

MASS PRODUCED BUILDING SYSTEM FOR UNSKILLED LABOR

By:

Angelo Petrozzelli, Boston Architectural Center,
Certificate of Architecture, 1966

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
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June 1972

Department of Architecture, May 12, 1972

Thesis Supervisor

Chairman, Department Committee On
Graduate Students

Rotch





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405 Saratoga Street
East Boston, Massachusetts 02128

May 12, 1972

Dean William Porter
School of Architecture and Planning
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts

Dear Dean Porter:

In partial fulfillment of the requirements for the degree of Master in Architecture, I hereby submit this thesis entitled "Mass Produced Building System For Unskilled Labor".

Respectfully yours,

Angelo Petrozzelli

Enclosure

ABSTRACT

A Strategy For Developing A Mass Produced Building System For Unskilled Labor

by Angelo Petrozzelli

Submitted to the Department of Architecture on May 12, 1972 in partial fulfillment of the requirements for the Degree of Master of Architecture.

It should be noted that this thesis is a continuation of an earlier submission by the office of Imre and Anthony Halasz, Inc. and various other participants. This submission was part of the H.U.D. Operation Breakthrough Program RFP No. H-55-69.

The reason for selecting the development of a mass produced building system for unskilled labor is my reaction to presently available housing systems that by their size and complexity create a physical and human strait jacket ill suited to user participation in any stage of its development or existence. This thesis prepares the ground work for a building system sympathetic to this need and applicable in the immediate future at minimal cost.

It is the hope that this thesis will stimulate a research program to develop a full-scale model to test and improve the system.

The illustrations shown in the text deal with housing, but the system is not limited to this use. It seems to adapt well to other building types with similar clearance and span requirements.

Thesis Supervisor: John Steffian
Associate Professor of Architecture

ACKNOWLEDGEMENTS

I wish to express my deepest gratitude to Professor John Steffian and Professor Waclaw Zalewski for their unselfish participation during this study for my graduate work, and I wish to include in my thanks the many faculty members and staff of the Department of Architecture.

I wish to thank my associates within the staff of the architectural office of Imre and Anthony Halasz, Inc. especially Imre and Anthony Halasz for giving me the opportunity to complete my work at the institute and for their contributions to my academic enrichment. I also wish to thank them for the personal relationship which has developed not only during this experience, but also within the last five years since I have known them.

My gratitude extends to Mr. Frank Ransome of the Wheeling Steel Corporation, and Mr. Kenneth Sisson of American Architectural Iron, for help in obtaining the structural members and universal connection development.

Finally, my deepest gratitude to the members of my immediate family, especially my parents, for understanding and unflinching support over the number of years it has taken me to complete my education. Without their support I do not know what I would have done. I also wish to thank my personal friends who have encouraged me to continue with my studies.

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**GOALS AND DESCRIPTION
OF THE SYSTEM**

A. BUILDING SYSTEM CONCEPT

1. GOALS AND DESCRIPTION OF THE SYSTEM

a. General

The basic rationale underlying the concept of this proposed building system is that the system should not only fulfill the needs for shelter but also should become a source of employment, primarily for the unskilled of our society. The essential feature of this system is simplicity, based on the following objectives and solutions.

- i. Participation by the unskilled or semi-skilled members of society, who would be able to erect, and maintain the system with minimal training and supervision.
- ii. Minimal capital investment for production and construction so as to allow immediate application in any volume, anywhere and throughout the country.
- iii. The use of available commercial products in order to minimize new building components. A few of the system components may be especially fabricated, but the parts will be standard. It is hoped that these components will be stocked in local outlets.

- iv. Shop fabrications should be done with minimum investment on the part of the supplier. Fabrication of some of the components may be accomplished on the site at first in order to keep investment to a minimum.
- v. The components shall be of a size and weight that can be handled manually by two people. This will result in modest spans and small components. Small component size will allow greater individual freedom for different assemblies and will allow the system to be adapted to a wide variety of needs.
- vi. Simple mechanically fastened joints are intended for the entire system without using special equipment and skilled labor.
- vii. A universal joint is proposed at all intersections of structural members.
- viii. The system will expand or contract in every direction due to the use of the universal joint. Change and growth can occur without disruption of the finished spaces already occupied.
- ix. The system will take advantage of readily available components from other systems that are practical and usable.

- x. High standards of quality, low cost, easy adaptability to individual preferences, combined with the consumer's possible involvement in the production and marketing process, should assure his acceptance and identification with the housing product.

Following this logic the system consists of a series of independent structural frames with replaceable infill panels that constitute all finished surfaces. Prefabricated mechanical units will form an integral part of the system.

- b. Architectural

The architectural character of the system.

- i. Additivity

One of the chief dangers generated by prefabricated and preassembled industrial systems is that they often eliminate flexibility. This system, both in the relationships of its components to each other and in the components themselves, is based on the principle of additive flexibility. The resulting environment, be it an individual house or a complex settlement, can be molded and articulated according to specific needs and human desires rather than forced into an imposing preconceived industrial strait jacket.

ii. Component Parts

The principle of additivity is maintained by the relatively small size of the basic floor and wall panels between the structural frames. Since the assembly of the components is designed for the utmost simplicity, the number of joints does not adversely influence cost. However, by virtue of modest spans, small components, and great individual freedom of different assemblies the system can adapt itself to a wide variety of needs. Old systems based on large component parts often offended our sense of human dignity by limiting additive modulation. The selection of the smallest component parts, readily available through the regular channels of the construction industry has its advantages not only in cost, easy handling, self-help, etc., but chiefly in that the small component parts enable the user to contribute to the form of his environment, exercise choice and initiative, and thus restore his pride in his place of living because he can adapt the system to his specific needs and requirements.

iii. Diversity

Since the system consists of relatively small components and a very large degree of additive flexibility, it can adapt itself to different housing densities, site conditions, and individual needs. Since the wall panels are designed for additive flexibility, they can adapt to different climatic conditions, as well as various zoning and building code requirements.

The main test of every contemporary system is its behaviors in terms of change and growth. The proposal allows change and growth on different levels.

It can most easily expand in every direction by virtue of the universal joint.

It permits the alteration of the standards of housing units themselves, even in higher densities, by exchanging components without interfering with the rest of the units.

Since the proposal does not concern itself with a building as a product, but with an additive process it will change itself through field experience, demand, research and human ingenuity.

The ease of assembly implies the ease of dismounting. Change and growth demands addition as well as removal of parts in relation to the whole, without disruption.

c. Structural

i. Low-rise Construction

The basic structure consists of a light gauge metal frames and infill panels that form all finished surfaces.

A prefabricated "universal" joint piece, which is placed at every intersection between frame members, allows simple attachment of column and beam units. No element exceeds 150 pounds in weight. All frame connections in the field are by high tensile bolts. Details are such that while all the frame parts will be prefabricated in a shop, all assembly will be handled by unskilled labor, without any hoisting equipment.

All panels, for floors, exterior and interior walls and partitions, are of standard manufacture and are set into the frames by simple connections. The use of advanced fastening devices is contemplated to assure easy, rapid and safe assembly. Fairly large tolerances

are employed to avoid the need for exacting precision.

The frame structure is designed to withstand all vertical loading and the effects of wind or earthquake forces.

ii. High-rise Construction

The system is adaptable to any building height with the provision that it becomes a subsystem in a megastructure whenever it exceeds four stories. In such a case a basic concrete frame, consisting of columns, core walls and floor slabs at four-story intervals will be constructed. The structure serves as a four-hour fire barrier, both in vertical and horizontal planes, in addition to its load bearing function. The low-rise light gauge steel frames and infill panels will be plugged into the megastructure, with provisions for fire protection.

While the megastructure will demand skilled labor, all the infill structure will be manufactured and assembled exactly as the low-rise units.

d. Interior Work

Prefabricated assemblies of stairs, cabinets,

partitions and closets are introduced into the system, at a wide variety of possible modular applications, allowing any pattern of growth and change.

e. Mechanical, Electrical

The general approach, here as well as in the structure, is based on the following premises:

- i. Simple mechanical installation by unskilled labor.
- ii. Individual control of the mechanical system in each dwelling and independence from occupants of other units.
- iii. Possibility to change, remove or upgrade the mechanical installations.

A suggested outline specification has been developed for some housing units investigated. These are included in the Appendix.

f. Foundations

The system is designed to be supported at discrete points, the cases of the frames. As such, it is applicable to practically any soil condition. The flexibility of the steel frames and the tolerances between infill panels make the system relatively insensitive to minor differential settlements of the supports.

SYSTEM ADAPTABILITY

2. SYSTEM ADAPTABILITY

a. Housing Types and Scope

The proposed system will allow maximum freedom of choice and degree of self-participation at densities up to 15 units per acre. At these densities the capacity for growth and change can be employed to a very large extent. Simple family detached or attached homes can expand in all directions in small or large increments by the use of building components (stair, mechanical unit) and by use of columns, universal joints and panels.

The limit of the proposal serving as a primary system is in the range of 40 dwelling units/acre.

The accompanying illustration assumes the following restraints:

100% parking

on-grade parking

limited walking distance from car to units
walk-up with maximum two flights of stairs
emergency and service traffic only within
the residential matrix

no more than four stories (possible duplex
on top)

Residential densities higher than 40 u/a will
adapt the proposed components as infill or

secondary systems. These densities will change the rationale of parking relationships and circulation considerations in general.

The attached site application addresses itself to the upper limits of the system in terms of its residential densities as demonstrated in the general site matrix. This type of site utilization is a long neglected prototype for urban housing.

The well known later day prototypes in the lower and upper extremes of urban residential densities did not fulfill the aspirations and promises of their urbanistic conception. Not only did they stereotype their architectural presence but a non-compromising social segregation followed. The careful study and revitalization of middle density housing is most timely and necessary. The proposed system is best suited to such middle density applications while still effective in all other types of residential development.

b. Climatic Areas

No restriction.

Steel frame is designed to resist any specified horizontal and vertical load. Infill construction is such that any insulation value is attained by using an appropriate insulating blanket.

c. Geology and Soils

The system is usable on soils with poor natural drainage and unstable soils, due to the relative flexibility of the structure which is capable of adjusting to differential settlements without excessive stress. All infill panels allow minor distortion without damage to them.

d. Site Topography

At sloping sites footings with piers of adjustable length will allow the use of the system both in the same form as on flat sites as well as with the introduction of partial lower levels.

e. Site Size

The system is adaptable to any site size.

f. Site Situations

The basic concept of the system, its simplicity in the use of unskilled labor and finished light materials that are available anywhere, renders it applicable to any site situation and basically independent of local labor and material supplies. The presence of existing or removable structures does not restrict the applicability of the system.

g. Changes

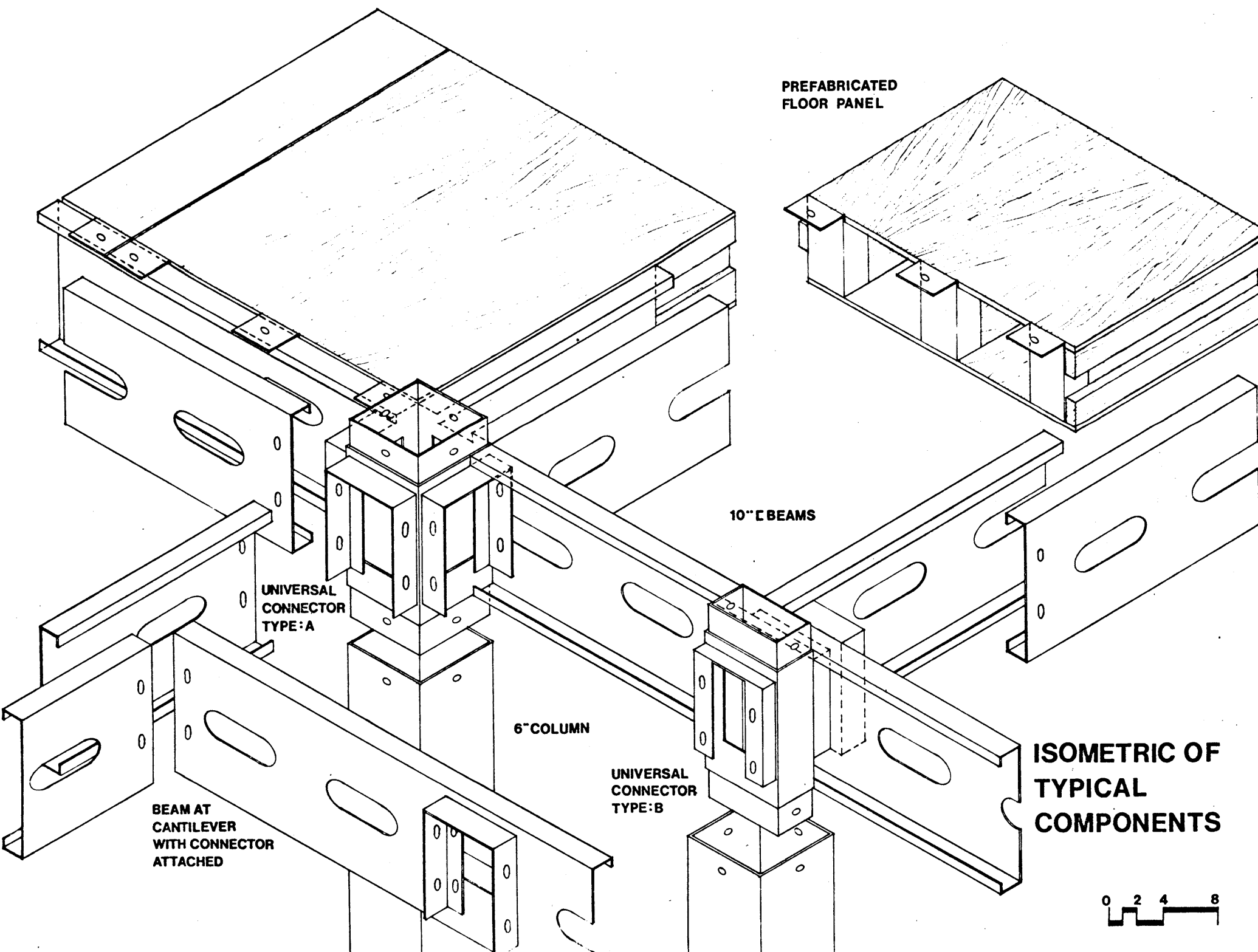
All components are removable or can be added on, as desired. Thus the standard of surface finishes,

cabinets, etc. can be improved at any time by simple exchange of panels. Expansion and rearrangement are handled similarly. In many cases the frame may be erected at the time of construction, to serve as porch or terrace, and later enclosed by snapping the finished panels into the frames.

h. Regional Applications

No restriction.

