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**408 355**

**CORRUGATED  
BOARD  
FURNITURE  
STUDY**

**NO. OCD · OS · 62 · 273**

**NORMAN STEUER ASSOCIATES  
SAN FRANCISCO, CALIFORNIA**

**PREPARED FOR THE DEPARTMENT OF DEFENSE - OFFICE OF CIVIL DEFENSE**

**JUNE 1963**

OCD REVIEW NOTICE

This report has been reviewed in the Office of Civil Defense and approved for publication.

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## CORRUGATED BOARD FURNITURE STUDY

### I. BACKGROUND

A. Corrugated board furniture was previously tested successfully in the U.S.N.R.D.L. 100 person experimental shelter.

B. Suitability of experimental furniture was observed.

C. During the first tests in 1959 shelterees complained about the lack of seats, especially seats with backs.

D. Newly developed corrugated chairs and benches (by Norman Steuer Associates) were tried in July 1960 with the result that all chairs failed completely in 36 hours but the benches, although in poor shape, lasted a full five days.

E. Structural analysis of the chairs showed that although strong enough there was no provision for locking the slots tightly. Any rocking motion imparted to the chair by the user caused the seat section to work loose from the back. Entire weight of the occupant then caused the top taped section to break loose.

F. Investigation of benches showed the basic design to be sound but the corrugated board was too light.

G. Abrasive action of cement floor on pedestal support bases indicated that pedestals should have greater area (in board thickness) of contact with floor to cut down on abrasive and crushing effect.

H. Discussion with NORMAN STEUER ASSOCIATES and fabricators resulted in a lock-type development tongue being cut from chair back to connect through pierced back. A pencil, dowel or tightly rolled tube of paper placed through the hole in the tongue locked it against the back.

I. Heavier board, 350-lb. and 500-lb. (bursting strength) was recommended for next chair and bench prototype tests.

J. Chairs and benches were placed in use in the U.S.N.R.D.L. Cafeteria for a two-week period.

K. Every effort was made to expose the corrugated board furniture to maximum wear and some people were observed walking and jumping on the horizontal surfaces with no appreciable destructive effect to the board.

L. A table prototype, of corrugated board, was discussed with NORMAN STEUER ASSOCIATES but due to questions of fabrication and imminence of the next test no prototypes were built.

M. Following the two-week U. S. N. R. D. L. Cafeteria test the furniture was examined for defects and failures. As a result of this examination the 500-lb. (bursting strength) bench and chair, the former with 5 pedestals rather than 4, were selected as most satisfactory at this time.

N. Subsequent tests on the bench proved the only collapse was at the extreme end due to a cantilever condition.

O. Heavier board pedestals resisted wear on contact with cement floor.

P. Repeated assembly and disassembly of the chair had no deleterious effects. Miscellaneous holes, knife marks, etc., did not weaken the chairs appreciably.

## II. SUMMARY OF U. S. N. R. D. L. PRELIMINARY TESTS

A. Corrugated board constitutes a cheap, practical answer to the problem of outfitting shelters.

B. It is now felt that development of a suitable table could be effected that would cost perhaps 50% less than the cost of conventional tables now used.

C. There is a possibility of simplification of table top and addition of a surface coating to protect the board and aid in cleaning.

## III. CONTRACT NO. OCD-OS-62-273 (June 30, 1962)

A. This contract was to continue the development of the corrugated board furniture through design, prototype construction and testing of a table for 10 people, the design of low cost storage bins and the improvement of bench and chair design.

B. Contractor (Norman Steuer Associates) was also to provide production engineering to the point where accurate costs of large scale procurement could be estimated.

## IV. OPERATIONAL STEPS (as proposed by contractor)

- A. Preliminary Research and Study
- B. Preliminary sketches and scale models
- C. Full scale models
- D. Testing
- E. Review results

(The above method of operation was followed during the several test stages covered later in this report.)

## V. PRELIMINARY RESEARCH AND STUDY

A. U. S. N. R. D. L. reports were reviewed and human engineering studies were made to form a check list of important factors to study as well as improvements that would be plus factors. Each group of steps prior to testing followed a procedure of Research, Study, Numerous Sketches, 1/4 and 1/2 scale models to test.

B. During this period and subsequent review, we developed a list of factors against which we could check each proposed design, or model. A number of our list of check points are in the following:

### 1. BOARD MATERIAL

- a) Strength of board in relation to weight and low cost.

### 2. BOARD SURFACE and/or PROTECTIVE COATINGS

- a) Resistance to tear, scuffing, soilage, humidity, flame, hot dishes, extensive abrasion.

### 3. BOARD FATIGUE

- a) At scores, joints, taped sections, ends or top surface pressure.

### 4. BOARD UNITS

- a) Least possible number of pieces to aid in simplified assembly and disassembly.

### 5. BOARD RESILIENCY

- a) Greater comfort for use of bench and chair without sacrificing material board strength.

### 6. ASSEMBLY and DISASSEMBLY

- a) Simple method to aid in frequent assembly and disassembly without accelerating board wear.

### 7. HUMAN ENGINEERING FACTORS (Project items in use)

- a) A minimum of rough, corrugated edges at seat, leg or arm contact level with table, bench or chair.
- b) Sufficient leg room at table and bench.
- c) Sufficient elbow room at table.
- d) Stability of table laterally and at four corners.
- e) Ease of lifting table and bench to clean underneath.

