A HOUSING SYSTEM:
CAPABLE OF ADAPTING TO VARYING TOPOLOGICAL CONDITIONS

By:

PAUL DEAN HOAG

Bachelor of Architecture
University of Oklahoma (1971)

Submitted in Partial Fulfillment of the Requirements for the Degree of MASTER OF ARCHITECTURE, ADVANCED STUDIES

At the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
May, 1973

Author . . . .
Department of Architecture

Certified by . . . .
Thesis Advisor

Accepted by . . . .
Chairman, Departmental Committee
On Graduate Students

May 11, 1973

Dean William Porter
School of Architecture and Planning
Massachusetts Institute of Technology

Dear Dean Porter:

In partial fulfillment of the requirements for the degree of Master of Architecture, Advanced Studies, I hereby submit this thesis entitled:

A HOUSING SYSTEM:
CAPABLE OF ADAPTING TO VARYING TOPOLOGICAL CONDITIONS

Respectfully,

Paul Dean Hoag

ACKNOWLEDGEMENTS

The author gratefully acknowledges the following people who assisted in the development of this thesis:

Professor Waclaw P. Zalewski, Thesis Advisor
Department of Architecture, M.I.T.

Professor Eduardo F. Catalano
Department of Architecture, M.I.T.

Professor Arthur Bernhardt
Department of Architecture, M.I.T.

This thesis is dedicated to Linda and Chat.

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ABSTRACT

A HOUSING SYSTEM: CAPABLE OF ADAPTING TO VARYING TOPOLOGICAL CONDITIONS

By: Paul Dean Hoag

Submitted to the Department of Architecture on May 11, 1973, in partial fulfillment of the requirements for the degree of Master of Architecture, Advanced Studies.

This thesis is intended to develop an industrialized system for housing produced in the factory, using both concrete and steel as structural materials, with the capability of being erected on a site with varying topological conditions.

The written section of this thesis provides a brief description of the system developed and establishes areas of concern, long range potentials, and constraints within which the design proposal is made.

The design proposal demonstrates how modular coordination of basic living elements with given interior components can generate many combinations of modules ready for shipment and erection. Using the sample modules and varying the module length, the proposal illustrates the many variations possible and demonstrates new site planning concepts generated by these units.

INTRODUCTION

An expanding and shifting population within the United States has its impact focused on the urban areas of the country. These urban centers already contain over 50% of the total population and are increasingly faced with growth constraining factors of excessive land costs as competition for the diminishing available land becomes a more determinant factor. Much of the steep slope land in these urban areas is within easy access of the urban cores of the various cities. As a result, the available sloped land could become highly desirable from a development standpoint.

Because of the close relationship of the sloped land areas to the urban cores, and man's need to be near his work, it becomes apparent that the sloped land might be utilized for housing. This could be a potentially desirable solution for the urban areas already faced with serious housing shortages.

At the same time, the basic structure of the typical house in the United States remains unchanged past mid-century despite early attempts in the use of mass production as far back as the early 1900's. This has resulted in the continually spiralling labor and material costs of traditional on-site construction.

The publicity of Moshe Safdie's Habitat at Expo 67, the Operation Breakthrough project sponsored by the Department of Housing and Urban Development, and the success of the mobile home have encouraged architects, engineers, and manufacturers to seriously study the potential of dwelling modules. These modules are suitable for factory production, and are capable of being transported over our present highway system. Once the modules have reached the site, they are positioned by cranes and organized in various configurations. This approach is a faster and cheaper method of constructing housing than the conventional on-site method, and will become increasingly more economical as traditional construction labor costs rise. Another important aspect of industrialized housing is the ability to maintain a higher standard of quality control not presently being achieved in conventional construction.

The attempt of this thesis is to develop an industrialized system for housing with the capability of adapting to the urban areas where high slope ratio of the surrounding terrain prevents expansion under present conventional construction methods. This system utilizes the present factory technology to produce a finished concrete or steel modular unit which can be transported to the site, and stacked in an overlapping configuration to reflect the topography of the site or in a vertical, more conventional high-rise configuration.

AREAS OF CONCERN AND RESTRAINT

UNIT TYPE

Individually shipped manufactured units that incorporate minimum volumes of shipped air and maximum use of existing technology.

UNIT SIZE

a. 14' - 0" maximum shipping width.

b. 70' - 0" maximum shipping length.

c. 13' - 6" maximum shipping height.

BUILDING CONDITIONS

a. For high, medium, and low-rise density.

b. Middle-upper middle income groups.

c. Provide apartment units with 1-4 bedrooms.

d. Structural materials to be concrete or steel produced and assembled in a factory.

DESCRIPTION OF THE SYSTEM

The system developed is made of either concrete or steel floor, wall, and ceiling panels that are welded together to form modular units for housing. The units are completely finished except for the final utility connection at the site and minimum interior finishing where more than one module make up a single dwelling unit. These modules can be arranged to form different apartment types and sizes. Emphasis is placed on direct resolution of structural and mechanical needs, while minimizing the restraints these functions have on planning.

The objective of the terraced configuration is to provide the capability of conforming to different topological conditions. Slopes of the sites for the terraced situation can vary from approximately 15 to 32 degrees and maintain comfortable exterior pedestrian circulation up and down the slope. For slopes greater than 32 degrees, pedestrian circulation will be limited to stairs with intermediate landings between apartment levels or through the use of inclined elevators.

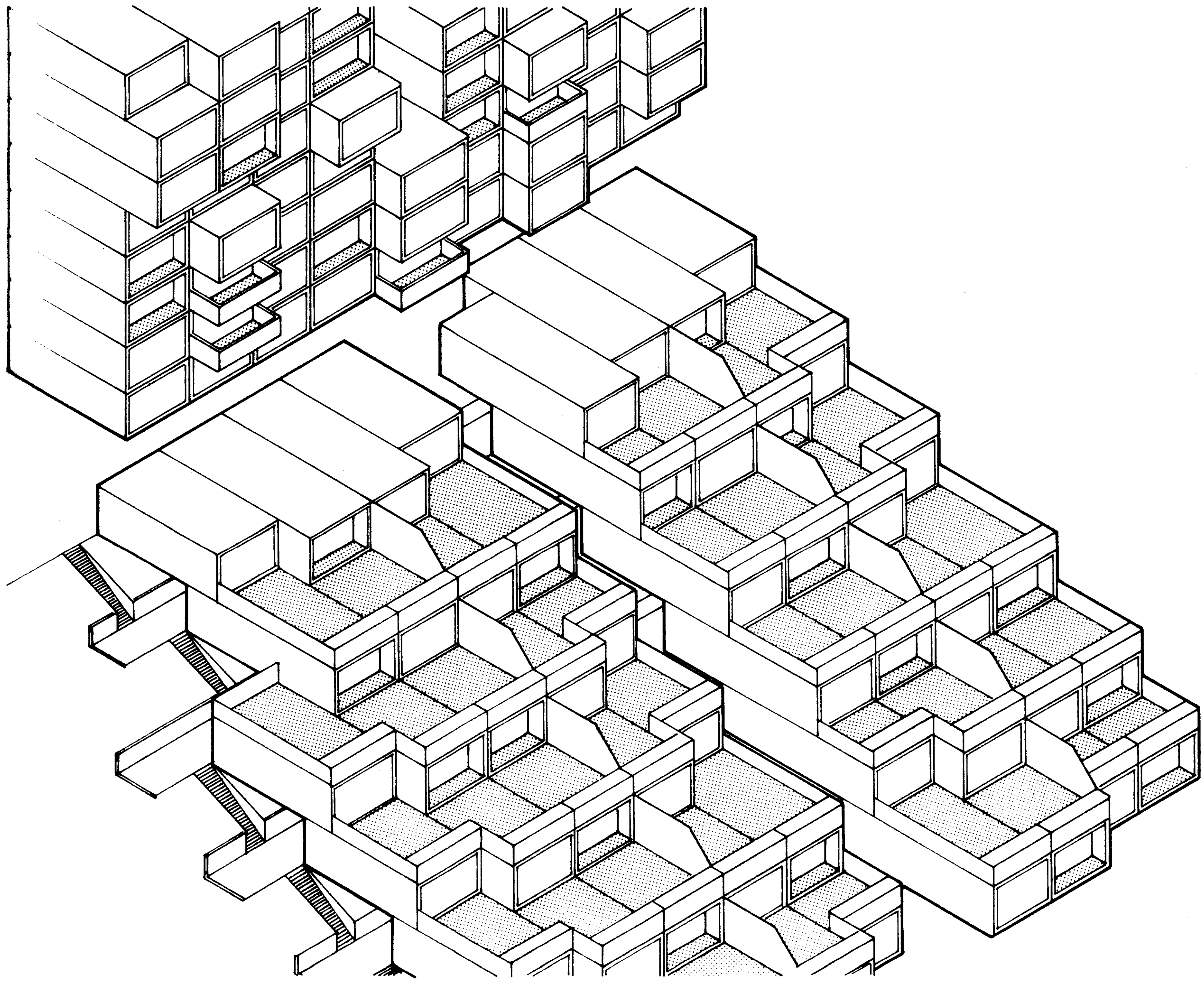
To incorporate the system in a more conventional high-rise configuration, it is necessary to provide full-storey trusses at every fifth level thereby carrying four levels of modular units. These levels at the trusses could then be left open or infill construction provided to maintain a pedestrian street. The infill construction might then become more apartment units or commercial and public space. A typical core of elevators and firestairs would be constructed at the bottom of the slope and wherever necessary to provide ingress and egress to the high-rise configuration. The high-rise building then in turn could serve as a supportive structure in terms of services and circulation for the terraced configuration.

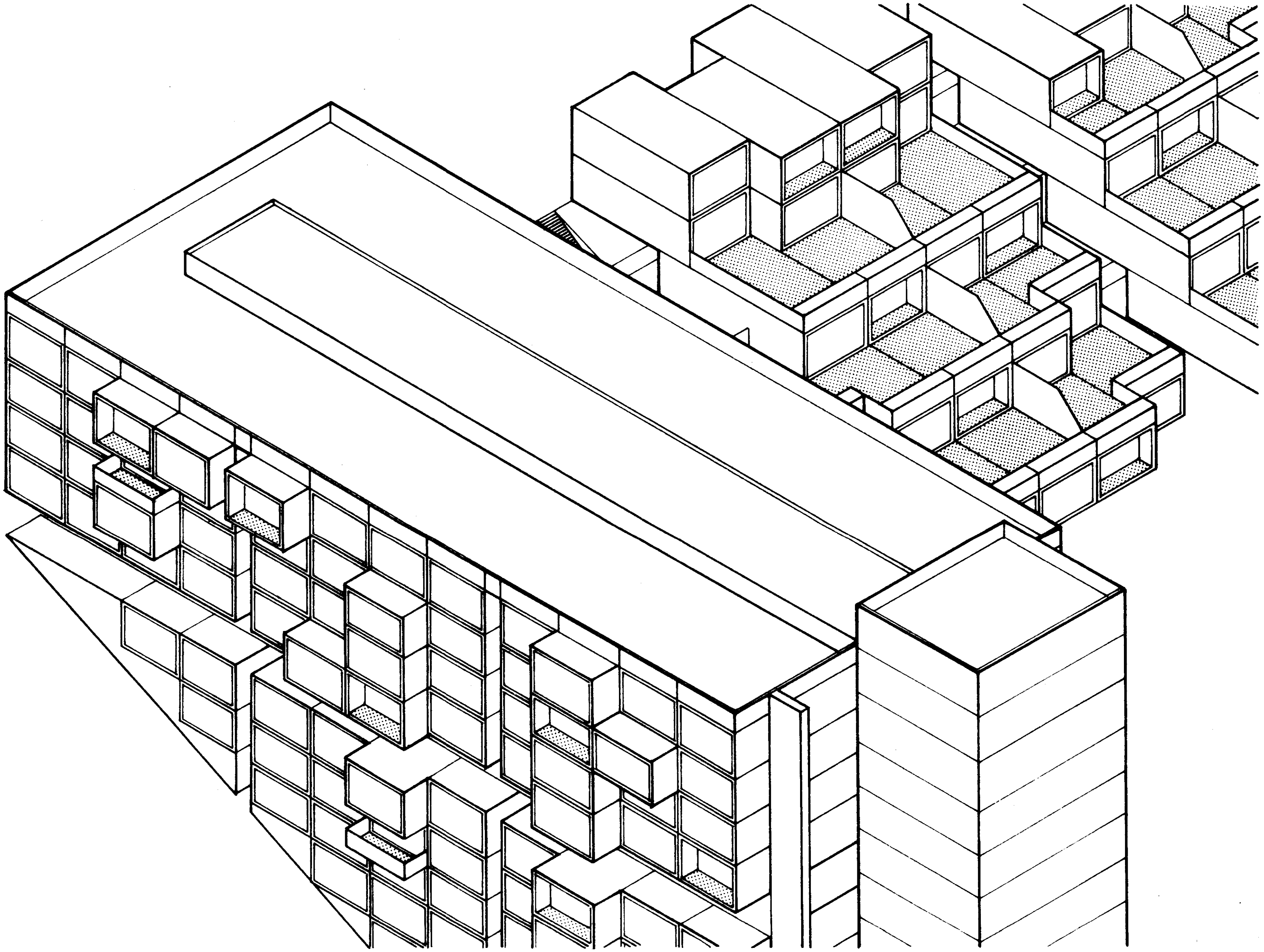
Structural System

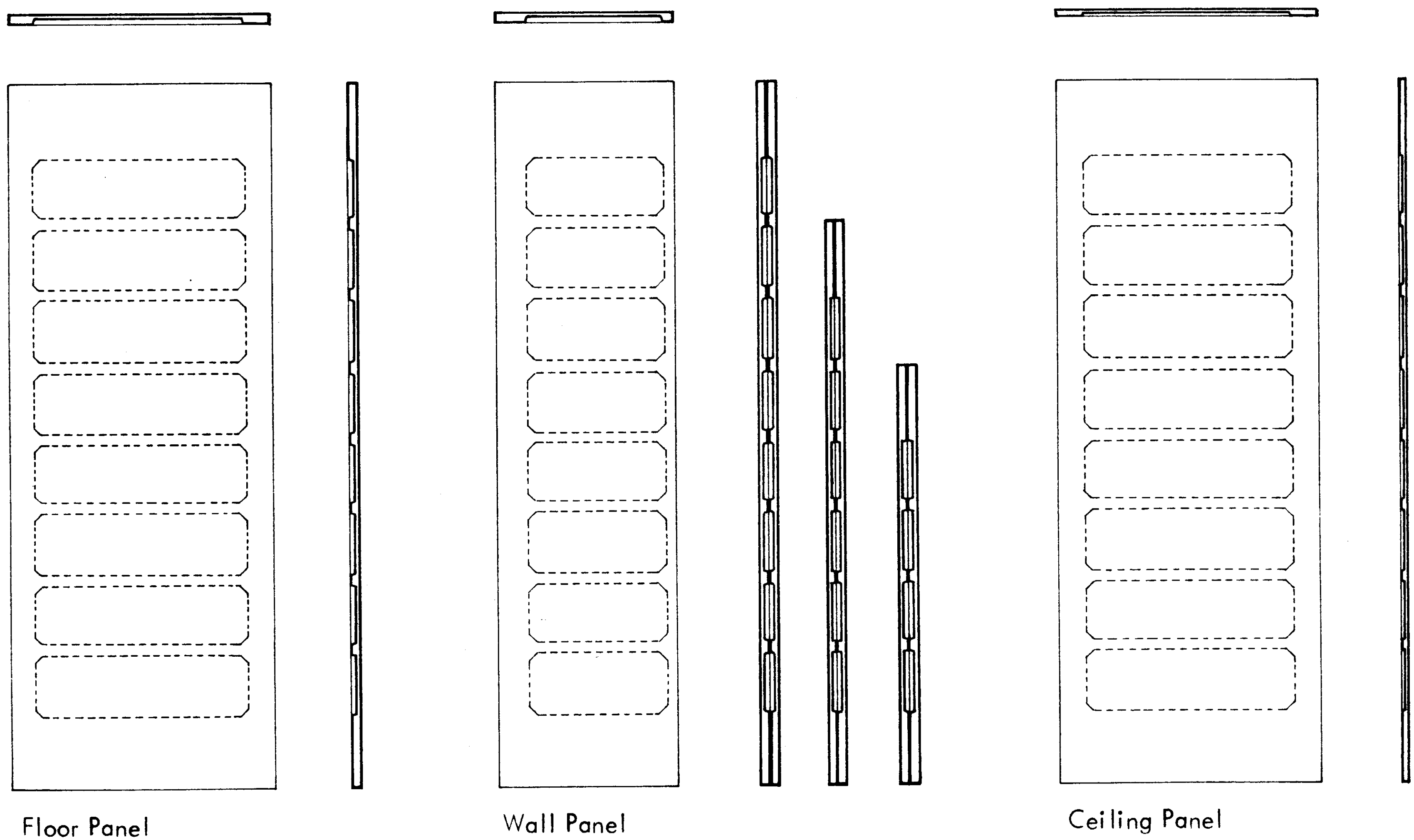
The basic structural element is the modular box of either lightweight reinforced concrete panels or steel truss walls. The concrete unit has vertical ribs cast in at intervals of 3' - 6", while the steel unit has a system of alternating vertical trusses and steel columns. In either case, the walls act as beams and are load bearing with welded connections. The ribs or columns allow for horizontal displacement of the modules at 3' - 6" intervals, thus determining the different slopes of the terraced configuration, while lessening the weight of the modules in either configuration.

Mechanical System

Heating, ventilation, and air conditioning are provided by either fan coil, or hot water radiation units with air conditioning being an option. Final utility connections are made after the modules are placed at the site. Kitchen and bathroom exhausts are ducted through the utility chase to points pre-determined in the total plan.







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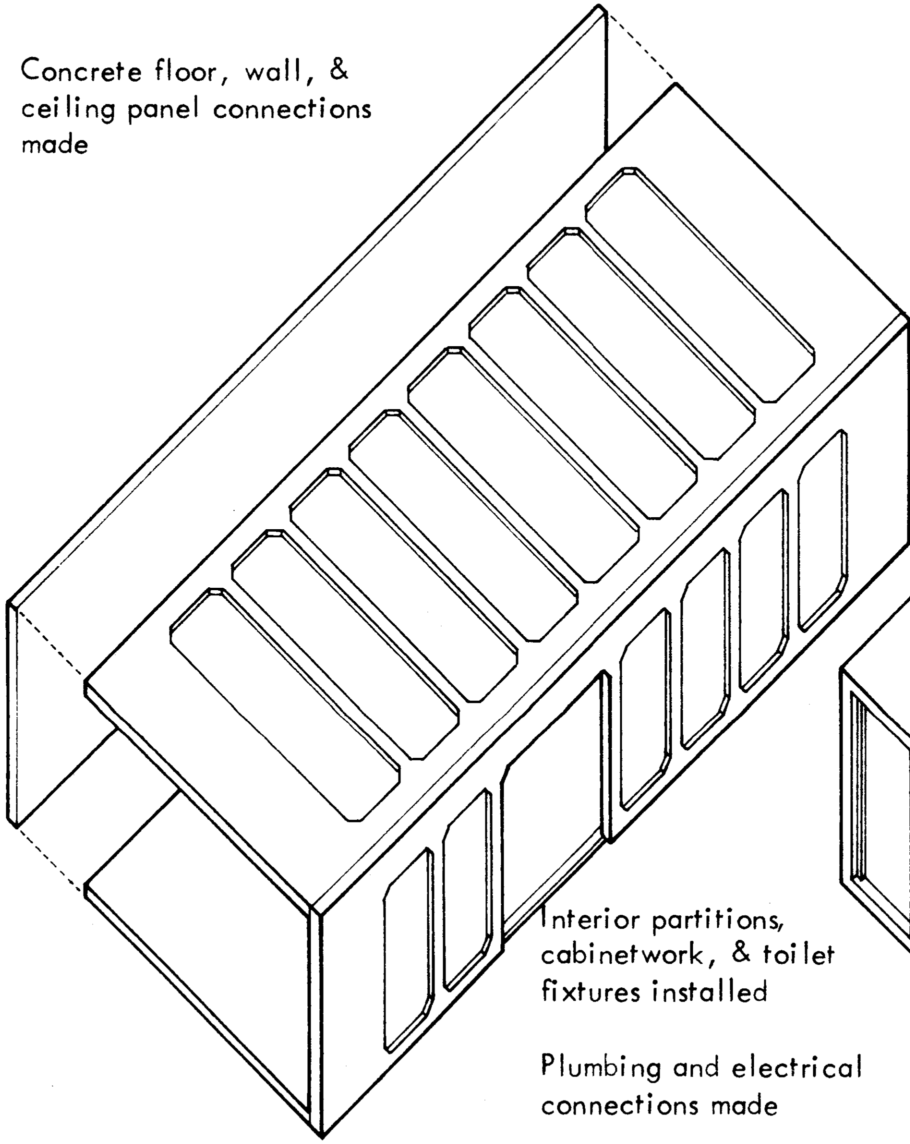

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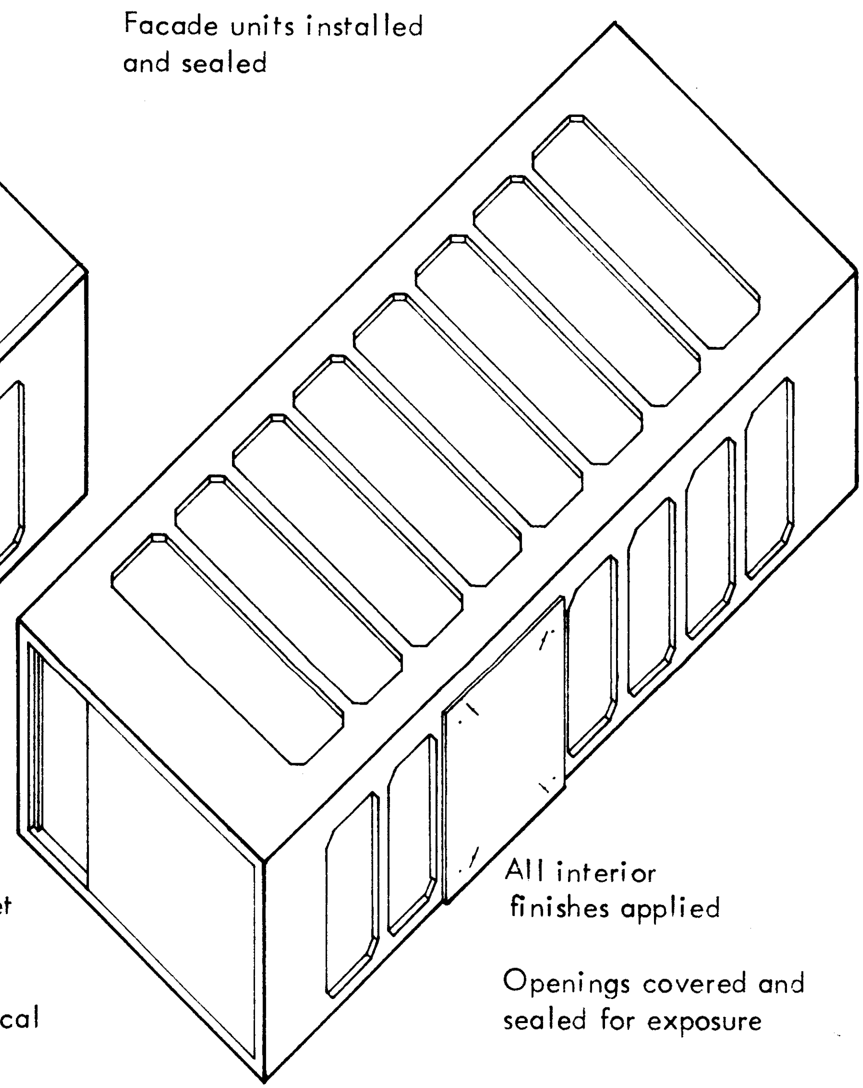

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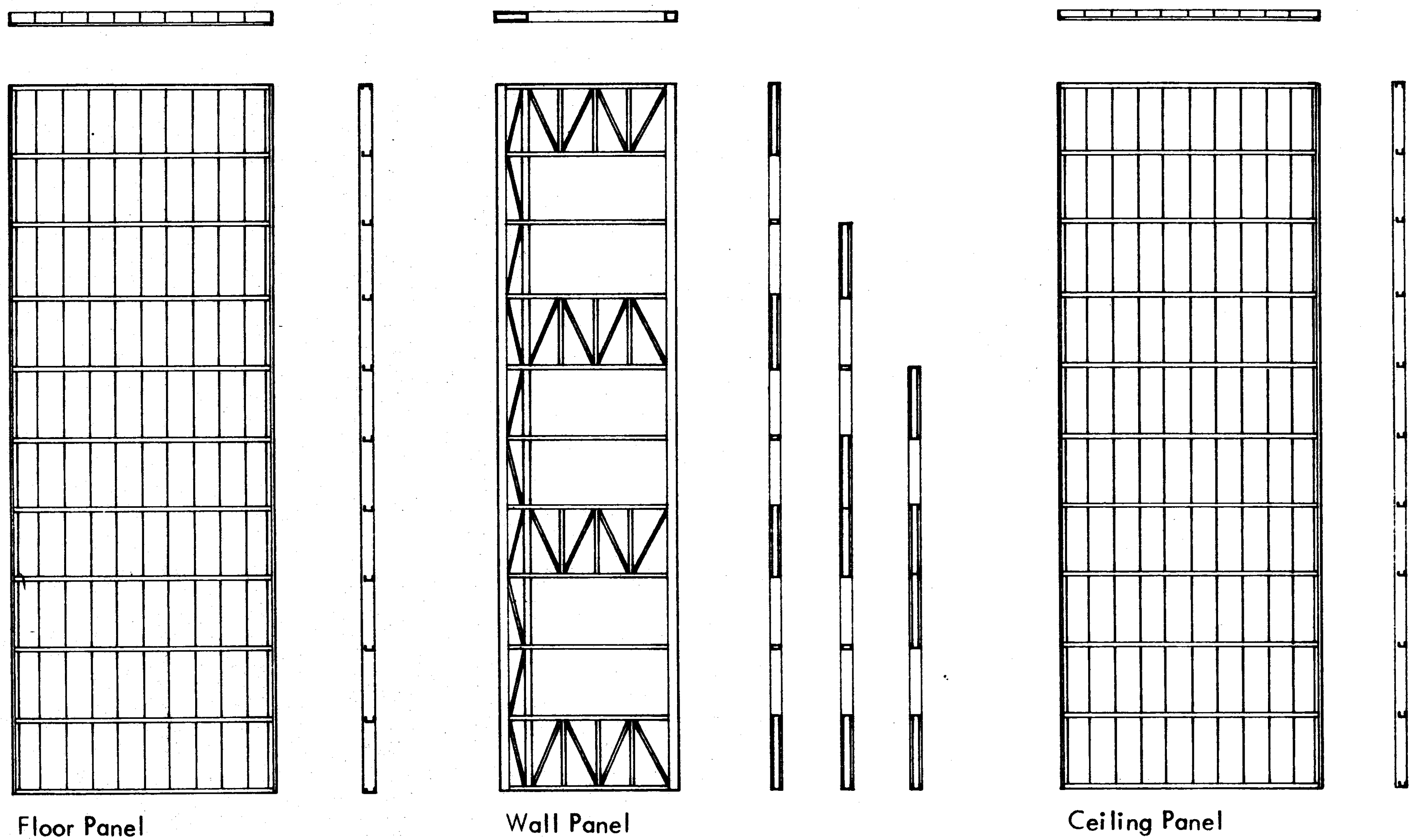

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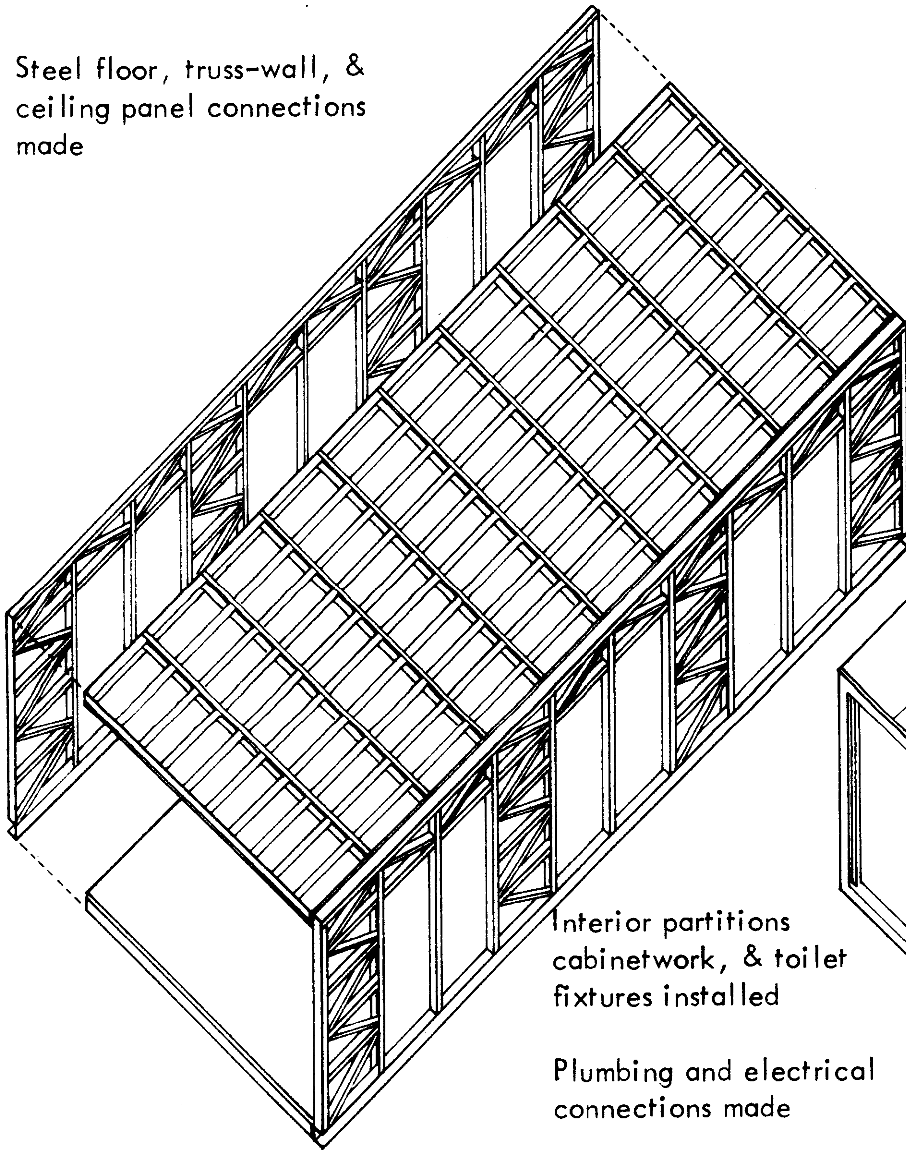

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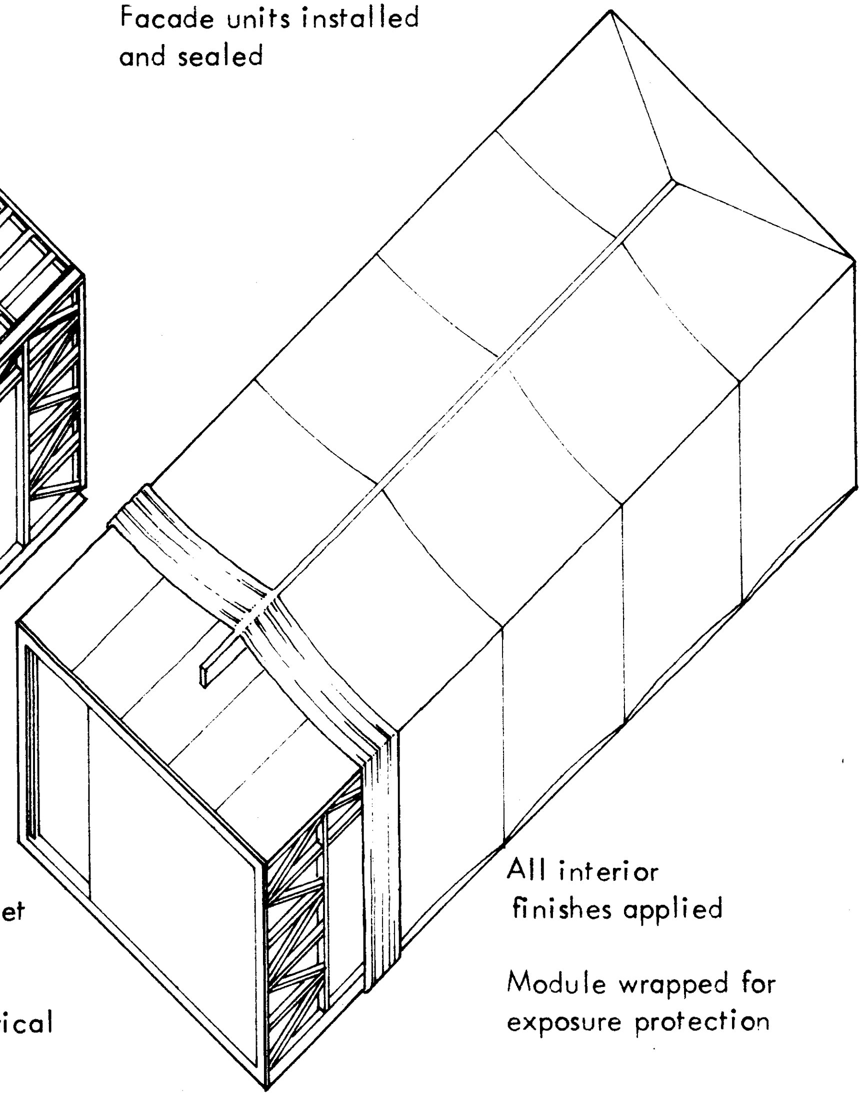

