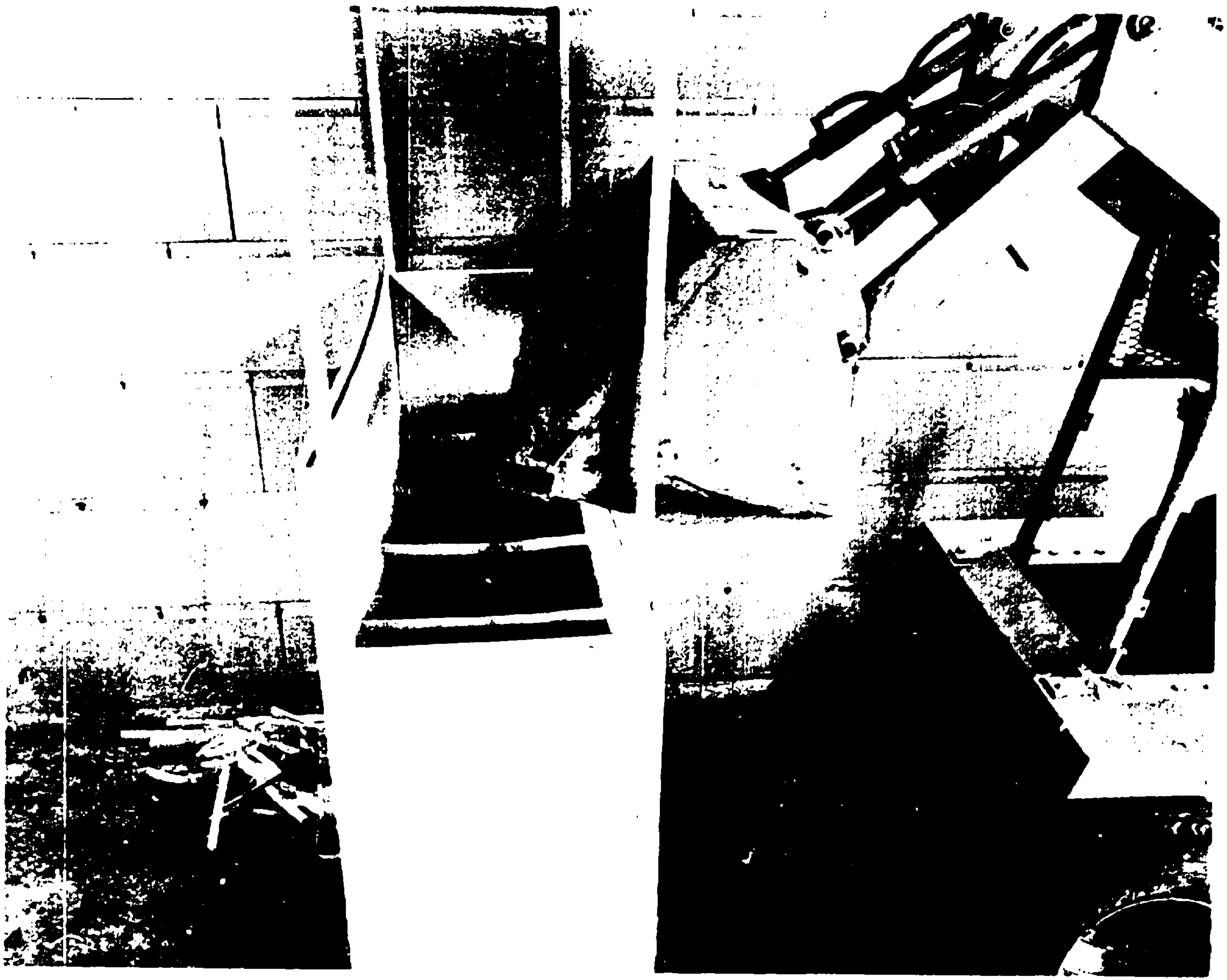


Fig. 46 - Wet Sand Loading A Wing Wall

SAND ANALYSIS

TYPE Mason Sand DATE May 8, 1971

SOURCE Fischer Sand & Gravel TESTED BY Carrington

WET OR DRY Wet

ASTM C-144-62T SCREEN TEST (1000 gram sample)

Screen Numbers	Gross	Tare	Net	% Passing
4	--	--	--	100
8	384.7	373.0	11.7	98.9
16	366.9	324.0	42.9	94.6
30	523.2	405.5	117.7	82.9
50	1059.1	448.2	610.9	21.8
100	449.6	258.0	191.6	2.6
200	416.0	396.4	19.6	0.6
Pan	372.6	366.2	6.4	--

Dry Sand Weight 96 lbs/cu ft

Wet Sand Weight 92 lbs/cu ft

Fig. 47

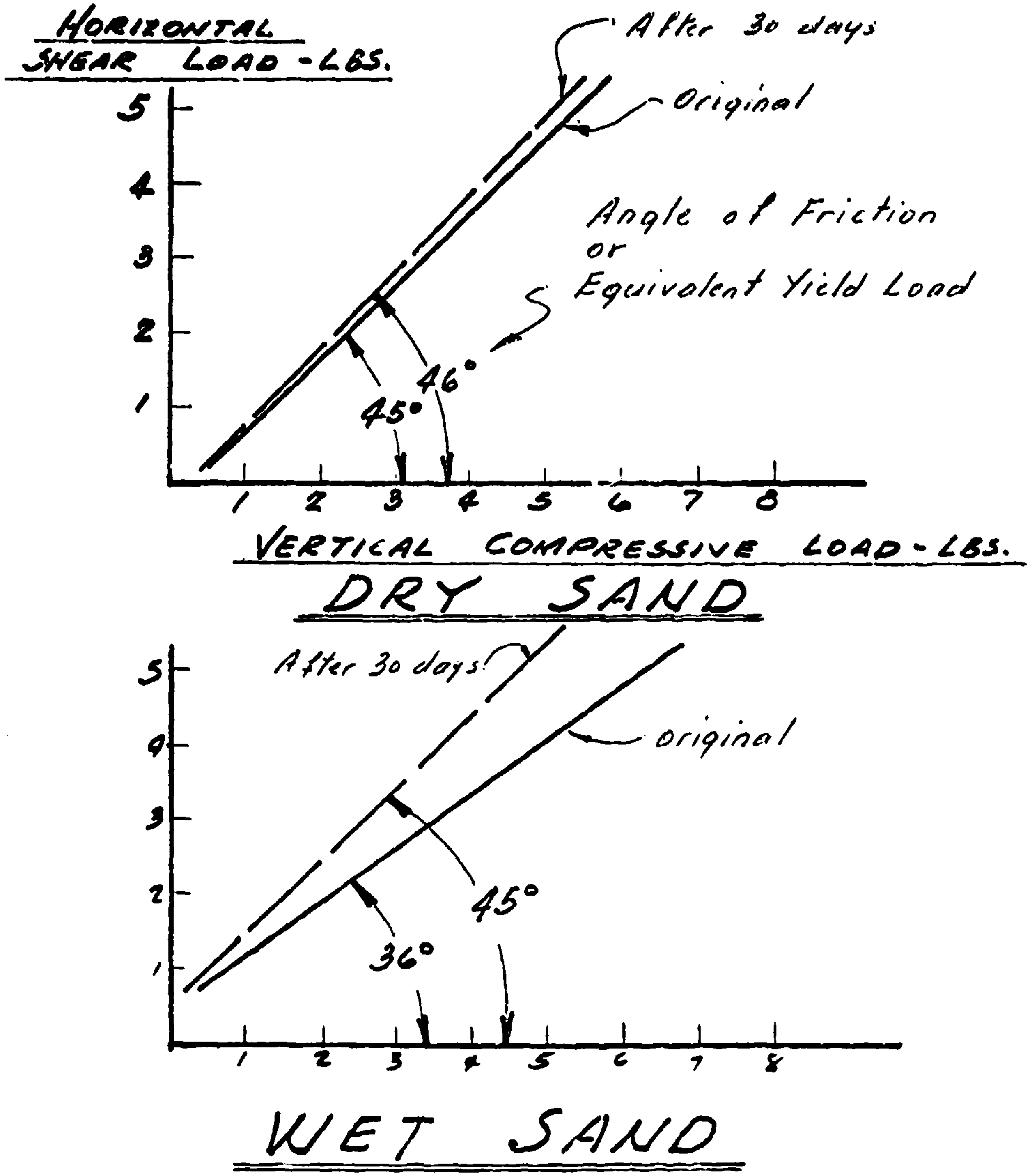


Fig. 48 - Change of Wet and Dry Sand Angle of Friction Versus Time
(Measured with Jenike-Johanson Inc. Flow Factor Tester)

The angle of friction of both wet and dry sand increased after 30 days loading. An increase in angle of friction reduces lateral wall pressure and therefore reduces the load on the foam wall and wall ties.

The slack in band wall ties permitted some of them to assume a flat horizontal position when loading with wet sand. No attempt was made to straighten them, and consequently greater loads were placed on them due to the additional vertical sand load. Band loads would be reduced if they are straightened while loading sand.

All wall ties were made undersize to compensate for foam compression at saw cuts. Since wall pressure is maximum at the base and minimum at the top, ties should be made in incremental lengths to form a vertically straight wall when loaded with sand. It is recommended radii be heat formed on all wall tie saw cuts so that a vertical straight wall will be formed with equal length bands.

The long term reliability of adhesively bonded glass fabric wall ties is questionable. It is recommended wall ties be fabricated from high strength nylon or dacron webbing with ends lapped and sewn for maximum lap strength.

20.5 Testing

Assembly of the compartmented structure No. 2, photos Figures 49 through 53 was completed June 3, 1971. It will be tested and observed for the duration of the contract, August 31, 1971. Deflection of end wall boards, where deflect on is maximum, was measured periodically to check creep characteristics with respect to wall thickness, wet and dry sand, and the two wall tying systems.

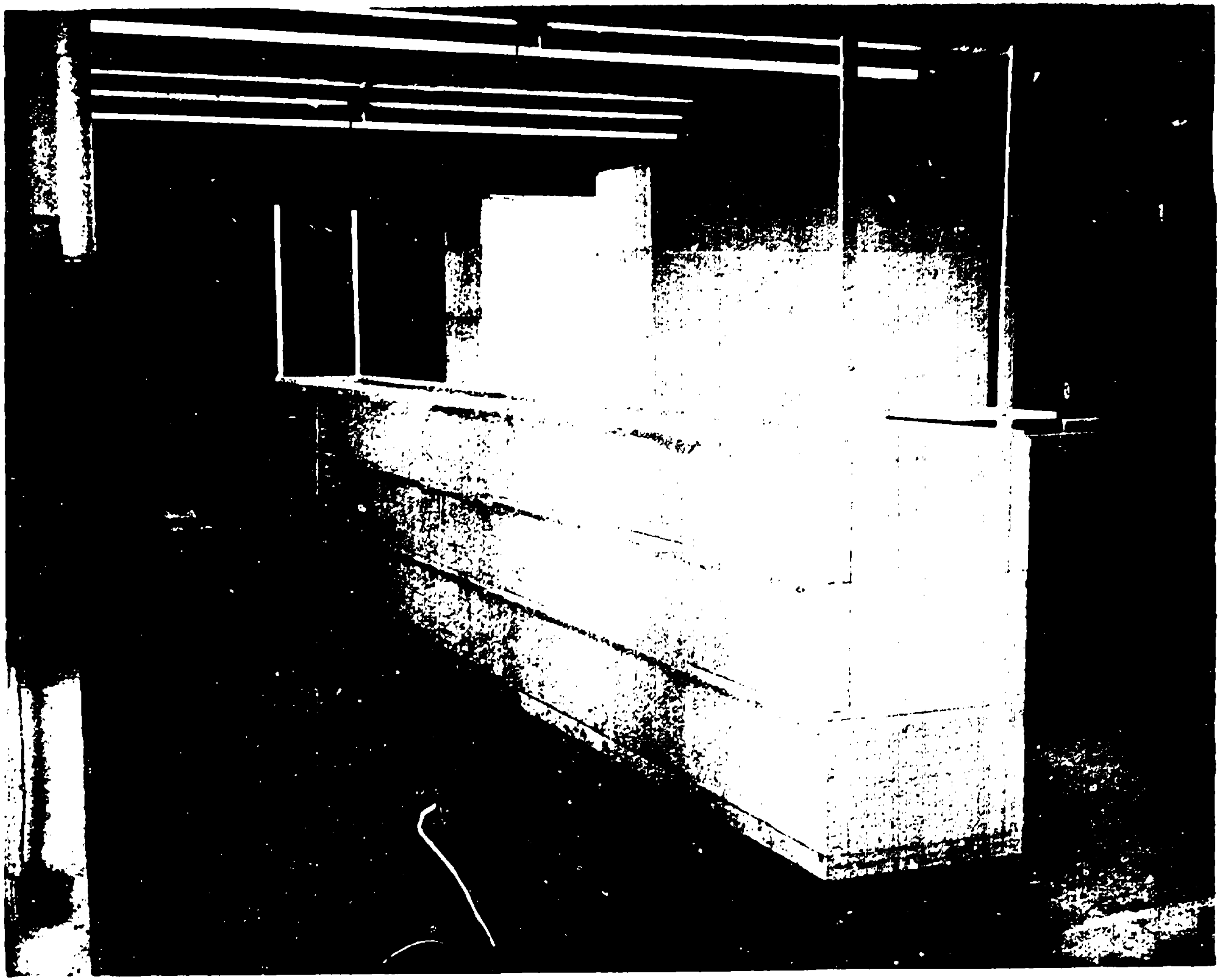


Fig. 49 - Partially Assembled Center Wall with 2" and 3" Wing Walls With Spline/Fabric Wall Ties In Back Ground

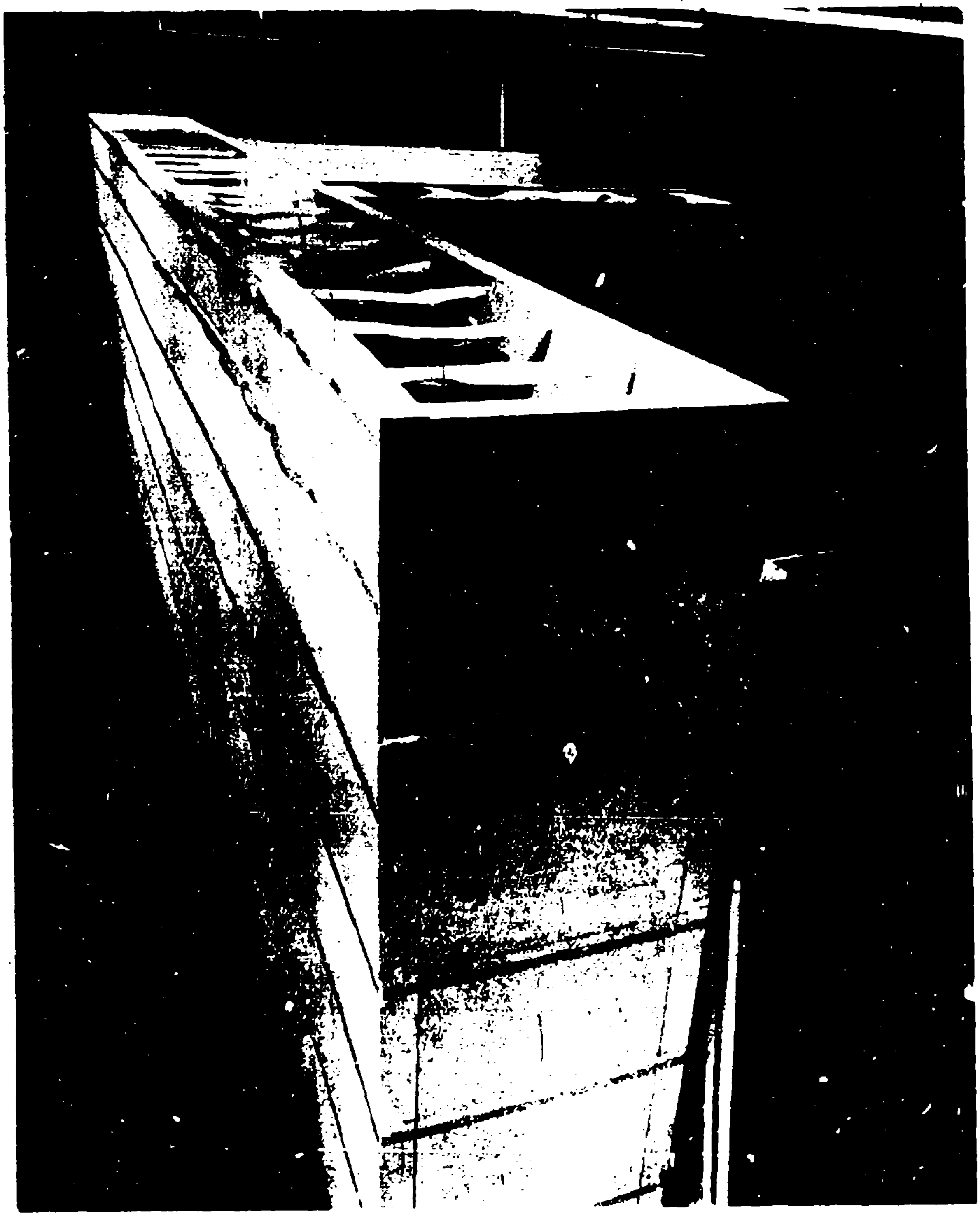


Fig. 50 - Partially Loaded 8 foot High Center Wall

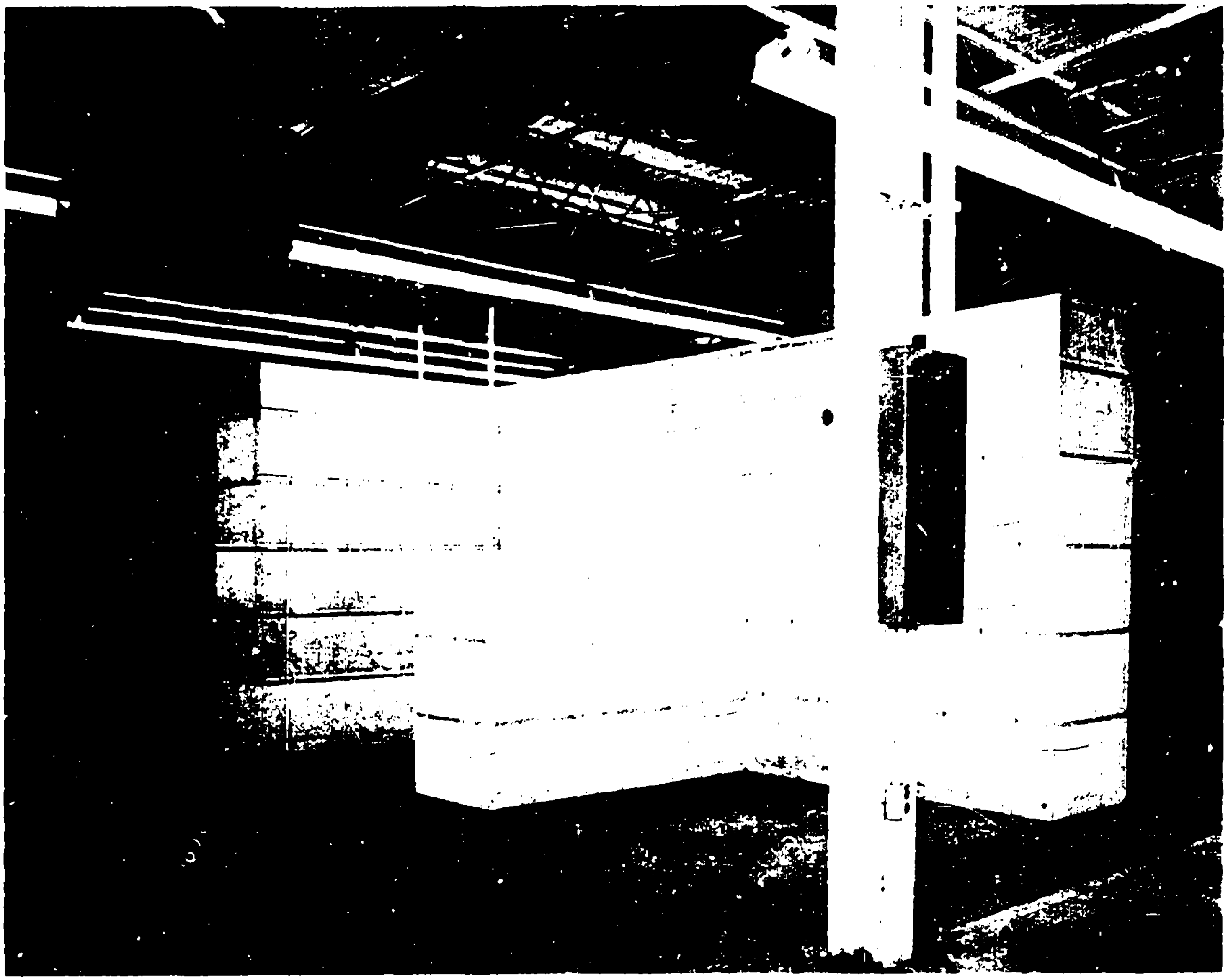


Fig. 51 - Magazine Section Near Completion

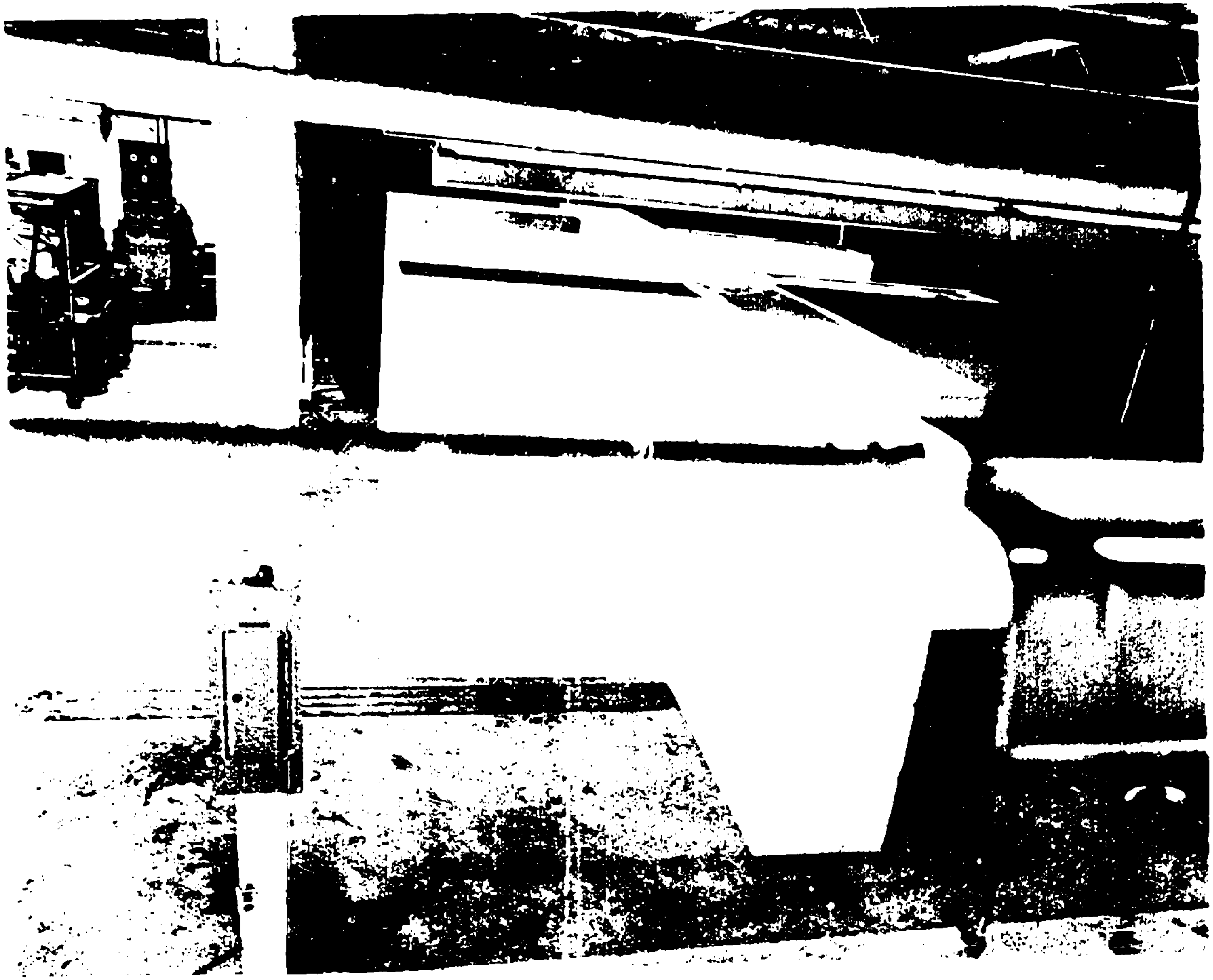


Fig. 52 - Top View of Completed Compartmented Magazine Section

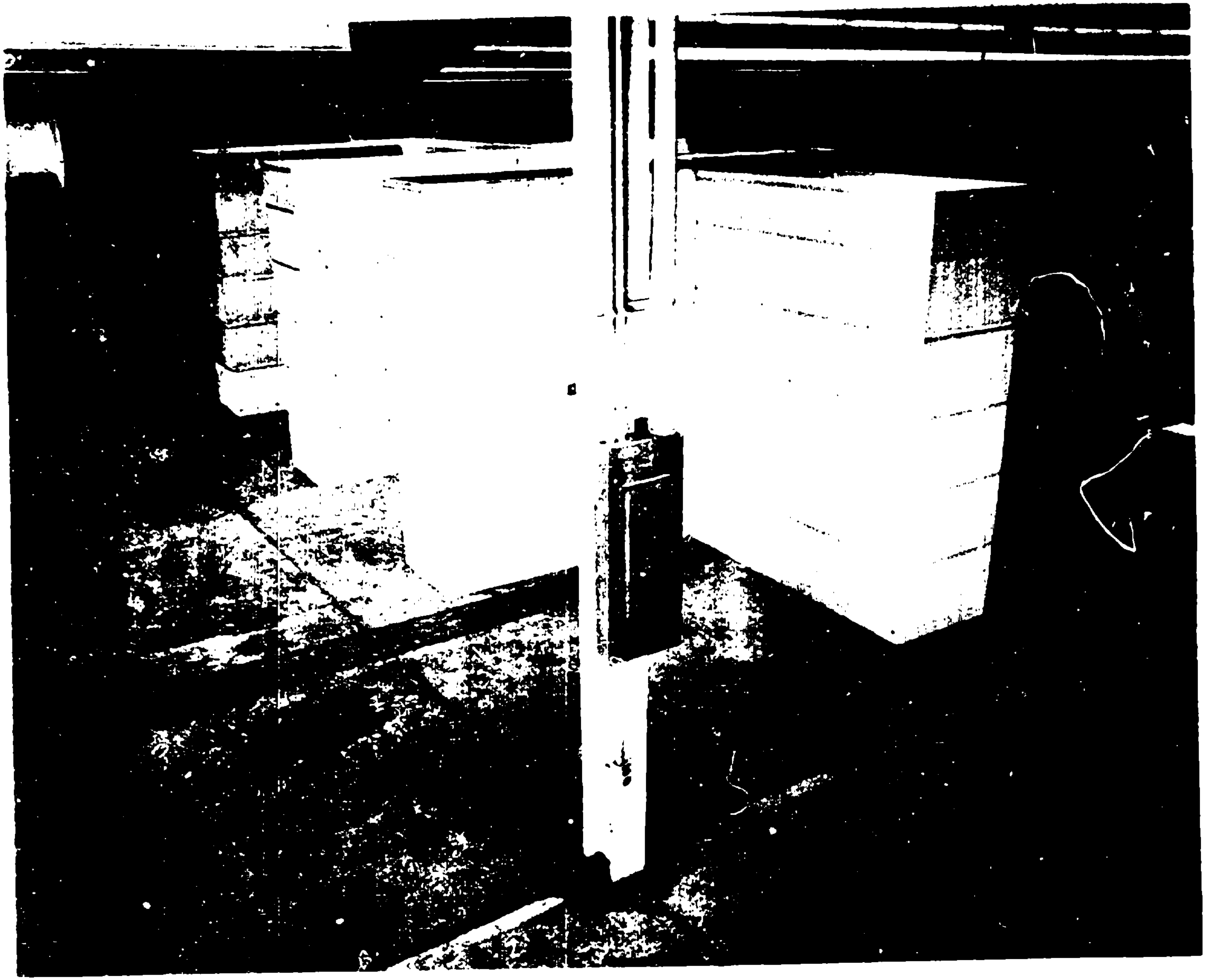


Fig. 53 - Completed Compartmented Magazine Section

21.0 CONCEPT EVALUATION

The four basic foam wall concepts of board, panel, box and block systems were evaluated based on the requirements set forth in the beginning of this report.

