A SYSTEM OF INDUSTRIALIZED HOUSING
FOR
DEVELOPING NATIONS

by
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TECHNOLOGY

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July 19, 1962

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Dear Sir:

A thesis entitled "A System of Industrialized Housing for Developing Nations" is hereby submitted in partial fulfillment of the requirements for the degree of Master of Architecture.

Respectfully submitted,

Jay R. Carow

ACKNOWLEDGEMENTS

THE AUTHOR WOULD LIKE TO EXTEND GRATITUDE FOR THE HELPFUL ADVICE AND CRITICISM OF THE FOLLOWING PEOPLE WITHOUT WHOSE ASSISTANCE THIS THESIS WOULD HAVE BEEN IMPOSSIBLE:

PROF. CARL KOCH

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A System of Industrialized Housing for Developing Nations

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B. Arch., Illinois Institute of Technology, 1961

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ABSTRACT

In today's world, dominated by industrial power, millions of people are without adequate shelter. While internationally many political and economic barriers exist, a solution to the problem lies dormant in the industrial potential of the United States.

This thesis will present a design whereby the productive capacity of Armco Steel and Ford Motors could produce a low-cost, light-weight housing unit with enough flexibility to provide a variety of planning solutions. The product would be easily transported to a developing country where assembly would utilize native labor and materials.

Thesis Supervisor: Carl Koch

I. INTRODUCTION

The world of today faces a problem of providing shelter for its rapidly increasing population. The nations most affected by this increase are those just beginning their conversion from an agrarian to an indistrialized economy. These countries have the highest birth rates and the most fluid shift of population from rural to urban areas. Great quantities of people live in subminimal housing on the edges of the large cities in these developing nations. Attempts to alleviate this condition through public housing have failed due to an inability to provide an adequate number of units.

While the peoples of the world live in hovels, the great productive capacity of America's industry engages itself in manufacture of products for a style-conscious nation. The irrational demands of Americans force changes in design continually at a cost of millions of dollars yearly. Military spending of government dollars absorbs a great bulk of industrial power. With a reduction in the arms race this money could be diverted to help foreign peoples. The often criticised foreign aid dollars could be used for the benefit of the people and not the rulers. American-produced housing units would be shipped abroad as aid and assembled with the foreign nations' labor.

II. PROGRAM

Before attempting to design a mass-produced housing unit a program is required which describes the American production facilities, and the labor, materials, climate, and needs of the foreign country.

Armco Steel and Ford Motors, the theoretical producers of the housing unit, provide a wealth of items, mainly in steel.

Armco's production is chiefly in sheet steel. From this sheet are fabricated structural members through welding; rolled sections, typical of which is the ribbed sheet used to cover walls and roofs; and connectors of all sizes and shapes. Armco distributes its large rolls of sheet metal, which often has a protective coat of aluminum or zinc applied at the mill, to fabricators throughout the country. The largest common roll is 96".

Rolled sections are produced from the rolls of steel. In a continuous operation the sheet steel is fed into a series of rolls. Each roll exerts a bending pressure upon the sheet until the desired shape is obtained after twenty or more rolls are passed through. This process is the least expensive method of stiffening thin metal in quantity. Any desired length may be cut from the rigidified sheet.

Armco Steel has taken a keen interest in building components. In fact, the majority of products from the Armco finishing plants consist of component parts for the assembly of buildings.

Ford Motors on the other hand produces complete items. Many of the materials destined for final assembly in the Ford automobile are products of Ford factories. Ford operates their own glass plants, steel mills, foundries, stamping plants, engine plants, and, of course, assembly plants. The economy of operation is achieved through quantity production involving efficient assembly lines. Most of the steel items in an automobile are products of stamping. Large presses with up to 200 tons of pressure exertion shape sheet steel into fenders, roofs, oil pans, doors, and other automobile components. Tolerances are minimal and stamped pieces fit easily together in the assembly line production. The largest stamped item of Ford is the station wagon roof--120" x 96". The assembly line funnels together parts and steadily turns out end products in a most effective manner. The final cost is low due to an inexpensive collection of bulk raw materials, company manufacture of component parts and materials, and quantity production.

While Armco and Ford could easily market a finished product from their facilities, unquestionably the housing unit should be of such a design as to preclude costly shipping charges for materials already available in quantity in the country of destination. Design should certainly necessitate a housing package of great compactness. The material of the house must prove to be economical both in original cost and transportation cost. This requirement places an emphasis on thin elements that can be nested one in another. Air space should be avoided if possible in shipping. Size is not too much of a factor in the shipping process but should be considered in the handling between port and final site.

At the country of destination native materials could be provided to aid in the construction and finishing of the house. Materials for insulation, doors, floor systems, and windows could be furnished from such common items as wood, earth, concrete, glass. Waste products could be considered as economical possibilities--wood chips, rice hulls, etc.

A possibility to be considered would be the advantage of using sub-assembly plants in the country of destination. At these plants stock items, shipped nested, could be assembled into larger, more substantial pieces. Plumbing, walls, windows, doors, wall panels and other housing components could be produced from American parts. Expensive American labor is avoided and precision workmanship which would not be available in the field is utilized.

Since the program would envision great quantities of housing, large pools of labor become a necessity in the country using the industrialized product. This labor organized into "construction battalions" would move from site to site erecting houses and instructing local people how to construct their own units from the packaged parts. After the construction workers moved to a different locale the operation could continue in the hands of the residents.

In the design of the unit inexperienced labor, as all of these workers would be initially, plays an important part. The design should be simple, constructed from few components, and provide tolerances for error. Pieces must not be overly large or awkwardly heavy so that a crew of more than two or three becomes necessary.

The houses should not be considered as being built two or three at a time but as a continually progressing operation much like the laying of a highway. Hundreds would be under construction at the same time.

A variety of plans becomes a necessity as does a flexible means of growth. Visual order and differentiation become important considerations when a large quantity of houses is to be built.

Housing should cover a range of incomes from the lowest to the medium. Growth should be possible in any direction horizontally or vertically. Service panels for electrical and plumbing should be capable of attachment anywhere in the shell of the house.

Another important design factor is climate. To provide a specific design climate the country of Uruguay was chosen. Uruguay lies in a temperate zone similar to that of California.

Uruguay's population is nearly three million. The capital and largest city, Montevideo, with 860,000 people has an estimated housing need of 60,000 units.

Although the design should be intended for Uruguay's use, consideration of adaptations for other climates becomes a vital goal.

The program for the housing unit has thus been established.