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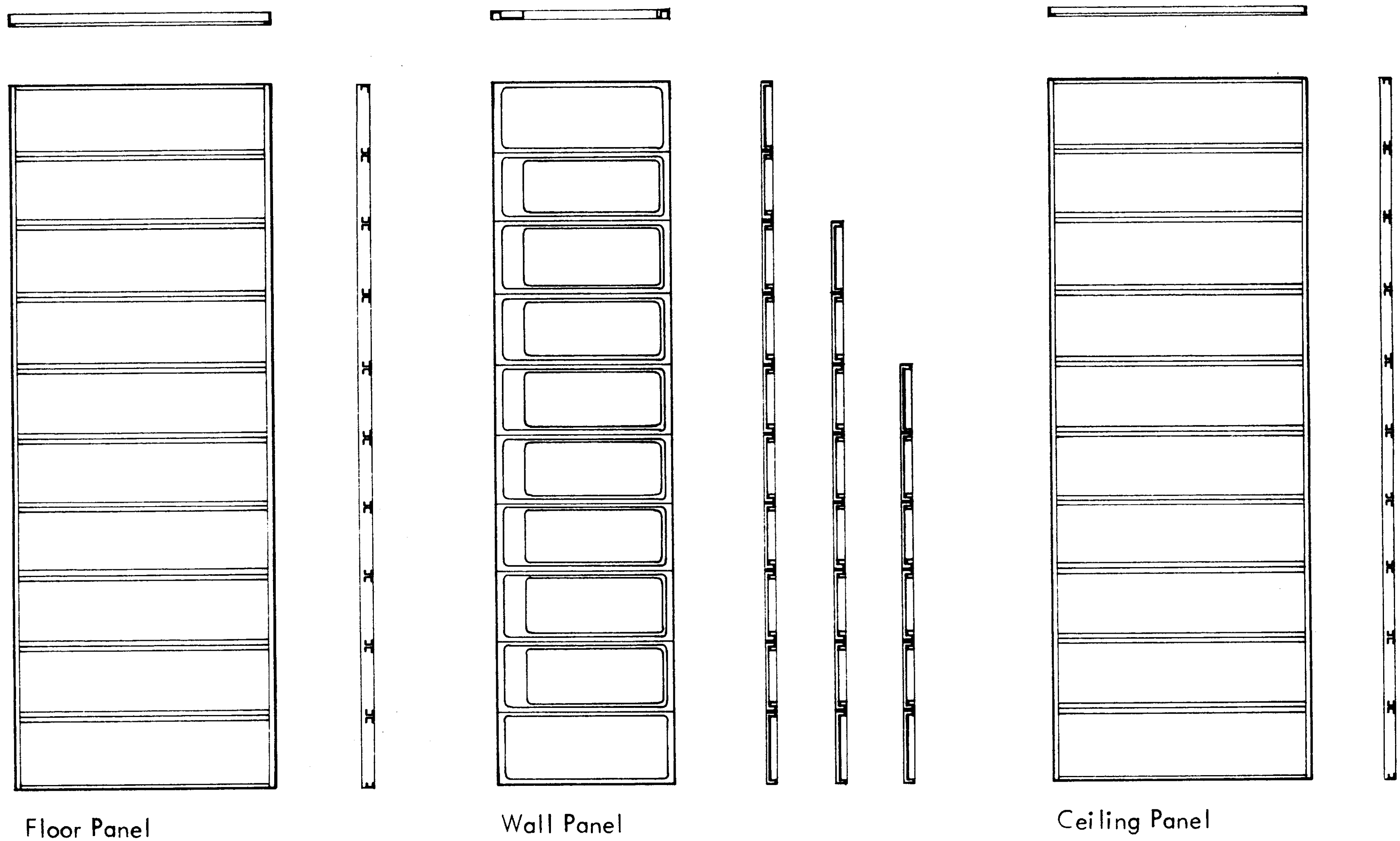

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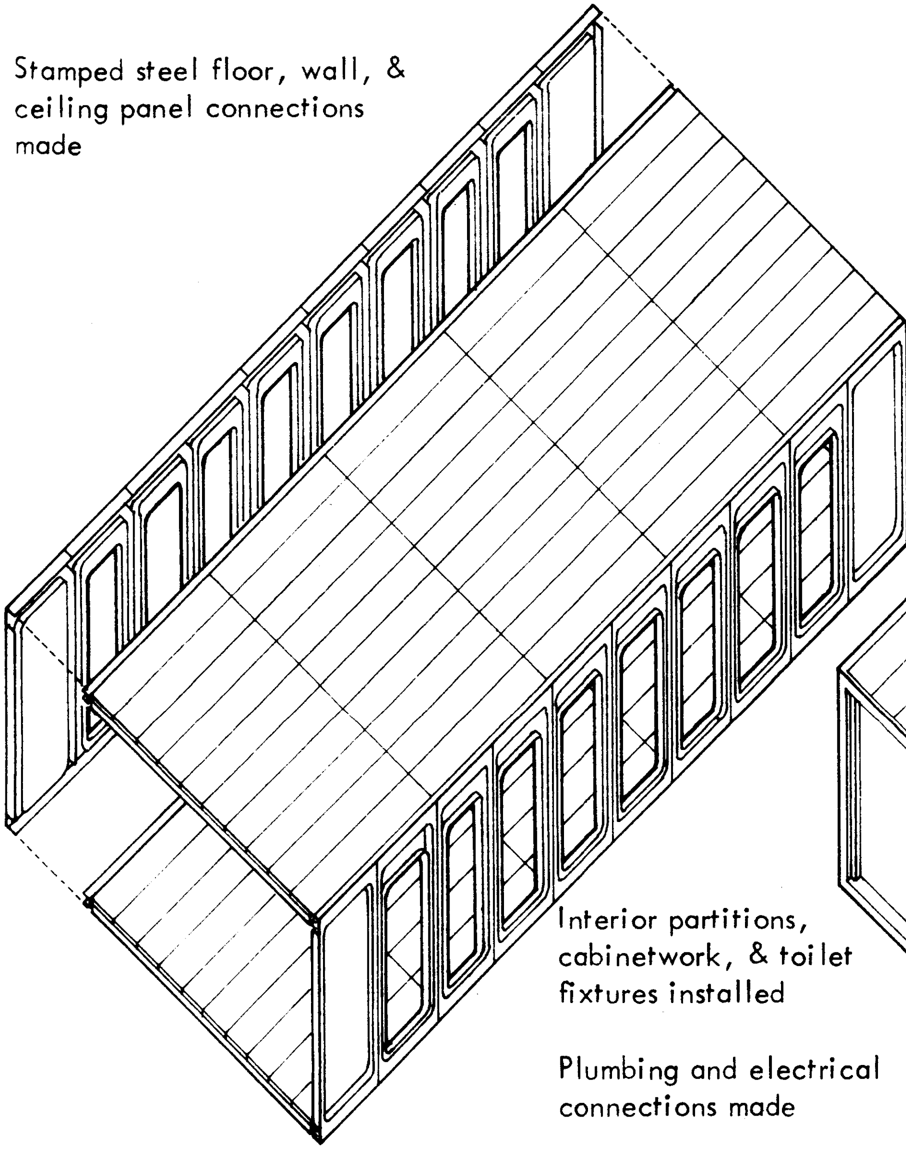

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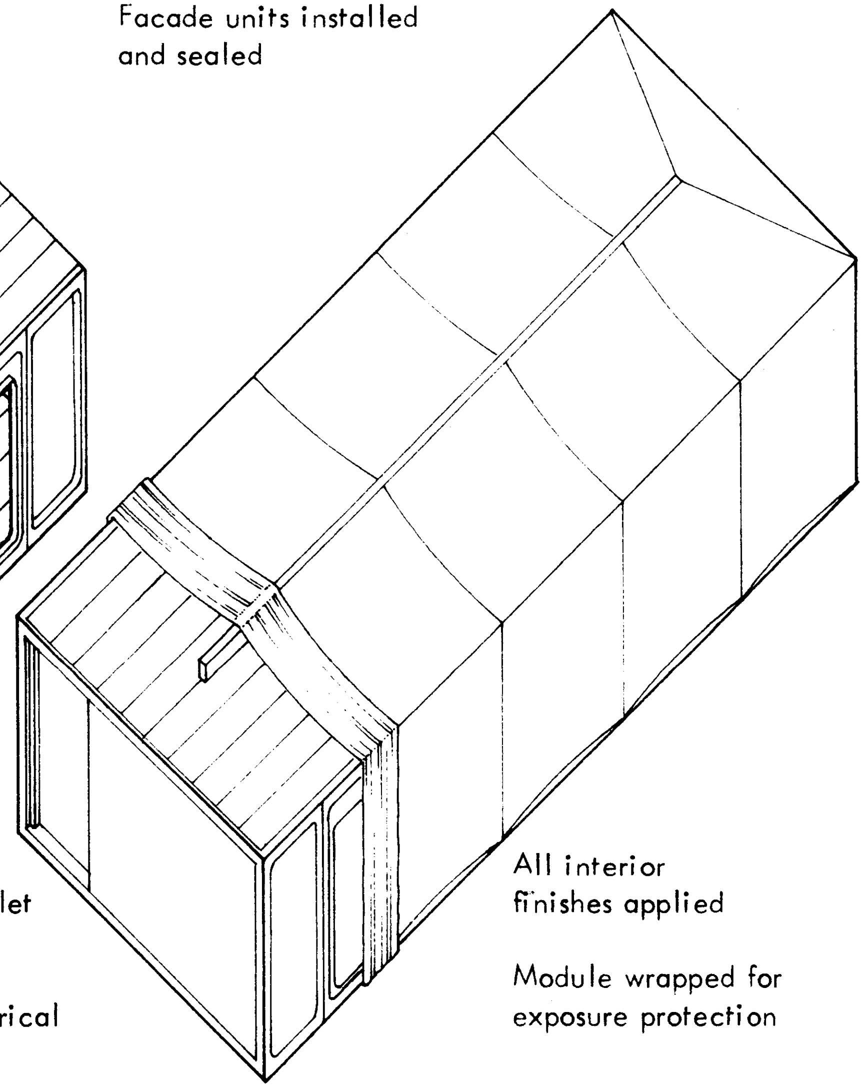

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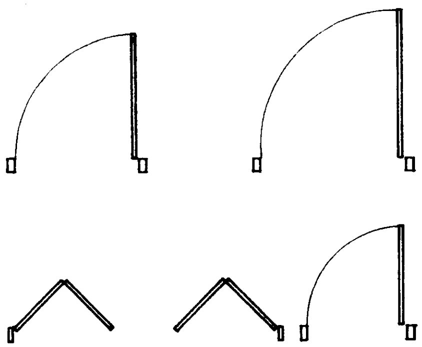

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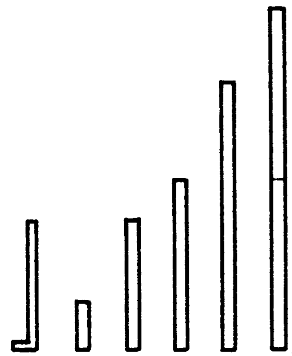

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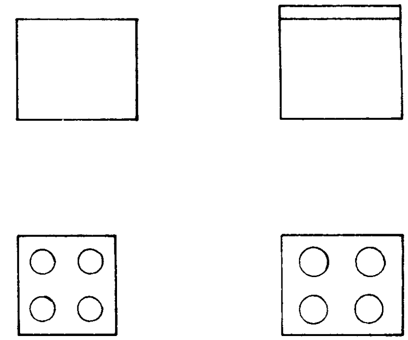

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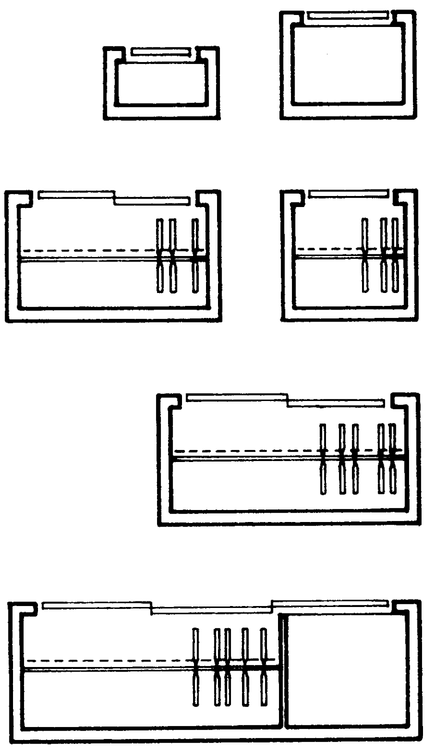

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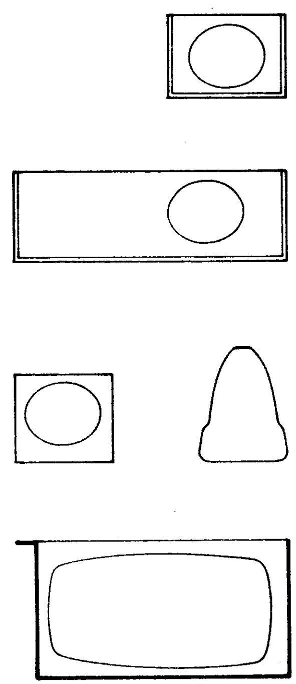
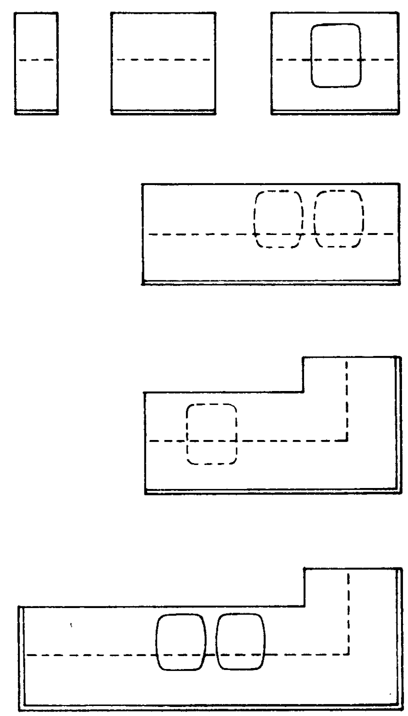
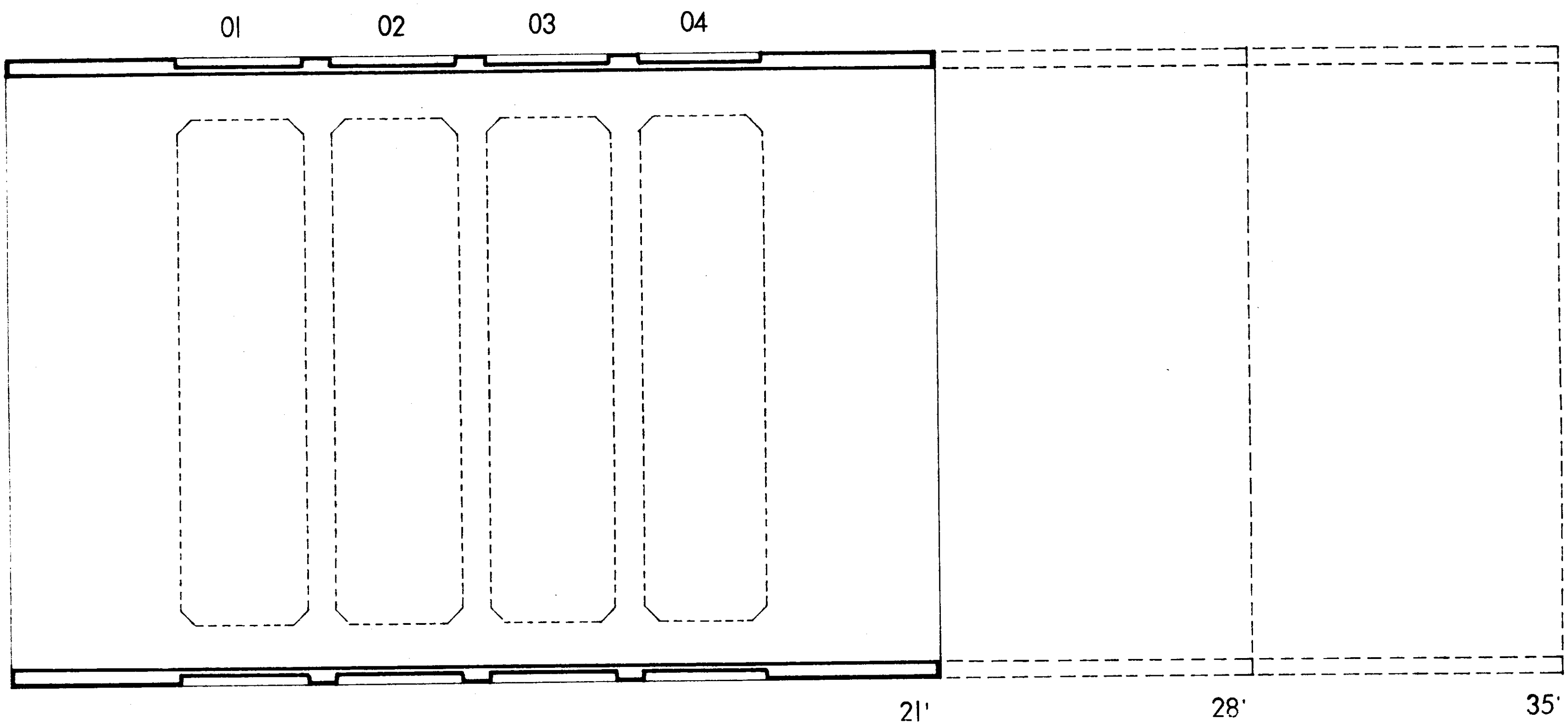


Fixtures



Cabinets/Worktops

INTERIOR COMPONENTS



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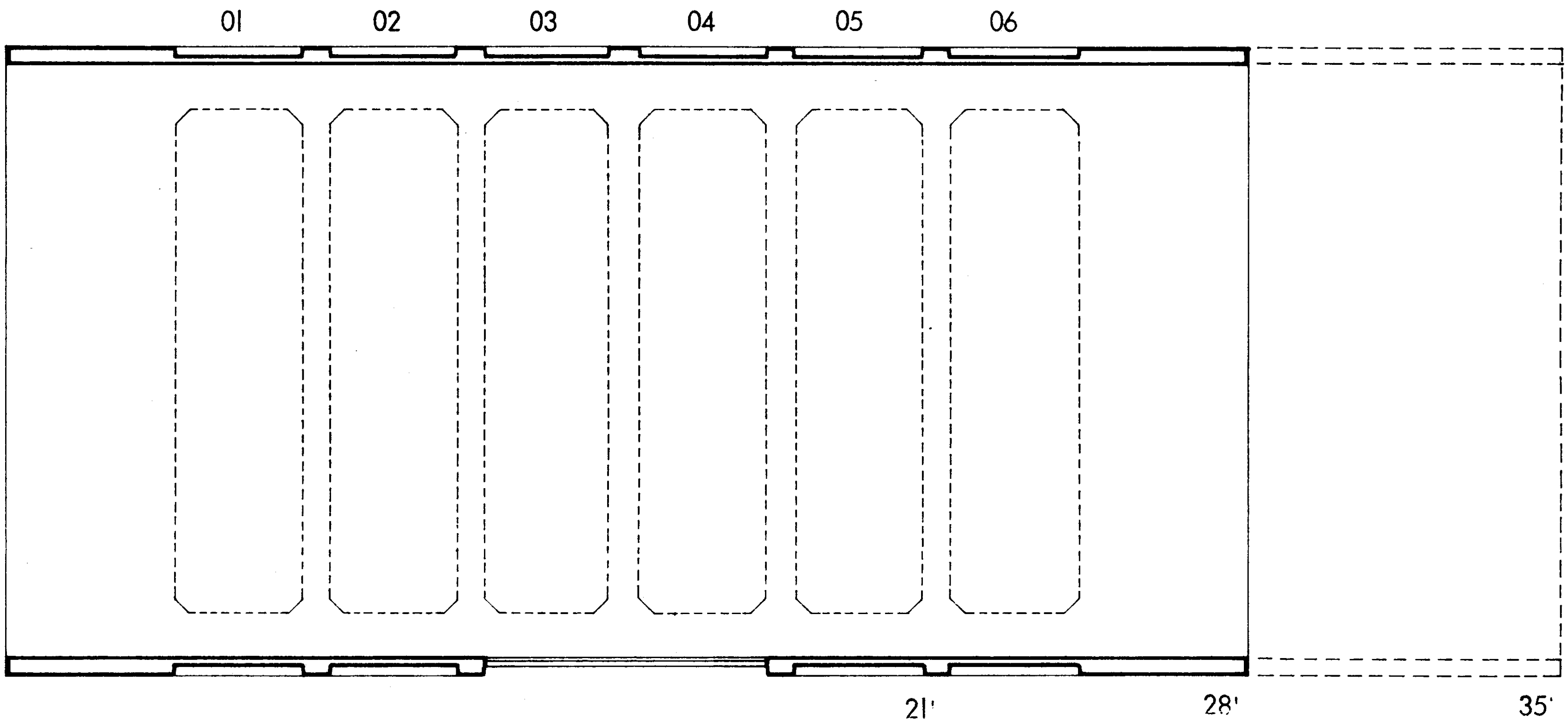

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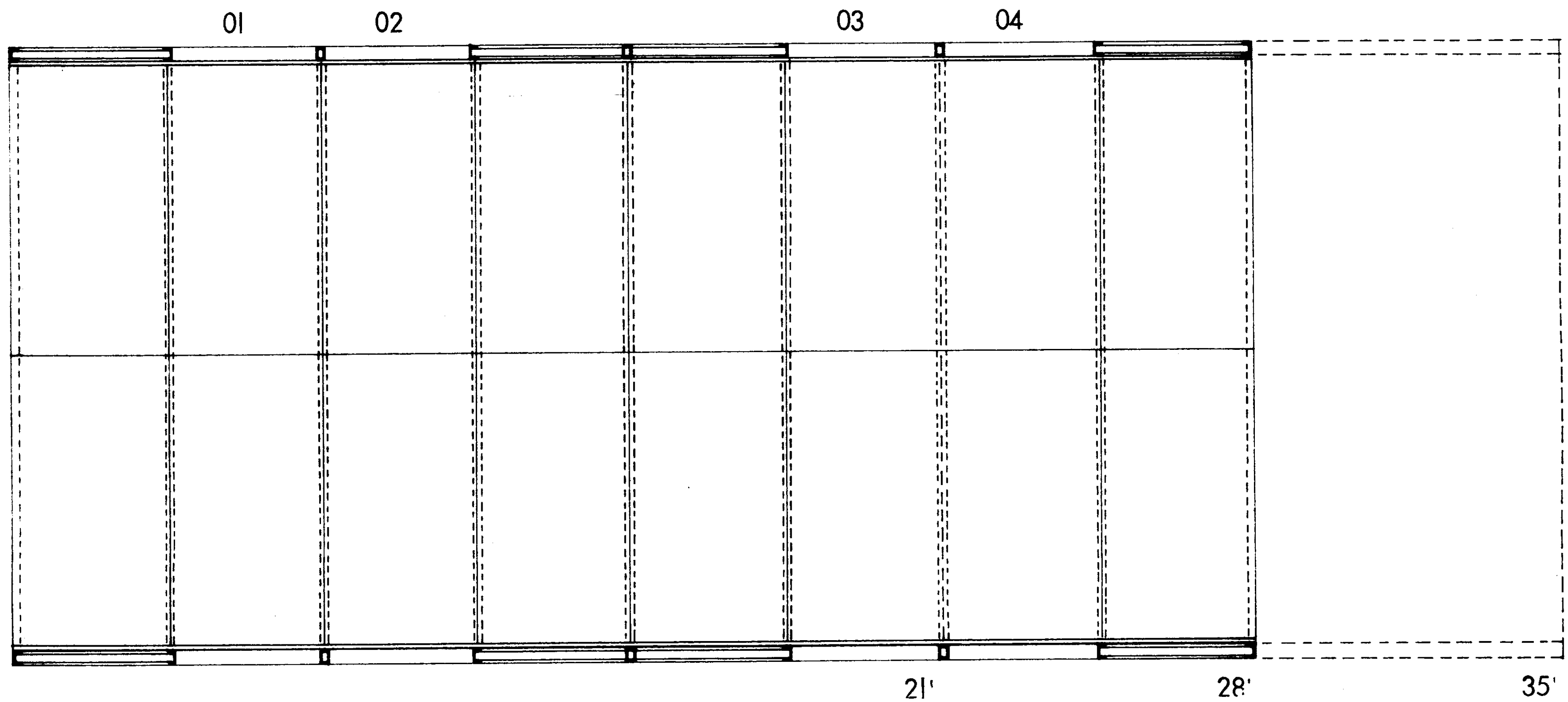

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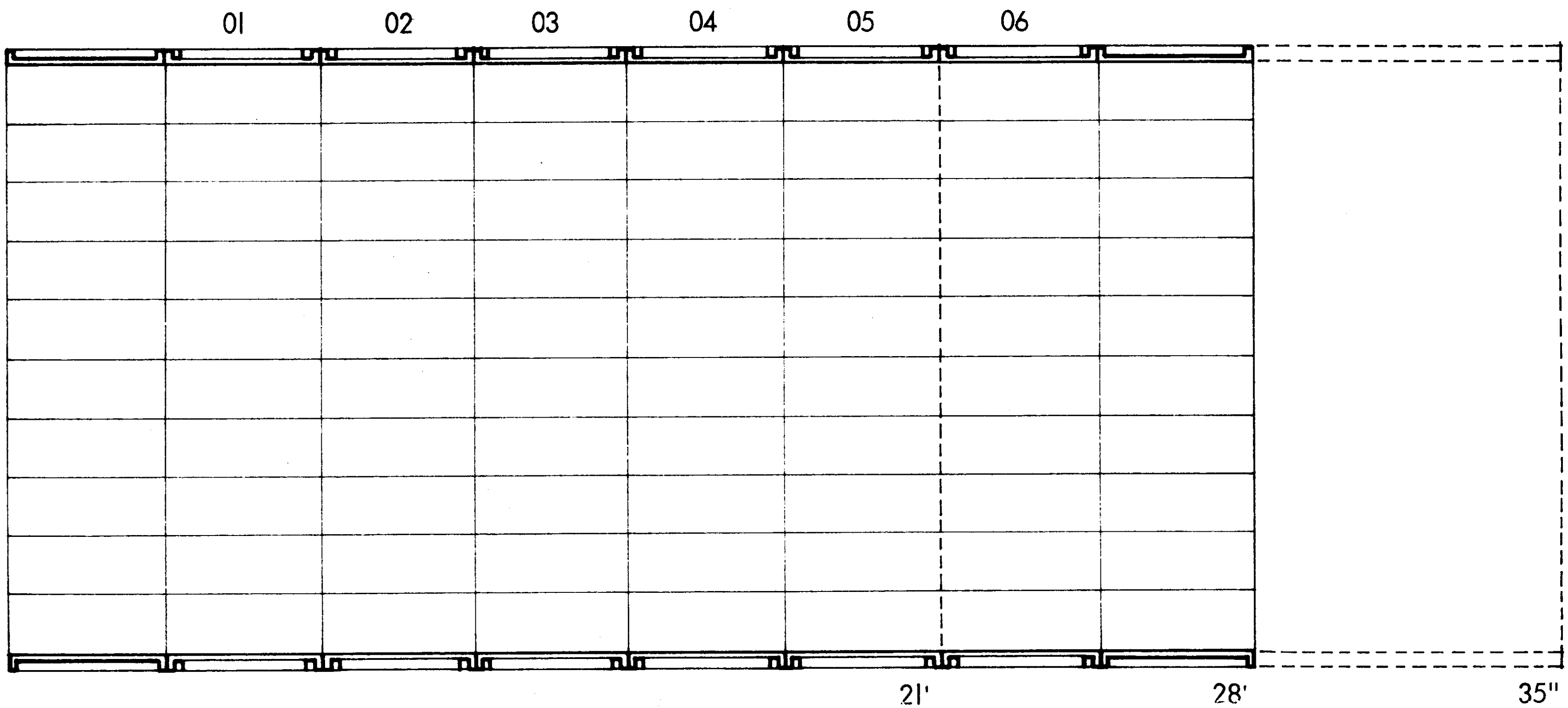

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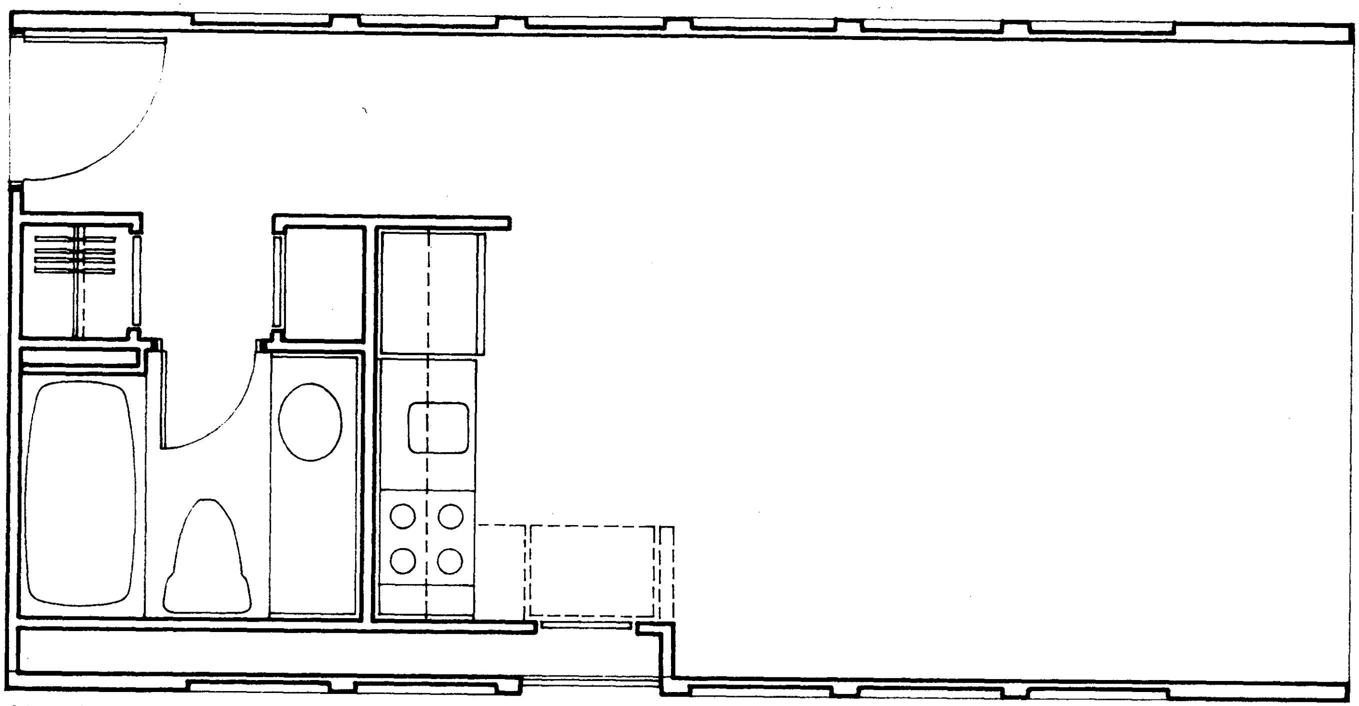
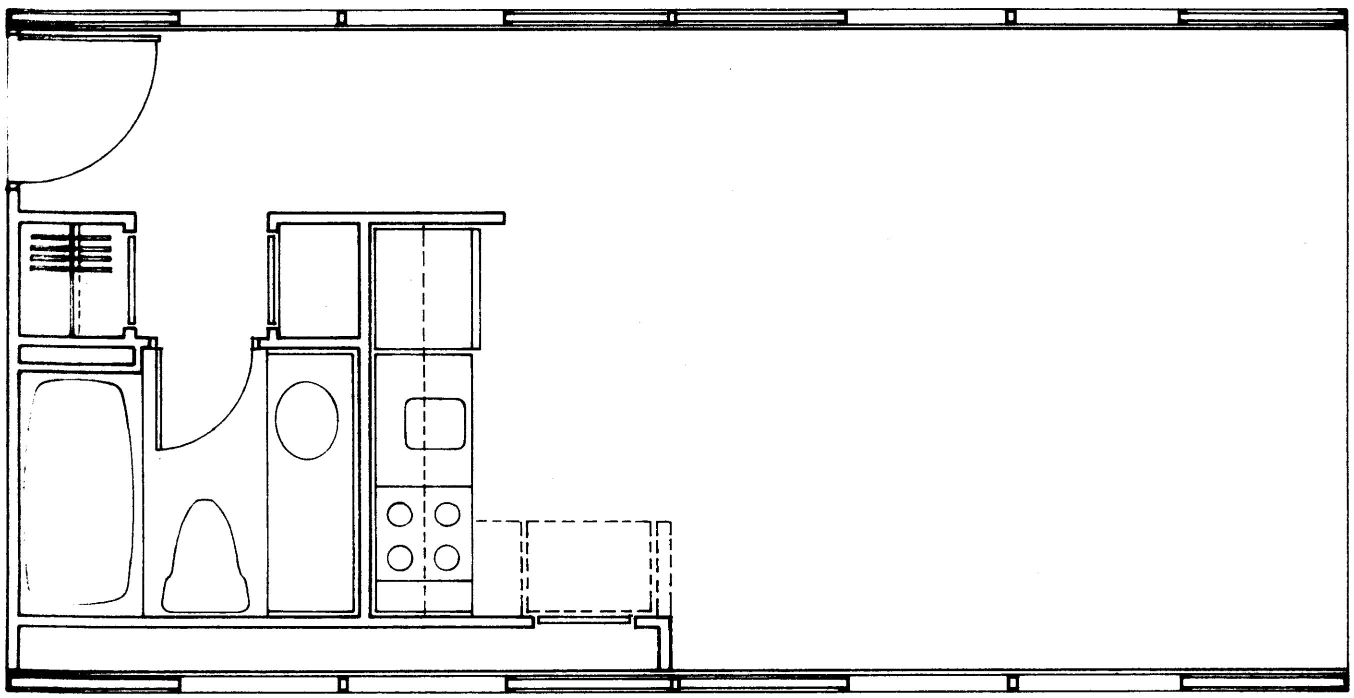


Unit bKL
Concrete

DESIGN MODULES



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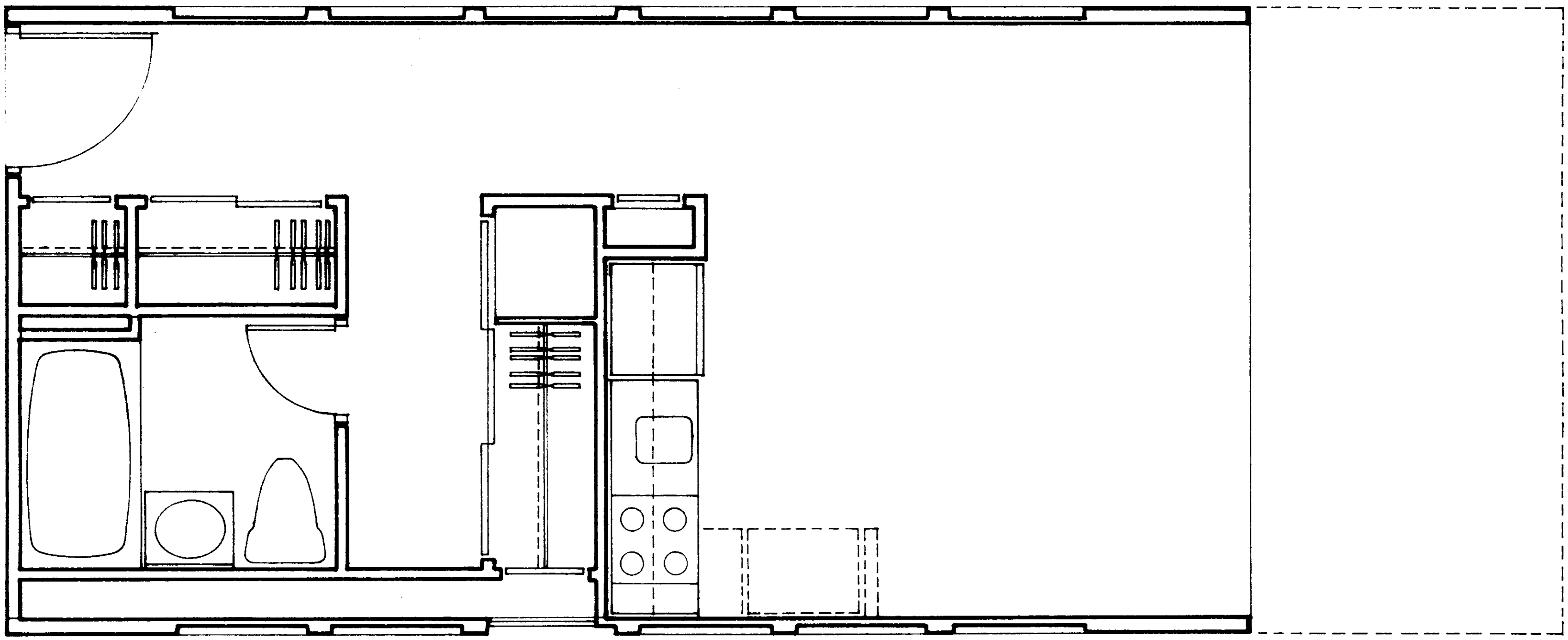