- f) Ability to stack tables and/or benches without disassembling.
- g) Minimum pedestal contact with floor to aid in minimum cleaning.
- h) Development of smaller table and bench units to allow for flexibility of use and ease of handling.
- i) Higher back on chair seat for comfort.
- j) Foolproof seat lock on chair.
- k) Simple printed instructions for assembly.

8. ADDED FEATURES (based on visual or color psychology)

- a) Color as part of board fabrication, protective coating or standard print (this latter is included in board fabrication cost) to make khaki-colored kraft board less drab.
- b) Use of color to print checker boards or other items on table top.

VI. FIELD TESTS (#1 and #2)

A. As the more promising designs progressed through the 1/4 and 1/2 scale model stage and checked out on the above list, we ordered full scale models to test under various conditions. In some cases we made full scale models ourselves.

B. From September 1962 to May 1963 a total of 15 separate tests of table, bench and chair designs were conducted in different places of Northern California and Washington, D.C., with test time ranging from 36 hours to two months.

C. First test was made in the galleries of the Marin Society of Artists of Kentfield, California to determine suitability of the first developmental models, in use, by adults and children.

D. Second test was made, concurrently, at U.S.N.R.D.L., Hunters Point, San Francisco, California, through contacts with Dr. Richard I. Cole. This test was by adults only in the cafeteria area.

E. Both test areas had 8' tables and benches and 10' tables and benches.

F. TEST RESULTS

1. The 10' table and 10' benches were revealed as too heavy and unwieldy to handle and bend for assembly and use.

2. Fractures occurred when bending at score lines was attempted.



3. Stability of table was considerably heightened by use of a horizontal corrugated girder placed under the entire table top length. However, this proved difficult in assembly.

4. In contrast to the wide hexagonal pedestals tested in 1960 these project items featured slender hexagonal pedestals.

5. The slender pedestals proved stronger than the broad hexagonal ones.

6. Rips occurred in assembly, partially due to the extreme length (10').

7. Intricate interlocking joints and tuck flaps (to achieve stability) slowed down assembly of project items.

8. At the end of two months the tables were in fair condition but benches had collapsed due to factors discussed above.

9. All items were found adaptable to use by both adults and children.

10. It was suggested by the above that a 5' table and 5' bench be considered as an alternative development.

#### VII. INTERIM RESEARCH

A. Further sketches, scale models and research time was devoted to table and bench to correct deficiencies uncovered in the first two tests.

#### VIII. FIELD TESTS (#3, 4, and 5)

A. These three tests were conducted at the office of Norman Steuer Associates, U. S. N. R. D. L. and at the Civil Defense Training Center at Alameda, California.

B. New chairs were of an improved design to give a higher back rest to the occupant and a possible simpler assembly operation.

#### C. TEST RESULTS

1. One chair was assembled and disassembled 60 times with no apparent wear or fatigue on taped joints, scores or slots.

2. This same chair was exposed to a 40° to 80° temperature change, being placed near a steam radiator with no effect on board strength, taped joints, scored areas, surface texture or open corrugations.

3. Groups of 6 chairs at Alameda were subjected to a tabulation of individual use. Four of these were used respectively for a total of 3, 8, 8, and 14 hours.

4. Shortest time use was 1 minute and longest time use was 7 hours.

5. Weights of people ranged from 130 lbs. to 225 lbs.

#### IX. INTERIM RESEARCH

A. From the above data we instigated further structural design changes in the chair.

B. In the meantime research on the table and bench had culminated in new prototypes.

#### X. FIELD TESTS (#6)

A. The sixth test was run at Survival Associates, Inc. in Livermore, California in January, 1963. Arrangements were made with Dr. Keller and Dr. Hudgins of the Lawrence Radiation Laboratory in Livermore. These two scientists and their neighbors and families bought land and constructed their own underground fallout shelter to house a total of 100 people. This structure is 25' x 142'.

B. Due to their arrangement of individual family rooms, there are three central rooms left with dimensions of 9' x 45'. At the time of their test, we had 5' tables and benches under fabrication but not ready for the test.

C. Consequently we submitted, for testing, 10' and 8' tables and benches of a new one piece top construction that included a horizontal, vertical and diagonal bracing system and narrow 4-sided diamond shaped pedestals.

D. One table and bench was assembled in the presence of Dr. Keller. We proceeded to help him carry the remainder of the project test items (unassembled) into the shelter. They took over from there.

E. This new design eliminated all rough and open corrugations on any horizontal, vertical or diagonal surfaces except at both extreme ends of tables and benches.

F. TEST RESULTS (Following are quotes from Dr. Keller's letter).

1. Tables and benches were easy to assemble. In fact some were assembled by some of the older children (with no directions except those of Dr. Keller).

2. None became loose or tended to disassemble during the period.

3. Tables and benches longer than 5' were too awkward to handle due to restricted room and size of 8' and 10' board pieces.

4. Room sizes at SAI forced them to cut all units, greater than 5' in length, into two sections after 8 hours use.

5. All other dimensions were completely practical and adaptable.

6. Tops of tables and benches should be sealed. (This problem had been under study for some time.)

7. Tops of tables and benches should be reinforced by a flat rectangular piece of corrugated between top and pedestals. (These test items were of single weight board while the new 5' items, under fabrication, were already being made of DW (double wall) construction. At this point we discarded the 10' and 8' items except for the latter in comparison tests.)