SYSTEM COMPONENTS



PREFABRICATED
FLOOR PANEL

10" C BEAMS

UNIVERSAL
CONNECTOR
TYPE:A

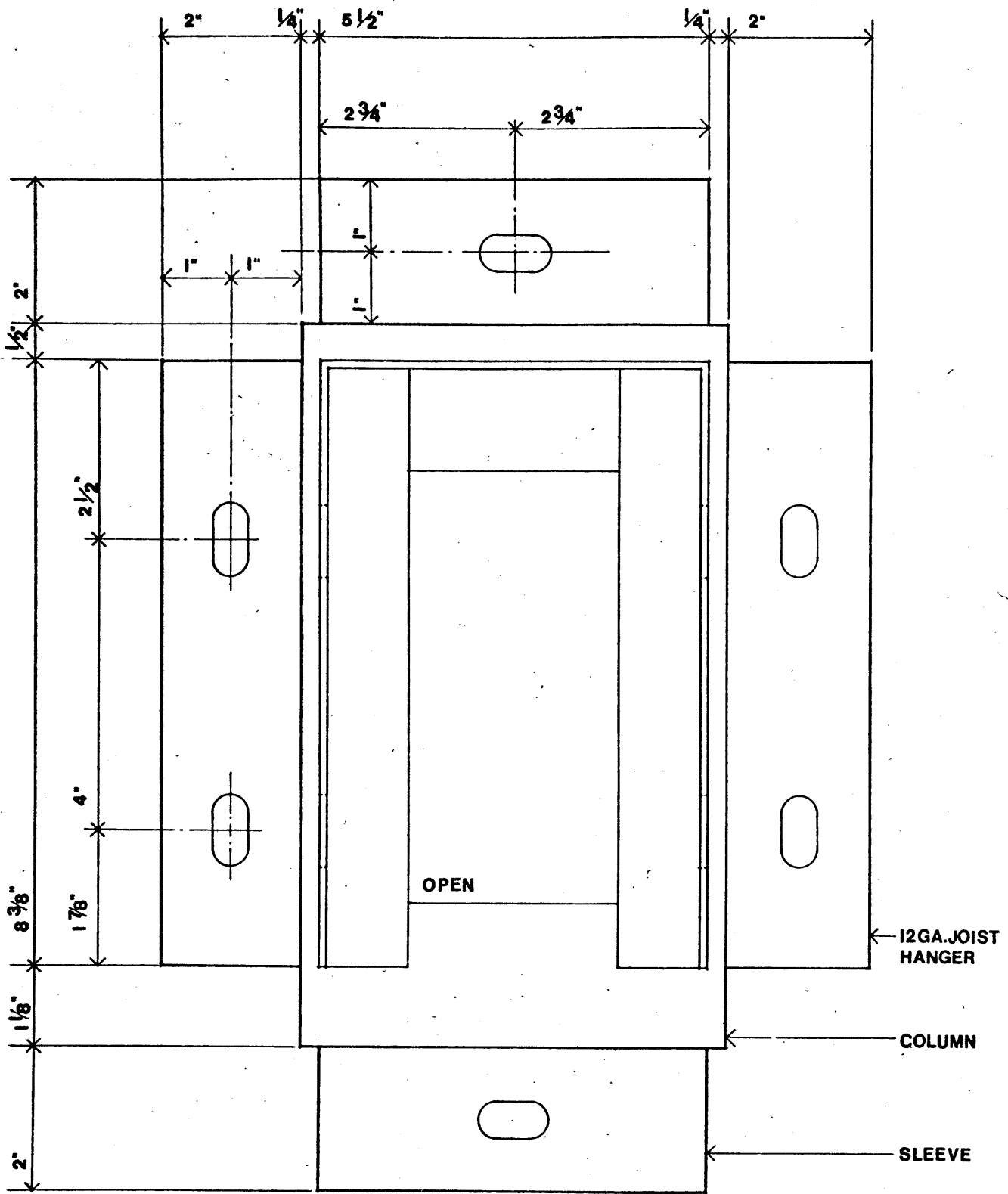
6" COLUMN

UNIVERSAL
CONNECTOR
TYPE:B

BEAM AT
CANTILEVER
WITH CONNECTOR
ATTACHED

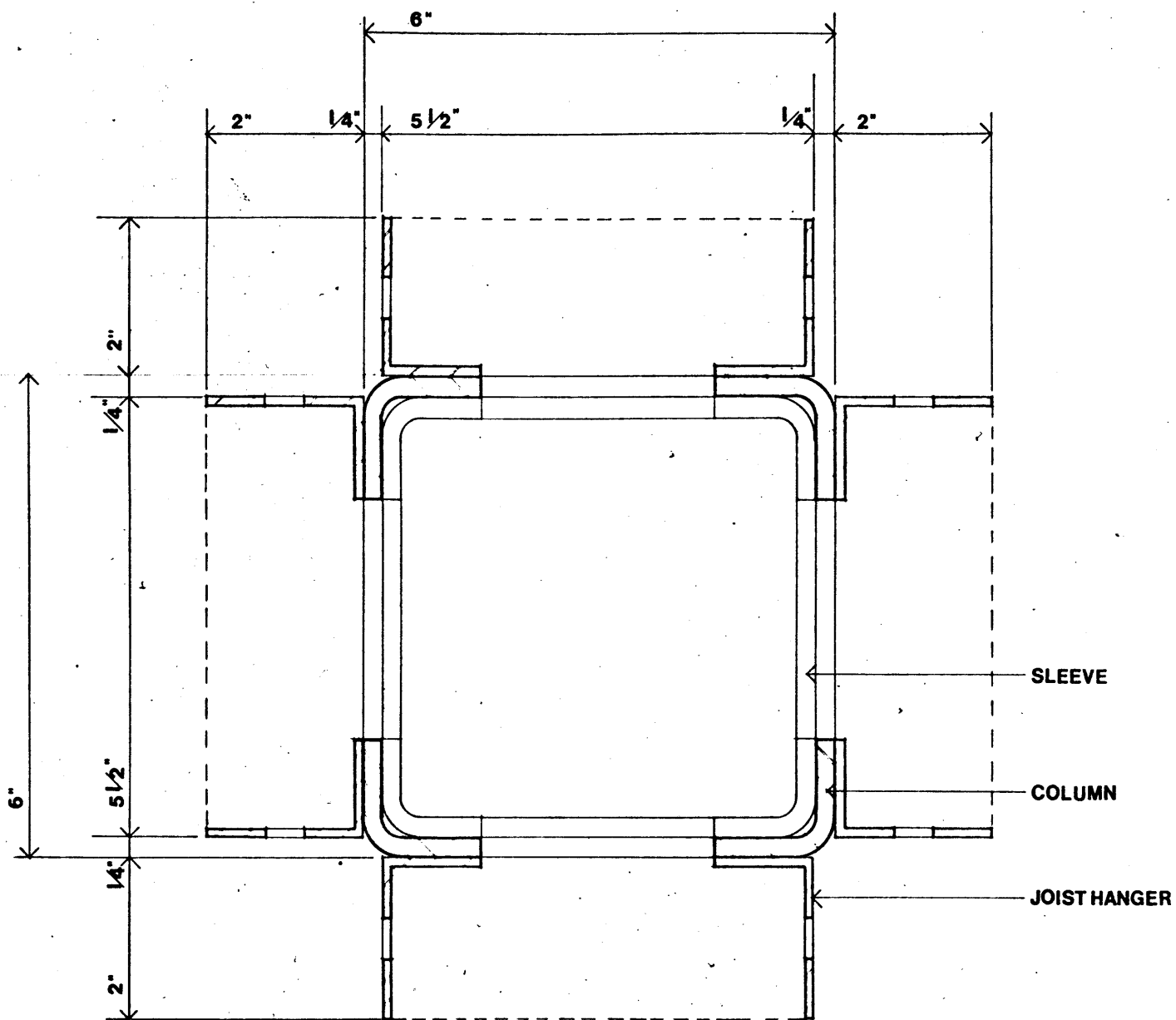
ISOMETRIC OF
TYPICAL
COMPONENTS





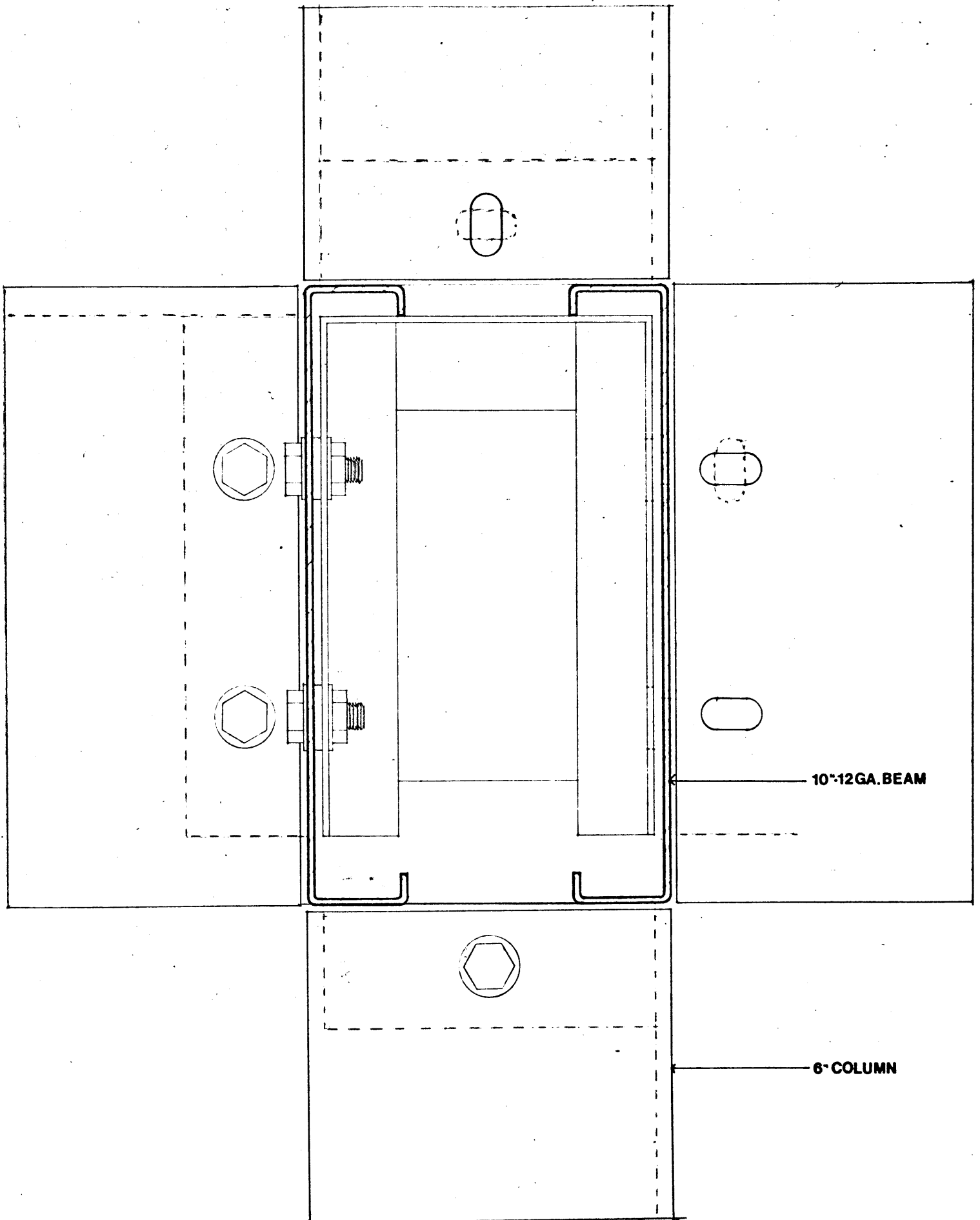
ELEVATION OF UNIVERSAL CONNECTOR: TYPE A





PLAN OF UNIVERSAL CONNECTOR: TYPE A



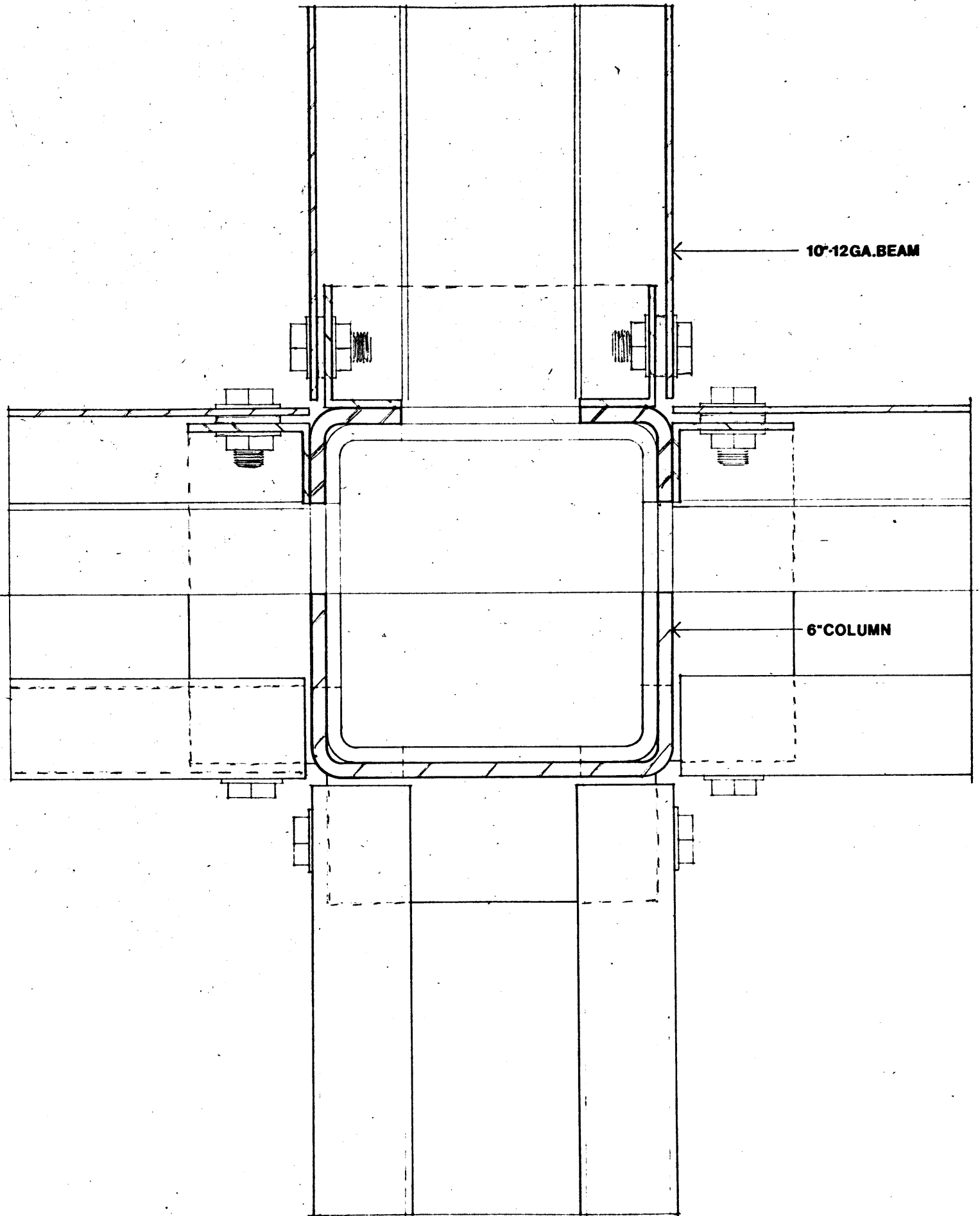


10x12 GA. BEAM

6" COLUMN

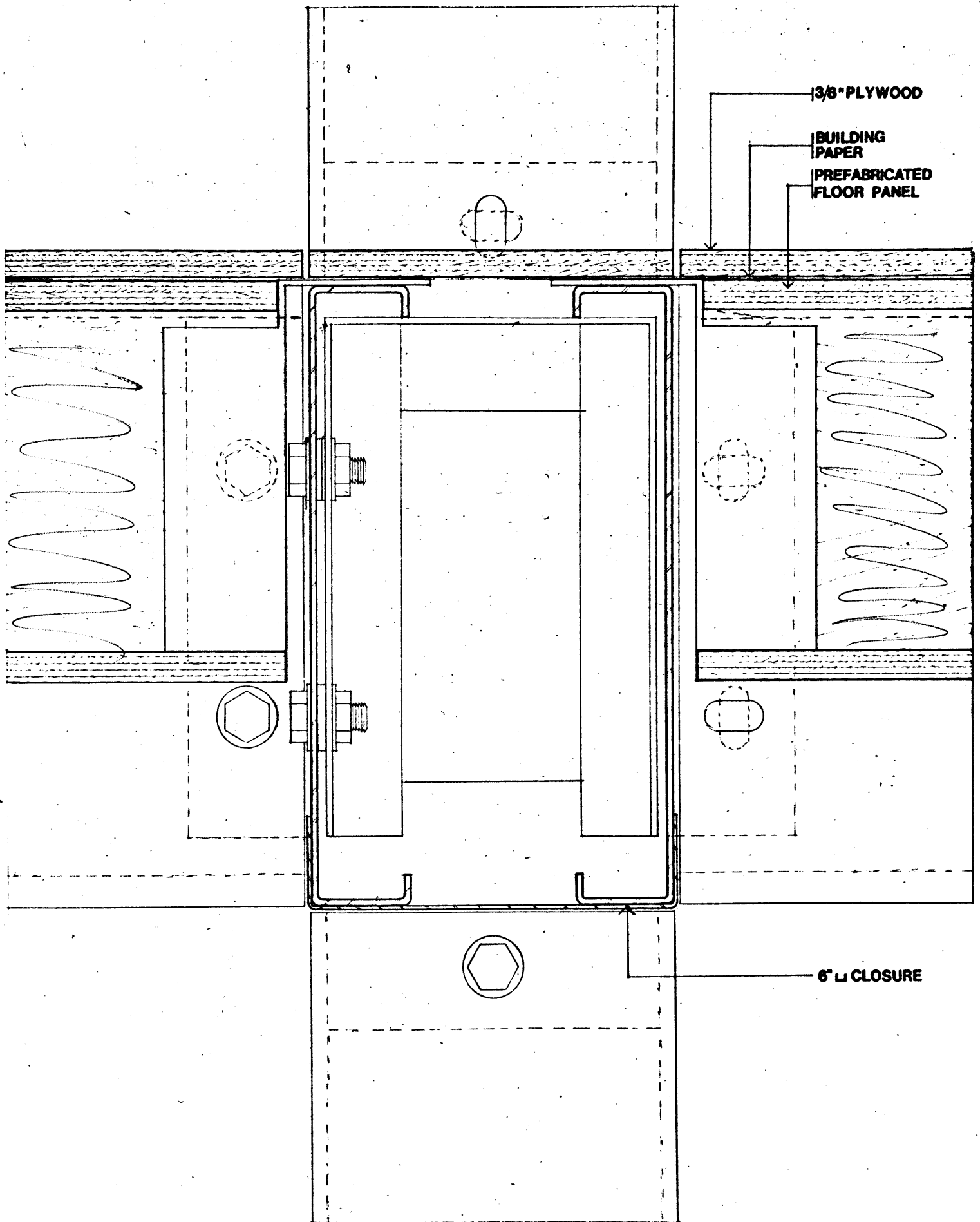
SECTION AT TYPICAL INTERIOR JOINT





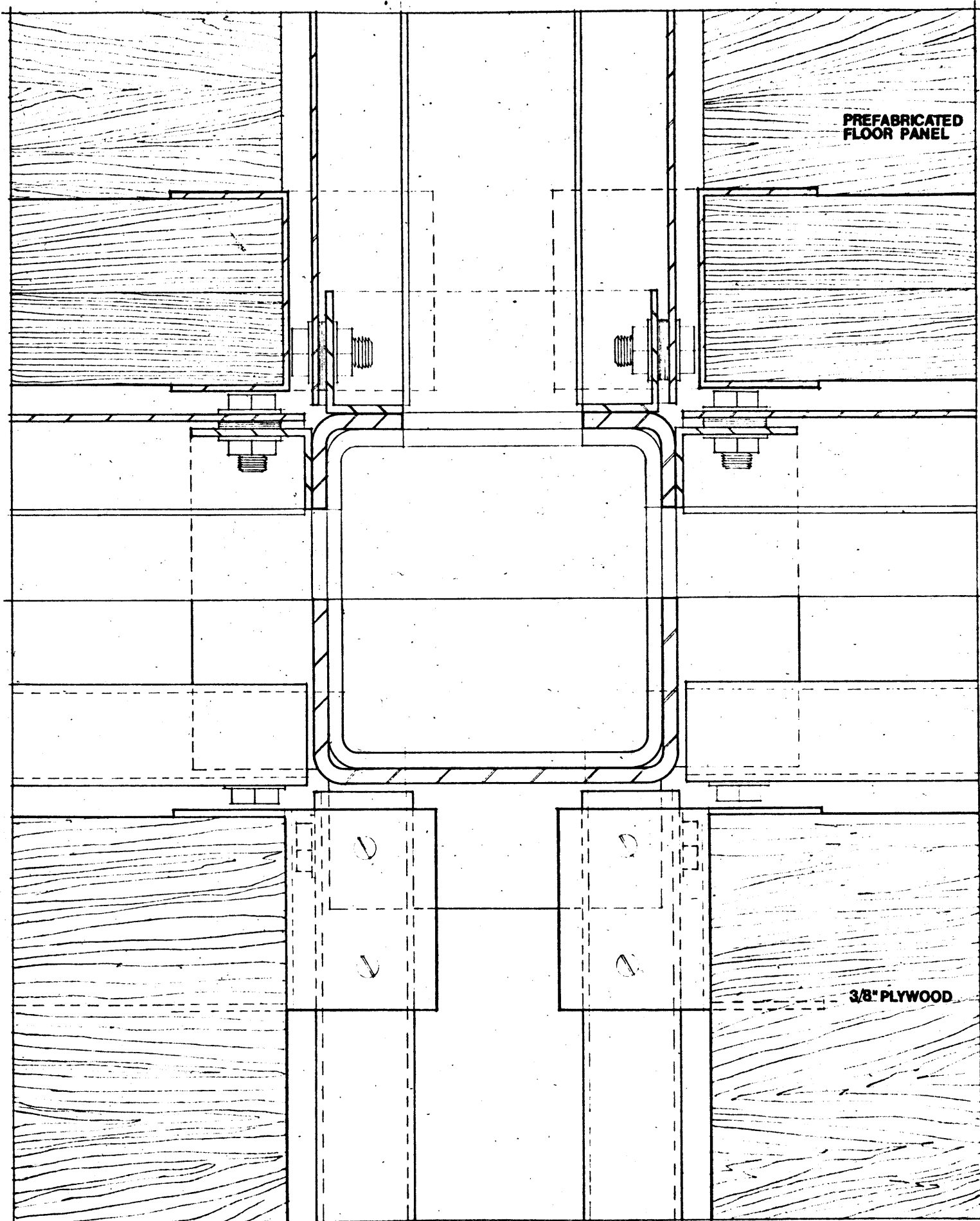
PLAN OF TYPICAL INTERIOR JOINT





SECTION AT TYPICAL INTERIOR JOINT



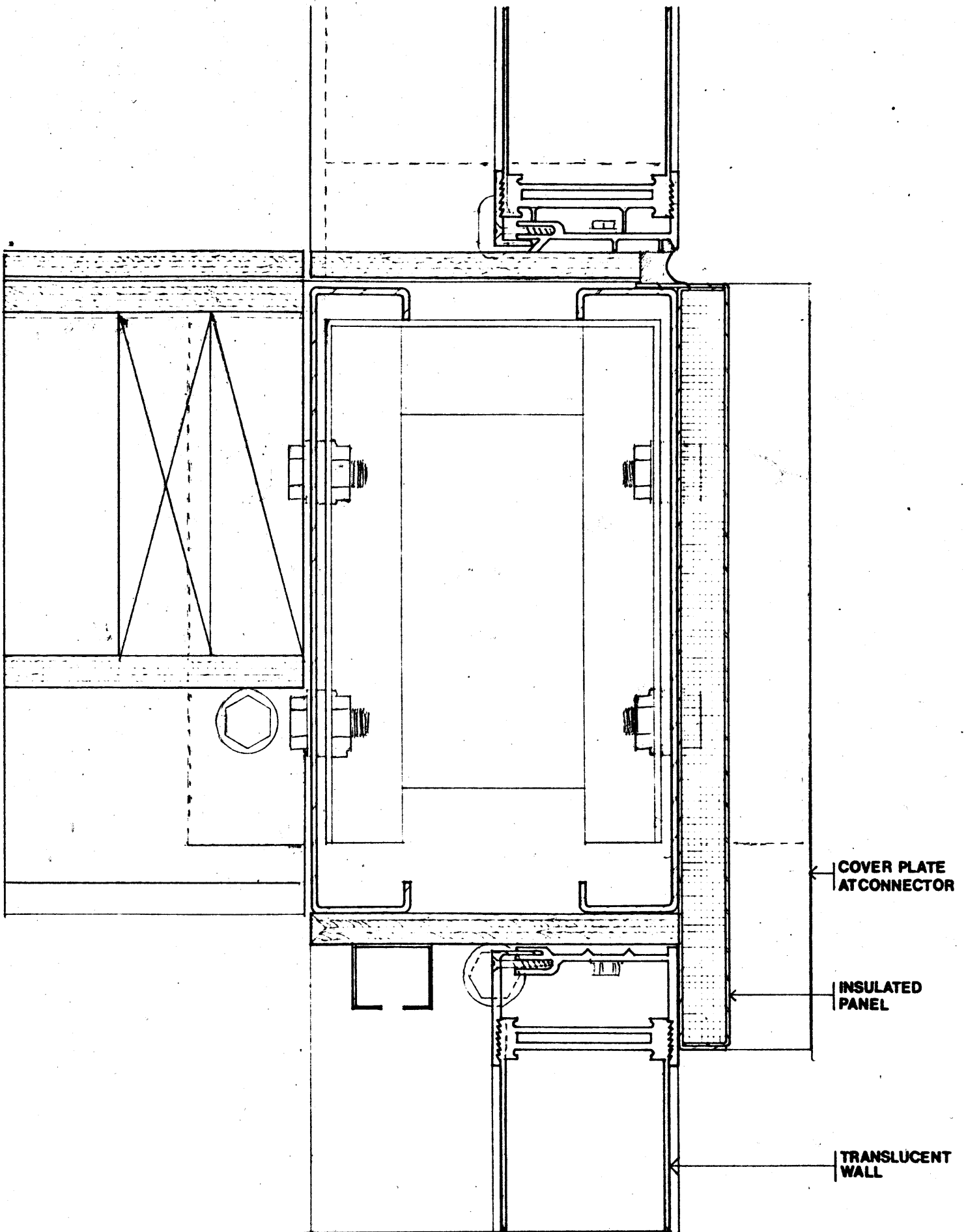


PREFABRICATED
FLOOR PANEL

3/8" PLYWOOD

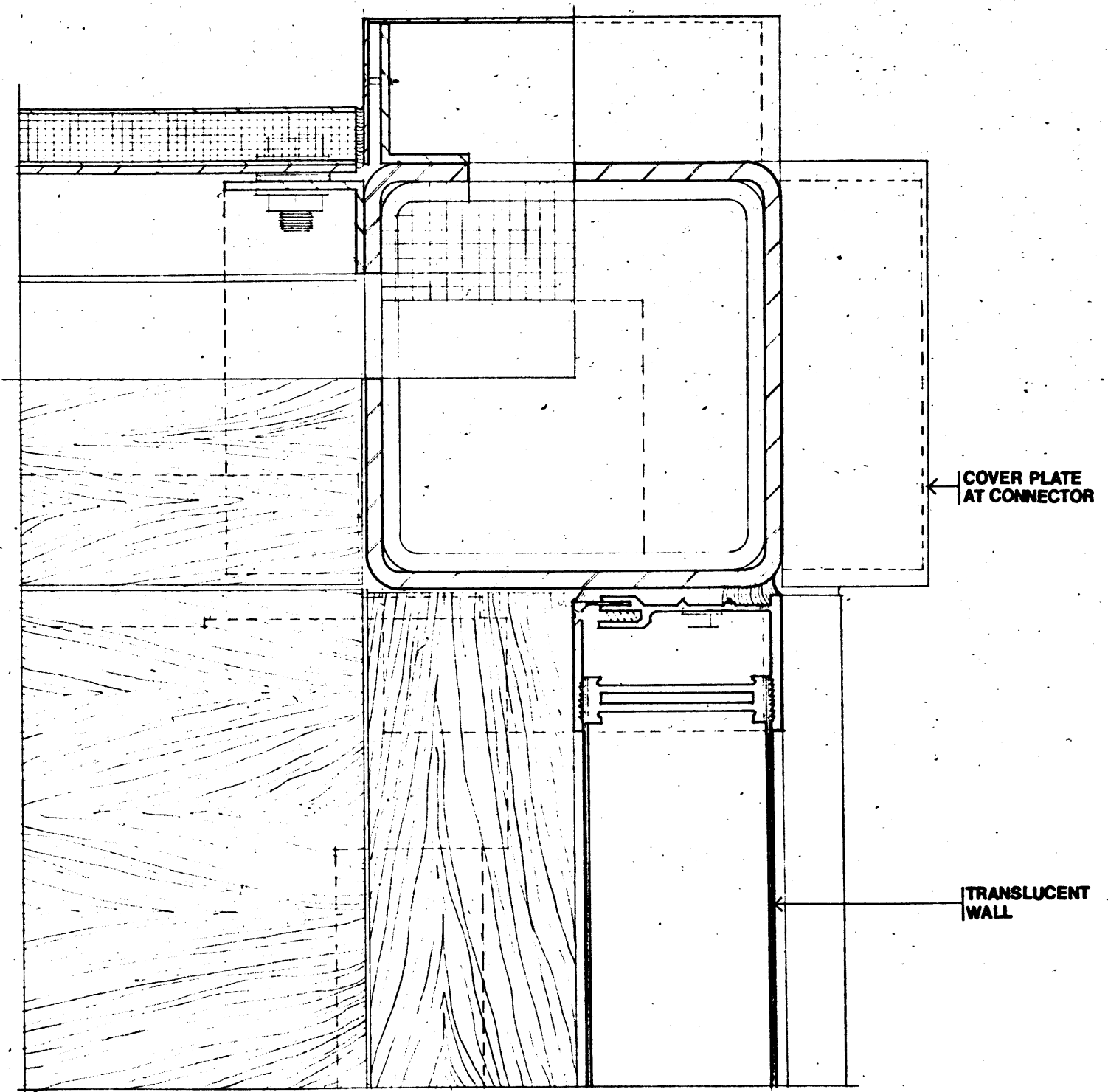
PLAN OF TYPICAL INTERIOR JOINT





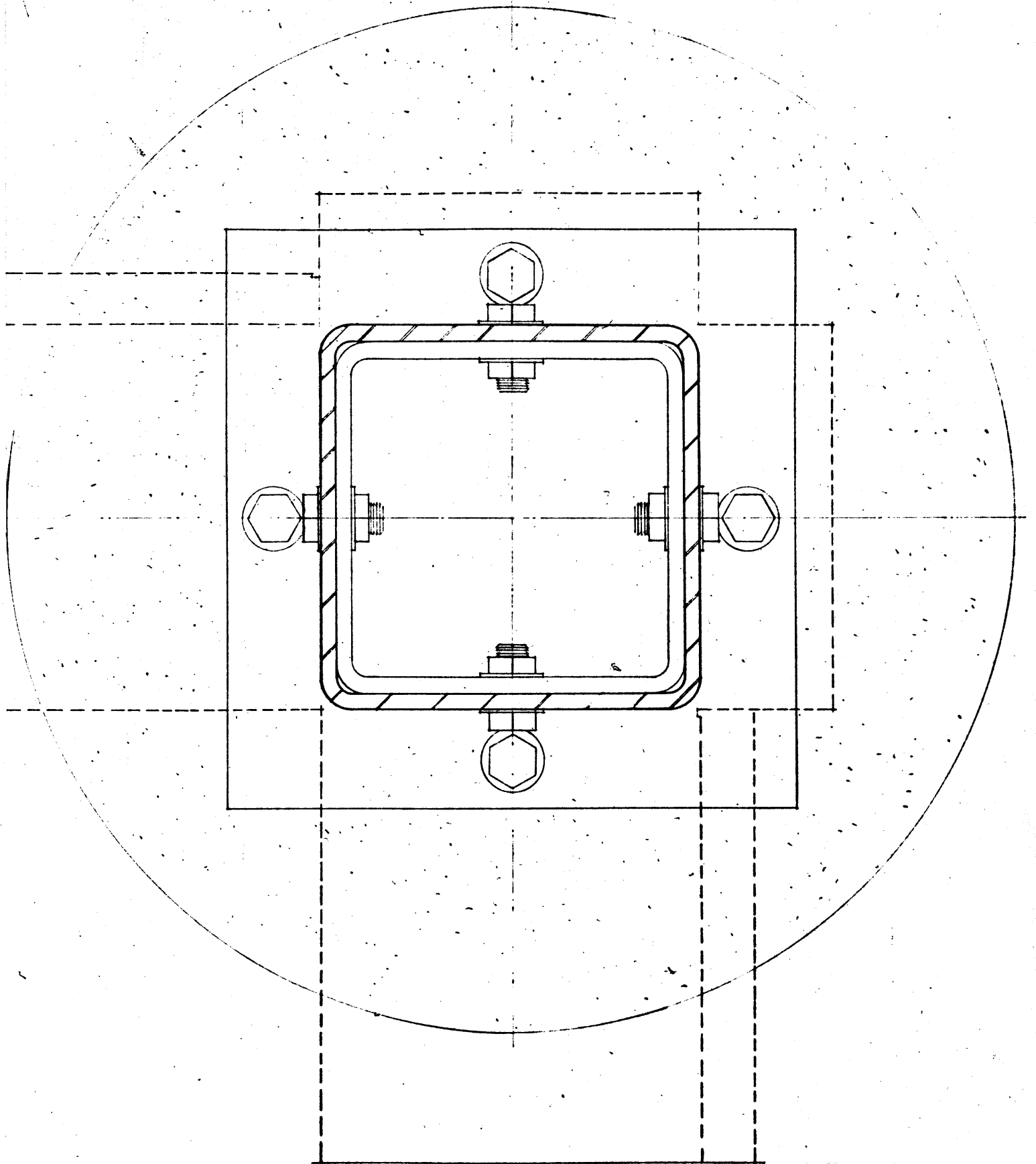
EXTERIOR WALL SECTION





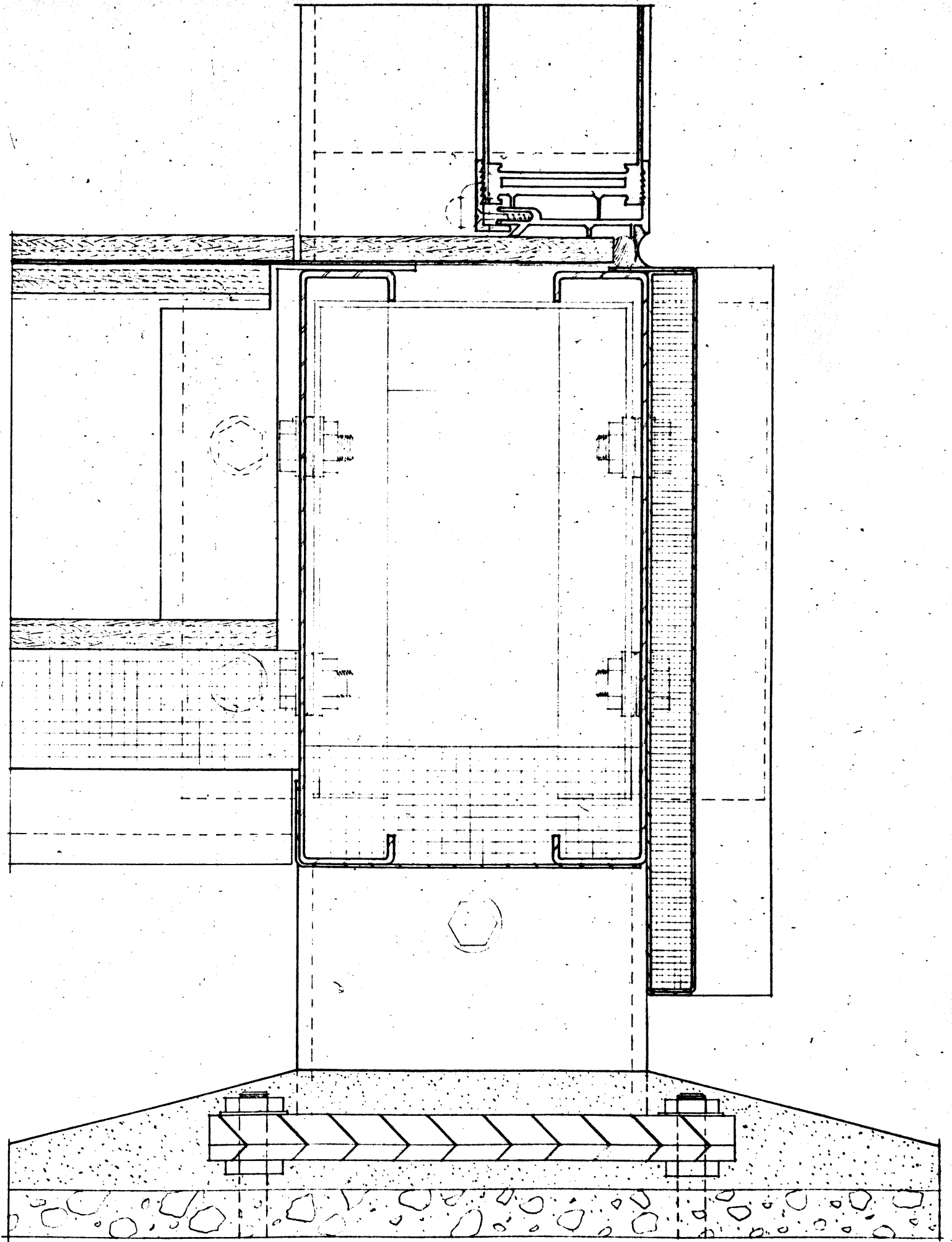
PLAN OF EXTERIOR CORNER



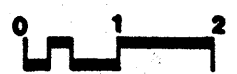


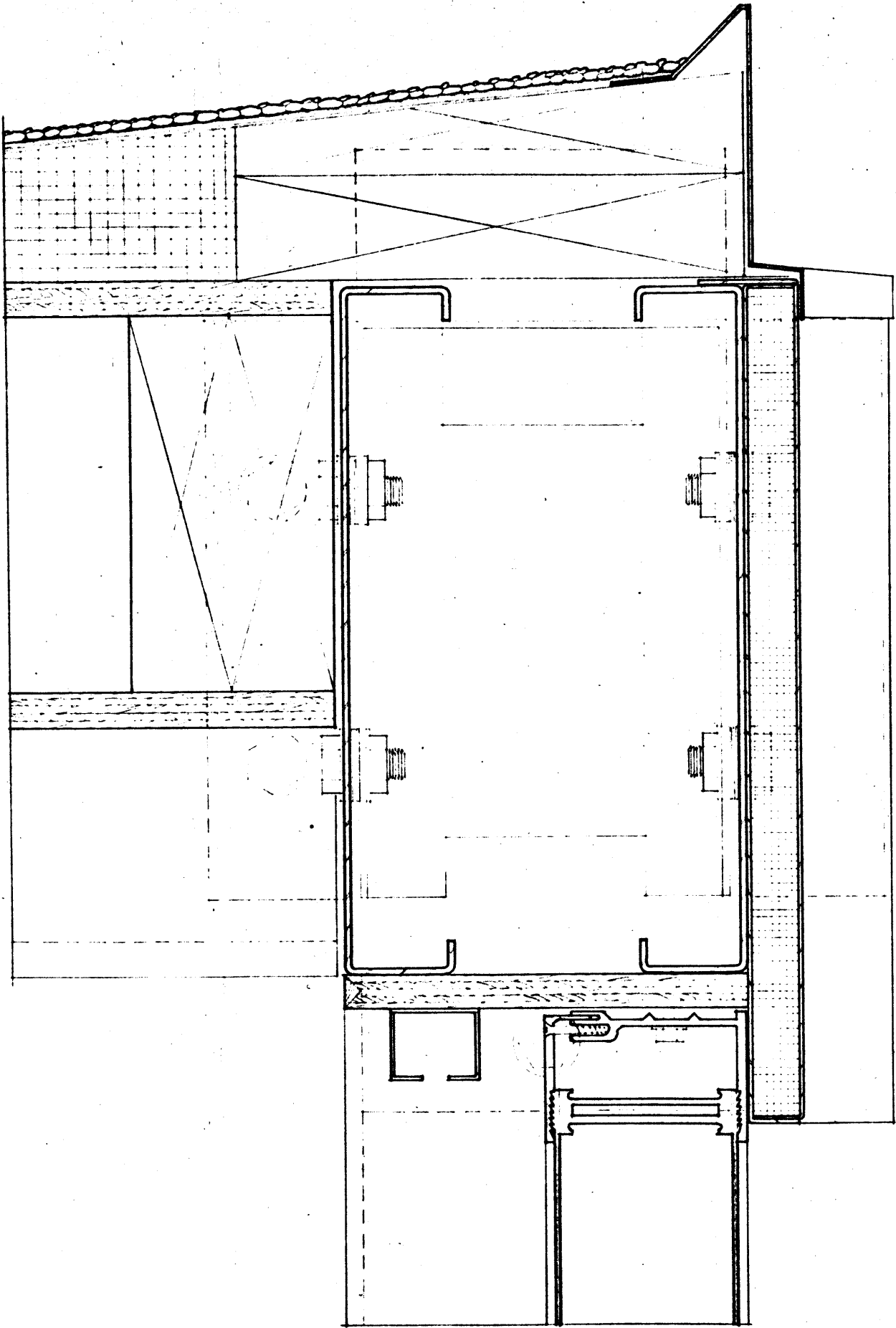
PLAN OF EXTERIOR CORNER AT FOUNDATION





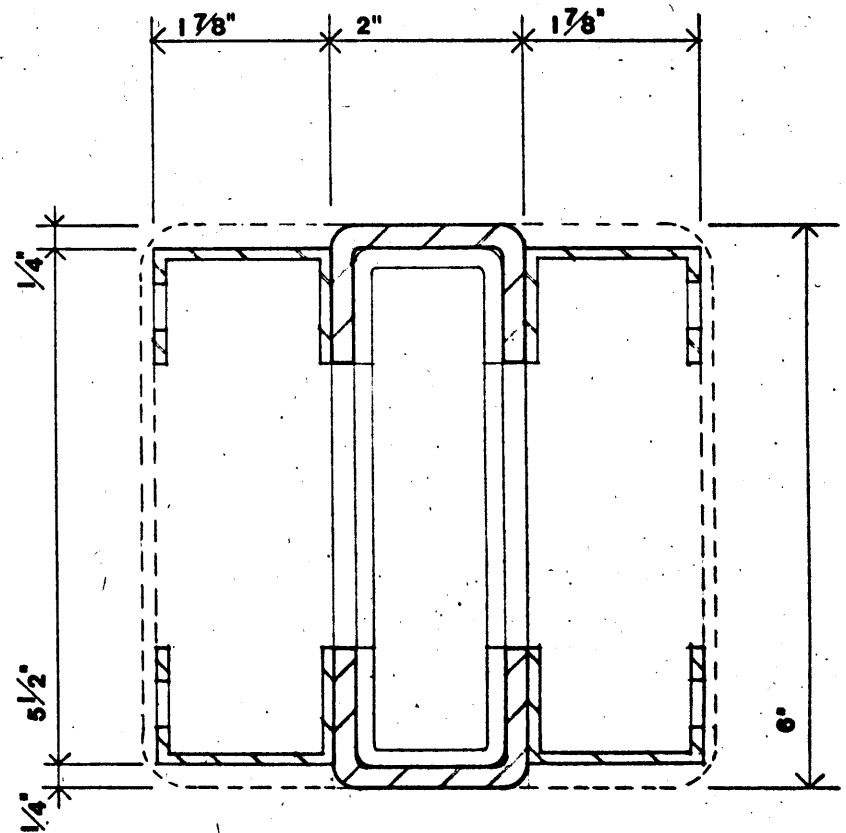
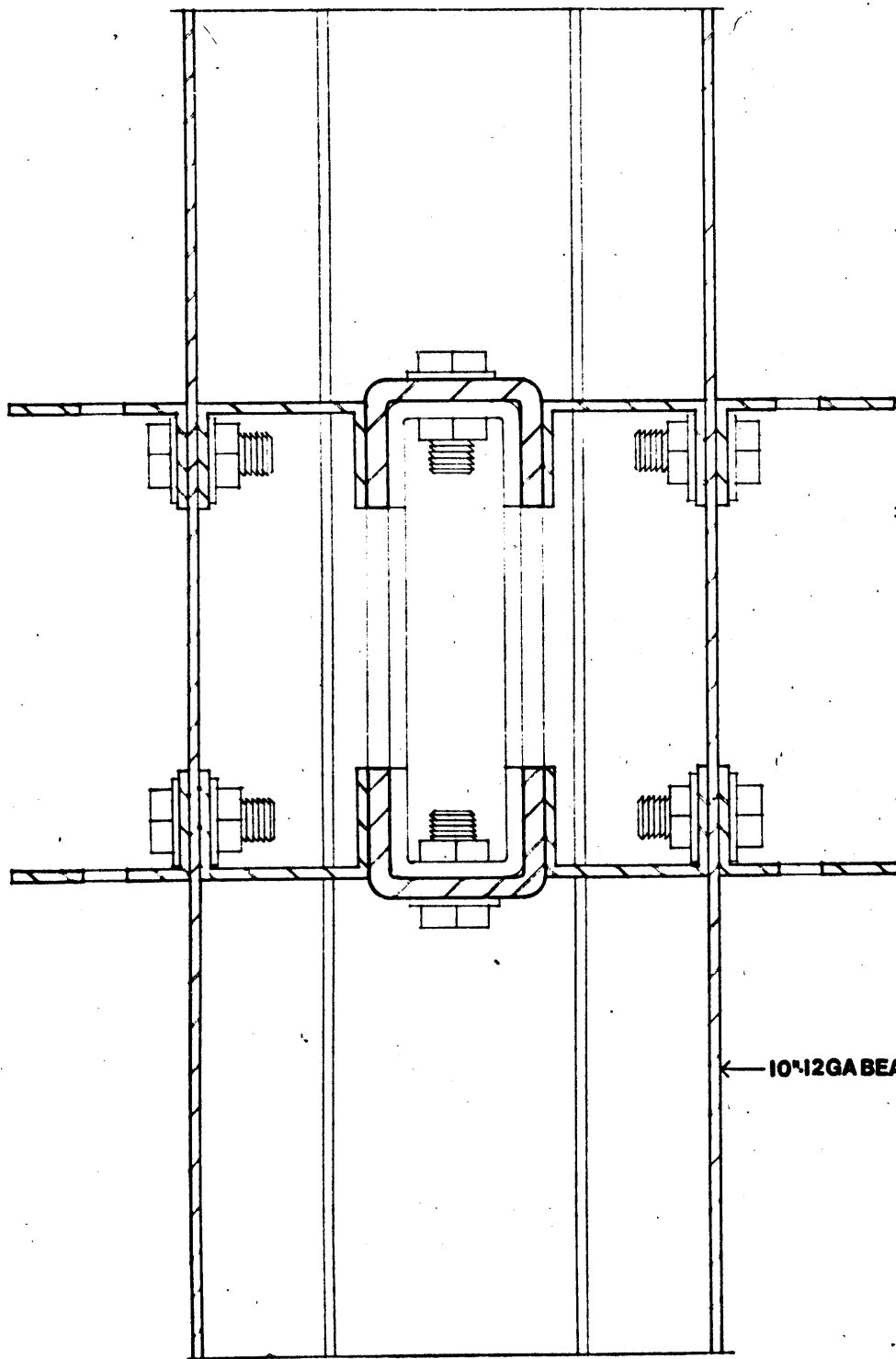
EXTERIOR WALL SECTION AT FOUNDATION