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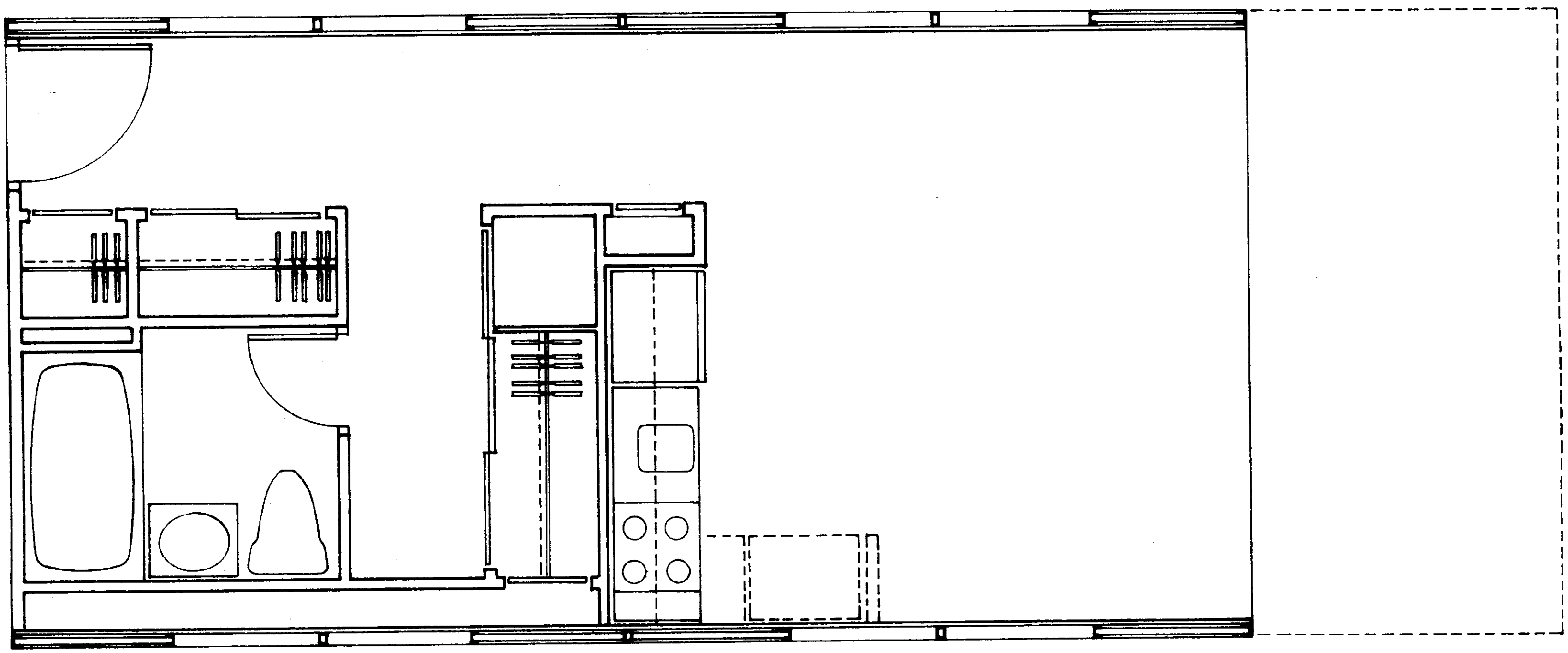

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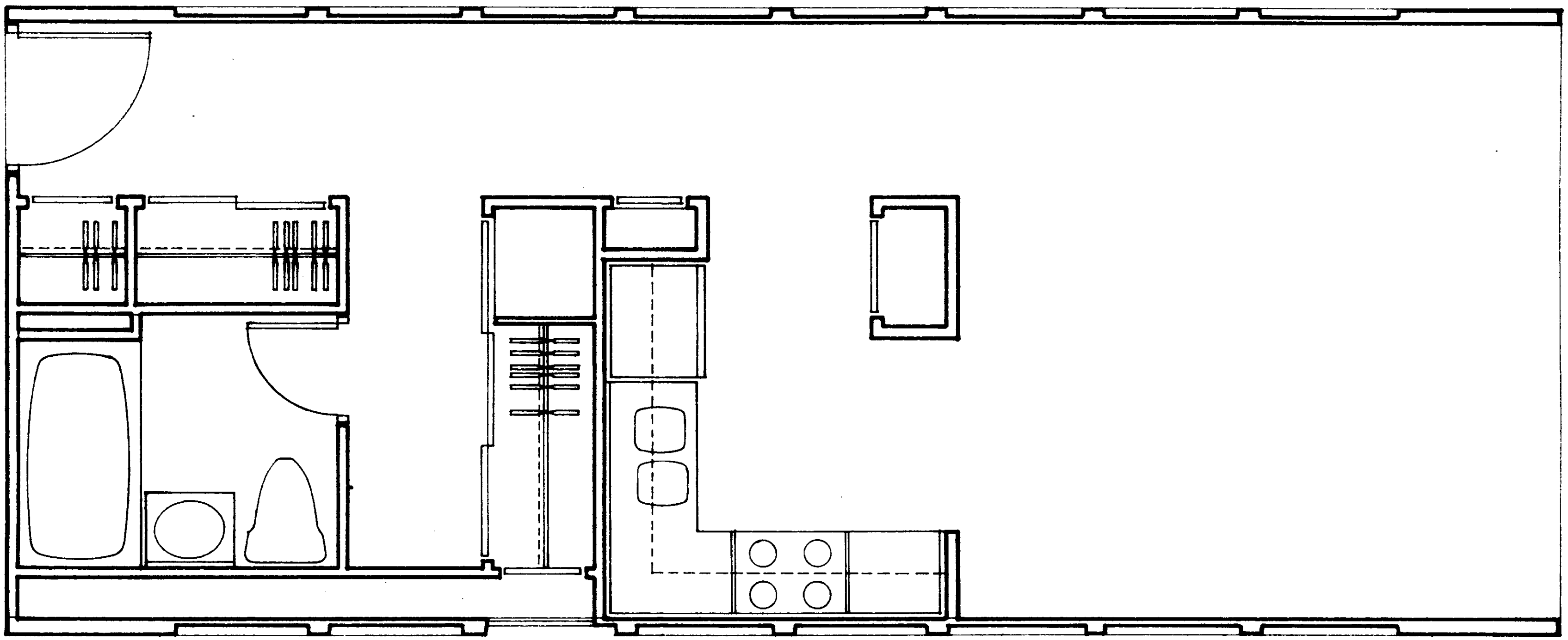

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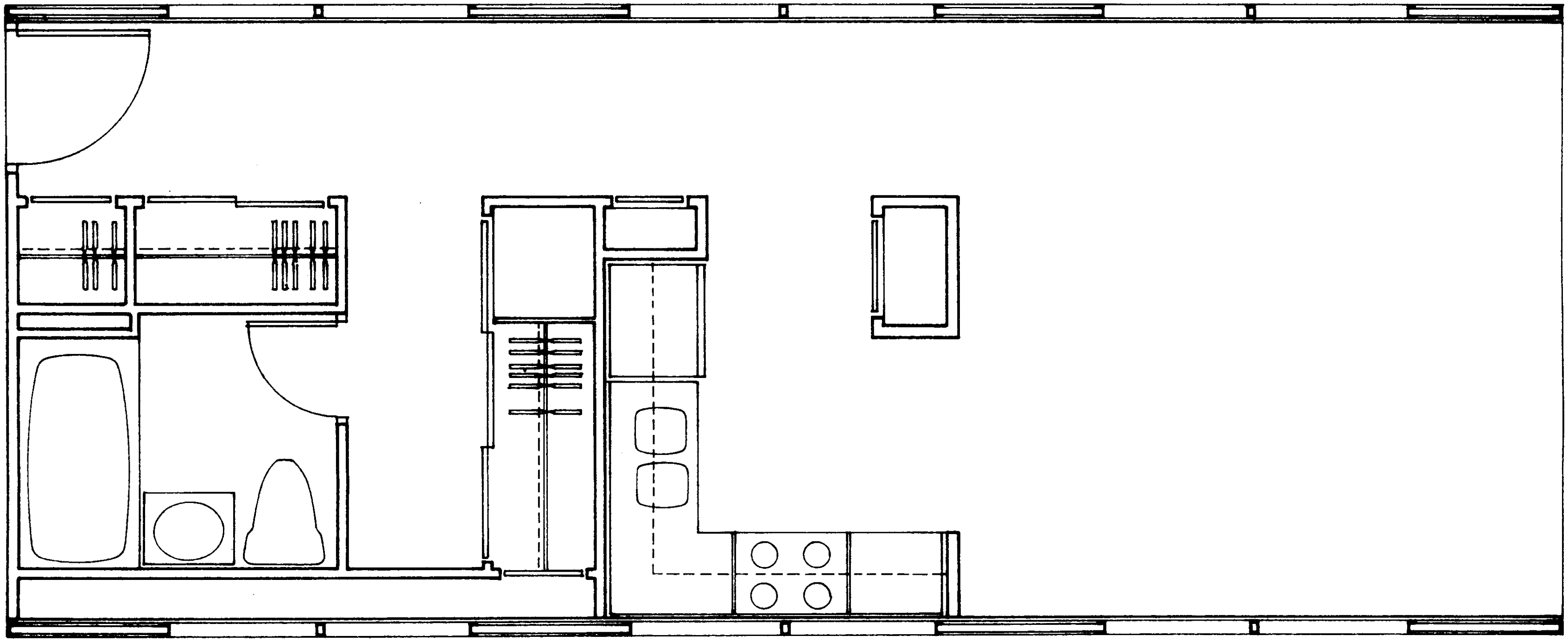

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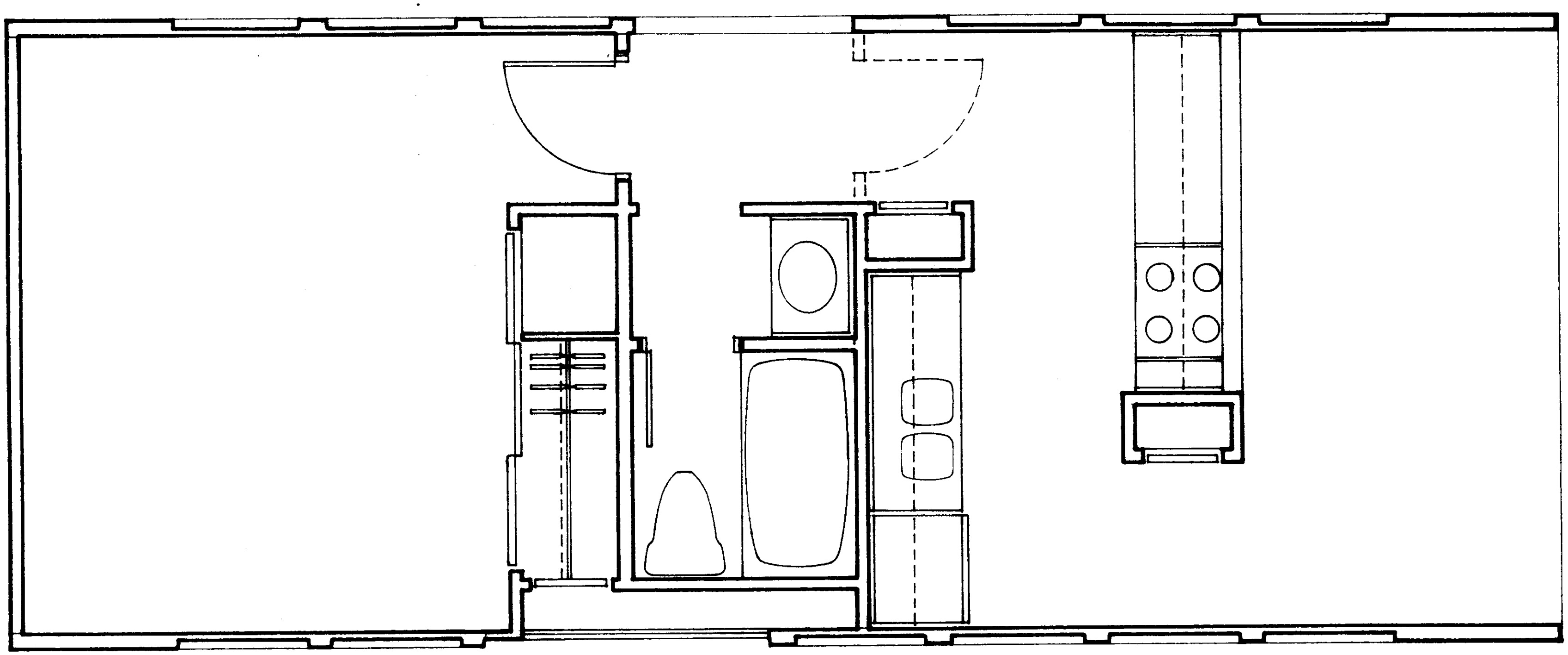

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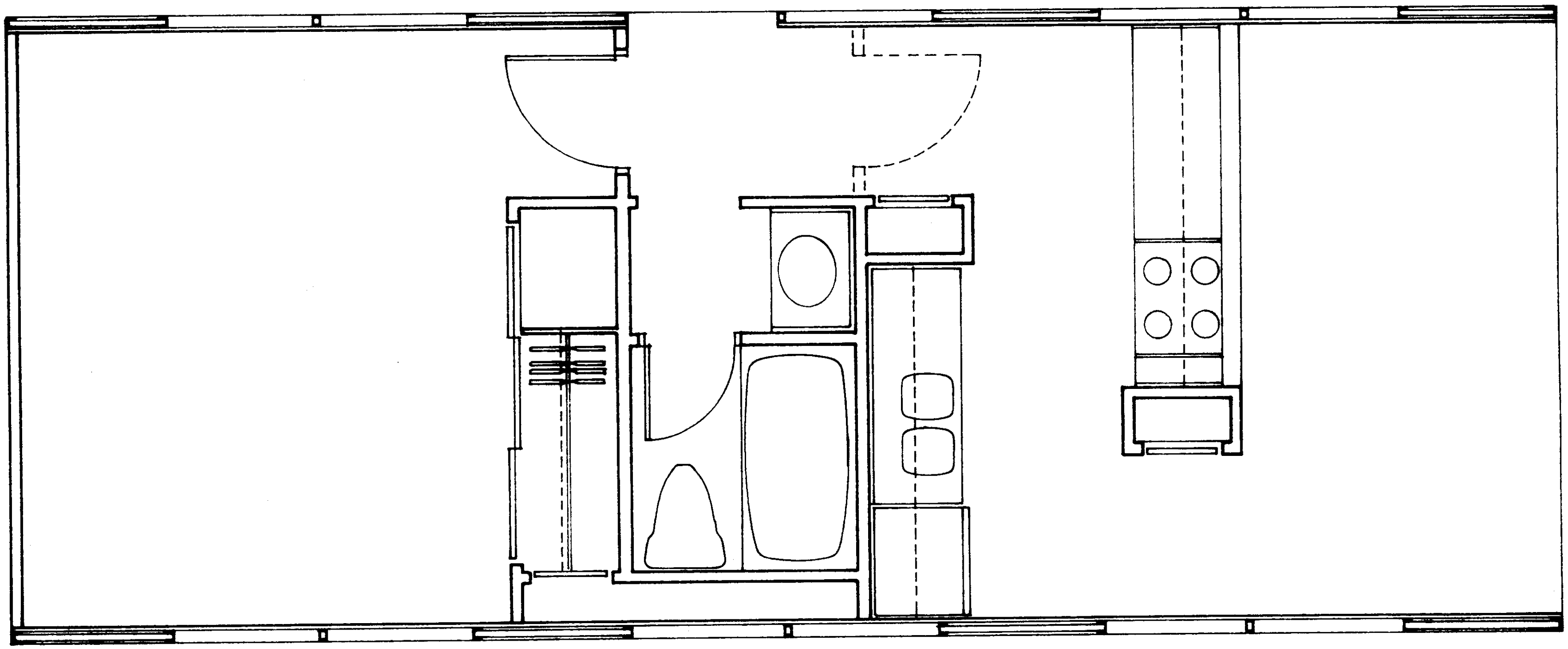

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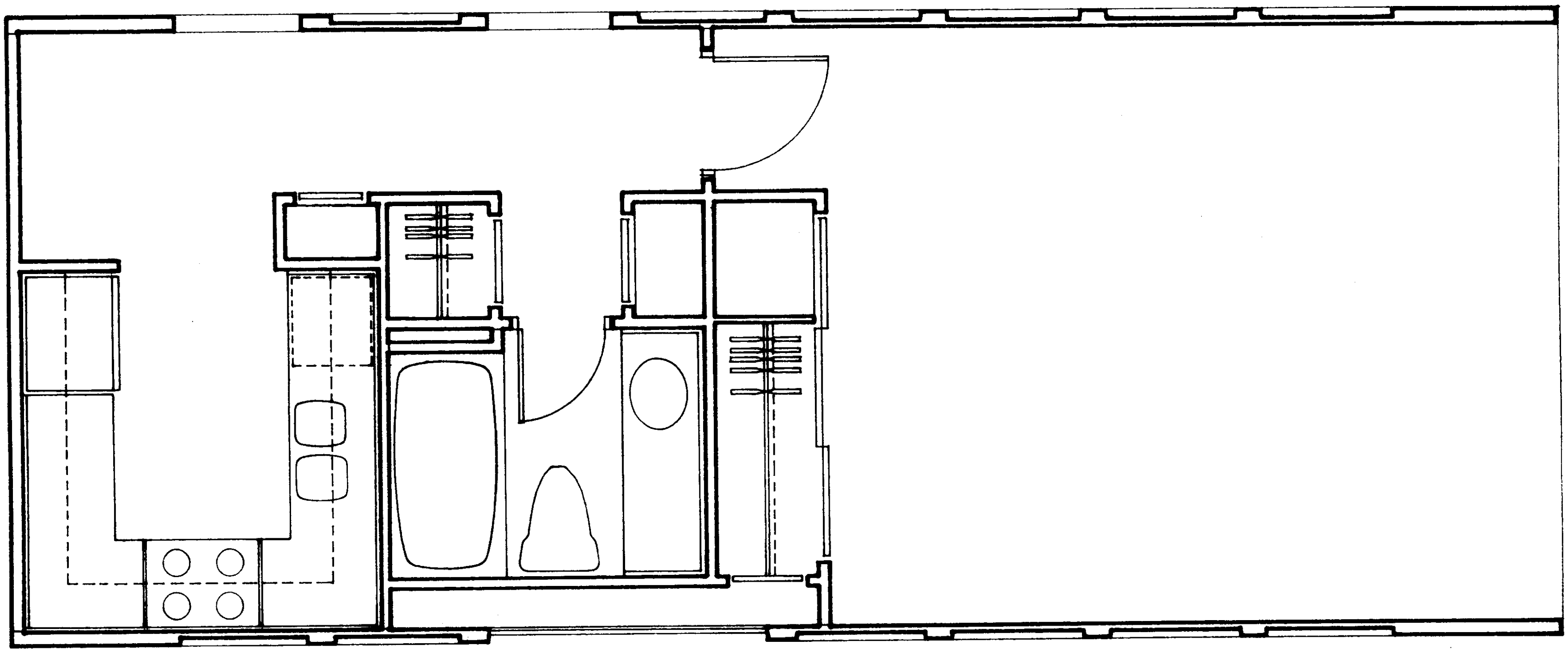

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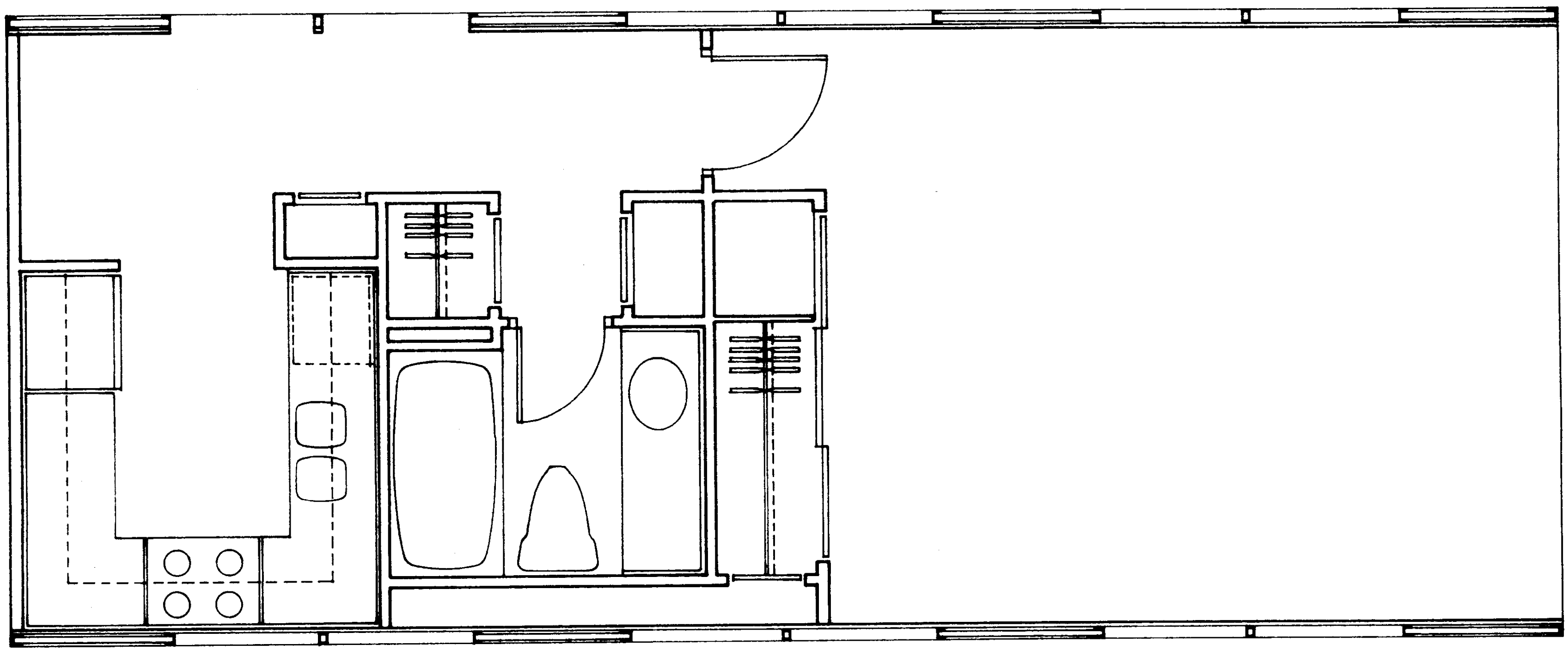

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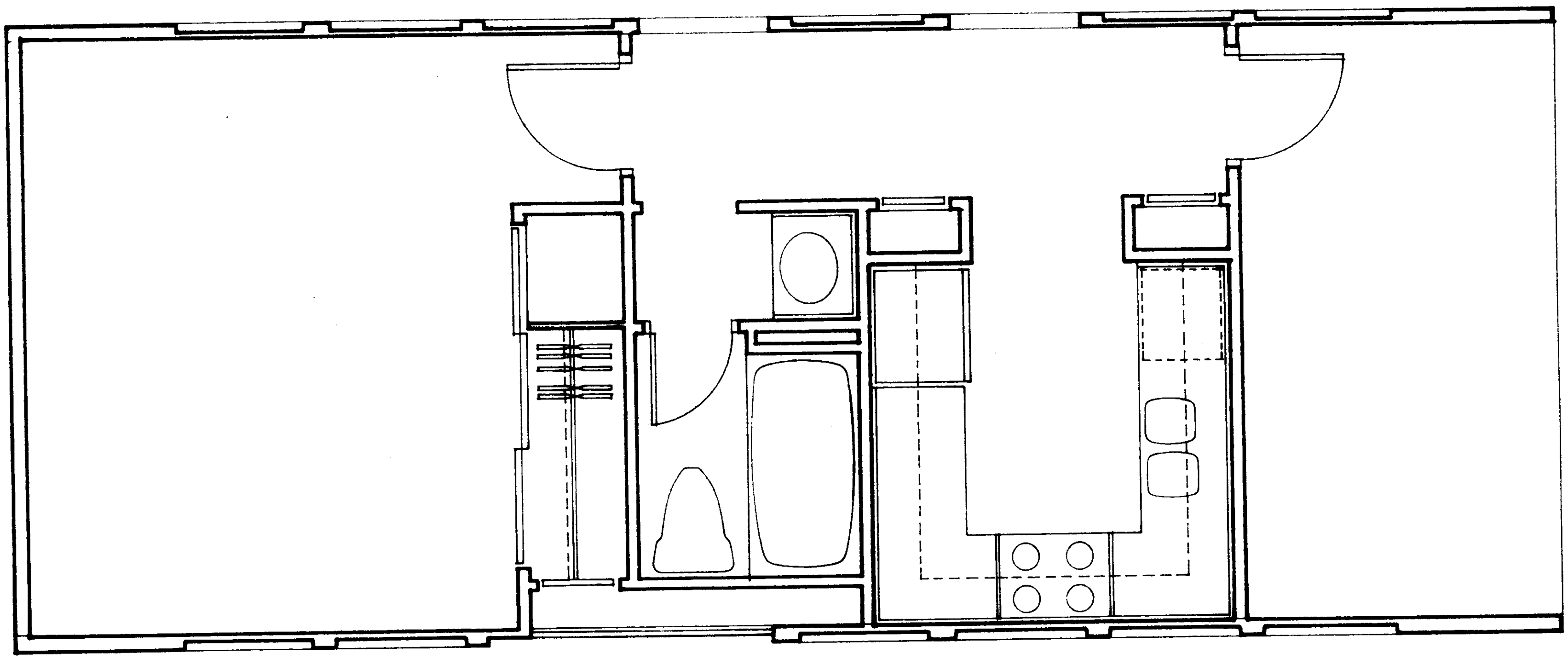

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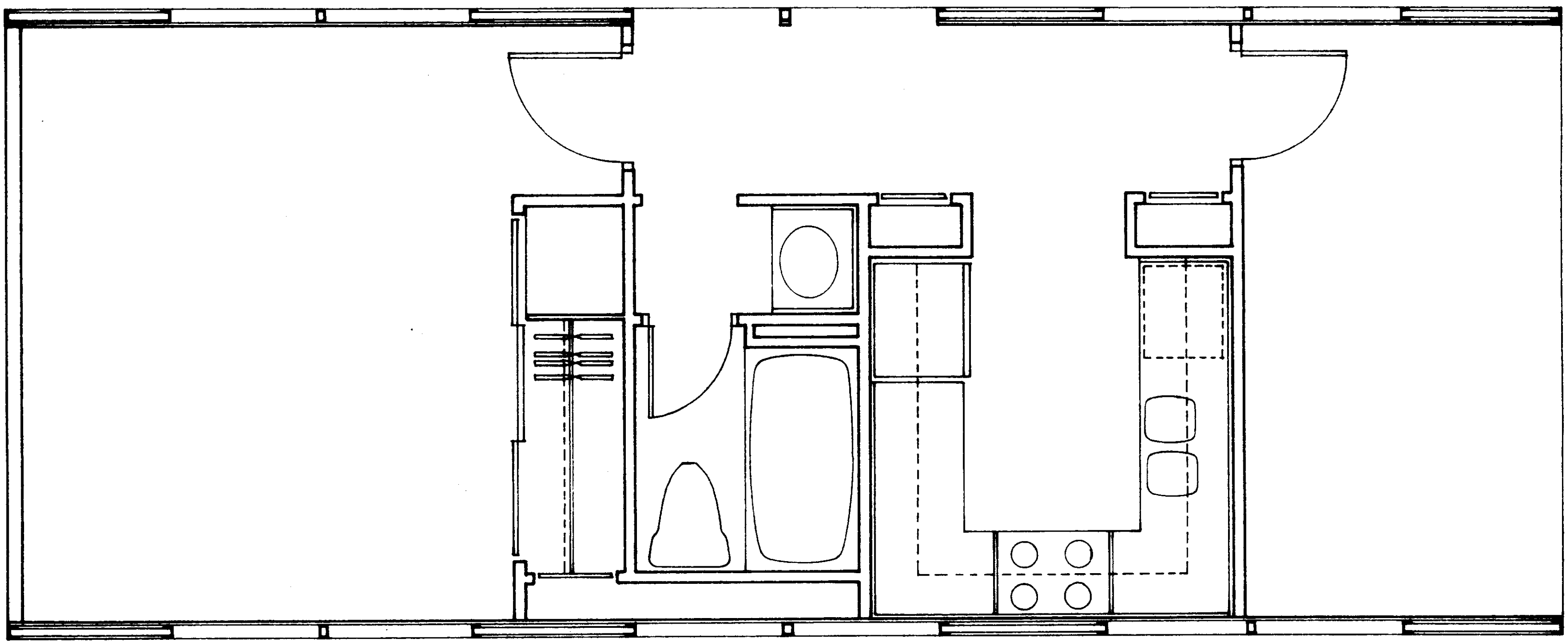

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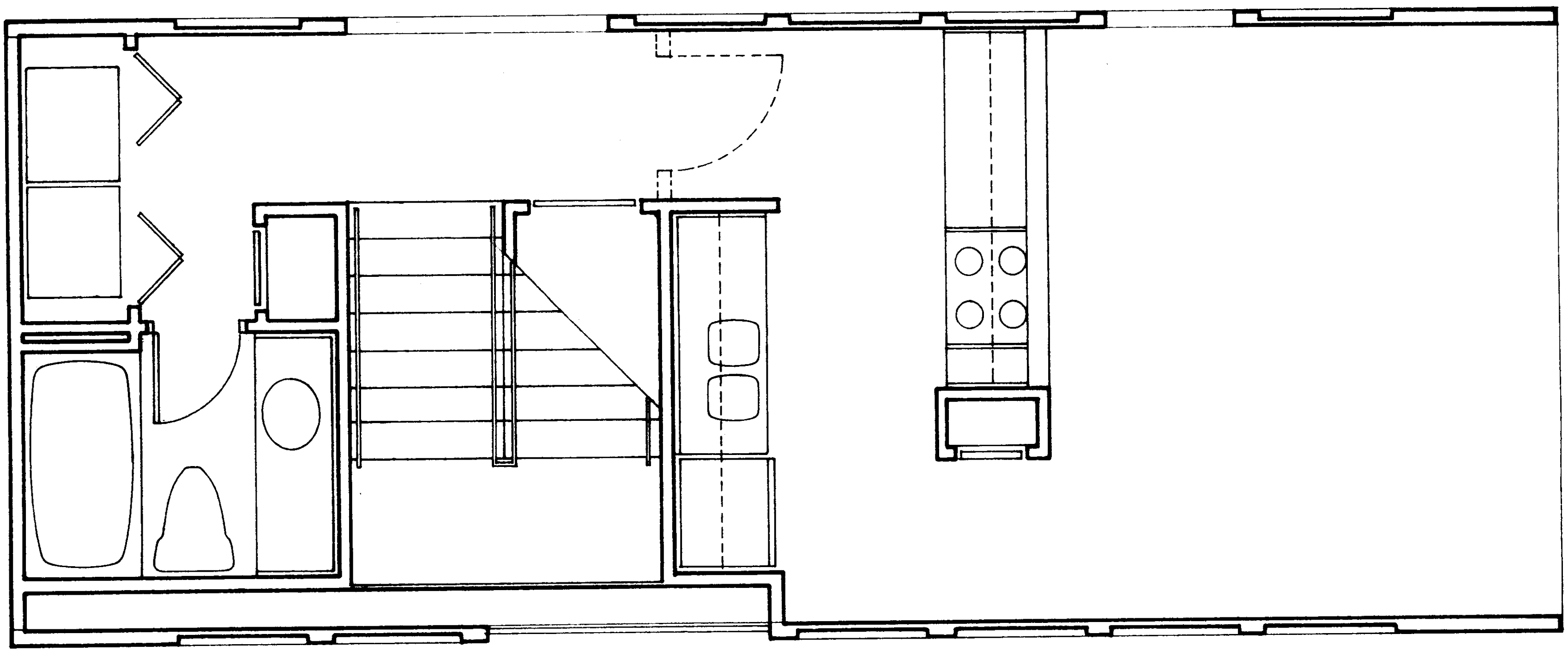

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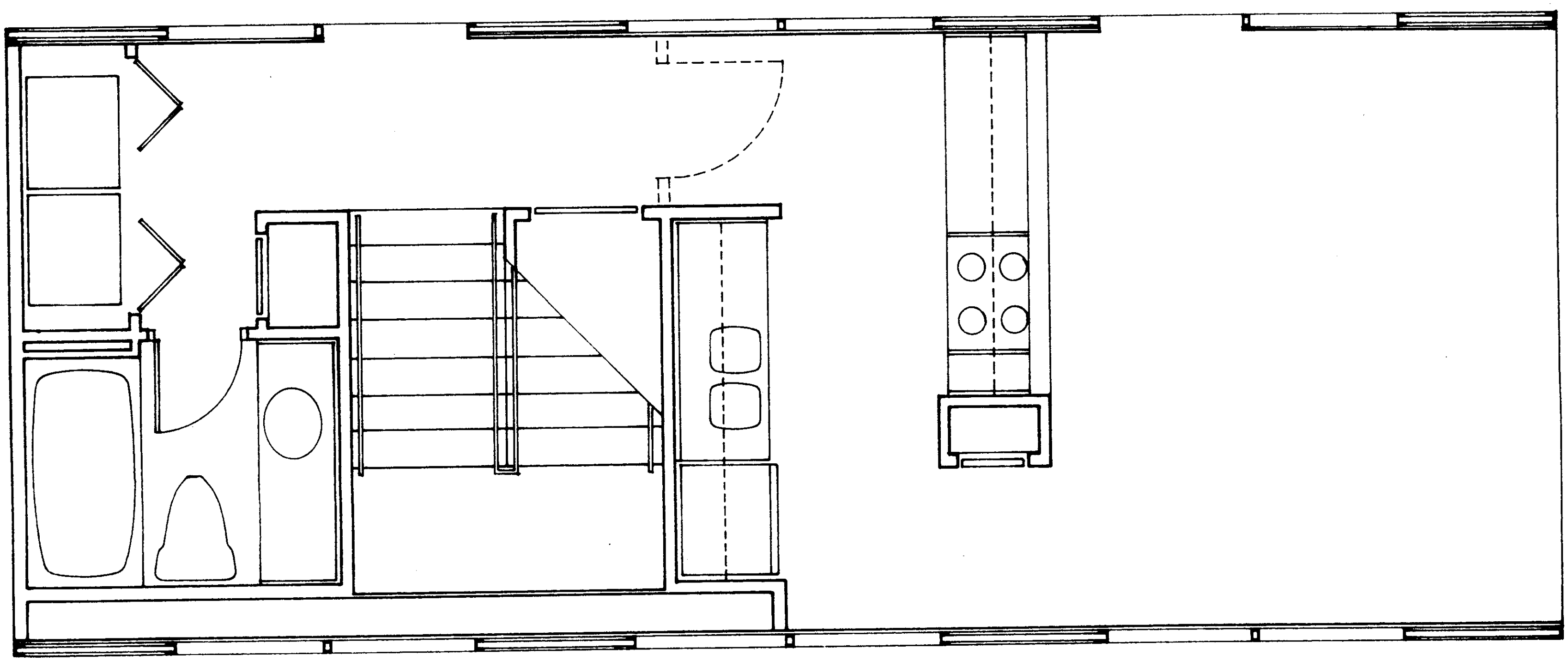