21.1 Magazine Dimensional Clearances

Selection of a wall system and the type of foam with the required wall thickness will determine dimensional clearances for aisles, headroom, etc. The Figure 54 sketch and tabulation lists various clearances for the different systems. Maximum clearances are attained using a board system of the highest strength high density polystyrene foam.

21.2 Cost

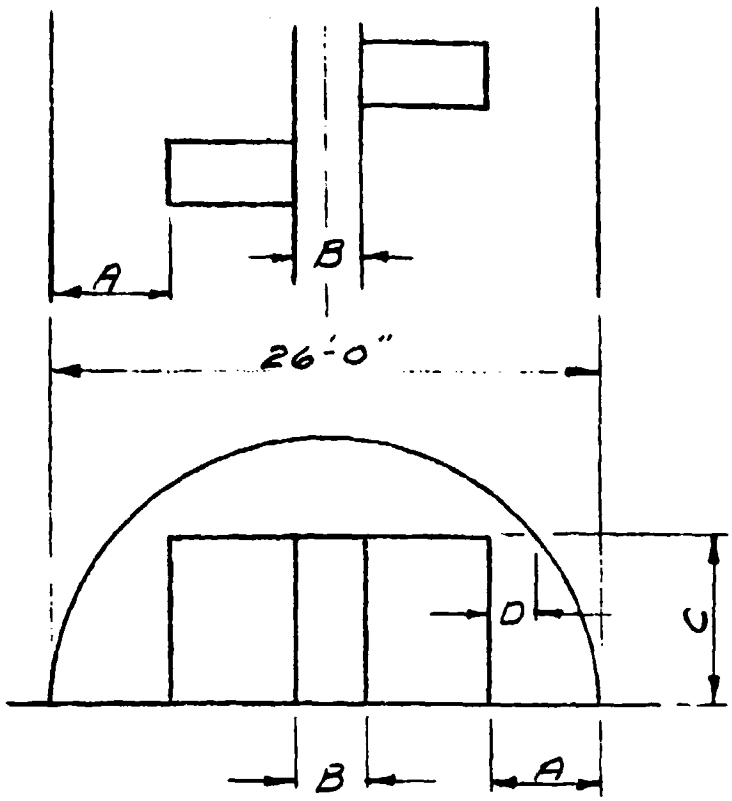
Direct estimated material costs for one compartmented magazine are tabulated on Figure 55. Extruded high density polystyrene foam is the lowest cost system when tooling for the block system is considered.

21.3 Other Evaluation Considerations

The table Figure 56 lists other significant system characteristics. Again the high density polystyrene board system has the advantage of minimum hipping volume, requires minimum sand and provides for the maximum number of compartments.

21.4 System Rating

The various systems were evaluated numerically with respect to the most significant criteria listed on Figure 57. The highest number classifies the highest rating. High density extruded polystyrene has the highest rating with four others grouped as second best.



System	Dimension A	B	C	D
Boxes	62"	44"	96"	27"
Blocks	69"	30"	96"	34"
Boards & Panels				
2"	71"	26"	98"	37"
3"	70"	28"	98"	36"
4"	69"	30"	98"	35"
5"	68"	32"	98"	34"
6"	67"	34"	98"	33"
7"	66"	36"	98"	32"
8"	65"	38"	98"	31"

BARRIER IGLOO CLEARANCE

Fig. 54

System	Material Type	Material Costs	Tooling Costs*	Fabrication Costs	Accessory Materials Cost	On-Site Assembly Costs	Total Costs
Boards	Urethane 3	$5250.00	0	$1410.00	$ 800.00	$ 850.00	$8310.00
Boards	Expandable Polystyrene Beads 6	$1680.00	0	$1750.00	$ 800.00	$ 900.00	$5130.00
Boards	Extruded Polystyrene 2	$1550.00	0	$1650.00	$ 800.00	$ 850.00	$4800.00
Boxes	Urethane 2	$3370.00	$36000.00	$5030.00	0	$1230.00	$9670.00*
Boxes	Expandable Polystyrene Beads 2	$1980.00	$60000.00	$2650.00	0	$1230.00	$5860.00*
Blocks	Urethane 1-1/4	$1312.00	$ 3500.00	$2378.00	$1000.00	$ 900.00	$5590.00*
Blocks	Expandable Polystyrene 1-1/4	$ 865.00	$ 5700.00	$1825.00	$1000.00	$ 900.00	$4590.00*

* Tooling Costs are not included.

Fig. 55 - Cost per Standard Igloo (Estimated)

	Board Ft. Required	No. of Ties Required	Shipping Volume Cu. Ft.	Pallets Required (463L)	Sand Required Cu.Yd.	Number of Compartments	Man Hrs. to Erect
Boards Urethane	10,500	950	875	3	90	15	250
Boards Expandable Polystyrene Beads	21,000	950	1750	6	90	14	250
Boards Extruded Polystyrene	7,000	950	585	2	90	16	250
Boxes Urethane	27,000	0	4150	11	200	14	300
Boxes Expandable Polystyrene Beads	27,000	0	4150	11	200	14	300
Blocks Urethane	11,930	950	790	3	90	15	300
Blocks Expandable Polystyrene Beads	11,930	950	790	3	90	15	300

Fig. 56 - Factors Under Consideration

22.0 CONCLUSIONS

(1). Over 50% of the vertical sand load is carried by the side walls due to wall friction.

(2). Wall friction reduced lateral wall pressure by 30% of theoretical values neglecting wall friction.

(3). A plastic foam barrier wall system is technically and economically feasible.

(4). Commercially available urethane, extruded polystyrene and expanded polystyrene bead foam can be used as walls to contain the required amount of sand.

(5). Simplicity of fabrication and assembly is possible using commercially available board stock foams.

(6). The high density extruded polystyrene foam board concept meets the barrier system requirements better than other systems.

(7) Although the spline/fabric wall tying method presented the neatest appearance, reliability of this adhesive bonded tying system is not as good as the banding system.

(8). Under normal storage conditions lateral wall pressures decrease with time, and the rate is greater with wet sand than it is with dry loaded sand.

(9). Wet sand exerts a greater lateral wall pressure initially when it is compacted or loaded and dumped from heights above 4 or 5 feet.

	A	B	C	D	E	F	G	H	Total
Boards - Urethane 4# Density	3	3	3	3	5	3	5	2	27
Boards - Bead Board 1# Density	2	2	1	2	5	4	5	4	25
Boards - Extruded P/S PZ-1623	5	5	5	5	5	5	5	4	39
Boxes - Urethane 4# Density	1	1	1	1	1	3	2	1	11
Boxes-Exp. P/S Beads 4# Density	1	1	1	1	3	3	1	3	14
Blocks - Urethane 4# Density	4	4	4	4	1	3	2	3	25
Blocks-Exp. P/S Beads 4# Density	4	4	4	4	3	4	1	5	29

Criteria

A. Logistics
B. Simplicity
C. Space Utilization
D. Material Volume
E. Technology
F. Strength/Cost Ratio
G. Tooling Cost
H. Costs

Fig. 57 - System Evaluation Rating

23.0 RECOMMENDATIONS

(1). Although an 8-foot high barrier wall of 2-inch thick foam has been standing two months, or until contract termination, a 3-inch foam wall is recommended for the prototype field installation.

(2). Parallel with the 3-inch compartment wall, it is recommended a dummy 2" wall be assembled in a similar manner for purpose of long term observation.

(3). The banding system of wall tieing is recommended for the prototype field installation.

(4). Although the banding system is satisfactory, improved wall tieing materials and methods should be investigated.

(5). Heat formed radii on wall tie saw cuts are recommended.

(6). It is recommended wall ties be fabricated from high strength nylon or dacron webbing with ends lapped and sewn for maximum lap strength.

(7). Although board stock plastic foam barrier systems can be field fabricated, improved quality and workmanship will result from factory prefabricated systems packaged and shipped to the storage site with assembly instructions.

(8). Since commercial foam board standard width is 16 inches and wall ties are recommended on 16 inch centers, wall boards of full and half sizes, 80 inches and 40 inches, respectively, are recommended.

24.0 REFERENCES

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DNA 2840F

"PROTECTIVE BARRIER SYSTEM FOR MUNITION STORAGE"

PART II

"FABRICATION, ERECTION AND MAINTENANCE PROCEDURES"

FINAL REPORT

August, 1971

by

A. J. Palfey
V. L. Hannaford

Defense Nuclear Agency

Washington D. C. 20305

Contract: DASA01-71-C-0018

This Effort Supported by Defense Nuclear Agency Under:
NWE D Subtask Code NA 006 Work Unit Code 04

The Dow Chemical Company
Functional Products And Systems
Midland, Michigan 48640

2.1

SUMMARY

This portion of the Final Report for Contract DASA01-71-C-0018 contains the fabrication, erection, and maintenance procedure for the optimum improved barrier system which emerged from this contract work.

This section includes the specifications for the multicellular extruded rigid high density polystyrene foam boards plus the material for tying the foam boards to help support sand loads. In addition the drawings are included for all the necessary foam configurations and the ties which go together to form the system walls. Included also are the sequence of operations needed to erect from these foam configurations the walls, filled with sand, which produce the final improved barrier system. Maintenance and tear down procedures are also part of this section of the report.

FOREWORD

This final report covers Phase I of a two phase project by The Dow Chemical Company for the development of a protective barrier system for munitions storage. Phase I, under the Defense Nuclear Agency contract DASA01-71-C-0018, 1970 October 20 through 1971, August 31, covers the research and development of a system including laboratory testing of a full scale barrier wall model section. Phase II covers the factory fabrication and field installation of a protective barrier system in a munitions storage magazine at NAD, Earle, New Jersey, with Dow providing fabricated materials and construction supervision.

The final report of the Phase I program is divided into two sections. Part 1 covers the research and development work from which recommendations are made for the Part 2 section covering material specifications, engineering drawings, fabrication, assembly, sand loading, and maintenance procedures.

The DNA Contracting Officer Representative (COR) for this contract is LTC W. D. Nelson, U.S.A. LTC Nelson and Mr. Charles L. Haney, J-4C1 (DNA) established the requirements for this project and gave valuable assistance in guiding the project with their broad knowledge in munitions storage.

In addition the authors wish to acknowledge the technical assistance of Mr. Wm. P. Hovey of The Dow Chemical Company during fabrication, assembly and testing of materials and prototype models, along with the project management assistance furnished by H. S. Smith and B. A. Russell.

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LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

In October, 1970, a research and development program was initiated with Dow Chemical U.S.A. to design an improved barrier system for munition protection in storage magazines. The current experience with stacked sandbag compartment walls has not been entirely satisfactory for various reasons such as deterioration of certain types of bag material, instability of walls due to settling of the sand and sand leakage, requirement for frequent inspection and maintenance to prevent wall toppling and creating a hazard to stored weapons.

This research and development program identified an improved barrier system that had a superior combination of performance properties and economics. Part I of this report has the data and conclusions leading to the selection of this system, while this portion of the report, Part II, contains the necessary information for fabrication, erection and maintenance of this improved barrier system.

The component specifications, fabrication, erection and maintenance procedures for the improved barrier system will be covered. This portion of the final report will allow the application of the barrier system to any compartmented magazine with the flexibility as to the number of wing walls desired as well as variations in the height and length of center wall which may be desired.

2.0 THE OPTIMUM BARRIER SYSTEM

The optimum improved barrier system involves the use of multicellular extruded rigid high density polystyrene foam boards instead of sand bags to retain sand. A typical layout of this system in a compartmented magazine is shown in Figure 1. The system is built using three (3) inch thick foam board stock for the center and wing walls. A groove and spline design is used to interlock the various boards together to form a wall, Figure 2 shows a

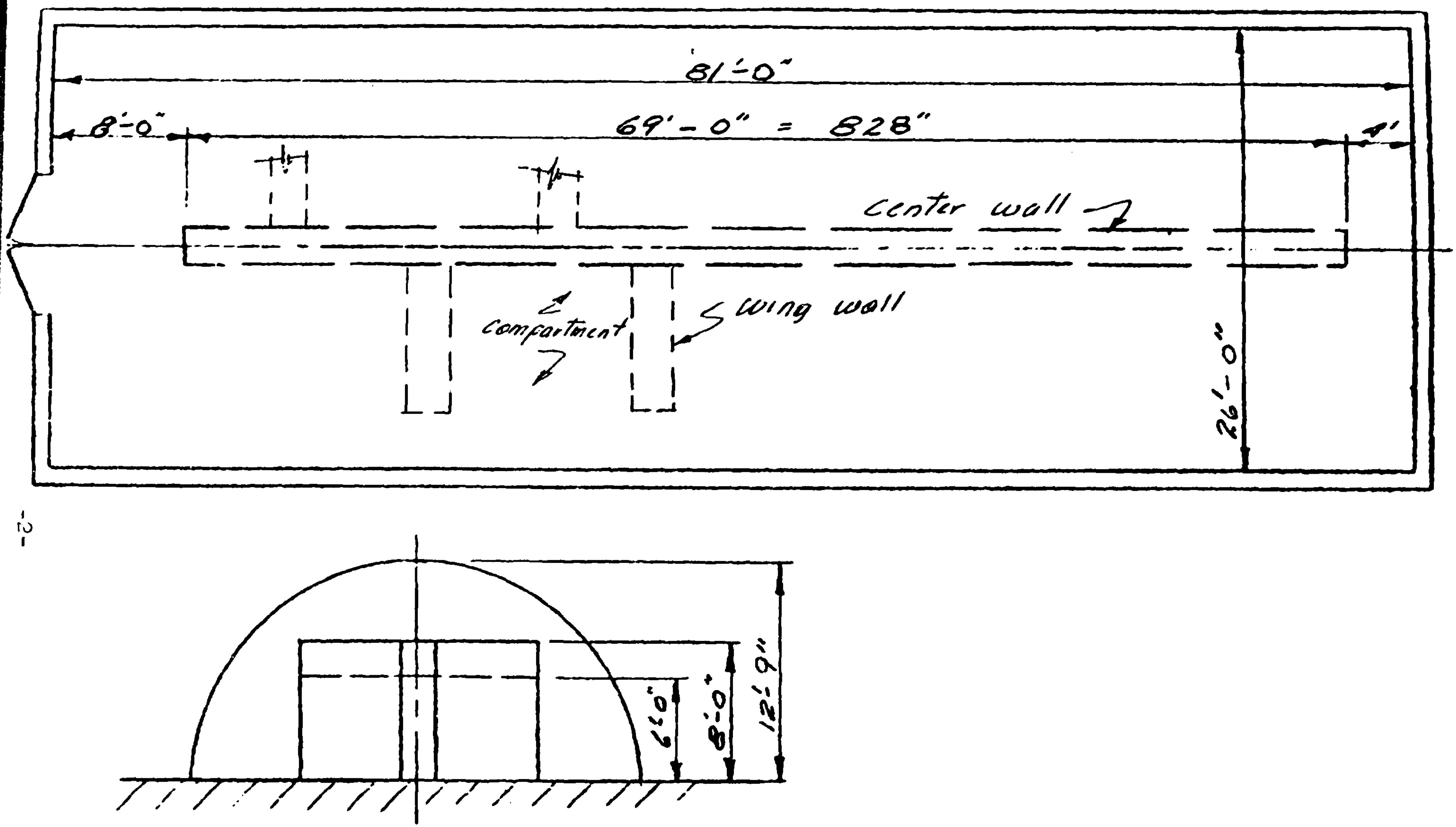


Fig. 1 - Standard Compartmented Magazine

typical barrier system. A loop tying system is used to tie the walls together. The loop ties not only support the sidewalls but assure proper (22") spacing between walls. The center wall is constructed in modules of 80" and 40". By following this pattern, the attached drawings (see Appendix B), can be followed with no special boards needed to establish the final total length. The standard center wall lengths that would be available using this format are shown in Figure 3. This table applies to the center wall boards only, the wing wall boards will be 6'-0" or 72".

3.0 MATERIAL SPECIFICATIONS

3.1 High Density Polystyrene Foam

Specifications for the high density polystyrene foam to be used in fabricating the barrier system boards and splines are included as the Appendix A of this report. Figure 4 shows a picture of typical foam board.

3.2 Wall Ties

Wall ties for the No. 2 and final prototype wall section were fabricated from glass filament tape. Figure 5 shows a photo of the wall tie being installed. Since the long term properties of this material are questionable, webbing with lapped and sewn ends is recommended. Specifications for this webbing are also included in Appendix A of this report.

3.3 Packaging

Packaging shall comply with standard commercial practices and provide for protection against damage during shipment. Packaging may be in the form of cleated plywood boxes or a weatherable cover of light colored opaque material for protection from physical damage and ultraviolet radiation.

Fig. 2 - Typical Barrier System

40"	=	3'-4"
80"	=	6'-8"
120"	=	10'-0"
160"	=	13'-4"
200"	=	16'-8"
240"	=	20'-0"
280"	=	23'-0"
320"	=	26'-8"
360"	=	30'-0"
400"	=	33'-4"
440"	=	36'-8"
480"	=	40'-0"
520"	=	43'-4"
560"	=	46'-8"
600"	=	50'-0"
640"	=	53'-4"
680"	=	56'-8"
720"	=	60'-0"
760"	=	63'-4"
800"	=	66'-8"
840"	=	70'-0"
880"	=	73'-4"

Fig. 3 - Standard Center Wall Lengths

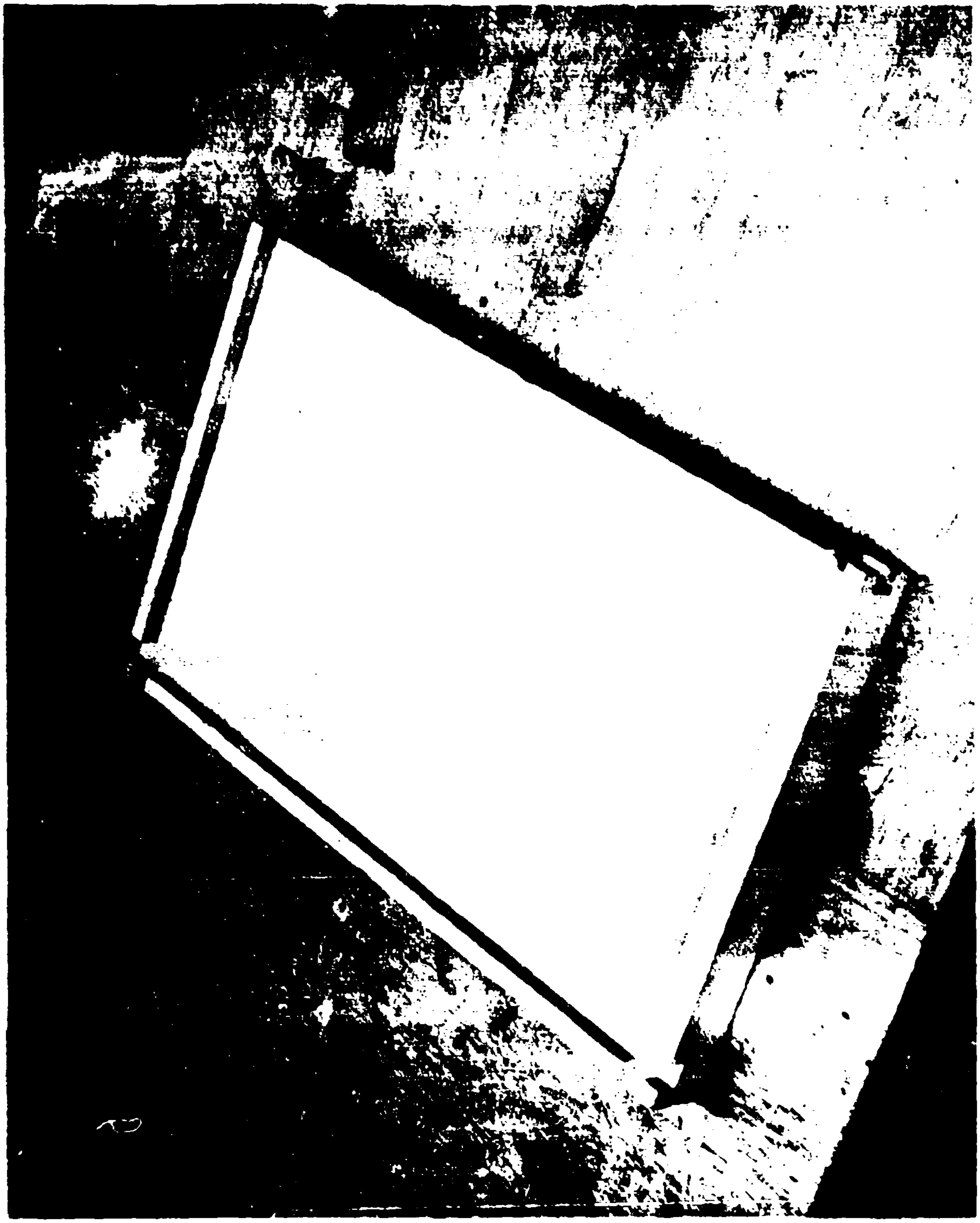


Fig. 4 - Typical Foam Boards

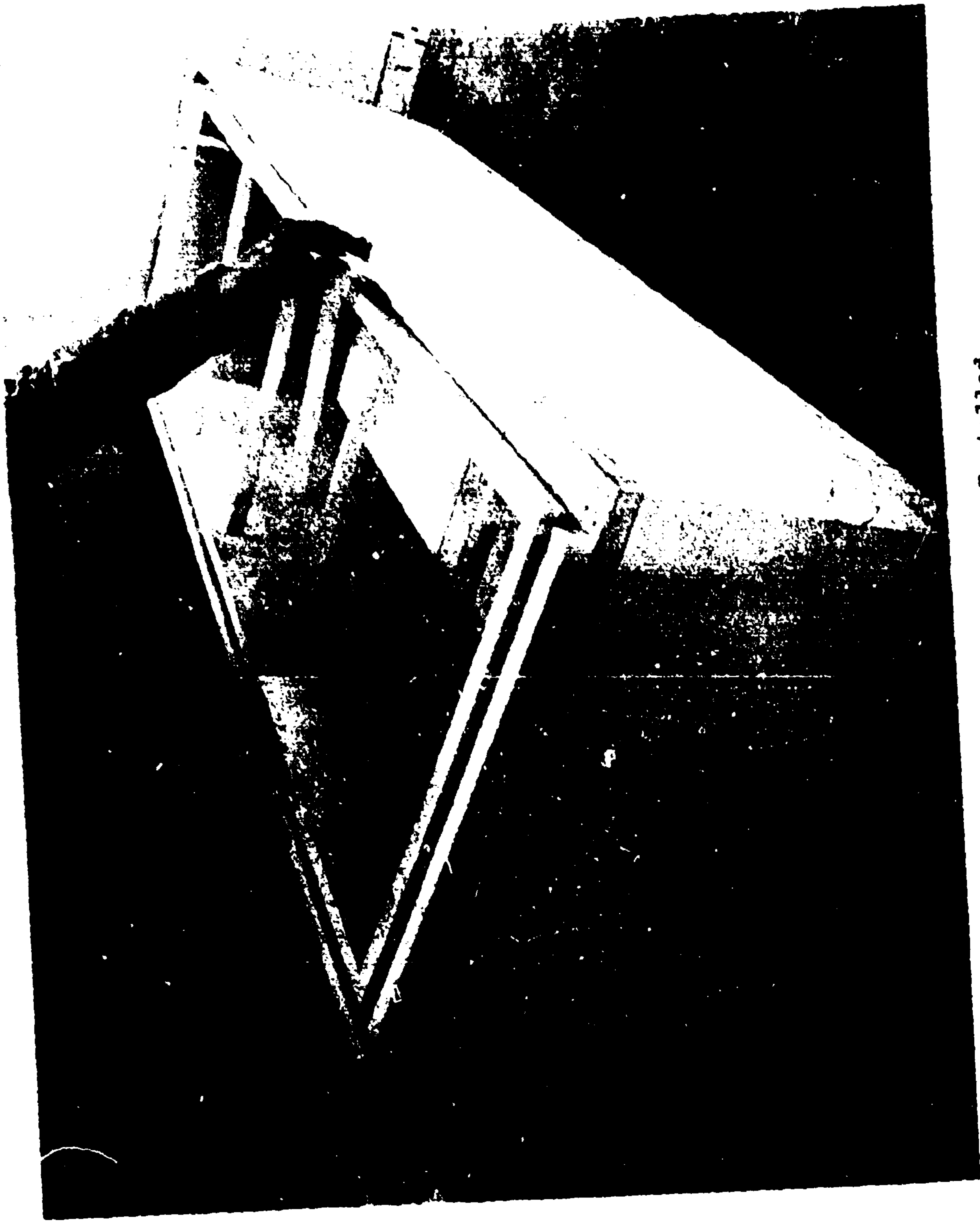


Fig. 5 - Wall Tie Being Installed

4.0 DRAWINGS AND ASSOCIATED LISTS

4.1 Parts List

The Parts List for the various sub-assemblies has been compiled to enable a compartmented magazine to be erected by establishing the length of the center wall based on Table 1 and by establishing the number of wing walls desired. See Appendix B. For example, in a typical magazine we might wish a 70 foot long center, 6 foot high barrier wall and 15 wing walls. Figure 6 shows the boards needed to install this complete system.

4.2 Drawings for Foam Components in Appendix B

In Appendix B are the drawings (assembly, sub-assembly and details) of all necessary foam parts. The drawings include drawing number PY-1578-3D through PY-1578-37D. Attached with the drawings are the Parts List for the sub-assembly, Drawing No. PY-1578-6D and 7D of the Center Wall and the Parts List for the sub-assembly, Drawing No. PY-1578-4D, of the 2" thick Wing Wall and the Parts List for the sub-assembly, Drawing No. PY-1578-5D, of the 3" thick Wing Wall. With these drawings and parts lists it is possible to fabricate the necessary components for the erection of a compartmented magazine with center wall within the dimensions as shown in Figure 3.'

4.3 Drawings for Wall Ties

Wall ties will be fabricated from specified material as noted in Appendix A under Section 4.1 Drawing No. PY-1578-41D (Figure 12) covers the wall tie dimensions, sewing pattern and lap distances.