8. Pedestals proved extremely strong.

#### XI. INTERIM RESEARCH

A. Modular arrangement of 5' units and protective coatings were studied at this time.

#### XII. FIELD TESTS (#7 and #8)

A. Seventh and eighth tests were made at OCD Region 7, Santa Rosa, California and again at Alameda, where we set up 2 (8') benches and 1 (8') table, and 4 (5') benches and 2 (5') tables of double wall construction for a comparison of ease of assembly, disassembly, ease of handling, space use, flexibility of use, modular design, etc.

#### B. TEST RESULTS

1. A member of our staff and I called on both Santa Rosa and Alameda.

2. At Santa Rosa a woman assembled these items before a group of 6 men and 6 women to show the ease with which it could be done.

3. Strength, mobility and flexibility of the 5' tables and benches was easily proven.

4. It was agreed (by pictures taken on the spot) 4 (5') benches around a square of 2 (5') tables provide a more roomy arrangement where possibly 12 to a maximum of 14 to 16 people (adults and children) could be placed. This actually lowers the per person use cost.

5. The 5' table and bench has a number of possible combinations.

a) One 5' table and two 5' benches to seat 4 or 6 in a small intimate group.

b) Two 5' tables and four 5' benches arranged tandem to seat 10.

c) Two 5' tables and four 5' benches in a square (4' x 5') to seat from 10 to 16. This has the advantage of an arrangement more like a home than like a barracks or mess hall.

### XIII. INTERIM RESEARCH

A. Protective coatings reached a degree of perfection ready for test, as at this point it was fairly certain all engineering and practical human engineering factors (in assembly and use) had been resolved.

### XIV. FIELD TESTS (#9, 10, 11, 12, 13, 14 and 15)

A. First protective coatings were applied to multiple test units in March, 1963.

B. Since these prototypes were still produced by hand, the coating had to be likewise applied. In mass production, as estimated in our preliminary pricing by cost analysis, this coating would be applied automatically as part of the automatic corrugated fabrication.

C. Coating (Quilon C) chosen for this test has the following plus advantages:

1. Water proofs the surface
2. Flame resistant
3. Soil resistant
4. Strengthens the board
5. Abrasion resistant
6. Flexible and will not crack
7. Applied after corrugated board die cutting, it will protect open corrugated edges
8. Can be applied in colored pigment
9. Has FDA approval and is non-toxic

D. Multiple sets of tables and benches were set up at Santa Rosa, Alameda, and Hunters Point by April 1, 1963 and April 2 in Washington, D.C. This latter set was assembled, disassembled by Norman Steuer in the presence of many OCD officials.

E. Salient points and advantages were explained to this latter group.

F. In addition, within the past month three single tests (1 table and 2 benches) have been made by Norman Steuer at his residence and that of two other people to get what is a more comparable consumer reaction.

1. Foods of various types and temperatures are tried on table surface.

2. People of diverse weights sit upon the benches.

3. Tables and benches are tried on uneven ground to test stability and strain points.

4. Assembly is directed by vocal orders (no printed directions) to test simplicity.

#### XV. RESULTS OF TESTS

A. It is apparent, that the 5' prototypes of table and bench are as close to human engineering perfection as is possible to attain at this time.

B. Protective coating, in color acceptable to all, needs further testing.

#### XVI. CORRUGATED CHAIR

A. A simple, and we believe, foolproof locking device is being tested at this time. Final observations will be made in the final report. (See Page 15)

B. It became apparent in all other previous tests, of other designs of chairs, that we were faced by vital problems of assembly.

C. The original chair folded flat, stored flat, could be assembled and disassembled easily and without confusion.

D. In attempting to get a square or x-shaped base (rather than triangular for greater stability) we were forced to make the prototypes of at least two pieces.

E. This had a pronounced disadvantage in that one or another of the pieces, when the chair was disassembled, could get mislaid and the remainder was useless.

F. Our decision, at this point, was to return to the original triangular based chair because of its general stability, one piece construction, no lost parts, ease of assembly and minimum possible cost through less use of board.

G. It may be wise to note at this time that this chair has one limitation found also in delicate wood chairs, namely, no one should tip it back because this puts undue strain on its stability.

H. Additional tests are now being finalized on a "cross lamination" corrugated board which would enable us to use a stronger, lighter weight board with a lower cost per unit.

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## XVII. SUMMARY

### A. CORRUGATED BOARD (Advantages)

1. Lower cost, in relation to other materials.
2. Lighter weight and easier to store and stack.
3. Lighter weight and easier to move about.
4. Lighter weight combined with strength.
5. General fabrication anywhere.
6. Disposability of units (no surplus problem).

### B. TABLES AND BENCHES

1. Can be stored flat when not in use.
2. 5' size, of table and bench, is very easy to handle.
3. 5' size is very easy to assemble and disassemble.
4. Contemporary design appearance is very pleasing. (See pages 16 and 17)
5. Modular design can seat small intimate groups (1 table and 2 benches) easily without wasting space.
6. Modular design (2 tables and 4 benches) can seat at least 10 (in tandem). (See page 14)
7. Modular design (2 tables and 4 benches in a square) can seat 12 possible (6 adults and 6 children) in a several family grouping of homelike table conditions.
8. On this basis less tables and benches may be needed.
9. When not in use tables and benches need not be disassembled but merely stacked one on top of the other out of the way. Lightness of units makes this easy.
10. The modular design will permit reuse and recombination of units daily into other uses.
11. Modular design provides work and activity to alleviate monotony.
12. 5' size makes it possible to use for card games without using a larger 10' space.
13. Other combinations are possible beyond the modular design arrangements mentioned.