III. DESIGN OF THE HOUSING UNIT

In the design of the unit the first investigation was to find a material for the structure. Steel became the logical material for several reasons, the most important being the great variety of use Ford Motors and Armco Steel make of this material. If these corporations were to enter the housing for foreign countries market, steel would be the easiest means of entry.

Steel in thin, formed sections becomes very strong and light. With the ability of nesting of parts steel becomes economical to ship.

While steel has many disadvantages one of which is cost it is probably the best, present day material for use in an industrialized process.

The design of the unit began with considerations for a roof system. This system placed emphasis upon being light-weight, strong, easily erected and transported. After investigation an arched sheet was decided upon. By curving the metal strength is added. Thus a large area of roof is covered with a very thin skin of steel. The structural system of the roof, therefore, becomes a one-directional series of vaults.

Beneath the vaults arch shaped filler panels are needed to rigidify the roof. These panels are produced in a stamping operation and would nest one in another.

A beam to carry the roof can also function to carry the water from the arched steel to the roof edge. A U-shaped section works well. (Ill. 1) The beam is rolled into this shape with two flanges on the upper arms to receive the sheet steel roof panel. The edge of the sheet to connect with the beam is bent into an "S", thereby forming a groove to enfold the flange. The load of the sheet is transferred to the beam through the bearing of this groove on the flange. Bolt connections act only as positioners. The thermal expansion of the roof is absorbed in the play of the arms of the beam.

Insulation for the roof is provided with sheets 2' x 6', 3' x 6', or 6' x 6' hung between beams and filler plates. Insulations used for this ceiling panel and also for the wall panel described later could be produced from numerous items to be found in the country assembling the housing.

Asbestos cement would work well if the expense of the item were overcome. Plasterboard of a sufficient thickness to provide good insulation is another possibility. Rice hulls or wood shavings, waste products normally, could be mixed with small amounts of concrete to provide insulative panels. Sisal fibers, found in many South American countries, could also be employed. Expanded vermiculite and cement would furnish another alternative. Straw could when coated with glue or cement be utilized for insulation. Foam concrete, cardboard panels and cork are possibilities. Wood, if available, could provide a farther choice. This list could be expanded as the country advanced industrially into plastics, sandwiches and foams.

An air space between vaulted steel and insulation acts to isolate heat at the metal surface. To aid in the cooling of the steel the filler panels are opened to allow air circulation. This air space also carries electrical wiring throughout the unit.

Columns are made of two beam sections bolted together. The section is derived from a more narrow sheet being fed into the rolls. (Ill.2) Both beam and column may be nested for shipment. With a simple cut and fold the top of the column receives the shape of the beam. (Ill. 3) Since it is necessary to build a flexible system where other units can be added to the house at a later time, the beam reaches in length only the clear distance between columns. At the top of each column a short piece of a cut beam overhangs the column faces and receives the beam on a bed of asphalt. The column sections and beam seat are bolted into a unit in the field.

The roof system serves a functional purpose in the construction of the floor system. It acts as a form for the pouring of the concrete floor. A short foundation to floor column is used to support the roof elements temporarily. The ends are closed with wooden forming as

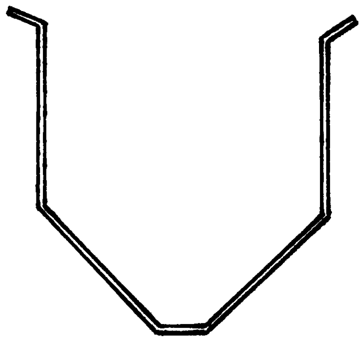

Illustration 1
Rolled Beam Section

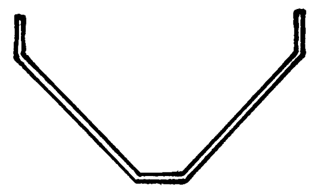

Illustration 2
Rolled Column Section

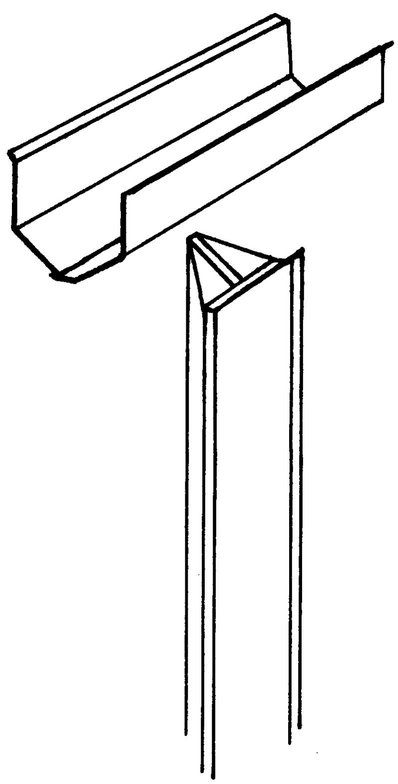

Illustration 3
Column and Beam Meeting

is the beam cavity. The floor is then poured. To prevent the steel sheet from buckling a larger number of filler panels are used. The resulting vaulted floor system is strong and needs very little steel reinforcing: a very light temperature mesh and two reinforcing rods over the beam. To compensate for the thrust of the last arch the filler panels in the last bay are lowered one inch and the sheet not fastened to the outside beam. Therefore, the floor thickness at the top of the arch becomes three inches in end bays as opposed to two inches in other bays.

The exterior walls are made of rolled steel panels backed with insulation. The same insulation as is used in the roof is used in the walls connection with the column is made simple by bolting to an angle attached to the column. The sheet overlaps the column and is tensioned to it through pressure exerted by the bolt. The shape of the steel provides an 83% surface coverage with a 3/4" air space (3/4" supplies the most insulative value for the least dimension [1]). The steel panels are nested and shipped to the country in two-foot units and there bonded to the native insulation to form a six-foot panel.

Doors and windows are fabricated from nested T-shaped sections sent to the country. These T-shapes are

1. G.D. Nash, The Thermal Insulation of Buildings, Dept. of Scientific and Industrial Research, Her Majesty's Stationery Office, London: 1955, pp. 7-8.

rolled sections. Sub-assembly shops assemble the total unit ready for site installation. Doors and windows can hinge directly to columns.

The service center of the housing unit contains the plumbing, and electrical utilities. Most wiring and all piping would occur in one wall panel 6' - 1" x 8'- 0". This panel can be placed anywhere in the house but is meant specifically to fit into the house as an outside wall. The back side of the panel is made of the same steel sheets as a typical wall panel without insulation. This steel could be removed from the outside of the house to service the mechanical or plumbing centers. This service panel certainly offers an opportunity for assembly line porduction either in the United States or abroad.