PARTS LIST

3" CENTER WALL - DWGS. NO. PY1578-6D & -7D

Item No.	Dwg. No.	Part Description	No. Req'd.
1	PY1578-17D	Board - Floor - Standard - End	1
2	PY1578-16D	Board - Floor - Standard	51
3	PY1578-14D	Board - Half - End	8
4	PY1578-8D	Board - Full - End	8
5	PY1578-9D	Board - Full - Standard	72
6	PY1578-15D	Board - Half - End - Top	2
7	PY1578-10D	Board - Full - Standard - Top	18
8	PY1578-22D	Board - End - Standard	10
9	PY1578-23D	Board - End - Top	2
10	PY1578-27D	Spline - Bottom	52
11	PY1578-25D	Spline - Corner Vert. - Wall Horiz.	28
12	PY1578-30D	Spline - End - Horizontal	12
13	PY1578-32D	Spline - Wall - Vertical - Butt	100
14	PY1578-18D	Board - Floor - Half - End	1
15	Figure 12	Wall Ties (85.8" ± 0.2")	260
16	Figure 12	Wall Ties (70" ± 0.2")	5

3" WING WALL - DWG. NO. PY1578-5D

Item No.	Dwg. No.	Part Description	No. Req'd.
1	PY1578-18D	Board - Floor - Half - End	15
2	PY1578-17D	Board - Floor - Standard - End	15
3	PY1578-16D	Board - Floor - Standard	45
4	PY1578-11D	Board - Wall	150
5	PY1578-12D	Board - Wall - Top	30
6	PY1578-22D	Board - End - Standard	150
7	PY1578-23D	Board - End - Top	30
8	PY1578-27D	Spline - Bottom	60
9	PY1578-25D	Spline - Corner Vert. - Wall Horiz.	210
10	PY1578-30D	Spline - End - Horizontal	210
11	Figure 12	Wall Ties (85.8" ± 0.2")	300
12	Figure 12	Wall Ties (70" ± 0.2")	75

Fig. 6 - Parts List for Typical Magazine Installation
(70 ft. long, 6 ft. high, 15 wing walls)

5.0 FABRICATION

5.1 Fabrication Of Foam Components

Using the detail drawings PY 1578-8D through PY ˋ8-37D, all parts or components can be fabricated using ε arc wood working tools. The required power tools are:

(1). Cut-Off Saw (power)
(2). Table Saw (power)
    a. Standard Blade
    b. Dado Blade
(3). Band Saw with thin blade (power)
(4). Hand Saw

See photos, Figures 7,8,9,10. Standard precautions should be followed when using the power tools. Figure 11 shows a typical group of finished foam pieces ready to package. As a guide, a cutting speed of 30 feet per minute (FPM) should be used for cut-off and spline fabrication. A cutting speed of 10 FPM should be used for all dado routing (clean grooves are desirable). The tie slots location and depth, see drawing PY 1578-33D through PY 1578-37D, are of major importance as is the radius at the bottom of the slot. The foam board lengths are of minor importance.

5.2 Fabrication Of Wall Ties

The fabrication of wall ties for both the center wall and the wing walls should be made of the materials as specified in Appendix A. Figure 12 and 13 cover a suggested check fixture for the two sizes (70" and 85.8") of wall ties required. The ties are of major importance to the functioning of the system. The proper lap distance and special attention to sewing is necessary.

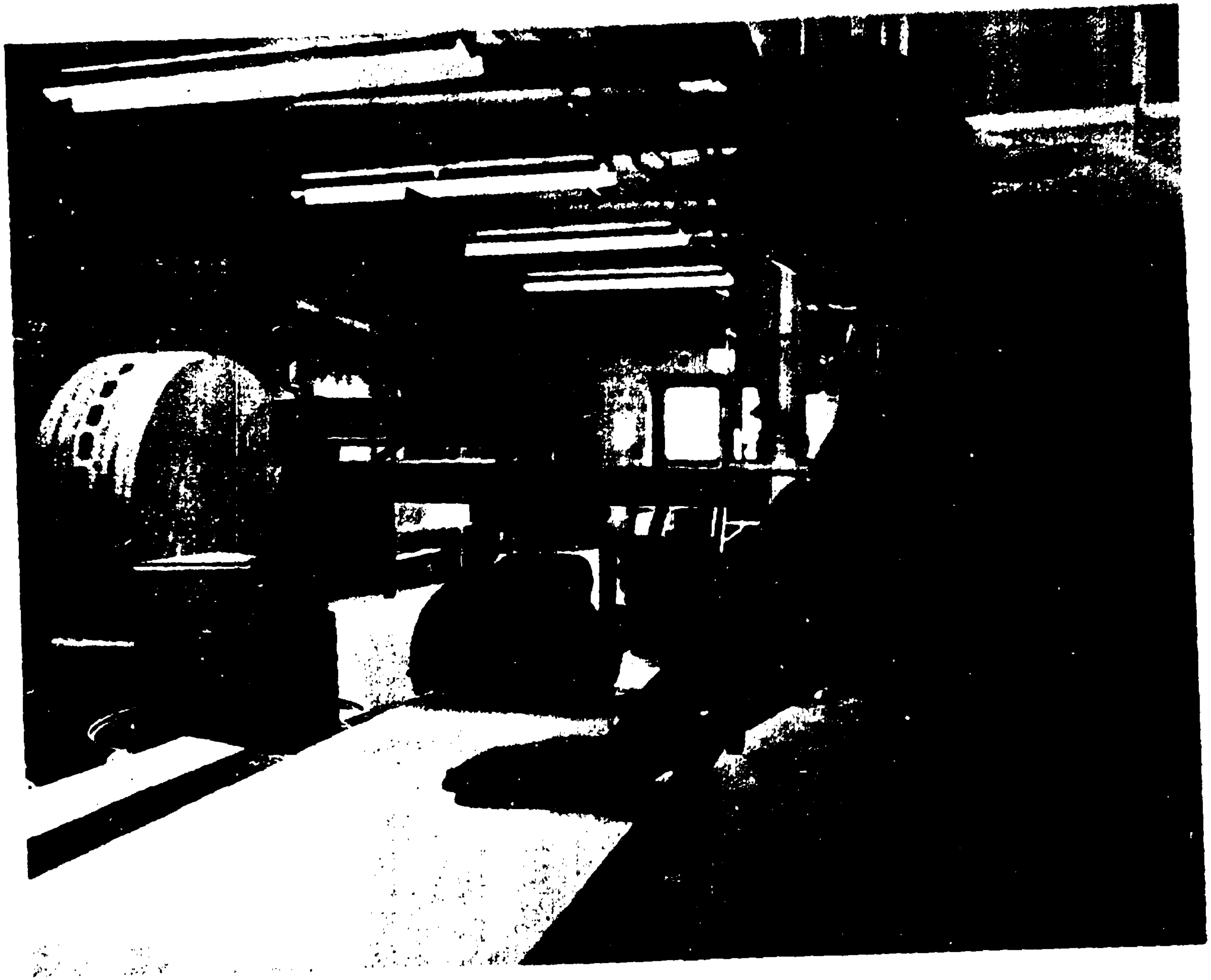


Fig. 7 - Prototype Fabrication - Foam Board Cut-Off

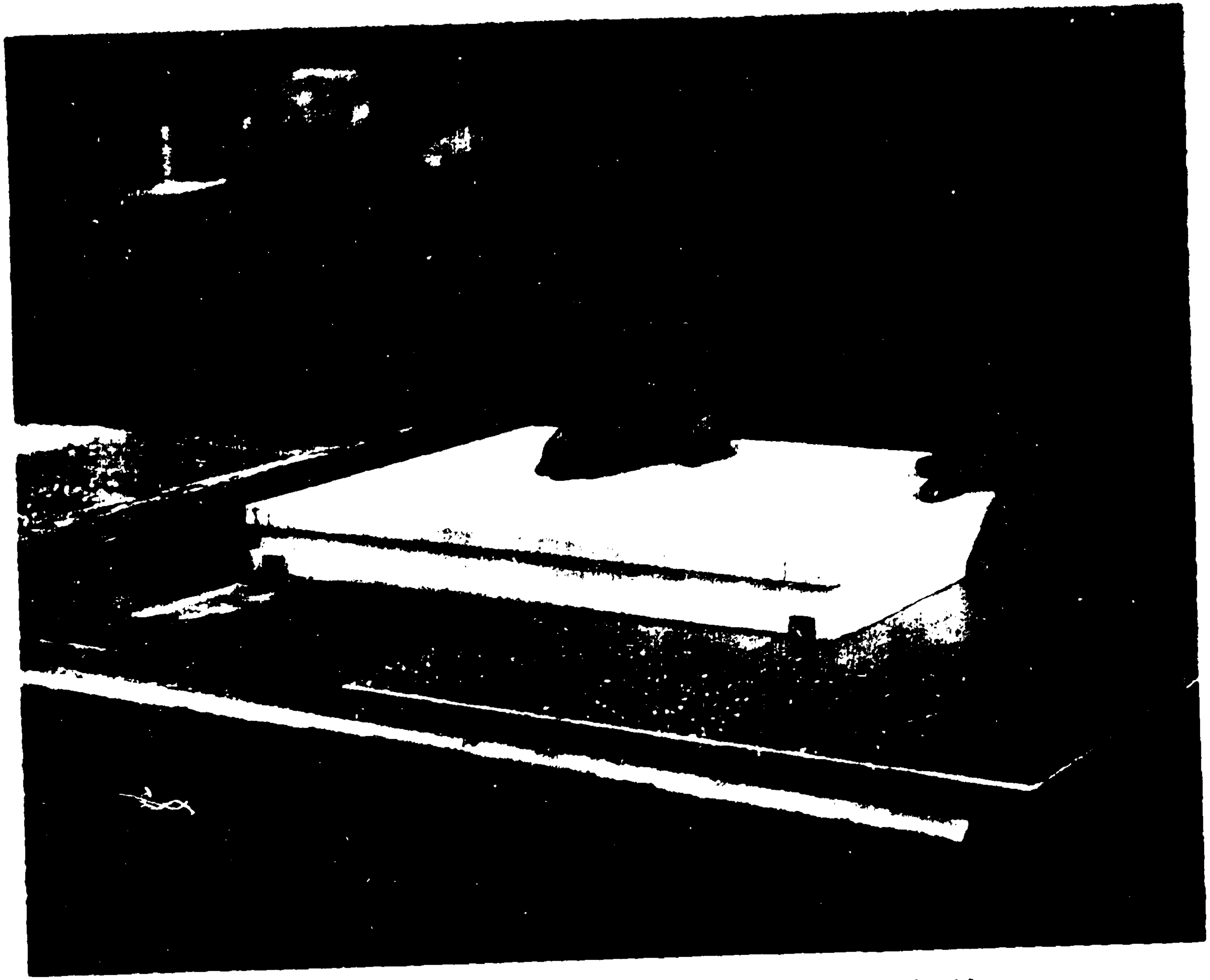


Fig. 8 - Prototype Fabrication - Foam Board Side Routing

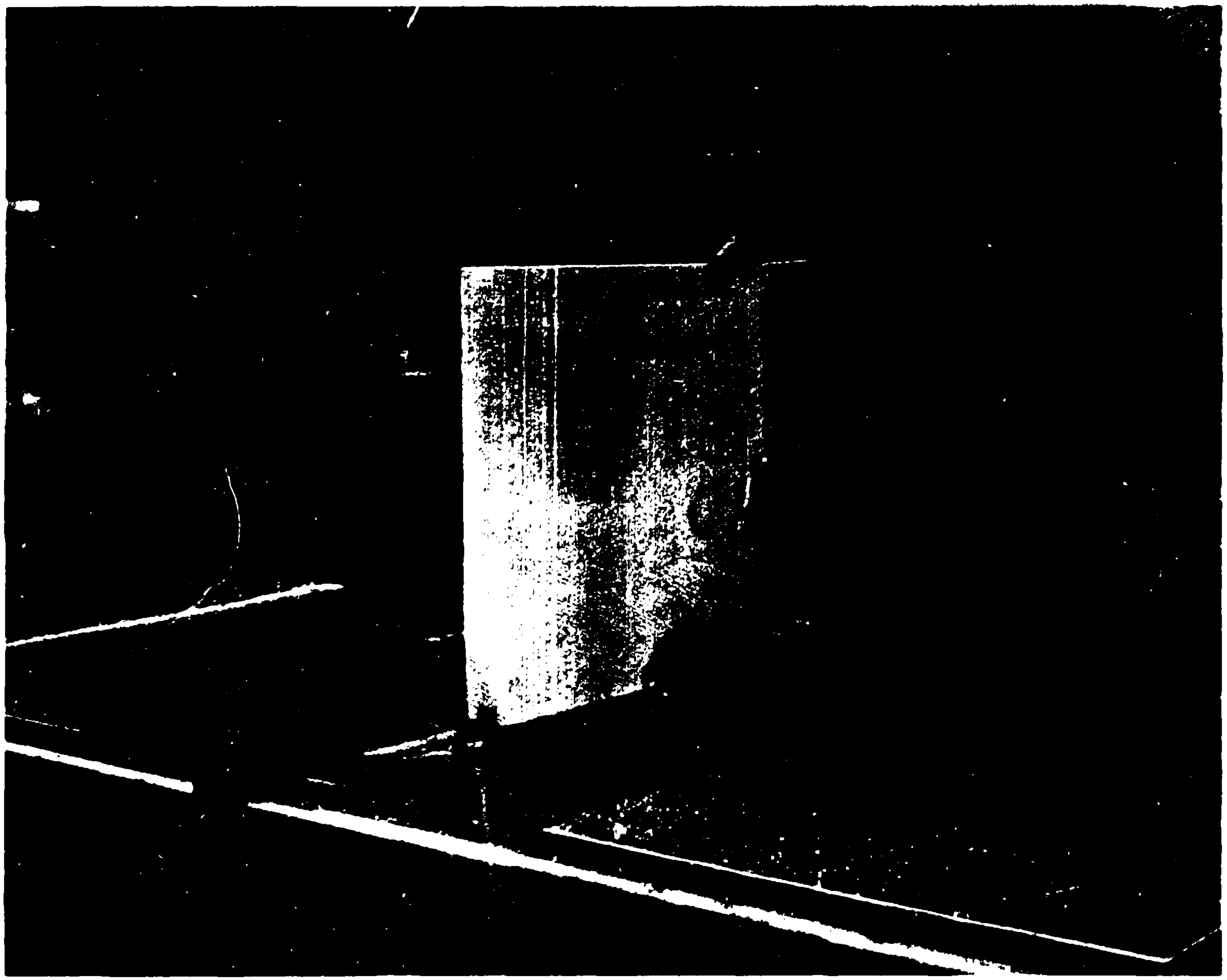


Fig. 9 - Prototype Fabrication - Foam Board Edge Routing

Fig. 10 - Prototype Fabrication - Foam Board Spline Cutting

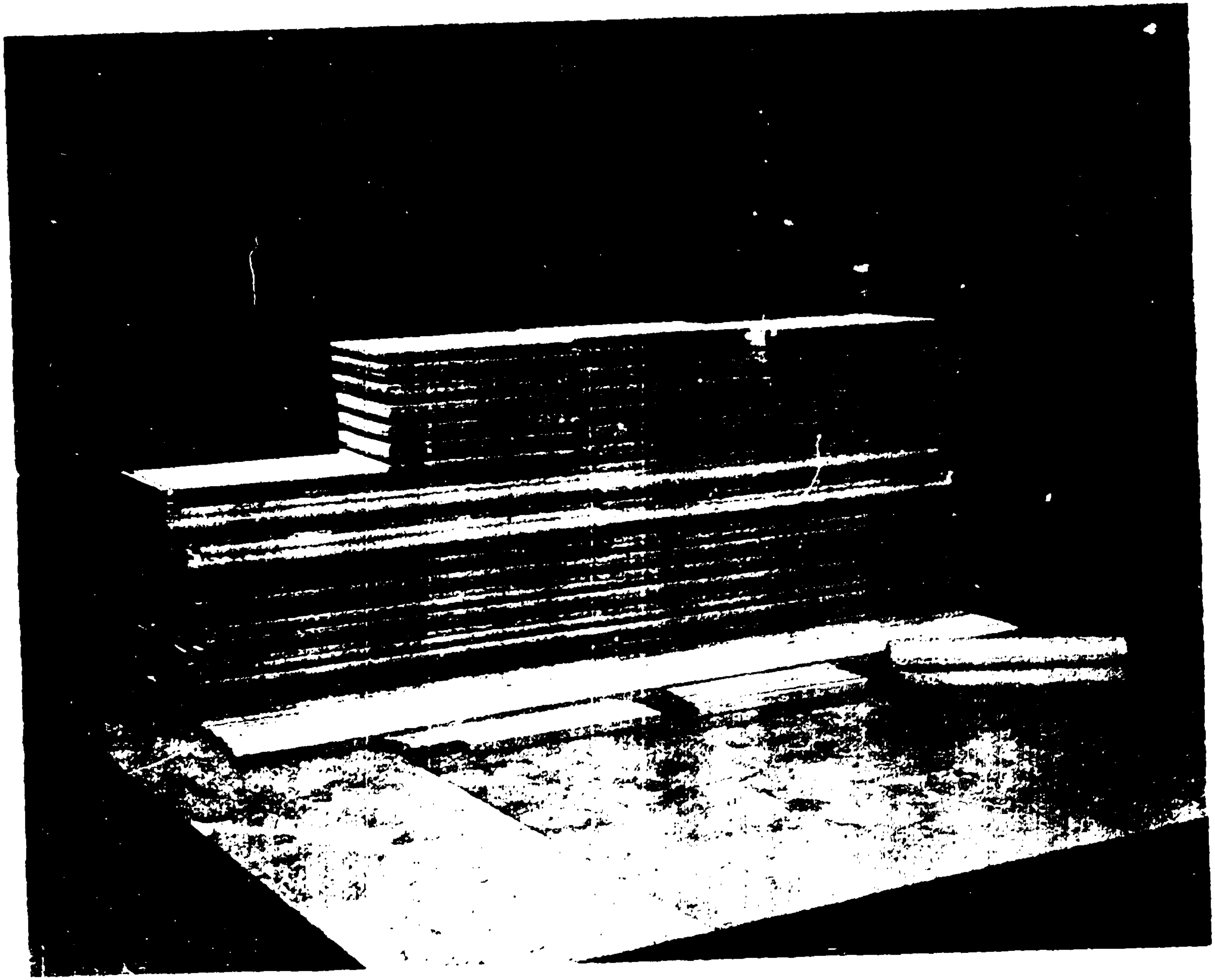


Fig. 11 - Finished Foam Boards Ready to Package

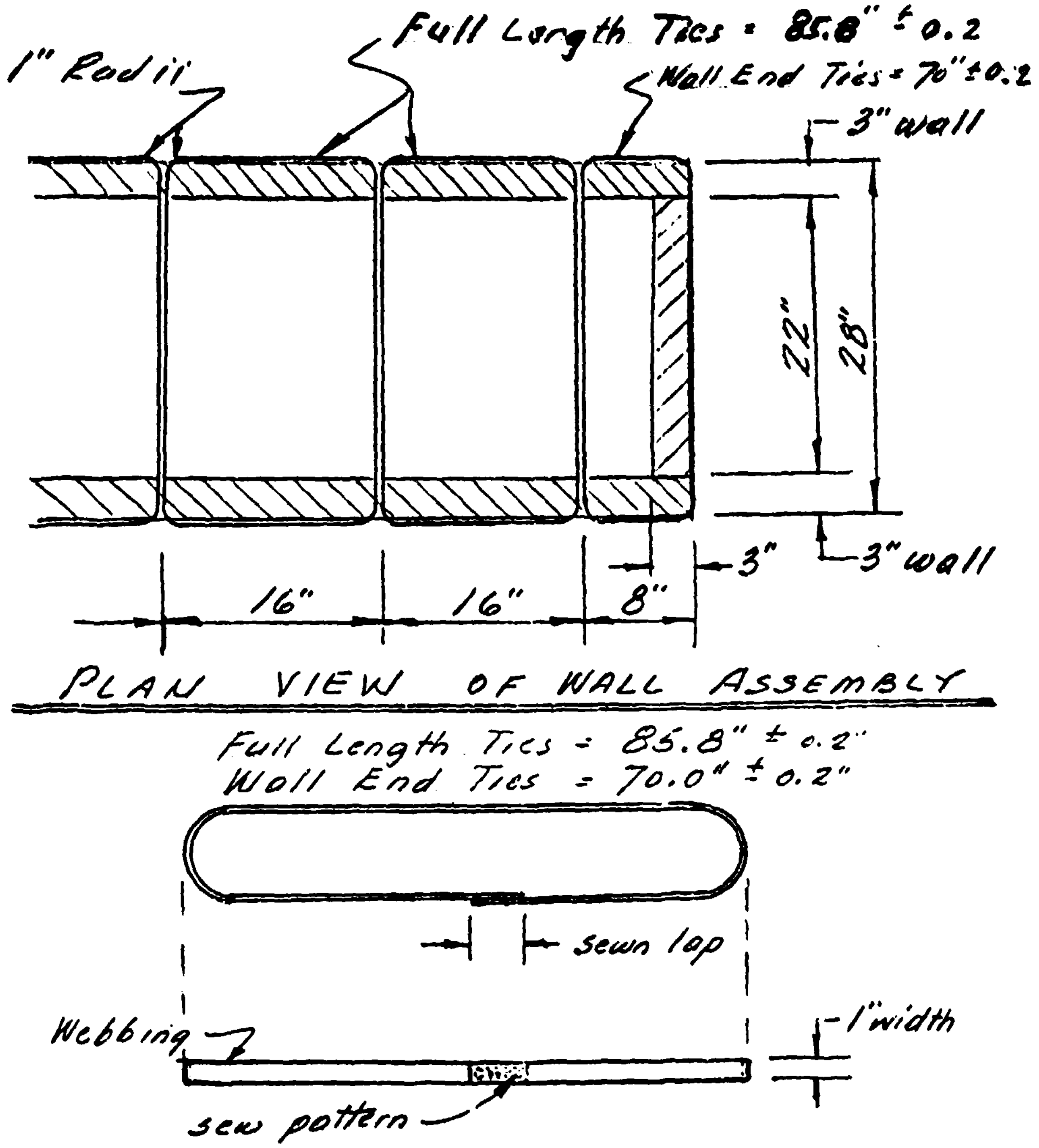
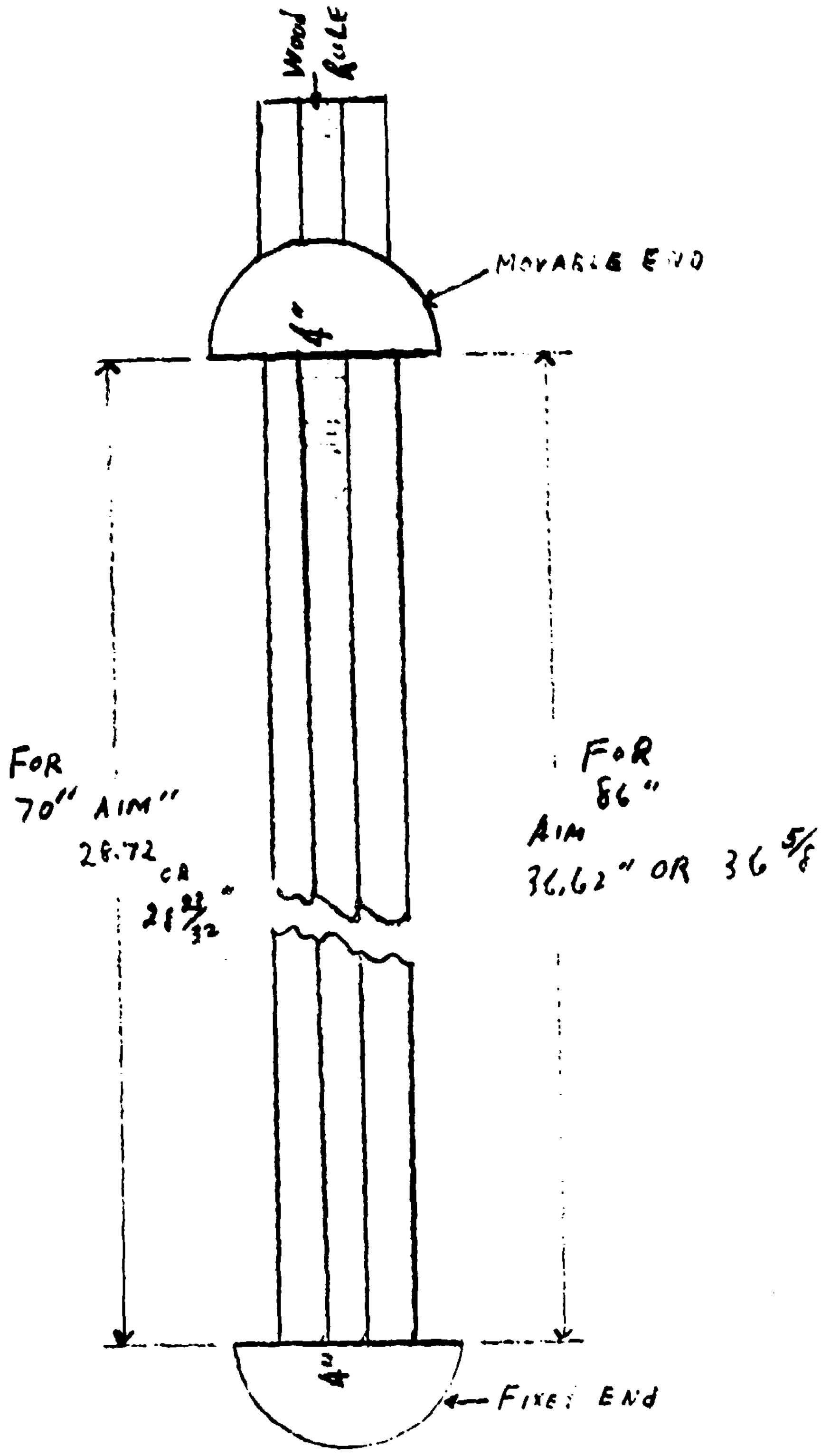


Fig. 12 - Wall Tie Detail
Wall Tie Fabrication and Assembly Details



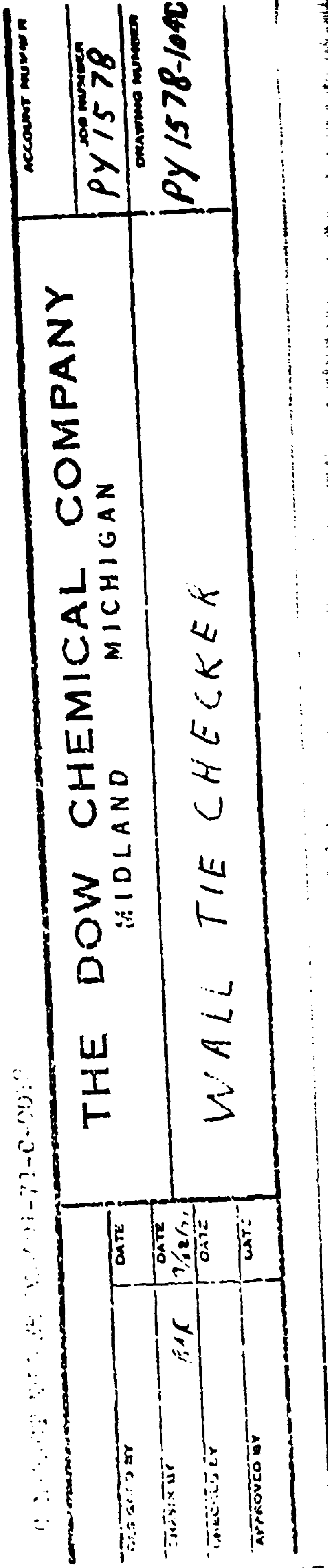


Fig. 13 - Wall Tie Checker

6.0 PACKAGING

6.1 Sequence Of Packing

6.1.1 Center Wall Component

The packing of these components should be in the reverse order of erection. Bottom boards and bottom splines should be stacked last on top of a pallet which is properly marked. With components properly marked and packaged, the center wall can be erected in an orderly manner.