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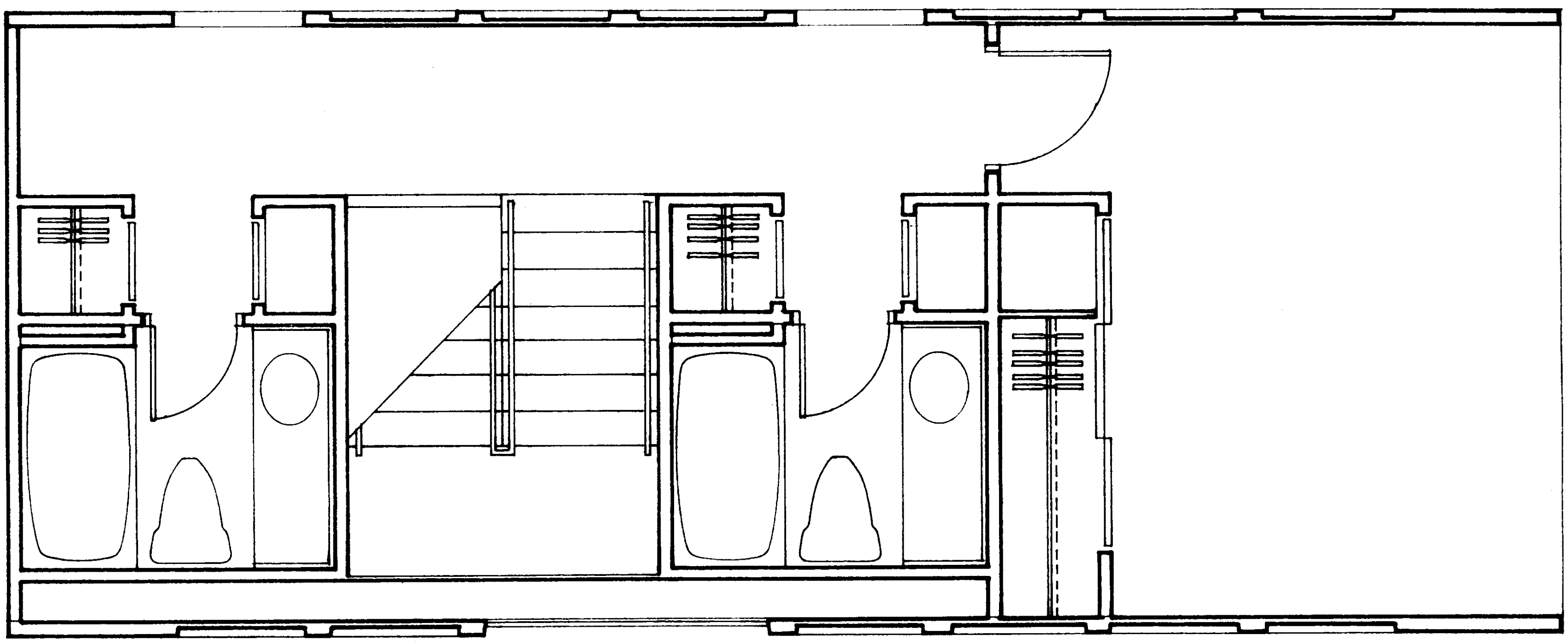

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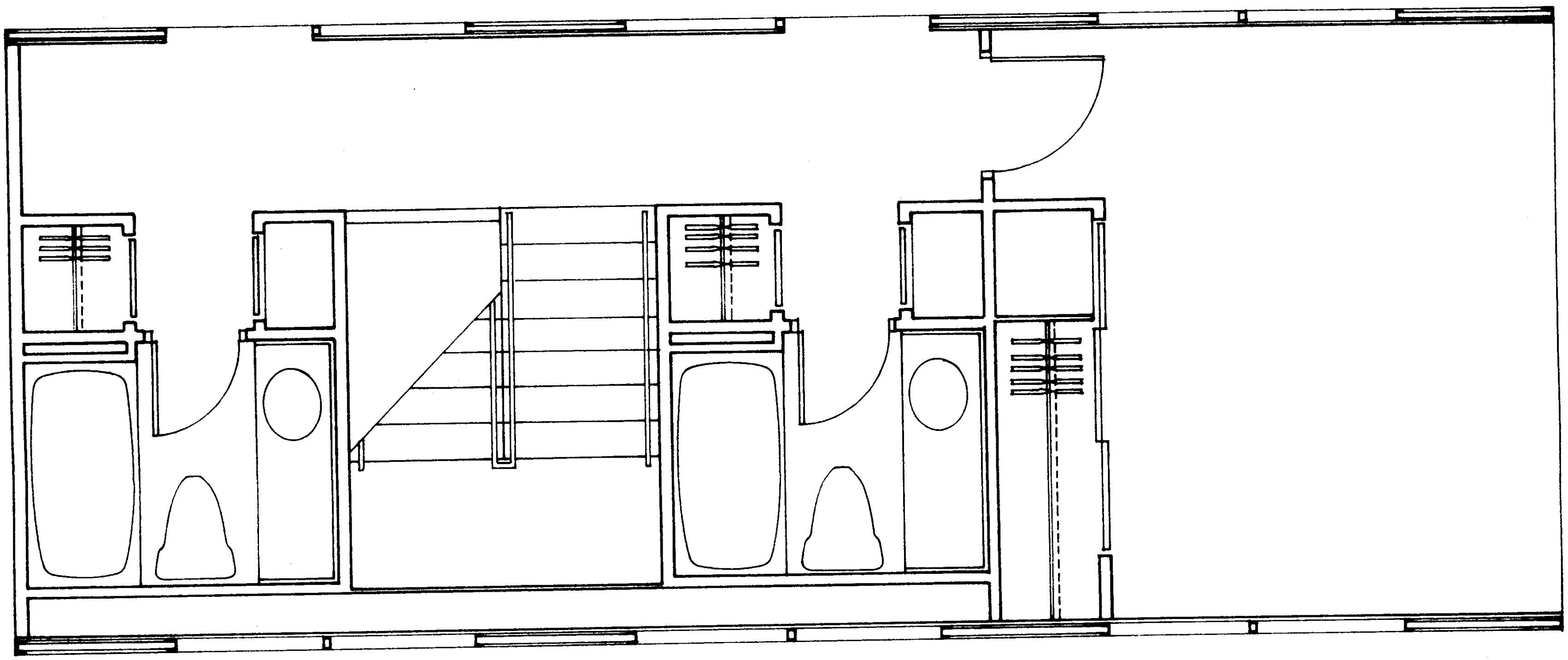

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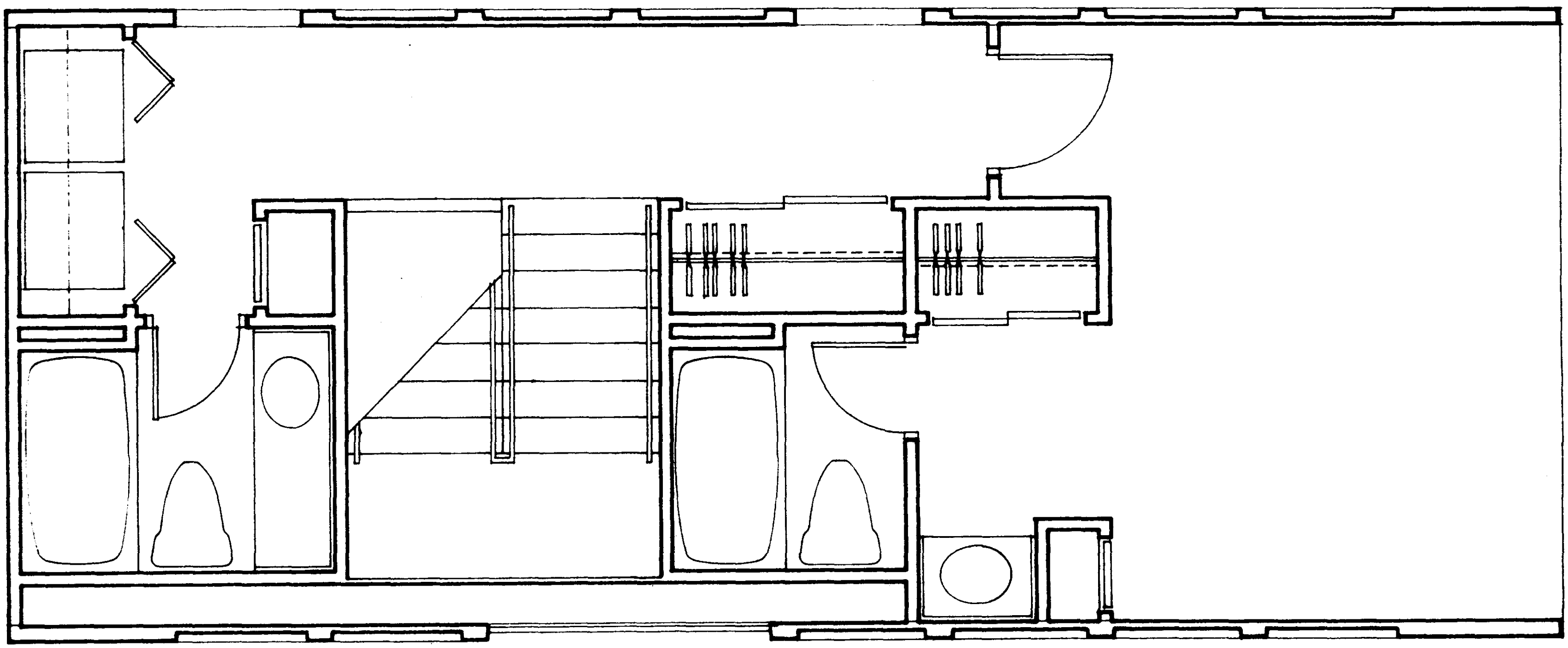

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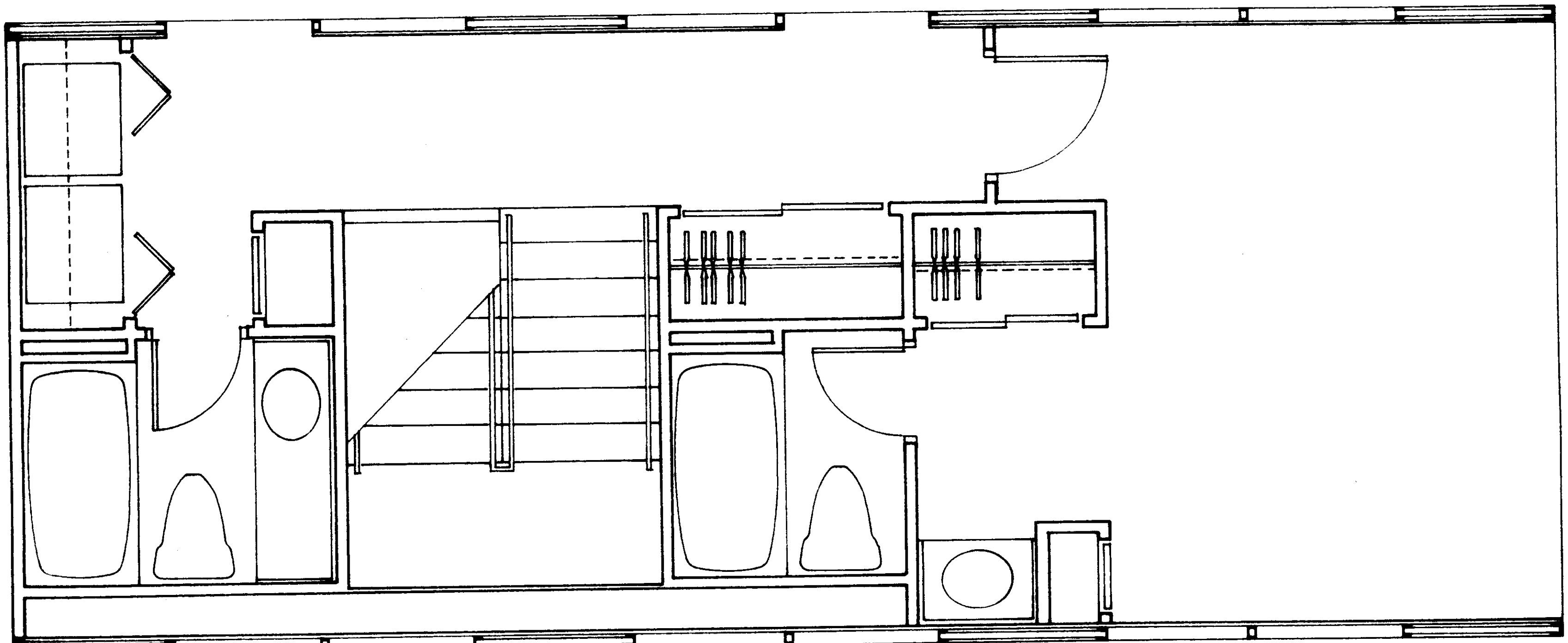

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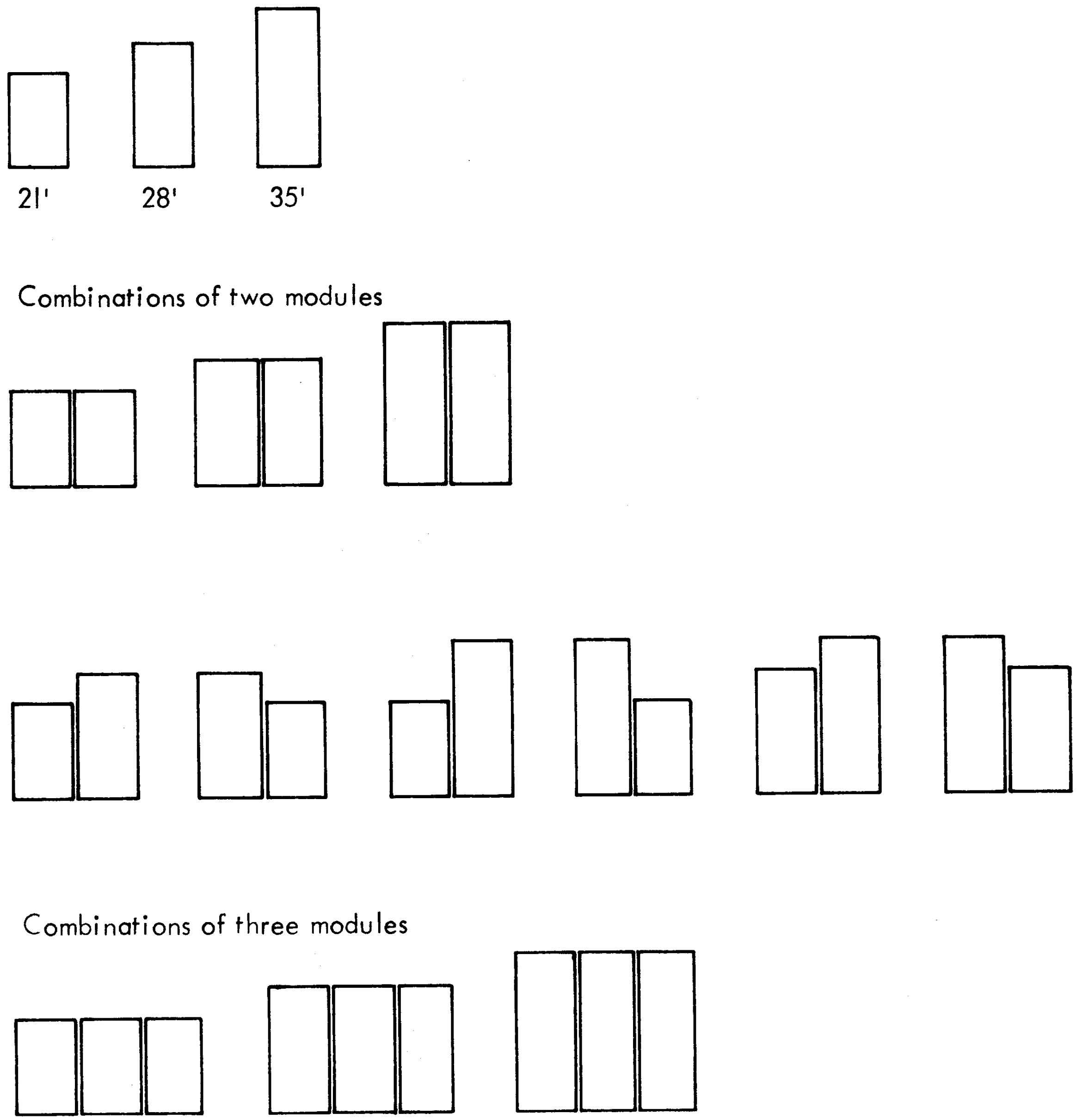

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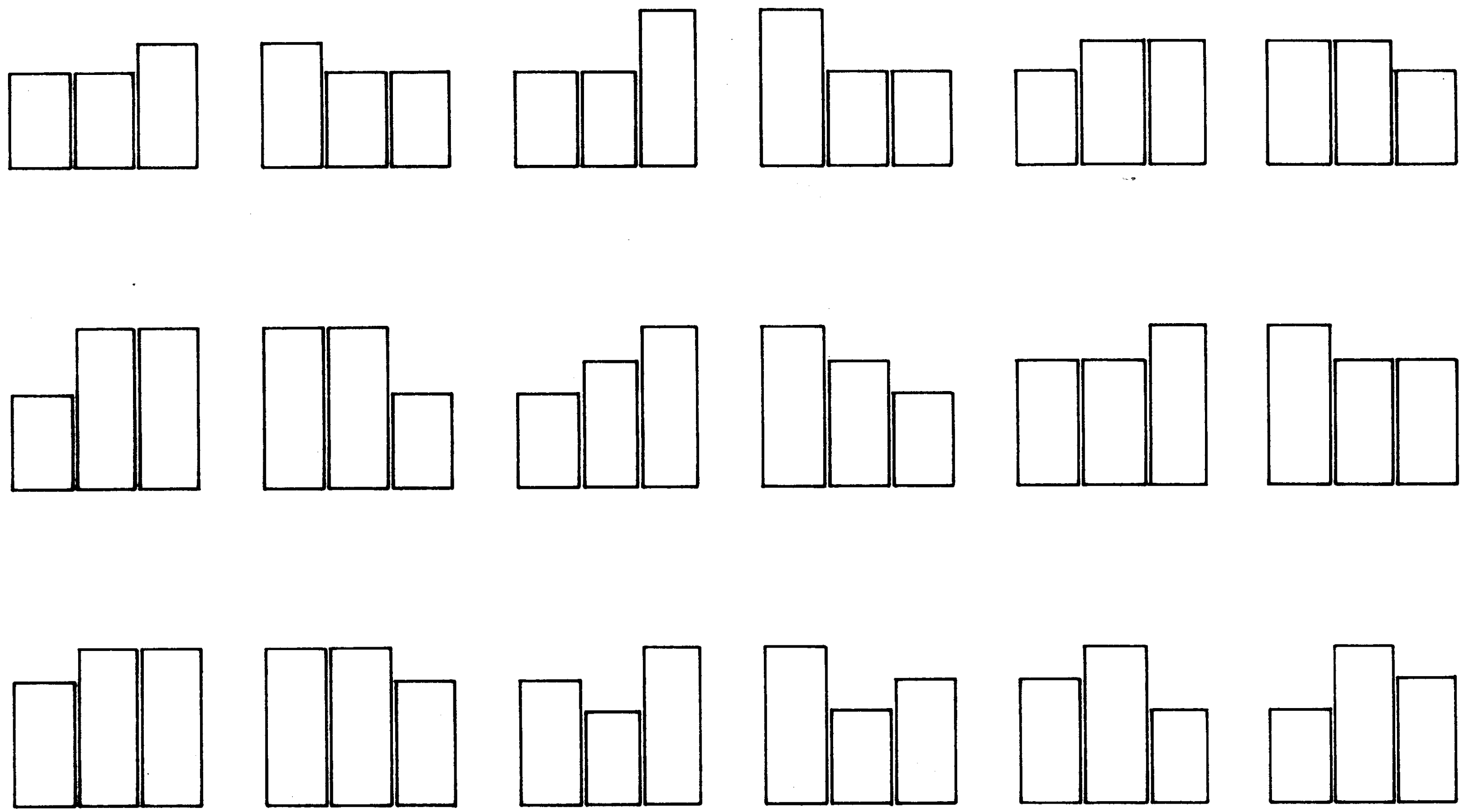

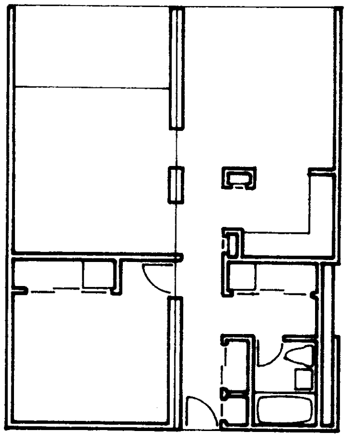

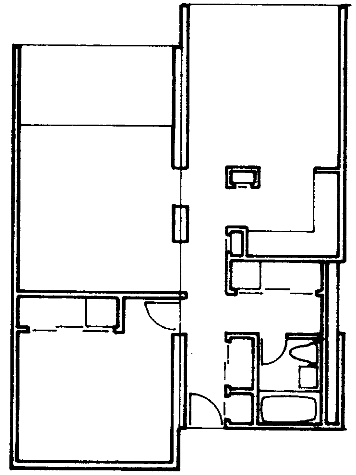

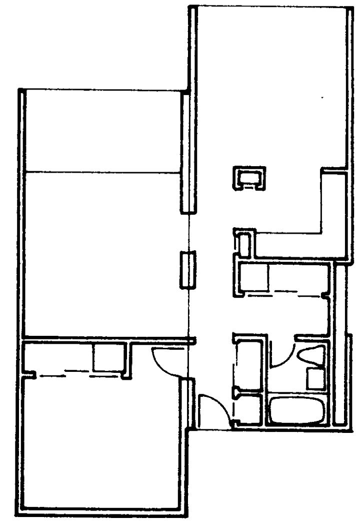

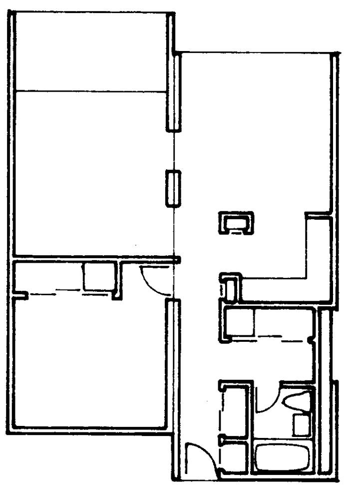

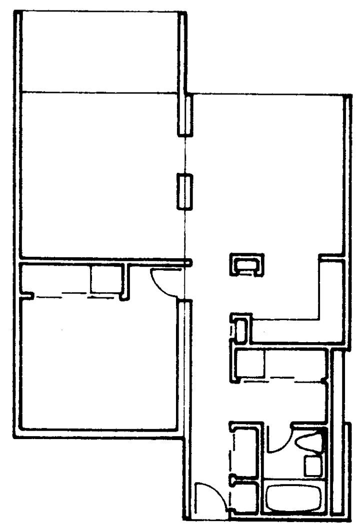

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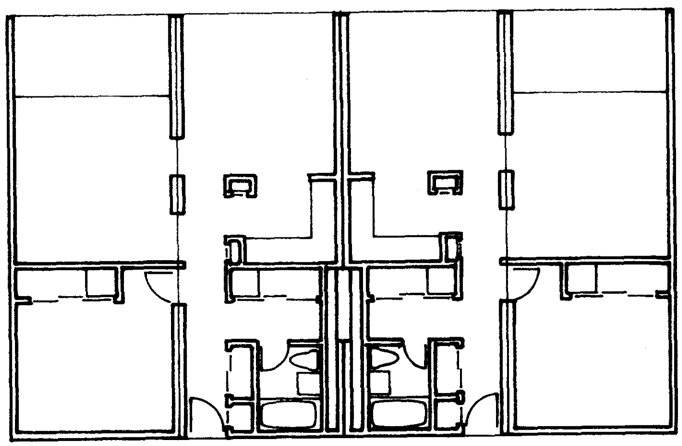

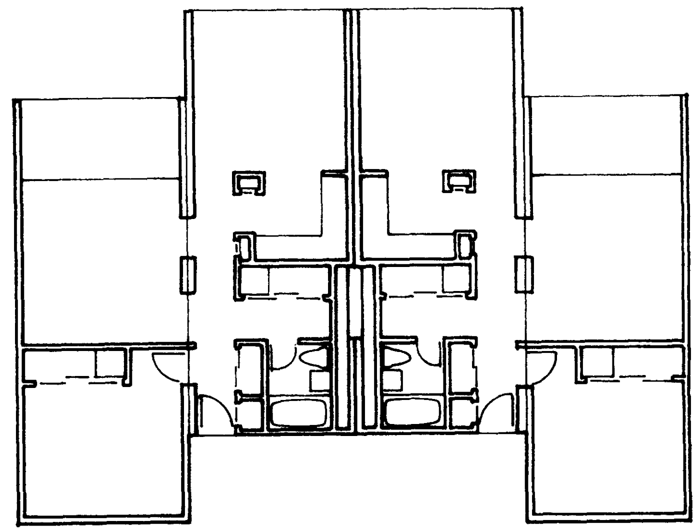

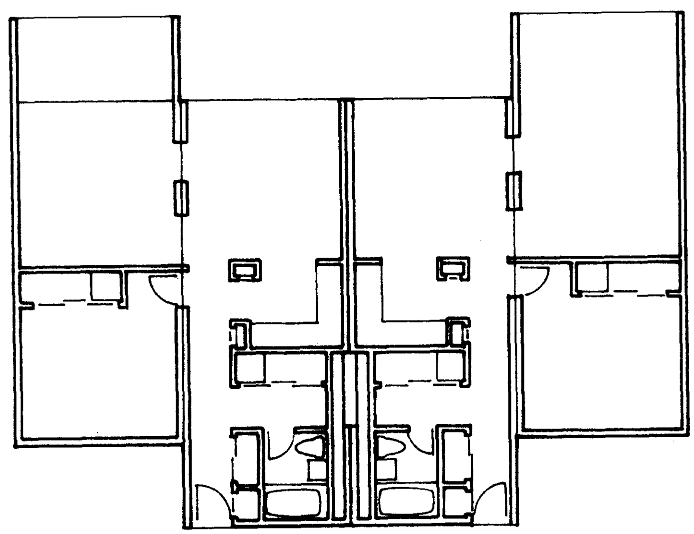

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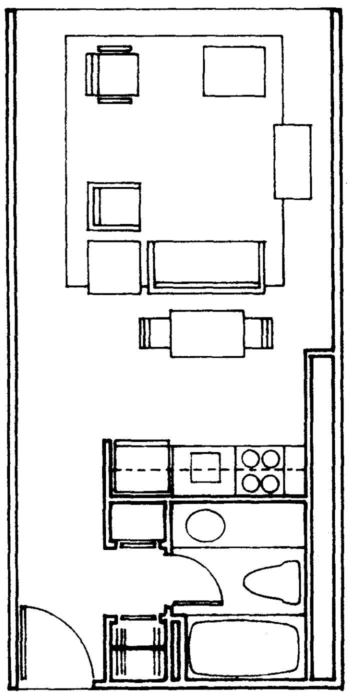
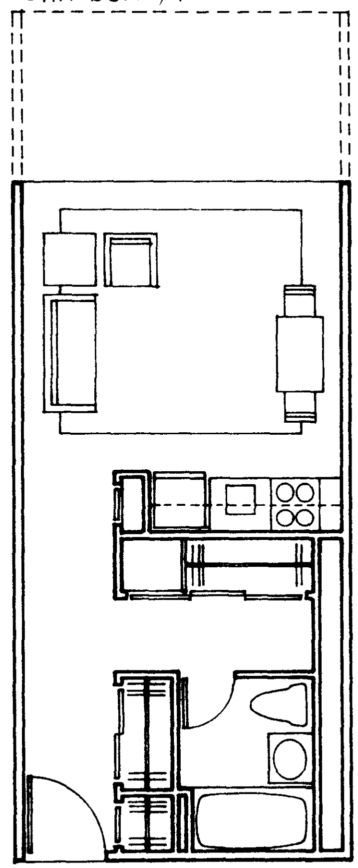
Unit bKL



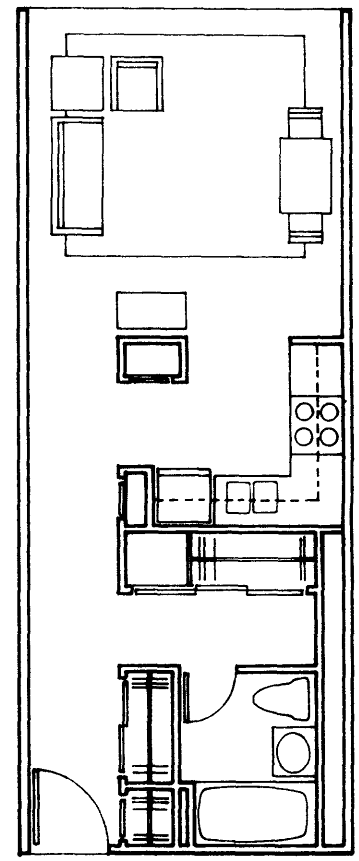
Type Al-Efficiency

Unit bcKL/1



Type A2-Efficiency

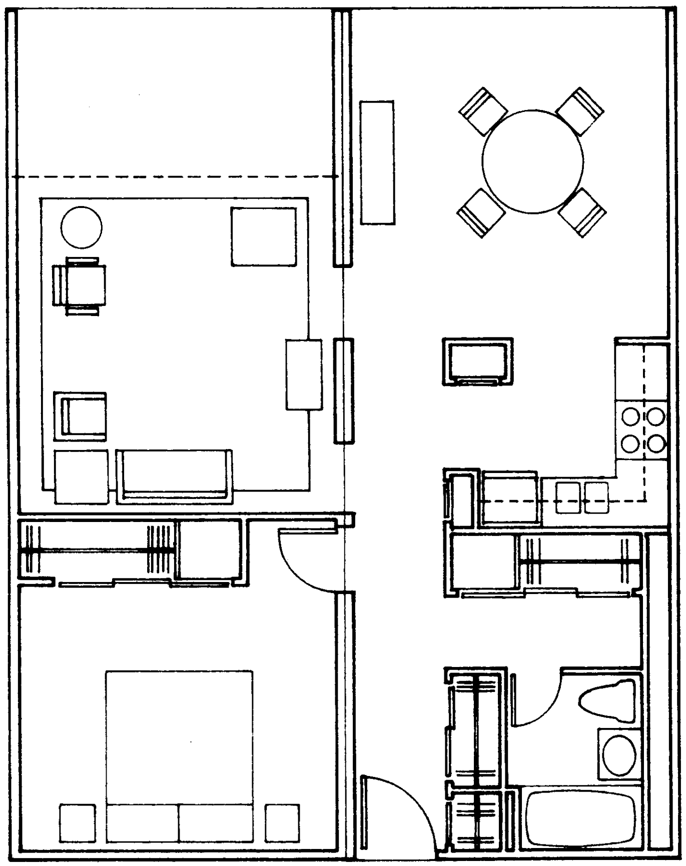
Unit bcKL/2



Type A3-Efficiency

APARTMENT PLANS

Unit bcKL/2



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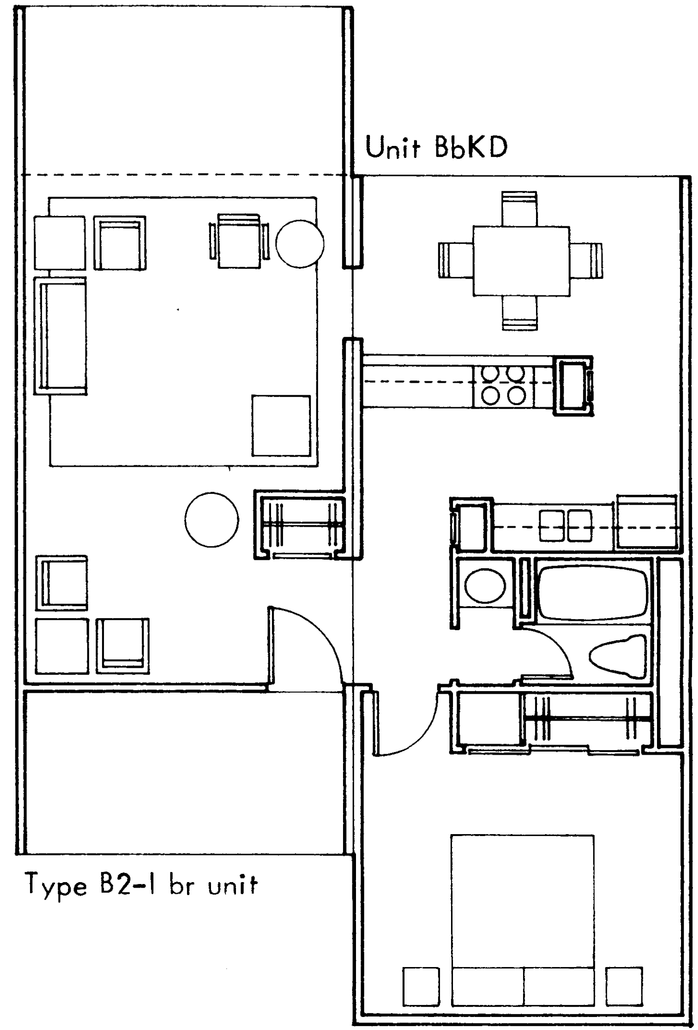
Unit BbKD



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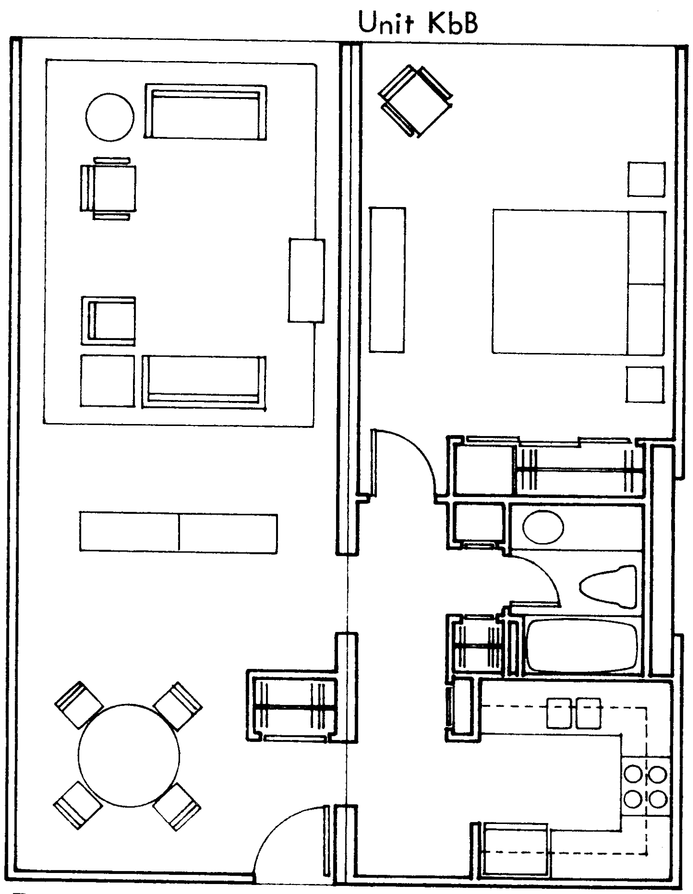