The economy of these housing units has been achieved through design using rolled shapes with insulative air spaces as well as dual use of steel elements as found in the roof system. The skeletal system of structure allows complete freedom in design of exterior walls. Any wall may be left completely open if desired.

IV. CONSTRUCTION PROCEDURE

With the arrival of the package of components on the site construction begins. Holes are drilled in the ground 6' - 7" on center in two lines 13' - 2" apart. If hollow vitreous tiles are available these will be inserted in the holes and the dirt backfilled around them. The steel column sections are placed in the tile and beams attached with seat angles to these columns. Filler panels are next fastened between beams every 18". The whole system of beams, columns and fillers is then leveled and adjusted with the use of props between the ground and the beams. When all parts are level and properly positioned concrete is poured into the tile around the column providing the house with foundations.

The steel sheet is next oiled and sprung across the filler panels from beam to beam. The sheet is fastened to the beam. A wood filler cap running over the top of the beam is positioned. This piece of wood prevents the concrete from filling the beam and protects the connection of beam and sheet from the concrete. The ends between columns are blocked with pieces of wood cut to fit the arch of the steel sheet. This wood is fastened to the columns. Wood forming between columns in the 13'-2" direction fits into the end beam and has half a filler cap added. This forming is also fastened to the beams. Temperature mesh and reinforcing over the beams is next placed. The concrete is poured into this formwork. A seat angle attached to columns as well as rods passing through the column and floor together.

While the concrete is setting, the upper columns are bolted together and placed over the lower columns. The upper and lower columns are then bolted together.

With the setting of the concrete the wooden forms are removed and the metal forms dropped to the ground by removing the seat angle supporting the beam. The form parts would be disassembled. The beams are lifted into place in the roof and attached. Filler plates are fastened between beams ~~and~~ in a similar manner to the floor formwork. The steel would be sprung between beams and attached.

The service panel is next installed in the unit. Electrical wiring is run under the metal roof. Plumbing and electrical lines enter at one point only.

Insulation panels are lifted between beams and filler panels there to be fastened with steel running strips. Wall panels already assembled are inserted between columns and bolted to angles attached to the columns. Doors and windows are hinged to the columns. Interior partitions of a native or inexpensive material can be attached anywhere in the housing unit. The steps are bolted together and then onto the frame of the unit. A layer of asphalt tiles, cork or some other similar material finishes the floor and the house is ready for occupancy.

V. PLANNING USAGE OF HOUSING UNITS

The module of 6' - 7" established in this design functions well for a number of purposes. For housing units compactness of plan is achieved in an efficiency unit and one, -two- and three- bedroom units. The service panel in these plans provides water for bathroom as well as kitchen in one location. The module allows a three-foot door and window to be inserted between columns as well as a six-foot steel panel or six-foot window panel. Beams span two modules in housing units, three in other units.

Several possibilities arise for combinations of housing plans. Row houses are easily assembled of any length. Changes in these units could easily occur with simple changes in interior partition arrangements.

El shaped houses with courts, a very economical use of the land, can advantageously be formed either free-standing or with common walls.

Developments serviced with community kitchens and bathrooms are a distinct possibility in poorer neighborhoods. As peoples' incomes increase services could be added to their houses.

Two story apartment houses are possible with the pouring of two floors and the use of more columns of stronger capacity.

School units are ideally formed from the use of the longer beam -19'-9" span. A longer overhang shelters window areas and corridor. Other community functions could be housed in similar structures. A solution for the areas of the world with a higher temperature range is also desirable. The temperate climate design can with a few changes be adopted for the warmer areas.

To provide protection from the direct rays of the sun, to window and door openings, the overhang of the roof would be increased to four feet or more. The seat at the top of the column would be increased accordingly to receive the larger sheet. The end bays would be left empty protecting the side elevation from the sun.

Exterior walls could be of the same construction as before, steel sheet and insulation. However, these panels could be shorter leaving a line of openings under the protection of the overhangs. Simple hinged panels opening outwards could be used to protect against heavy winds.

Doors could be more numerous and be made of simple louvered steel panels so that air could flow through the house at all times yet protection against water would be maintained. The space under the span of the beam at the sides of the house could be provided with a track and doors that could be slid to the ends of the elevation and thereby completely open two sides of the house to the air. This would be advantageous to cool the house on hot nights and to open the house to the air on the side away from the sun during the day.

The end filler panels in this solution would be replaced by simple stamped truss panels that would be fitted with screens; thus, the underside of the roof would be completely open to air currents at all times. The cooling of this space would be greater than in the temperate solution.

Heavier insulation is naturally necessary in these houses. The wall panels and ceiling may be made in any thickness. In combination with the overhangs and air-flow roof this unit could be quite cool. Use of reflective steel would aid even more.

In this warm-weather house and the numerous solutions of planning found, it becomes apparent that these housing units have a desirable function of versatility.

VI. ALTERNATE PROPOSALS

Of course the design presented could have a variety of alternates depending upon the availability of materials in the country to which it is shipped. During the design of the unit many possibilities for modifications appeared which are worthy of discussion here.

An alternate roof system seemed feasible. This system was rejected due to a large number of problems. Basically it involves nothing more than using the curve in the metal sheet in the reverse position of that used in the design presentation. The steel sheet would then be in tension from beam to beam. (Ill. 4) Filler plates would still be necessary across the roof to keep the panel from rumbling during a wind. These filler plates due to their shape would be weakest at the center--precisely where strength would be needed for bracing between beams. Other problems envolved would be necessity of using a gutter and drain system to carry the water from the center of the bay to the ground, an inability to use the same filler plates to reinforce the sheet when used for a form for the concrete floor (the steel would have to be inverted to achieve the same curve as in the design presented), and the difficulty of developing a two story system.