6.1.2 Wing Wall Components

All components (bottom boards and splines, end boards and splines, wall boards and splines and vertical corner splines) for one (1) wing wall may be packaged as a unit. If one follows this procedure for wing wall packaging, a total assembly is intact and can be readily positioned within a magazine. Even if packaged together in larger units, wing walls should be separated from center walls to avoid erection problems.

6.1.3 Assembly Instructions

The Parts Lists along with the exploded views and instructions for assembly shall be packaged in a waterproof envelope and added to the units before protective overwrap.

6.2 Protection Of Components

The unitized bundles mentioned above should be palletized using a 84" x 52" pallet. This size pallet makes it compatible with commercial trailers and also the U.S. Air Force 463L pallet system by combining two (2) of these units. For more complete environmental protection, each pallet should have an overwrap of poly-coated kraft paper in accordance with standard commercial packaging.

7.0 QUALITY ASSURANCE

It is suggested that the fabricator have an inspection system to assure quality of the outgoing barrier system.

7.1 Quality Program

The contractor should use as a minimum Mil-I-45208A, Inspection System Requirements, for a guide in setting up his inspection program. At his option, the requirements of the more stringent Mil-Q-9858A may be substituted.

7.2 Sampling and Inspection

The sampling and inspection, plus acceptance and rejection criteria may be based on Mil-STD-105 D, or Mil-STD-1235 depending upon the contractors inspection system. Figure 14 shows a suggested Quality Surveillance Program Flow Sheet which indicates check points where inspection might be appropriate.

8.0 ERECTION

8.1 Unpacking

Based on package marking, remove the protective overwrap from the pallet(s) containing the components for the center wall. Remove Drawings, Parts Lists and other necessary instructions. Check the components for completeness and damage. The same procedure should be followed for wing wall packages.

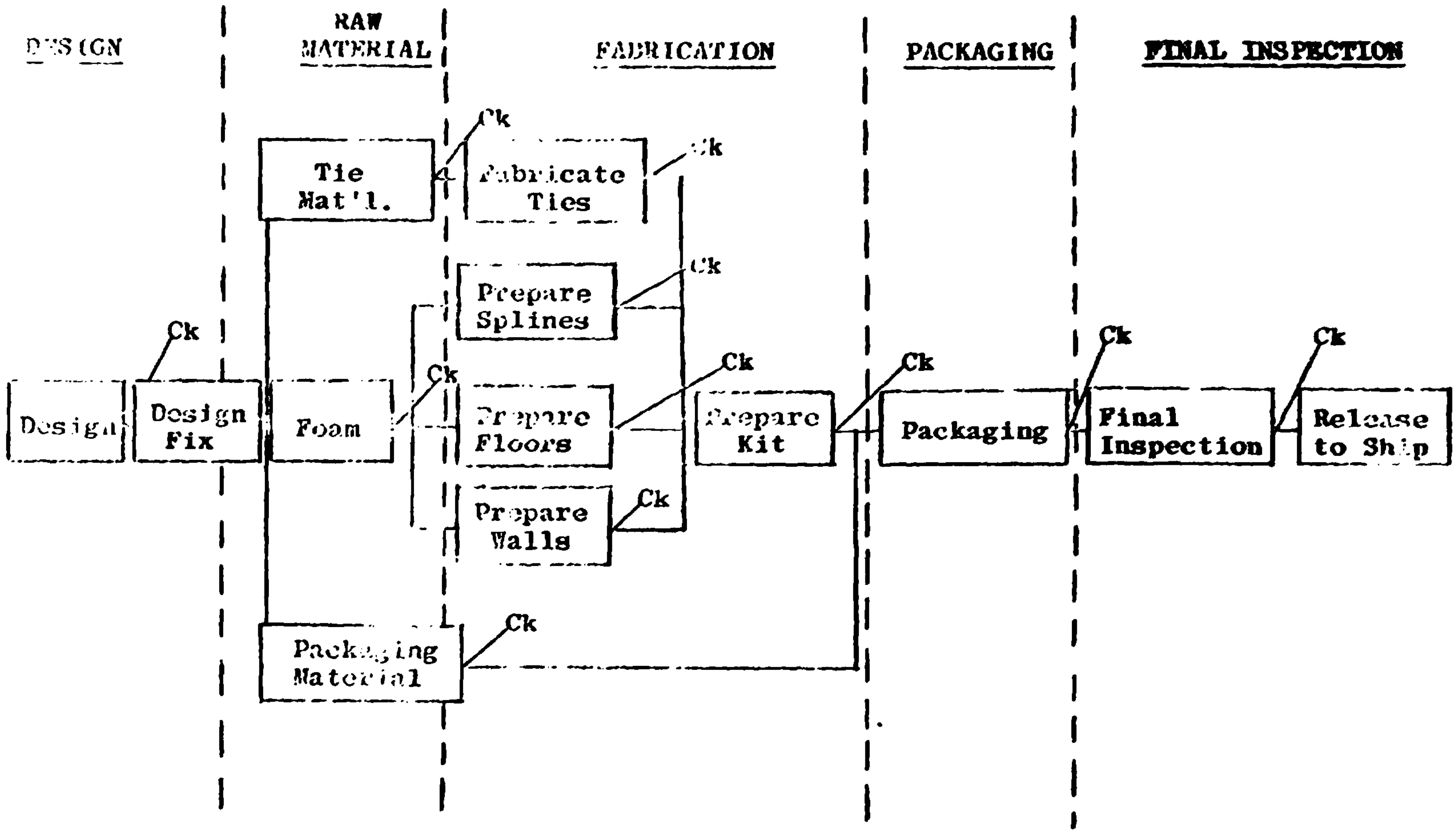


Fig. 14 - Quality Surveillance Program

8.2 Magazine Layout

The magazine, clean or clear of major obstructions, should be checked for the pitch or slope of the floor. If sand bags are present, clear centerline of bags by placing the sand bags along the outside walls. Determine and chalkline the centerline of the magazine. Also, draw a chalkline 14" each side of center line to locate center wall. Establish front entrance and rear wall clearances. See Figures 1 and 2 for typical compartmented magazine layout.

8.3 Erection of the Center Wall

With the bottom end board and bottom spline, start the erection of the center wall floor. Continue this layout using standard bottom boards and bottom splines until the total center wall length has been reached and end with another bottom board. See Figures 15, 16, and 17 for the general and exploded views of the structure. The standard lengths of the Center Wall are defined by Figure 3. Concurrently with the bottom boards and bottom splines, place the (72") horizontal wall splines in the proper position for longitudinal alignment. Use the chalk line so the center wall will be straight and true. Starting at the enclosed end of the magazine, start erecting the wall boards for the center wall. Using the end spline, place an end board in place. At the same time, place two standard (80") end wall boards in place, both sides. Continue placing standard wall board and vertical wall splines in place. To connect the end board with the wall boards, put a vertical (72") corner spline in place. As the first course of wall boards are being placed in position and starting at the first erected end board, start placing wall ties in the proper location. The wall ties will always be placed at the bottom of the

TYPICAL COMPARTMENTED MAGAZINE SECTION

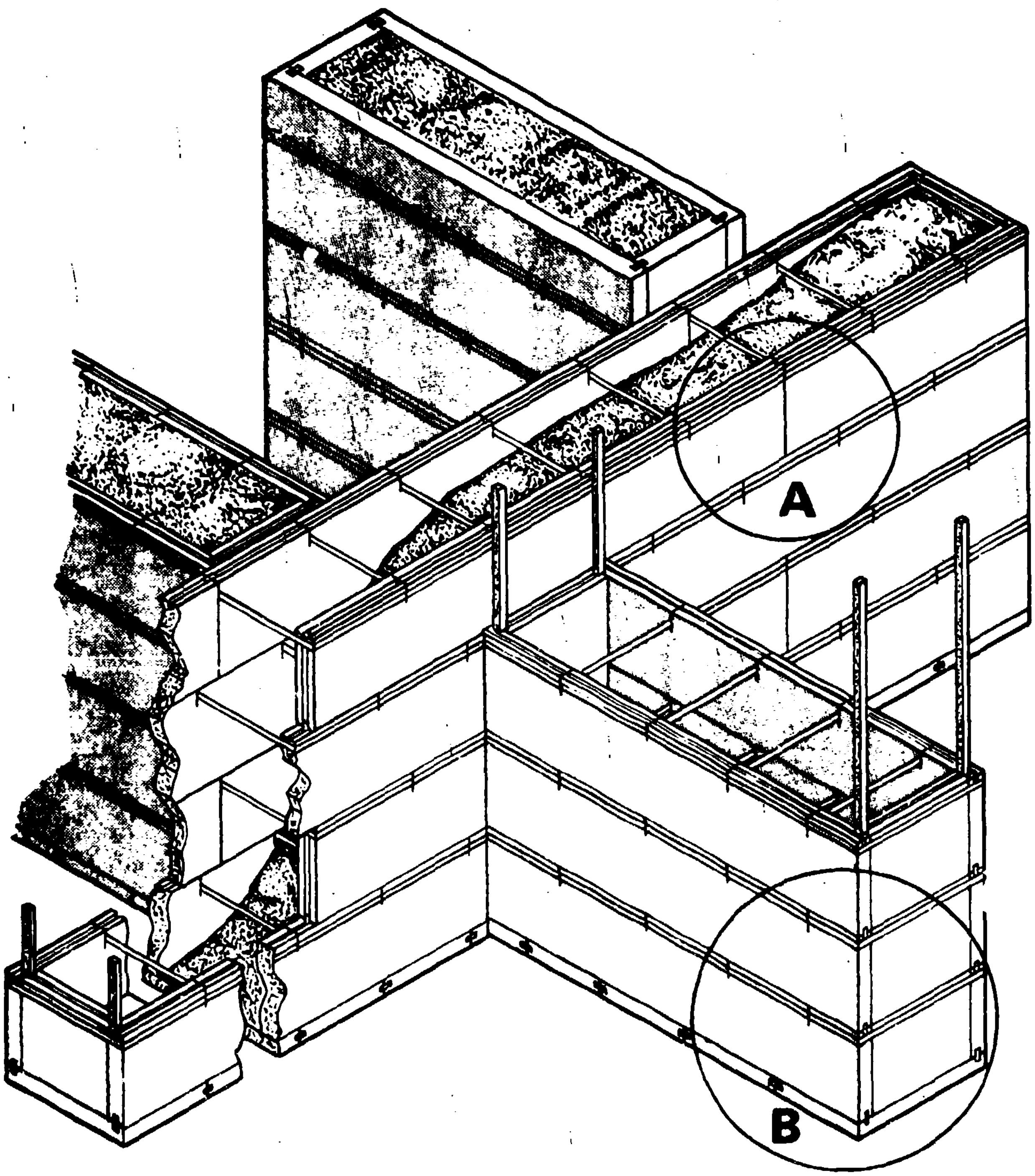


Fig. 15 - Typical Compartmented Magazine Section

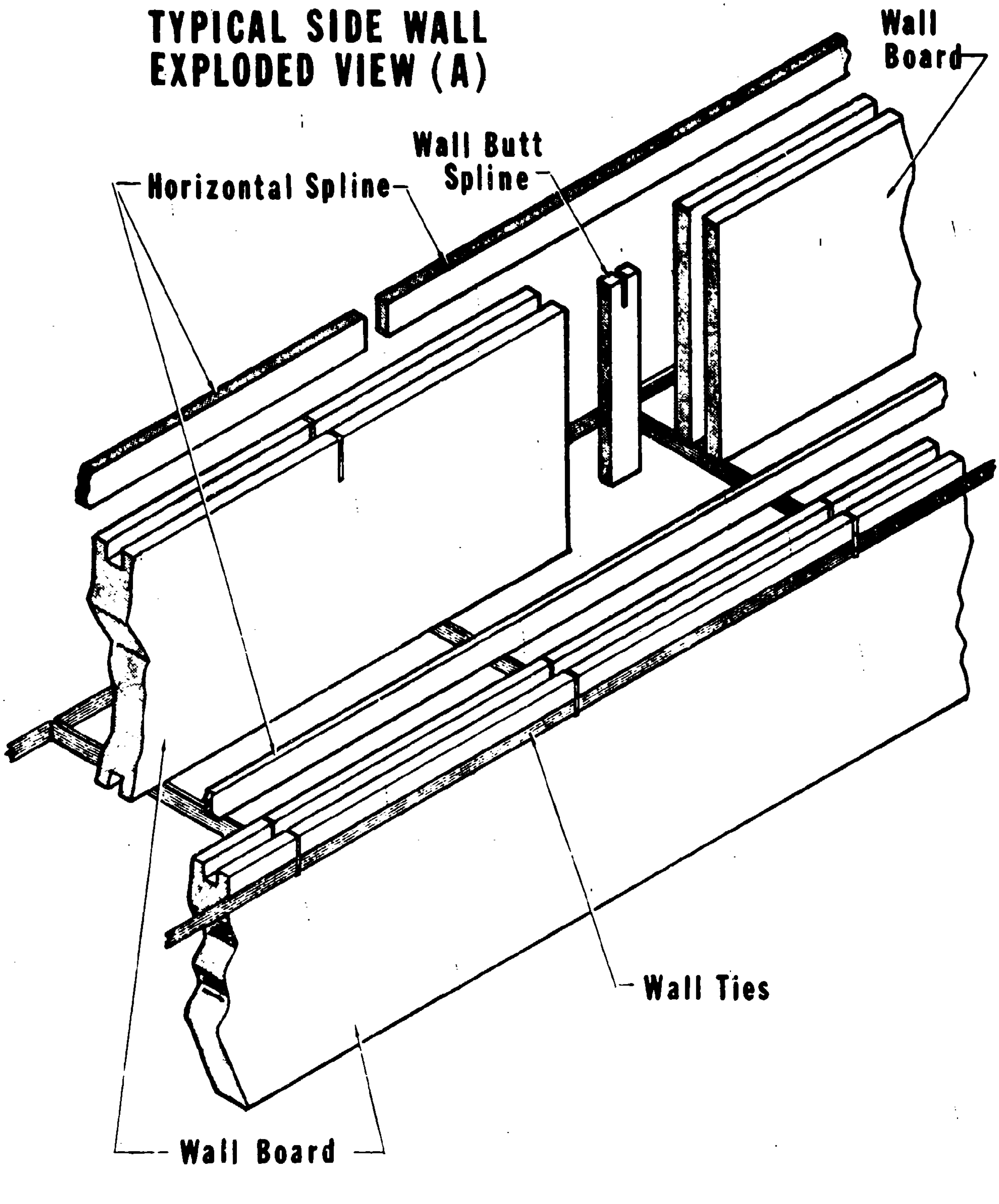


Fig. 16 - Typical Side Wall - Exploded View

TYPICAL WALL SECTION-EXPLODED VIEW (B)

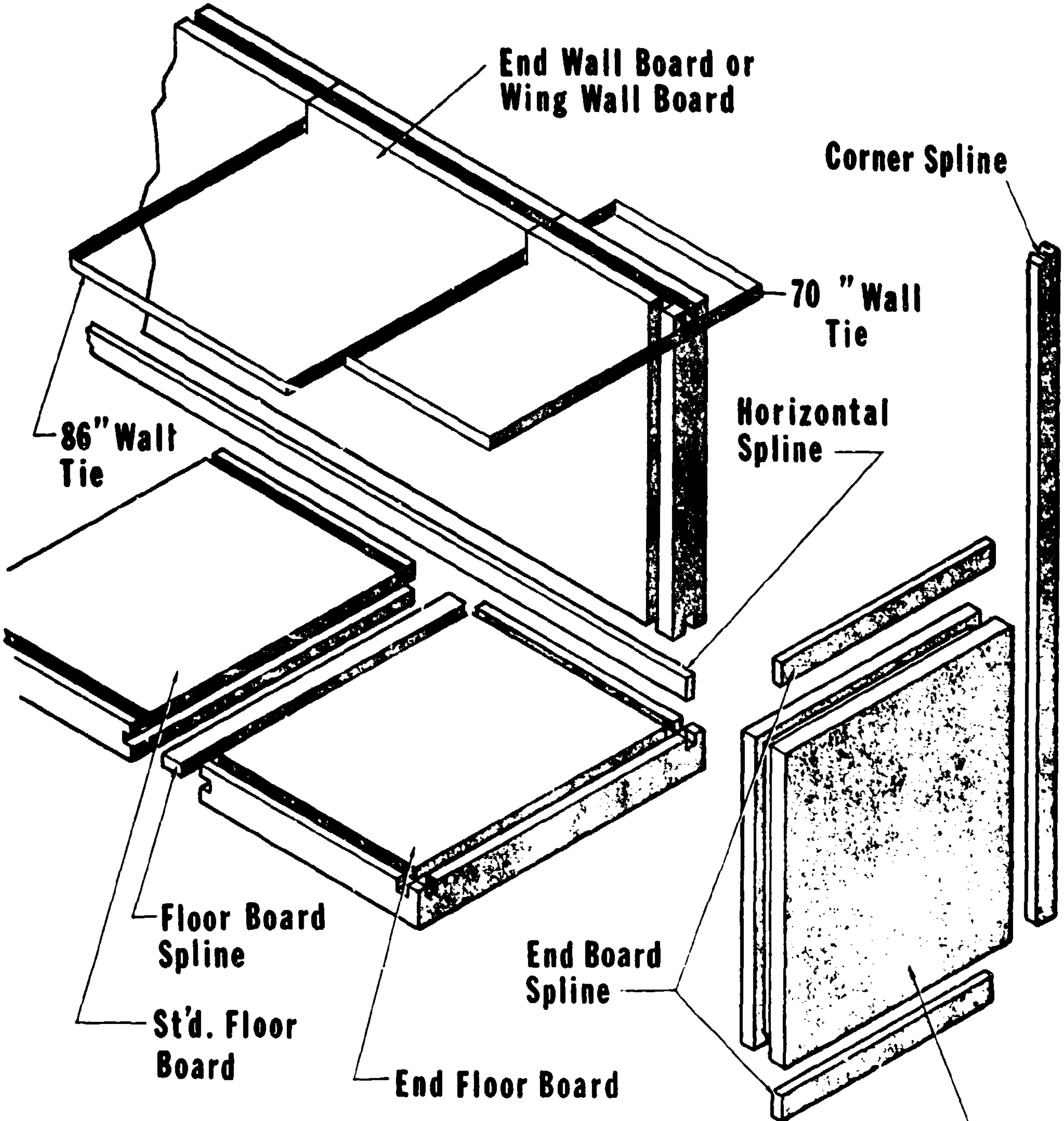


Fig. 17 - Typical Wall Section - Exploded View

slots provided so the wall ties do not interfere with the horizontal (72") wall splines. Wall ties will be placed so the exterior will have continuous ties and will be cross tied on 16" centers. With all wall ties in proper position for the first course of wall boards, place the horizontal (72") wall splines in position for the second course. See Figure 5, Wall Ties being installed. Again with the end board spline, place a standard end board in place on both ends of the center wall. The next course of wall boards will be started at the closed end of the magazine with a half sized (40") end wall board and then continuing on with standard (80") wall boards with vertical butt splines. This change in dimension of the starting end wall board (40") is done to insure staggered vertical joints throughout the center wall. The above procedure is followed for five courses of center wall boards. For the last course of the center wall, all wall boards and end boards are cut in half lengthwise. One half will be used on one side and the other half on the opposite side of the center wall. This is done to properly establish the total sand height at 6'-0" or 72". If desired, additional boards may be added at the top t[illegible]ce a higher wall.

8.4 Erection of a Wing Wall

Establish first, the location of all wing walls. Referring to Section 8.2, double check the pitch or slope of the floor at each wing wall location. This is necessary so the lowest wing wall board can be properly modified so the wing wall will be erected plumb and straight. The lowest wing wall board must be cut to have a taper consistent with the pitch or slope of the floor. By cutting the taper on the lowest wing wall board, the spline groove may be partially or totally removed. This groove (1" x 1" - centered) must be routed for proper assembly of each wing wall. With the lowest wing wall board properly modified, position the five bottom boards and splines in the correct location. Align the bottom boards with a horizontal (72") spline. Place two end boards at each end and then position the modified wing wall boards on each side. Connect the end boards and wing wall boards with a vertical (72") spline. Each wing wall will have five wall ties per course. One of the five wall ties will be shorter or on 8" centers. This snorter wall tie should be located so that it is positioned on the outboard (exposed) end of each wing wall. With the wall ties in place, a horizontal (72") wall spline should be placed in the wall board and the end board spline properly placed. This procedure will be repeated until five courses have been erected. For the top or last course, one end board and one wing wall board per wing should be cut in half lengthwise. One half will be used on one side and the other half on the opposite side. This is done to properly establish the total sand height at 6'-0" or 72". This procedure should be followed for all wing walls required for the compartmented magazine. As mentioned above, a higher wall may be constructed, if needed.

8.5 Sand Filling

The equipment required to fill the center wall and the wing walls can be from a shovel to a sophisticated system such as a conveyor belt and a bucket elevator. Common mechanical equipment, such as a small front end loader has proven to be flexible, fast and efficient. With a trained operator, walls 6'-0" high can be filled at a minimum rate of four (4) lineal feet per hour when considering all facets of the total system. Equipment of this nature should be considered desirable for the erection of compartmented magazines using this system. Appendix B contains a partial list of possible equipment suppliers for sand handling. The center wall will be erected first and for the sand filling phase of the erection, the center wall should be erected to a height of 32" or two boards and then filled with sand. This procedure should be followed in 32" steps, until the center wall is completely full. This procedure also applies to the filling of the wing walls. During the filling of the walls (center or wing), be sure the wall is in the proper location and that the wall is being erected straight and plumb. Due to the nature of the system, if the filling sand is permitted to exert off center loads, the wall will tend to lean in that direction making it necessary to physically shift that section of the wall (Center or Wing) to a plumb and straight position. For ease of erection, care should be exercised during the sand loading operation, to control the rate the sand is placed in the wall to avoid excessive wall vibration. The instructions, Parts Lists, and exploded views should be saved and retained in each compartmented magazine for later use.

8.6 Destaticizing

A static electricity charge may be accumulated in the wall when loading dry sand with low relative humidity. Based on the research of Woodland and Ziegler "Static Dust Collection of Plastics", the wall can be effectively destaticized by spraying with a detergent. The hydroscopic detergent forms a moisture layer on the wall which conducts the charge to ground. The most effective destaticizers tested are Arquad 18 - 50 by Armour and Company, Chicago, Illinois and Proctor & Gamble, ORVUS K Liquid.

It is recommended all barrier wall systems be sprayed after sand loading and before explosives are stored, unless they are tested with a voltmeter and are found to carry no static charge.

Fig. 18 - Sand Conveying Auger

9.0 MAINTENANCE PROCEDURE

9.1 Dismantling

If for some reason, a compartmented magazine requires alterations after erection or after a period of use, the dismantling of the walls, either Center or Wing Walls, is most easily accomplished with the use of a motorized auger (see Figure 18). By exercising a degree of care when dismantling, all components of the original retaining walls can be reused either in a different configuration or a different location. The auger can be used to transfer the sand from the retaining walls to a unit desired to transport the sand. By cutting an ample sized opening in the lowest end or wall board, an auger can be inserted and the sand can readily be transferred to another location or transport unit. As the sand is being removed, sections of the retaining wall (s) can be disassembled and stored for later use.

9.2 Damage Repair

The barrier walls are most vulnerable to damage during erection and loading. Damage may be avoided by protecting the center and wing wall ends with foam board or padded canvas.

Wall damage may be a punctured hole or broken board. Superficial holes with a height less than half the wall thickness will not leak sand due to the sand angle of repose. Such small holes may be plugged with rags, wadding or foam plugs as illustrated on Figure 19.

Larger holes may be repaired by trimming the foam opening and inserting a tapered foam plug from the inside as illustrated on Figure 20. After insertion, the plug joints may be covered with pressure sensitive tape to prevent sand leakage.