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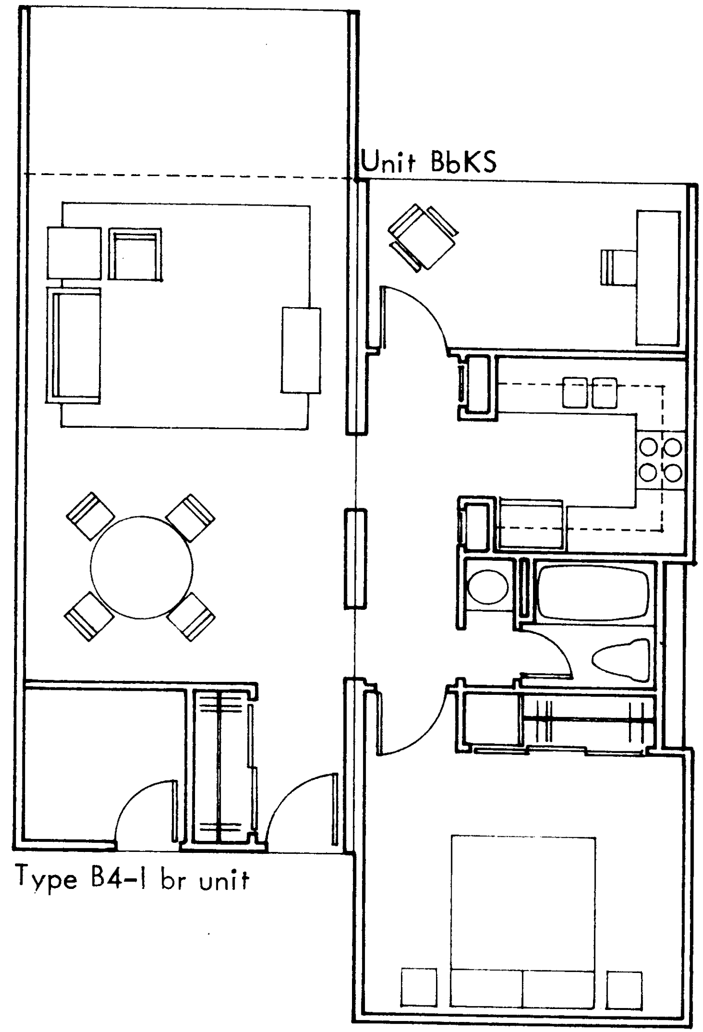
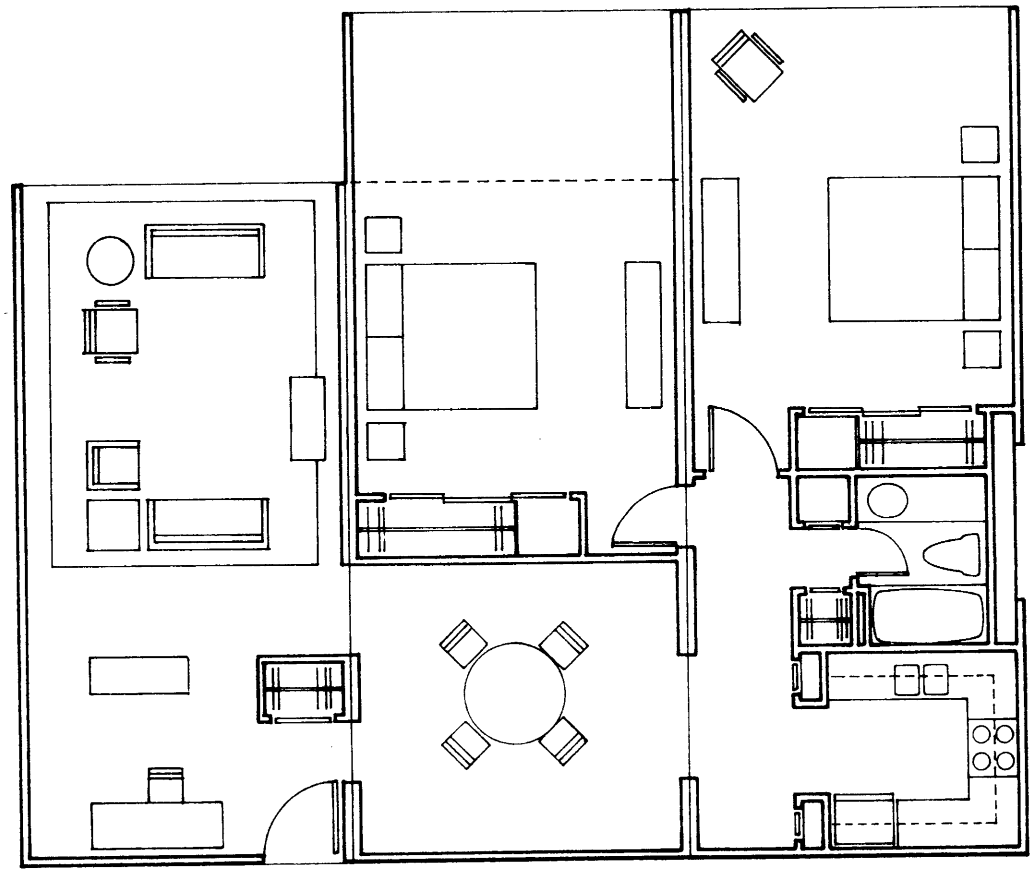
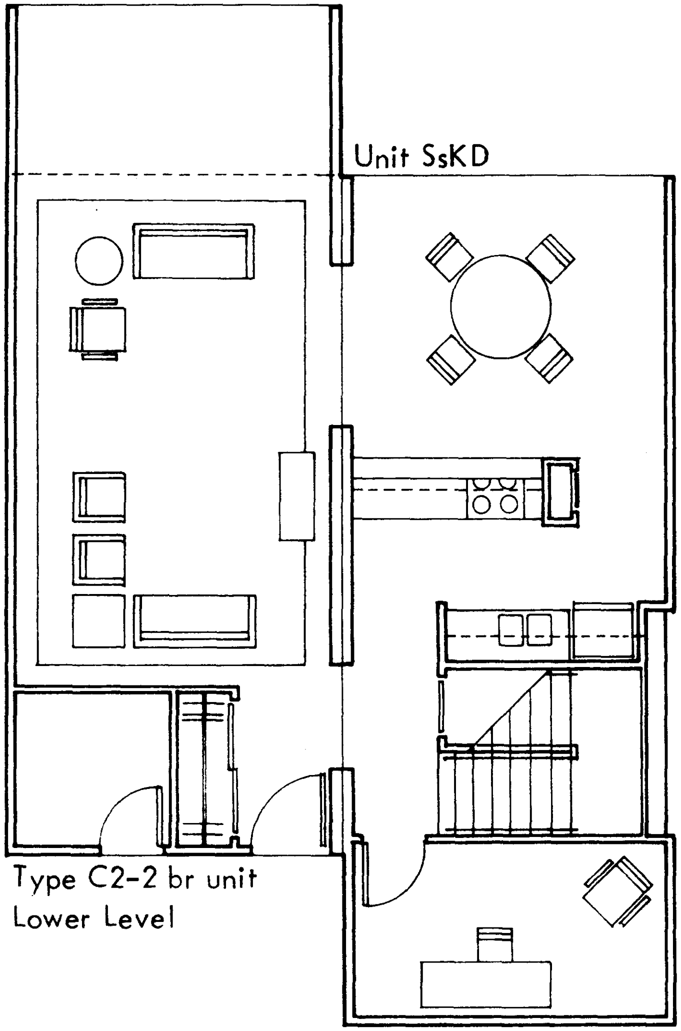