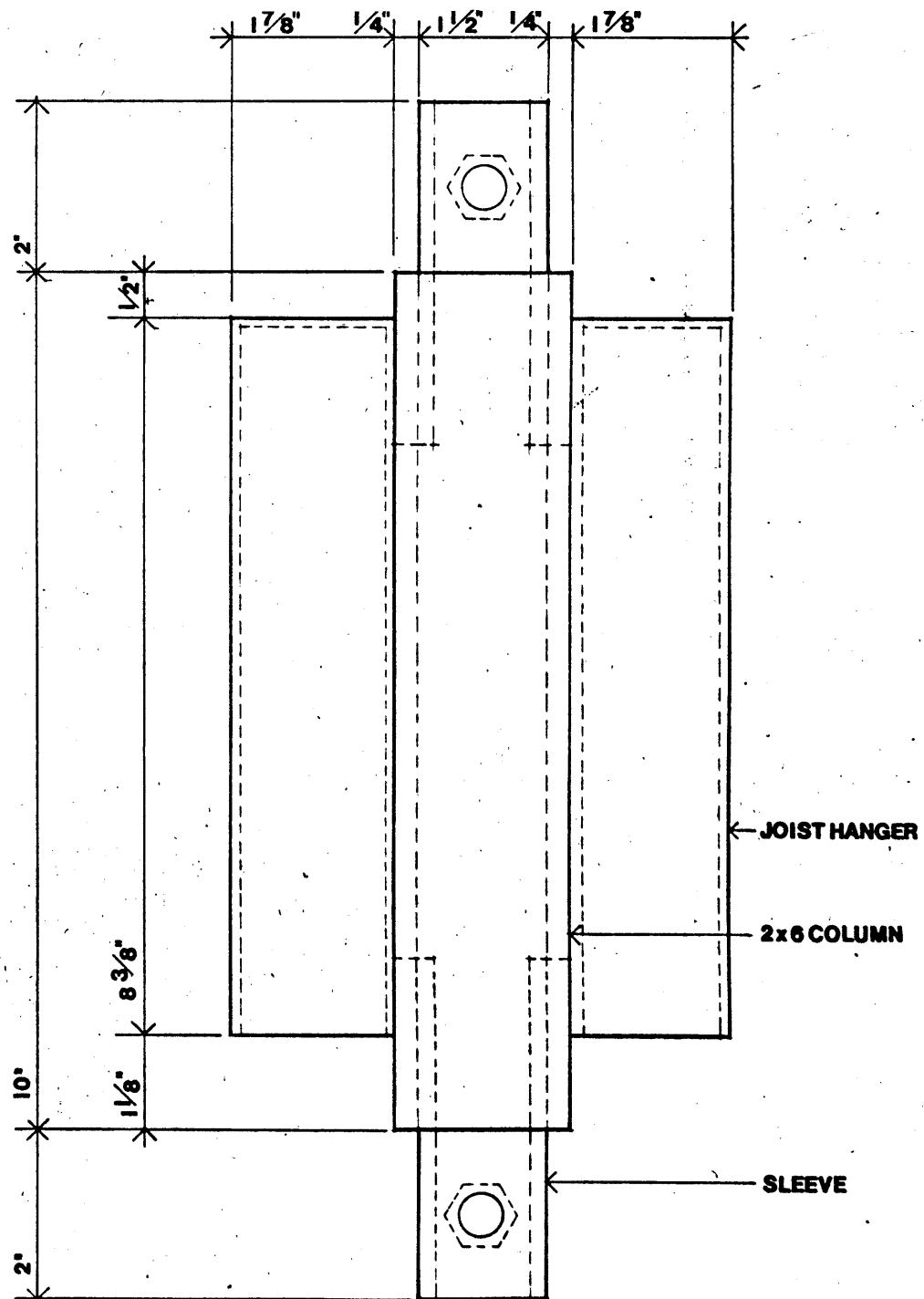
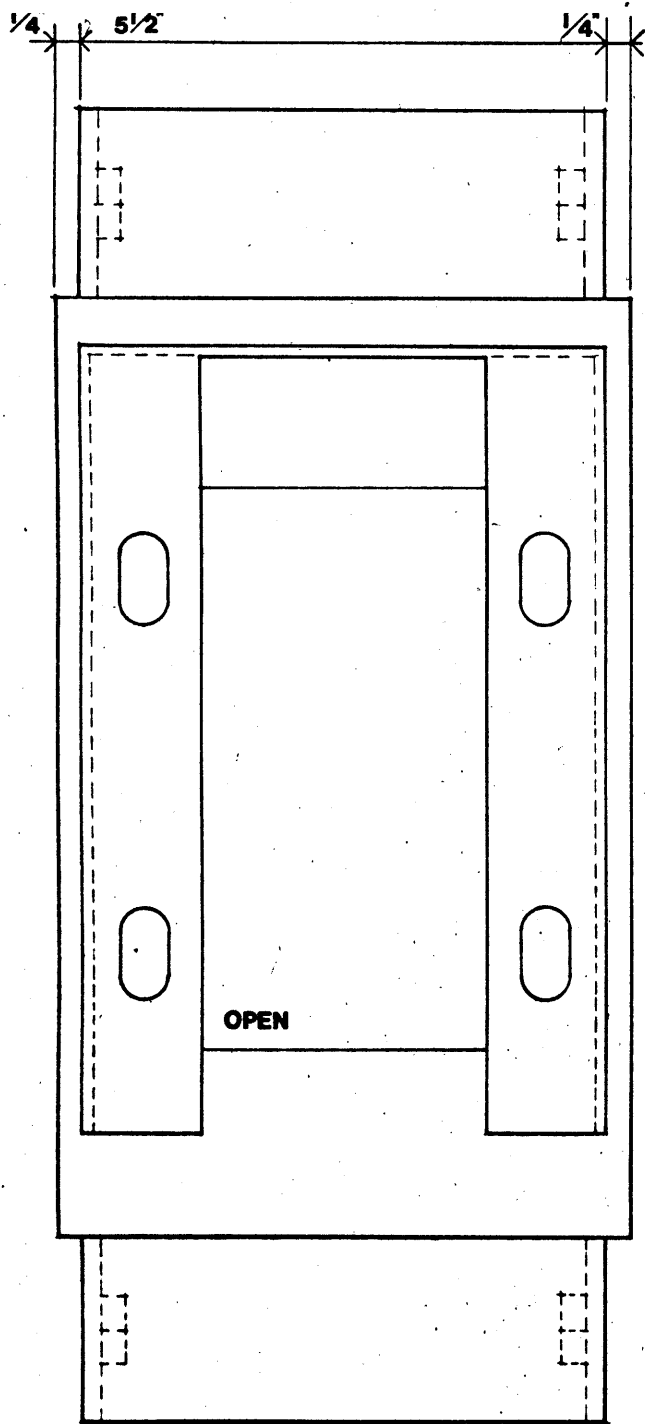
EXTERIOR WALL SECTION AT ROOF





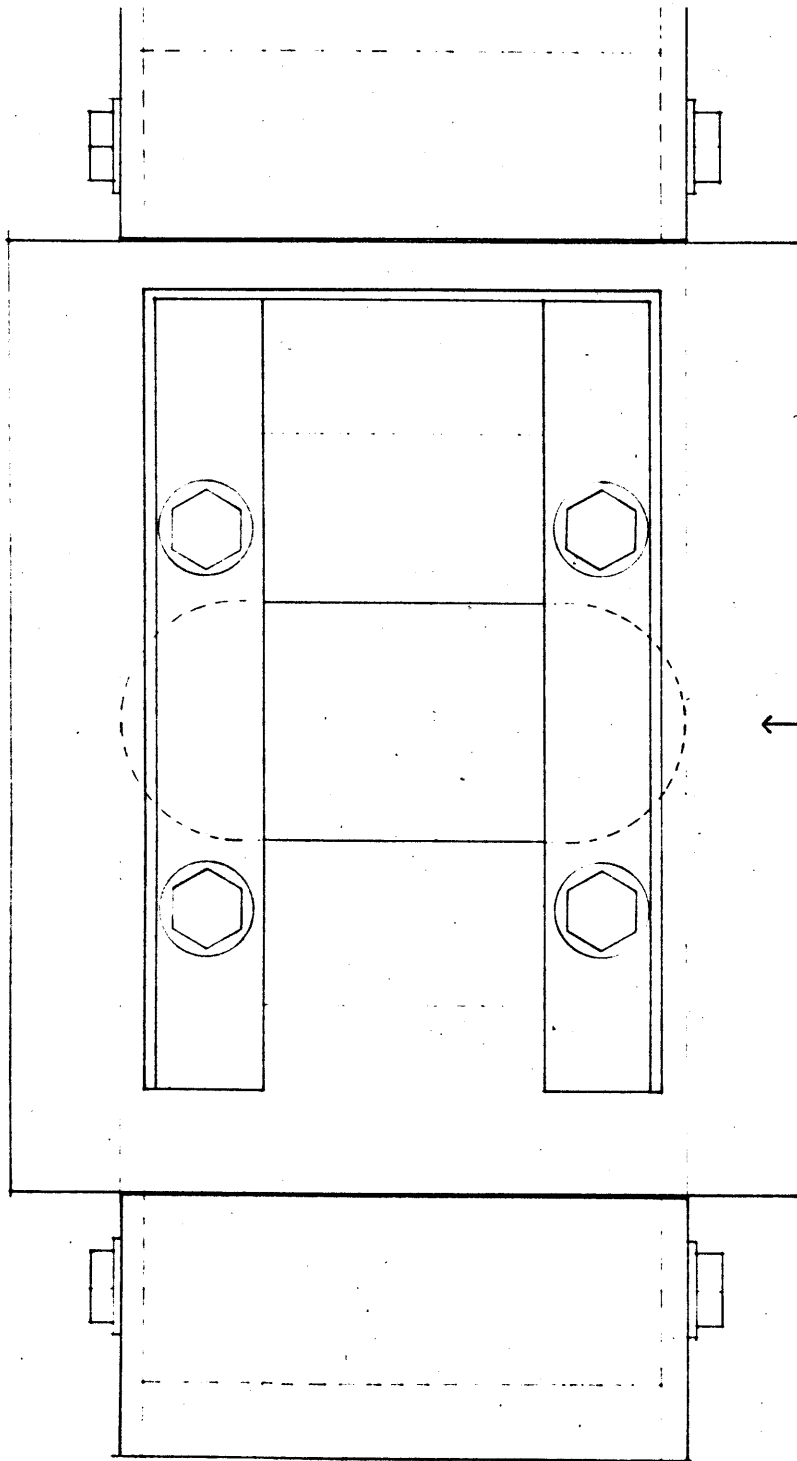
PLANS OF UNIVERSAL CANTILEVER CONNECTOR JOINT TYPE: B





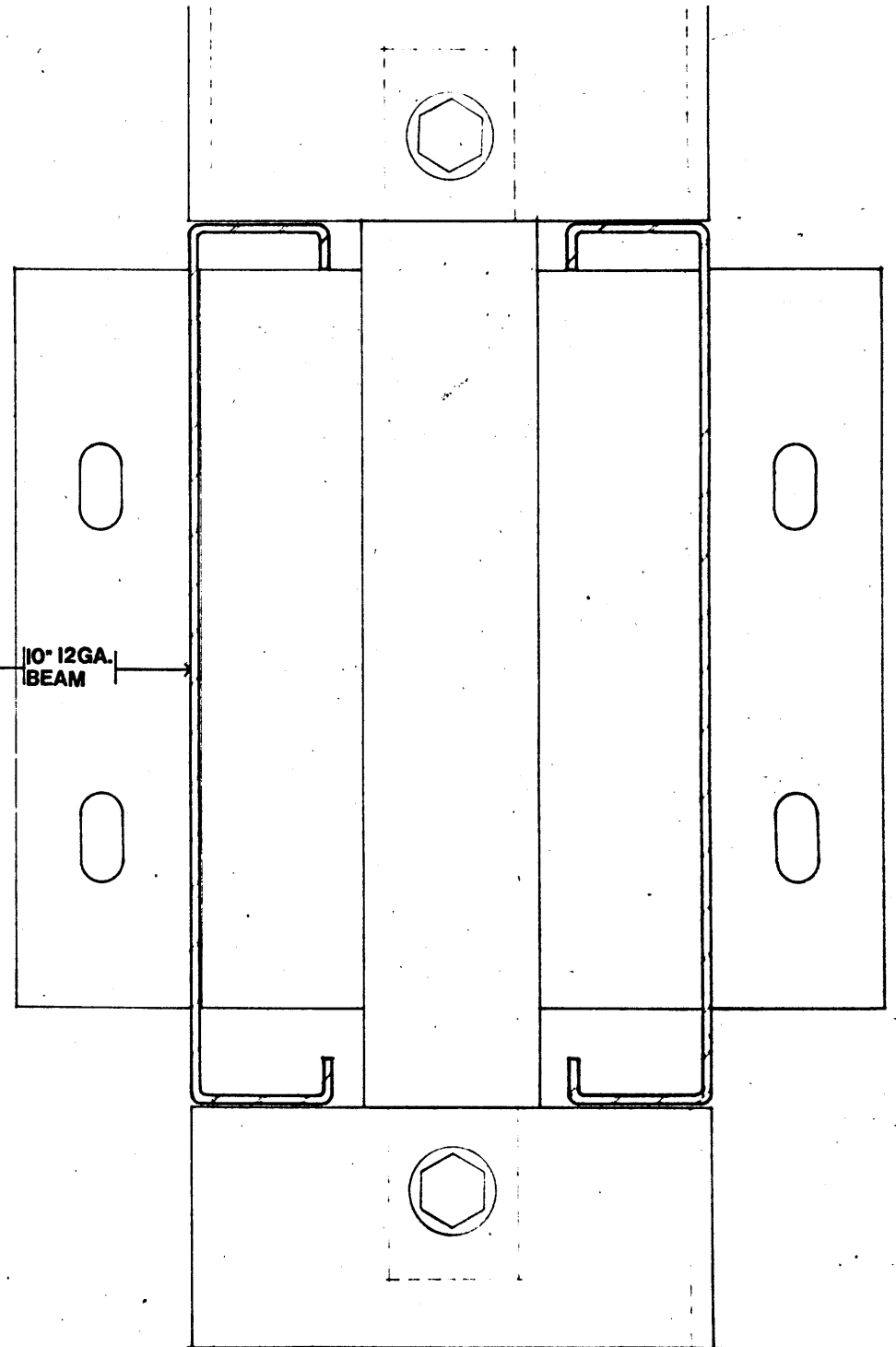
ELEVATIONS OF UNIVERSAL CANTILEVER CONNECTOR: TYPE B





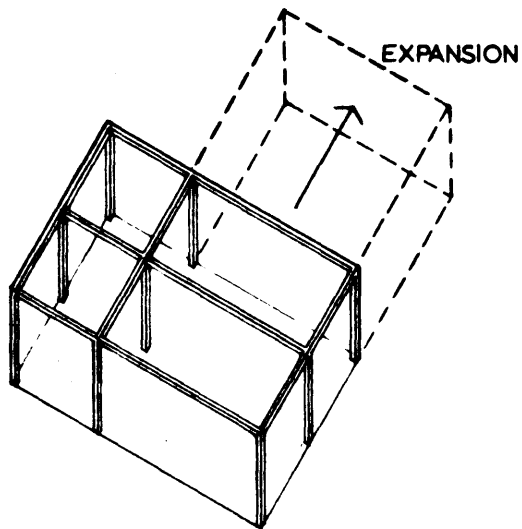
SIDE ELEVATION-TYPE B CONNECTOR

← 10" 12GA. BEAM →

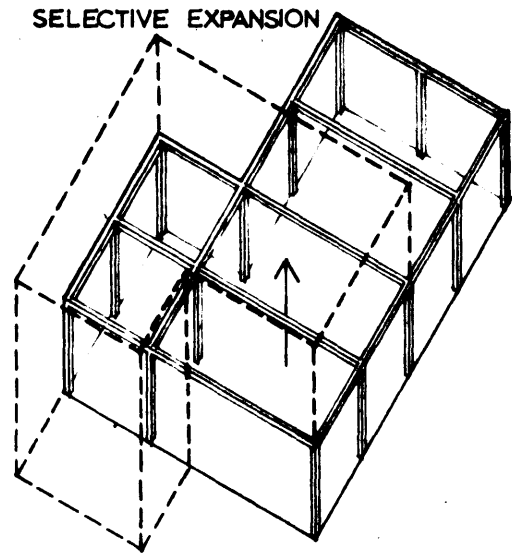


END ELEVATION

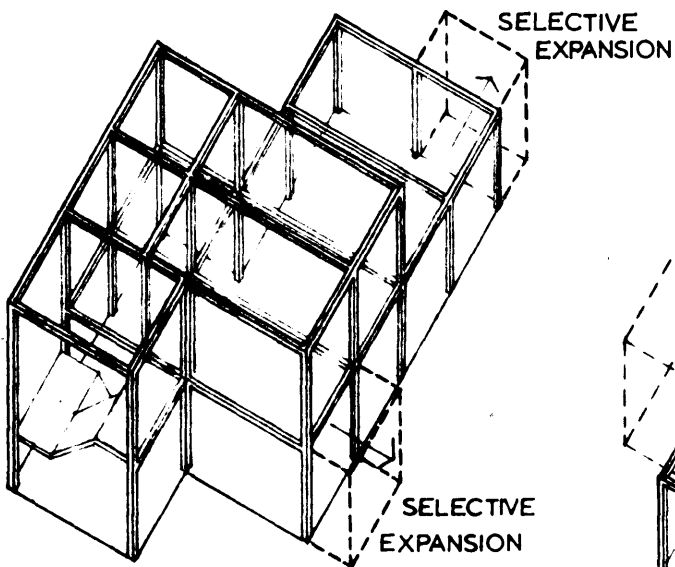




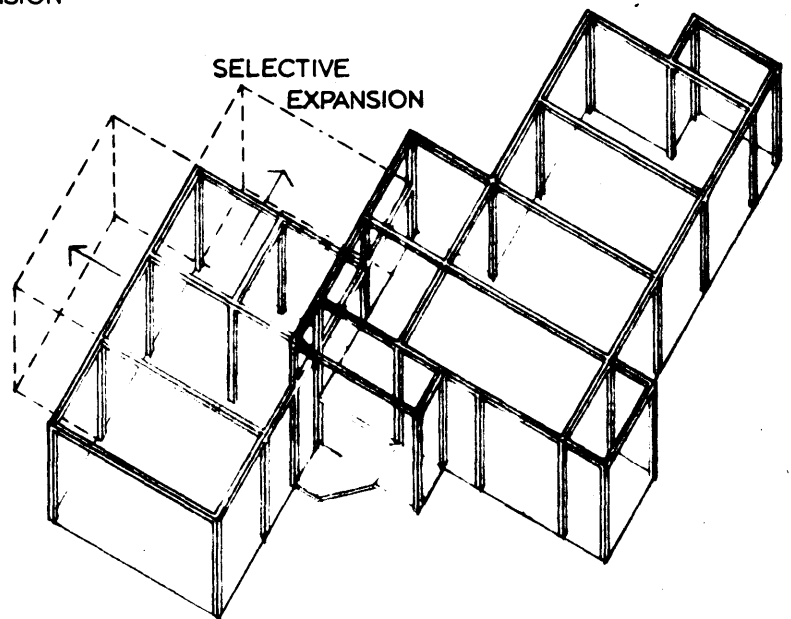
1 MINIMUM UNIT



2 1 BEDROOM UNIT

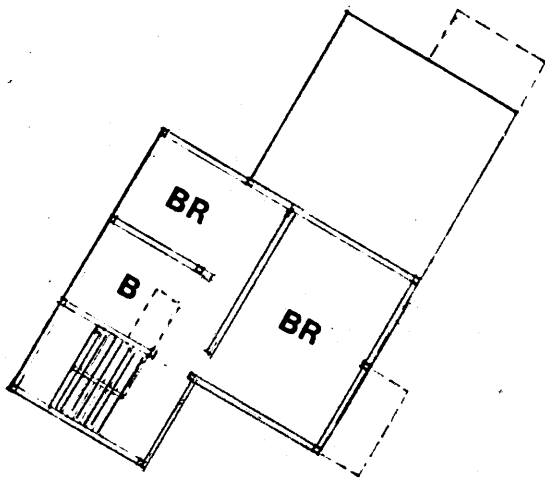
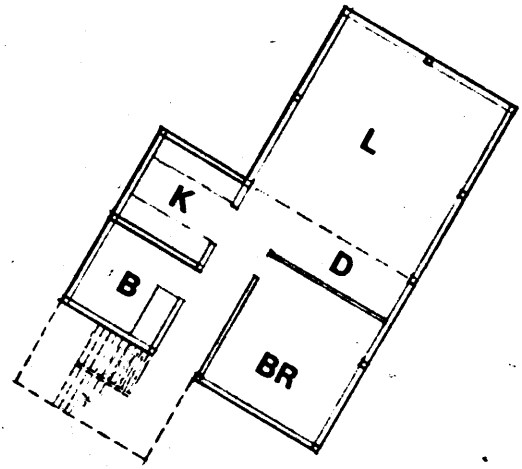
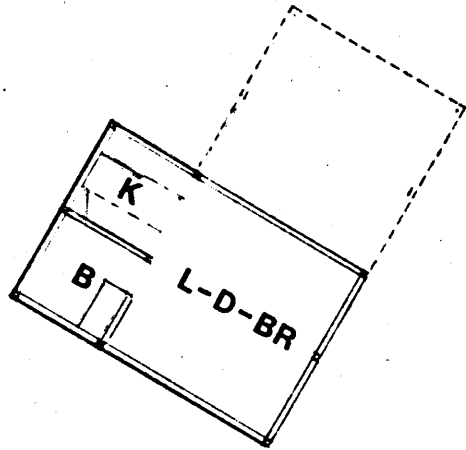


3 VERTICAL
3 BEDROOM UNIT

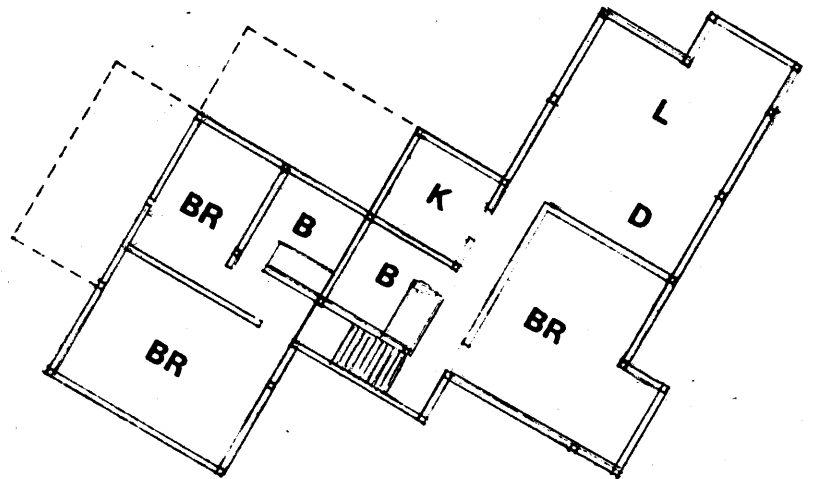


4 3 BEDROOM UNIT
ADAPTED TO SLOPING SITE

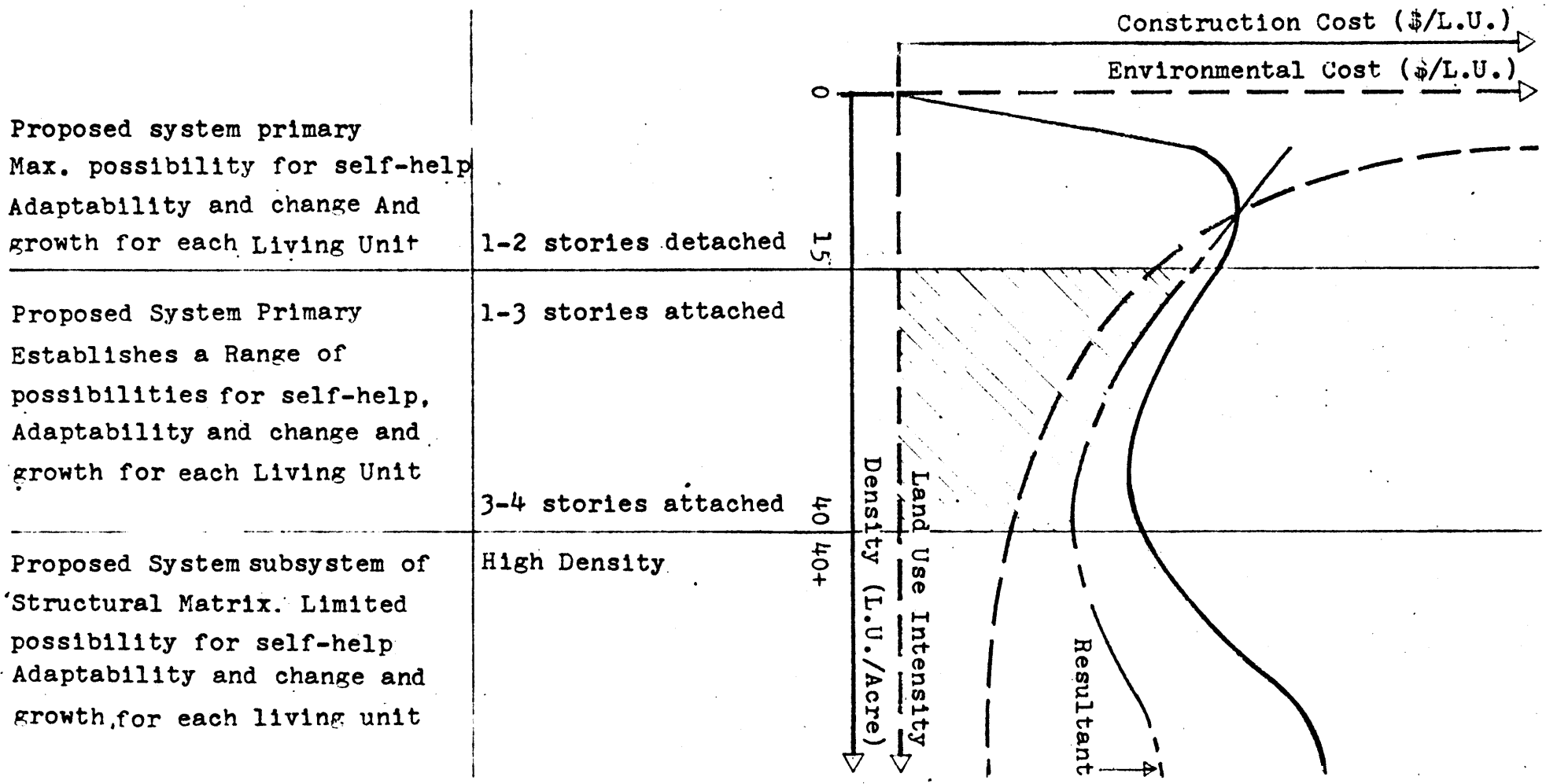
STRUCTURAL ADAPTABILITY



UPPER LEVEL



SYSTEM APPLICATION



SYSTEM APPLICATION DIAGRAM

SYSTEM APPLICATION DIAGRAM

This diagram is a generalized illustration of the relationship between cost and type of housing development. Housing is divided into three categories in terms of number of living units per acre. These categories and the implications of the proposed structural system for each category have already been discussed.

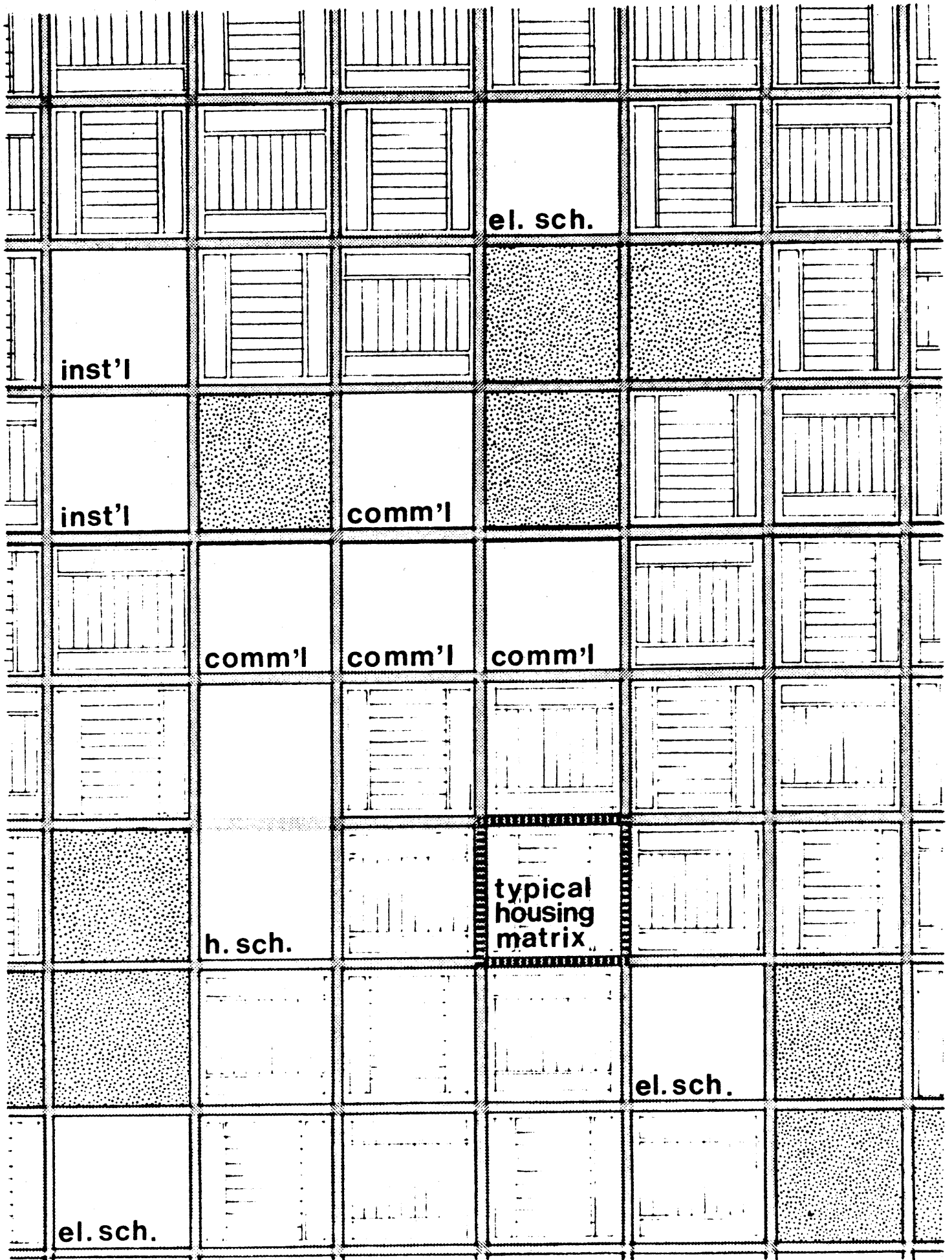
The solid-line curve in the diagram represents the relationship between construction cost and density of housing. The dashed-line curve represents the relationship between environmental cost and intensity of land use, i.e., the environmental factors, or costs, necessary to develop a socially and economically successful community. The underlying assumption is that the success of a housing development depends not only on the comforts provided by the living unit itself, but also on the services available to the community. These services range from utilities, open spaces, parks and recreation areas, schools, shopping centers, community centers, transportation networks, etc. to more abstract benefits which determine the quality of socio-economic life. Based on past experience with housing types and community development, it is assumed that the cost per living unit of these supporting services decreases as the intensity of land use, hence the sharing of facilities by larger numbers of living units, increases.