When a board is broken beyond repair, sand is removed as outlined in Section 9.1. Disassemble the section until the broken

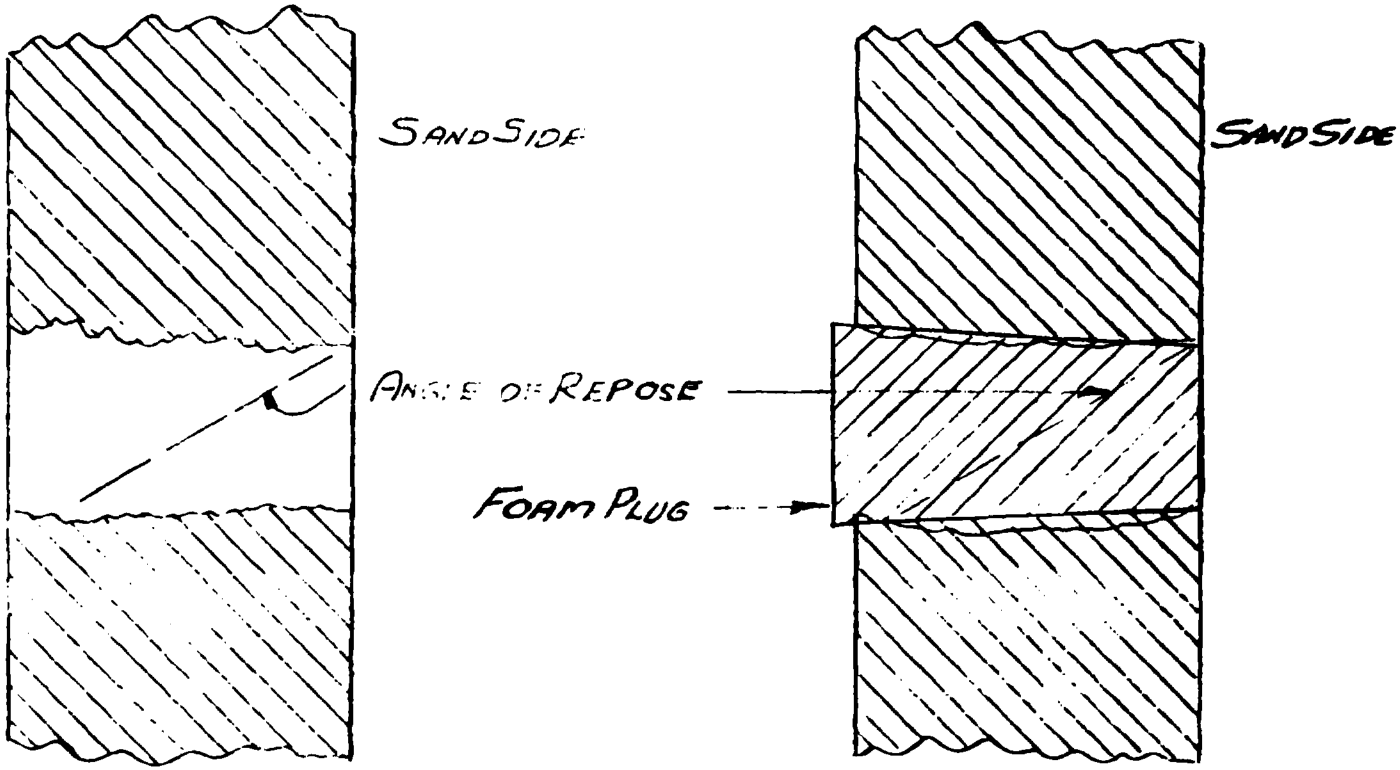


Fig. 19 - METHOD OF WALL REPAIR
SMALL HOLE WITH PLUG

DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY [illegible]	DATE [illegible]		JOB NUMBER PY1578
CHECKED BY [illegible]	DATE [illegible]	DETAILS WALL REPAIR WITH PLUG	DRAWING NUMBER PY1578-39D
APPROVED BY [illegible]	DATE [illegible]		

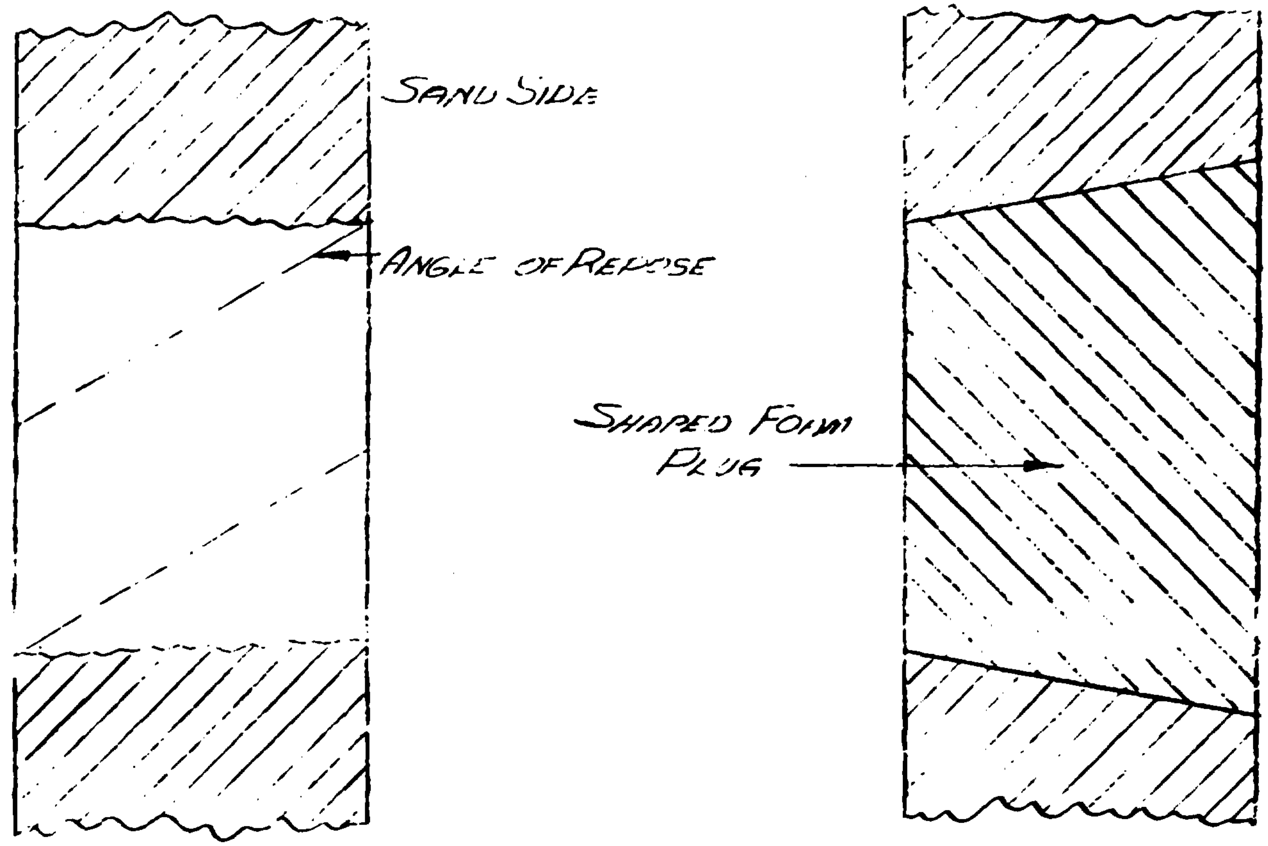


Fig. 20 - METHOD OF WALL REPAIR
LARGE HOLE - PLUG

DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1941-600
DRAWN BY	DATE 4/23/71		JOB NUMBER PY1578
CHECKED BY	DATE	DETAILS WALL REPAIR WITH PLUG	DRAWING NUMBER PY1578-40L
APPROVED BY	DATE		

board has been reached, saving other boards for reuse. Replace the broken board with a similar spare, reassemble and replace sand.

An inventory of spare boards and splines is recommended for rapid repair. For convenience these may be stored on top of the assembled barrier wall. The number of spare parts should be based on the number of compartments in the magazine.

In an emergency, rags, tape or a piece of foam may be temporarily used to cover a hole until permanent repairs are made. The main point is to keep an intact barrier by stopping sand flow.

In some cases broken foam boards may be salvaged by adhesive bonding. Polystyrene foam is not resistant to most solvents. Compatable adhesives such as epoxy, urethane or phenolics are recommended.

APPENDIX A

RAW MATERIAL SPECIFICATIONS

FOAM BARRIER SYSTEM

FOR PROTECTING MUNITIONS

TABLE OF CONTENTS

Page

1.0 RAW MATERIAL SPECIFICATIONS

1.1 Scope

This specification establishes the requirements for the foam boards, tie webbing materials and sand which together make up the Protective Barrier System.

1.2 Applicable Documents

The applicable documents in effect on the date of this material specification form a part of this specification.

1.2.1 Federal Specifications

HH-I-524A, Insulation Board, thermal (polystyrene) Fed. STD-123 Marking for civil agencies.

1.2.2 Military Standards

MIL-I-45208A-Inspection System Requirements.
MIL-Q-9858A-Quality Program Requirements
MIL-STD-105D-Sampling Procedure and Tables for Inspection by Attributes
MIL-STD-1235-Single and Multiple Continuous Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-129-Marking for Military Agencies
MIL-T-5038E, Tape, Textile and Webbing, Textile, Reinforcing, Nylon, Type IV

1.2.3 Commercial

ASTM - Methods for testing foam materials

1.3 Foam Board Specifications

1.3.1 Classification

The foam material will be extruded, expanded polystyrene foam boards equivalent to a pending Type III of the Federal Specification HH-I-524A May 23, 1966; "Insulation Board, Thermal (Polystyrene) having a minimum vertical strength of 100 psi.

1.3.2 Requirements

1.3.2.1 Material

The plastic foam board shall be formed by the expansion of polystyrene base resin in an extrusion process. The board shall be uniformly fused, homogeneous, and essentially unicellular.

1.3.2.2 Dimensions

1.3.2.2.1 Length. The length of the board shall be 108 inch minimum with a tolerance of -0 +1 inch.

1.3.2.2.2 Width. The width shall be 16 inches ± 1/16 inch.

1.3.2.2.3 Thickness. Thickness shall have a tolerance of ± 1/16 inch

1.3.2.3 Squareness of Ends

Deviation from square for the 16 inch width shall not exceed 1/16 inch.

1.3.2.4 Straightness

Board curvatures shall not be greater than those listed below.

Edge Bow - 1/8" maximum in 108" length
Face Bow - 1/2" maximum in 108" length
Saucer - 1/16" maximum in 16" width

1.3.2.5 Appearance

The surface shall be reasonably free of such flaws as dents, gouges, dirt, surface cracks or glazed areas. Color shall be uniformly light blue.

1.3.2.6 Physical Properties

The foam boards shall conform to the physical properties specified on Table 1.

1.3.3 Quality Assurance Provisions

Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for material meeting the specified requirements.

1.3.4 Packaging

1.3.4.1 Packaging will be standard commercial practice unless otherwise specified in the purchase order or contract.

1.3.5 Marking

1.3.5.1 Marking for civil agencies shall be in accordance with FED. STD. No. 123.

1.3.5.2 Marking for military agencies shall be in accordance with MIL-STD-129.

1.3.6 General Notes

1.3.6.1 Intended use. High density polystyrene foam board as defined in this specification is intended for use as retaining walls of sand in explosive storage structures at temperatures between -65°F. and +120°F. Protection of the material with a covering is not required, therefore, paragraph 6.1 of HH-I-524A does not apply.

1.3.6. Commercial sizes. Foam boards are available in the following sizes.

1", 2", 3", 4" thick by 16" wide by 9 ft. long.

1.4 Tie Webbing Material Specification

1.4.1 Classification

The webbing material for the ties shall be 1" Nylon as per MIL-T-5038E, Type IV.

1.4.2 Requirements

The woven webbing material shall be Nylon with uniform weave and no frayed edges.

TABLE 1

PHYSICAL PROPERTIES

		Test Method
Density lbs/cu ft	3.0 to 5.0	ASTM D-1622
Flexural Strength, lbs/sq in (minimum, extrusion direction) at 5% strain	70	ASTM C-203
Flexural Modulus lbs/sq in (minimum, extrusion direction)	2500	ASTM C-203
Compressive Strength lbs/sq in (minimum, perpendicular to board thickness) at 5% deflection	100	ASTM D-1621
Compressive Modulus lbs/sq in (minimum vertical) at 5% deflection	2500	ASTM D-1621
Flammability	Self Extinguishing	ASTM D-1692
Water Absorption % by volume (maximum)	0.10	ASTM C-272

1.4.3 Dimensions

Width. The width shall be nominal 1 inch.

Break Strength. The break strength shall be 1000 psi minimum. The color shall be light grey, white or olive drab.

1.4.4 Thread

Thread for sewing lap seams shall be Nylon.

1.5 Sand Specification

1.5.1 Classification

The sand used in this barrier shall meet delivery requirements for sand currently in use in barrier protection systems, free from gravel and other objects that might become secondary projectiles.

1.5.2 Requirements

Sand particle size shall not exceed 1/8". Wet or dry sand may be used; dry sand is preferred.

2.0 INCOMING QUALITY ASSURANCE PROCEDURE

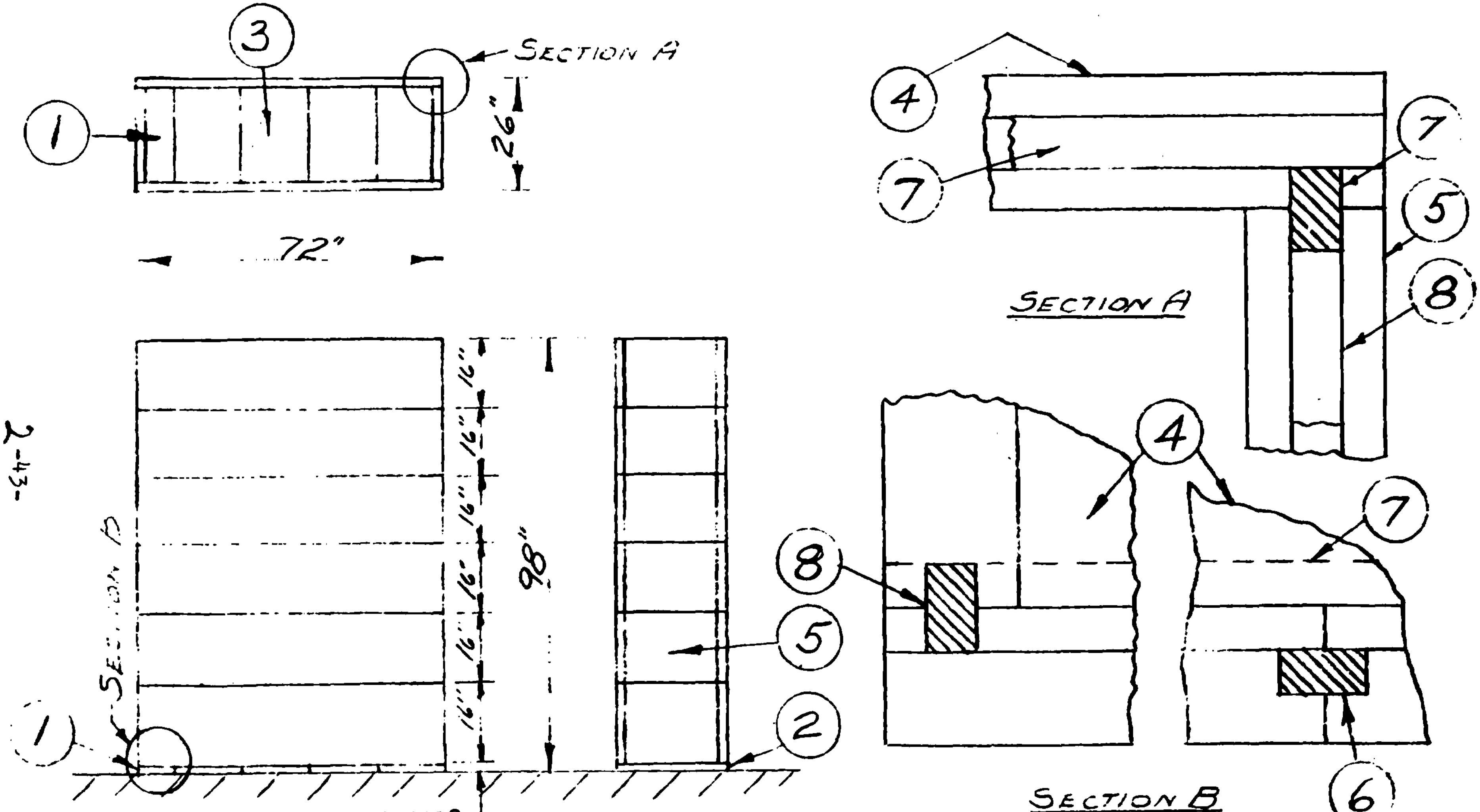
It is recommended that the fabricator have an adequate inspection system patterned after Mil-I-45208A or as an alternate Mil-Q-9858A. Both these documents describe inspection of incoming materials for conformance to specifications.

APPENDIX B

PARTS LIST

WING WALL, 2 INCH BOARD THICKNESS - DWG. NO. PY1578-4D

ITEM NO.	DWG. NO.	PART DESCRIPTION	NO. REQ'D.
1	PY1578-21D	Board - Floor - Short - End	1
2	PY1578-20D	Board - Floor - Std. - End	1
3	PY1578-19D	Board - F[illegible] - Std.	3
4	PY1578-13D	Board - Wall	12
5	PY1578-24D	Board - End	12
6	PY1578-28D	Spline - Bottom	4
7	PY1578-26D	Spline - Corner - Vertical	4
		Horizontal - Wall	14
8	PY1578-29D	Spline - Horizontal - End	14



CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY	DATE
DRAWN BY	DATE 6/8/71
CHECKED BY	DATE
APPROVED BY	DATE

THE DOW CHEMICAL COMPANY
MIDLAND MICHIGAN

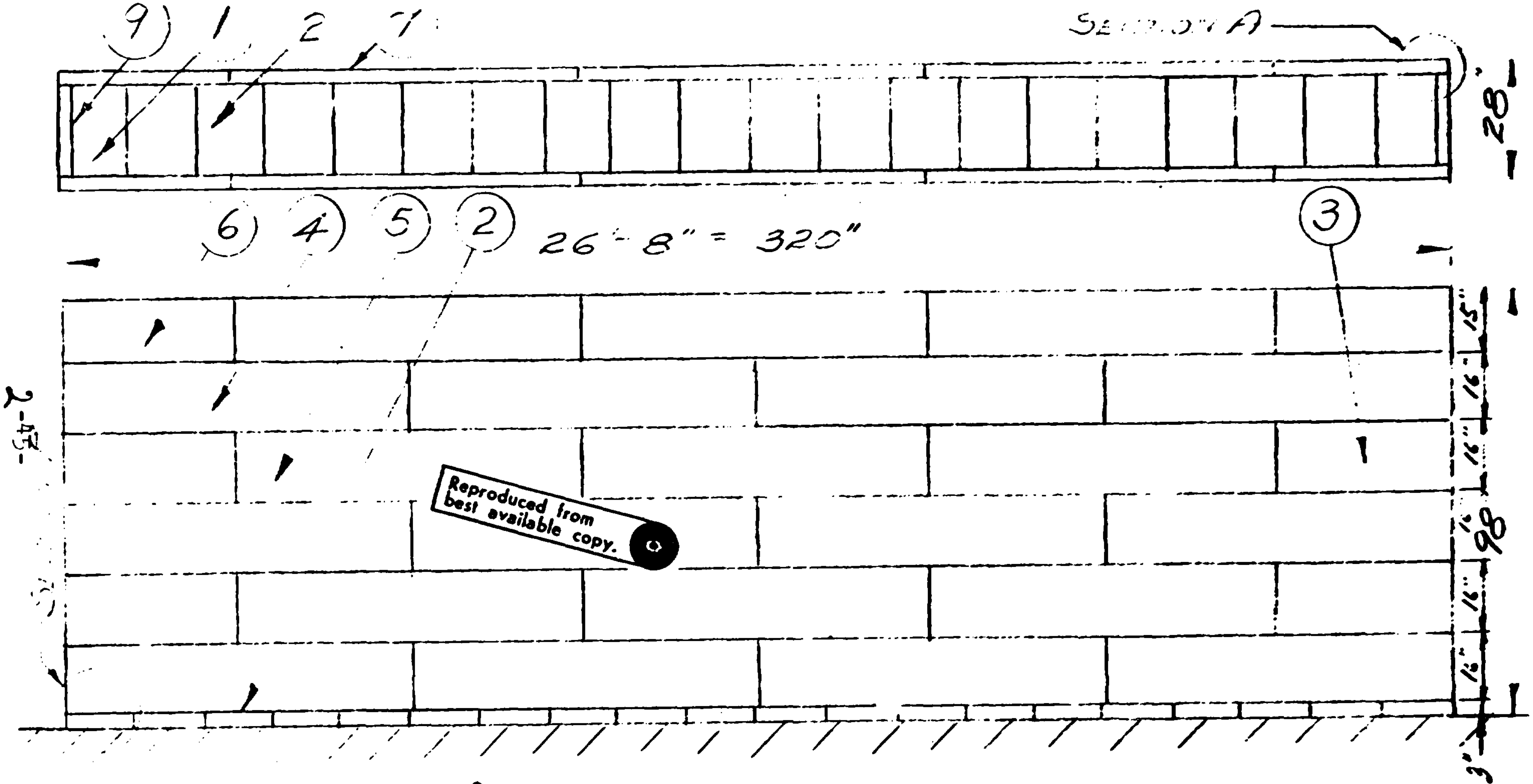
SUBASSEMBLY - PROTOTYPE TEST SECTION
WING WALL - 2" THICKNESS

ACCOUNT NUMBER 1841-600
JOB NUMBER PY1578
DRAWING NUMBER PY1578-4D

PARTS LIST

CENTER WALL (3" BOARD THICKNESS) - DWGS. NO. PY1578-6D AND -7D

ITEM NO.	DWG. NO.	PART DESCRIPTION	NO. REQ'D.
1	PY1578-17D	Board - Floor - Std. - End	2
2	PY1578-16D	Board - Floor - Std.	18
3	PY1578-14D	Board - Half - End	8
4	PY1578-8D	Board - Full - End	12
5	PY1578-9D	Board - Full - Std.	26
6	PY1578-15D	Board - Half - End - Top	4
7	PY1578-10D	Board - Full - Std. - Top	4
8	PY1578-22D	Board - End - Std.	10
9	PY1578-23D	Board - End - Top	2
10	PY1578-27D	Spline - Bottom	19
11	PY1578-25D	Spline - Corner Vertical	4
		- Wall Horizontal	70
12	PY1578-30D	Spline - End - Horizontal	14
13	PY1578-32D	Spline - Wall - Butt	42



CONTRACT NUMBER DASA01-71-C-0018

SEE DWG. NO. PY1576-7D FOR ...

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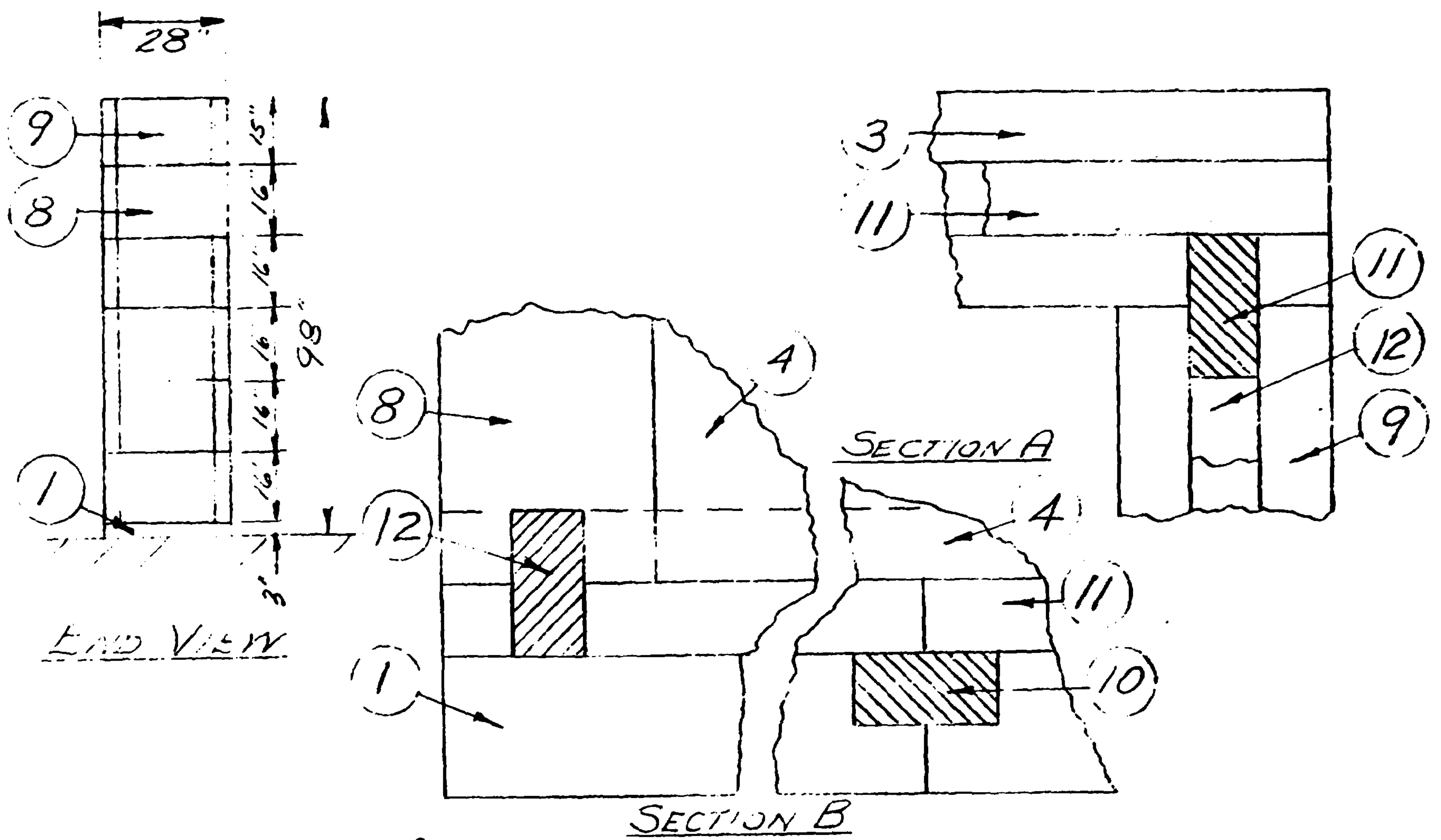
DRAWN BY	DATE 6/1/71		JOB NUMBER PY.578
CHECKED BY	DATE	... TEST SECTION	DRAWING NUMBER PY...-6D
APPROVED BY	DATE	CENTER WALL - 3" THICKNESS	



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REF. DWG. NO PY1578-6D

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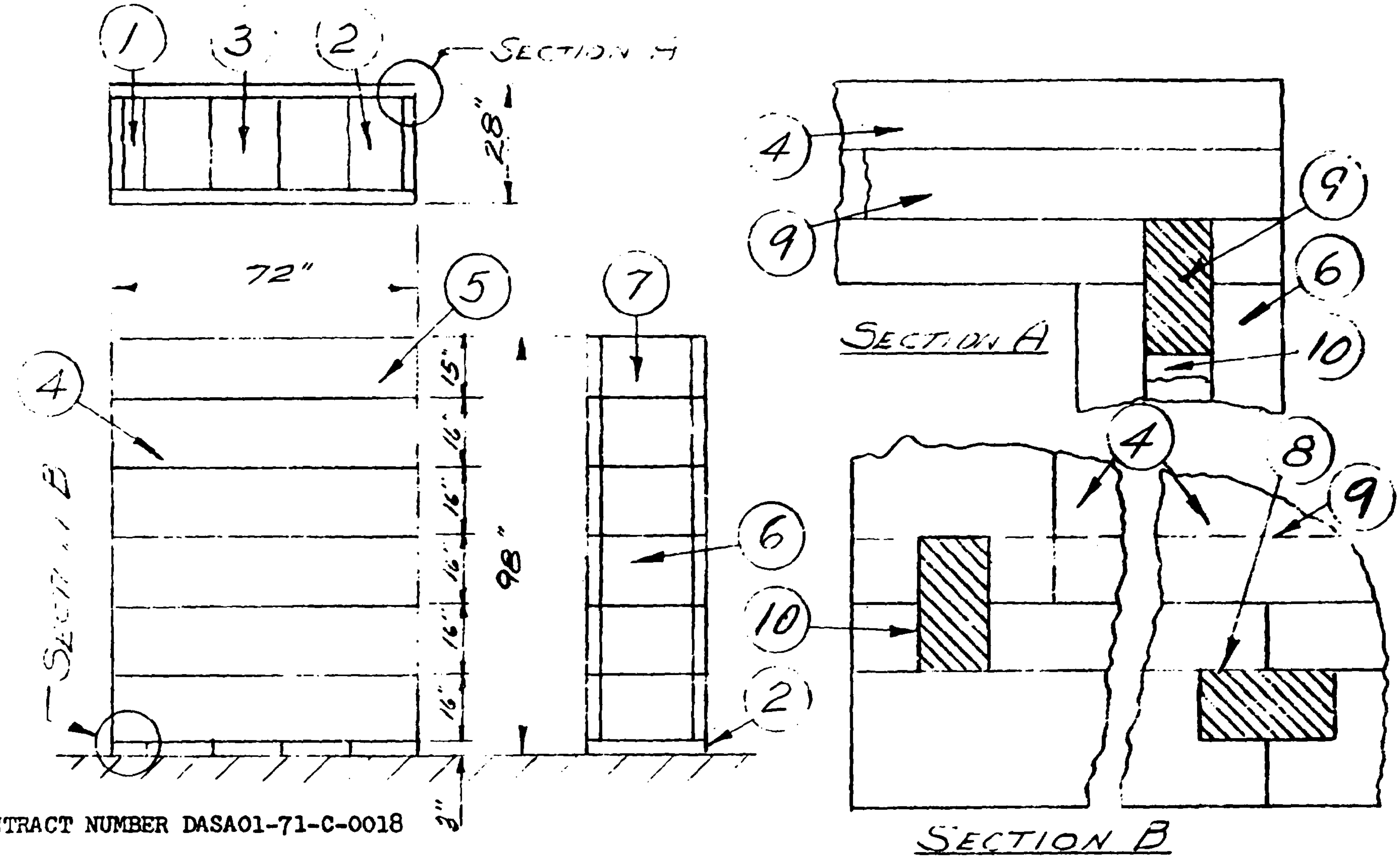
CHECKED BY	DATE	SUB-ASSEMBLY - PROTOTYPE TEST SECTION CENTER WALL - 3" THICKNESS	DRAWING NUMBER PY1578-7D
APPROVED BY	DATE		