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14. Protective coating makes surface fire retardant.
15. Protective coating makes surface easily cleaned.
16. Protective coating makes surface tougher.
17. Protective coating is non-toxic.
18. Minimum of rough edges, of corrugated, at seat, leg and elbow contact with furniture.
19. Protective coating can be provided in colors to avoid khaki-colored kraft board monotony.
20. Pedestals have minimum contact with floor to avoid abrasion and aid cleaning around.
21. Pedestals have great strength and give maximum leg room.
22. Pedestals lock securely with no possible chance of error in assembling.
23. Pedestals and one-piece horizontal-vertical-diagonal bracing system of top, allow no wobble of unit horizontally, vertically or diagonally.
24. Simple assembly of table and bench can be accomplished by a woman or an older child.
25. Minimum number of assembly pieces aids in lower cost and fewer mistakes in assembly.
26. Simple assembly will reduce need of complicated printed instructions.
27. Bench or table can be lifted easily by a woman or child.
28. Simple design and interlocking slots (pedestal and top) eliminate board fatigue or tearing.
29. Simple design of table and bench makes floor cleaning easy through minimum pedestal contact with floor.
30. Light weight of units makes cleaning easy since each can be lifted by a woman or a child.
31. It is possible, at no extra cost, to use table top as a game area by printing a checker board on it or some other device.
32. Top could also be printed in a table-cloth-like pattern such as stripes or checks.
33. Table top or two benches could be safely used as a rest area or emergency bed.

34. There is a maximum of leg room at tables due to minimum use of pedestals.

35. Anticipated cost for a 100 person shelter:

a) 10 (5') tables @ \$1.43 each	\$14.30
20 (5') benches @ 1.00 each	20.00
	<hr/>
Total	\$34.30

b) This cost amounts to 34¢ per person.

c) On a 2-week basis (3 meals per day) or 42 uses of each seat or eating area it amounts to \$0.008 per person use. (This does not take into account extra use for relaxation, card playing, games, etc.)

d) \$34.30 total cost is 90% less than previously projected 'rock bottom' prices of wood tables and benches.

C. CHAIR (See page 15)

1. Does not have as many advantages as table and bench because its uses (not widespread or general) are limited to relaxing.
2. It is lightweight.
3. Holds 250 to 300 lbs. (per person weight).
4. Has a foolproof back tab lock.
5. Styling, although contemporary, is not as 'sheer' as that of table and bench and for the definite reason of avoiding monotony.
6. Has been assembled and disassembled 60 times without board fatigue.
7. Can be made in colors.
8. Can be assembled by man, woman, or child.
9. Can be lifted and carried by a child.
10. Should not be tipped back (any more than any fragile wood design chair).
11. Price, at this time, although low is not firm enough to be quoted.

D. BIN (Personal effects box)

1. Prototype design and price will be available in the final report. (Price is estimated at 15¢ each as of June 1963)



E. FINAL

1. Corrugated board has proven to be a low cost, light weight, multiple use, colorful material of easy eventual disposability after its 100% use has been expended. Other potential uses, within the shelter should be carefully and methodically studied.

# FIVE FOOT TABLE & BENCH MODULES

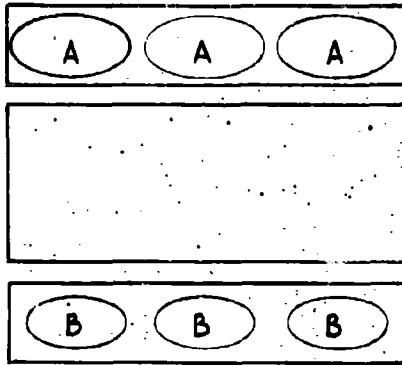
## SEATING POSSIBILITIES

A - LARGE ADULT (OVER 150 LBS.)

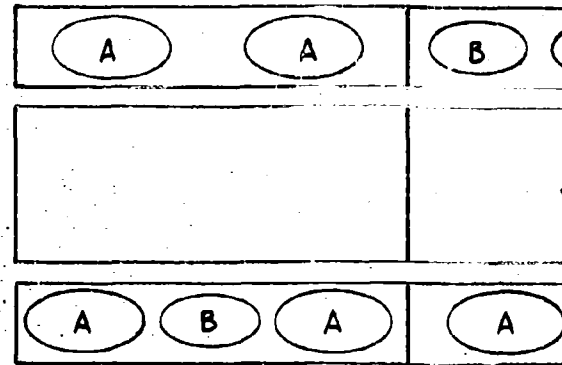
C - CHILD (AGE 6 TO 12)

B - SMALL ADULT (OVER 120 LBS.)