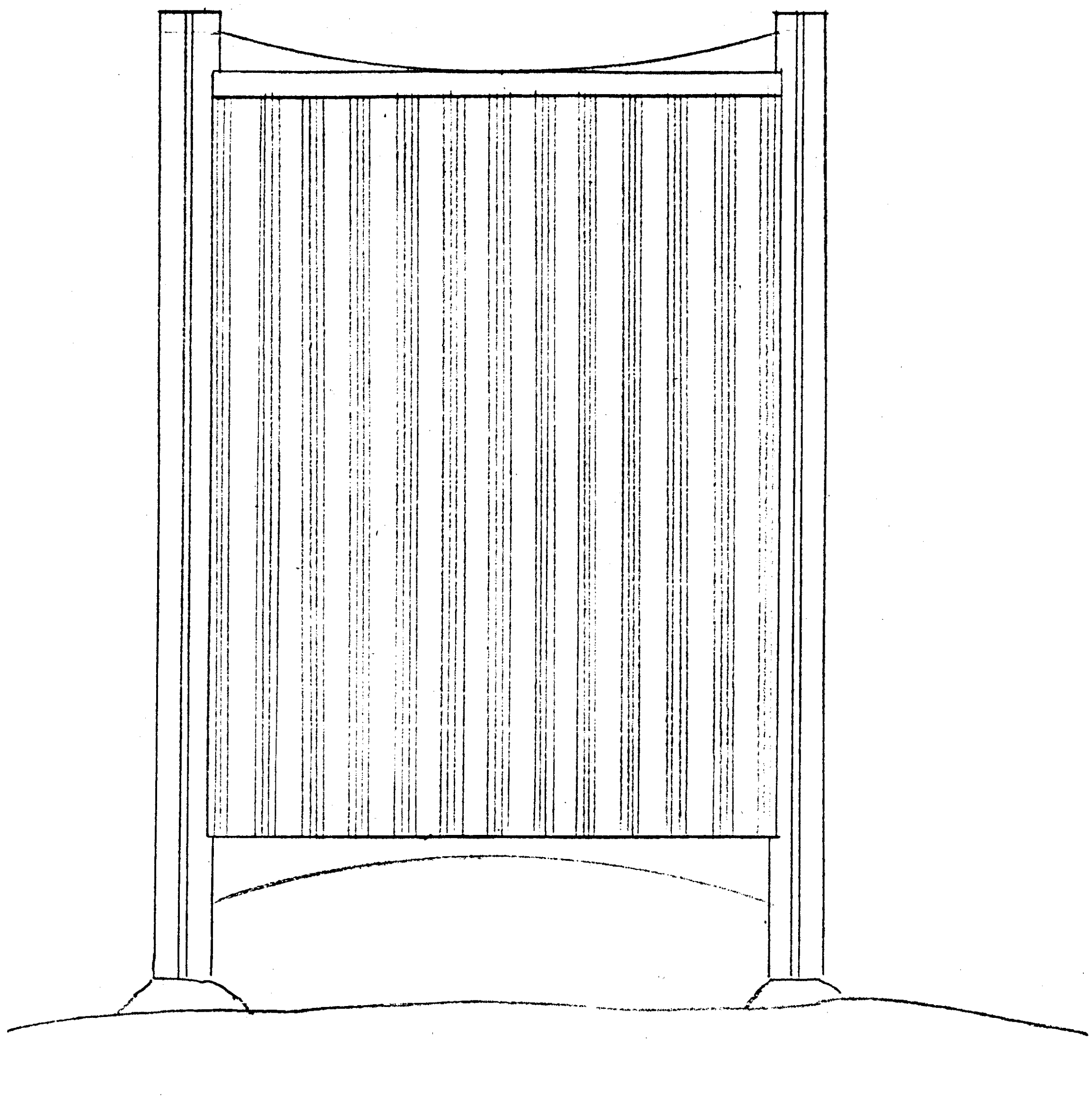

Illustration 4
One Bay - Concave Sheet Roof

A wall system that worked quite well is a possible alternate for countries where a loose insulating material is available in quantity. This material could be a waste product like wood chips or rice hulls or a commercially produced item like blanket insulation of glass fibers, orckwool, or shredded paper. The wall would be a hollow cavity boxed by two of the steel panels.
Spacers would keep the corrugated metal at the proper distance. Column attachments would be similar to the design presented. Insulation could be poured in after the panels were attached to the columns or if blanket insulation were used one surface could be installed, the blanket placed against it, and the second wall attached over the insulation. This same wall system could be used for common walls between units in row housing or apartments when the cavities were filled with sand or earth. The earth or sand if taken from below 18" of the surface would be quite free of animal life. A disadvantage of this system would be the interior finish of steel that would in all likelihood be cold and not too practical for easy attachment of shelves, cabinets, and other hanging objects.

The floors for the unit have a number of alternate possibilities. The most primitive form would be a compacted earth floor. The hat shaped section that receives the walls could bear on adobe blocks. The level of the compacted floor would be even with the top of these blocks and above the natural level of the ground level.

A wood floor could be installed easily spanning the six feet between beams with 1½" lumber. The beams in the floor would be attached permanently with clip angles and plates. Some deflection in the wood would be encountered but not too noticeable an amount. Insulation would probably be hung beneath the floor in the same manner as beneath the roof if necessary.

A concrete slab on grade could be utilized if the preparation work were not considered to be too great. There would be a saving of steel columns (floor to foundation) and concrete in this system.

With these possibilities of adaptation the housing unit could see service in any number of countries.

VII. CONCLUSION

The exploration of the field of low-cost, industrialized housing for developing nations has certainly exposed the author to the many problems with which it is necessary to cope if ~~an~~ answers ~~is~~ are to be found. The path of design is lined with pitfalls and is not easily traversed. The sense of architecture is often lost in a bewildering forest of plumbing pipes and bolts. The crying needs of the people force one to consider first the most elementary solutions and last the visual countenance of the solutions. Fresh thinking becomes difficult in the mists of academic training intended for a richly endowed society. But at the end of the path, one becomes aware of having gained an ability to provide some answers for questions to which too few are responding today. Further study can provide more solutions and hopefully see the actual provision of shelter on a large scale. The author wishes that an awareness of the housing problem will become more generally known in American architecture and that through this cognizance aid will be provided to the world. The author ~~wishes~~ hopes that American architects will become more aware of the serious housing problem, and that through this cognizance better living conditions will be provided to the world.