PARTS LIST

WING WALL (3" BOARD THICKNESS) - DWG. NO. PY1578-5D

ITEM NO.	DWG. NO.	PART DESCRIPTION	NO. REQ'D.
1	PY1578-18D	Board - Floor - Half - End	1
2	PY1578-17D	Board - Floor - Std. - End.	1
3	PY1578-16D	Board - Floor - Std.	3
4	PY1578-11D	Board - Wall	10
5	PY1578-12D	Board - Wall - Top	2
6	PY1578-22D	Board - End - Std.	10
7	PY1578-23D	Board - End - Top	2
8	PY1578-27D	Spline - Bottom	4
9	PY1578-25D	Spline - Corner Vertical	6
		- Wall - Horizontal	14
10	PY1578-30D	Spline - End - Horizontal	14



CONTRACT NUMBER DASA01-71-C-0018

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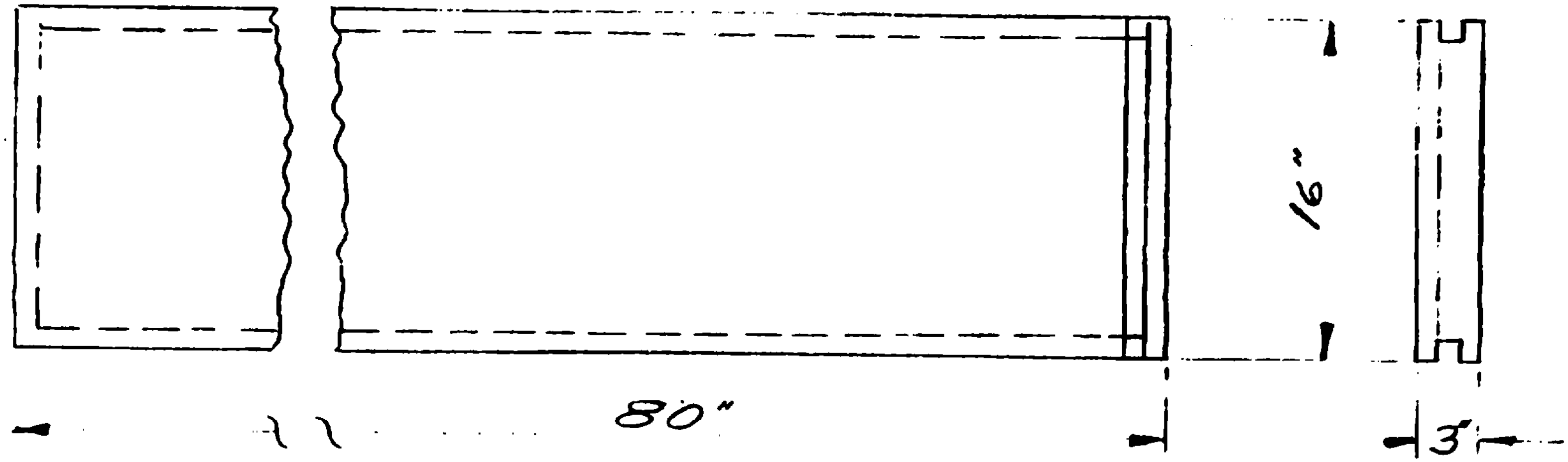
APPROVED BY	DATE	WING WALL - 3" THICKNESS	



BOARD - FULL - END
MAT'L - PZ 1623

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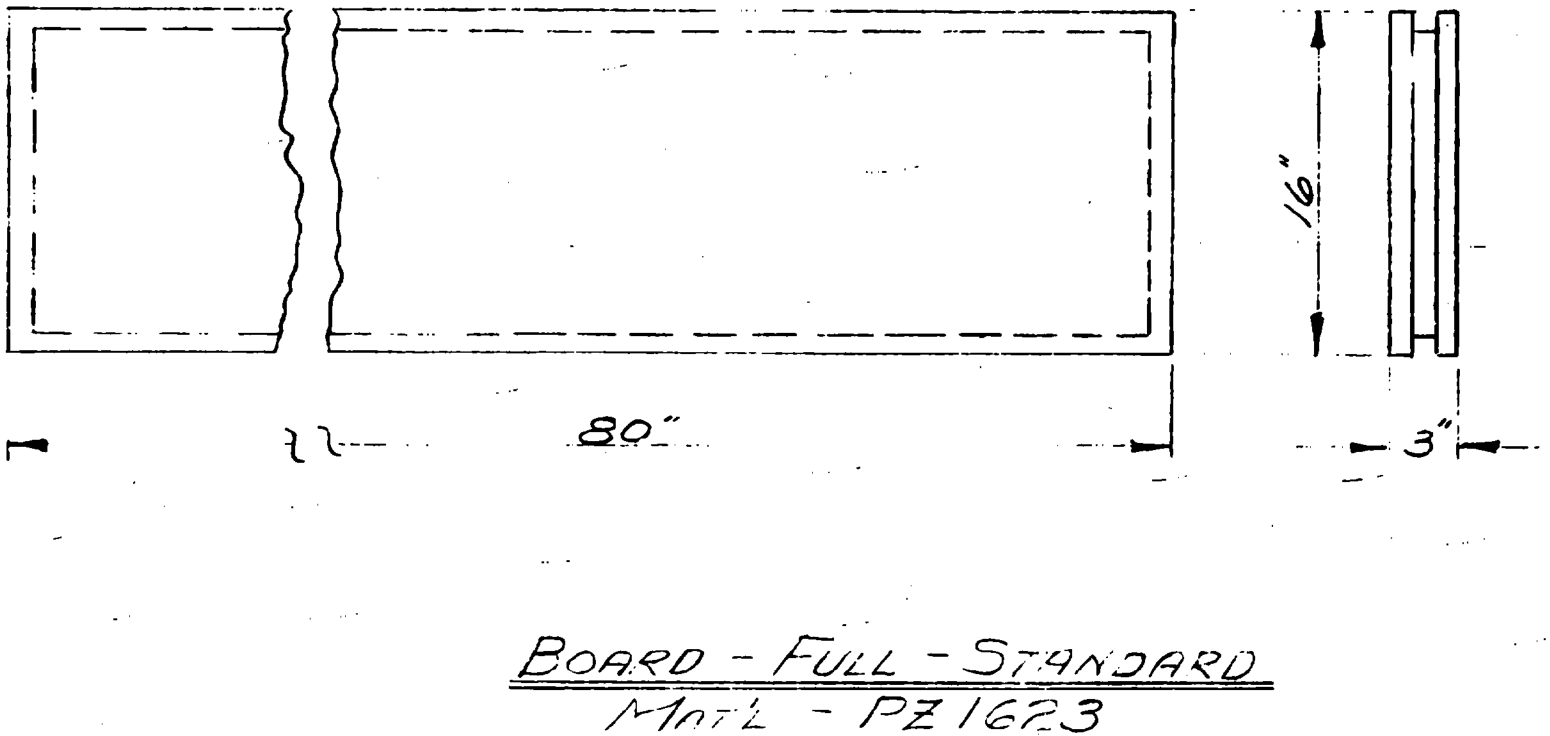

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THE DOW CHEMICAL COMPANY
MIDLAND MICHIGAN

DETAILS
BOARD - FULL - STANDARD - 3"

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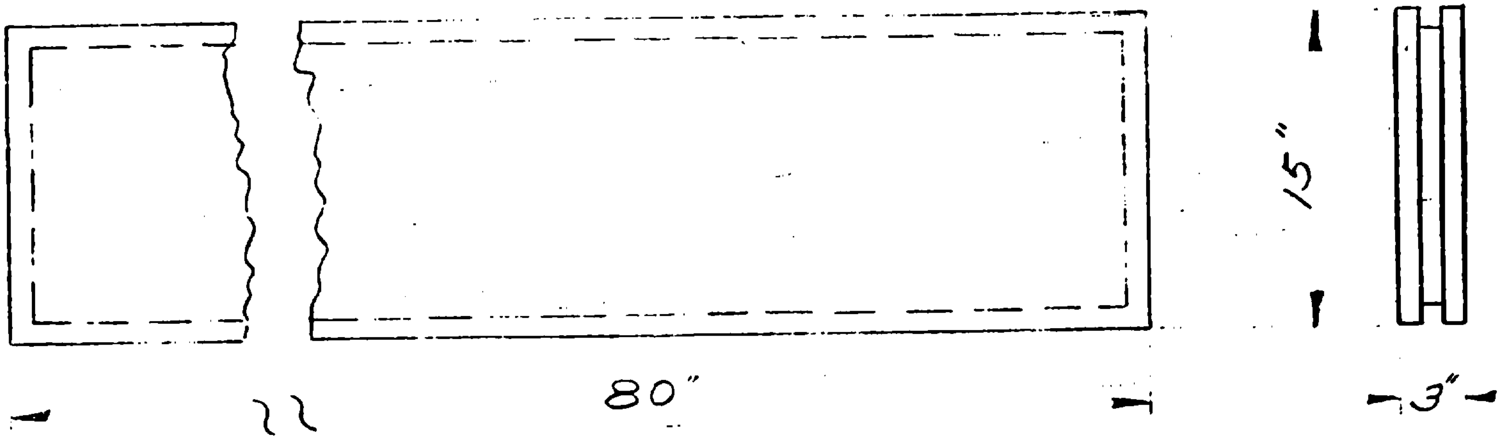

BOARD - FULL - STD. - TOP
MAT'L. - PZ1623

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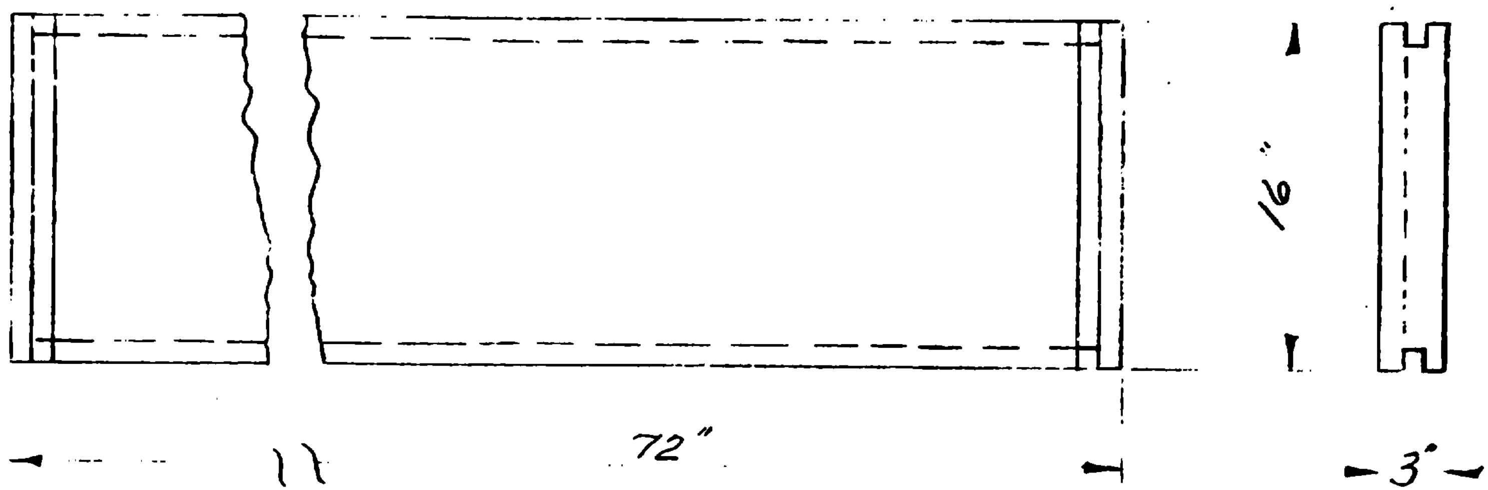

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DETAILS BOARD - WING WALL - 3"	DRAWING NUMBER PY1578-11D	

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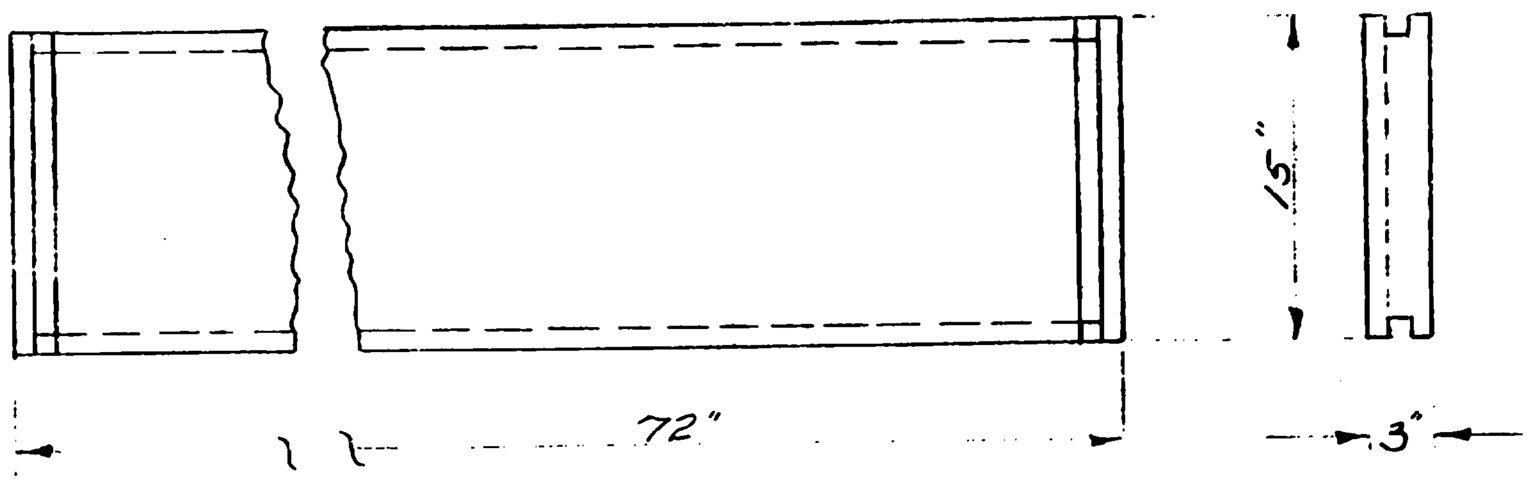

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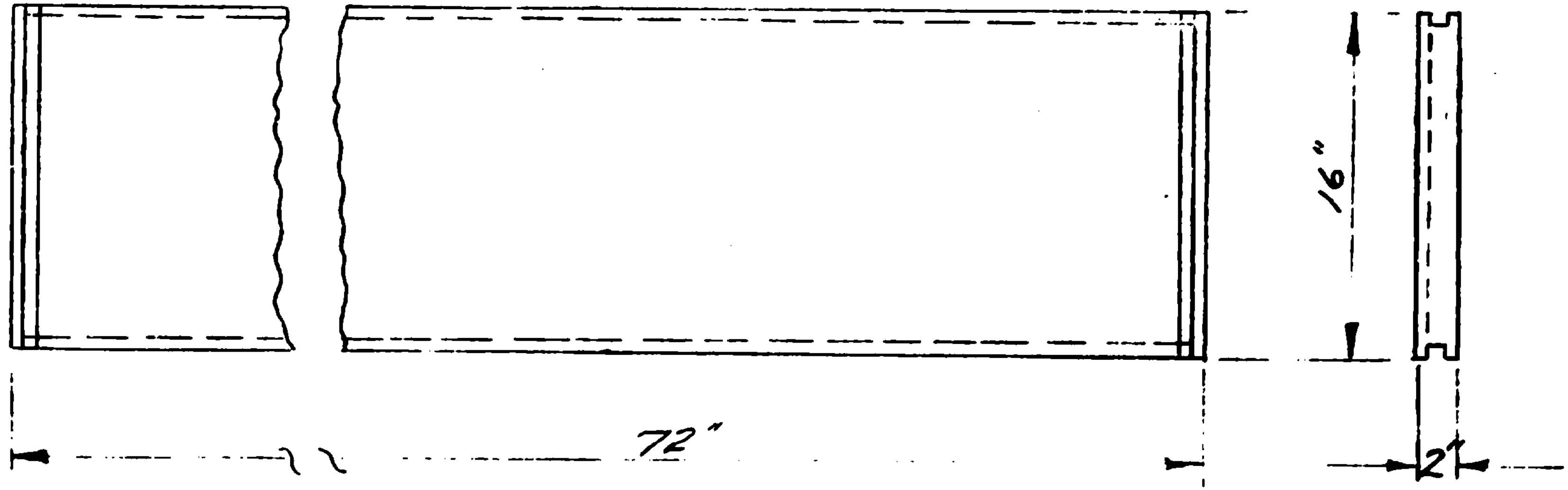

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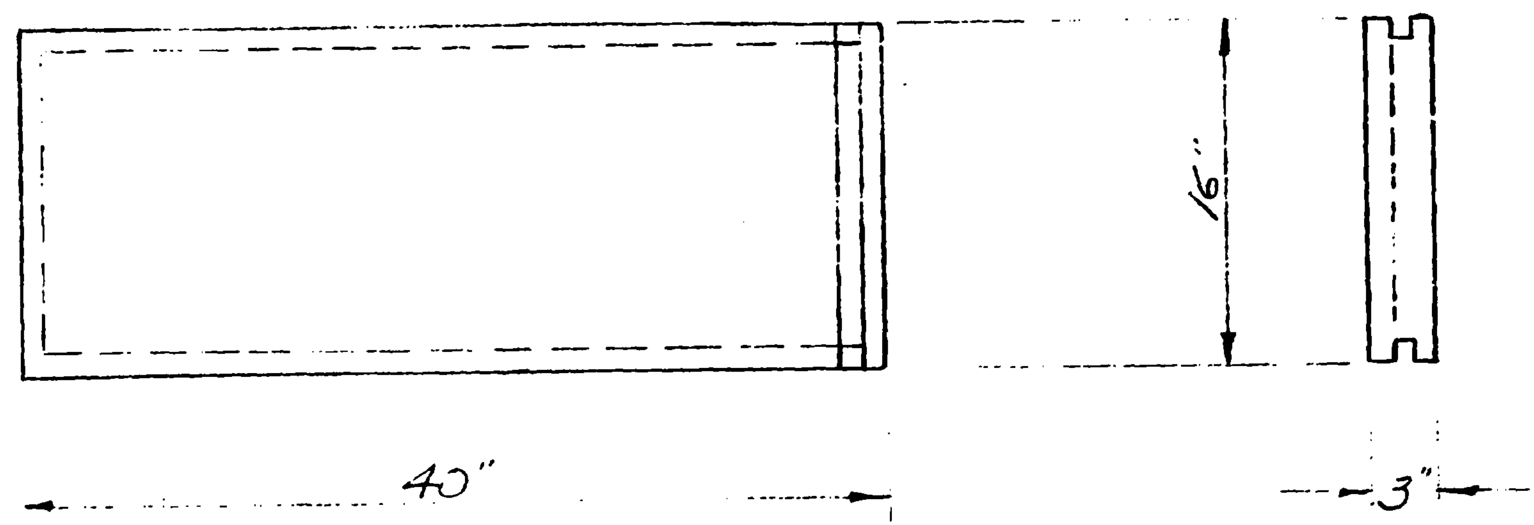

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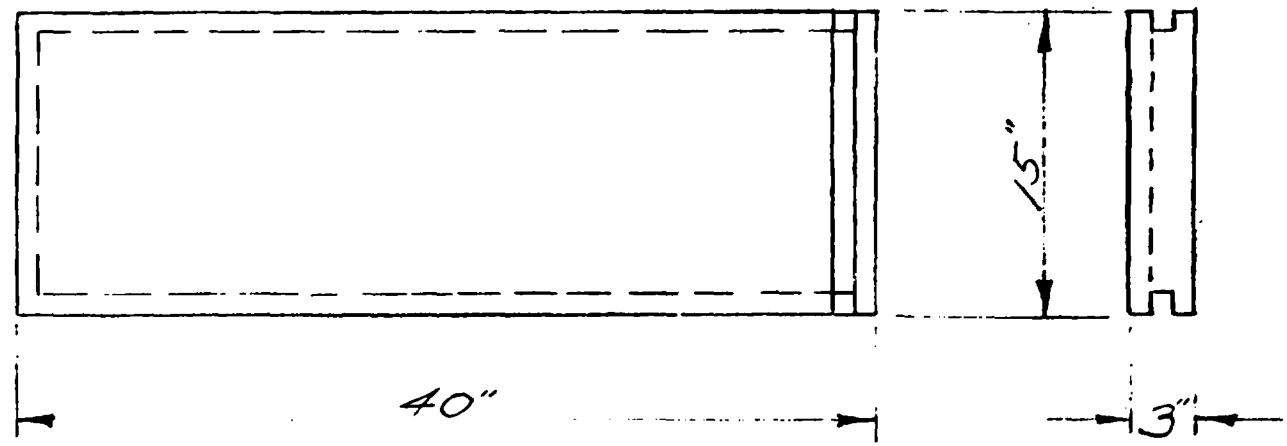

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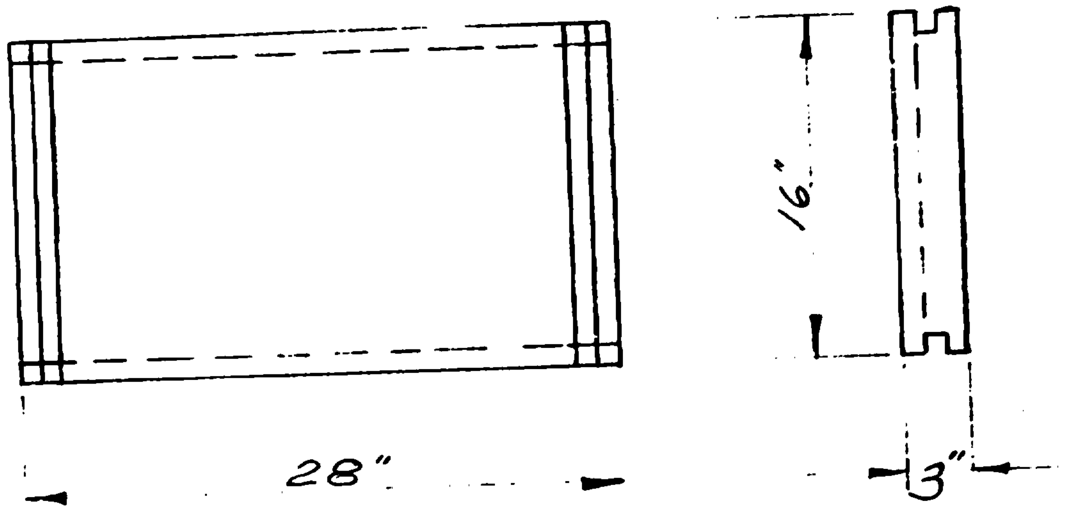

BOARD-BOTTOM-STD.
MAT'L. - PZ1623

CONTRACT NUMBER DASA01-71-C-0018

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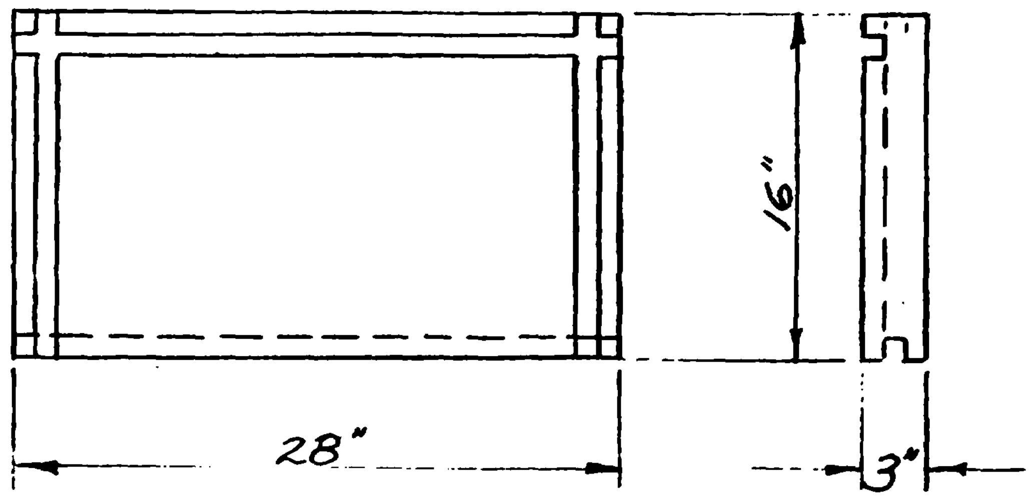

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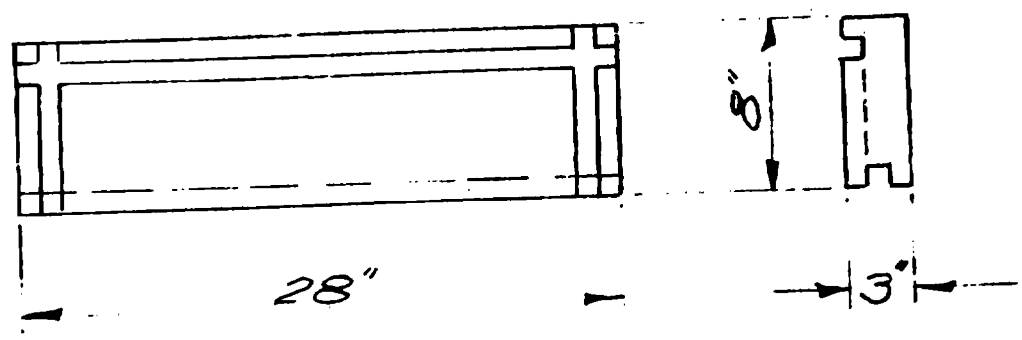

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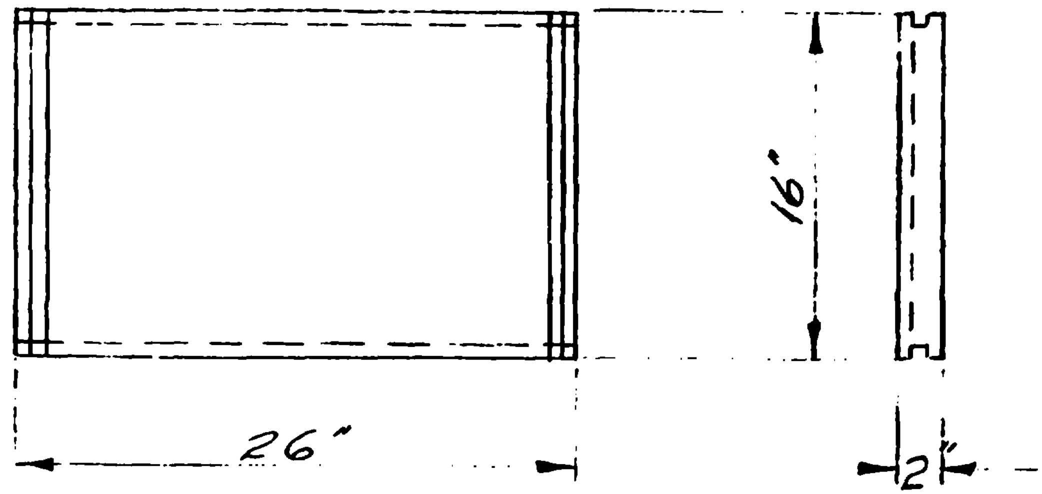