D - CHILD (UNDER 6)

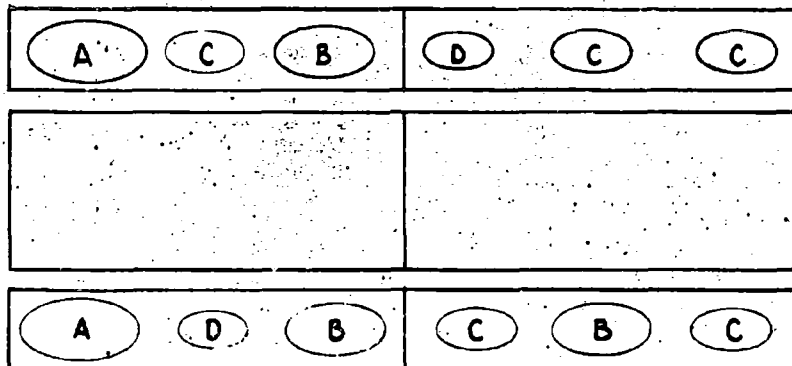


SIX PERSONS

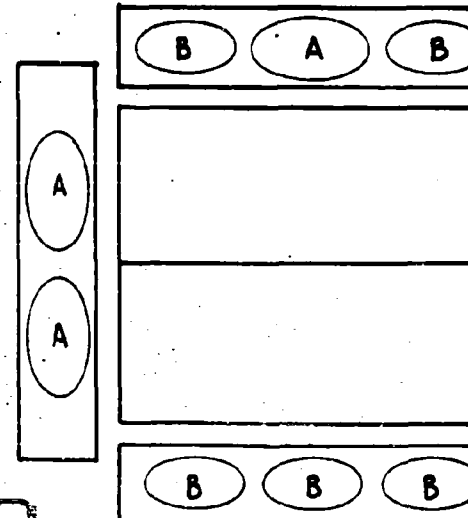


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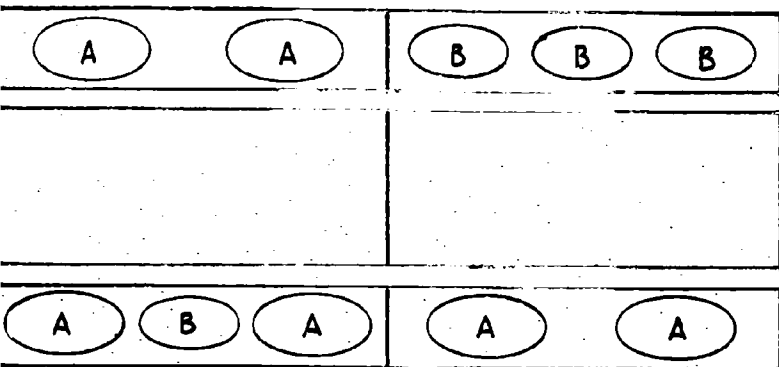
TWELVE PERSONS



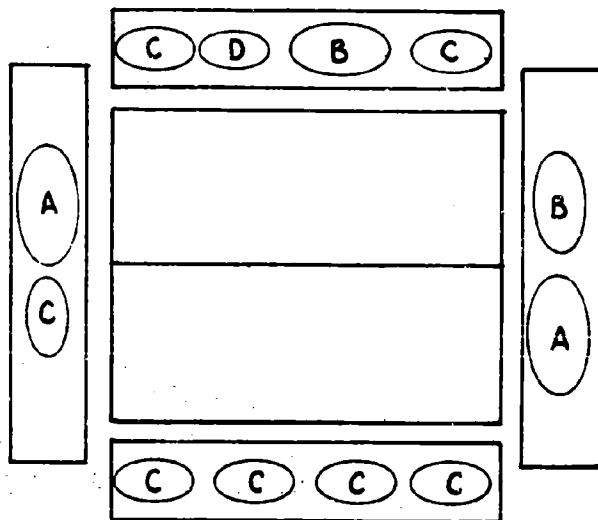
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**1**



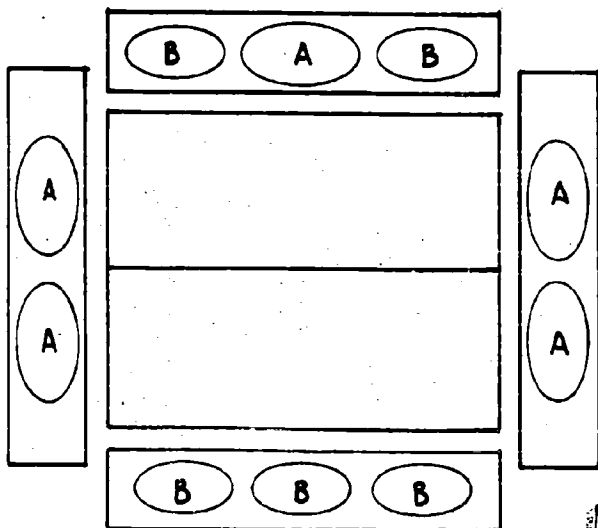
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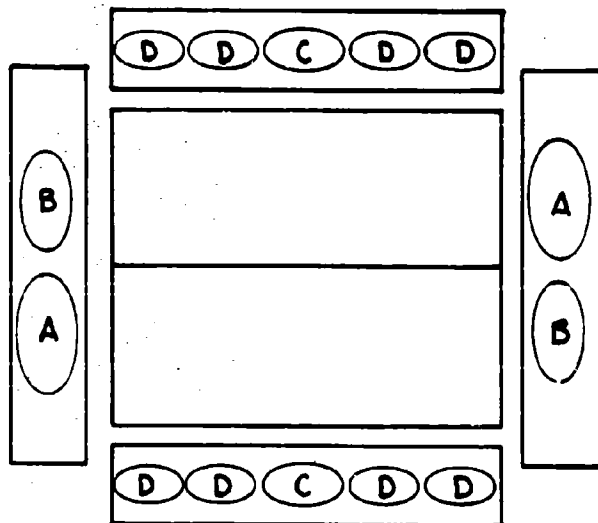
TWELVE PERSONS

THESE TWO ARRANGEMENTS ARE POSSIBLE WHEN CHILDREN ARE INVOLVED.