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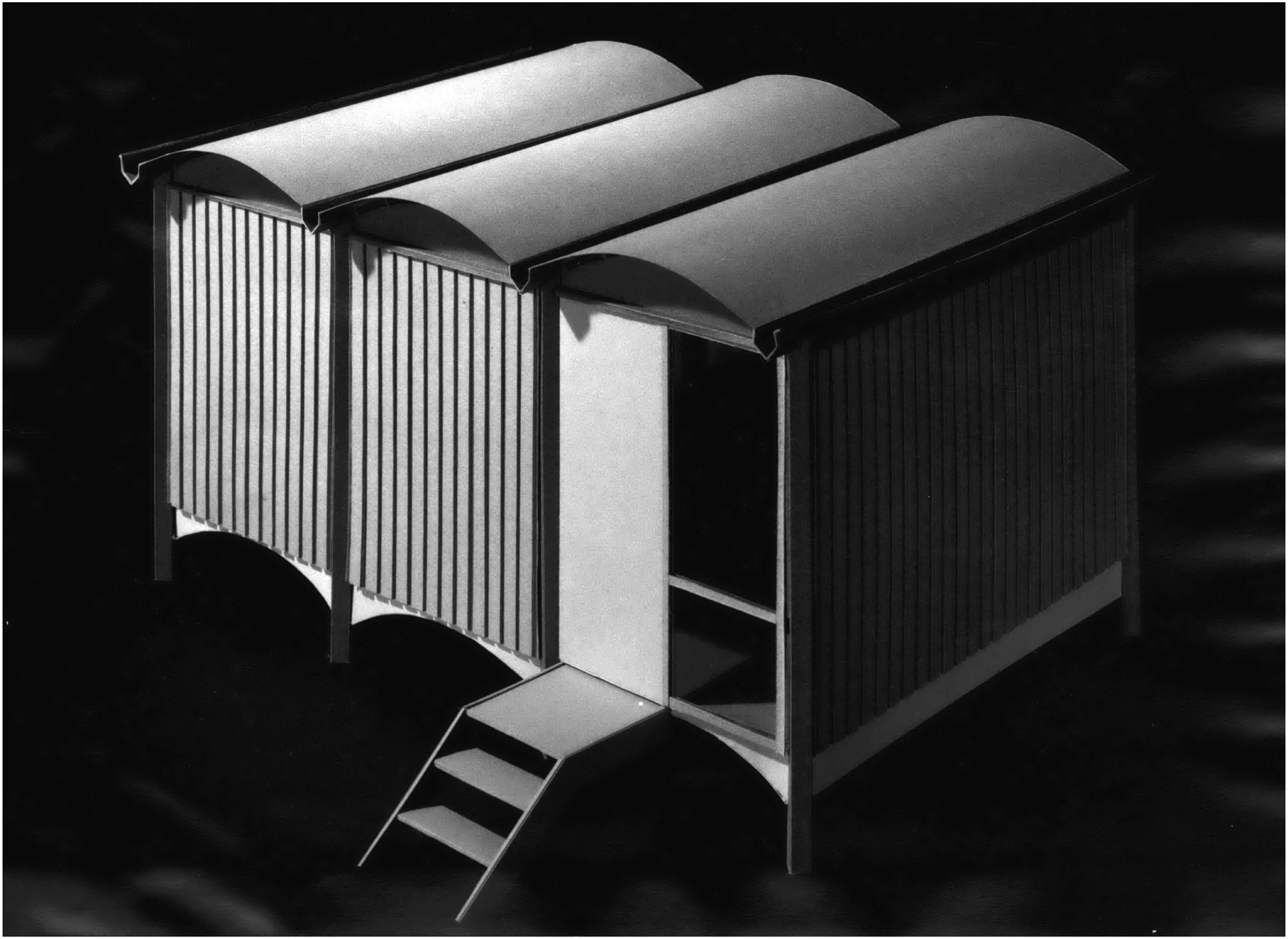
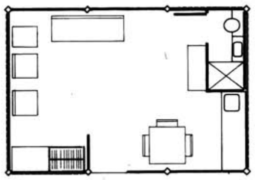
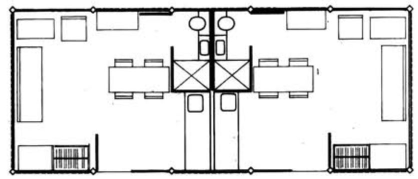
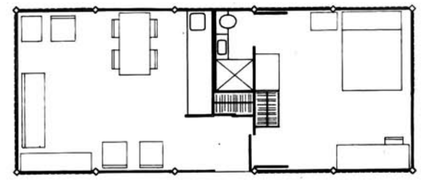




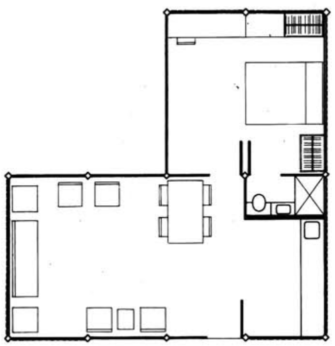
EFFICIENCY UNIT
254 SQ. FT.



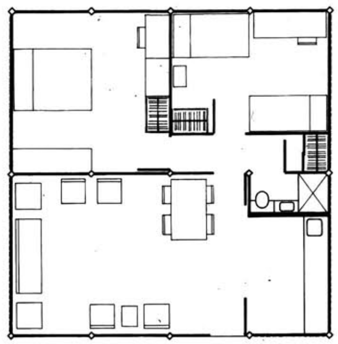
DOUBLE EFFICIENCY UNITS
211 SQ. FT. EACH



ONE BEDROOM UNIT
422 SQ. FT.

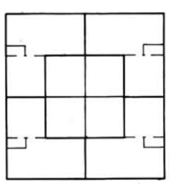


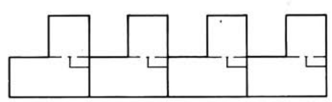
ONE BEDROOM EL UNIT
507 SQ. FT.

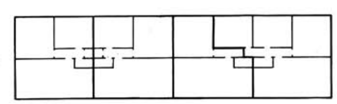


TWO BEDROOM UNIT
676 SQ. FT.

THREE BEDROOM UNIT
845 SQ. FT.