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MAT'L - PZ-1623

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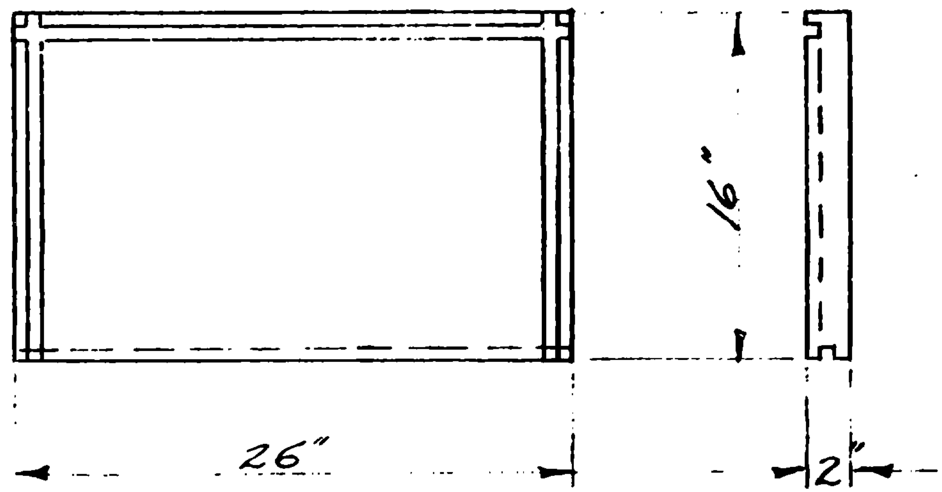

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MAT'L - PZ 1623

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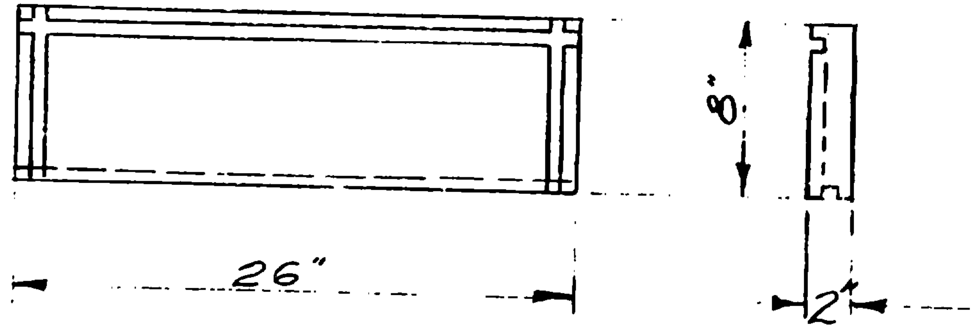

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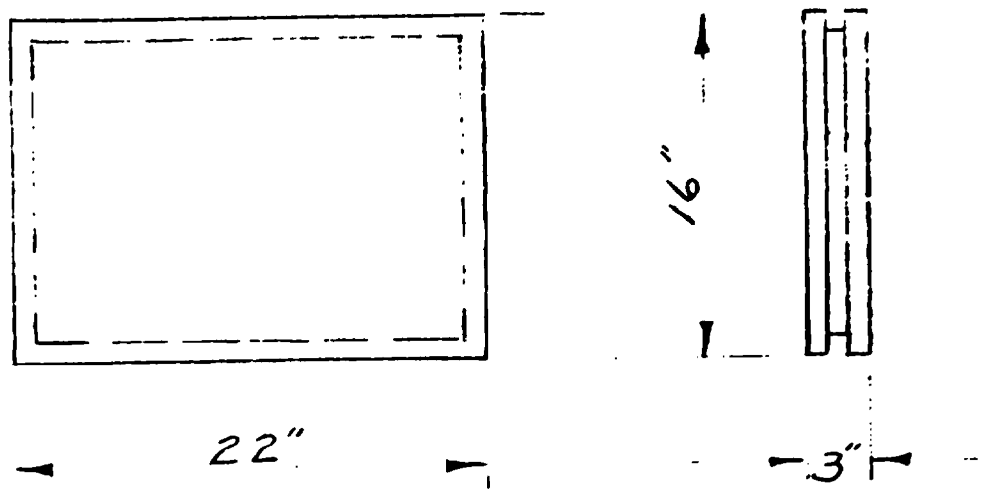

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MAT'L - PZ 1623

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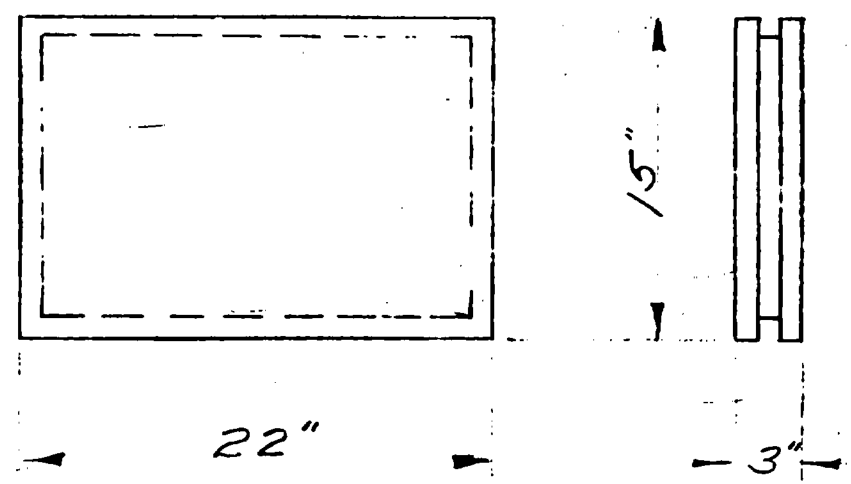

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MAT'L - PZ1623

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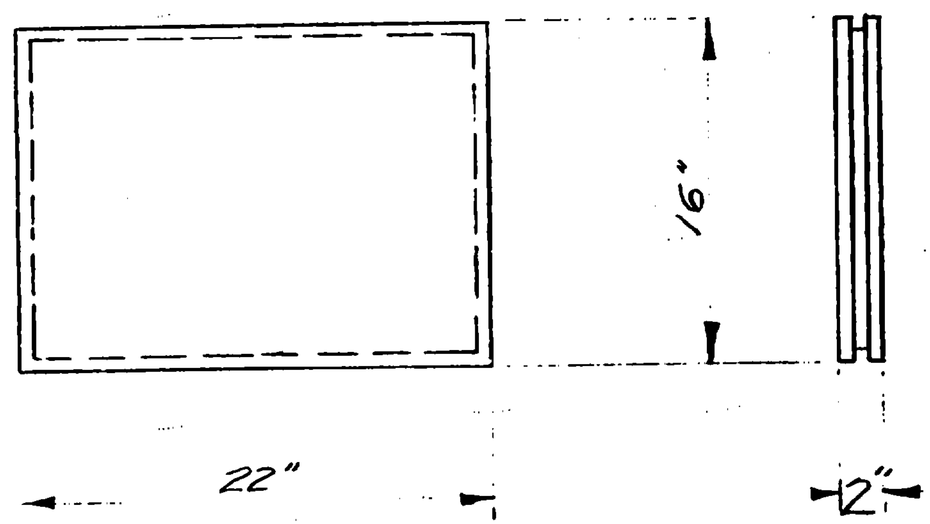
CHECKED BY	a J P	DATE 6/2/71
APPROVED BY	a J P	DATE 6/1/71

THE DOW CHEMICAL COMPANY
MIDLAND MICHIGAN

DETAILS
BOARD - END - TOP - 3"

ACCOUNT NUMBER 1841-600
JOB NUMBER PY1578
DRAWING NUMBER PY1578-23D



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MAT'L - PZ 1623

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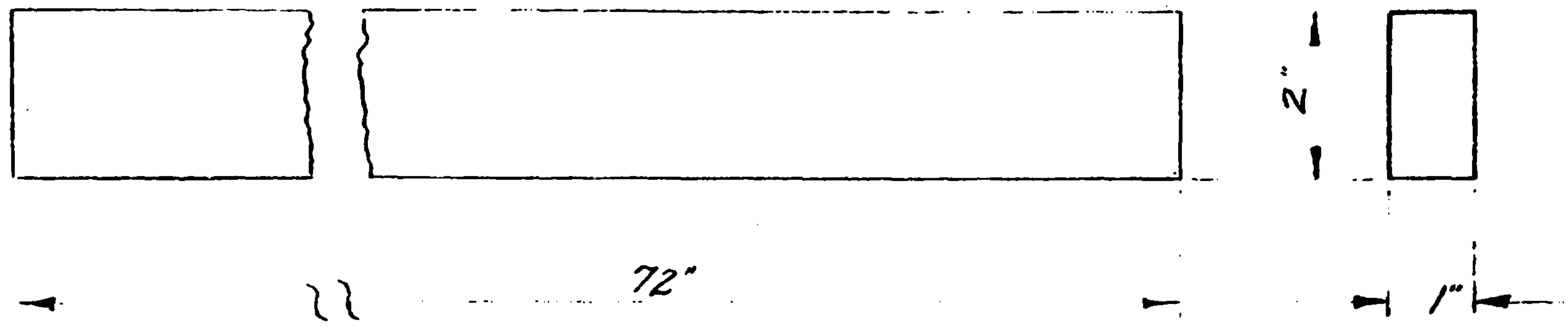
THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
	JOB NUMBER PY1578
DETAILS BOARD - END - STD. - 2"	DRAWING NUMBER PY1578-24D

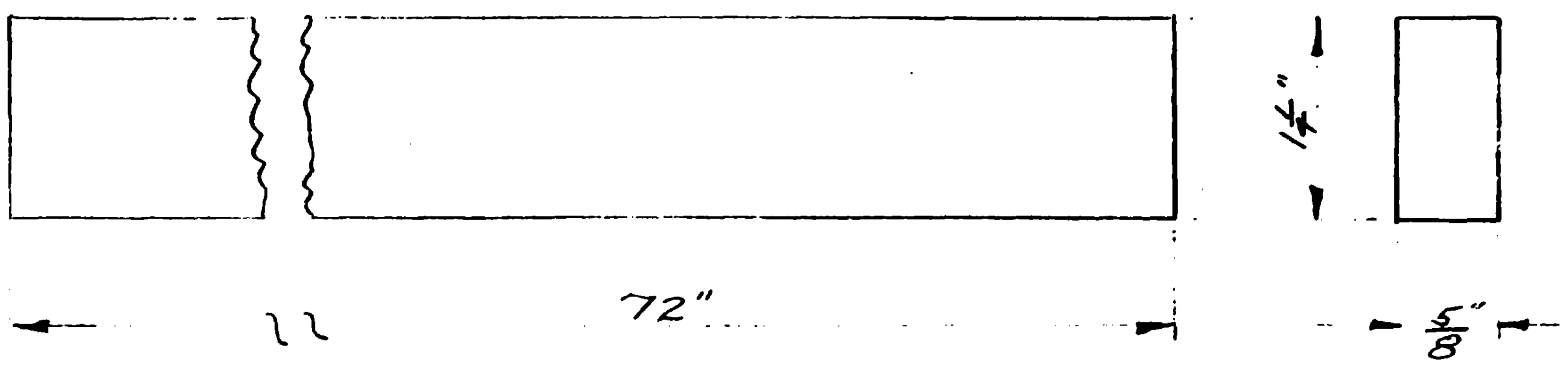
		DATE
DESIGNED BY		
DRAWN BY	[illegible]	6/10/71
CHECKED BY	[illegible]	6/24/71
APPROVED BY	[illegible]	[illegible]



SPLINE
MAT'L. - PZ1623

CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY [illegible]	DATE 6/10/71		JOB NUMBER PY-1578
CHECKED BY [illegible]	DATE 6/21/71	DETAILS SPLINE - FOR 3" THICK WALL	DRAWING NUMBER PY1578-25D
APPROVED BY [illegible]	DATE 6/21/71		

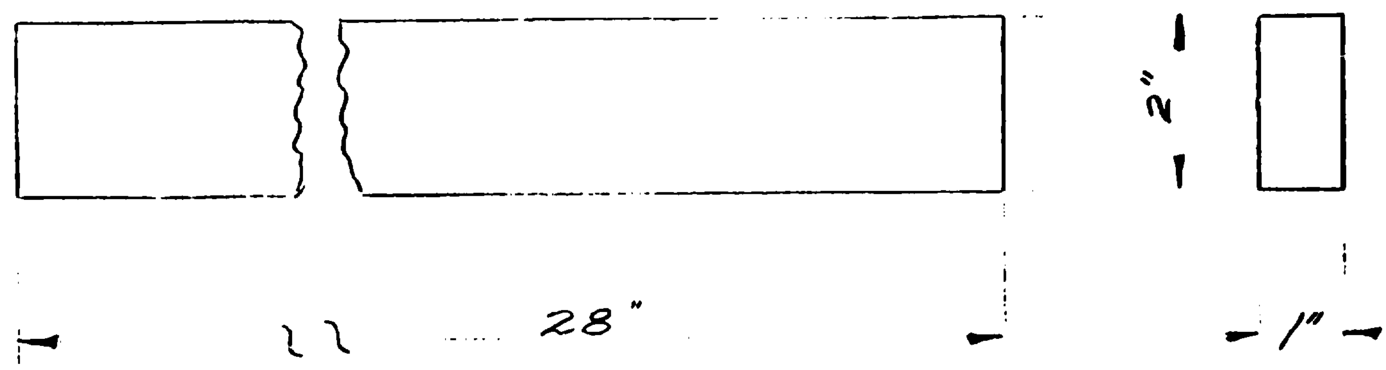


SPLINE
MAT'L. - PZ1623

CONTRACT NUMBER DASA01-71-C-0018

THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600 JOB NUMBER PY1578
DETAILS SPLINE - FOR 2" THICK WALL	DRAWING NUMBER PY1578-26D

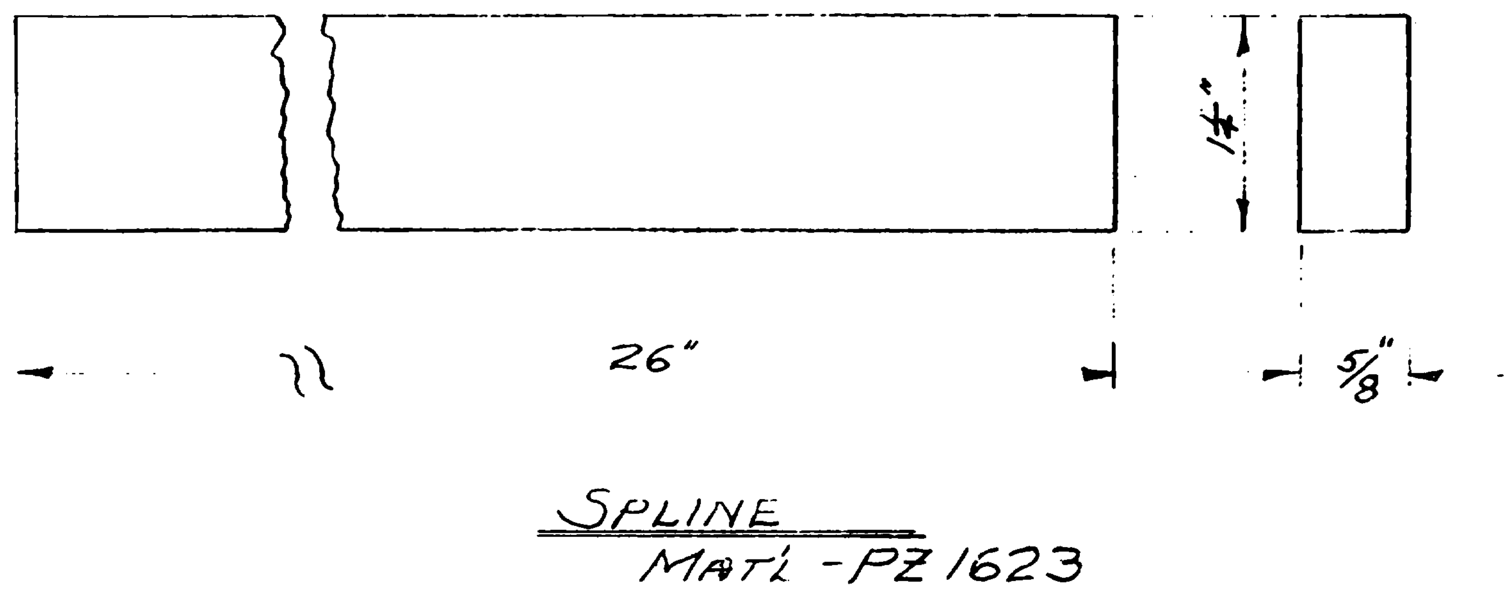
DESIGNED BY		DATE
DRAWN BY	[illegible]	DATE 6/10/71
CHECKED BY	[illegible] 6/24/71	DATE
APPROVED BY	[illegible] 6/24/71	DATE



SPLINE
MAT'L- PZ1623

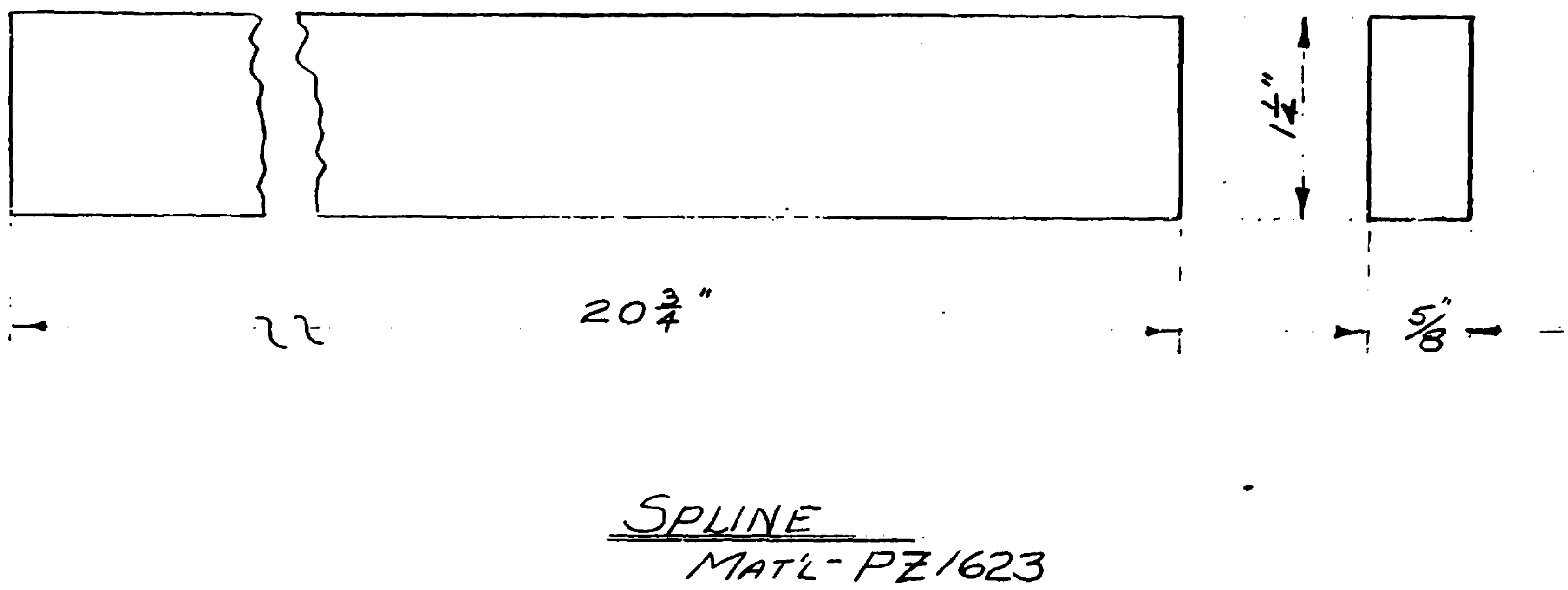
CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY [illegible]	DATE 6/10/71		JOB NUMBER PY1578
CHECKED BY [illegible]	DATE 6/7/71	DETAILS FLOOR SPLINE - FOR 3" THICK WALL	DRAWING NUMBER PY1578-27D
APPROVED BY [illegible]	DATE 6/7/71		



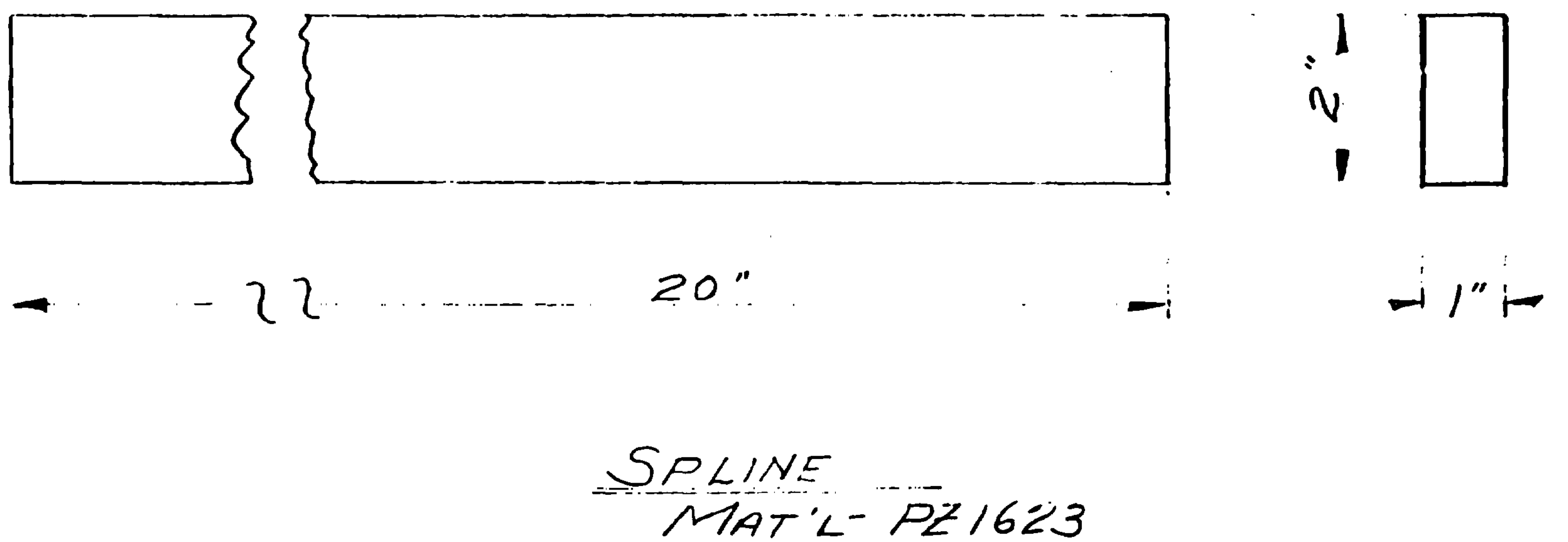
CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY	DATE 6/10/71		JOB NUMBER PY1578
CHECKED BY	DATE 6/24/71	DETAILS FLOOR SPLINE - FOR 2" THICK WALL	DRAWING NUMBER PY1578-28D
APPROVED BY	DATE 6/24/71		



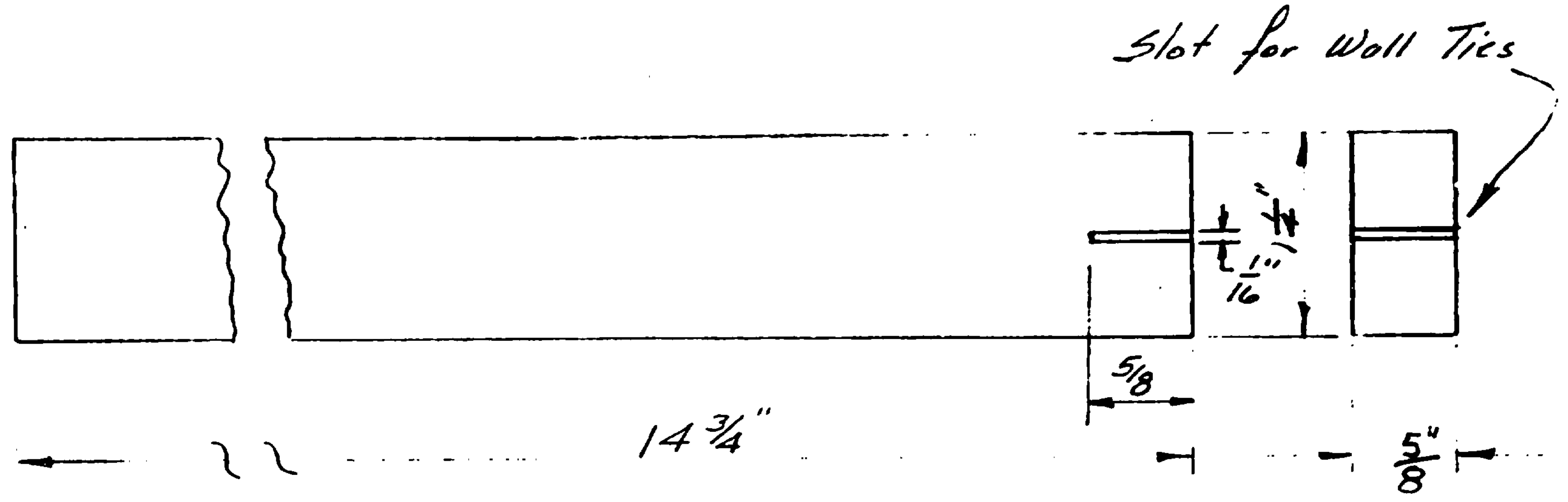
CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY	DATE 6/10/71		JOB NUMBER PY1578
CHECKED BY	DATE	DETAILS END WALL SPLINE - FOR 2" THICK WALL	DRAWING NUMBER PY1578-29D
APPROVED BY	DATE		



CONTRACT NUMBER DASA01-71-C-0018

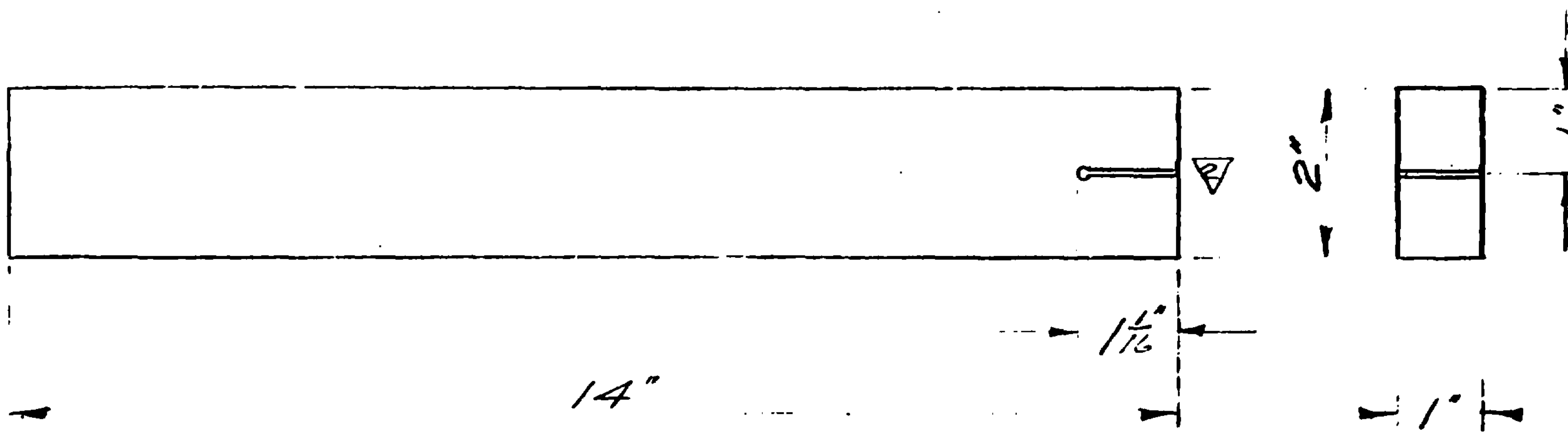
DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY	DATE 6/10/71		JOB NUMBER PY1578
CHECKED BY	DATE	DETAIL	DRAWING NUMBER PY1578-30D
APPROVED BY	DATE	END WALL SPLINE - FOR 3" THICK WALL	