However, this relationship is not directly proportional. The diagram indicates that the benefits of increasing land use intensity grow in smaller increments as increasingly high densities are reached.

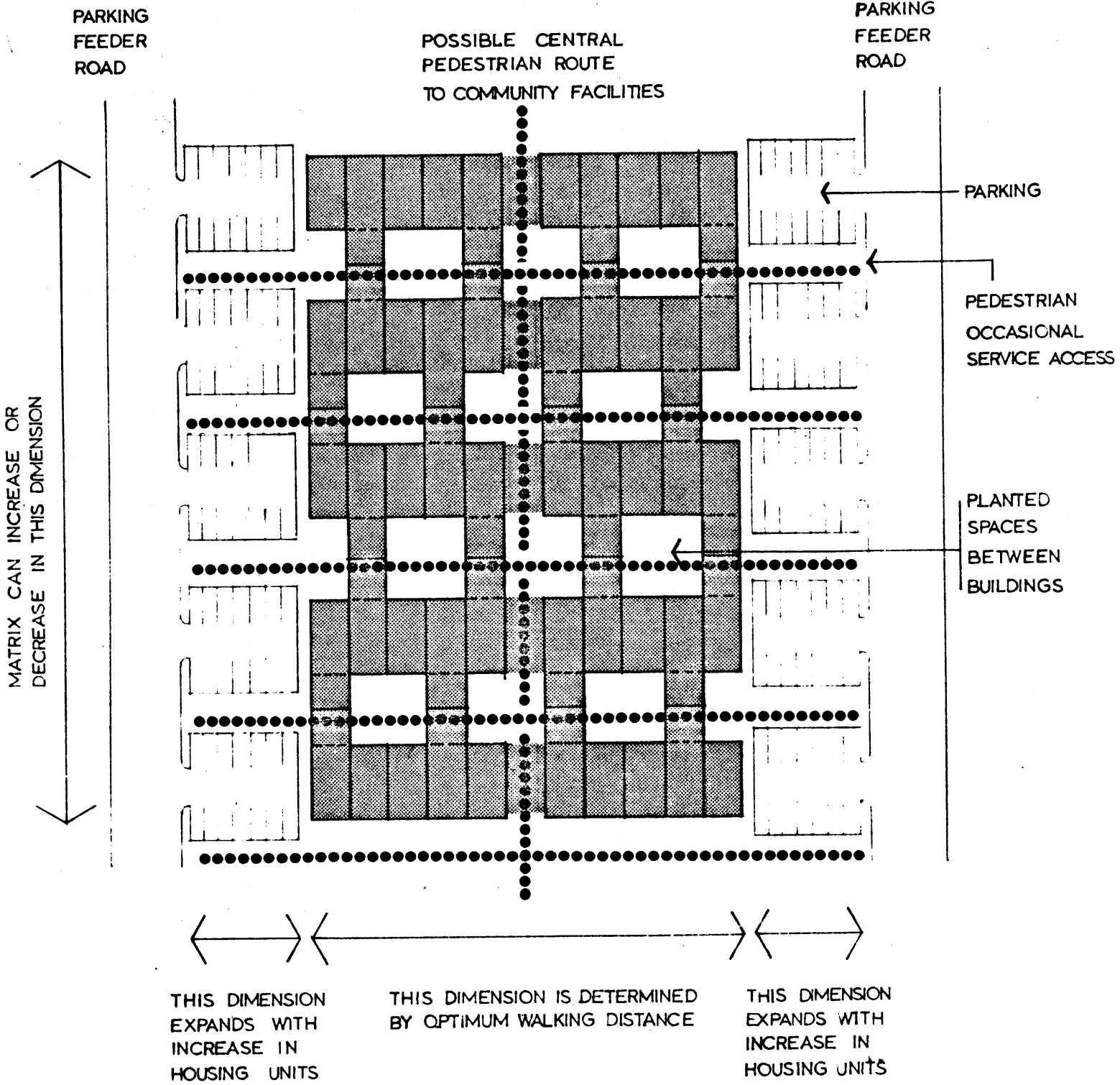
These considerations led to the selection of the 15-40 living units per acre density as the area of intensive study; (the shaded area in diagram). This type of housing was selected because it represents the low to medium range in terms of construction cost and promises better environmental benefits with increasing land use intensity.

The 15-40 living units per acre density was selected for intensive study because it appears to be more economical in terms of construction cost and of environmental cost, and also offers a desirable range of possibilities for self-help, adaptability, and change and growth for each living unit.

The proposed construction system may be used to develop a wide range of site plans at a density of 15-40 living units per acre. The "General Site Matrix" and the "Diagrammatic Layout of Housing Matrix" illustrates a possible application of this system.



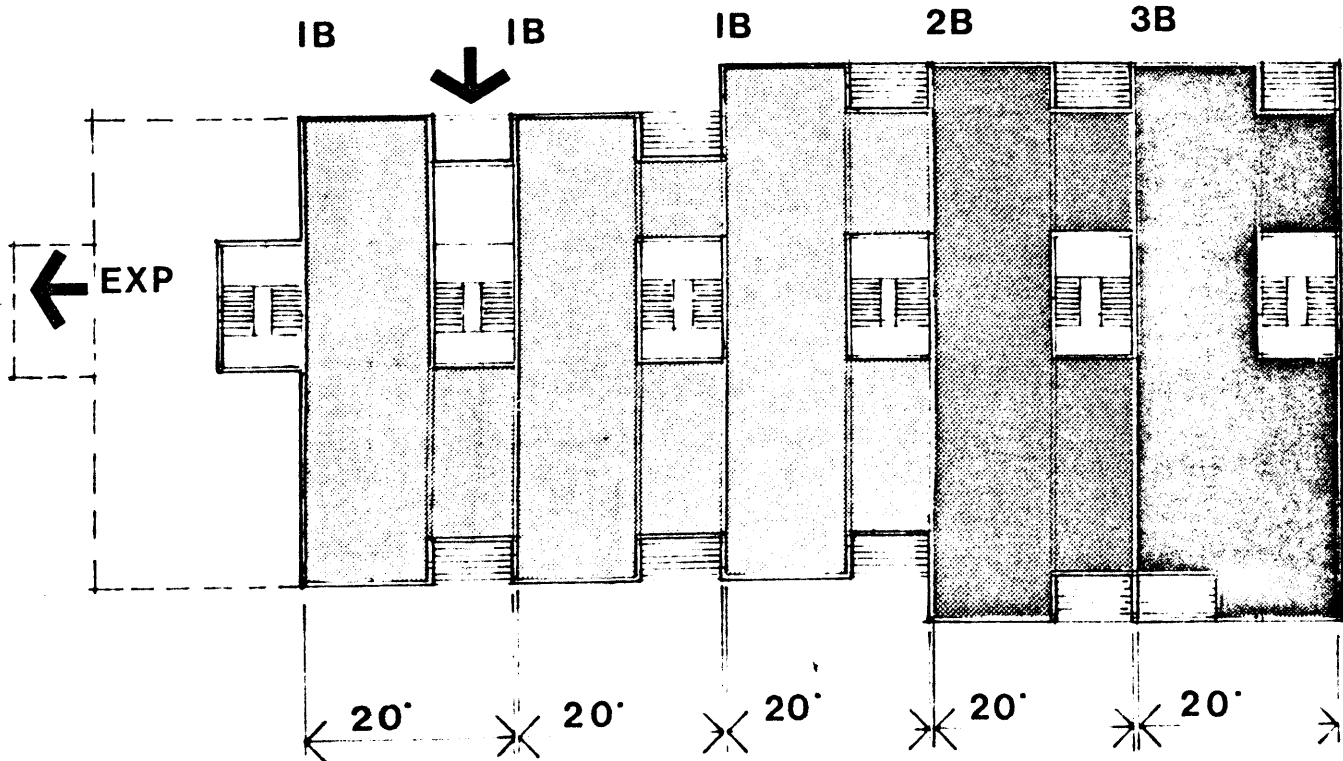
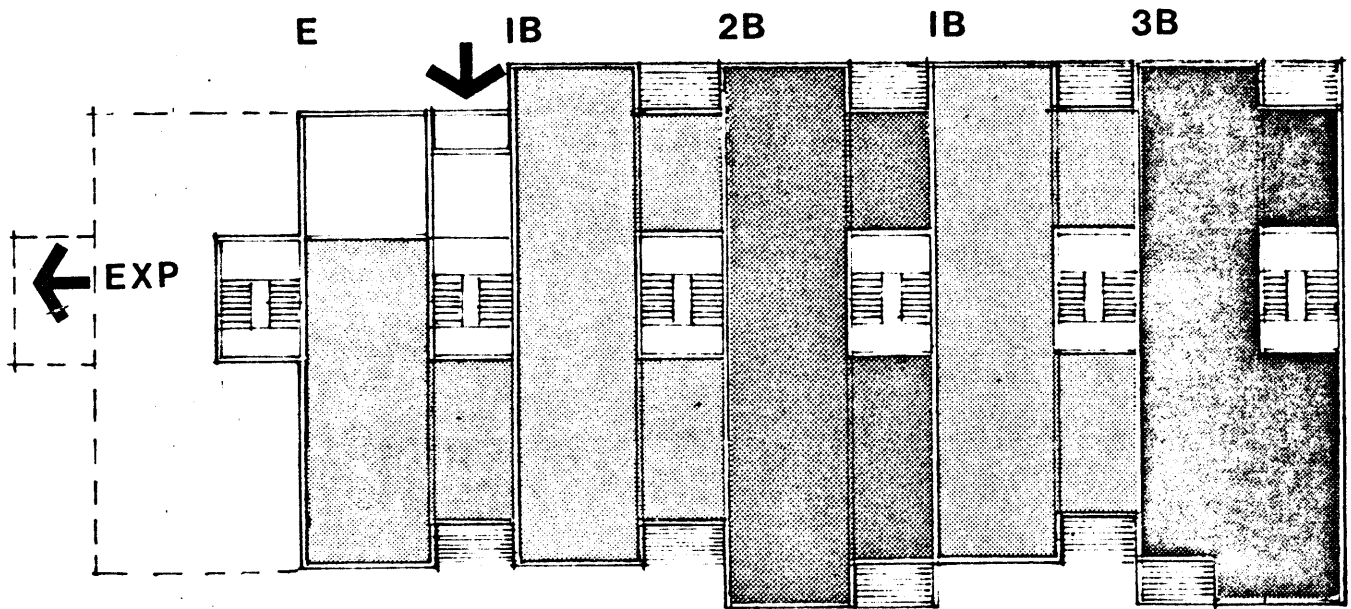
GENERAL SITE MATRIX



DIAGRAMMATIC LAYOUT OF HOUSING MATRIX

DIAGRAMATIC EXAMPLES OF HOUSING

TYPES: 20'-0" MODULE UNITS



POSSIBLE FAMILY GROUPINGS
20' UNIT MATRIX

LEGEND

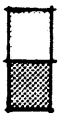
E ————— EFFICIENCY APARTMENT

1B ————— ONE BEDROOM APARTMENT

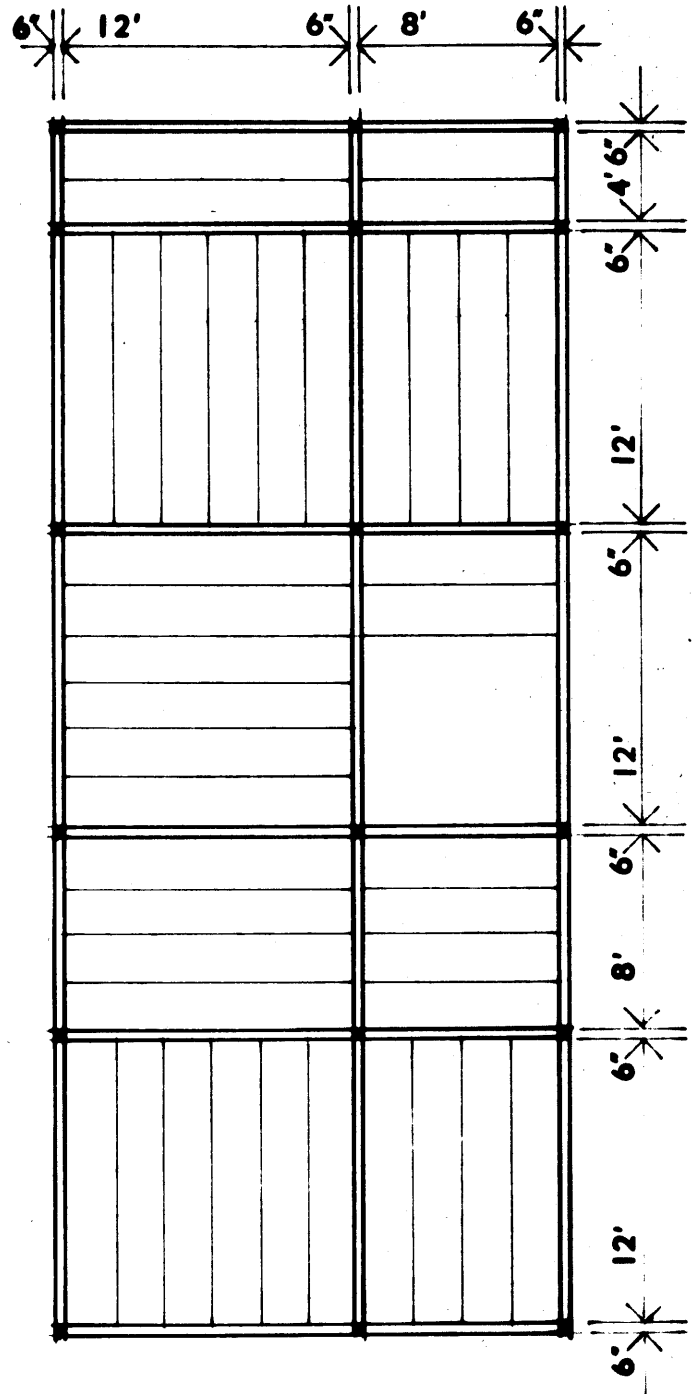
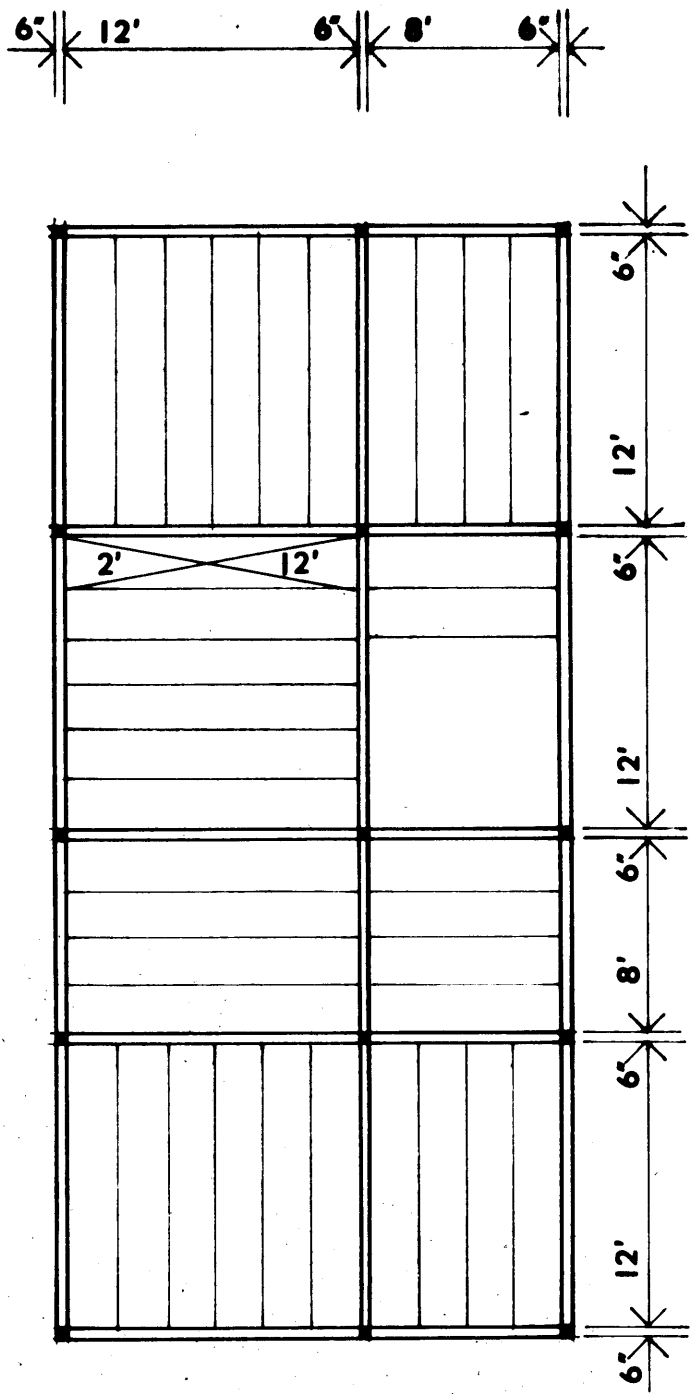
2B ————— TWO BEDROOM APARTMENT

3B ————— THREE BEDROOM APARTMENT

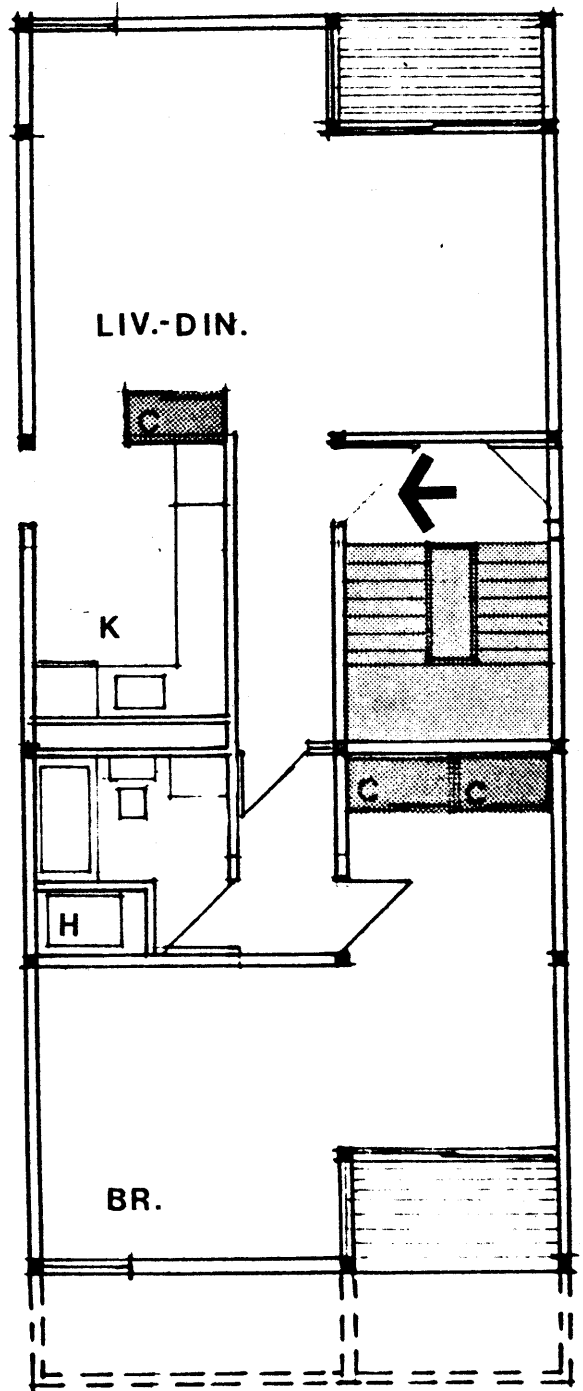
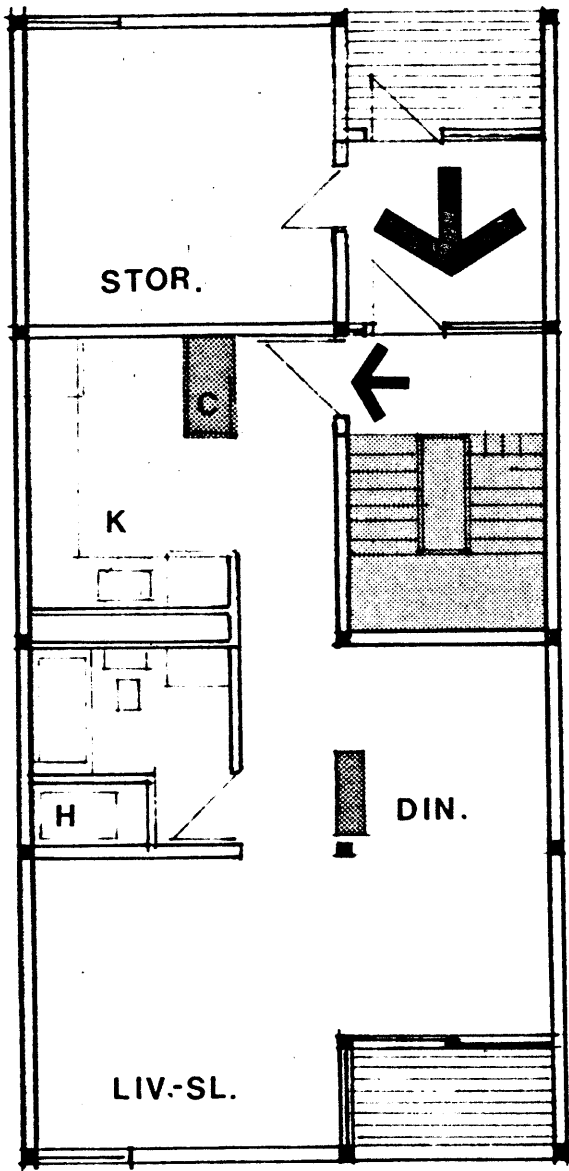
C ————— CLOSET



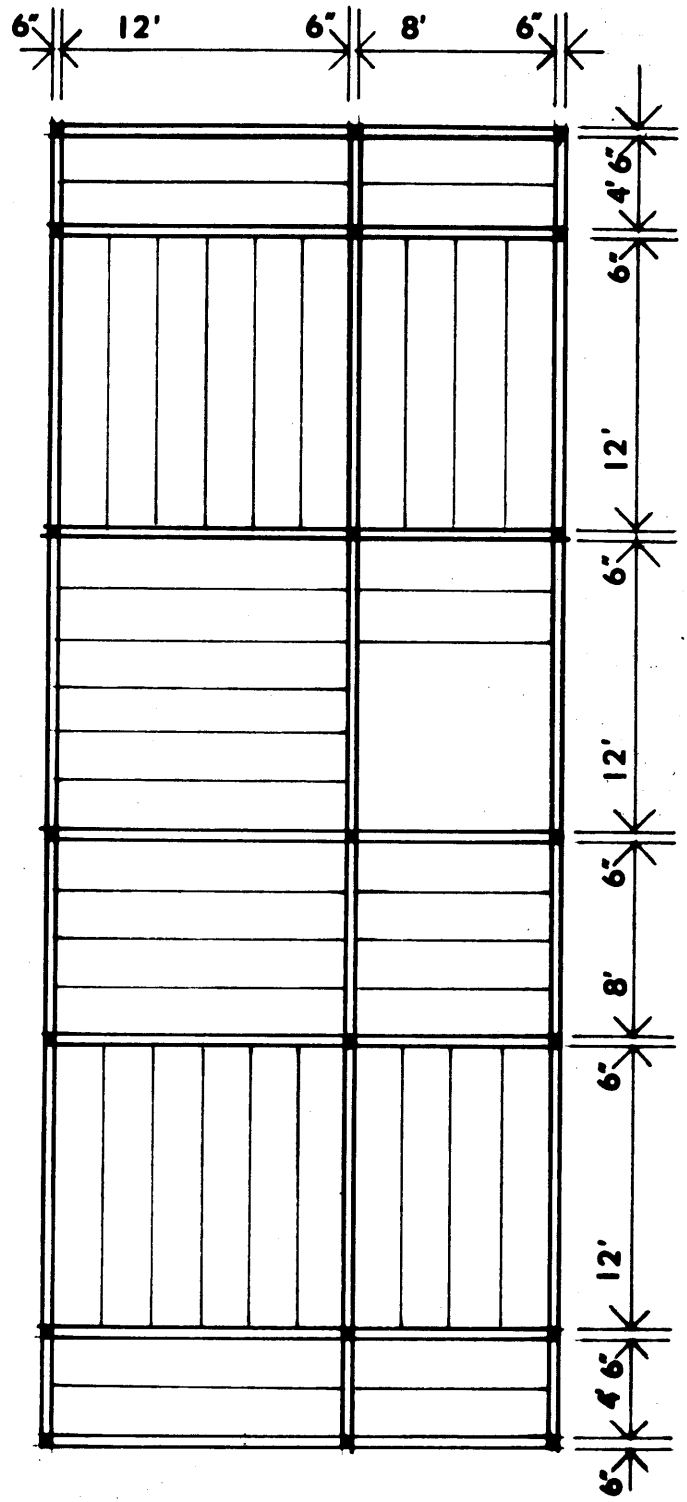
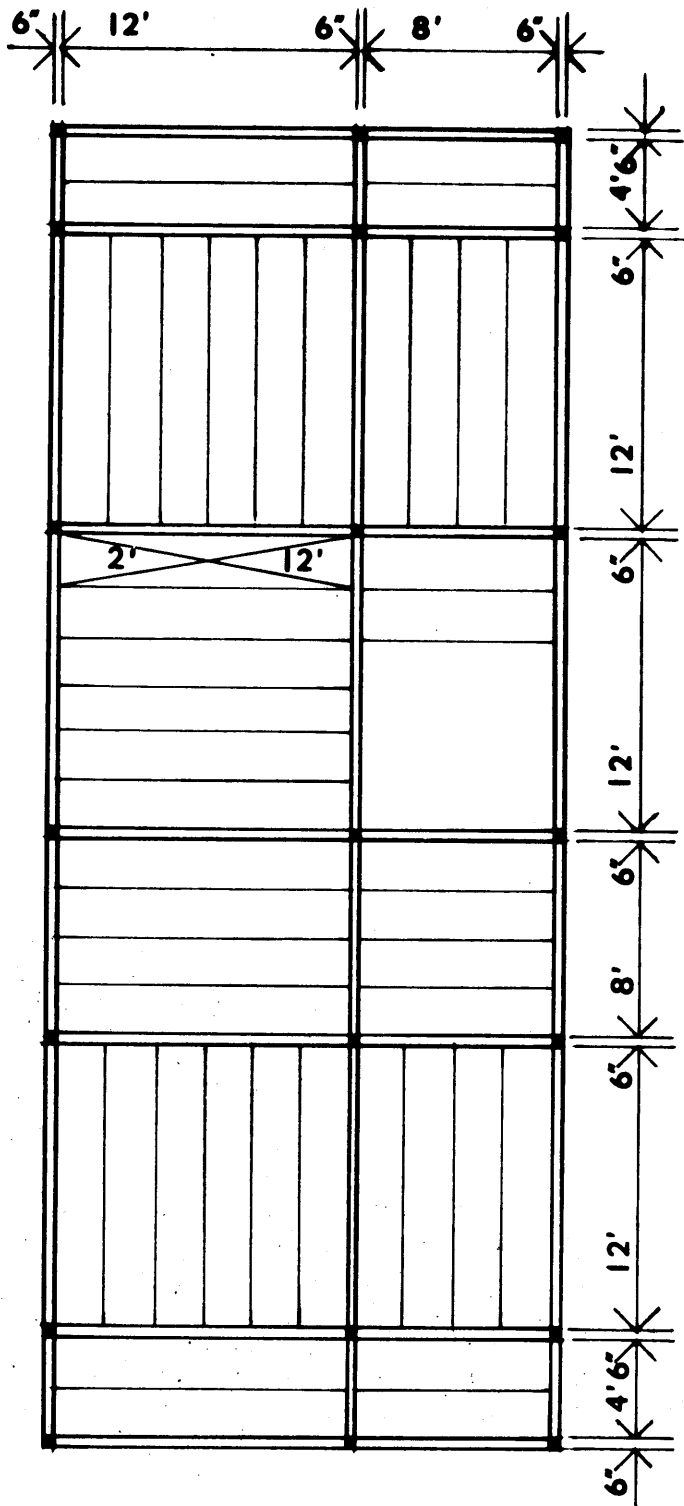
SHADED AREAS INDICATE POTENTIAL
PREFABRICATED COMPONENTS