Type B4-1 br unit

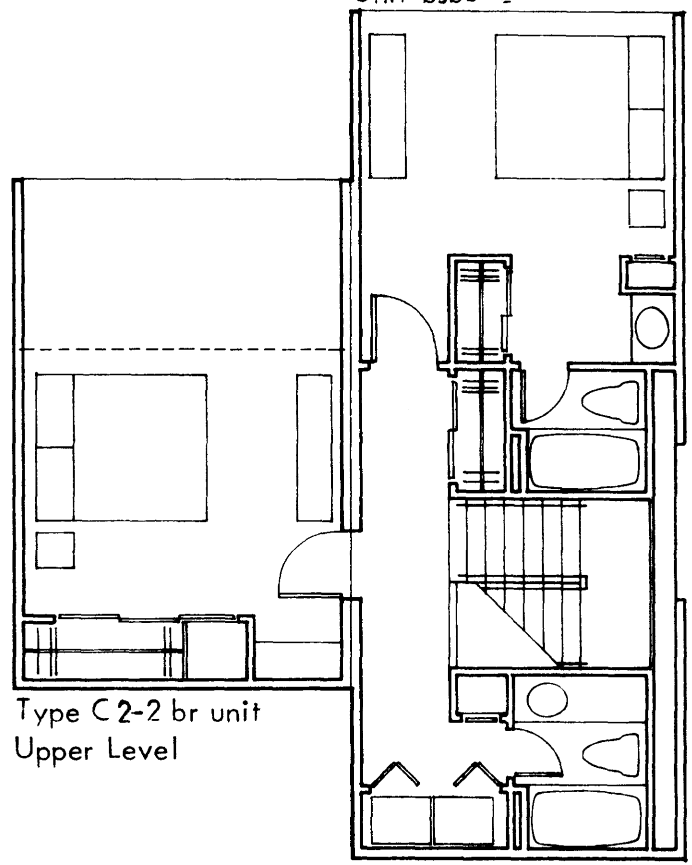
Unit KbB



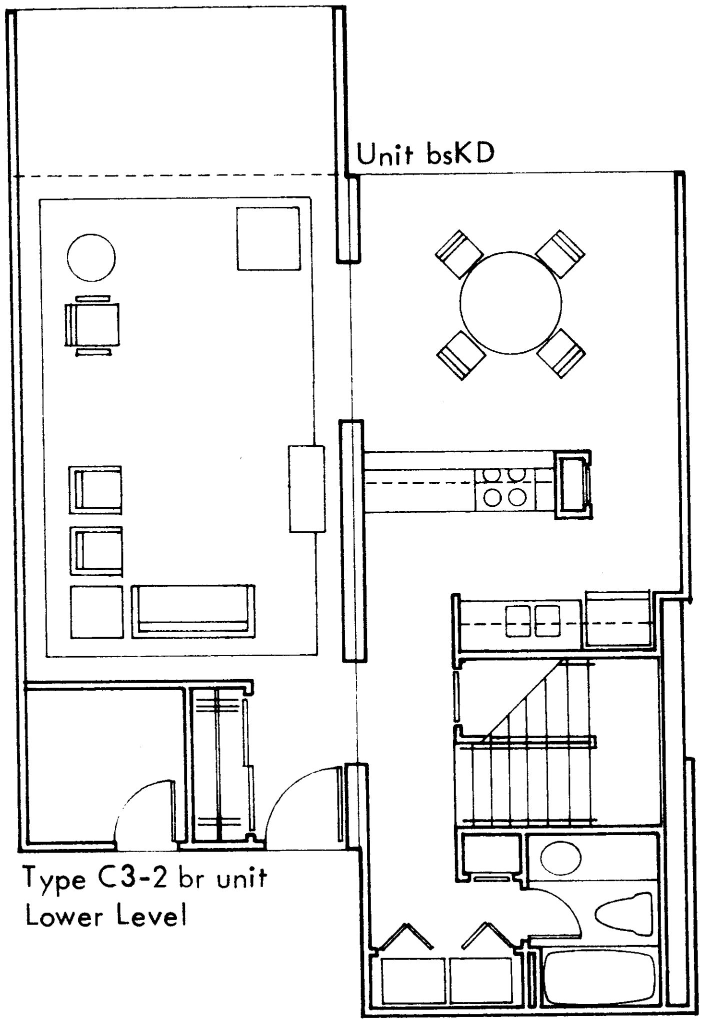
Type C1-2 br unit



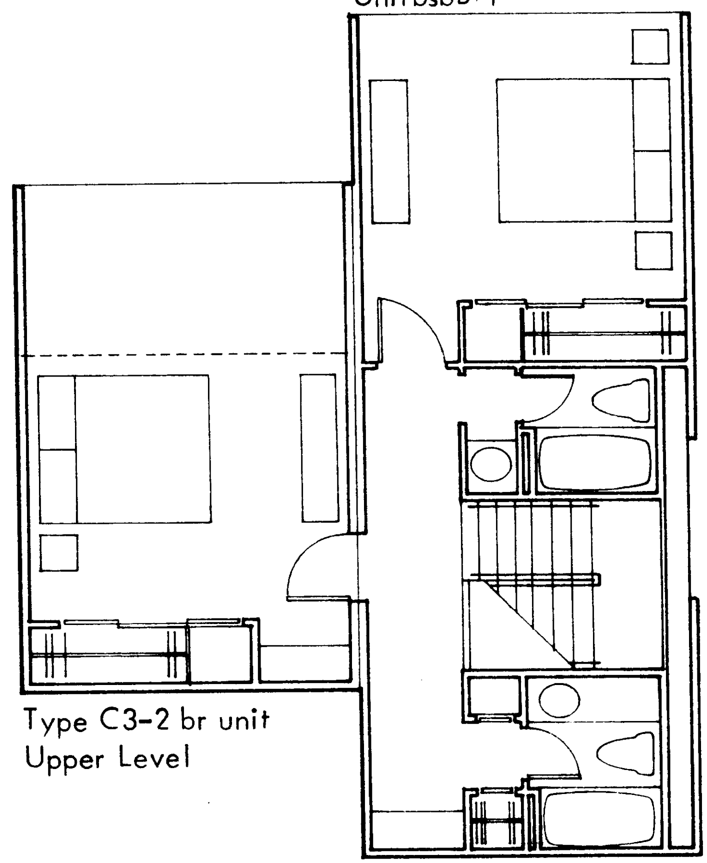
Type C2-2 br unit
Lower Level



Type C 2-2 br unit
Upper Level

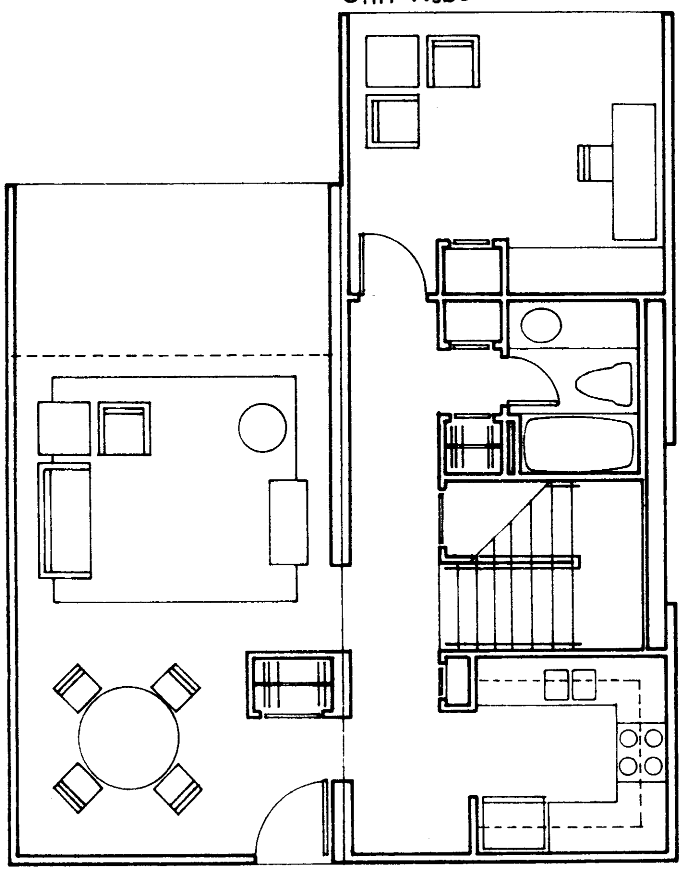


Type C3-2 br unit
Lower Level



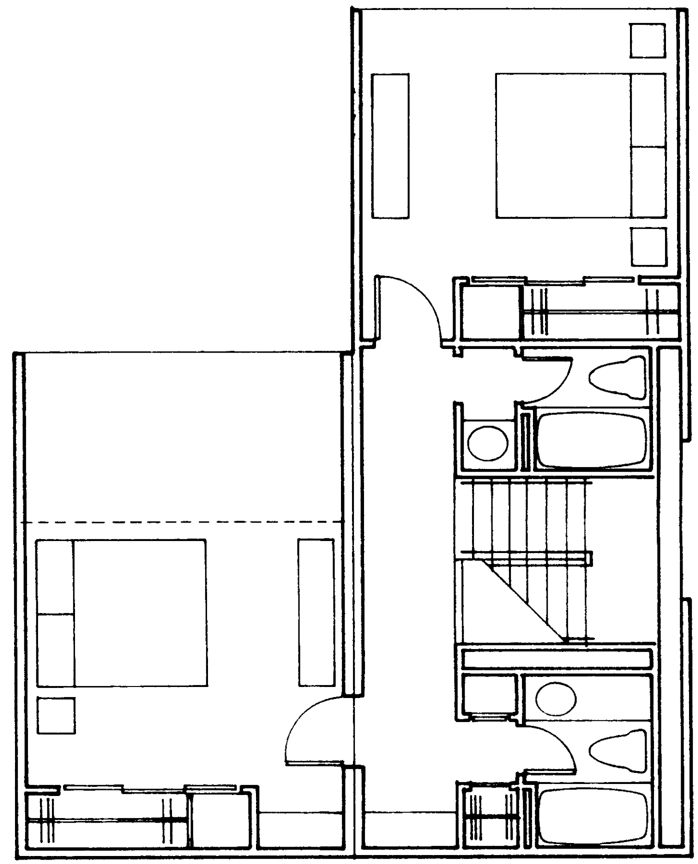
Type C3-2 br unit
Upper Level

Unit KsbS

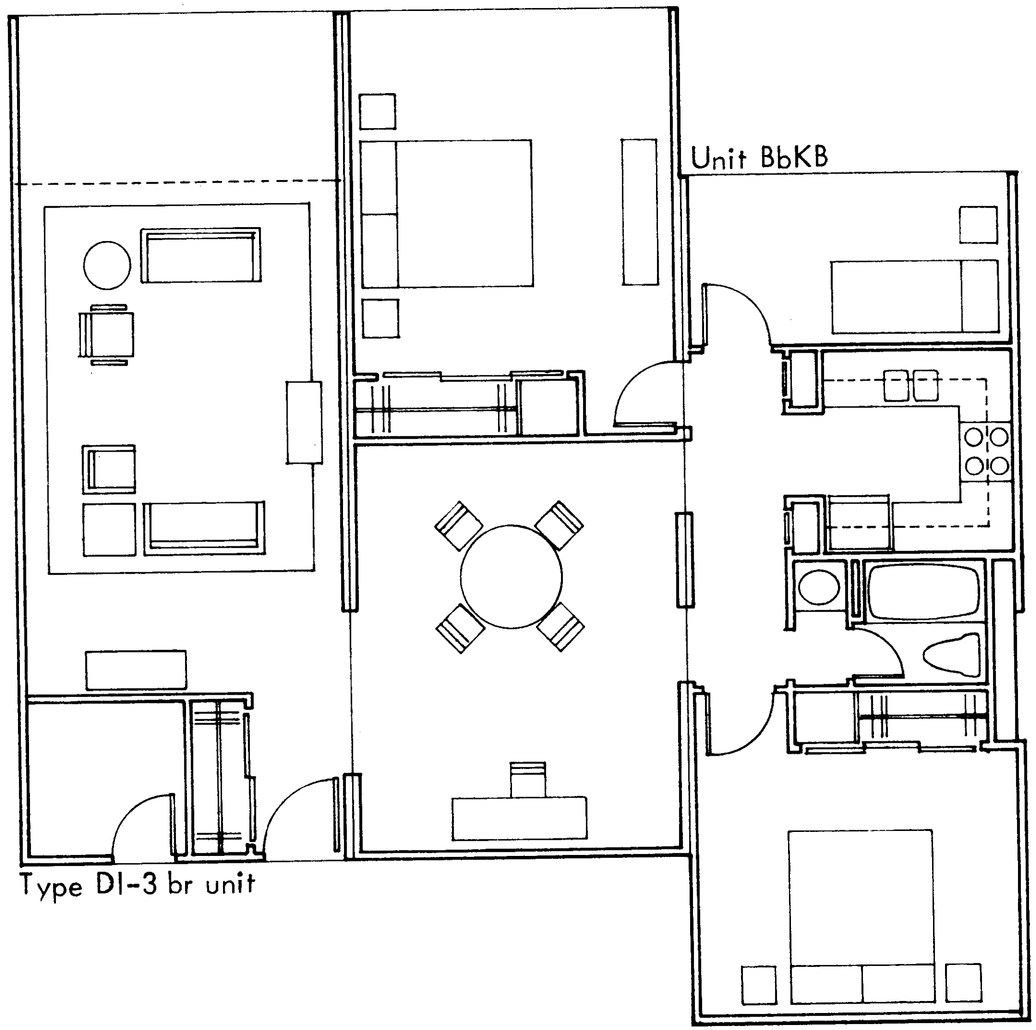


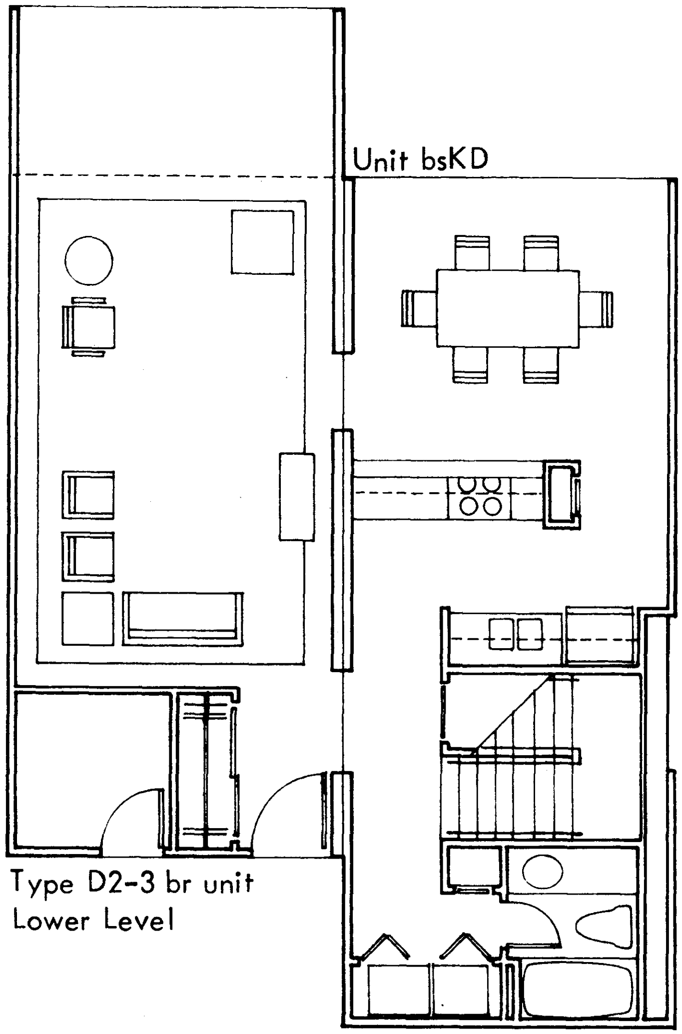
Type C4-2 br unit
Lower Level

UnitbsbB/I

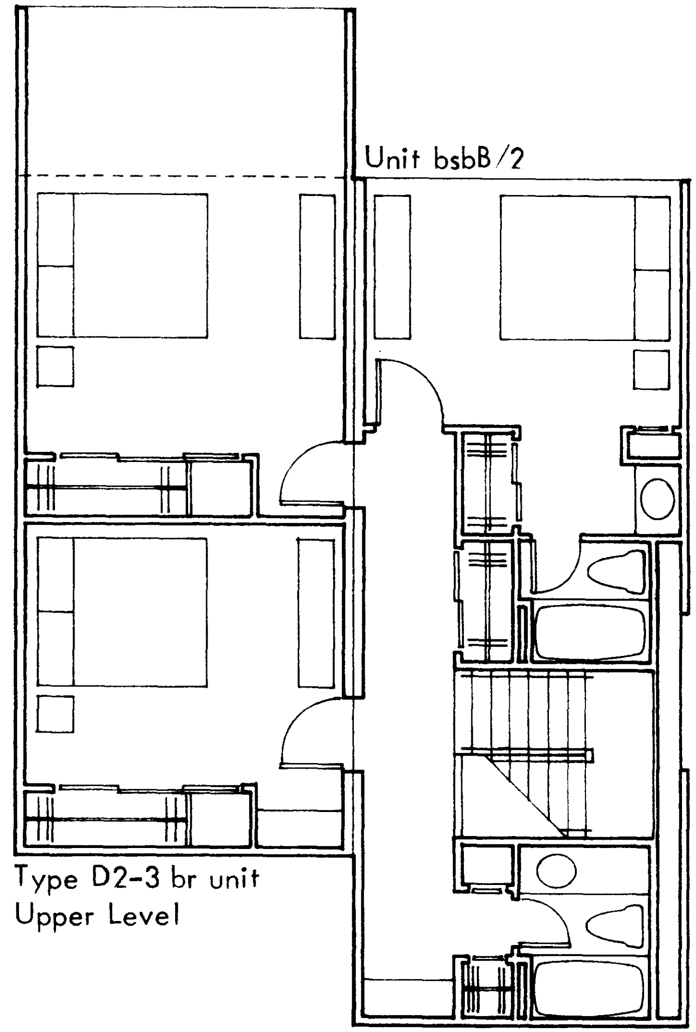


Type C4-2 br unit
Upper Level


Unit BbKB
Type D1-3 br unit

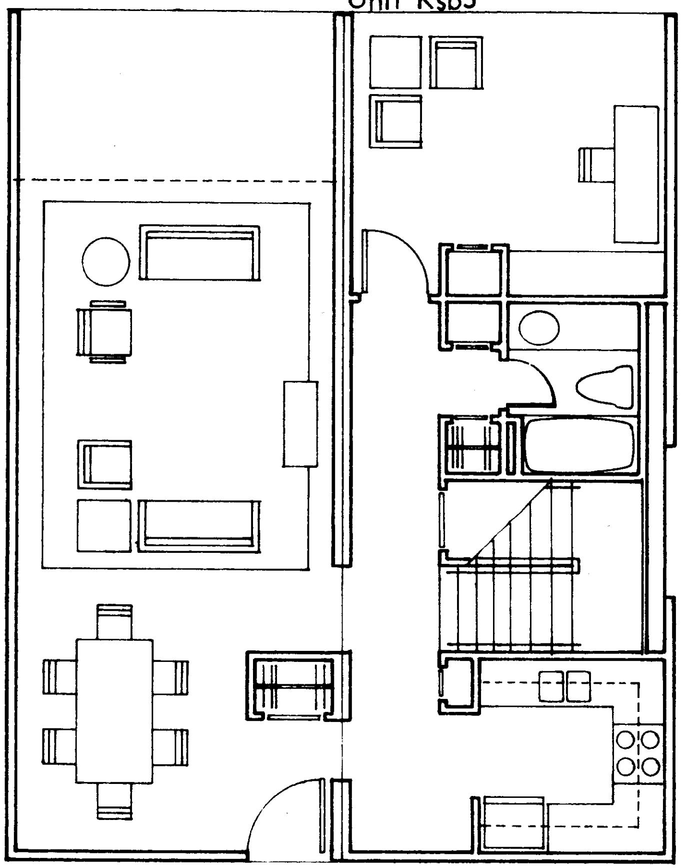


Type D2-3 br unit
Lower Level



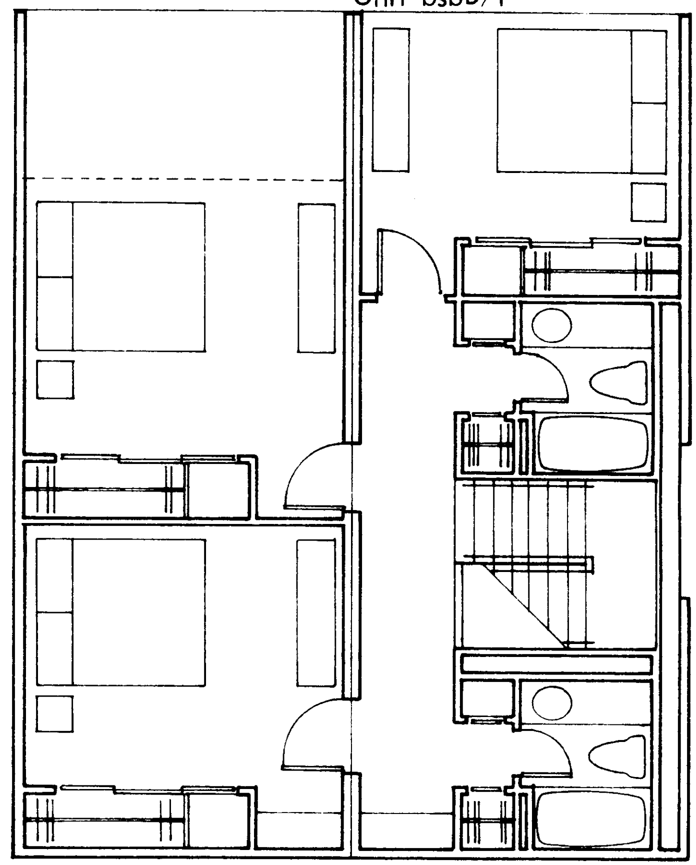
Type D2-3 br unit
Upper Level

Unit KsbS



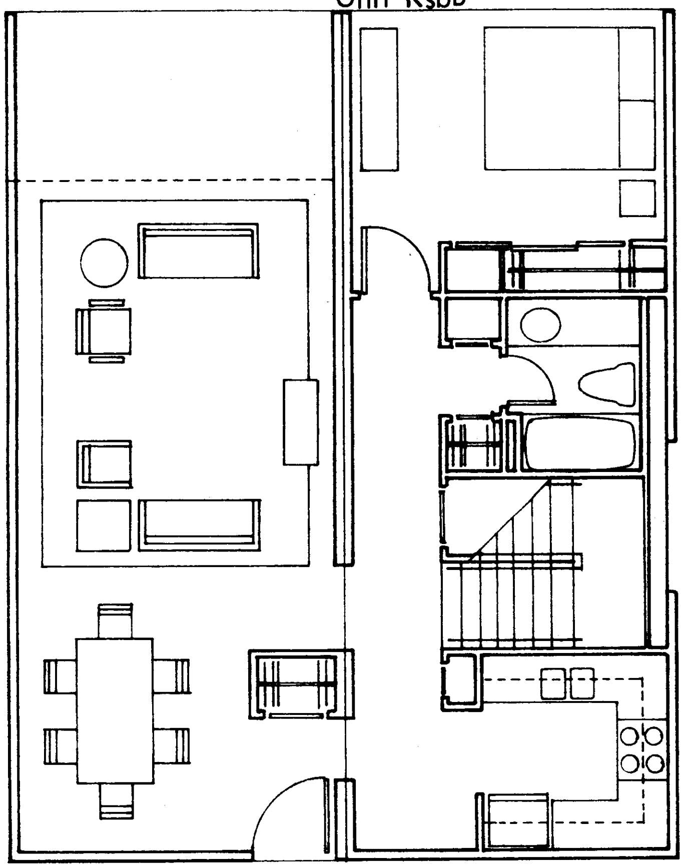
Type D3-3 br unit
Lower Level

Unit bsbB/I



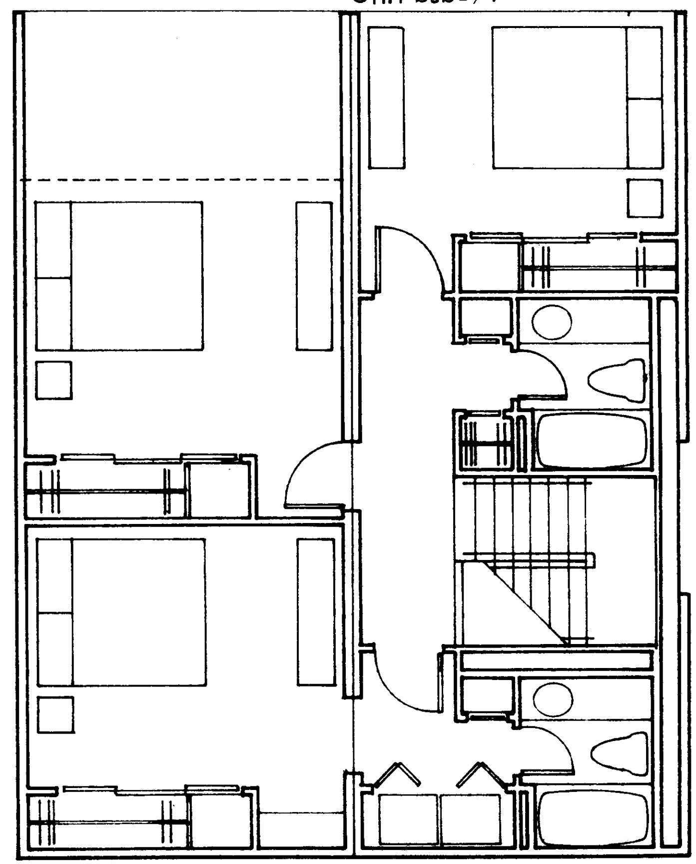
Type D3-3 br unit
Upper Level

Unit KsbB

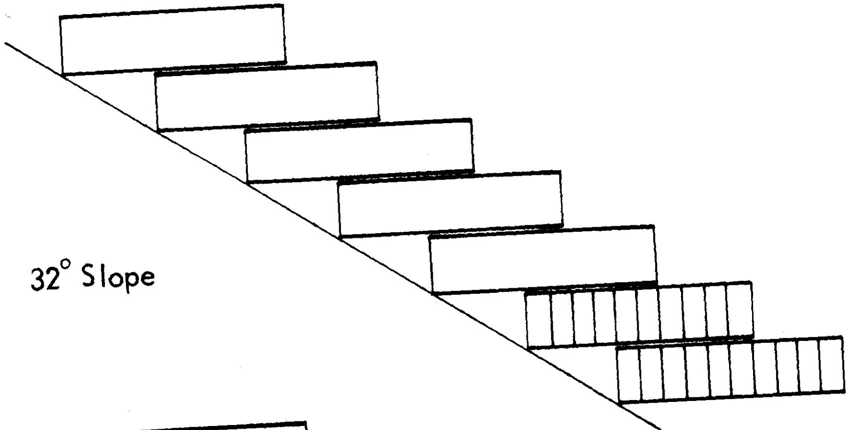


Type El-4 br unit
Lower Level

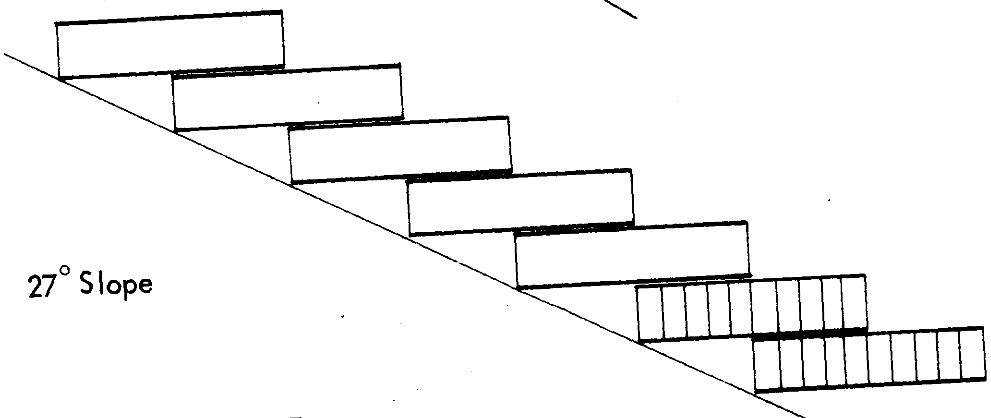
Unit bsbB/1



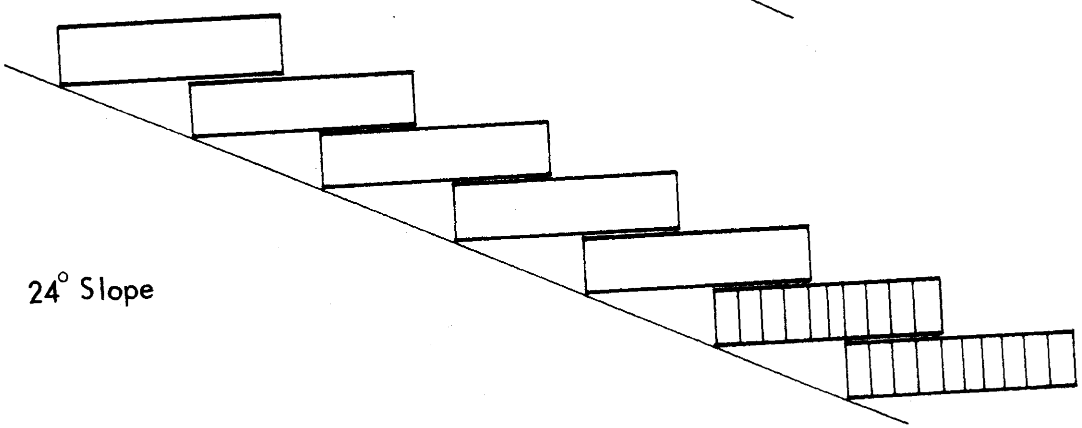
Type El-4 br unit
Upper Level



32° Slope

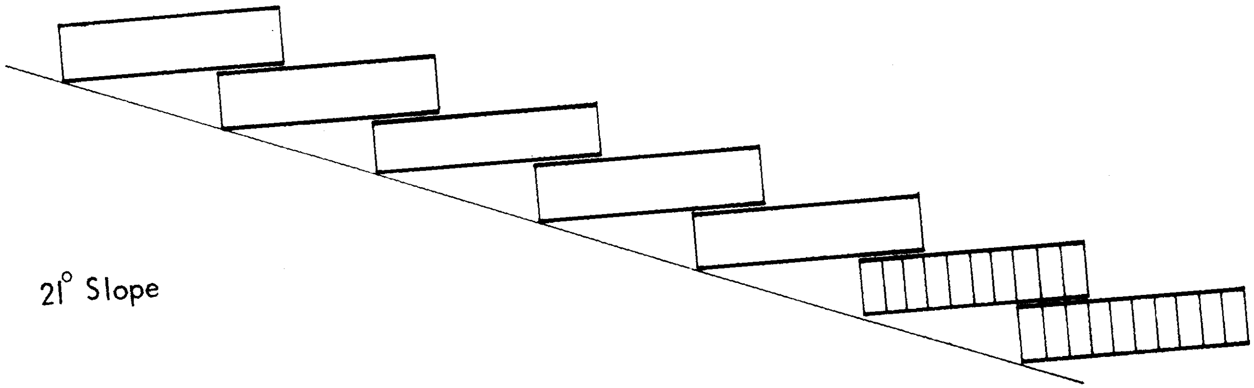


27° Slope

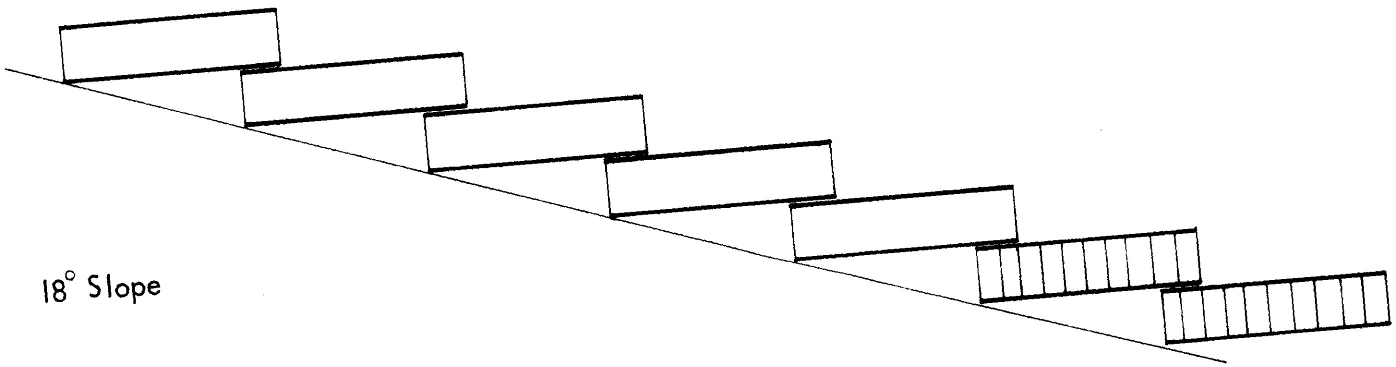


24° Slope

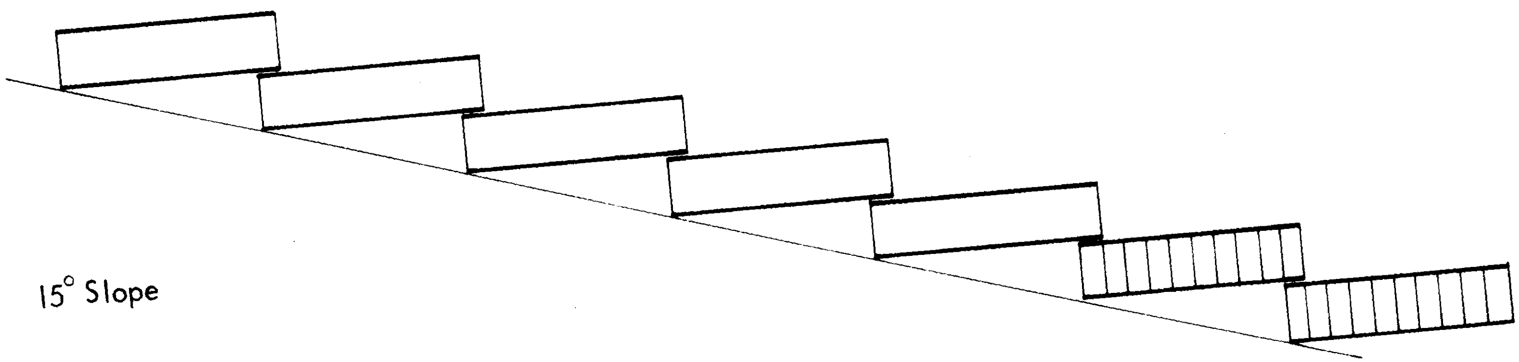
SLOPE ALTERNATIVES



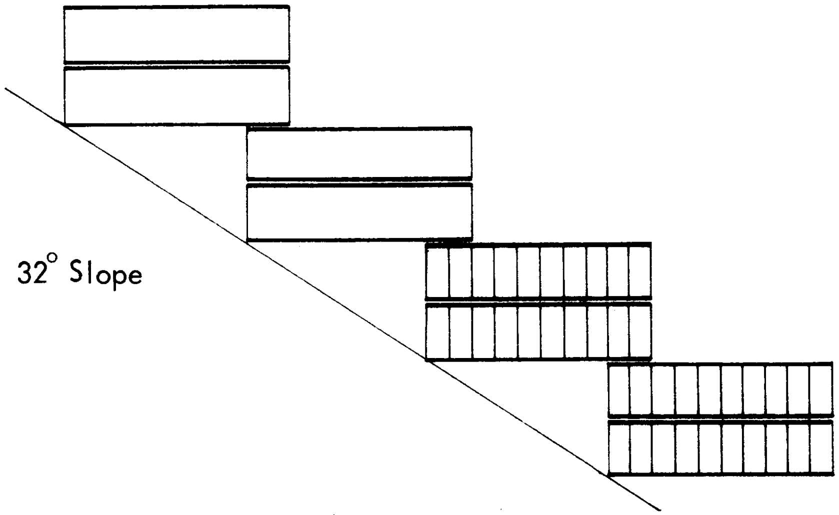
21° Slope

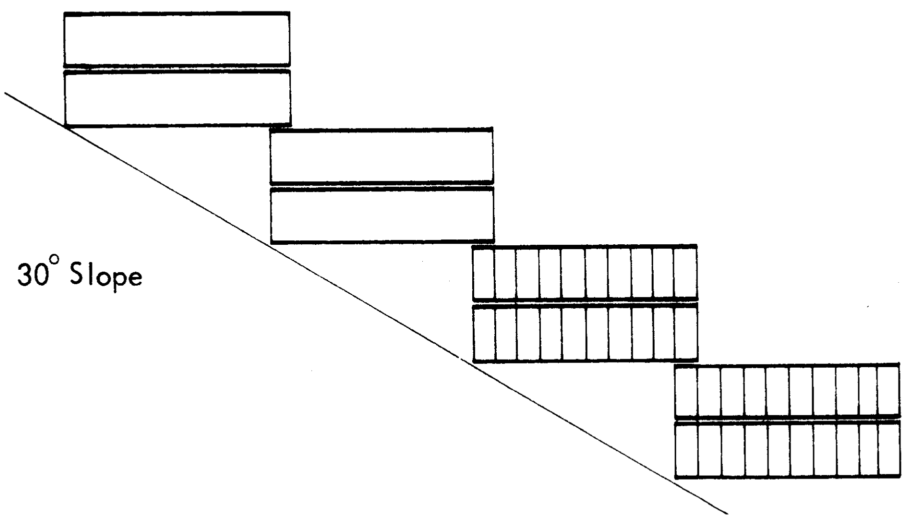


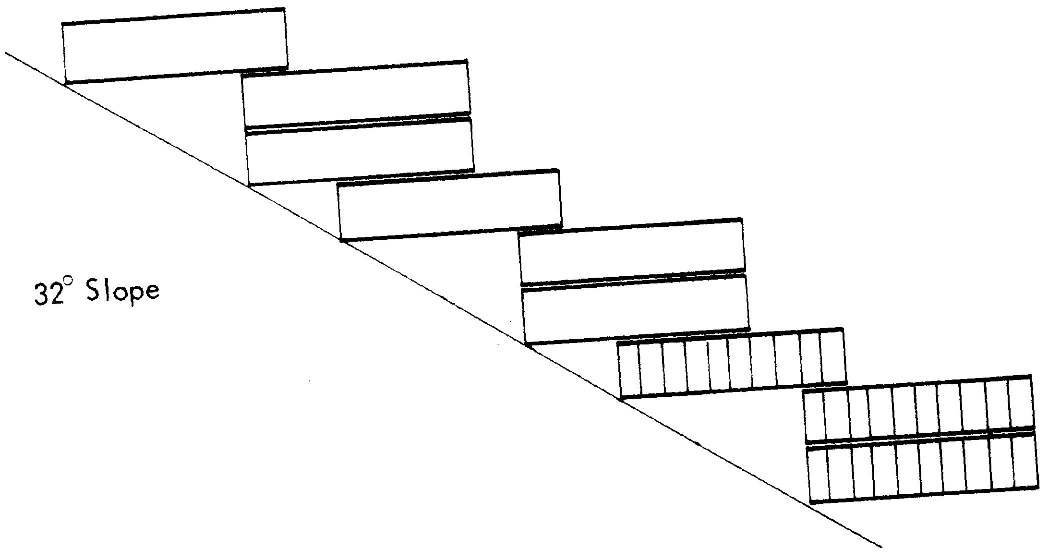
18° Slope



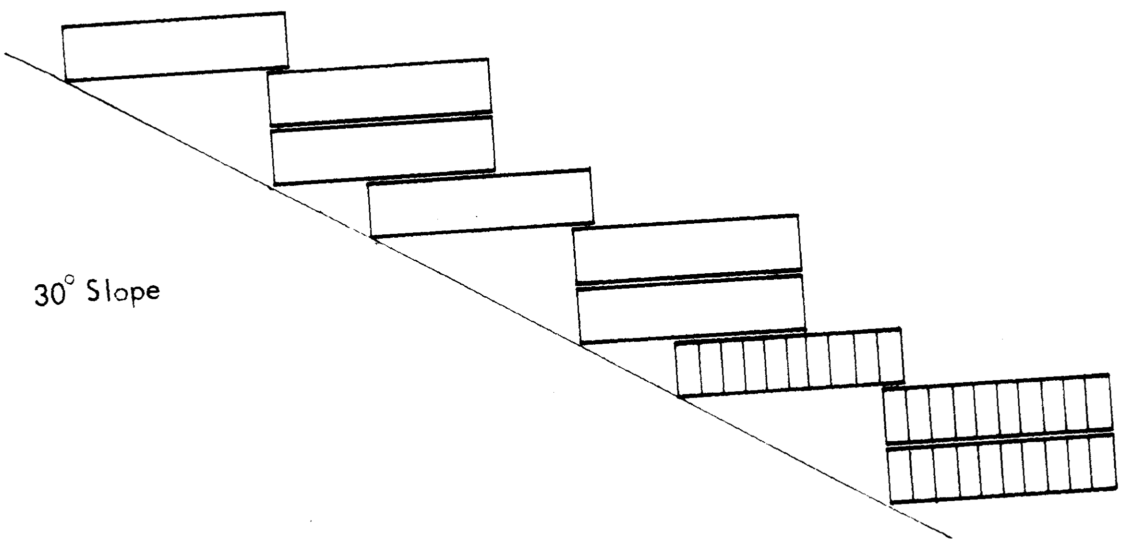
15° Slope


32° Slope

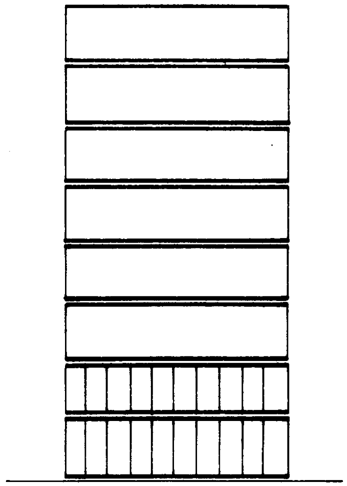

30° Slope



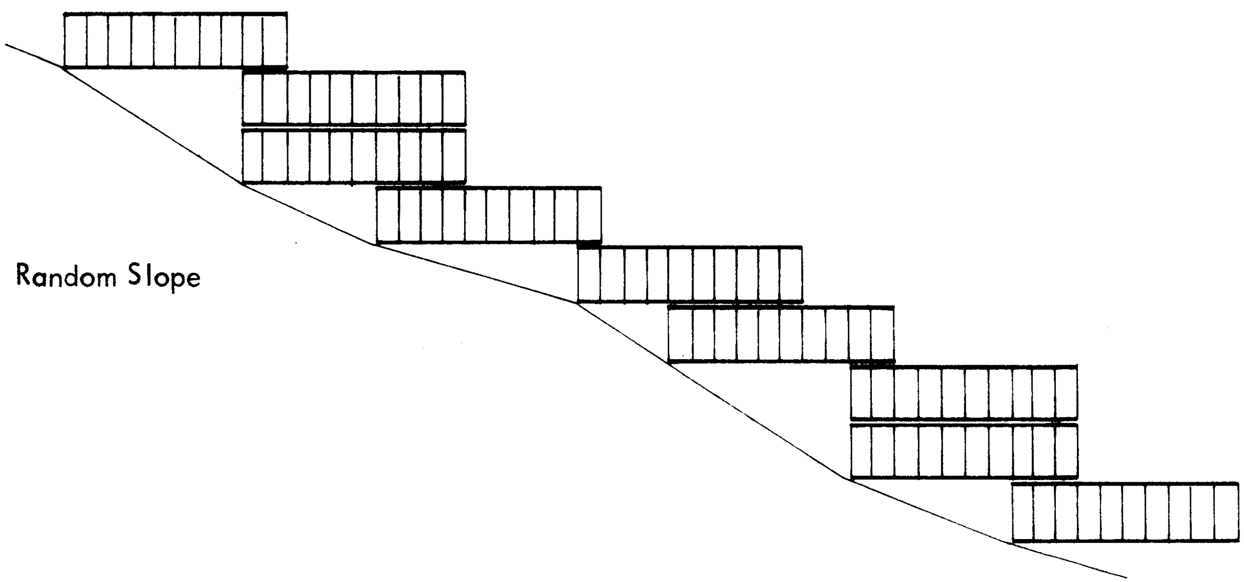
32° Slope



30° Slope

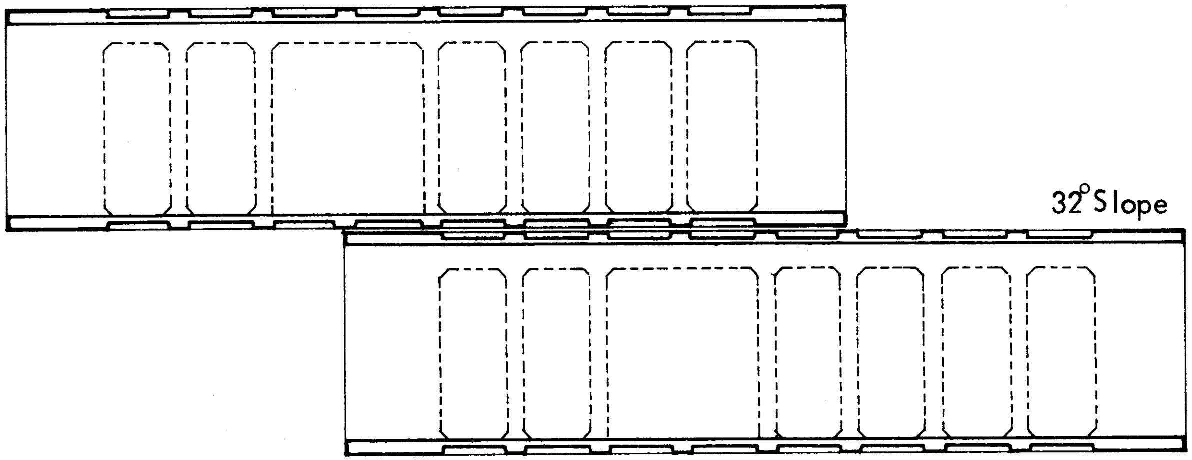


0° Slope
Vertically stacked units

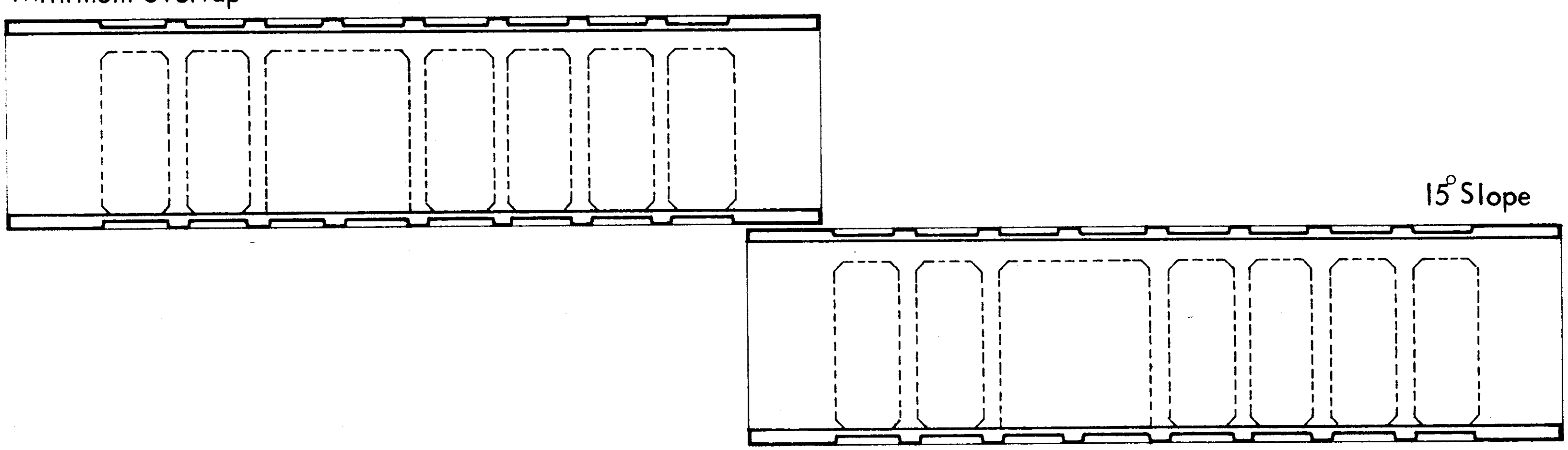


Random Slope

Maximum overlap

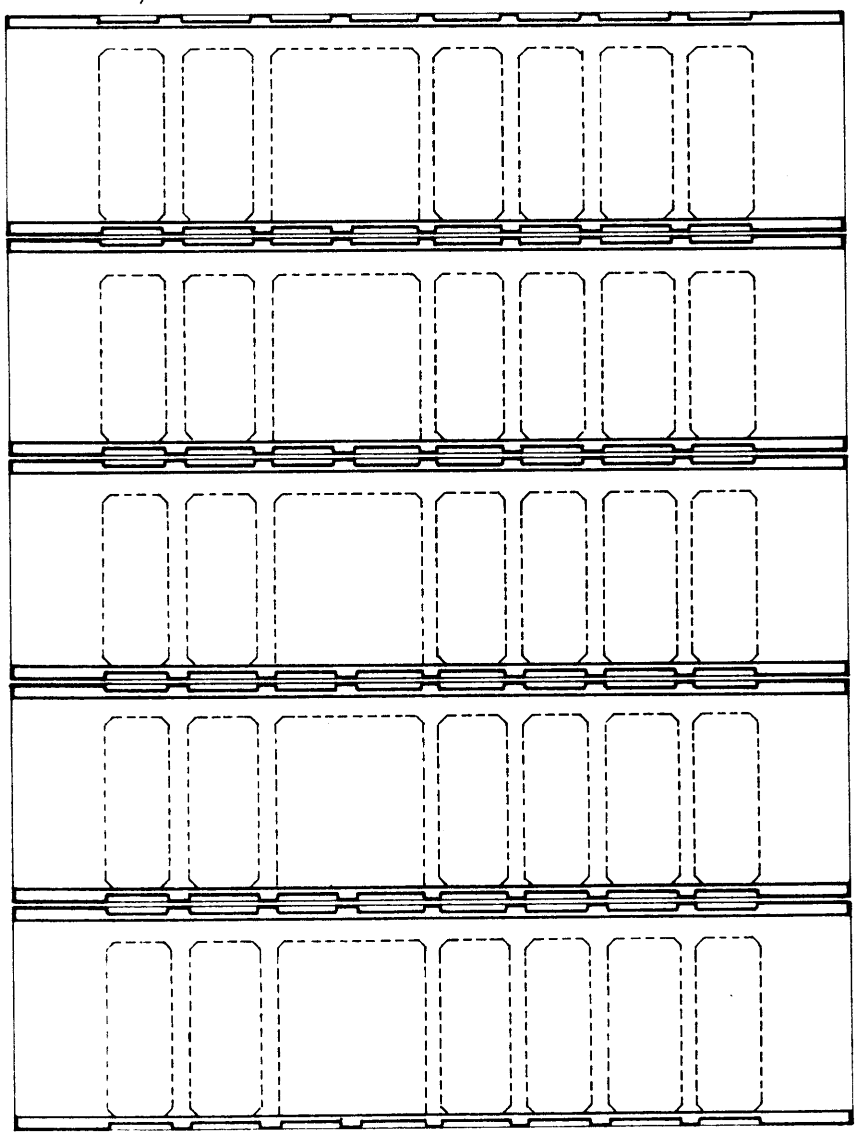


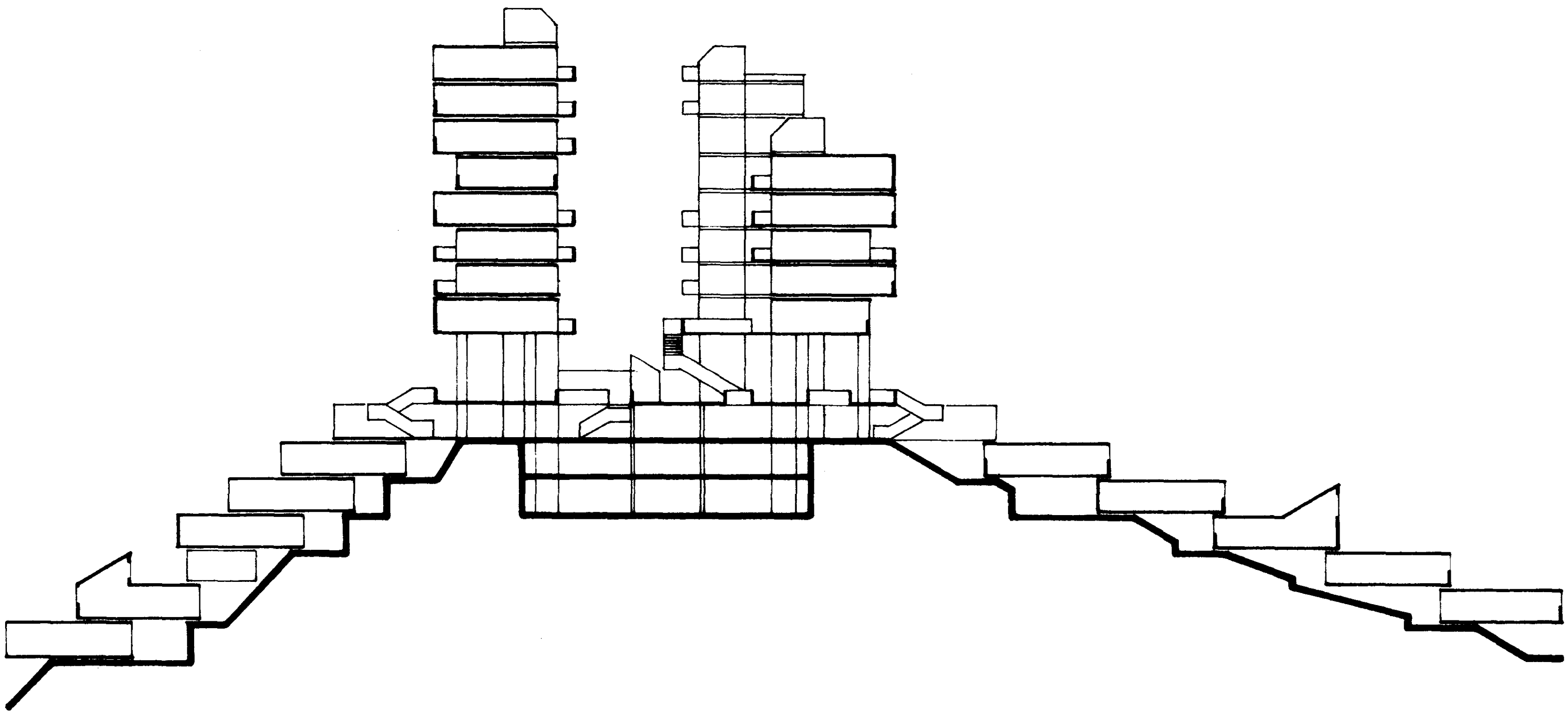
Minimum overlap



SECTIONS

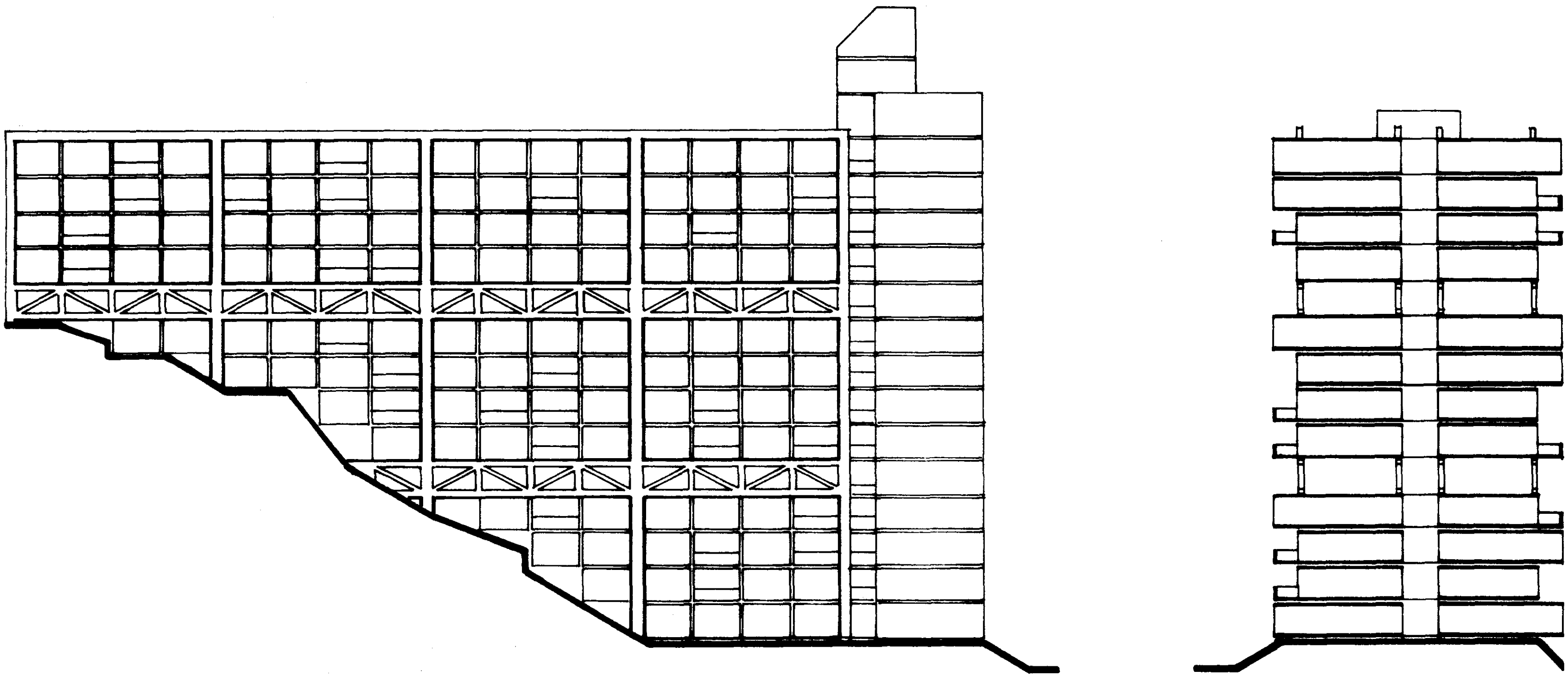
Vertically stacked units



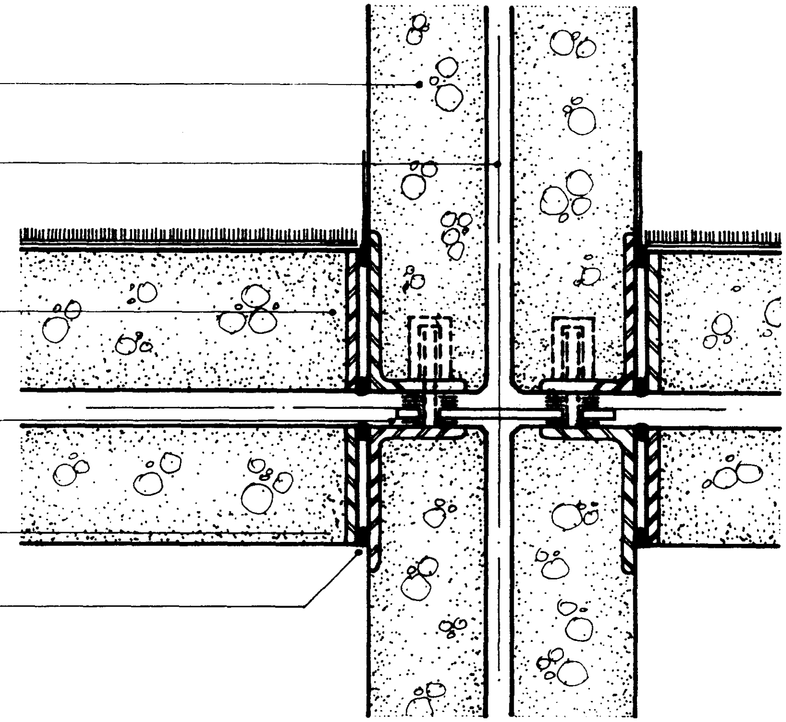


Terraced Configuration

GENERAL SECTIONS AND ELEVATIONS



High-rise Configuration



5" REINFORCED CONCRETE AT RIBS AND ENDS OF MODULAR UNIT

1" TOLERANCE BETWEEN UNITS

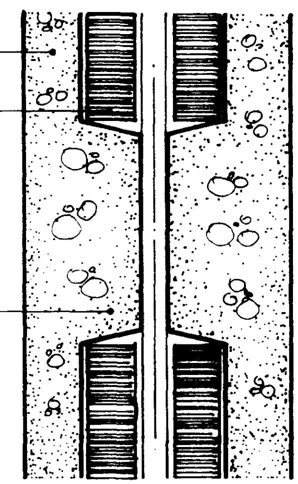
6" CONCRETE FLOOR SLAB WITH STEEL PLATES AT CONNECTIONS

STEEL PLATE

5" CONCRETE CEILING SLAB WITH STEEL PLATES AT CONNECTIONS

WELDED CONNECTION

SECTION AT JUNCTION OF FOUR MODULAR UNITS



2 1/2" WALL BETWEEN RIBS

RIGID INSULATION

REINFORCED CONCRETE RIBS AT 3'-6" O.C.