TEN PERSONS



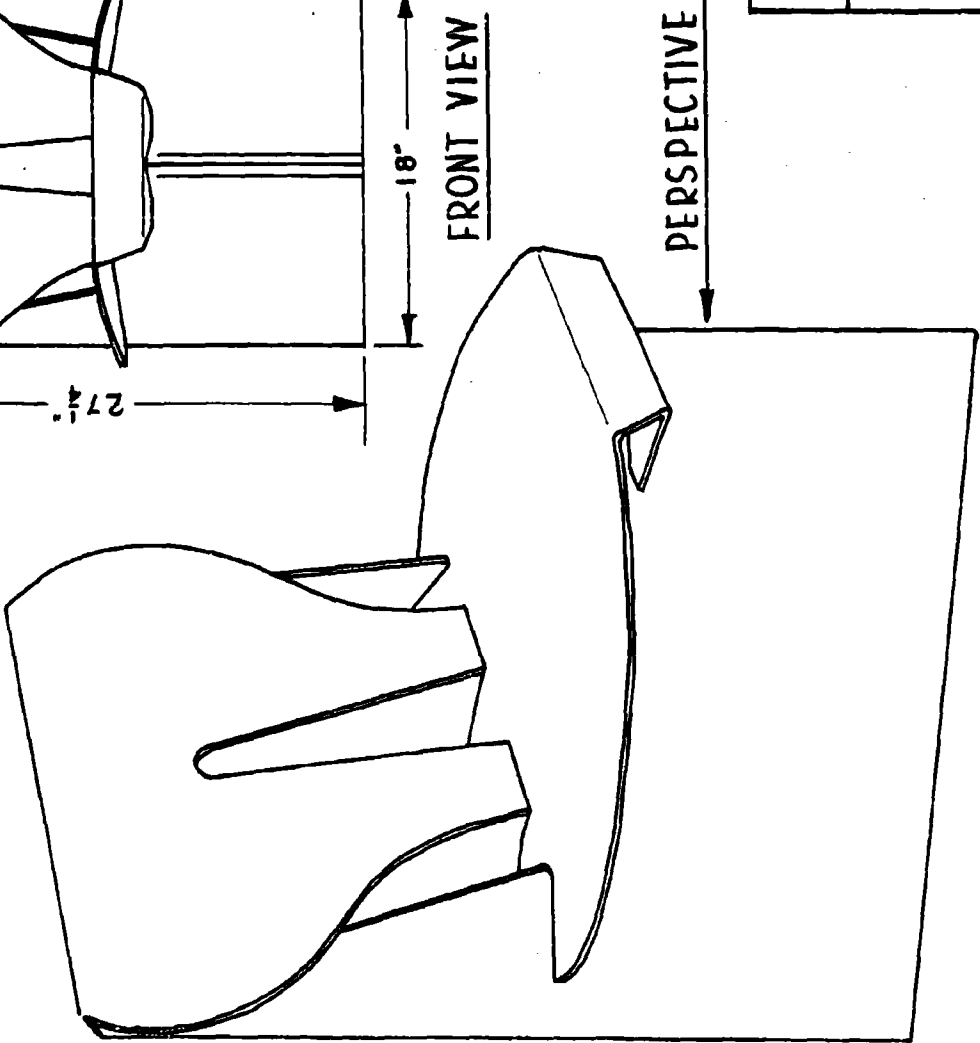
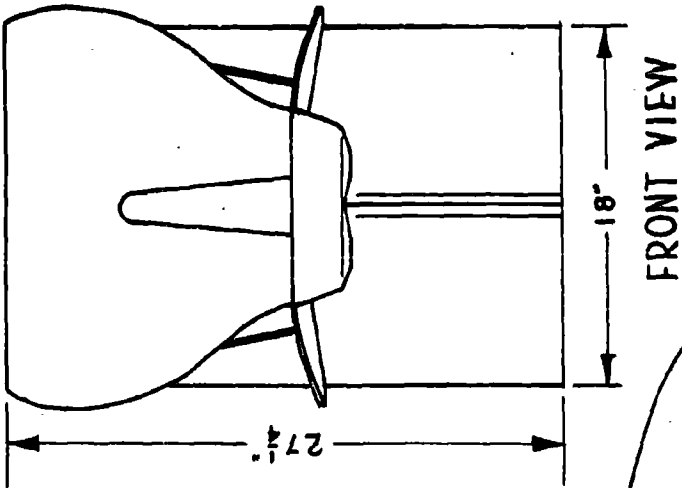
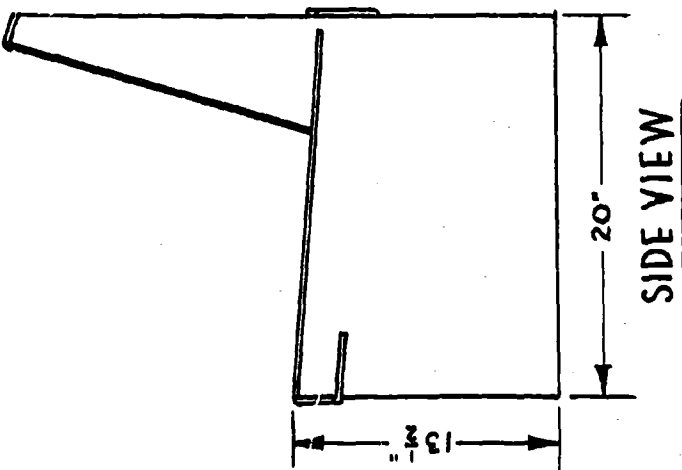
FOURTEEN PERSONS