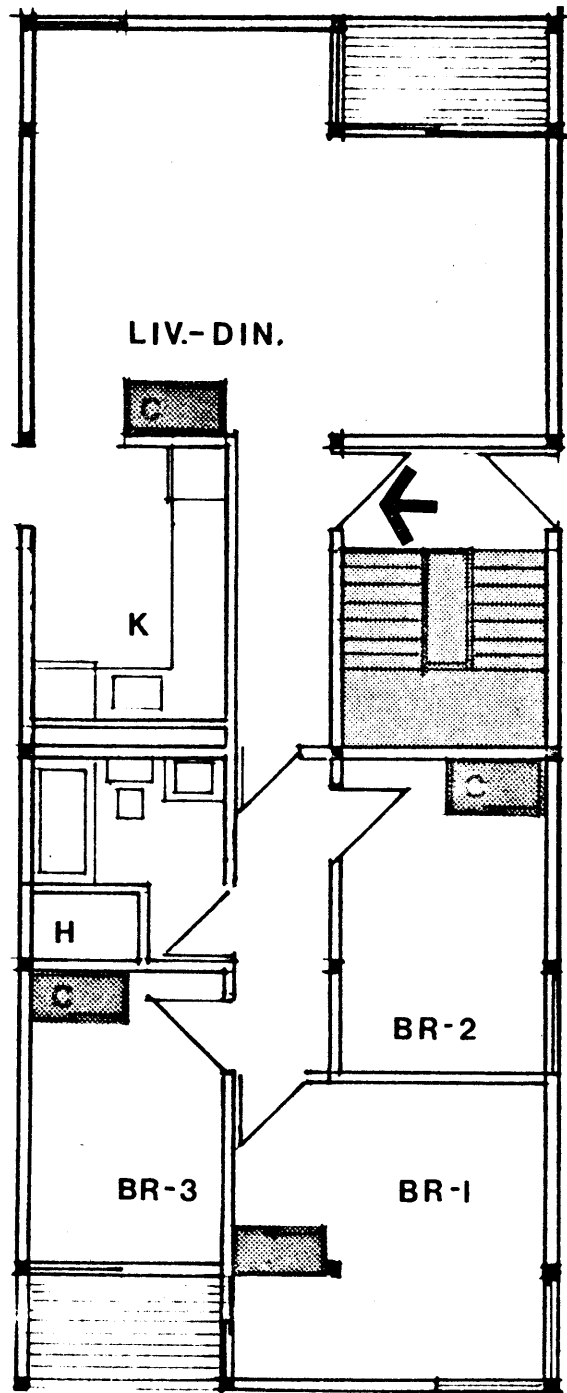
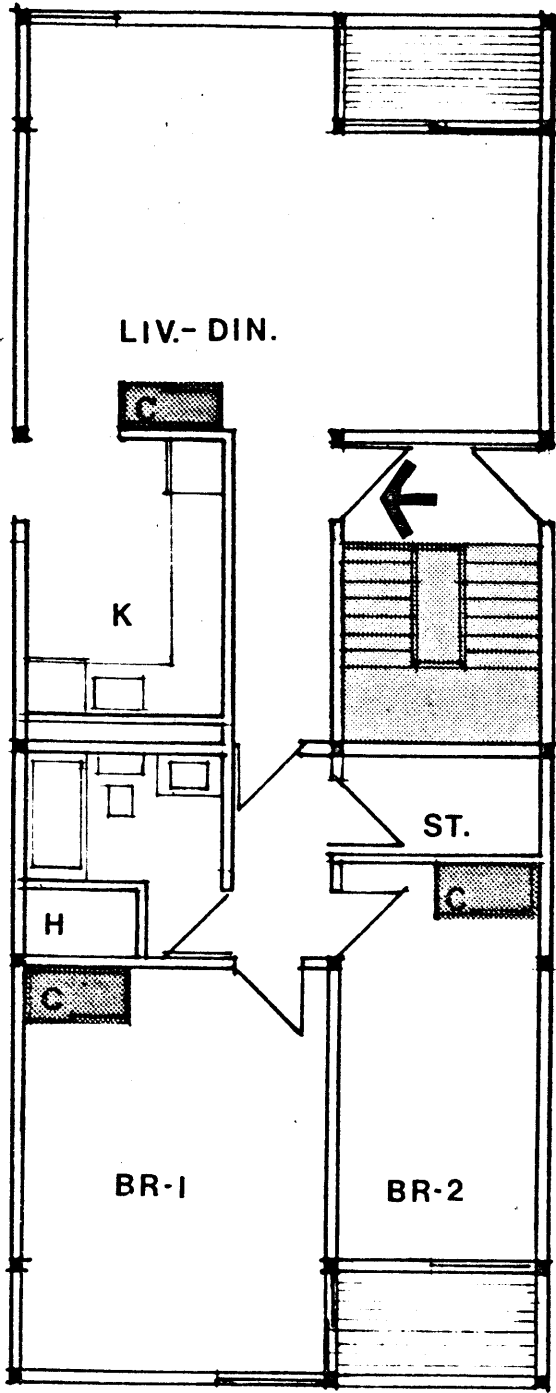
STRUCTURAL LAYOUT



E & 1B FLOOR PLANS



STRUCTURAL LAYOUT

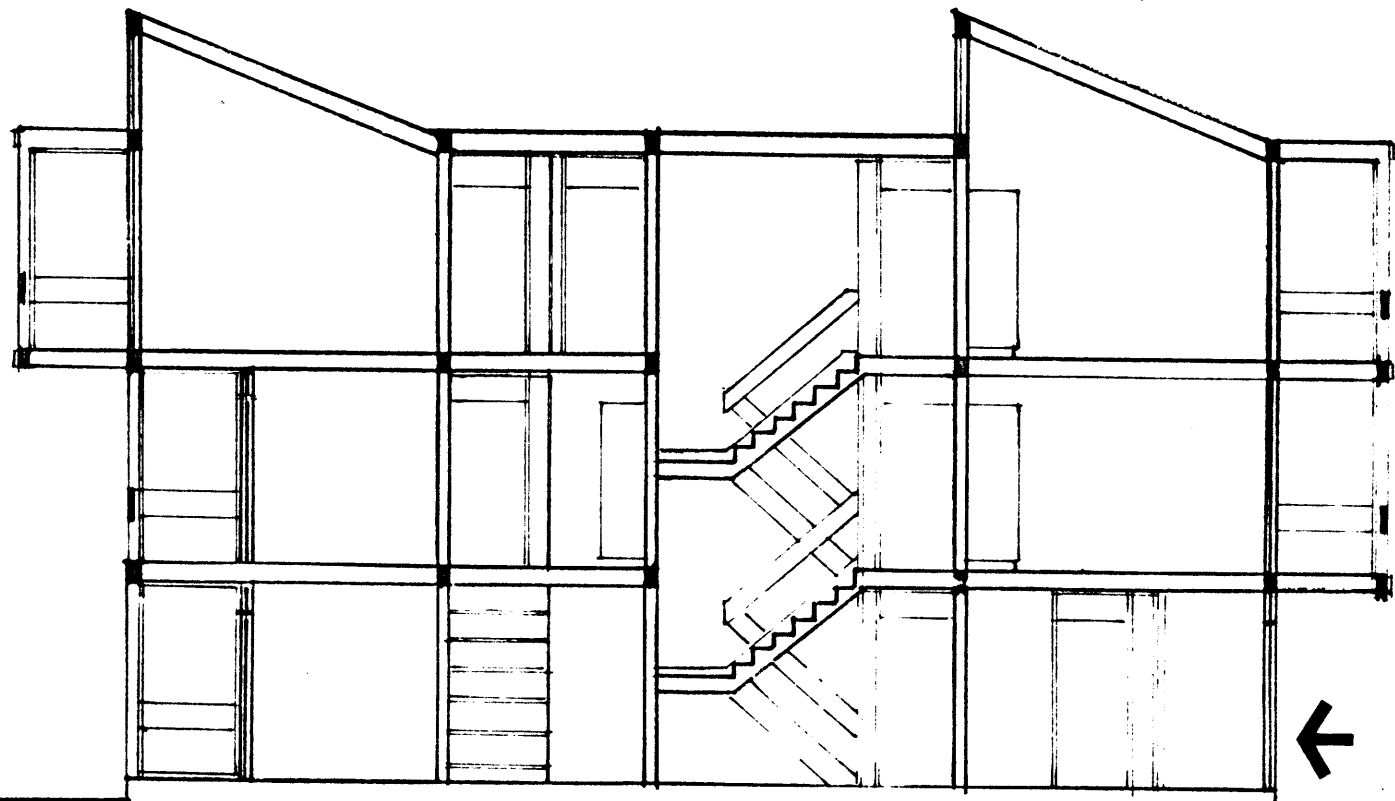


2B & 3B FLOOR PLANS

2B

1B

E



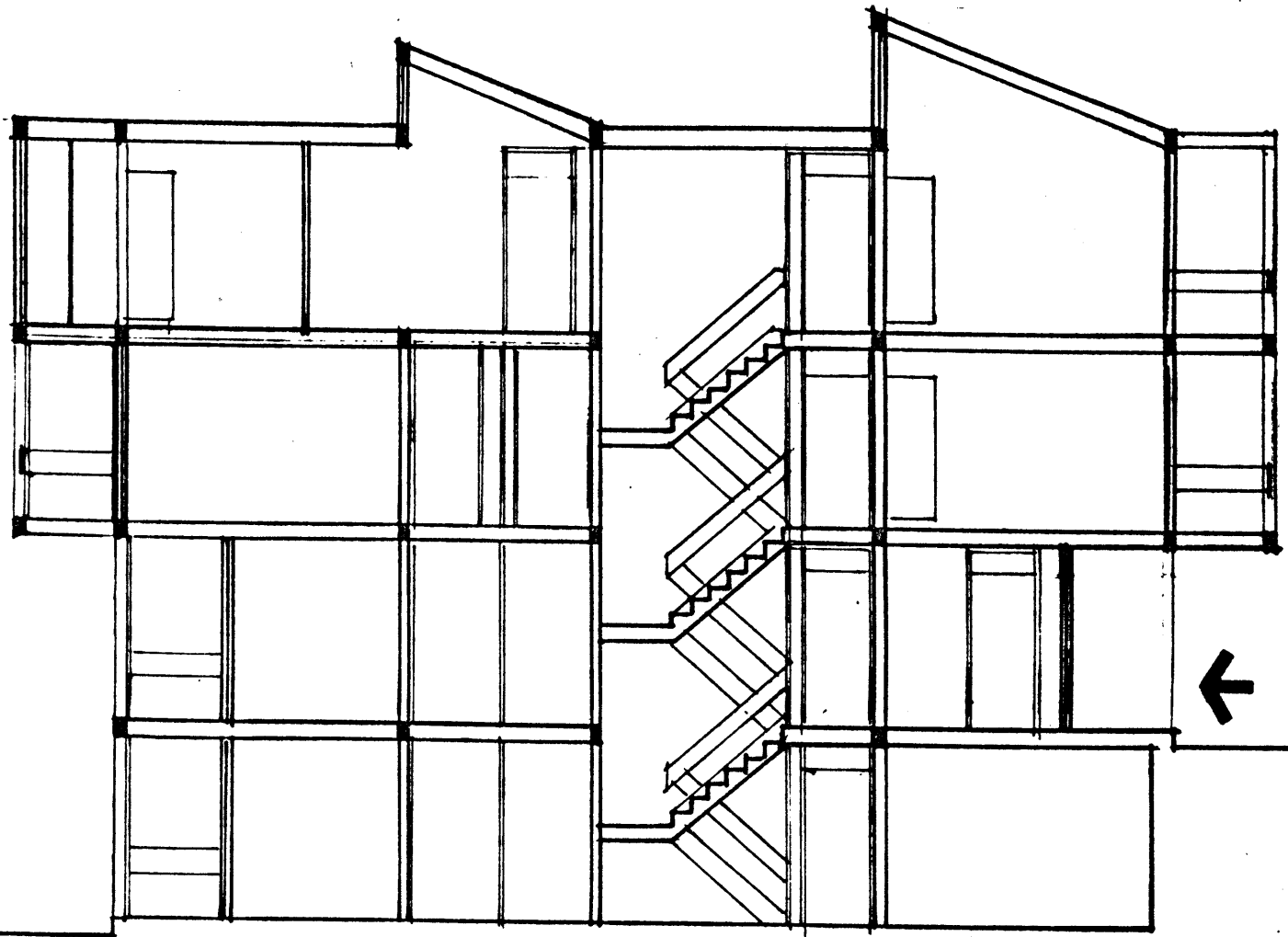
SECTION · 3 STORY

3B

2B

1B

E



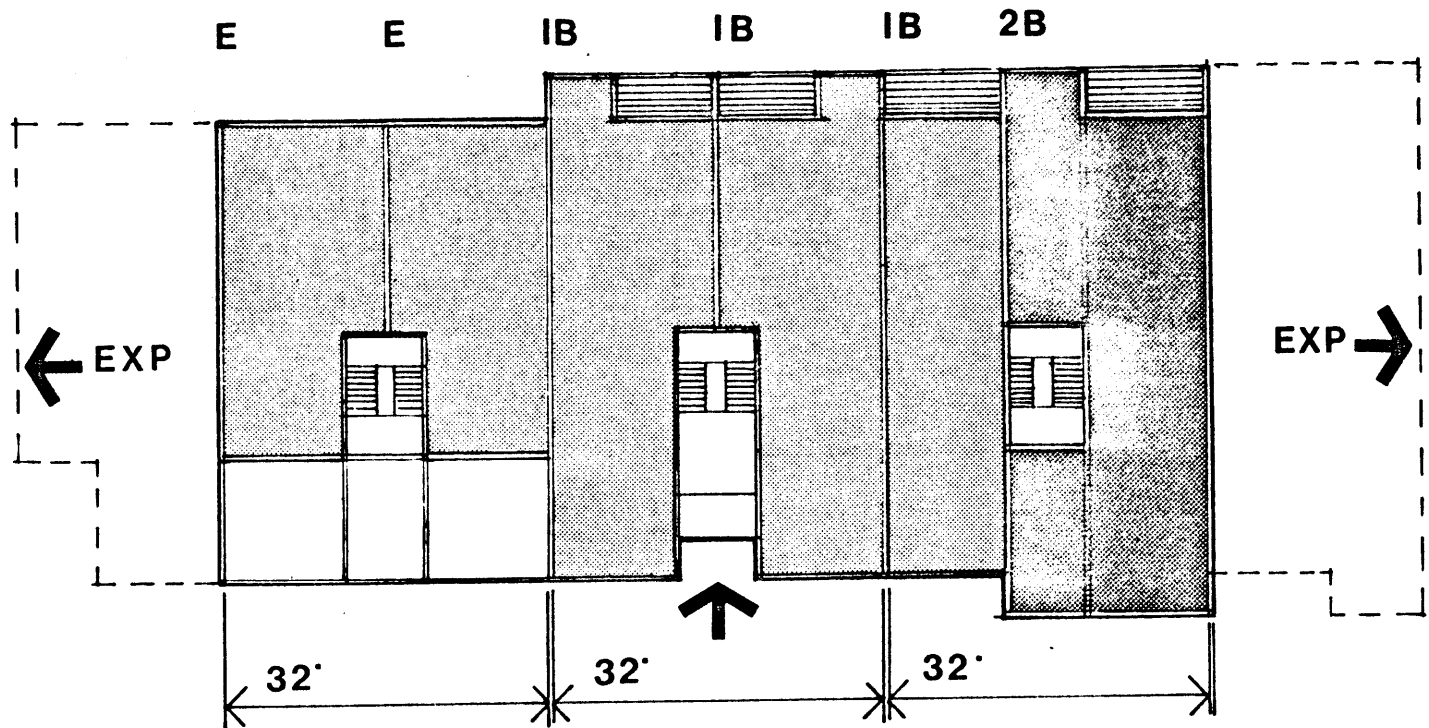
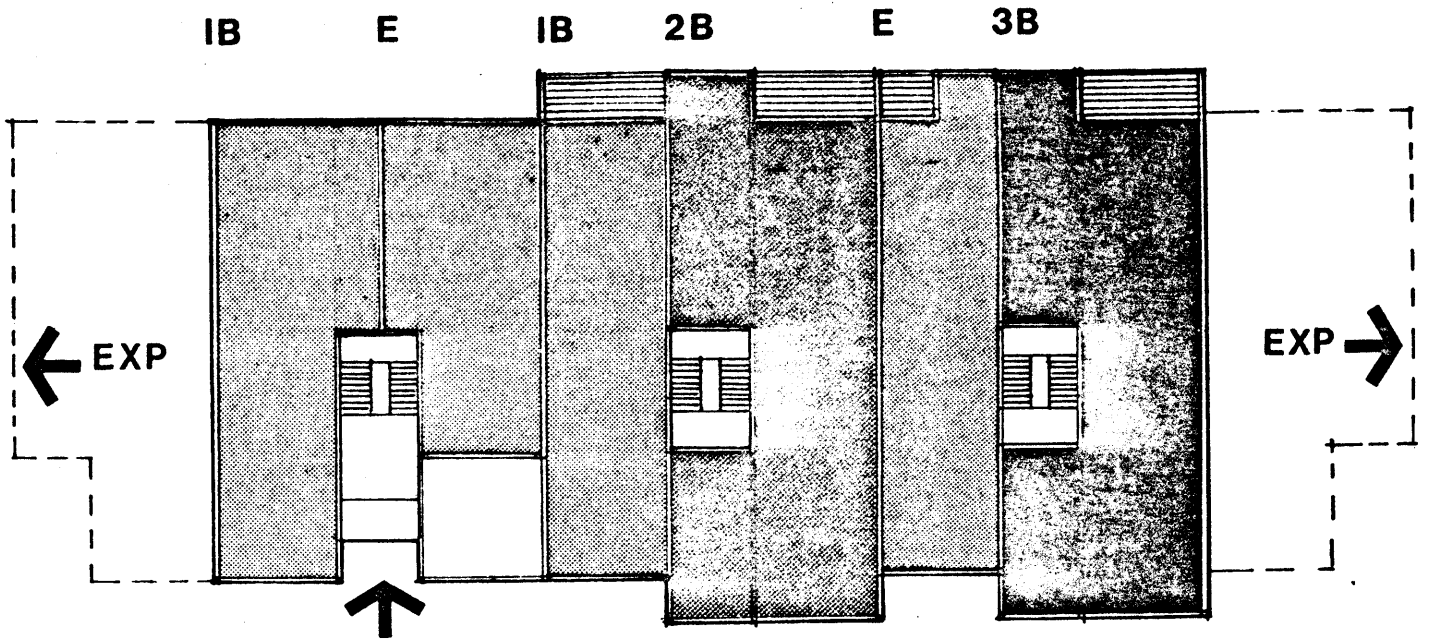
SECTION · 4 STORY

DIAGRAMATIC EXAMPLES OF HOUSING

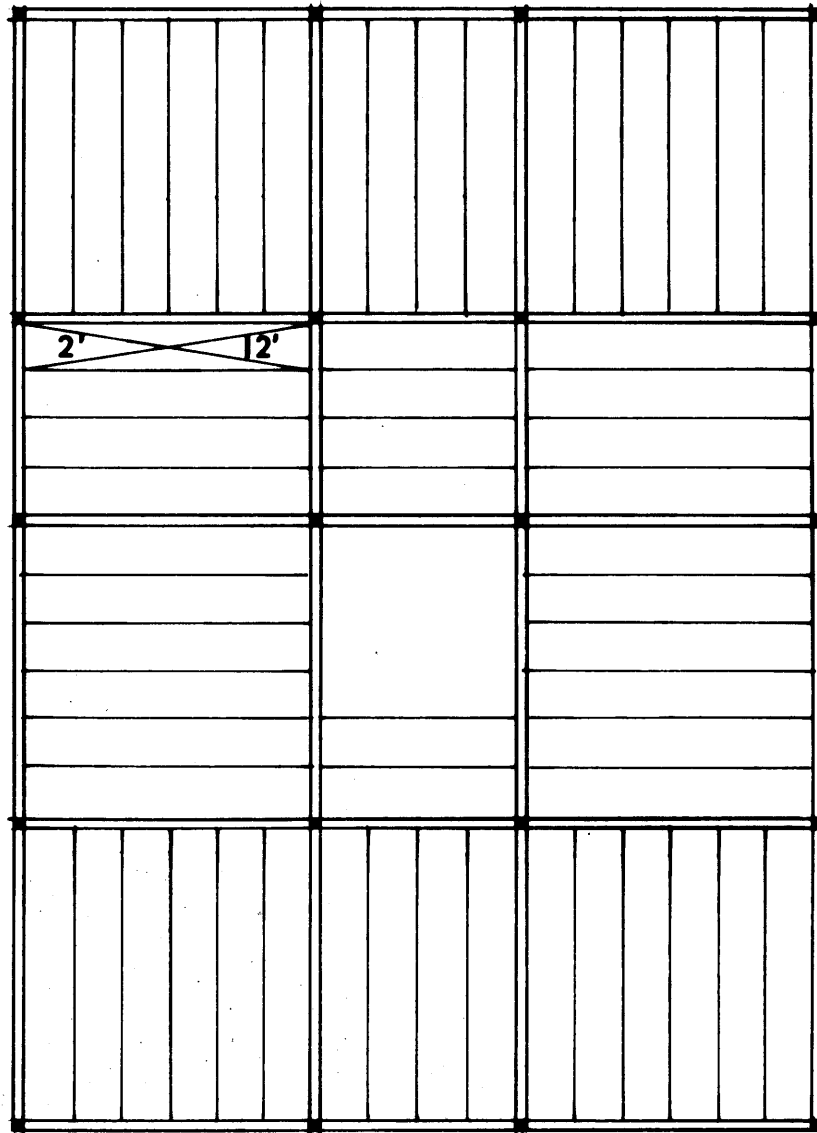
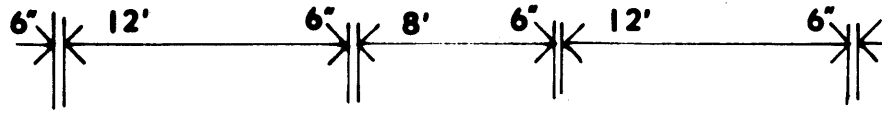
TYPES: 32'-0" MODULE UNITS

SPACE STANDARDS

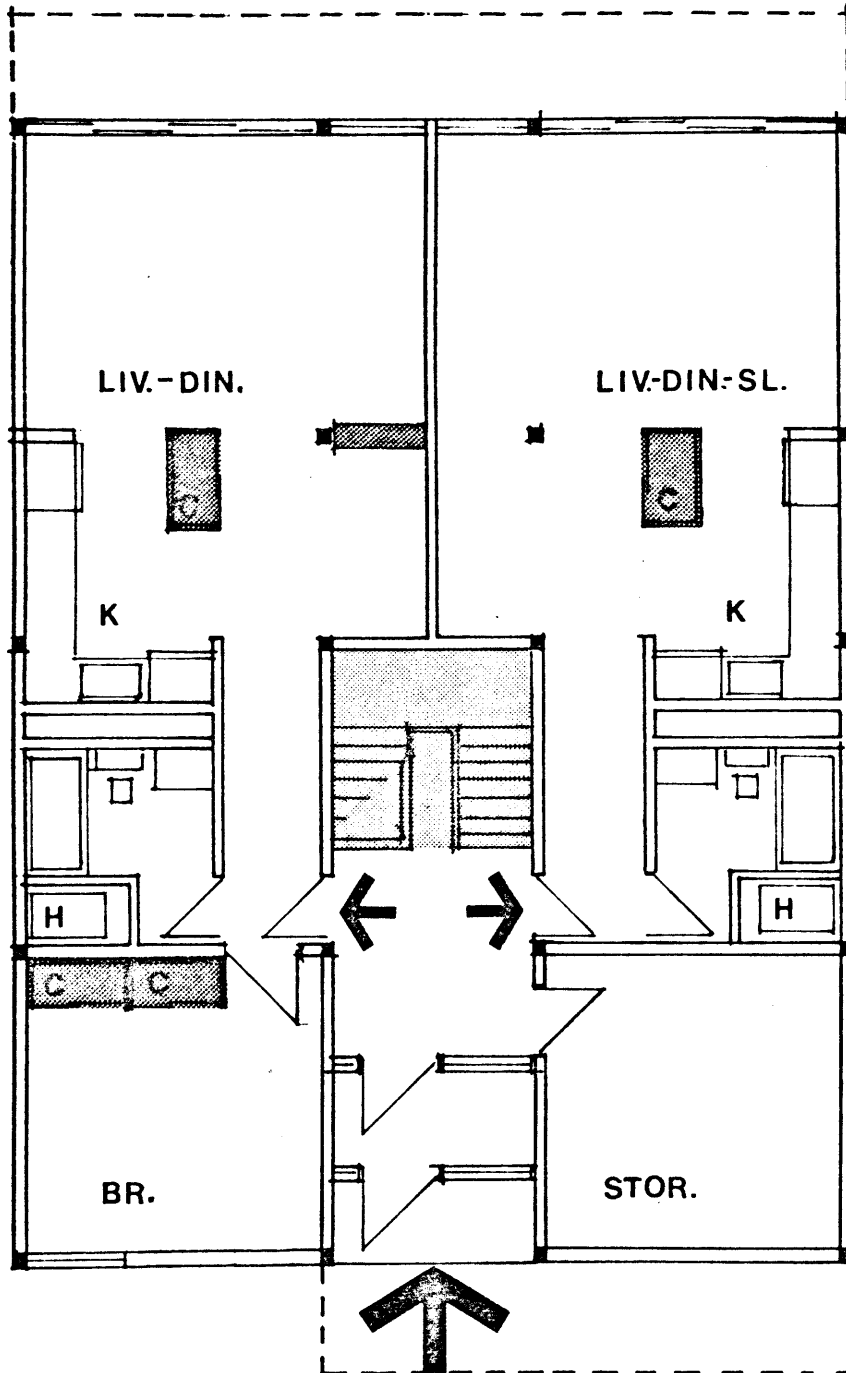
It is suggested that another method of reducing costs in housing units is by examining present-day space standards. Significant savings in low-cost housing can be achieved by a reasonable reduction in these standards. The following plans are based on English space standards currently recommended as minimum standards.



**POSSIBLE FAMILY GROUPINGS
32' UNIT MATRIX**

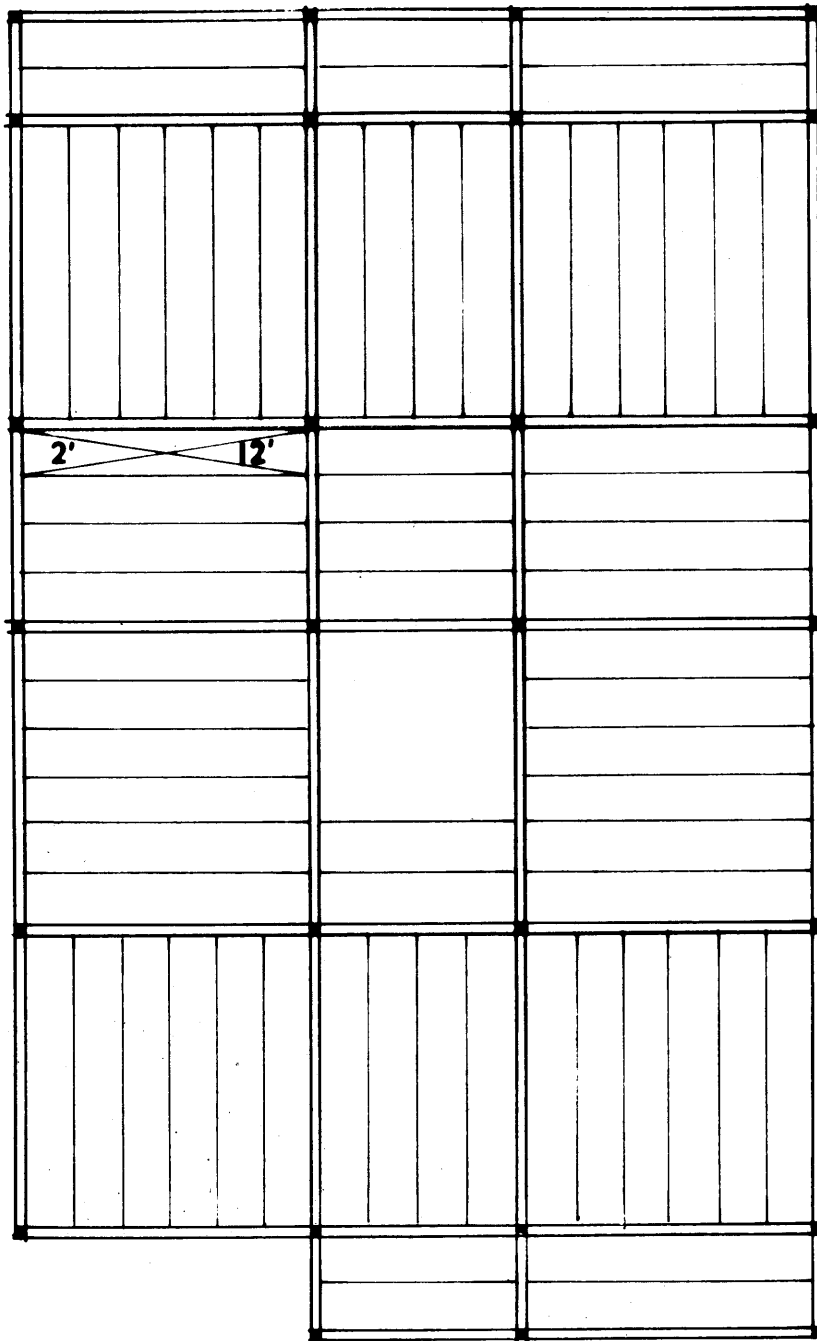


STRUCTURAL LAYOUT



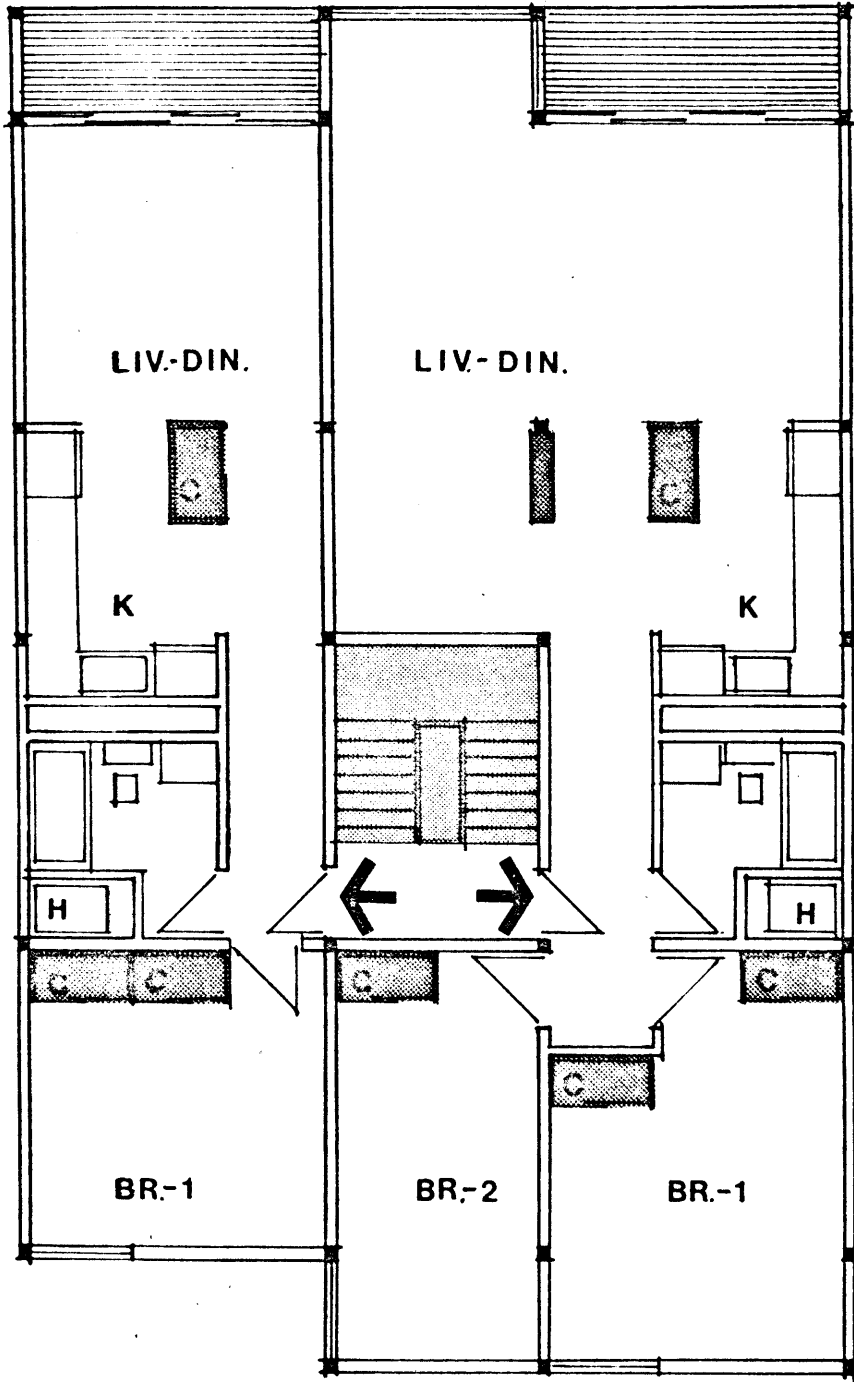
1B & E FLOOR PLANS

6" 12' 6" 8' 6" 12' 6"