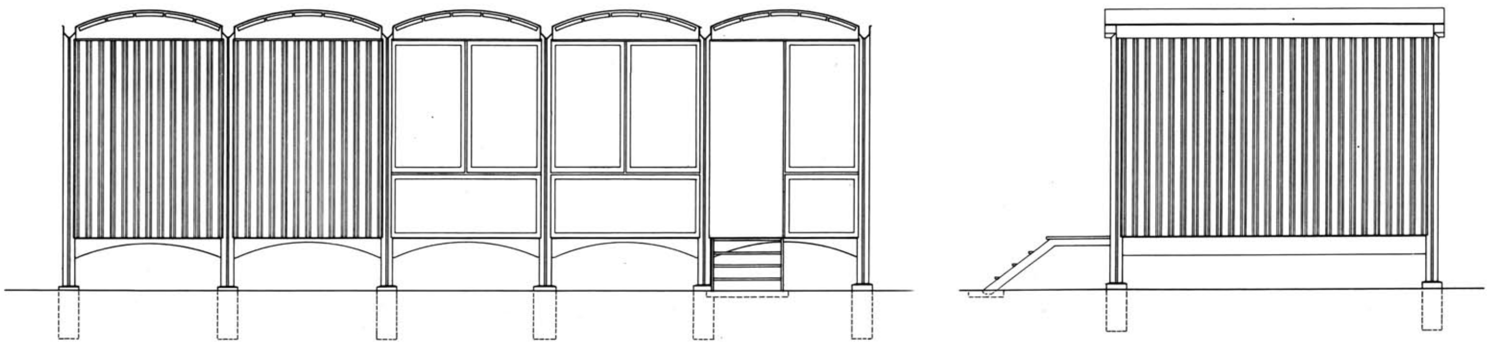


I

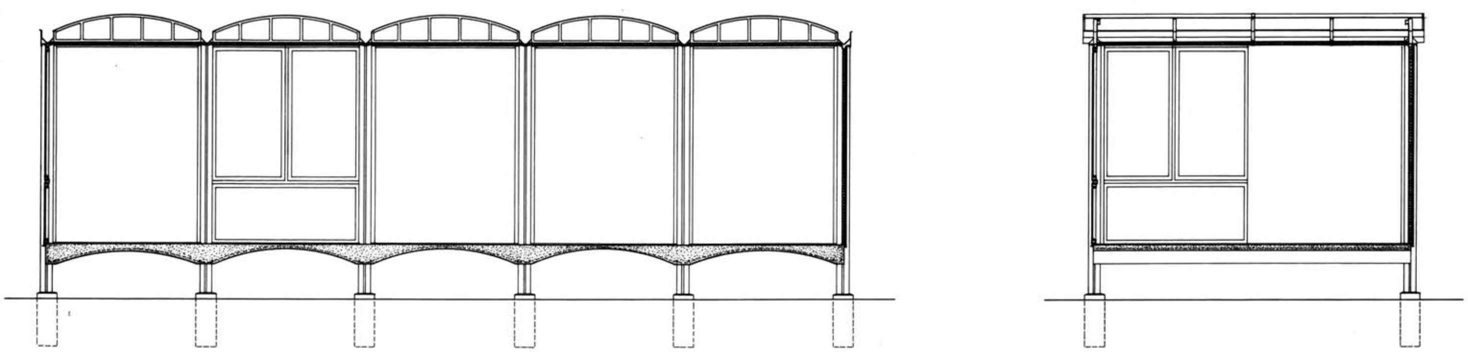
PLANS

A SYSTEM OF INDUSTRIALIZED HOUSING
FOR DEVELOPING NATIONS

MASTER OF ARCHITECTURE THESIS M. I. T.
JAY R. CAROW JULY 19, 1962



E L E V A T I O N S



S E C T I O N S

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II

ELEVATIONS
SECTIONS

A SYSTEM OF INDUSTRIALIZED HOUSING
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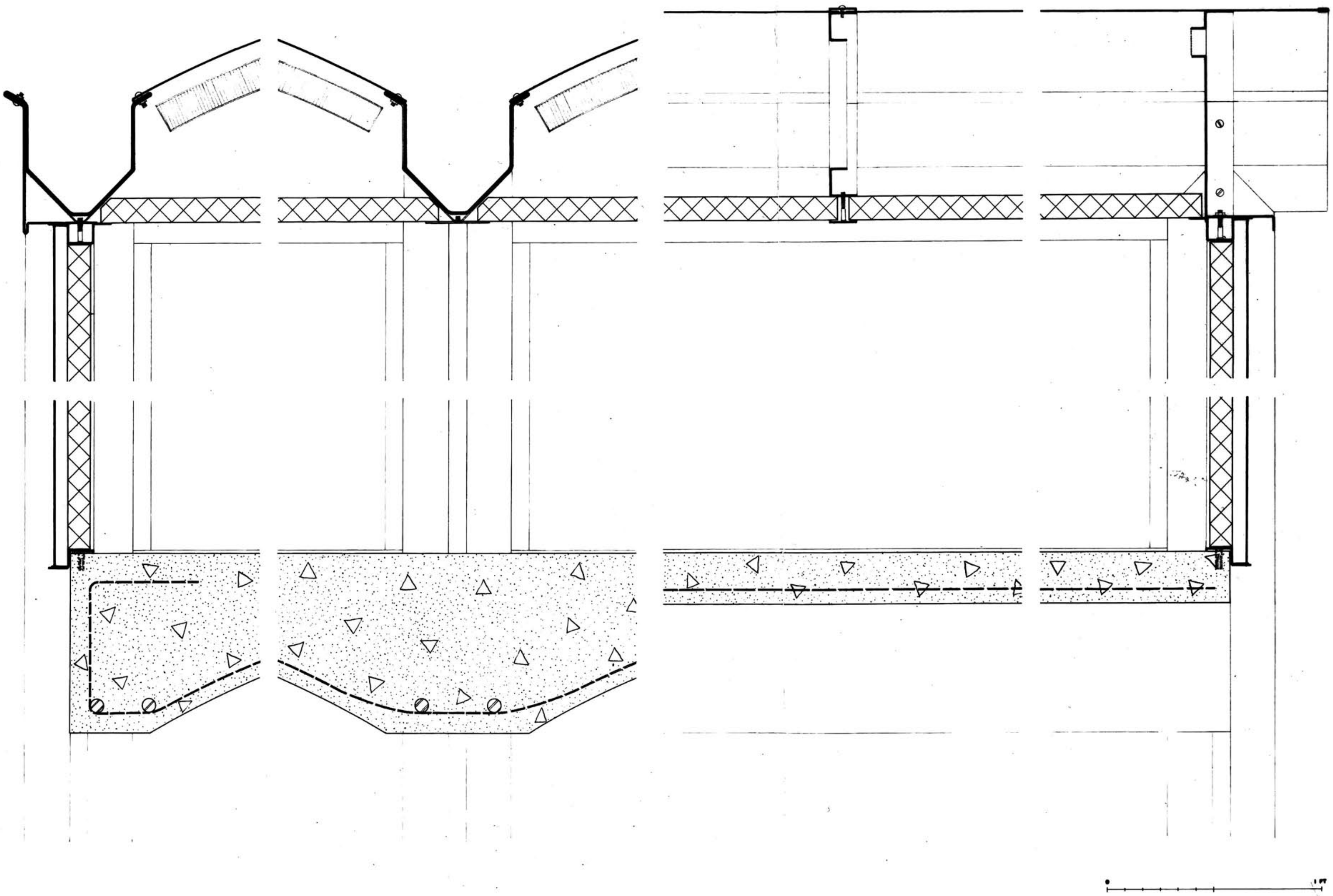