PLAN OF WALL AT RIBS OF TWO UNITS

CONSTRUCTION DETAILS

WALL BEYOND

FLOOR FINISH (CARPET)

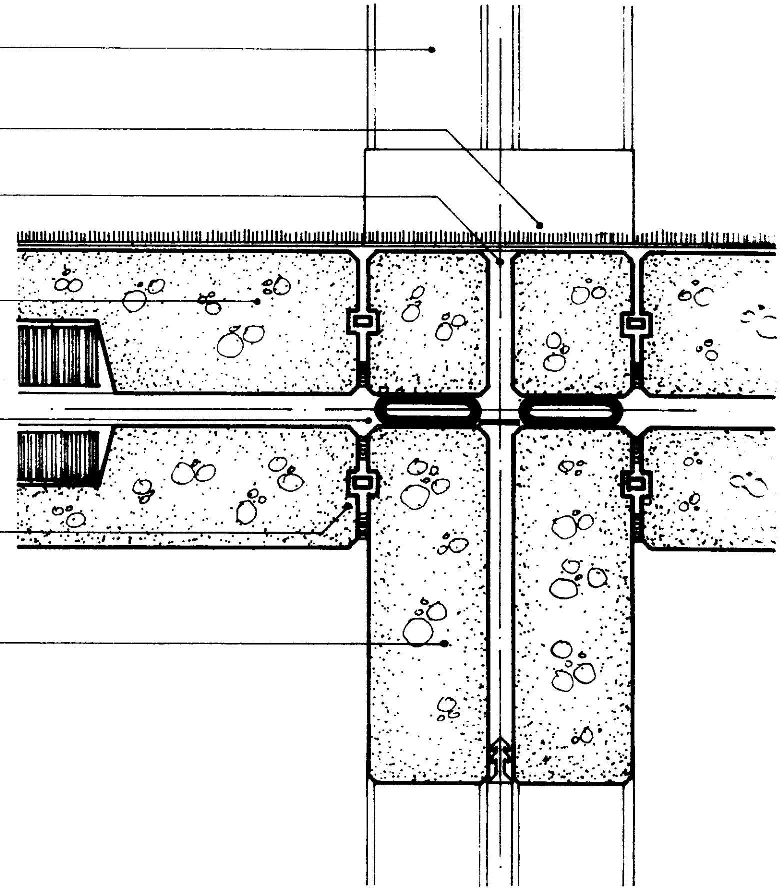
GROUT TO LEVEL

FLOOR SLAB AT
EDGE BEAM

NEOPRENE PAD

COMPRESSIBLE GASKET
AND SEALANT

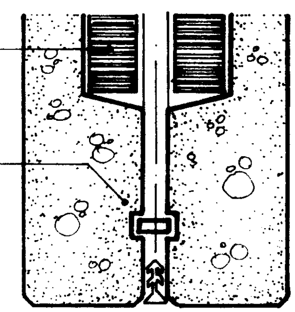
BEAM AT OPENING



SECTION AT OPENING BETWEEN UNITS

RIGID INSULATION

COMPRESSIBLE GASKET AND
PLASTIC INSERT



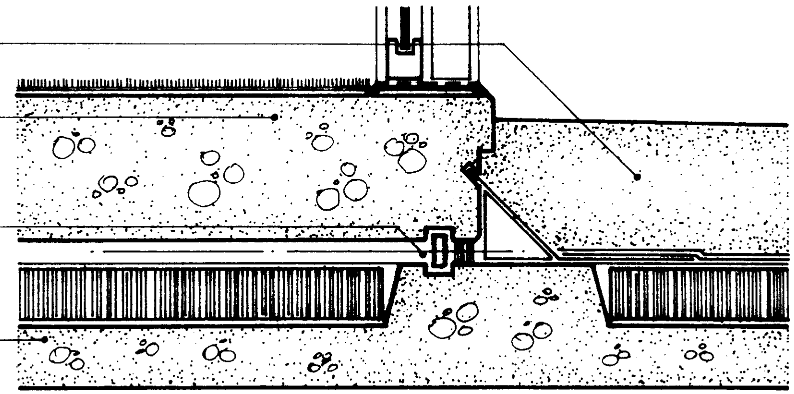
PLAN AT OPENING BETWEEN UNITS

BALCONY DECK

CONCRETE FLOOR SLAB

COMPRESSIBLE GASKET
AND SEALANT

RIGID INSULATION ON
CONCRETE CEILING SLAB

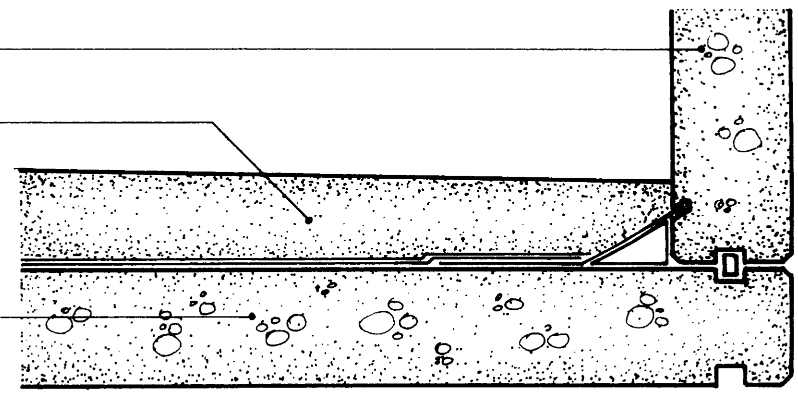


SECTION AT MODULE AND BALCONY

PRECAST BALCONY END UNIT

BALCONY DECK

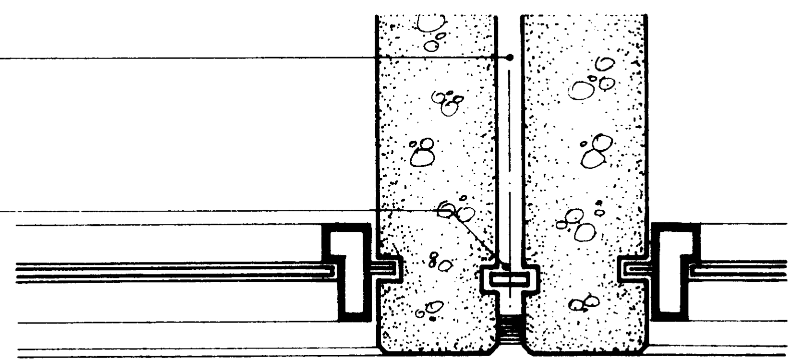
CONCRETE CEILING SLAB



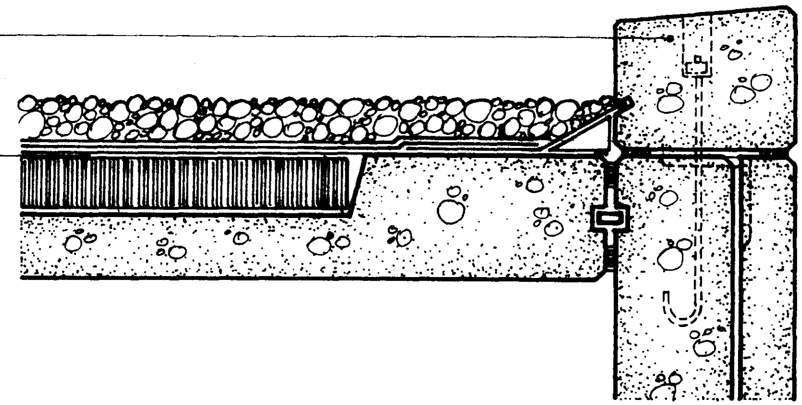
SECTION AT BALCONY

1" TOLERANCE

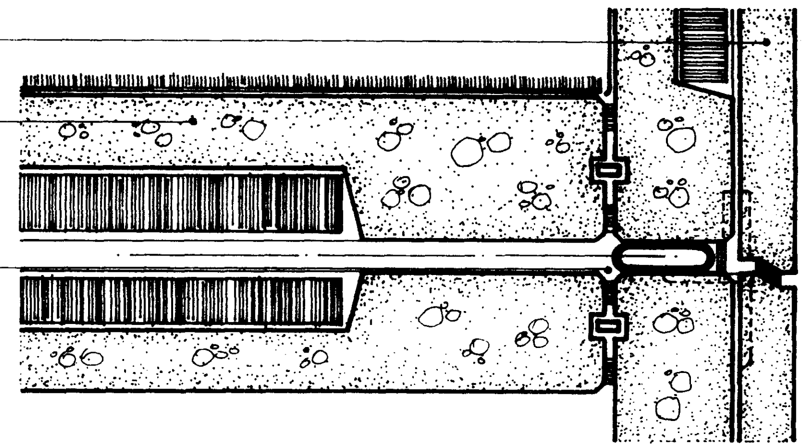
COMPRESSIBLE GASKET
AND SEALANT



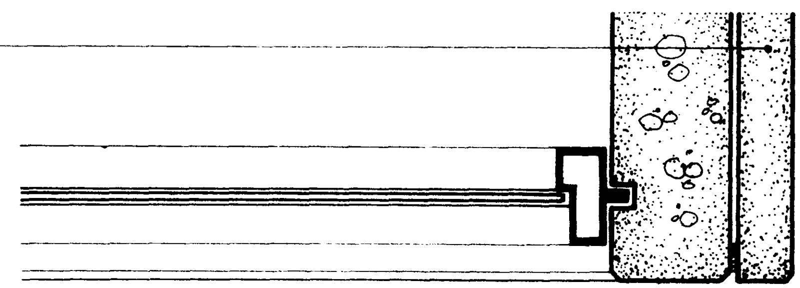
PLAN AT FACADE
BETWEEN TWO MODULAR UNITS



SECTION OF PRECAST PANEL AND ROOF



SECTION OF PRECAST PANEL AT JUNCTION OF TWO UNITS



PLAN OF PRECAST PANEL AT END WALL

GYPSUM WALL BOARD ON
METAL STUDS AT TRUSS WALL

BATT INSULATION

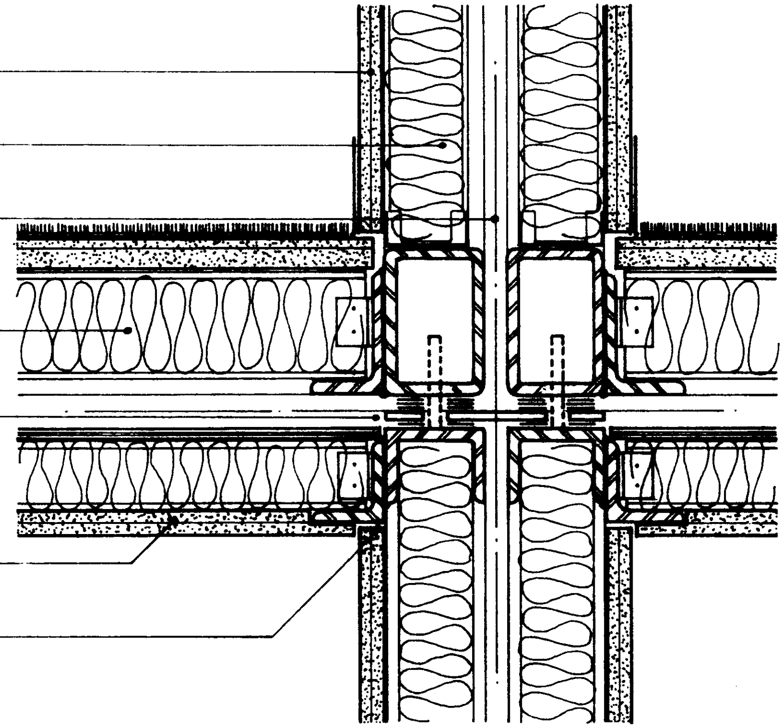
1" TOLERANCE

DECKING ON STEEL FLOOR JOISTS

STEEL PLATE

GYPSUM WALL BOARD AT CEILING JOISTS

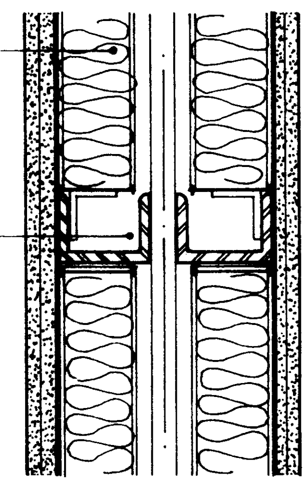
WELDED CONNECTION



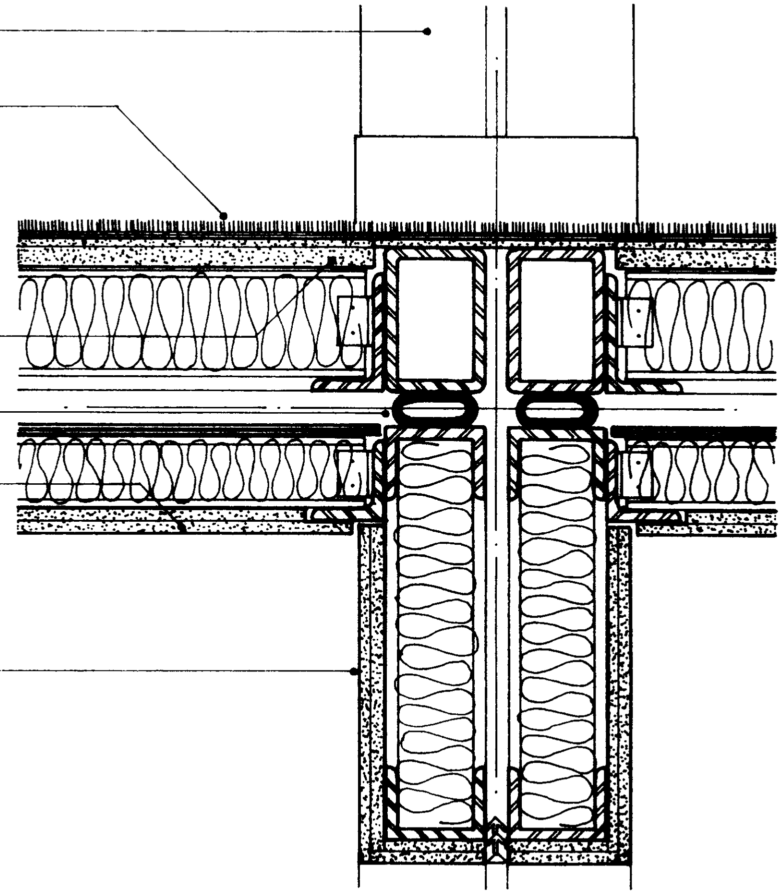
SECTION AT JUNCTION OF
FOUR MODULAR STEEL UNITS

BATT INSULATION

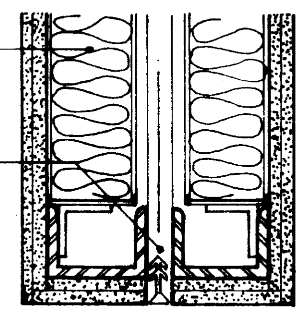
STEEL CHANNELS AT
VERTICAL TRUSS



PLAN OF WALL AT
COLUMNS OF TWO UNITS



SECTION AT OPENING BETWEEN UNITS



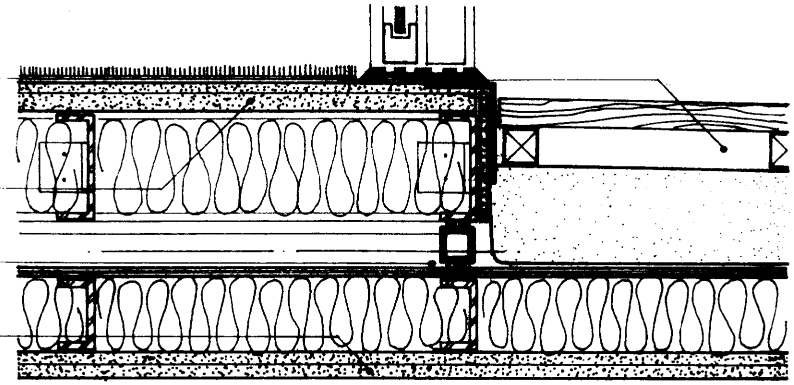
PLAN AT OPENING BETWEEN UNITS

BALCONY DECK ON
PLASTIC TOPPING

STEEL FLOOR PANEL

COMPRESSIBLE GASKET AND SEALANT

STEEL CEILING PANEL



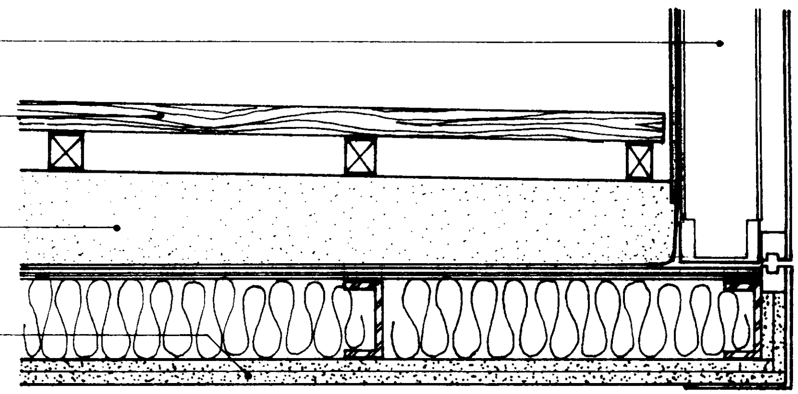
SECTION AT STEEL MODULE AND BALCONY

STEEL BALCONY END UNIT

BALCONY DECK

PLASTIC TOPPING

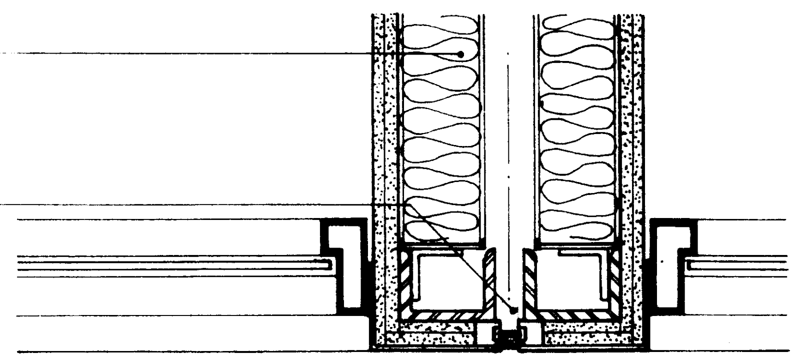
STEEL CEILING PANEL



SECTION AT BALCONY

BATT INSULATION

COMPRESSIBLE GASKET
AND SEALANT



PLAN AT FACADE
BETWEEN TWO MODULAR UNITS

REINFORCED CONCRETE PANEL
(OR STEEL TRUSS WALL) OF MODULAR UNIT

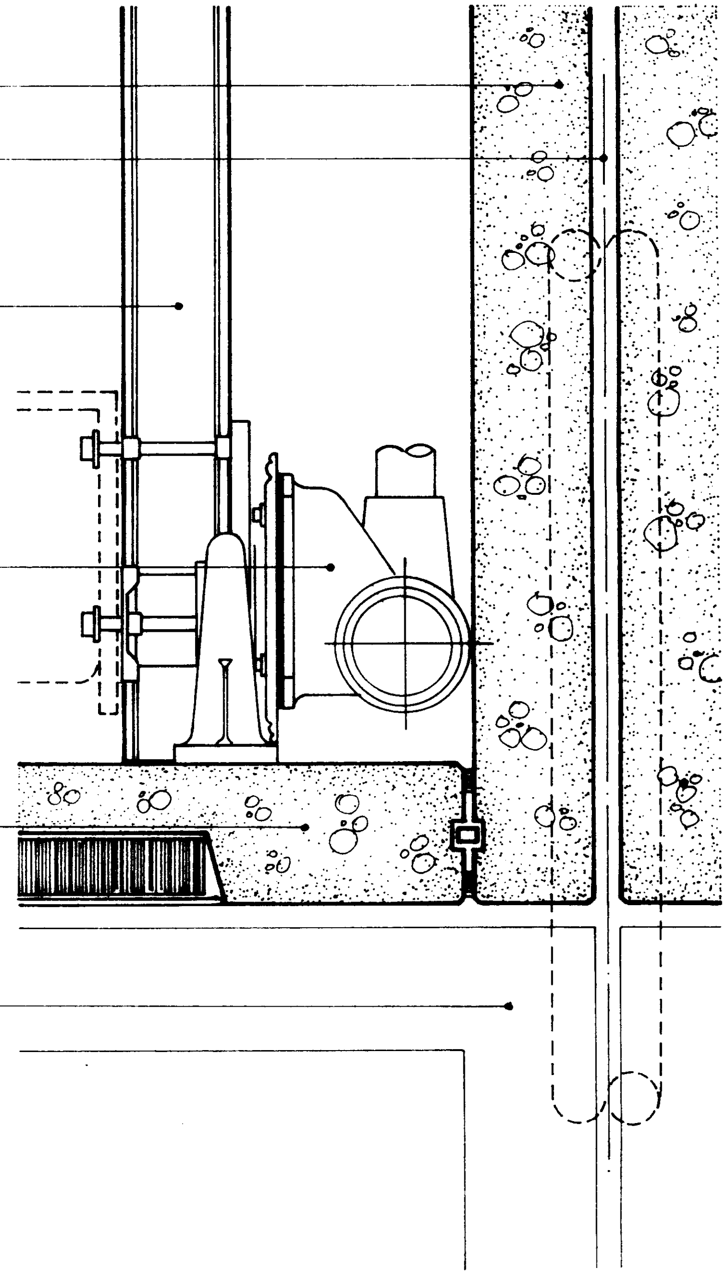
I" TOLERANCE

INTERIOR WALL PANEL
AT BATHROOM

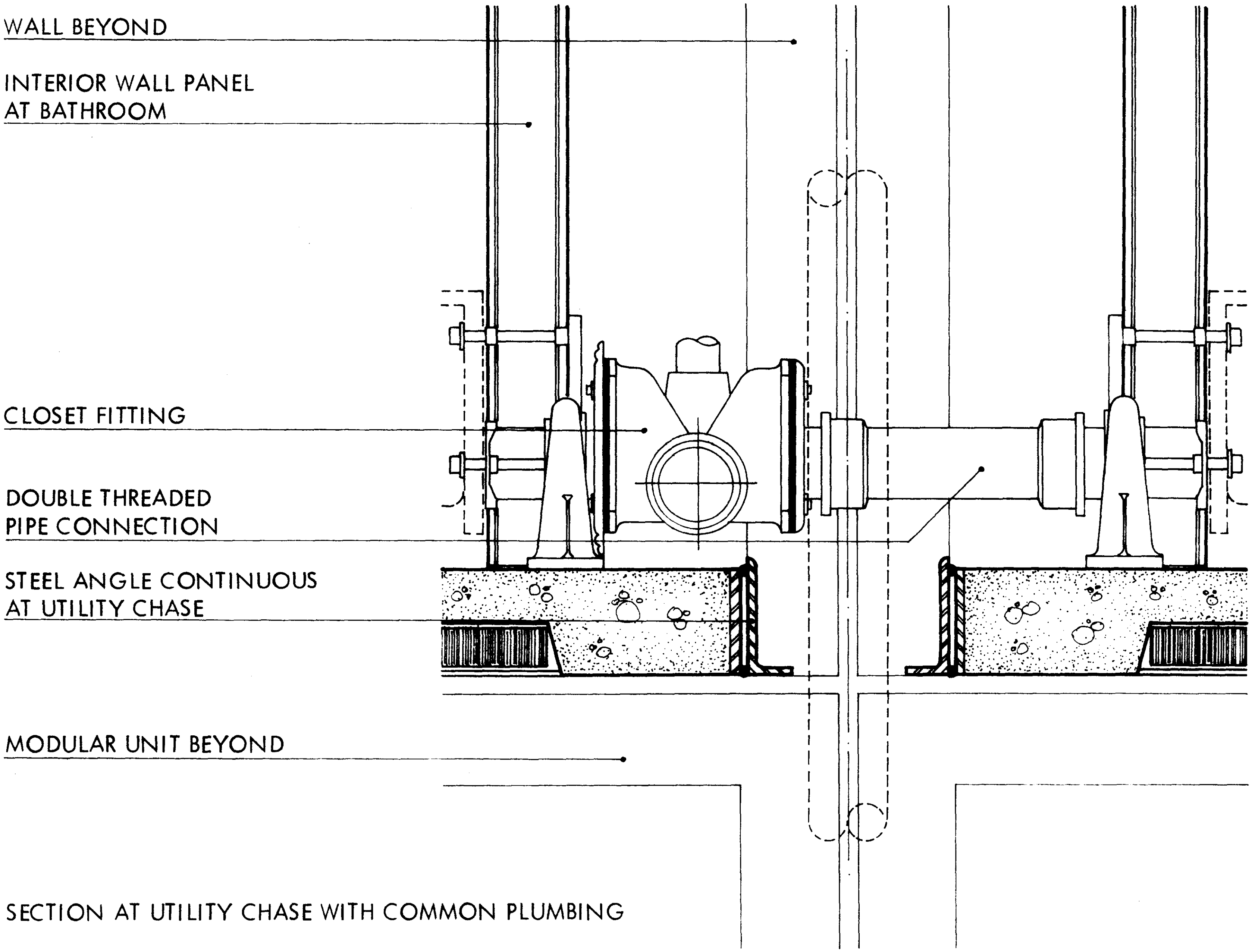
CLOSET FITTING

REINFORCED CONCRETE FLOOR PANEL
(OR STEEL FLOOR PANEL)