SPLINE - FOR BUTT JOINT
MAT'L - PZ1623

CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY	DATE 6/10/71		JOB NUMBER PY1578
CHECKED BY	DATE	DETAILS BUTT JOINT SPLINE - FOR 2" THICK WALL	DRAWING NUMBER PY1578-31D
APPROVED BY	DATE		

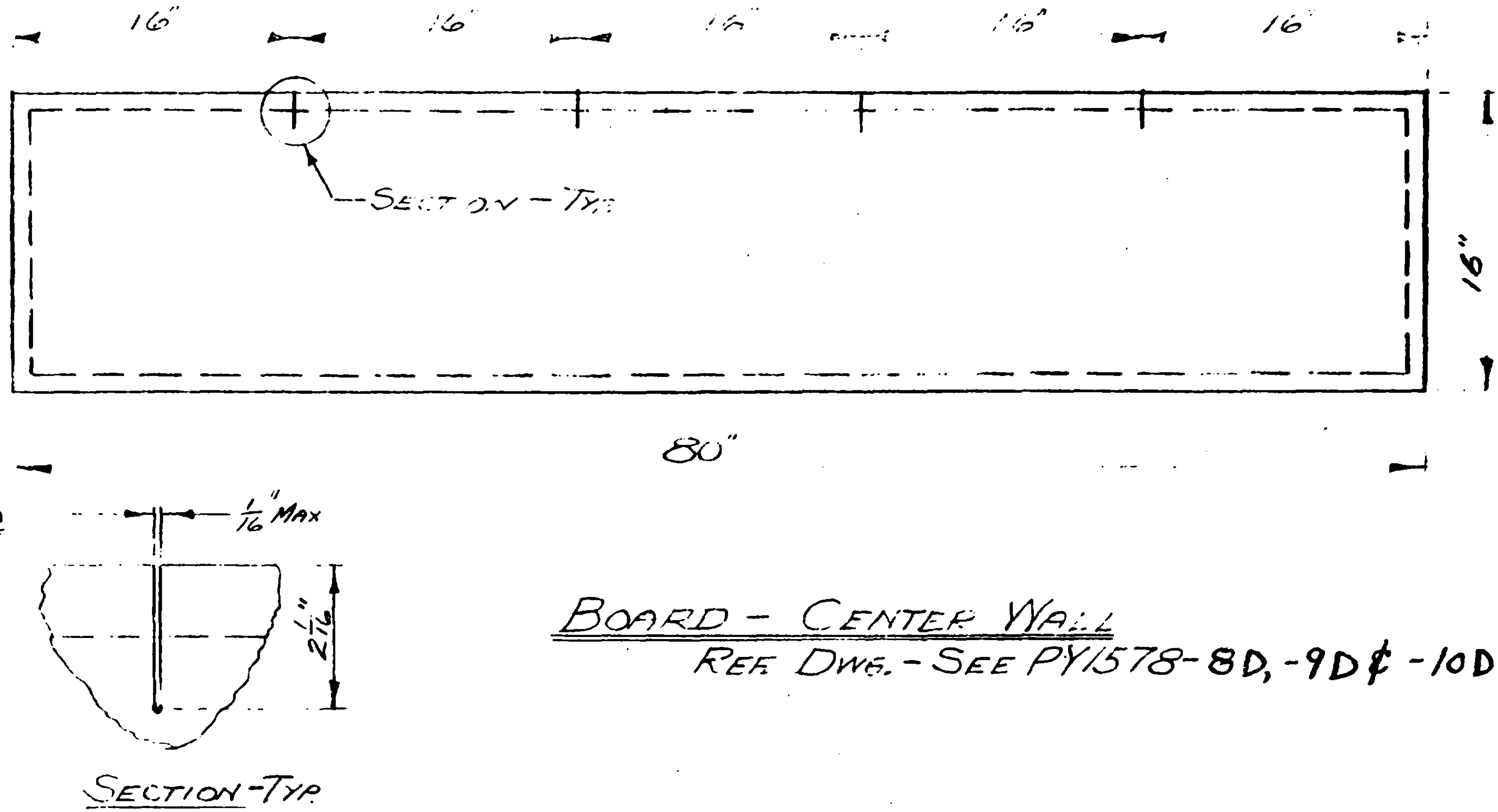


SPLINE WALL BUTT
MAT'L. - PZ1623

2 SLOT ADDED
1 TITLE CHANGED
REVISIONS

CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY	DATE 6/10/71		JOB NUMBER PY1578
CHECKED BY	DATE	DETAILS BUTT JOINT SPLINE - FOR 3" WALL	DRAWING NUMBER PY1578-32D
APPROVED BY	DATE		

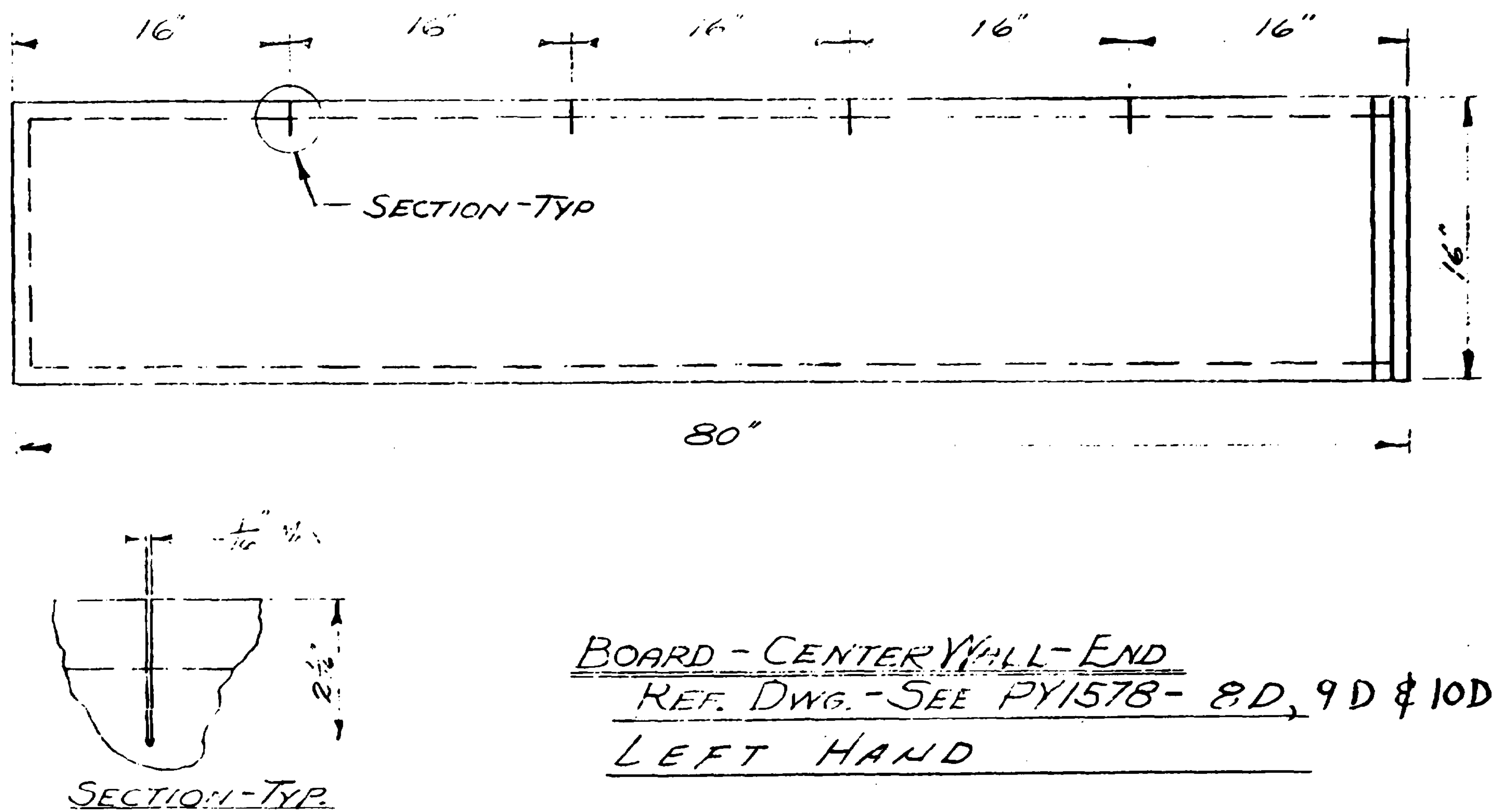


BOARD - CENTER WALL

REF DWG. - SEE PY1578-8D, -9D & -10D

CONTRACT NUMBER DASA01-71-C-0018

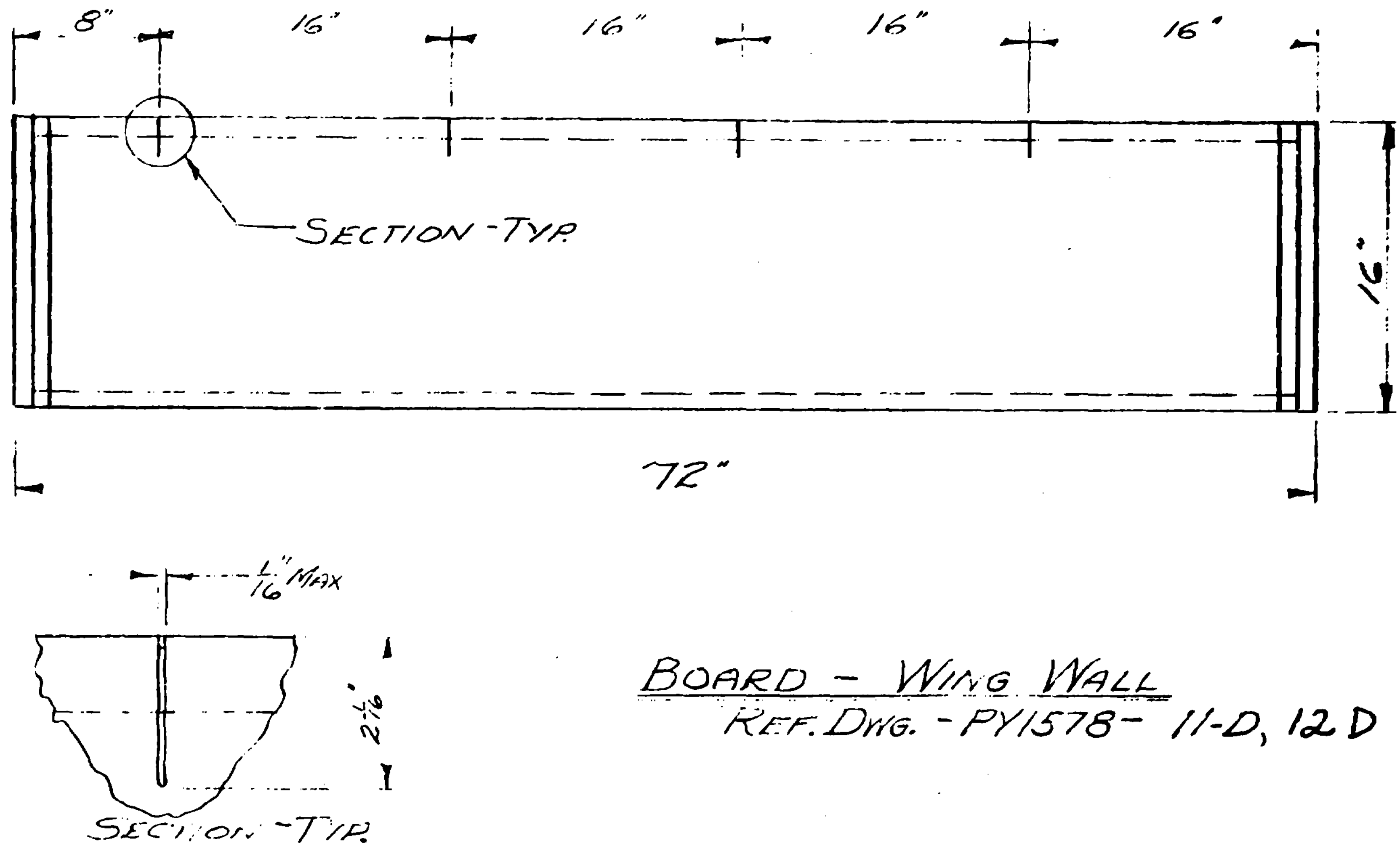
DESIGNED BY	DATE 5/17/71	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600 JOB NUMBER PY1578
DRAWN BY	DATE 5/21/71	TIE SLOT LOCATION DETAILS BOARD - CENTER WALL - 3"	DRAWING NUMBER PY1578-33D
CHECKED BY	DATE 6/24/71		
APPROVED BY	DATE 6/24/71		



BOARD - CENTER WALL - END
REF. DWG. - SEE PY1578 - 8D, 9D & 10D
LEFT HAND

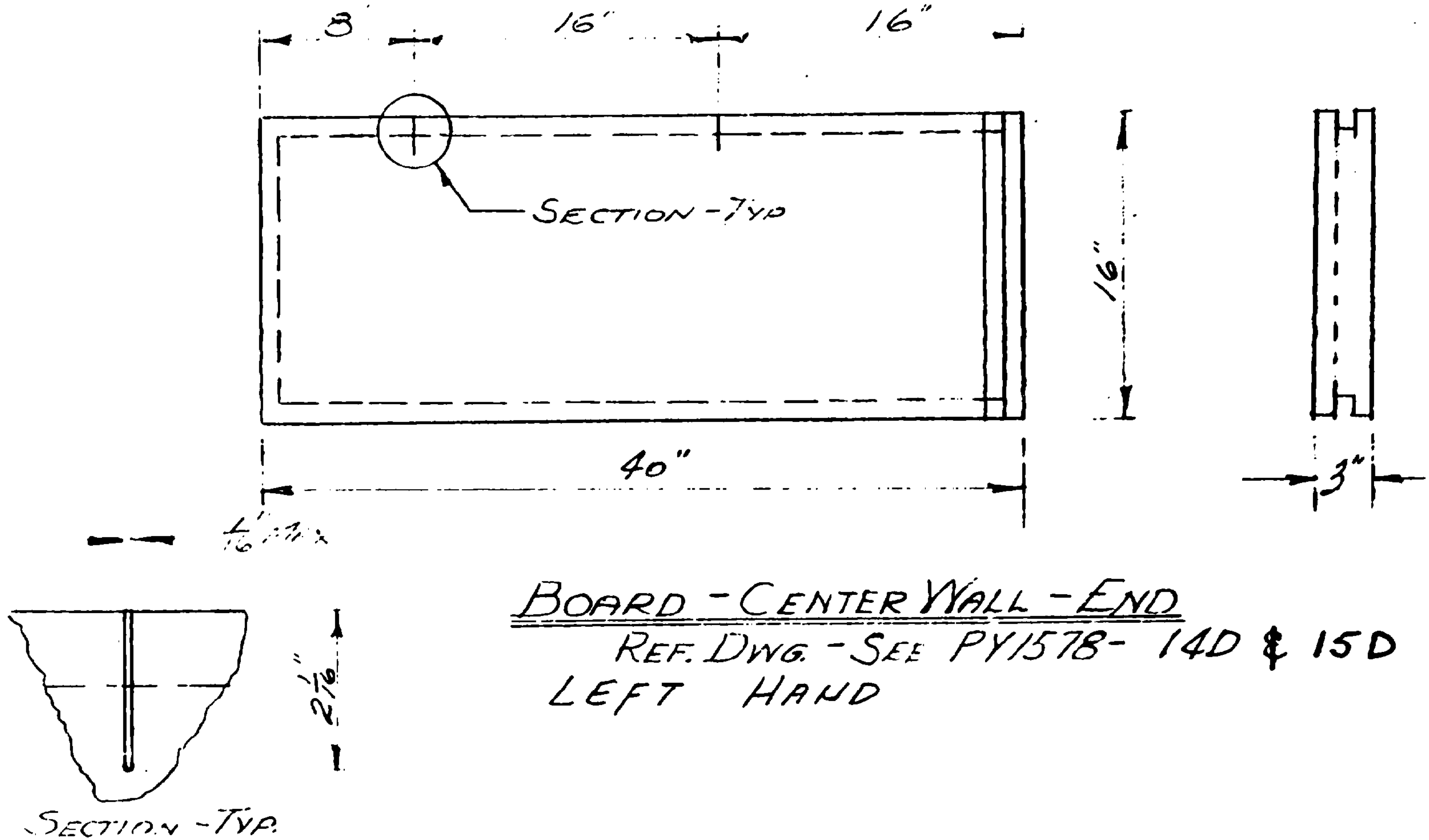
CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY	DATE 5/27/71	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY	DATE 5/27/71		JOB NUMBER PY1578
CHECKED BY	DATE 6/24	TIE SLOT LOCATION DETAILS BOARD - CENTER WALL - END - 3"	DRAWING NUMBER PY1578-34D
APPROVED BY	DATE 6/24/71		



CONTRACT NUMBER DASA01-71-C-0018

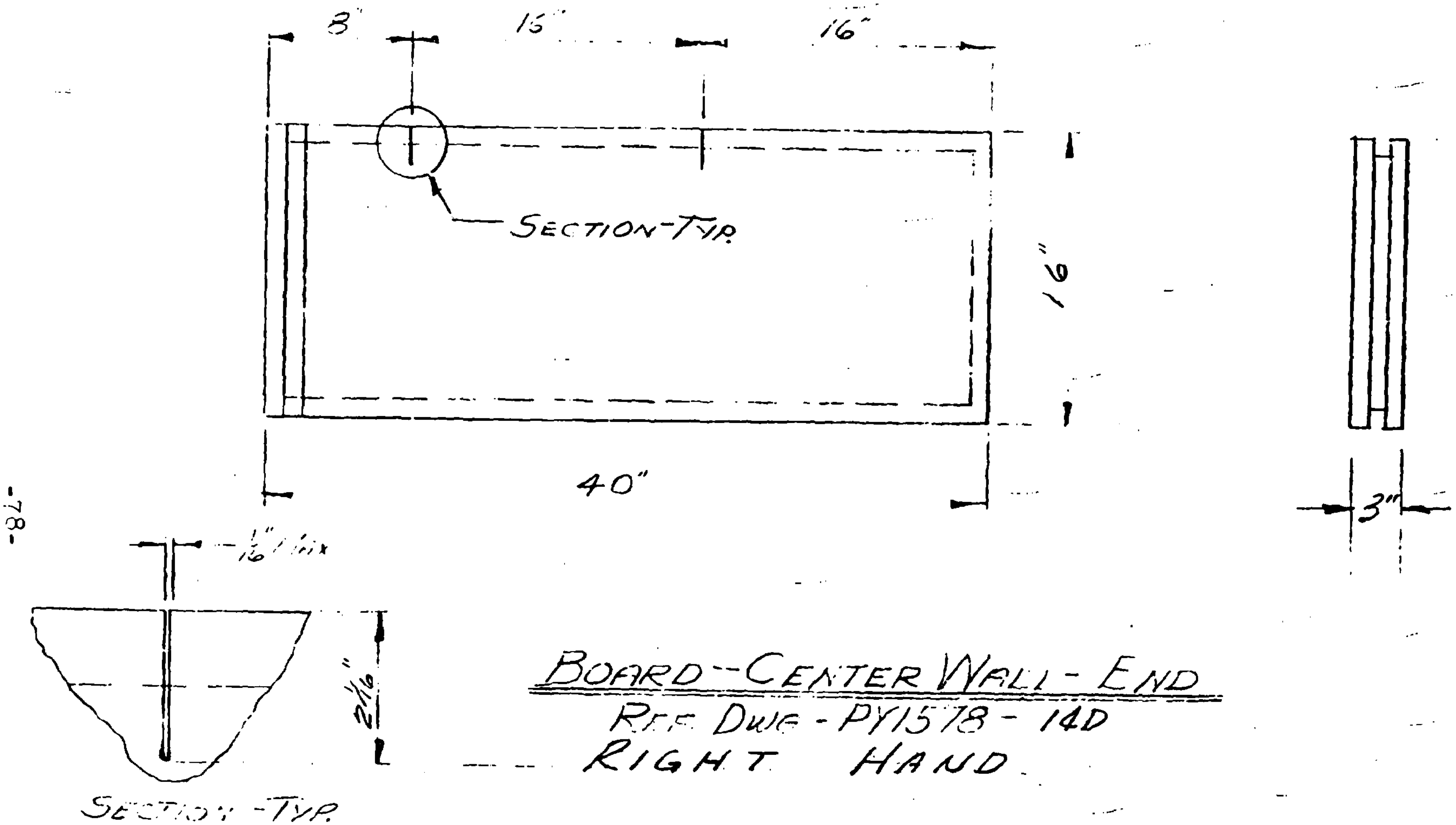
DESIGNED BY [illegible]	DATE 5/27/71	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY [illegible]	DATE 5/27/71		JOB NUMBER PY1578
CHECKED BY QW	DATE 6/24/71	TIE SLOT LOCATION DETAILS BOARD - WING WALL - 3"	DRAWING NUMBER PY1578-35D
APPROVED BY QW	DATE 6/24/71		



BOARD - CENTER WALL - END
REF. DWG. - SEE PY1578- 14D & 15D
LEFT HAND

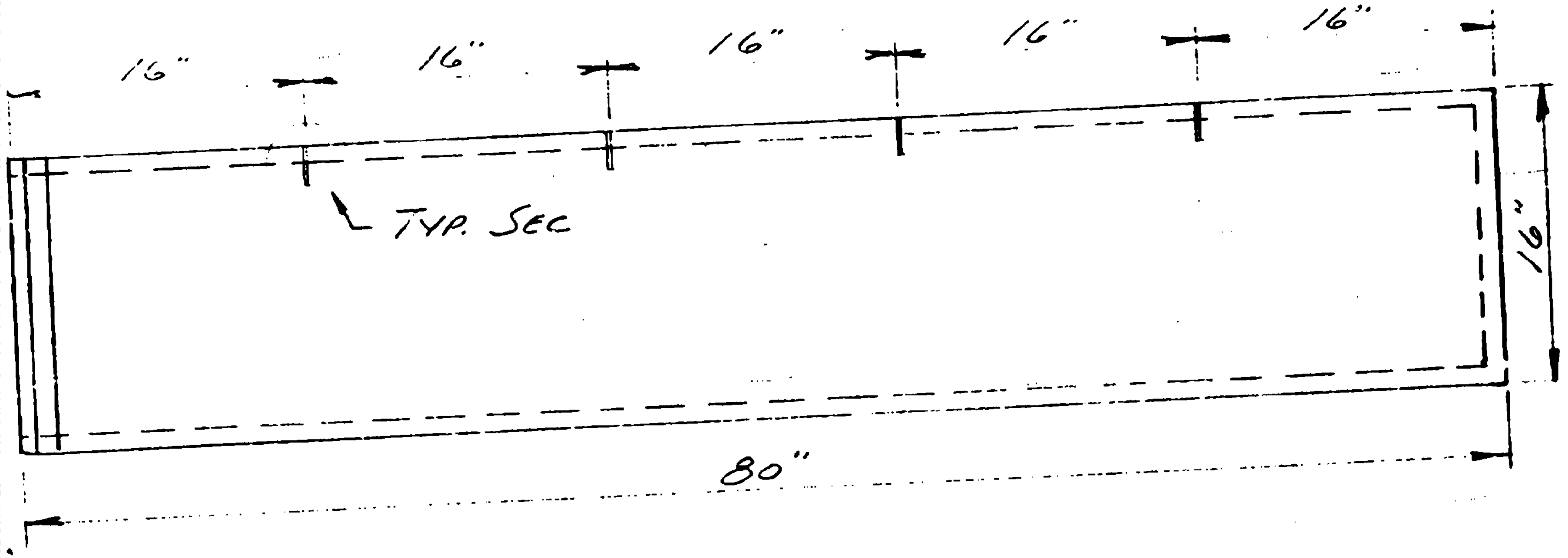
CONTRACT NUMBER DASA01-71-C-0018

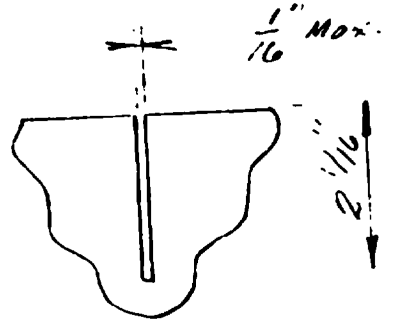
DESIGNED BY	DATE 7/28/71	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY	DATE 7/28/71		JOB NUMBER PY1578
CHECKED BY	DATE 6/24/71	TIE SLOT LOCATION DETAILS BOARD - CENTER WALL - END - 3"	DRAWING NUMBER PY1578-36D
APPROVED BY	DATE 6/24/71		



CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY	DATE	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER 1841-600
DRAWN BY	DATE		JOB NUMBER PY1578
CHECKED BY	DATE 6/24/71	TIE SLOT LOCATION DETAILS BOARD-CENTER WALL-END -3"	DRAWING NUMBER PY1578-37D
APPROVED BY	DATE 6/24/71		





TYPICAL SEC.

BOARD- CENTER WALL - END
RIGHT HAND
REF. DWG. PY1578 - 8D

CONTRACT NUMBER DASA01-71-C-0018

DESIGNED BY: AJP, DATE: 9/24-71	THE DOW CHEMICAL COMPANY MIDLAND MICHIGAN	ACCOUNT NUMBER: 600-1841
DRAWN BY: AJP, DATE: 9-24-71		JOB NUMBER: PY1578
CHECKED BY: DATE:	TIE SLOT LOCATION DETAILS BOARD - CENTER WALL - END - 3"	DRAWING NUMBER: PY1578-52D
APPROVED BY: DATE:		

APPENDIX C

SAND HANDLING EQUIPMENT

1.	Littleford Bros., Inc. 4141 Airport Road Cincinnati, Ohio	Screw Conveyors
2.	S. Howes Co., Inc. Silver Creek, New York	Belt Conveyors Screw Conveyors Buck Elevators
3.	The Bucket Elevator Company 24 Commerce Street Chatham, New Jersey	Belt Conveyors Buck Elevators Screw Conveyors
4.	Atlas Machine & Tool Corp. New Jersey	Mechanical Conveyors
5.	The Brady Conveyors Corp. Minneapolis, Minnesota	Belt Conveyors
6.	Conveyor System, Inc. Chicago, Illinois	Belt Conveyors
7.	Conair, Incorporated Franklin, Pennsylvania	Mechanical Conveyors
8.	Link-Belt Cont. Engr. Division FMC Corporation Chicago, Illinois	Belt Conveyors
9.	Stone Conveyor Company, Inc. New York, New York	Belt Conveyors
10.	Whitlock, Incorporated Division Applico, Incorporated Detroit, Michigan	Mechanical Conveyors
11.	Thomas Equipment, Ltd. Centerville, N.B., Canada	Front End Loader
12.	Clark Equipment Co.	Front End Loader
13.	John Deere Corp. Moline, Illinois	Front End Loader