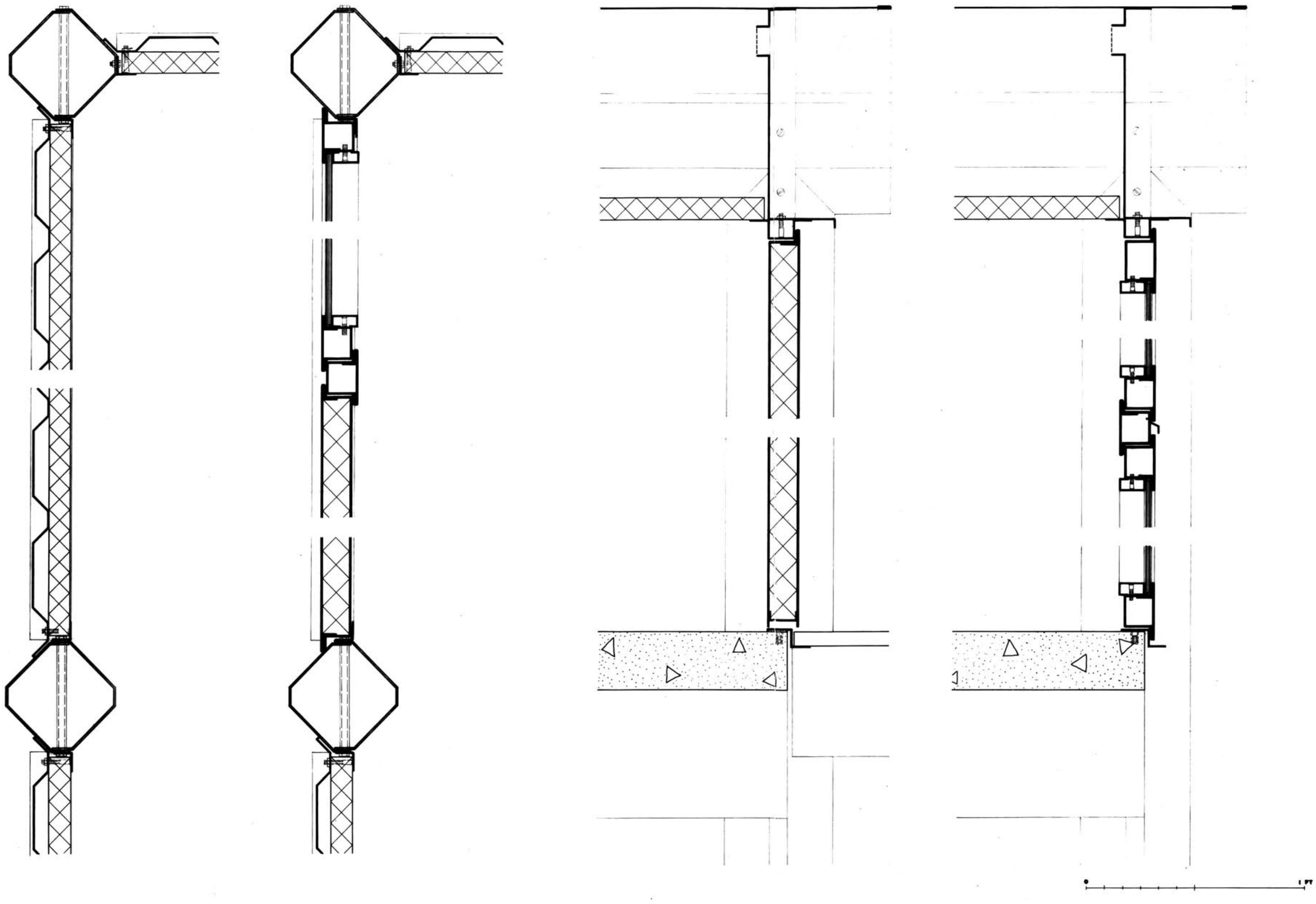
III

ROOF AND FLOOR SECTIONS

A SYSTEM OF INDUSTRIALIZED HOUSING FOR DEVELOPING NATIONS

MASTER OF ARCHITECTURE THESIS M. I. T.

JAY R. CAROW JULY 19, 1962



IV

WALL, DOOR AND WINDOW SECTIONS

A SYSTEM OF INDUSTRIALIZED HOUSING FOR DEVELOPING NATIONS

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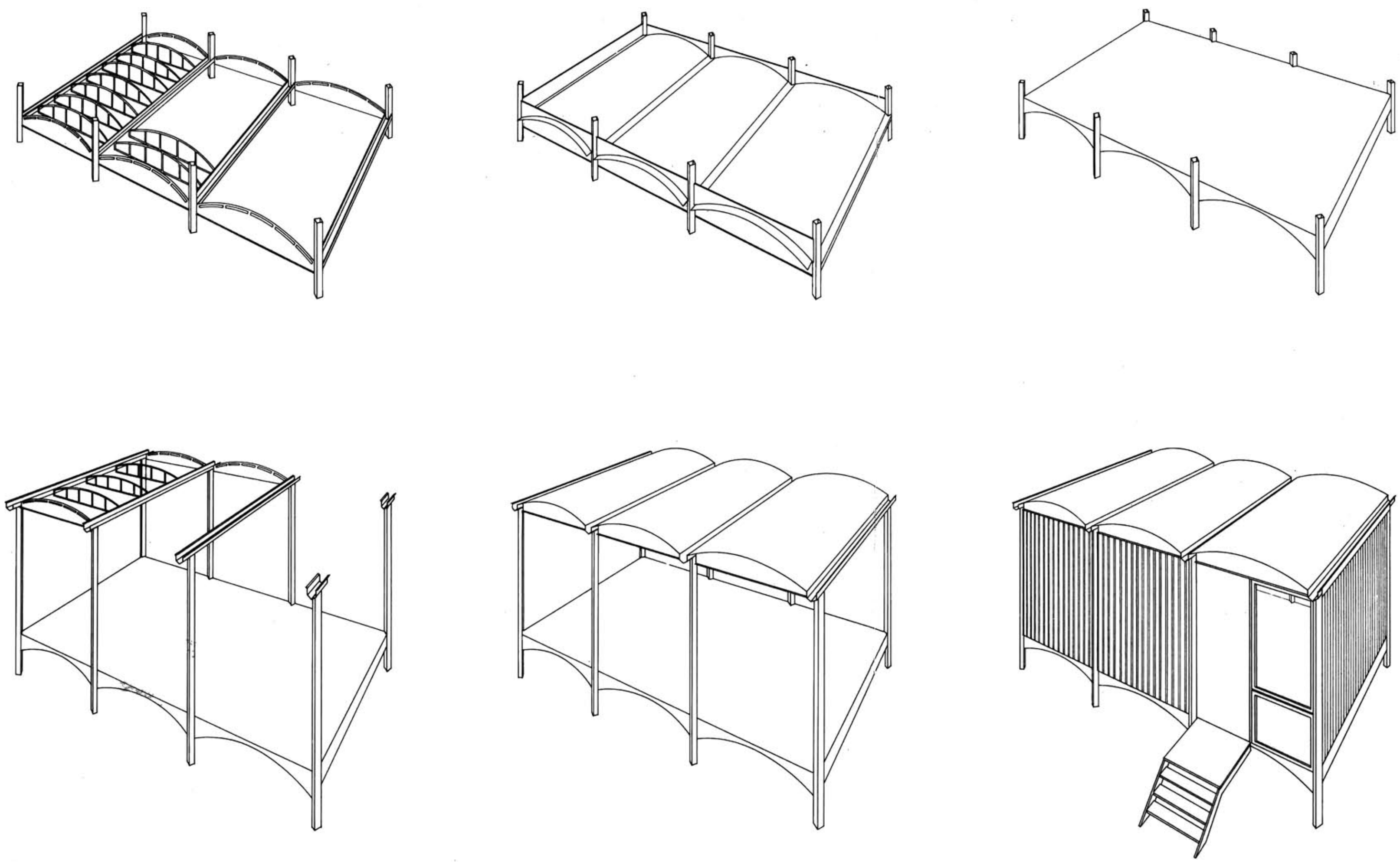