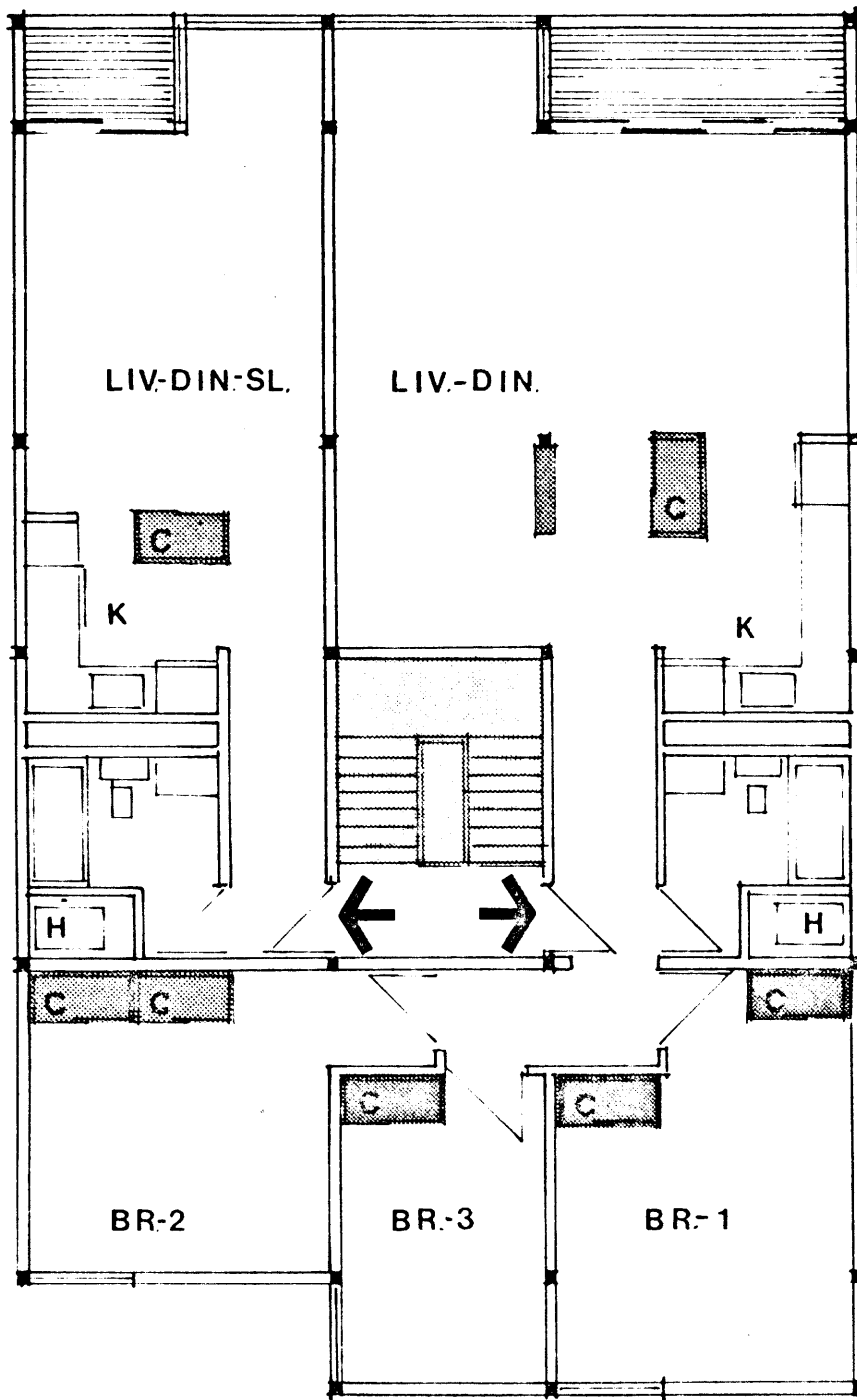


6" 4'6" 6" 12' 6" 8' 6" 12' 6" 12' 6" 4'6" 6"

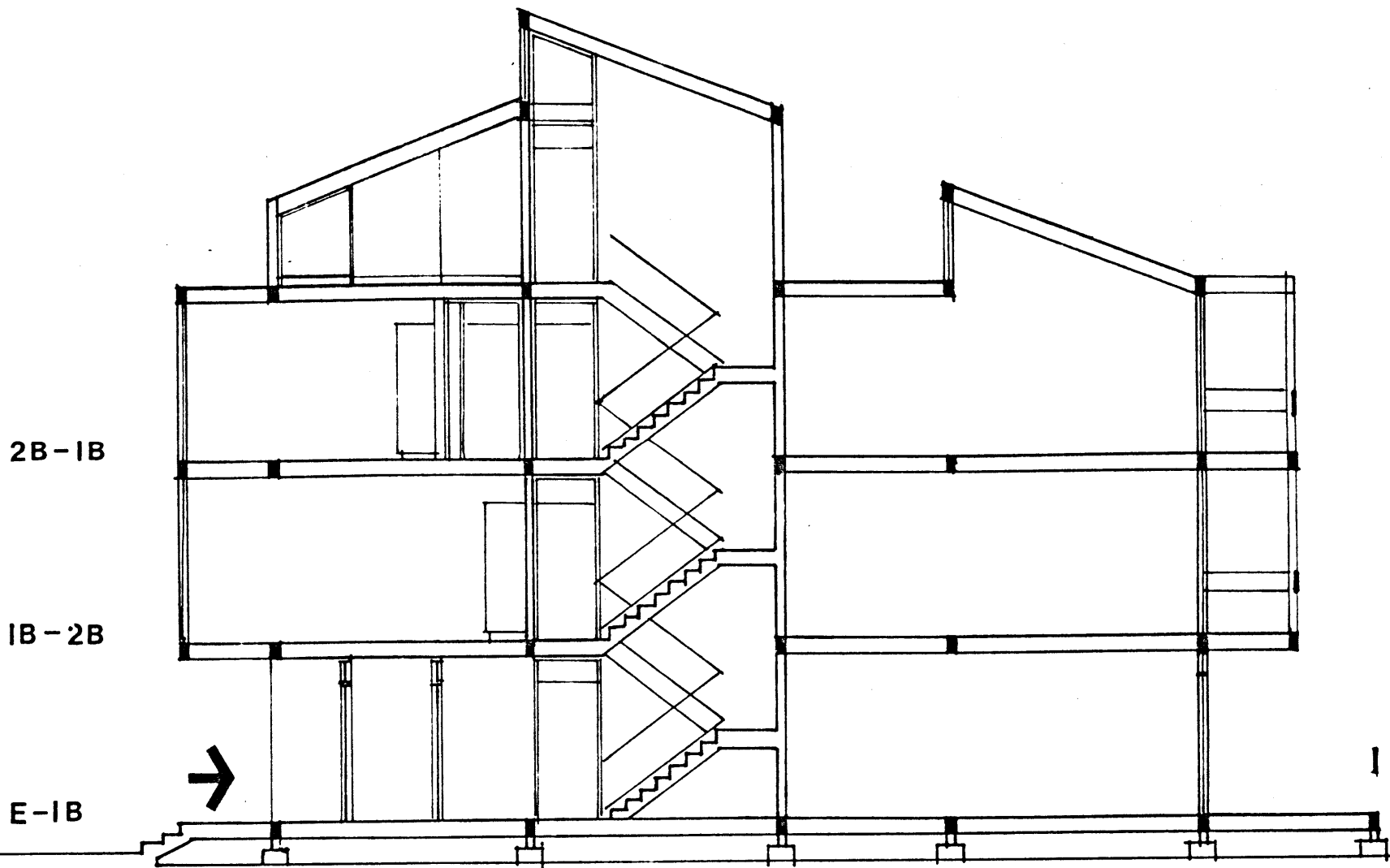
STRUCTURAL LAYOUT



1B & 2B FLOOR PLANS



E & 3B FLOOR PLANS



SECTION · 3 STORY

E-3B

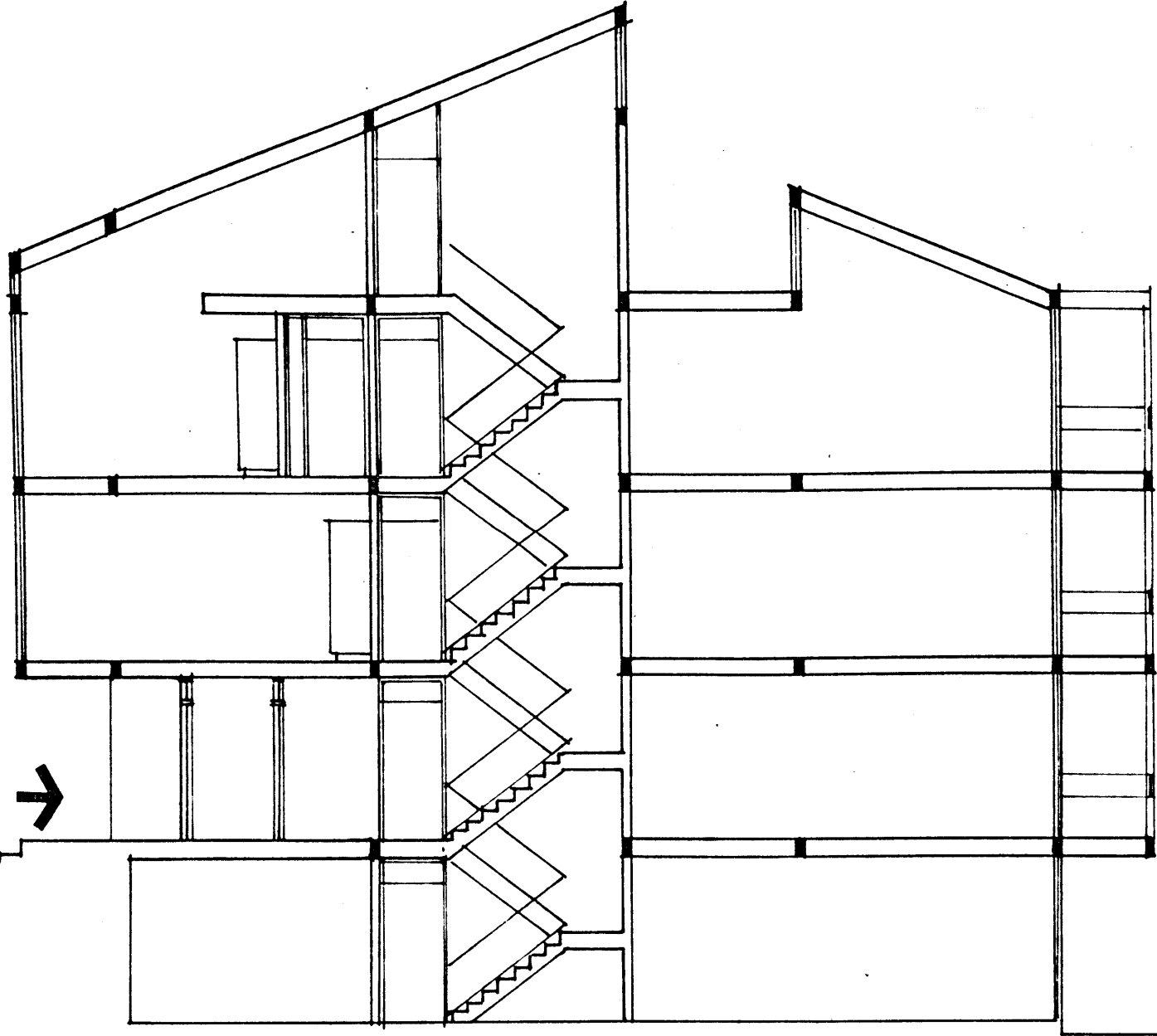
IB-2B

IB-E

E

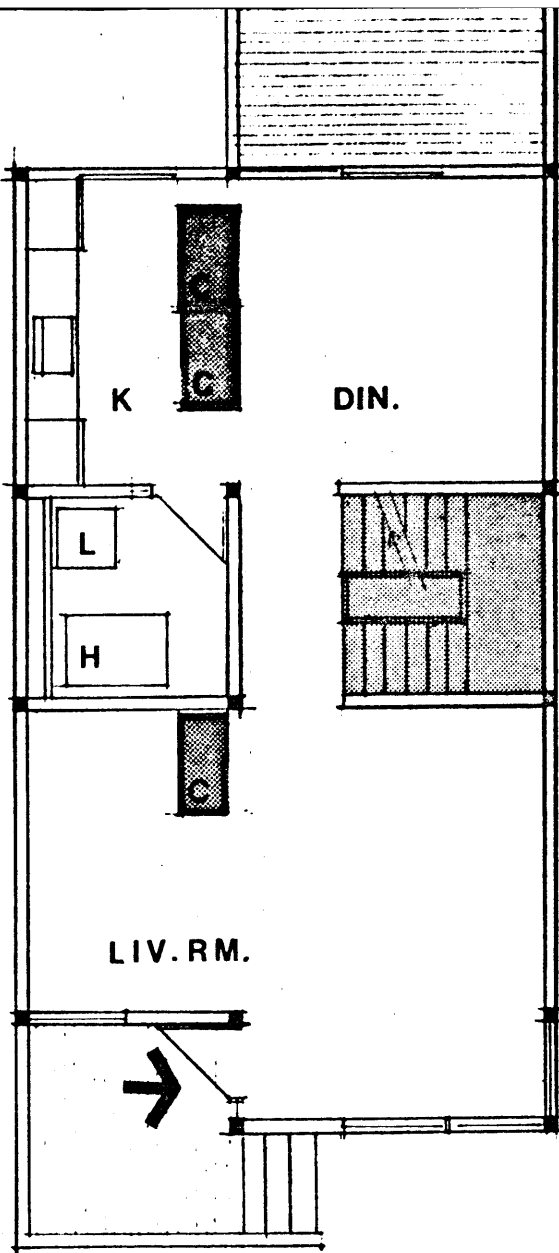


SECTION · 4STORY

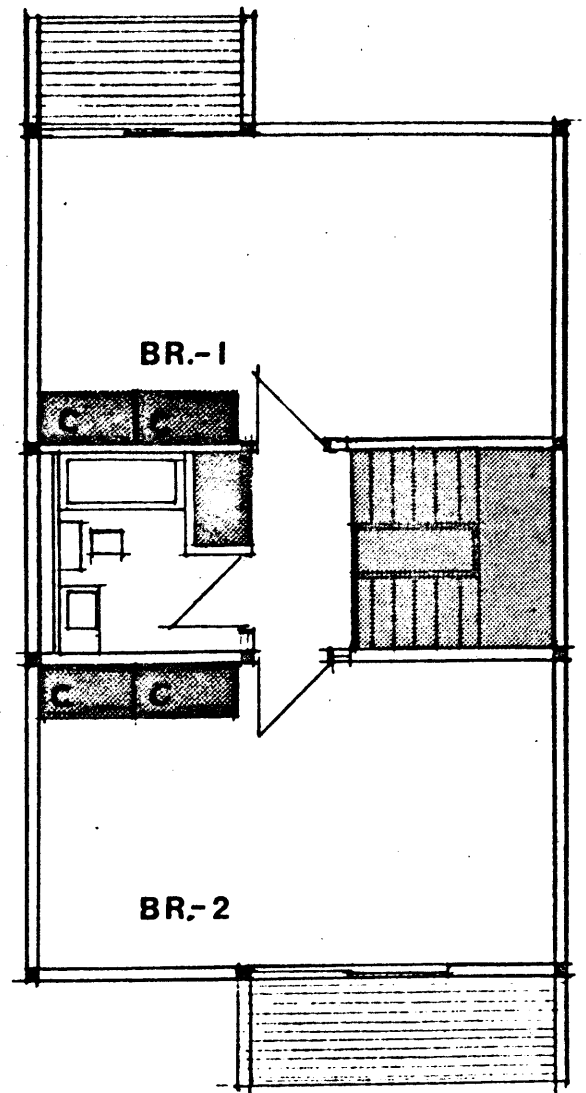


DIAGRAMATIC EXAMPLES OF HOUSING

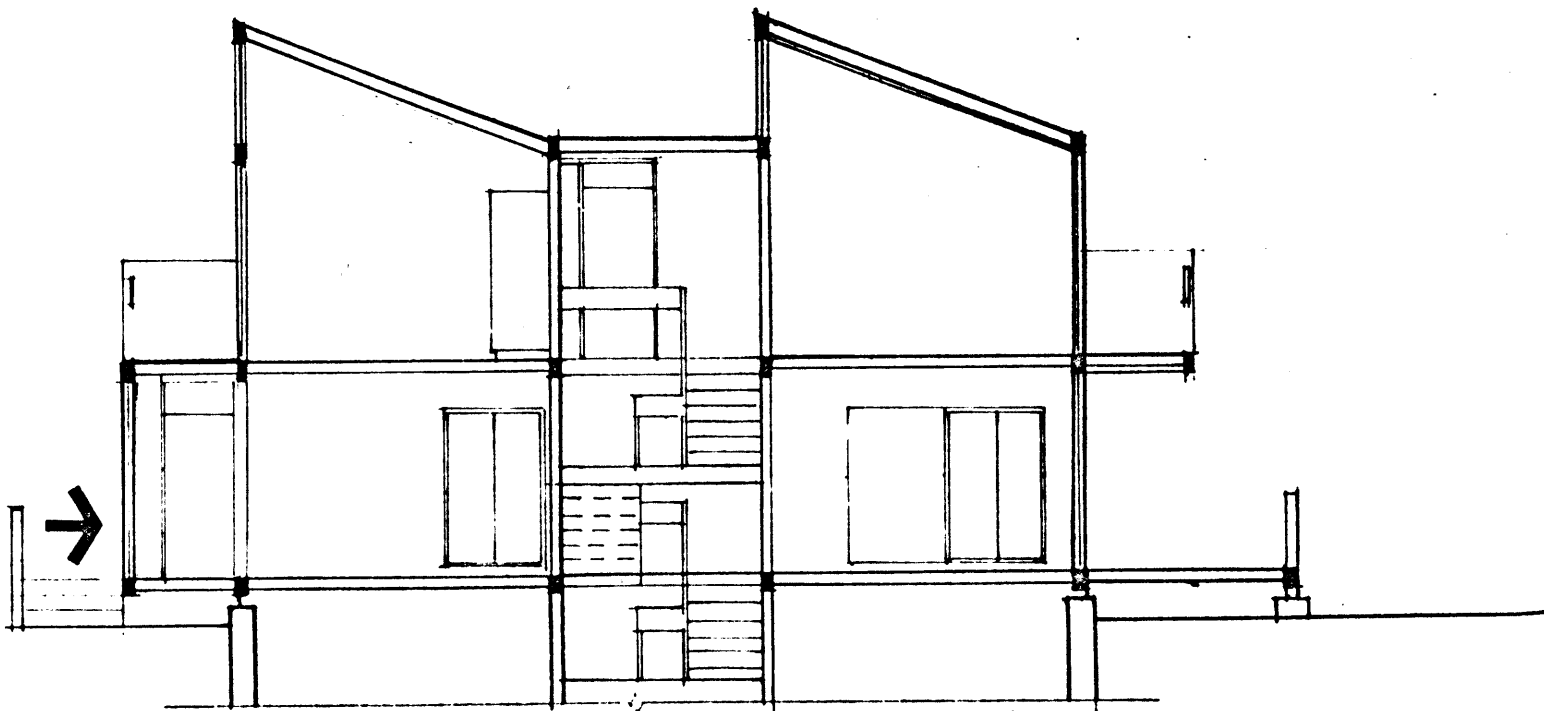
TYPES: TOWNHOUSE MODULE UNITS



1ST FL.

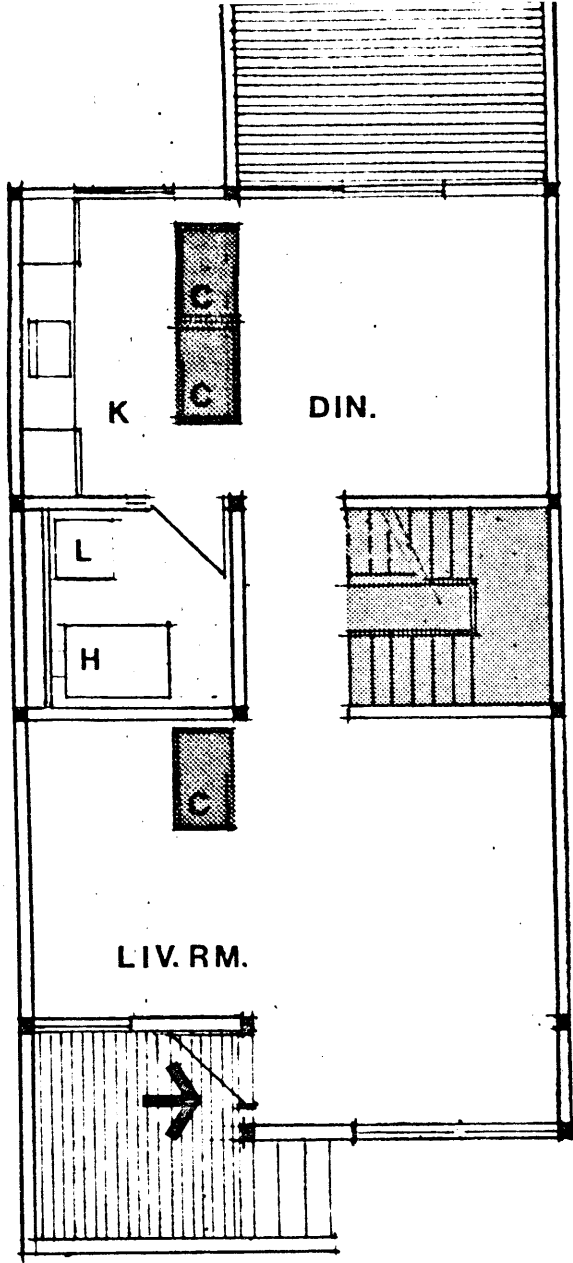


2ND FL.

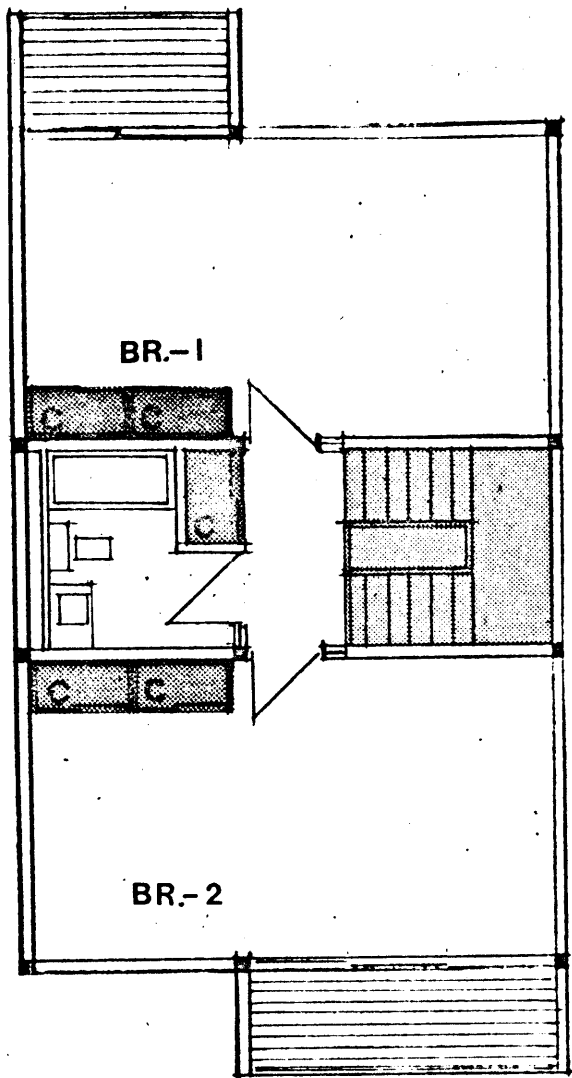


SECTION

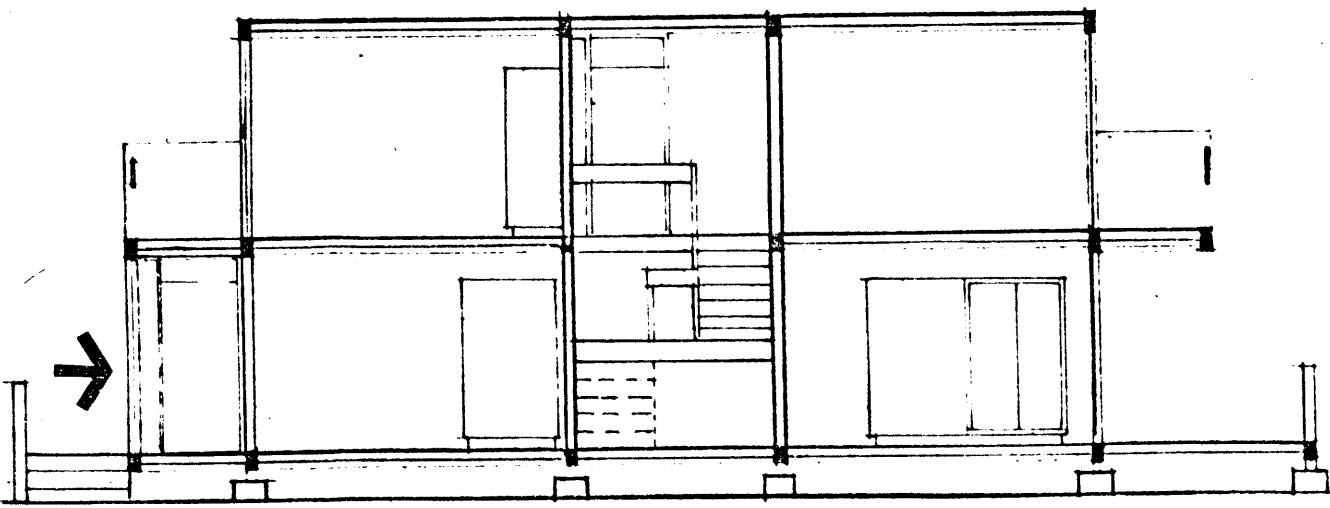
2B



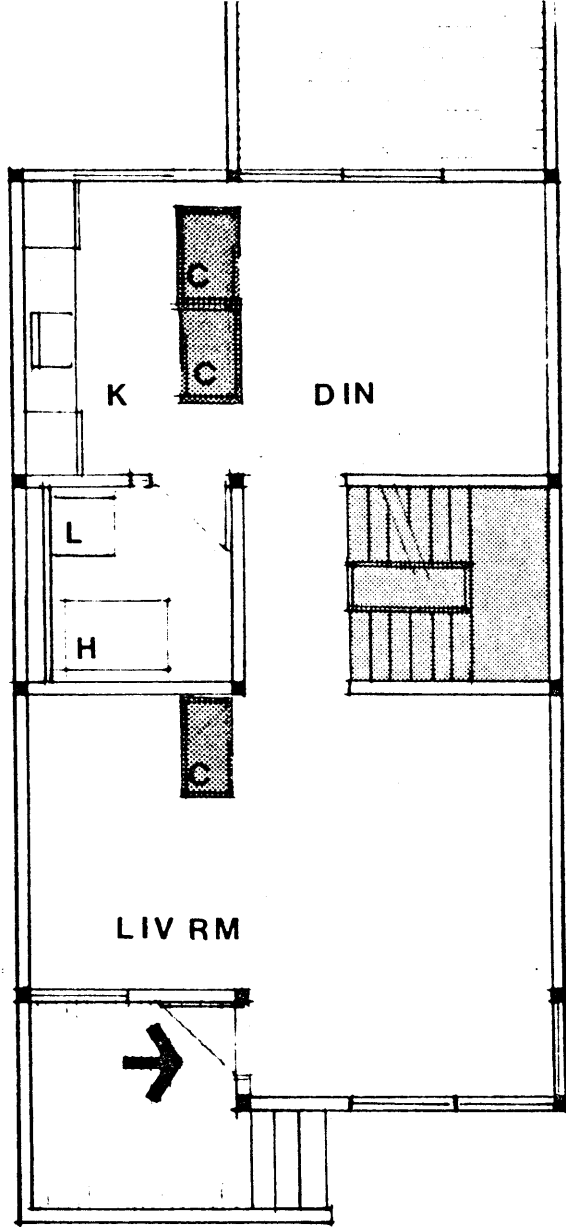
1ST FL.



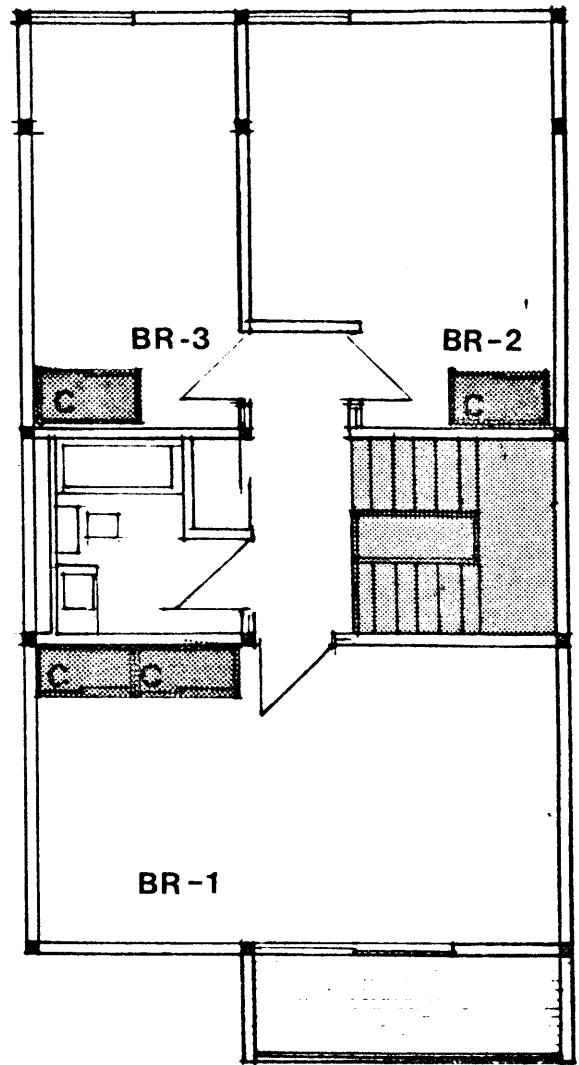
2ND FL.