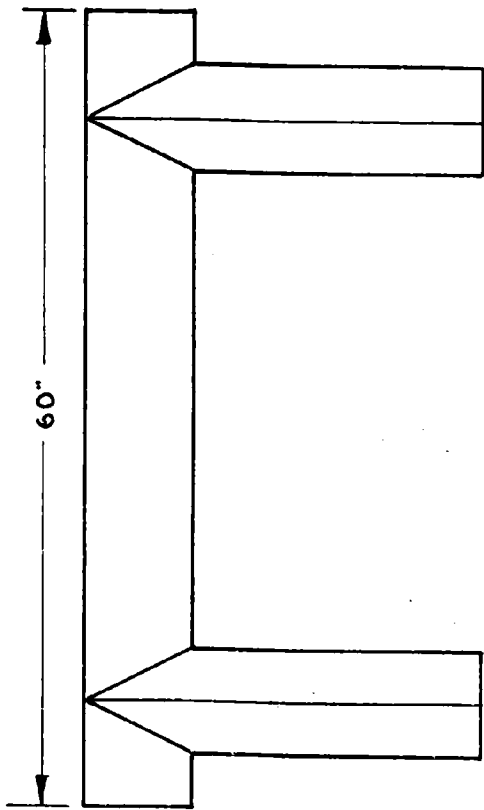
**2**

**NORMAN STEUER ASSOCIATES  
68 POST ST., SAN FRANCISCO, CALIF.**

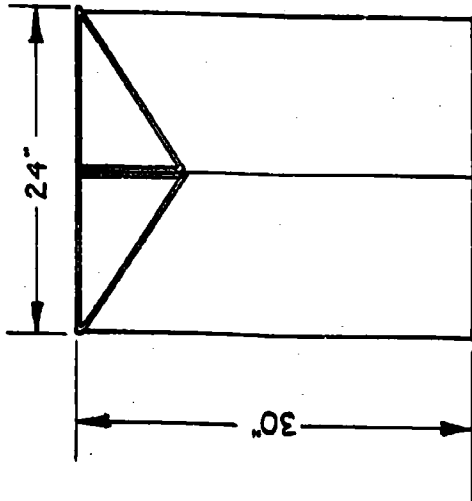
**SUBJECT:  
CORRUGATED BOARD TABLES  
AND BENCHES  
PATENT PENDING**



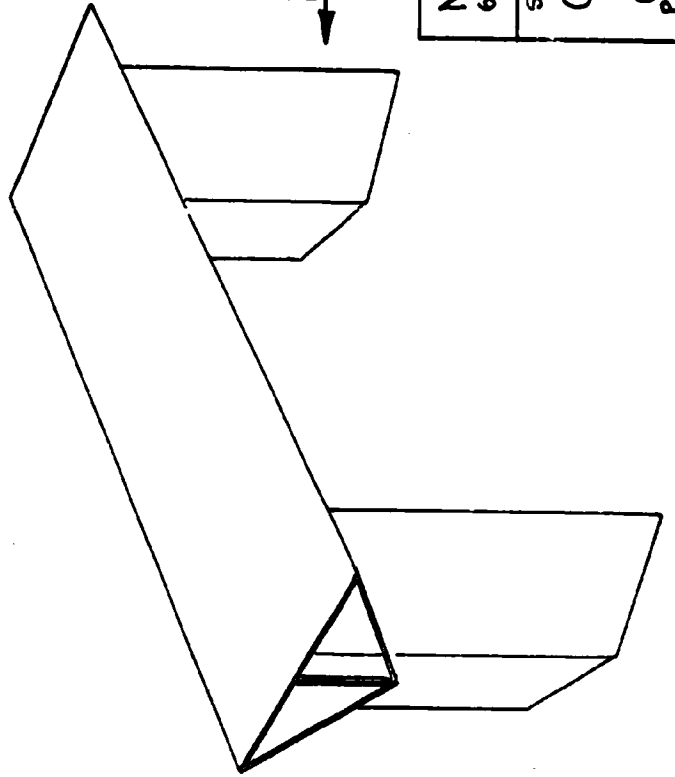
<b>NORMAN STEUER ASSOCIATES</b> 68 POST ST., SAN FRANCISCO, CALIF.	
<b>SUBJECT:</b>	<b>CORRUGATED BOARD CHAIR</b> BASIC DESIGN OF 1964 WITH IMPROVED TAB LOCK
<b>PATENT PENDING</b>	