V

CONSTRUCTION PROCEDURE

A SYSTEM OF INDUSTRIALIZED HOUSING FOR DEVELOPING NATIONS

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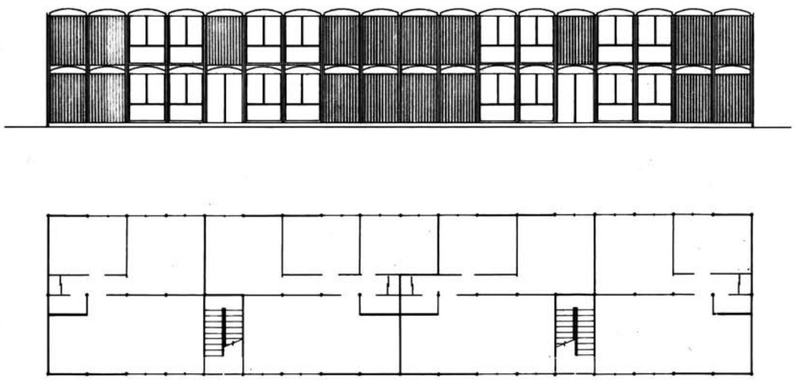
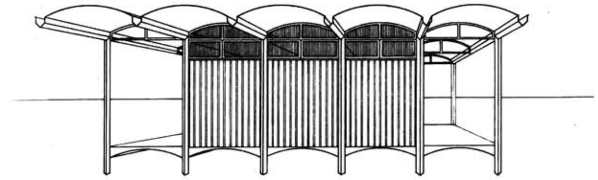
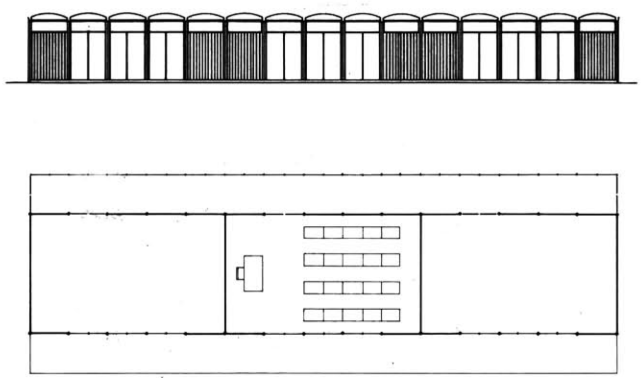


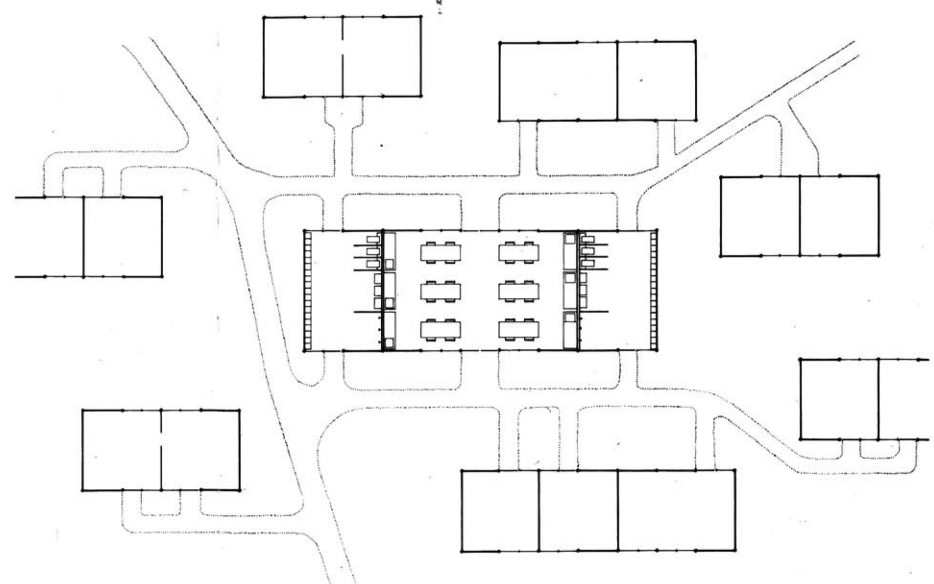
TWO-STORY APARTMENT
PLAN AND ELEVATION



HOT CLIMATE HOUSING UNIT
PERSPECTIVE



SCHOOL UNITS
PLAN AND ELEVATION



COMMUNITY GROUPING
PLAN

0 10 FT

VI

PLANNING
POSSIBILITIES

A SYSTEM OF INDUSTRIALIZED HOUSING
FOR DEVELOPING NATIONS

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JAY R. CAROW JULY 19, 1962