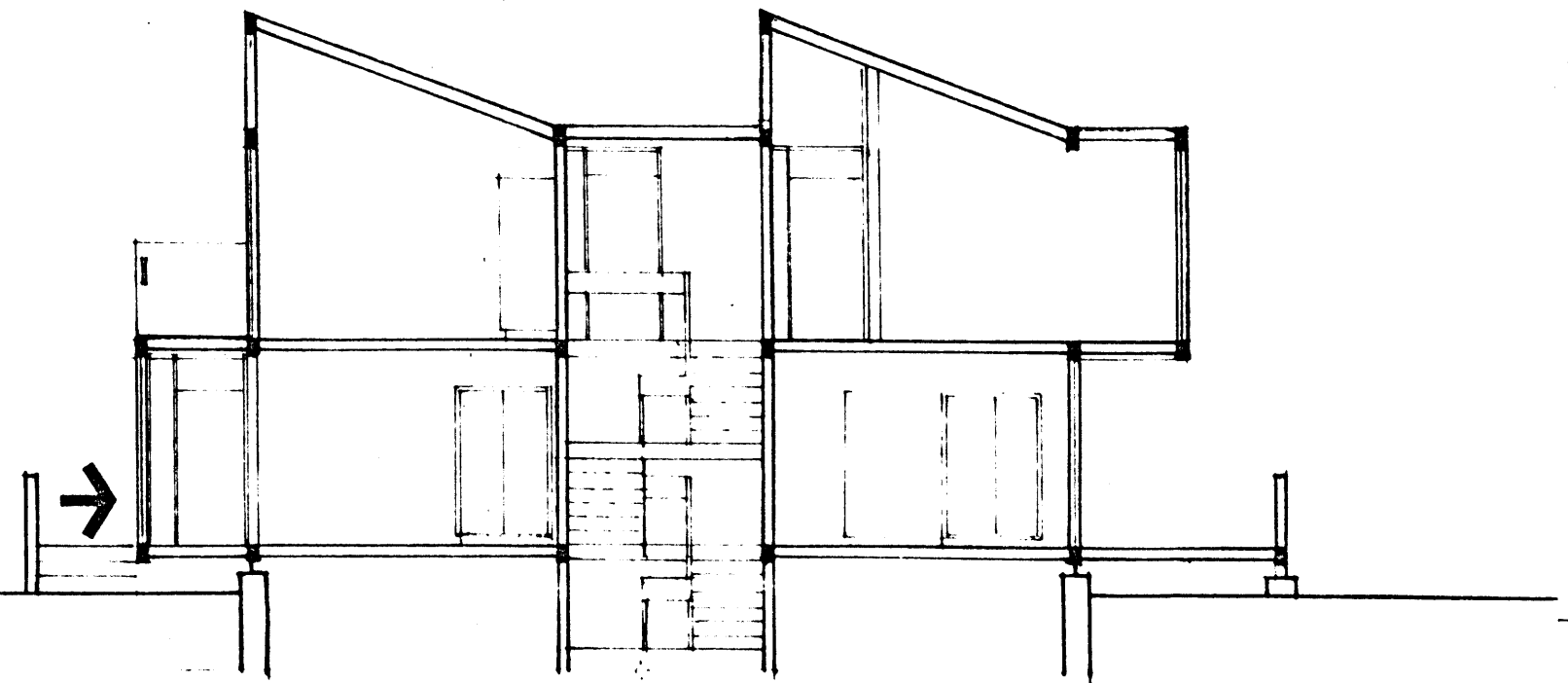
SECTION



1ST FL.

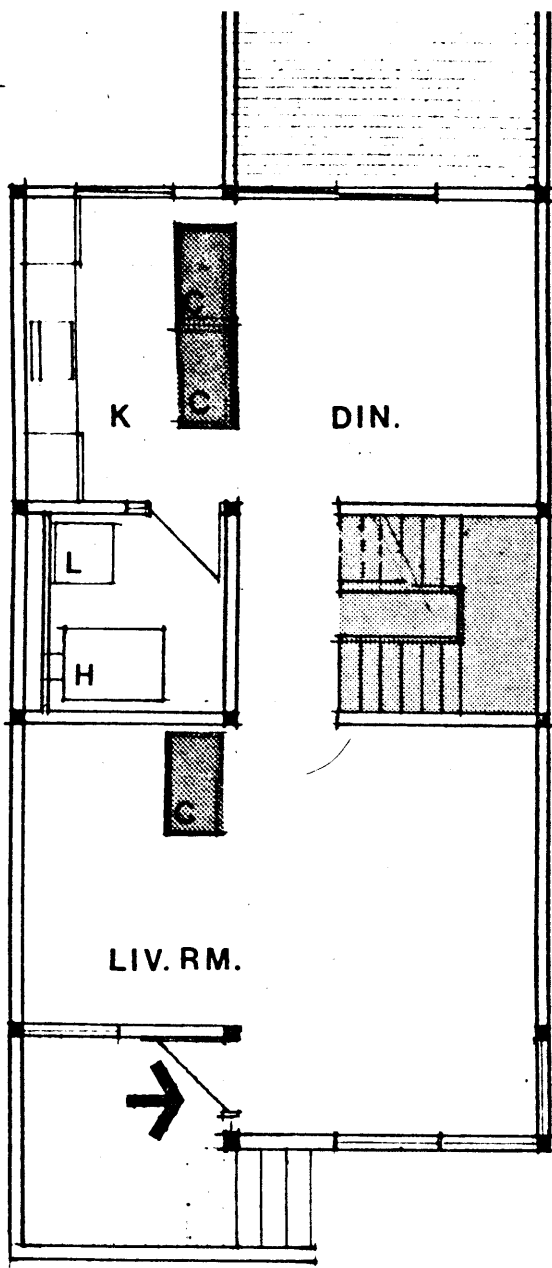


2ND FL.

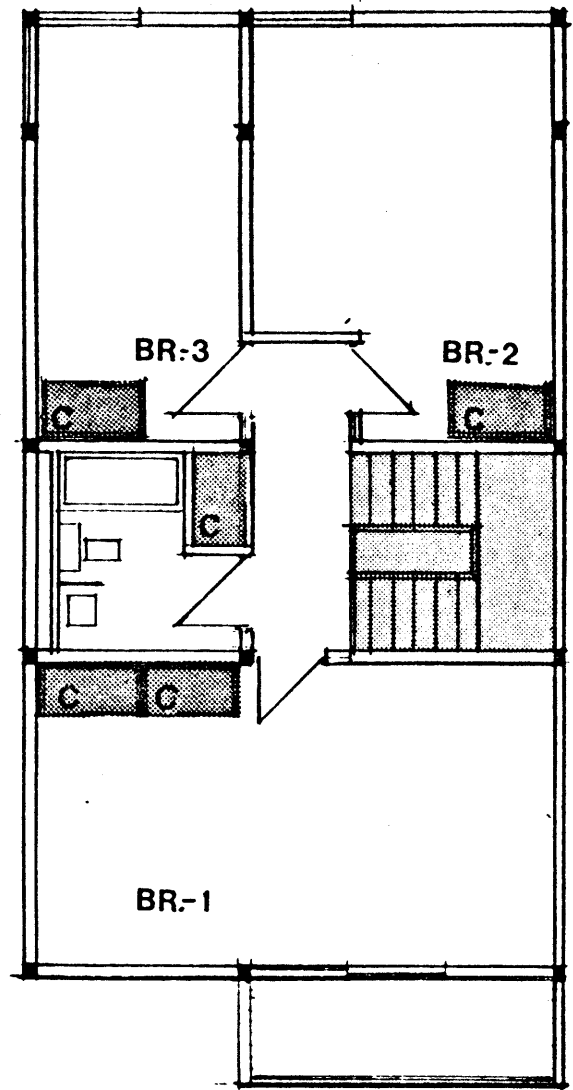


SECTION

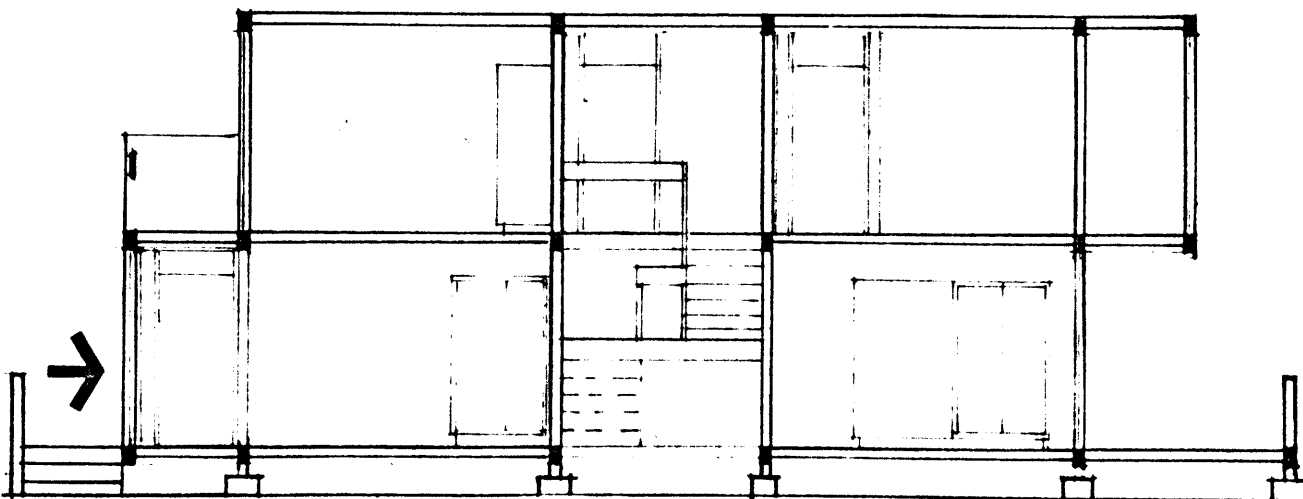
3B



1ST FL.



2ND FL.



SECTION

3B

APPENDIX 1

MECHANICAL SYSTEMS DEVELOPED FOR ILLUSTRATED HOUSE TYPES

**HEATING
PLUMBING
ELECTRICAL**

PLUMBING

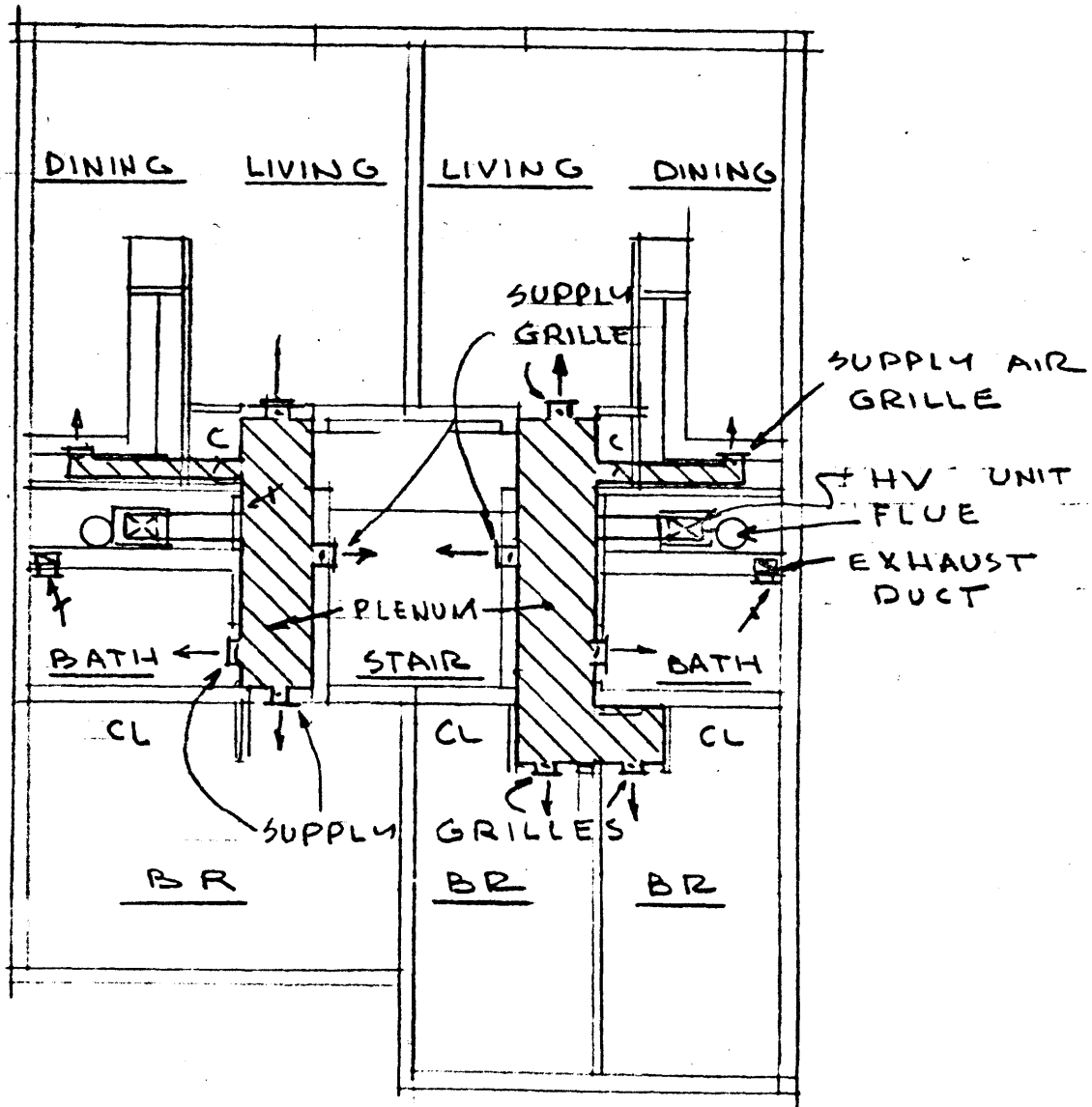
The basic design of plumbing is in accordance with the "Recommended Minimum Requirements For Plumbing" (Hoover Report) as published by the United States Department of Commerce. Consequently, all sanitary piping is not only inexpensive, but, as can be observed by inspection of the drawings, also lends itself in its simplicity to installation by unskilled labor. In single family isolated units, and where there is no incentive towards inclusion of hot water, individual hot water heaters are installed in each unit. Hot water heaters may be gas or electric as dictated by fuel and energy costs at each specific location. Where rent inclusion of hot water is permitted in multiple occupancy units, further economies can be realized by providing one hot water heater per building in lieu of one hot water heater per dwelling unit. Piping materials can be ferrous, nonferrous metal, or synthetic as indicated at each location by availability, adaptability, acceptance, and cost.

HEATING AND VENTILATION

Heating of each apartment is accomplished by a warm air furnace located in each unit and discharging directly into a ceiling plenum. The plenum is fabricated under the general construction, thus avoiding sheet metal work. The system can utilize fossil fuel or electricity as a source of heat as dictated by economic analysis at each location. The system requires no skilled labor to assemble in the field. Technicians are required only during initial firing where fossil fuels are incorporated and not at all where electric heat is utilized. Each apartment will have its own thermostatic control. Interior bathrooms are exhausted through shafts constructed in the general construction and topped by wind-driven turbine exhausters. Interior stairways are also similarly ventilated by means of wind-driven turbines at the top of the staircase. Both avoid expensive wiring, fans, and maintenance. Accordingly, installation of the heating system consists primarily of setting a single factory assembled warm air heating unit in place. Sheet metal duct work is almost non-existent. The heating system lends itself readily to rent inclusion of hot water or to individual metering as may be desired. It also lends itself to future installation of mechanical cooling.

ELECTRICAL

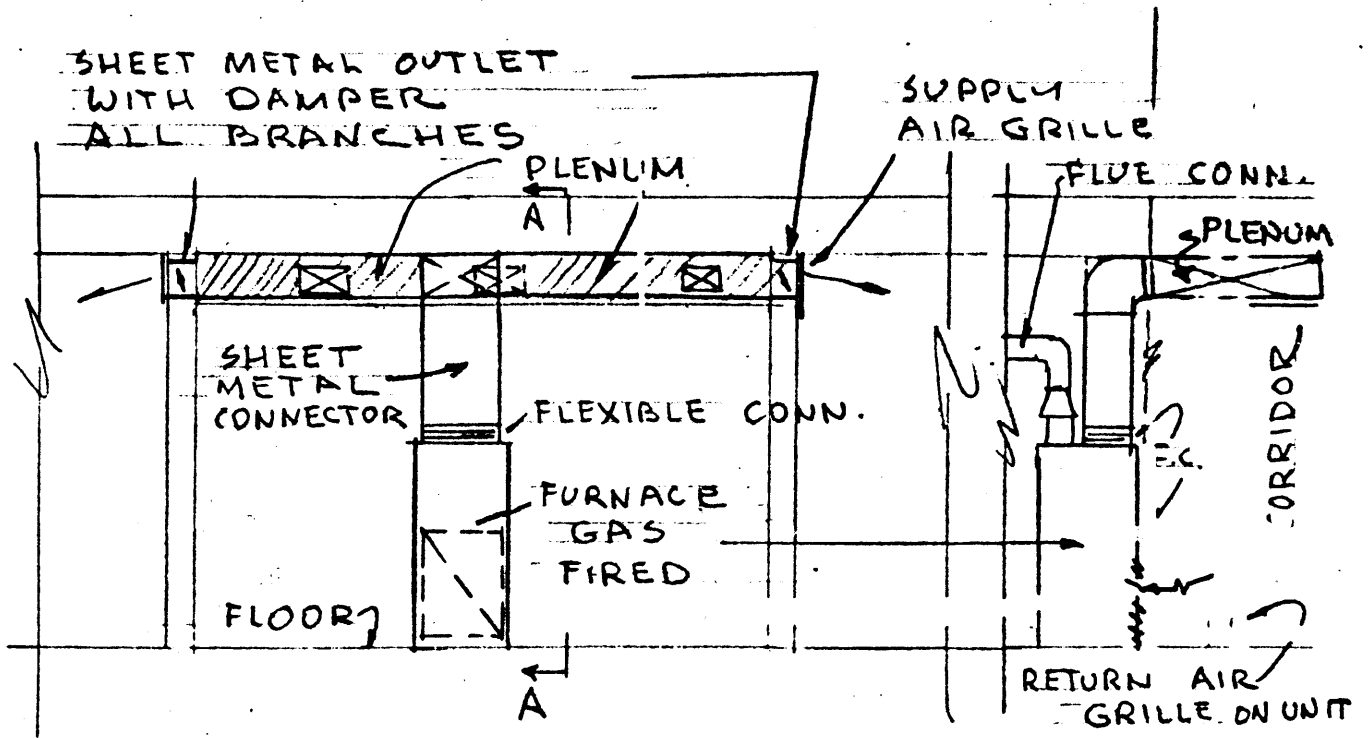
All wiring conforms to the requirements of the National Electrical Code. Individual fuse boxes in each apartment permit convenient servicing of the system by each tenant as well as individual or master metering of electrical consumption. Cooking can be electric or gas. Branch wiring is inexpensive aluminum not metallic sheathed cable. Telephone system can be readily prewired in the construction.



TYPICAL FLOOR PLAN

HEATING

SCALE: 1/8" = 1'-0"



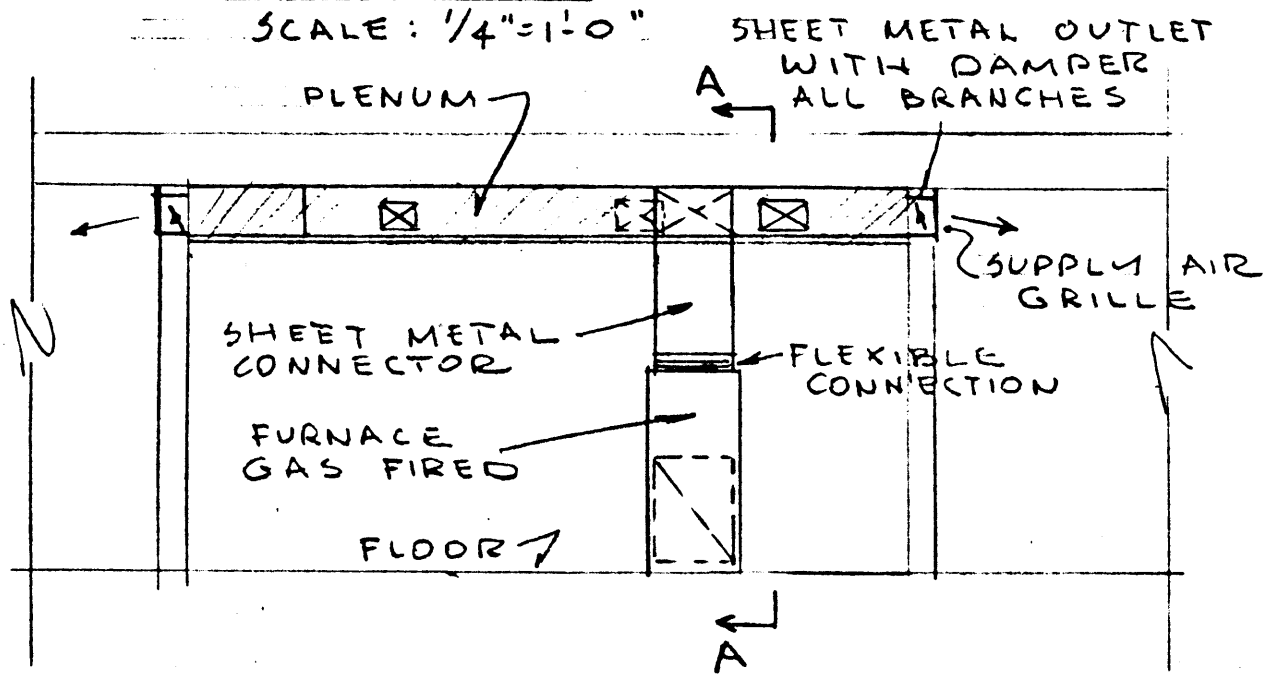
TYPICAL ONE BED ROOM

SECTION A-A

SECTION

SCALE: 1/4" = 1'-0"

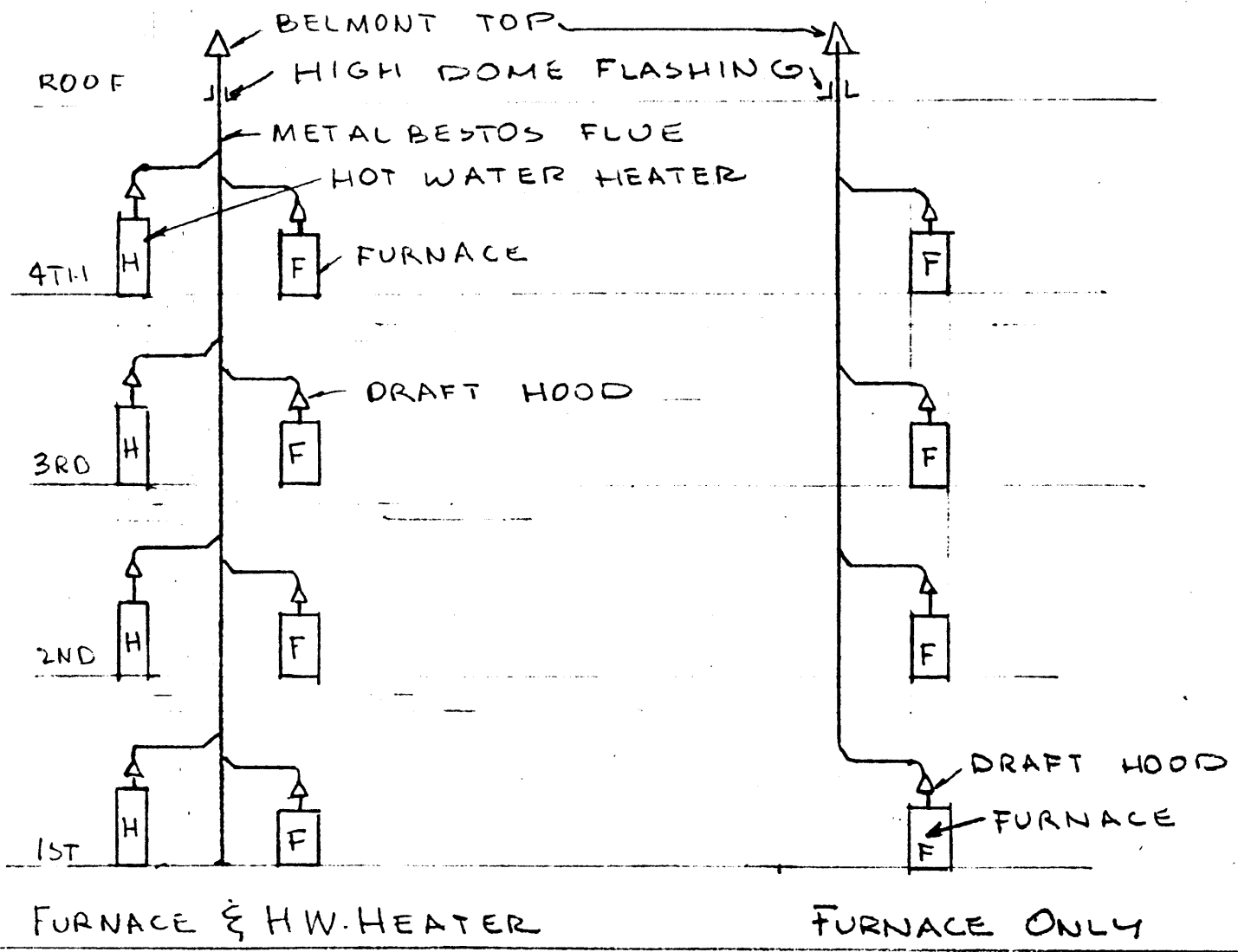
SCALE: 1/4" = 1'-0"



TYPICAL TWO BED ROOM

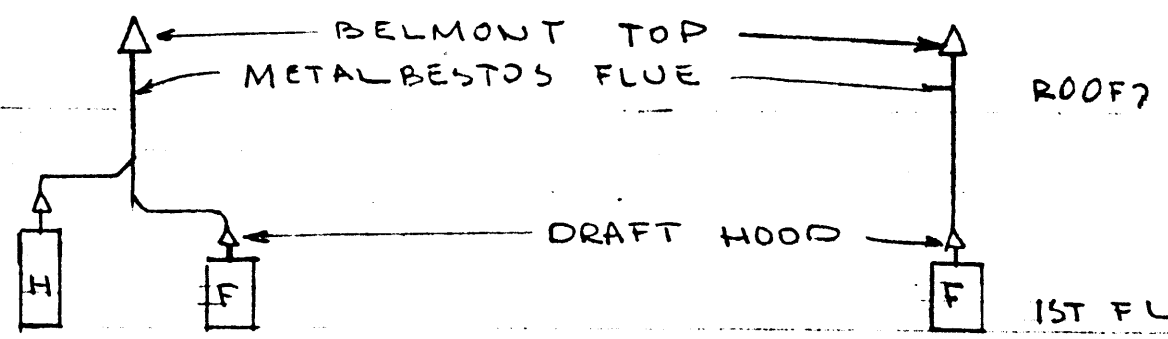
SECTION

SCALE: 1/4" = 1'-0"