SIDE VIEW

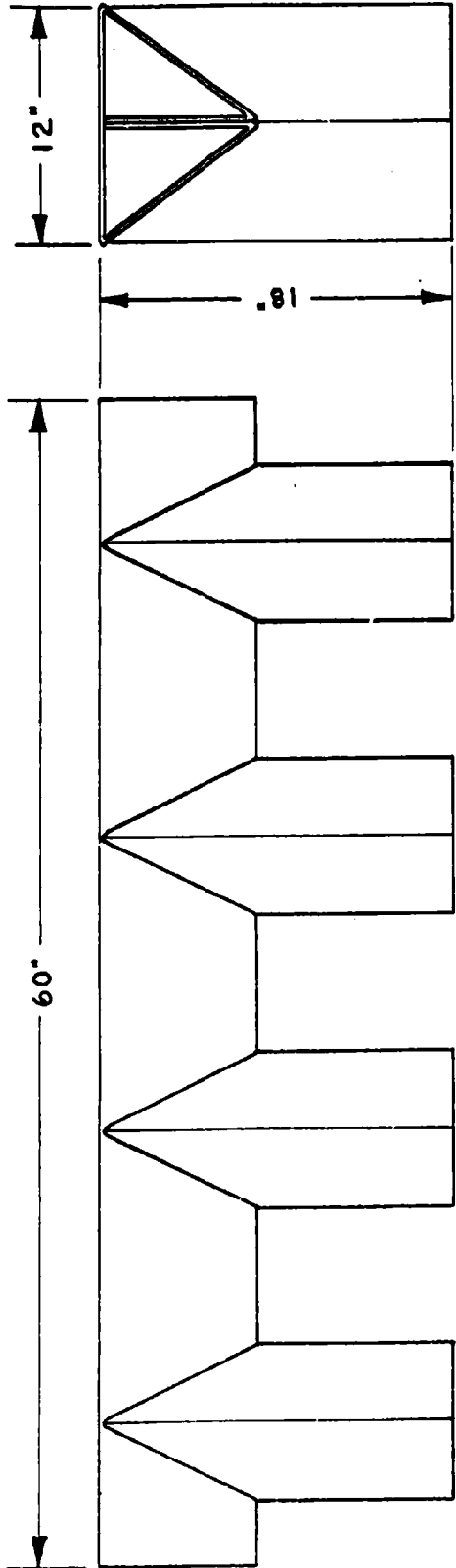


END VIEW



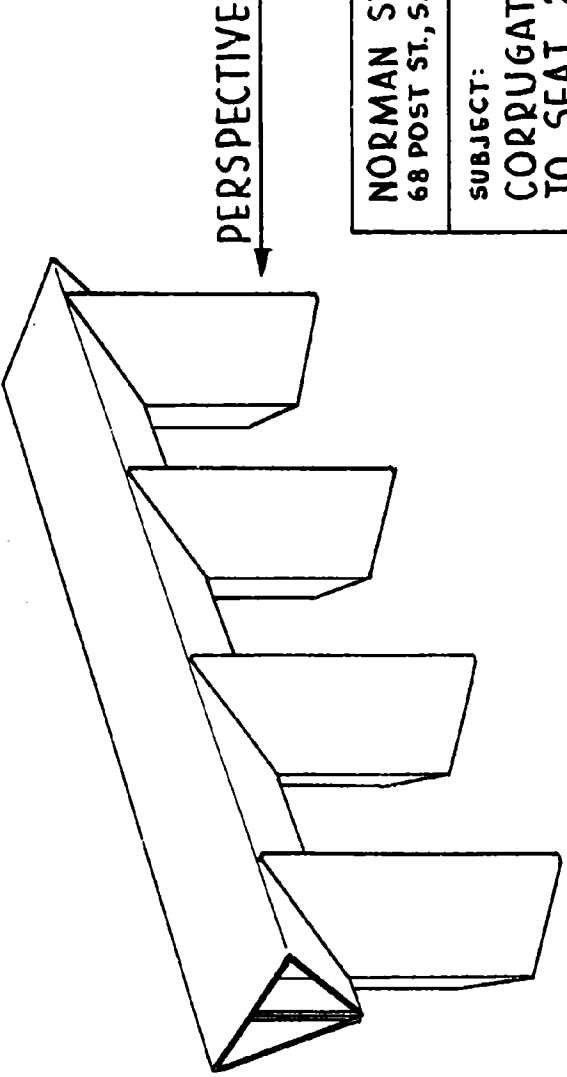
PERSPECTIVE

<p><b>NORMAN STEUER ASSOCIATES</b>          68 POST ST., SAN FRANCISCO, CALIF.</p>	<p><b>SUBJECT:</b>  <b>CORRUGATED BOARD TABLE</b>  <b>TO SEAT 10 PEOPLE</b>          (WHEN USED WITH ANOTHER 5 FOOT TABLE)  <b>PATENT PENDING</b></p>
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SIDE VIEW

END VIEW



PERSPECTIVE

NORMAN STEUER ASSOCIATES  
68 POST ST., SAN FRANCISCO, CALIF.

SUBJECT:  
CORRUGATED BOARD BENCH  
TO SEAT 2 OR 3 PEOPLE  
PATENT PENDING