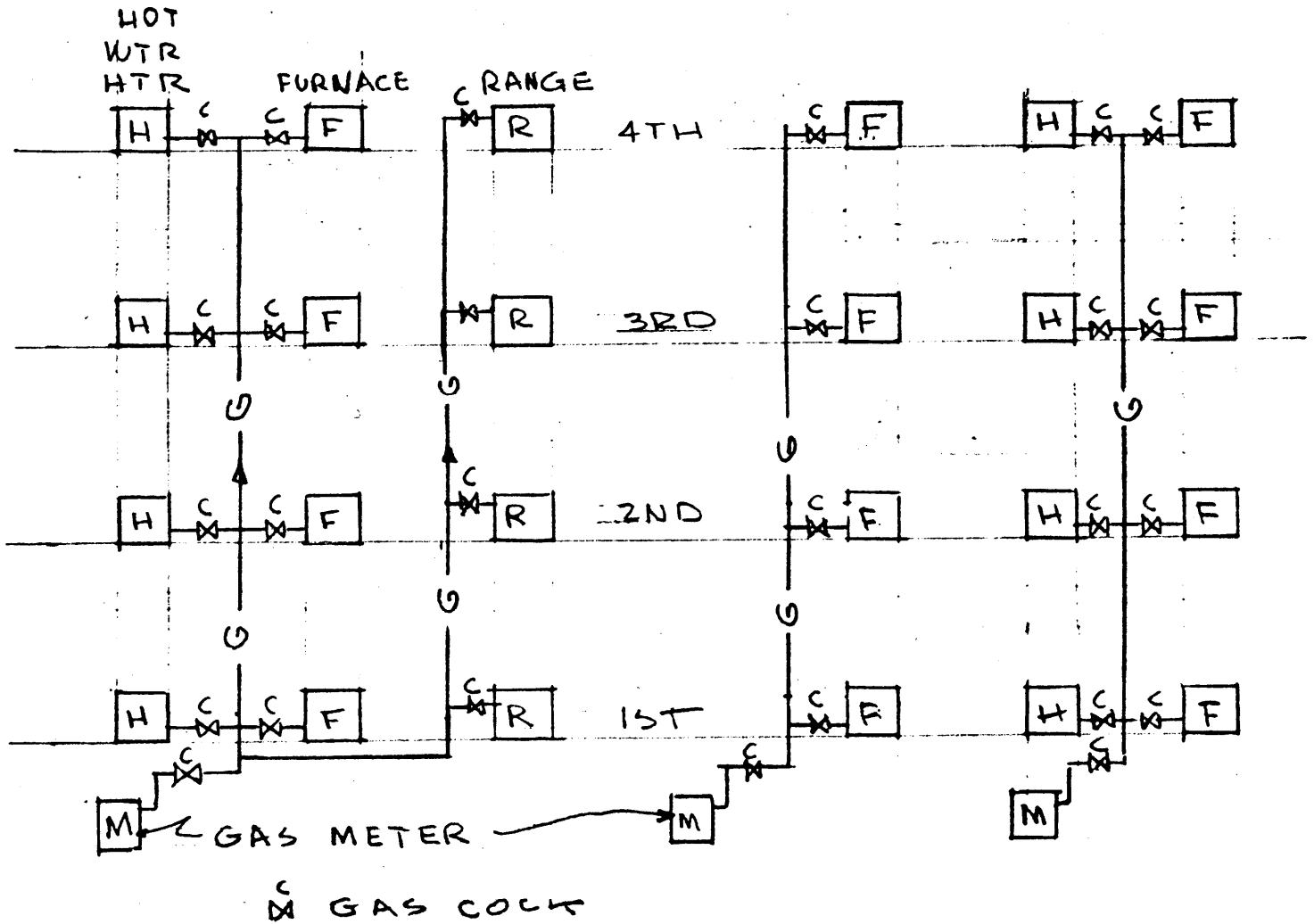
TYPICAL FLUE DETAILS

NO SCALE



TYPICAL FLUE DETAILS

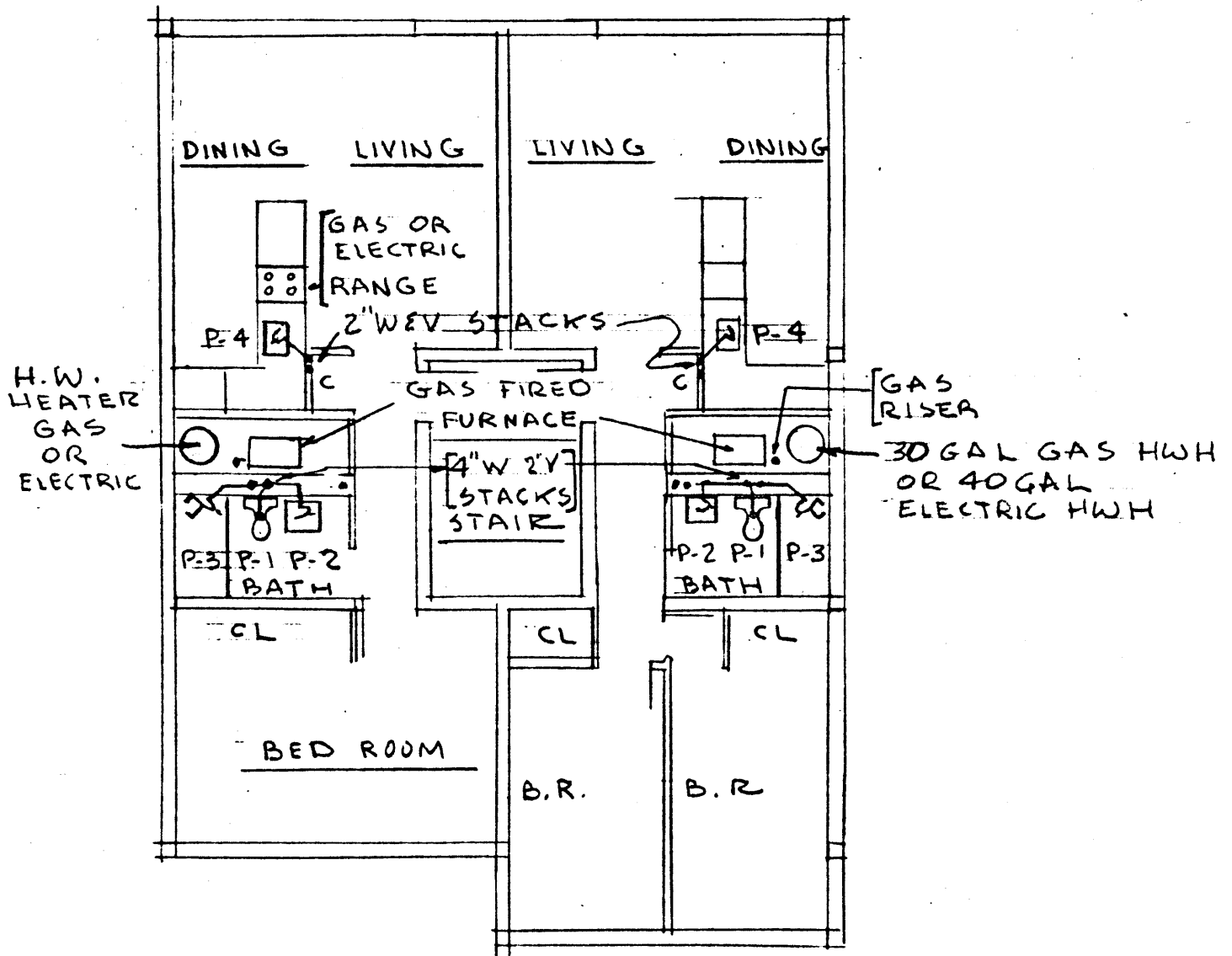
NO SCALE



TYPICAL GAS PIPING
 ALL GAS EQUIPMENT
 NO SCALE

TYPICAL GAS PIPING
 FURNACE ONLY
 NO SCALE

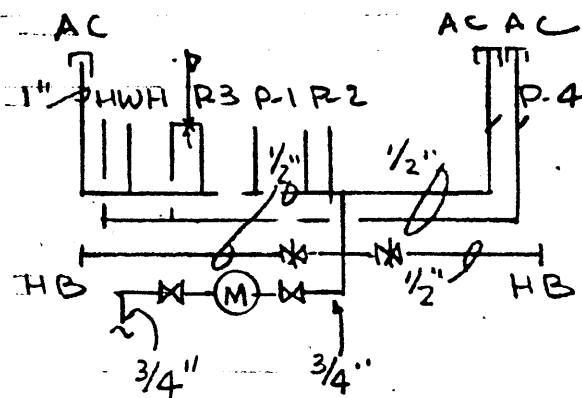
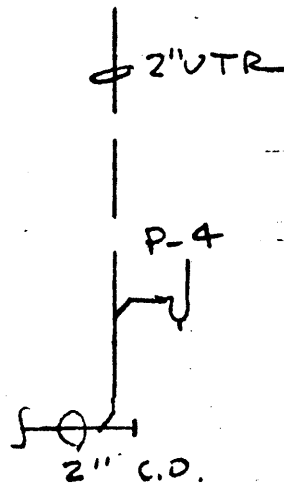
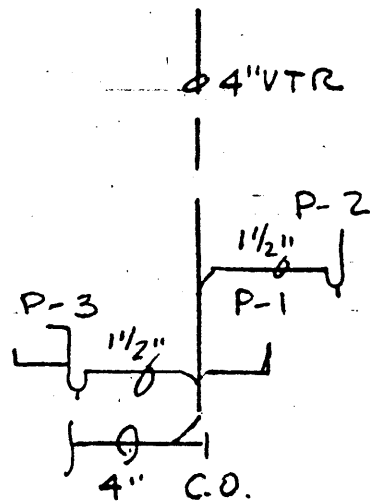
TYPICAL GAS
 PIPING
 FURNACE &
 HOT WTR HTR
 NO SCALE



TYPICAL FLOOR PLAN

PLUMBING

SCALE: 1/8" = 1'-0"



BATH

KITCHEN

C.W. & H.W.

WEV

WEV

RISER

RISER

RISER

DIAGRAM

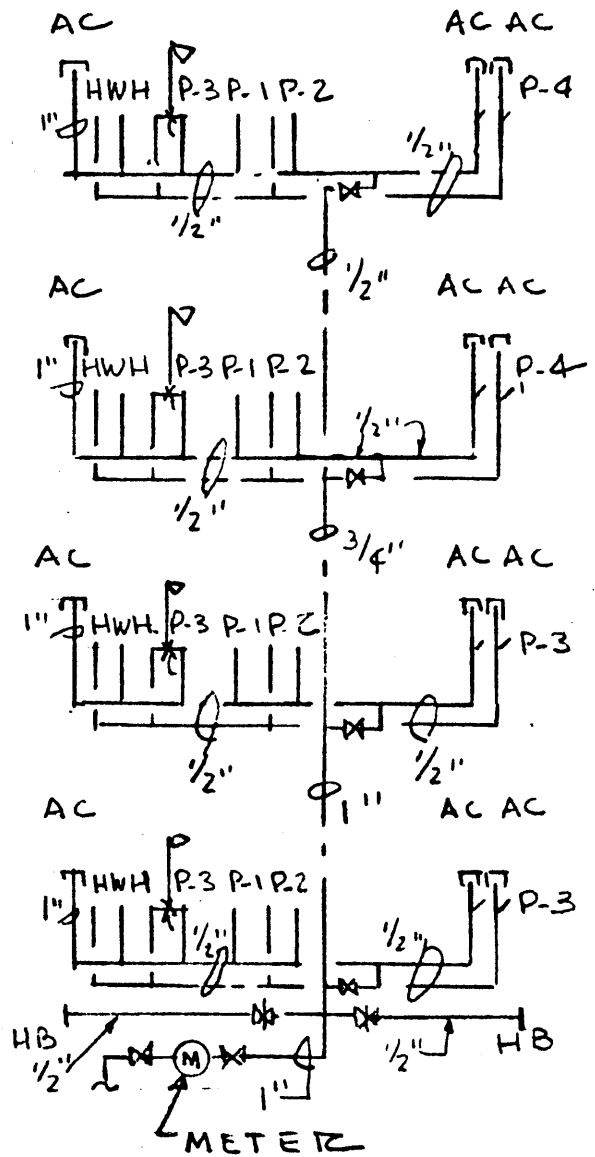
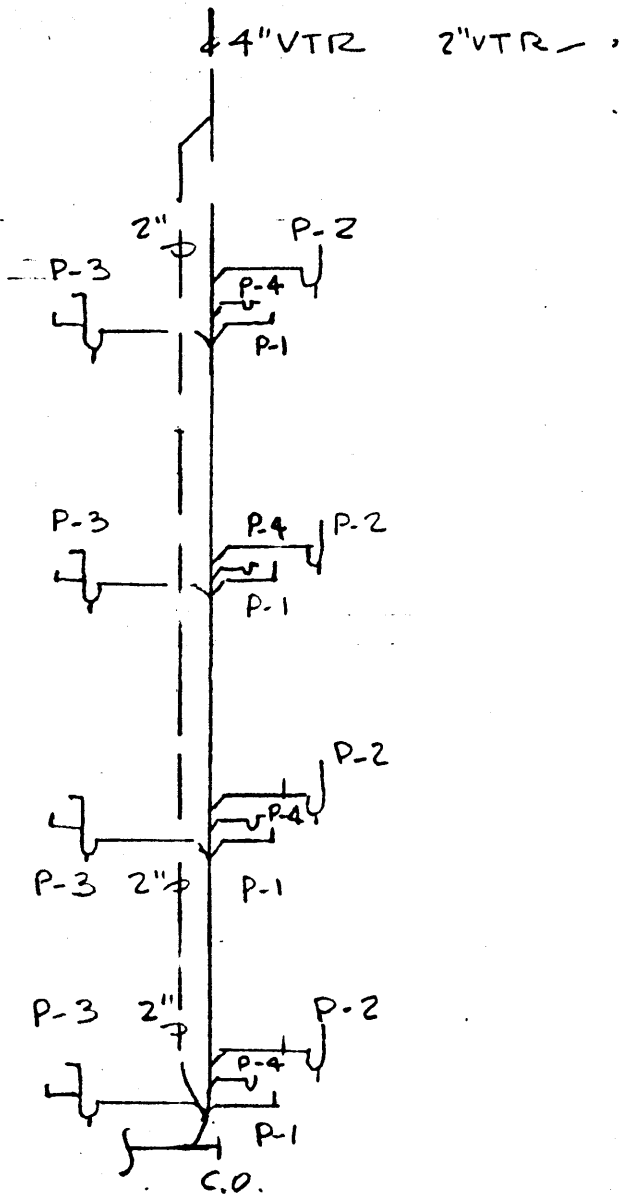
DIAGRAM

DIAGRAM

NO SCALE

LEGEND

- SANITARY WASTE W
- VENT PIPING V
- .-.-.- COLD WATER C.W.
- HOT WATER H.W.
- VTR VENT THRU ROOF
- H.B. HOSE BIBB
- C.O. CLEANOUT
- HWH HOT WATER HEATER
- P-1 WATER CLOSET
- P-2 LAVATORY
- P-3 BATH TUB
- P-4 KITCHEN SINK
- A.C. AIR CHAMBER



WEV RISER WEV RISER C.W. & H.W.

DIAGRAM DIAGRAM RISER

BATHS KITCHEN DIAGRAM

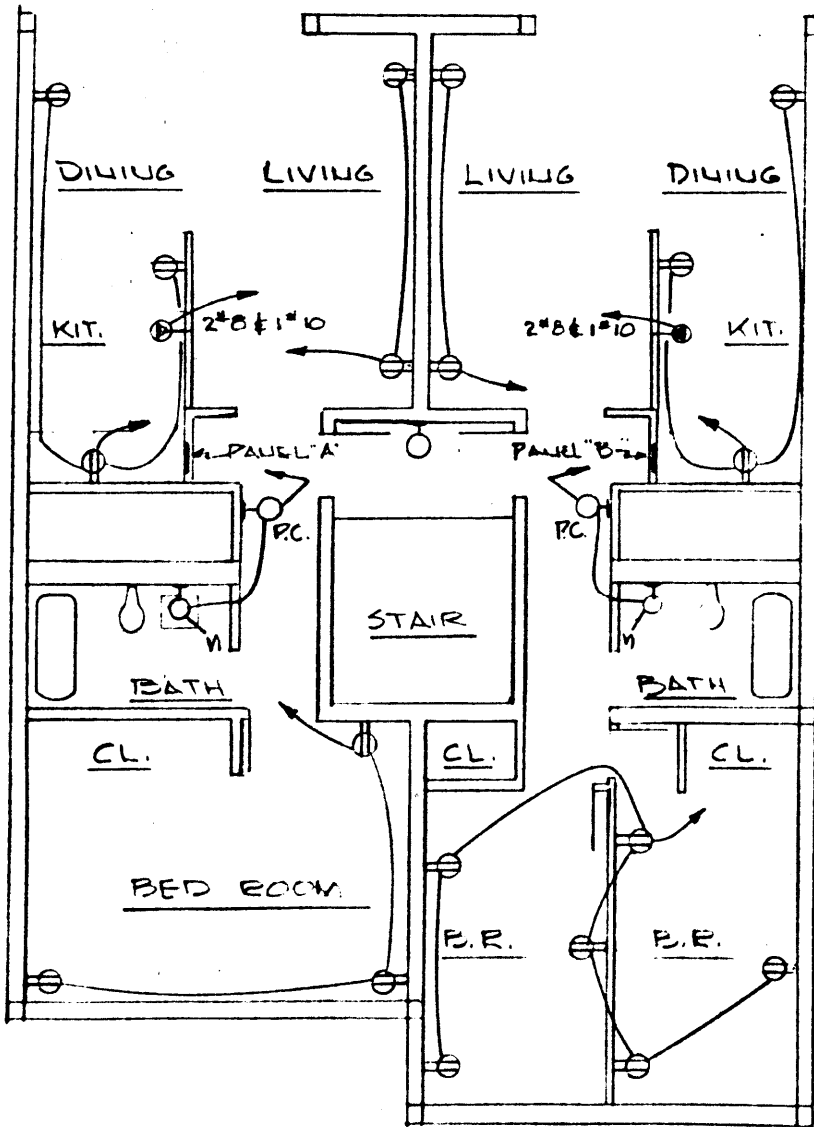
NO SCALE

LEGEND

- SANITARY WASTE W
- VENT PIPING V
- .-.- COLD WATER CW
- HOT WATER HW
- VTR VENT THRU ROOF
- HB HOSE BIBB
- C.O. CLEANOUT
- HWH HOT WATER HEATER
- P-1 WATER CLOSET
- P-2 LAVATORY
- P-3 BATH TUB
- P-4 KITCHEN SINK
- AC AIR CHAMBER

ELECTRICAL LEGEND

- LIGHTING PANEL
- HOME RUN TO PANEL
- S SINGLE POLE SWITCH
- ⊕ LIGHTING FIXTURE (WALL MTC.)
- ⊕ DUPLEX RECEPTACLE
- ⊙ RANGE OUTLET
- P.C. PULL CHAIN

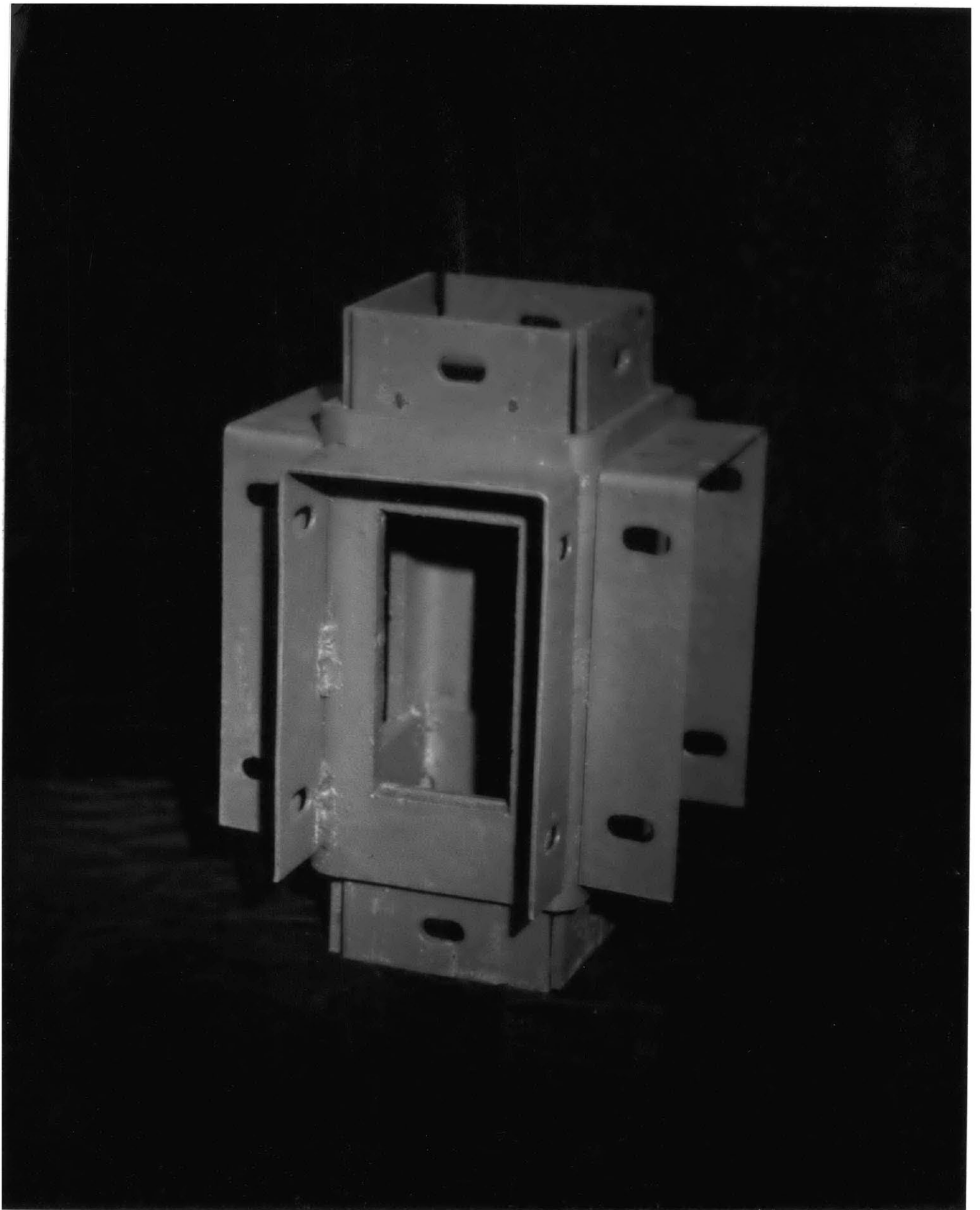


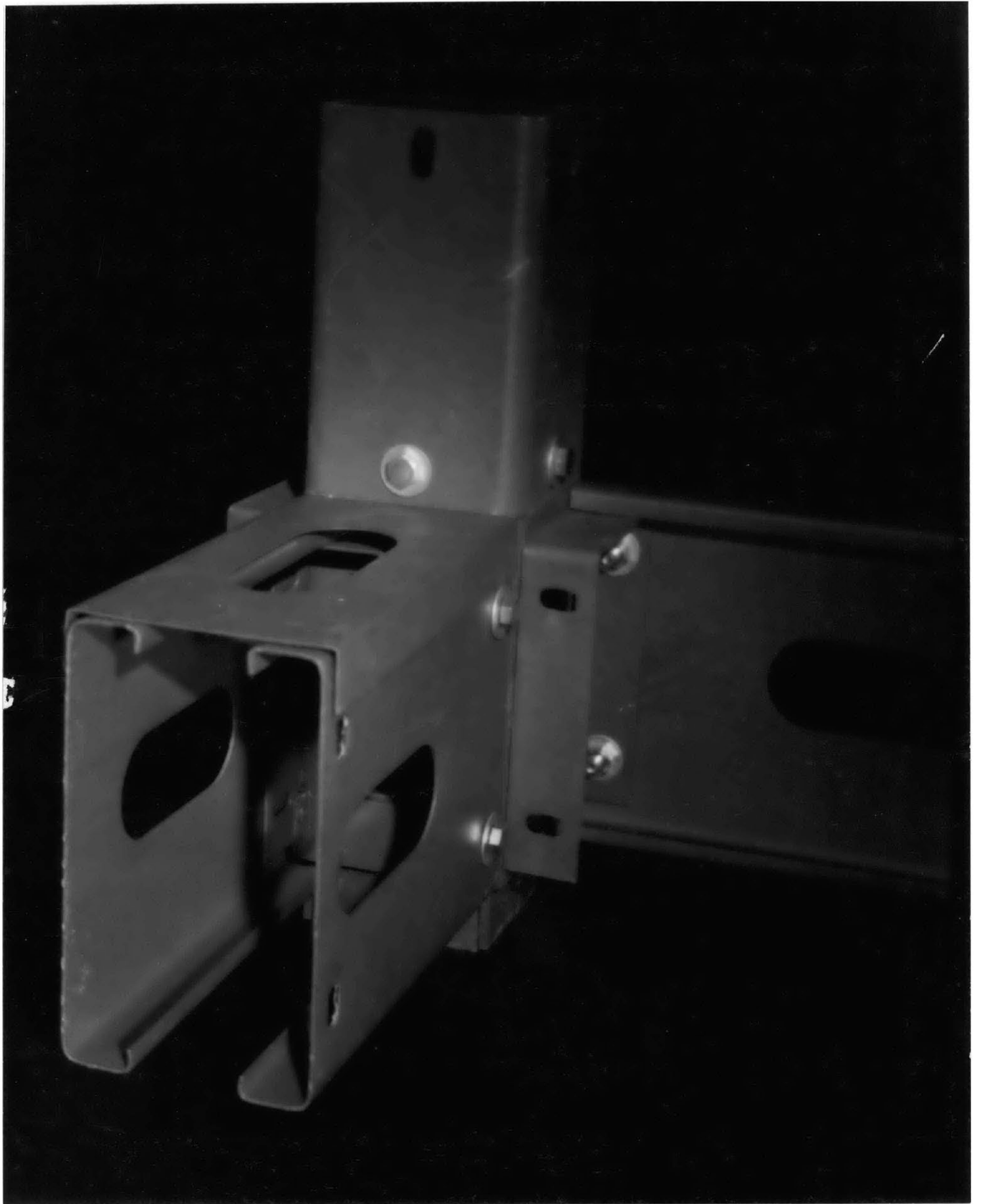
TYPICAL FLOOR PLAN

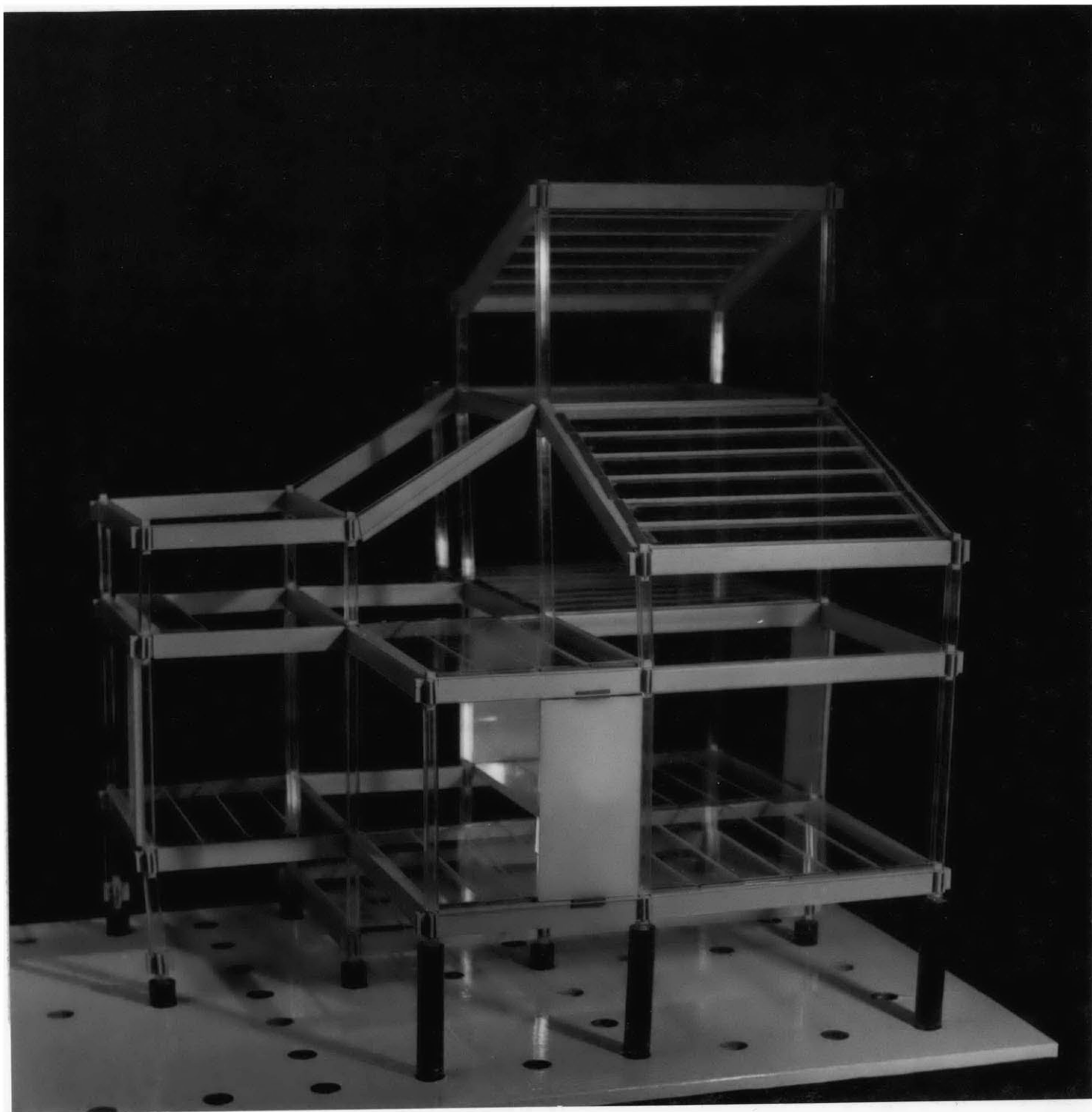
— ELECTRICAL —

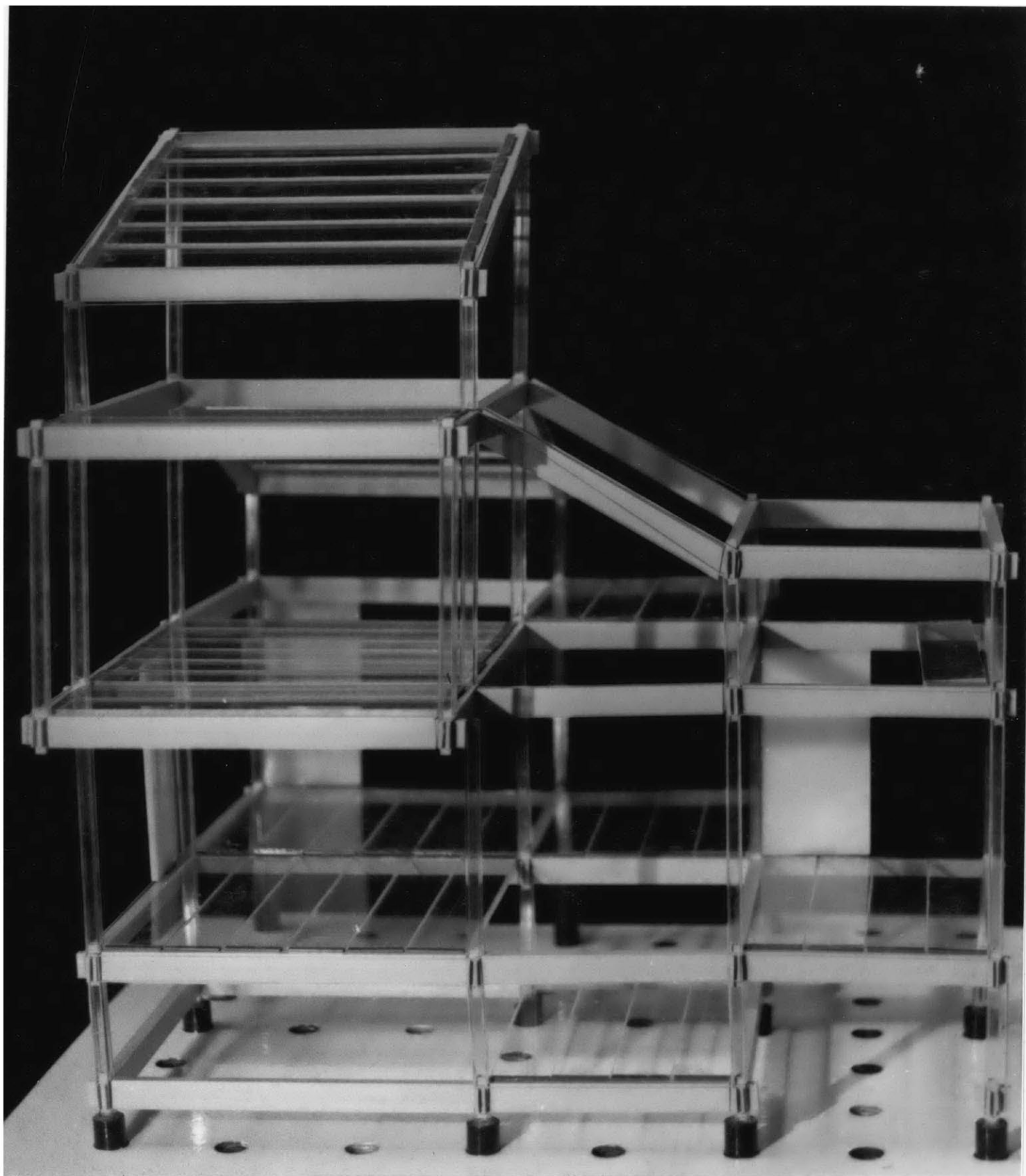
SCALE: 1/8" = 1'-0"

PHOTOGRAPHS OF MODELS









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