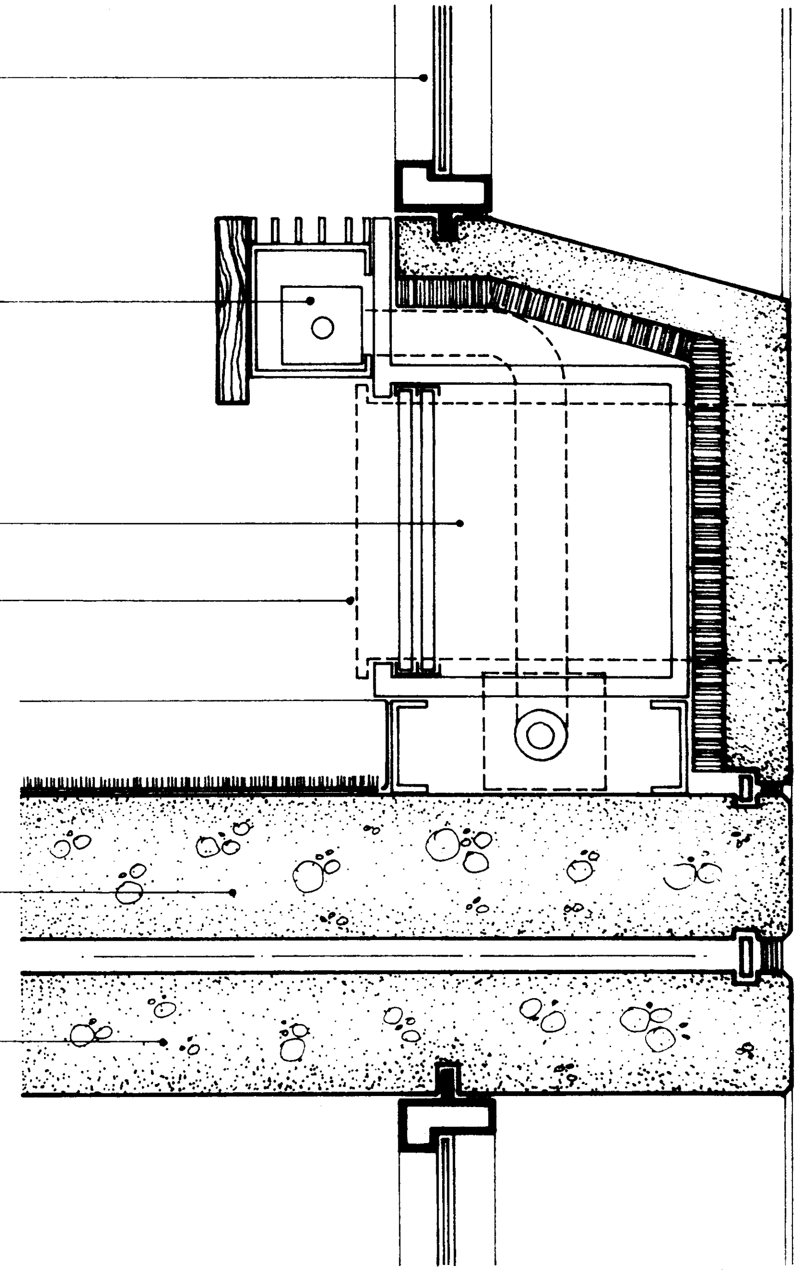
MODULAR UNIT BEYOND



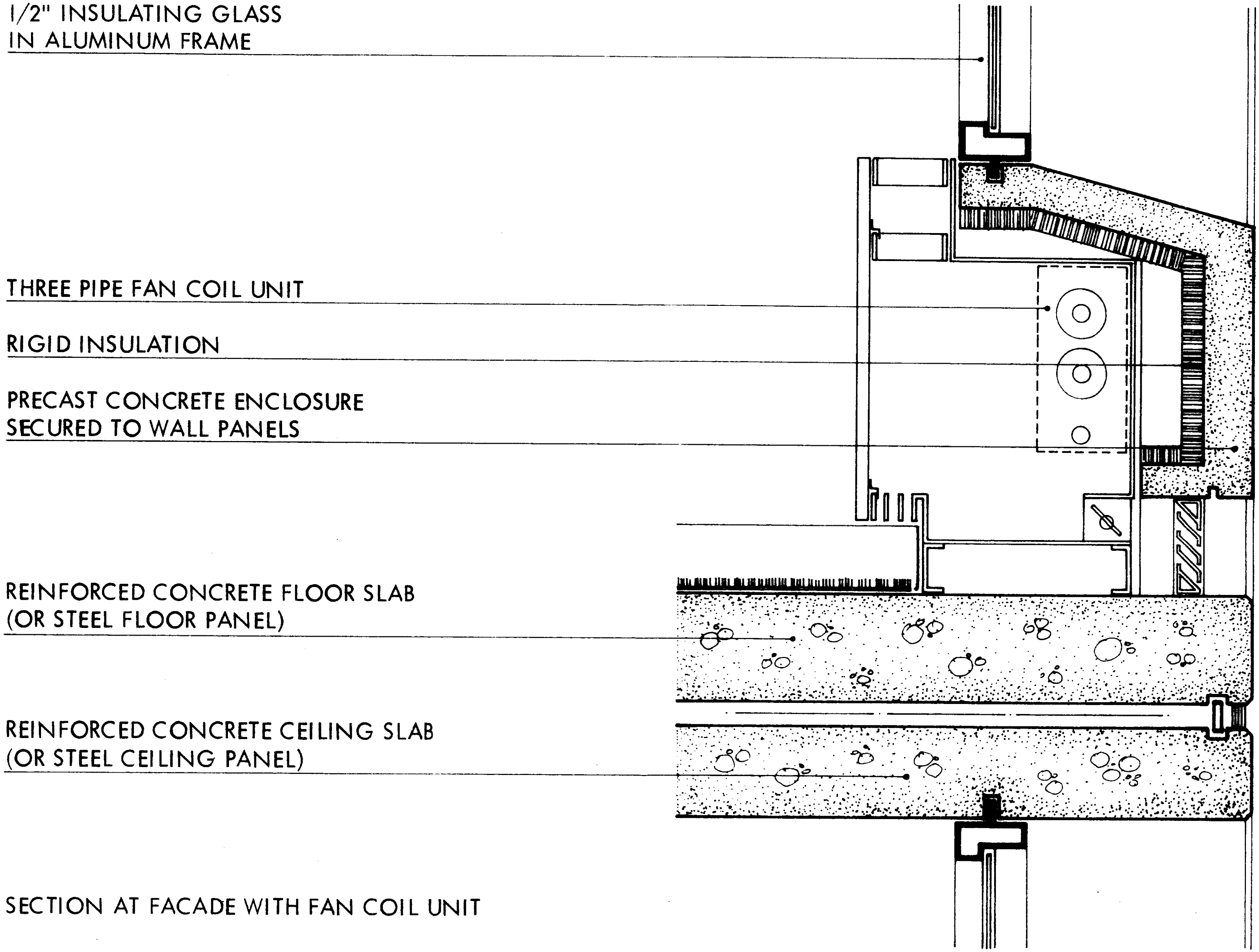
SECTION AT UTILITY CHASE
WITH INDIVIDUAL PLUMBING



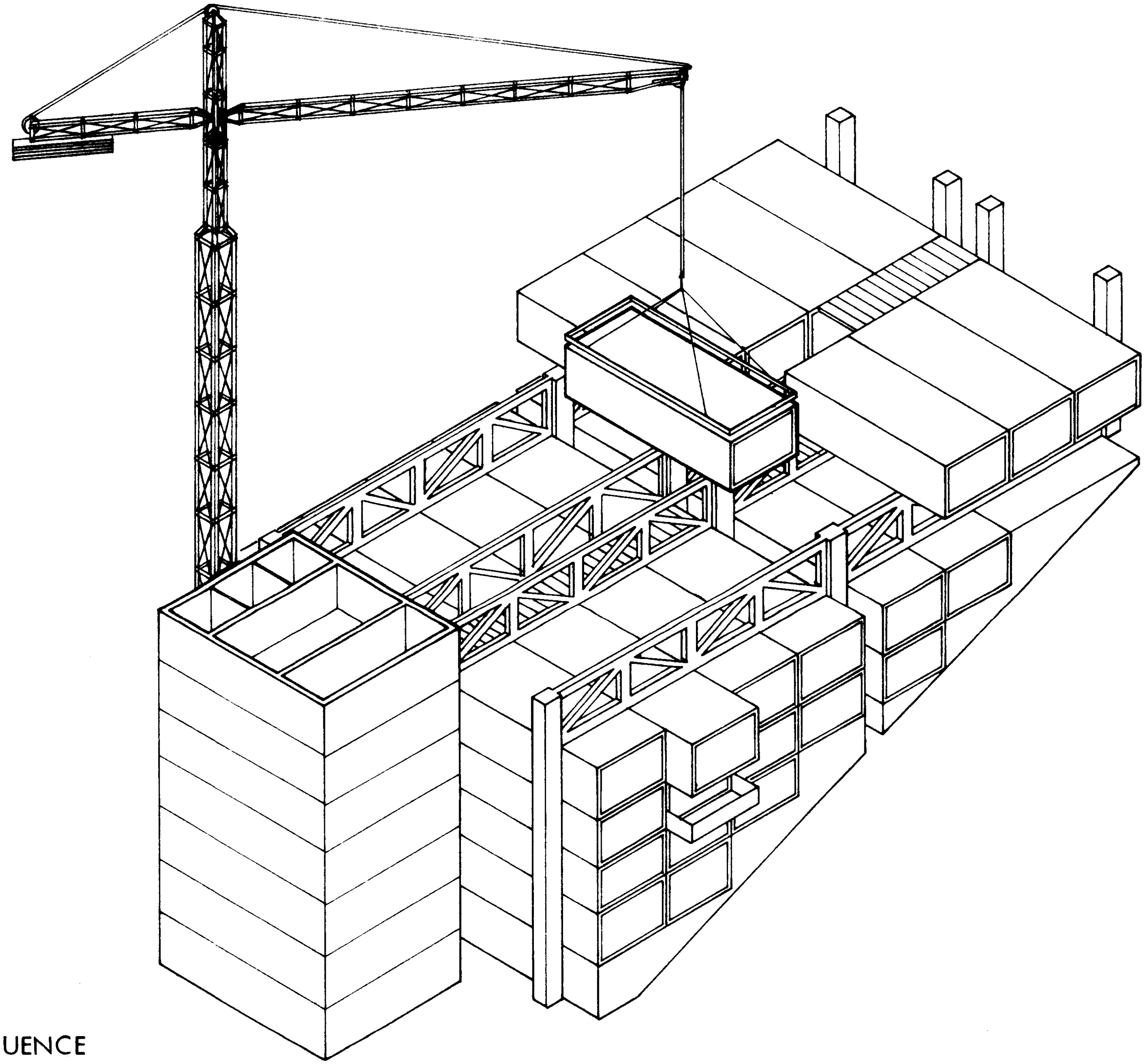
SECTION AT UTILITY CHASE WITH COMMON PLUMBING



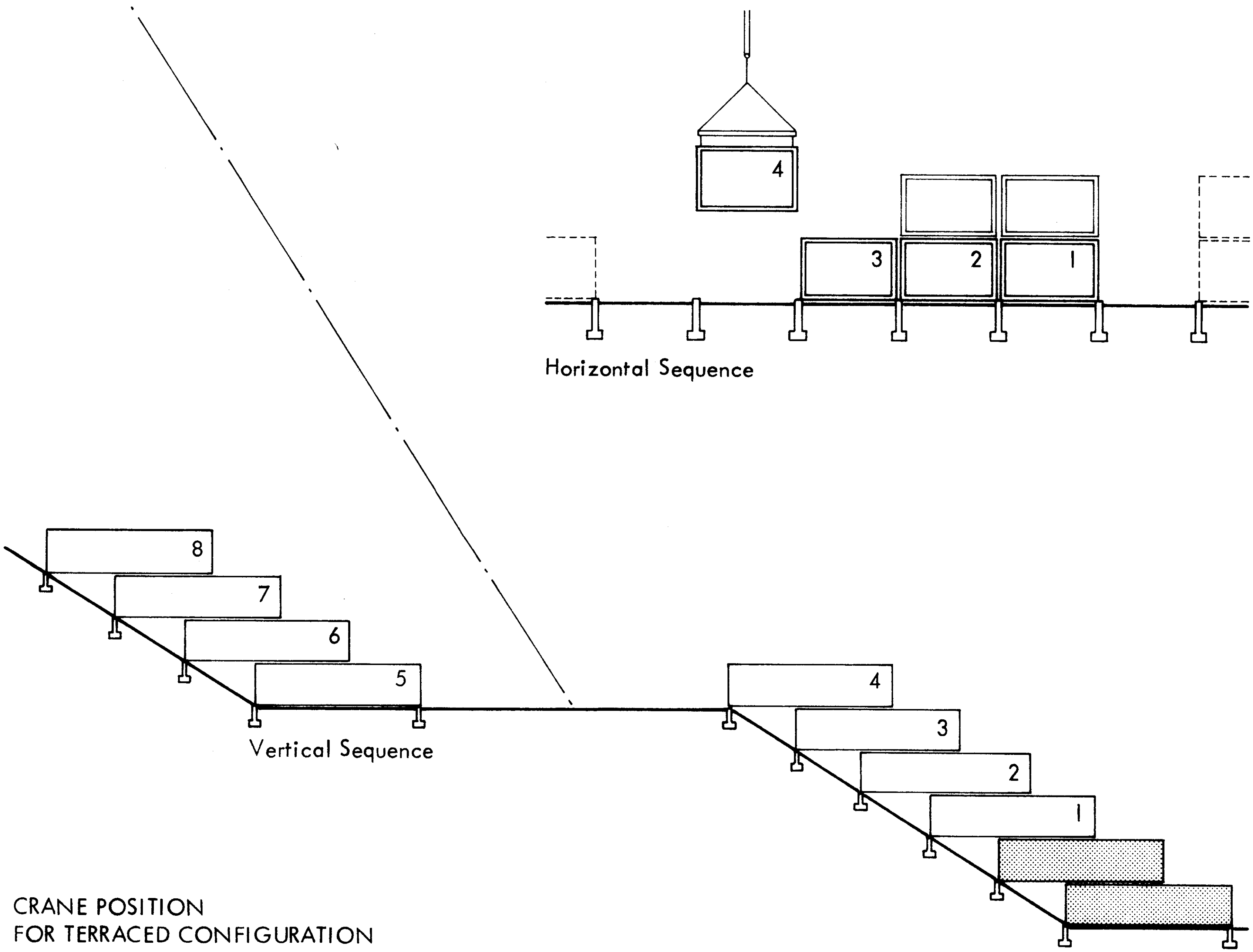
SECTION AT FACADE WITH RADIATION SYSTEM



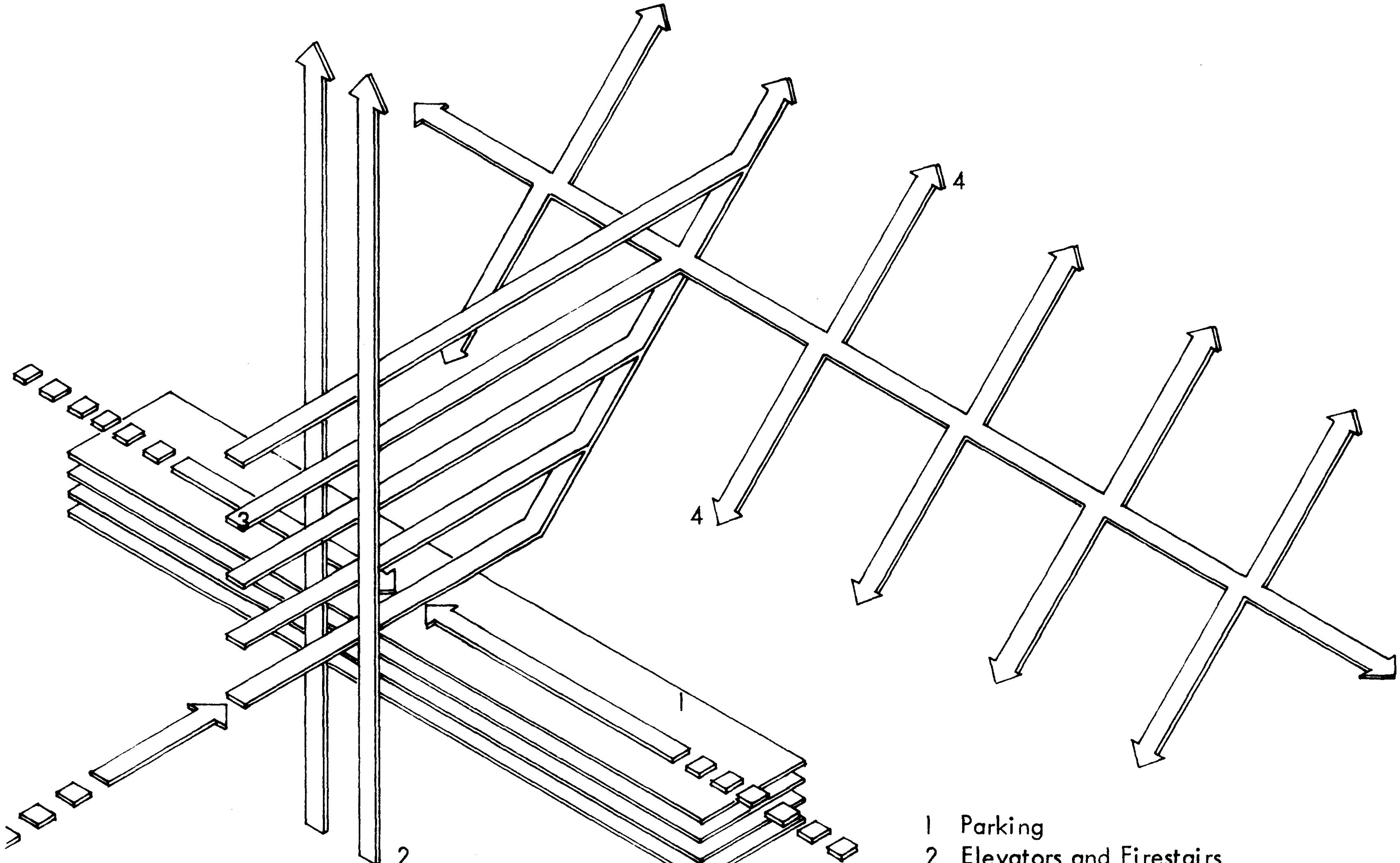
SECTION AT FACADE WITH FAN COIL UNIT



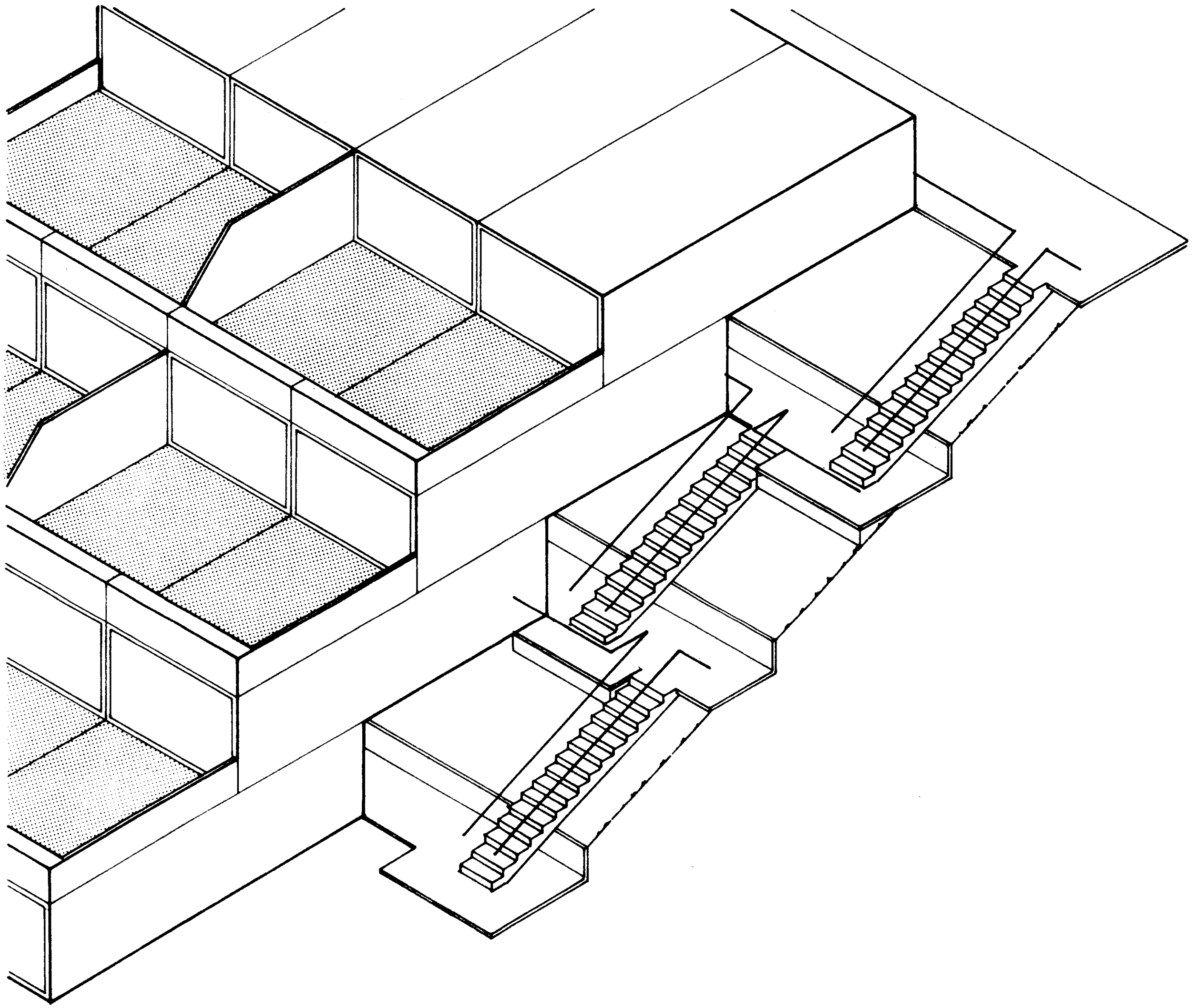
CONSTRUCTION SEQUENCE



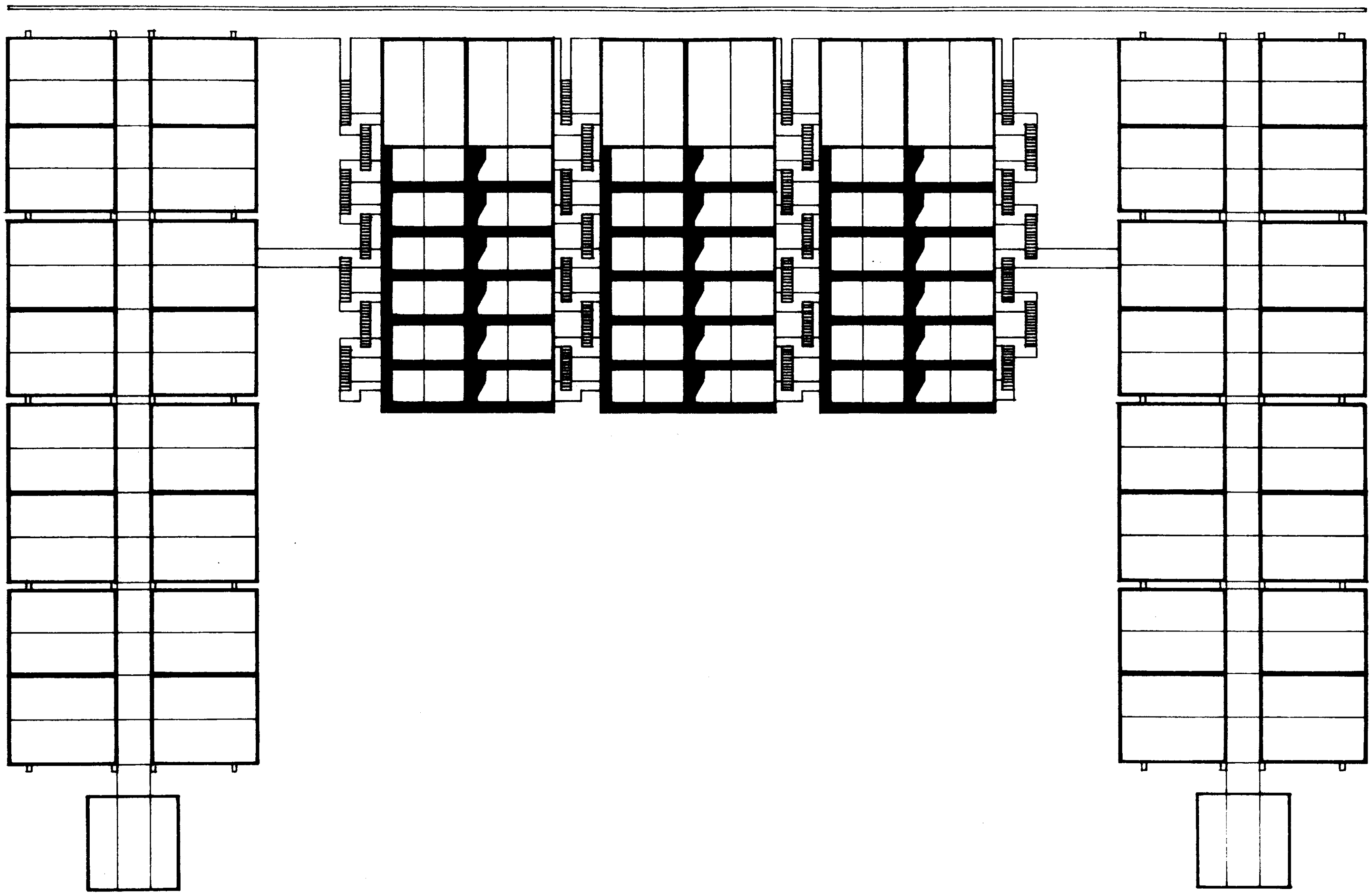
CRANE POSITION
FOR TERRACED CONFIGURATION



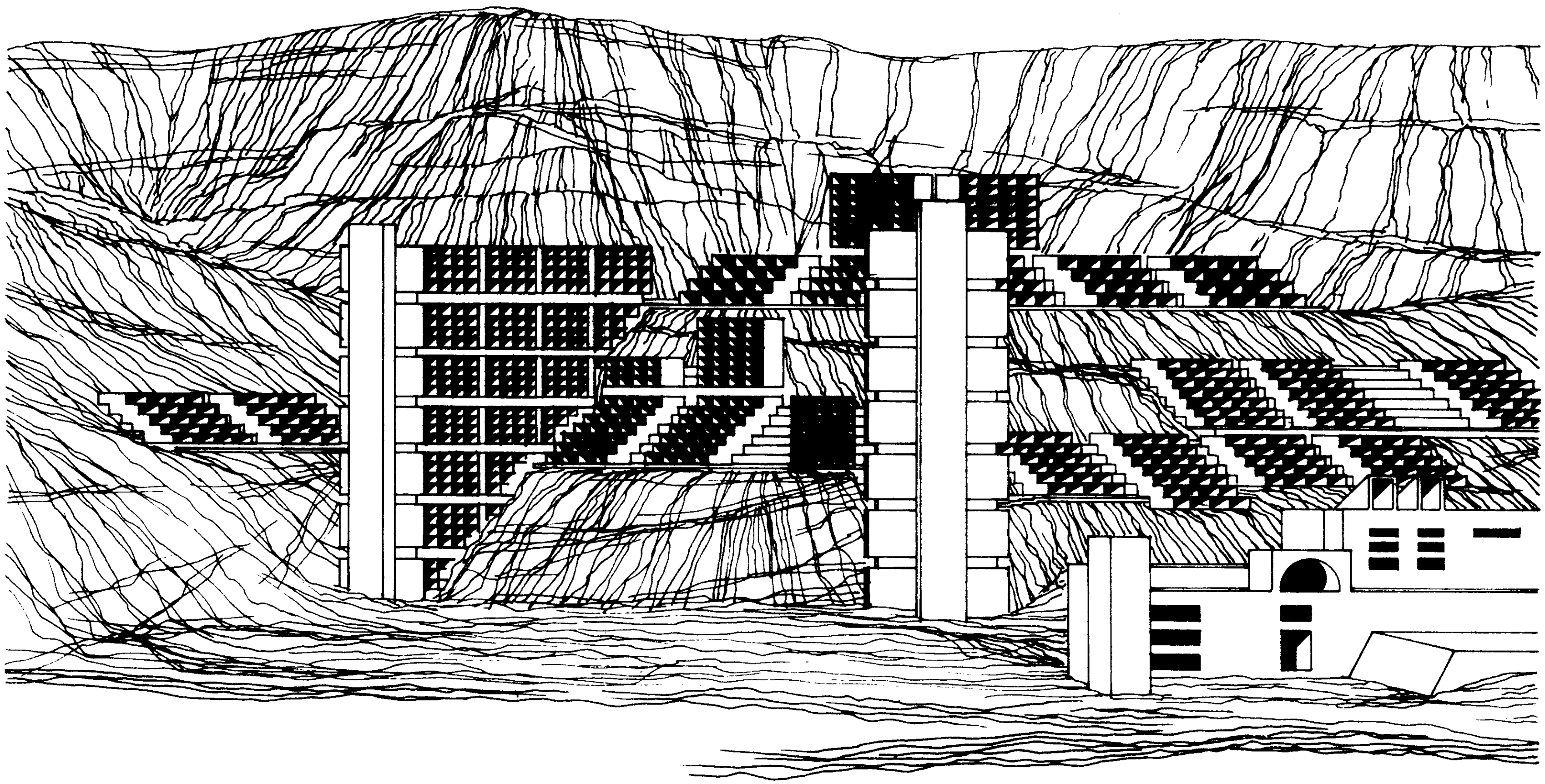
PEDESTRIAN CIRCULATION



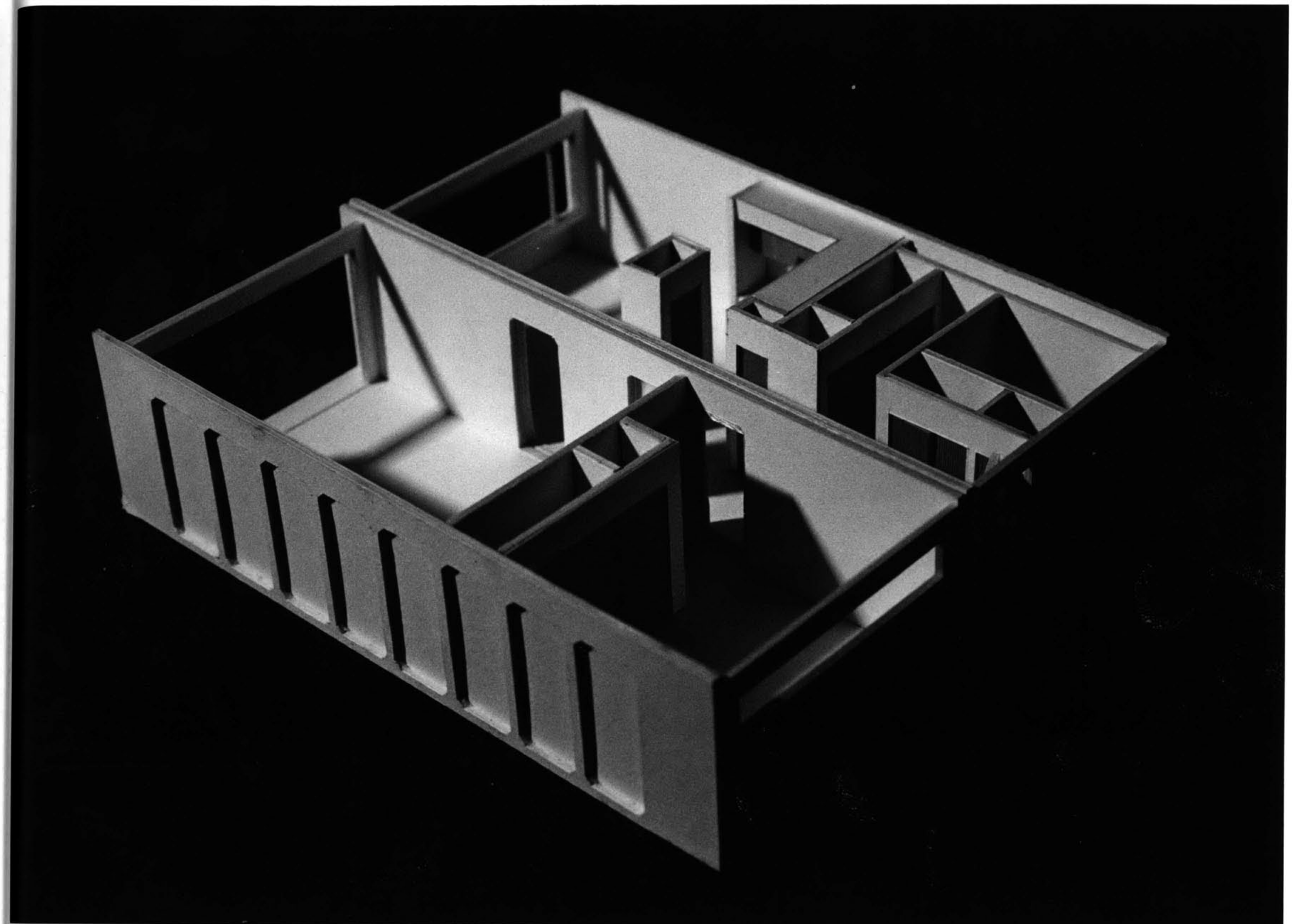
PEDESTRIAN CIRCULATION AT MAXIMUM SLOPE

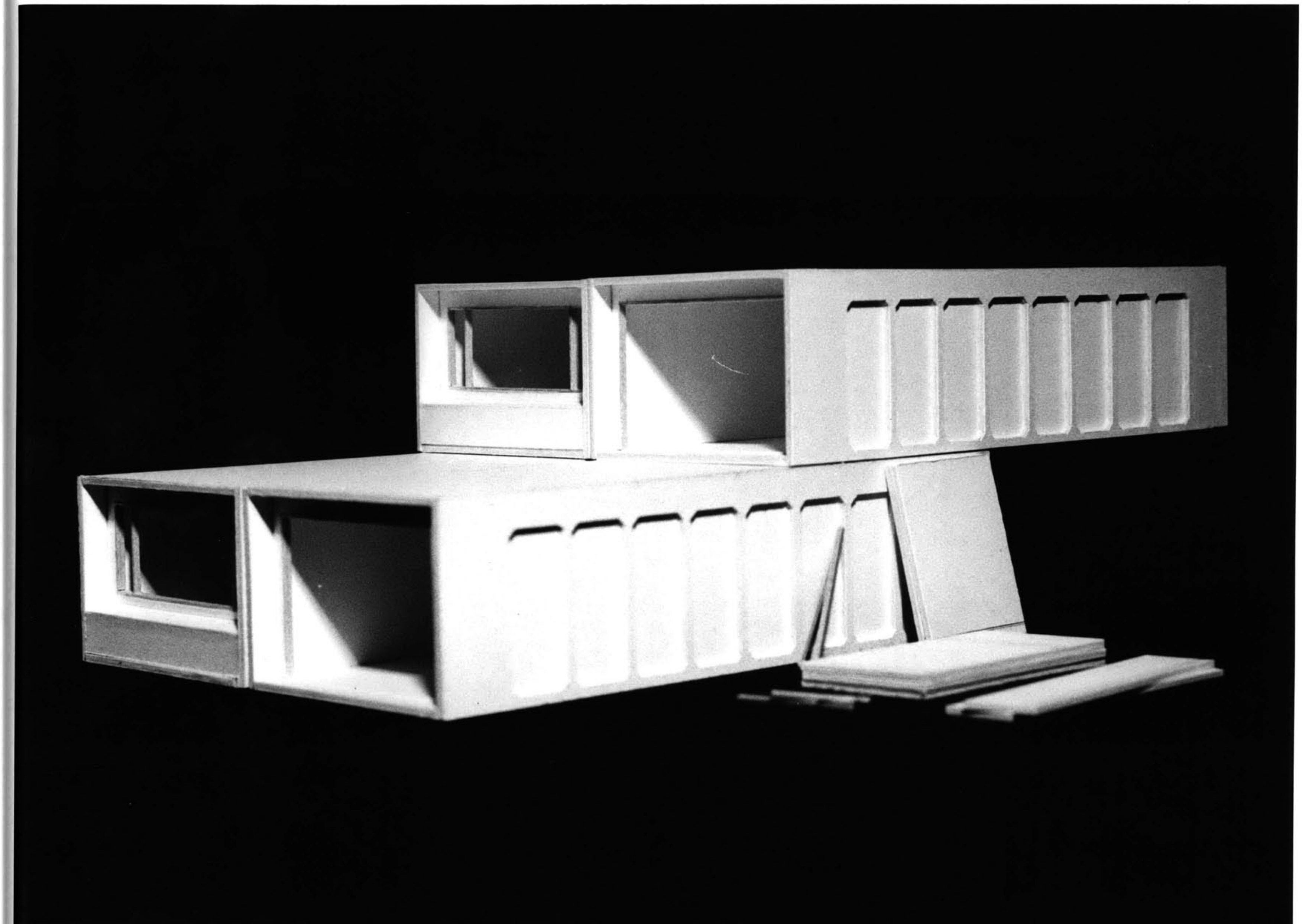


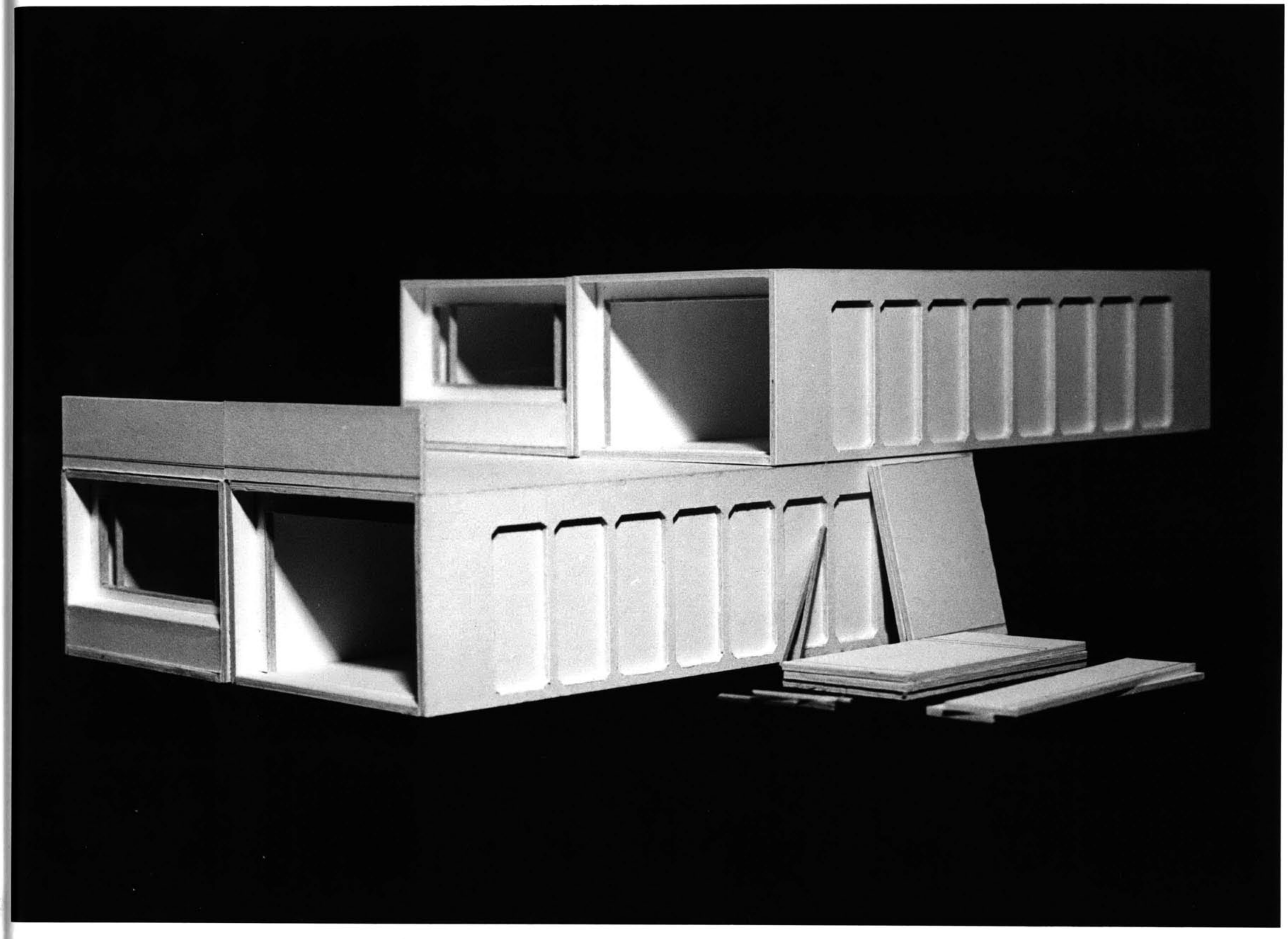
COMPOSITE SITE PLAN

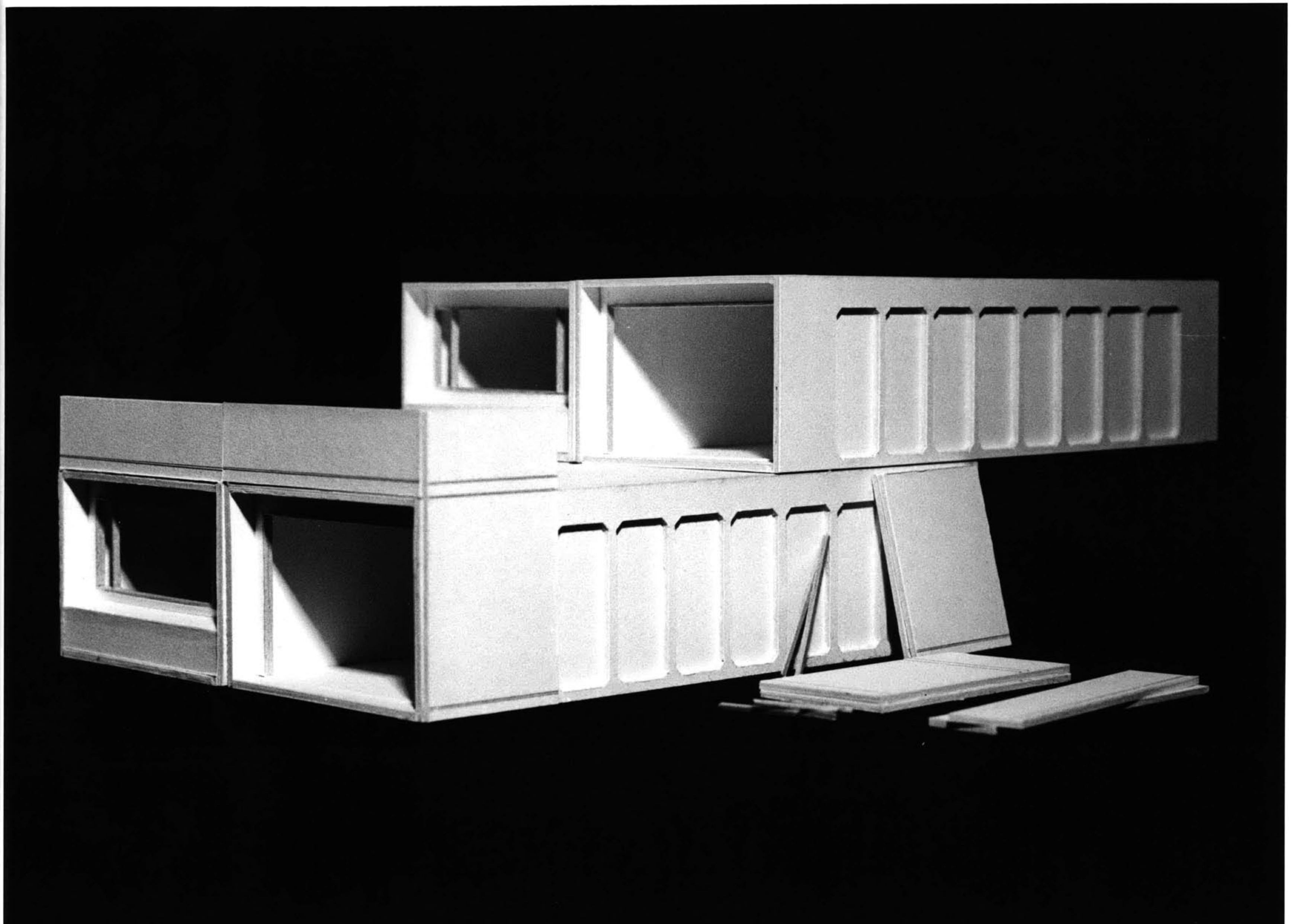


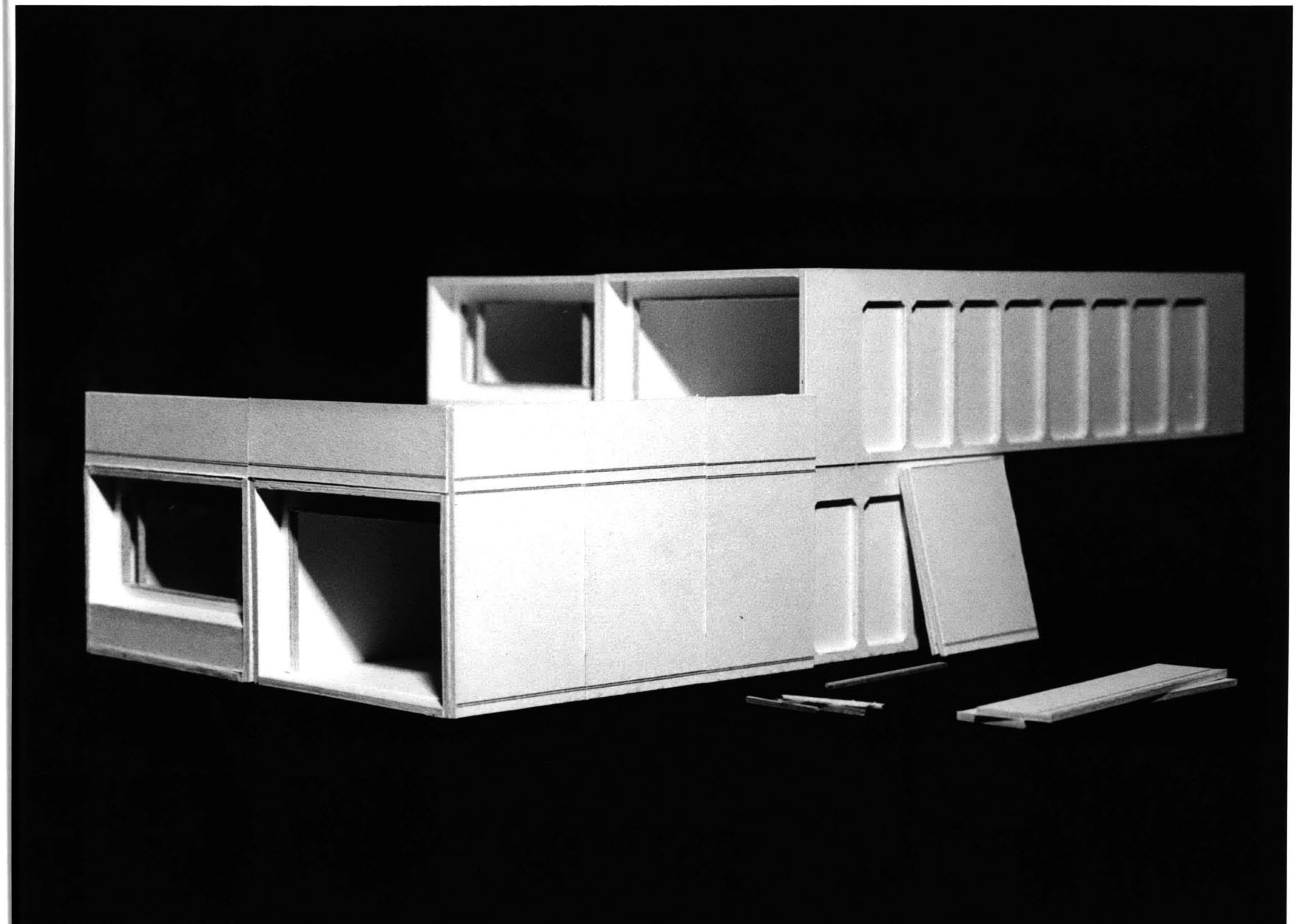
MODEL PHOTOGRAPHS

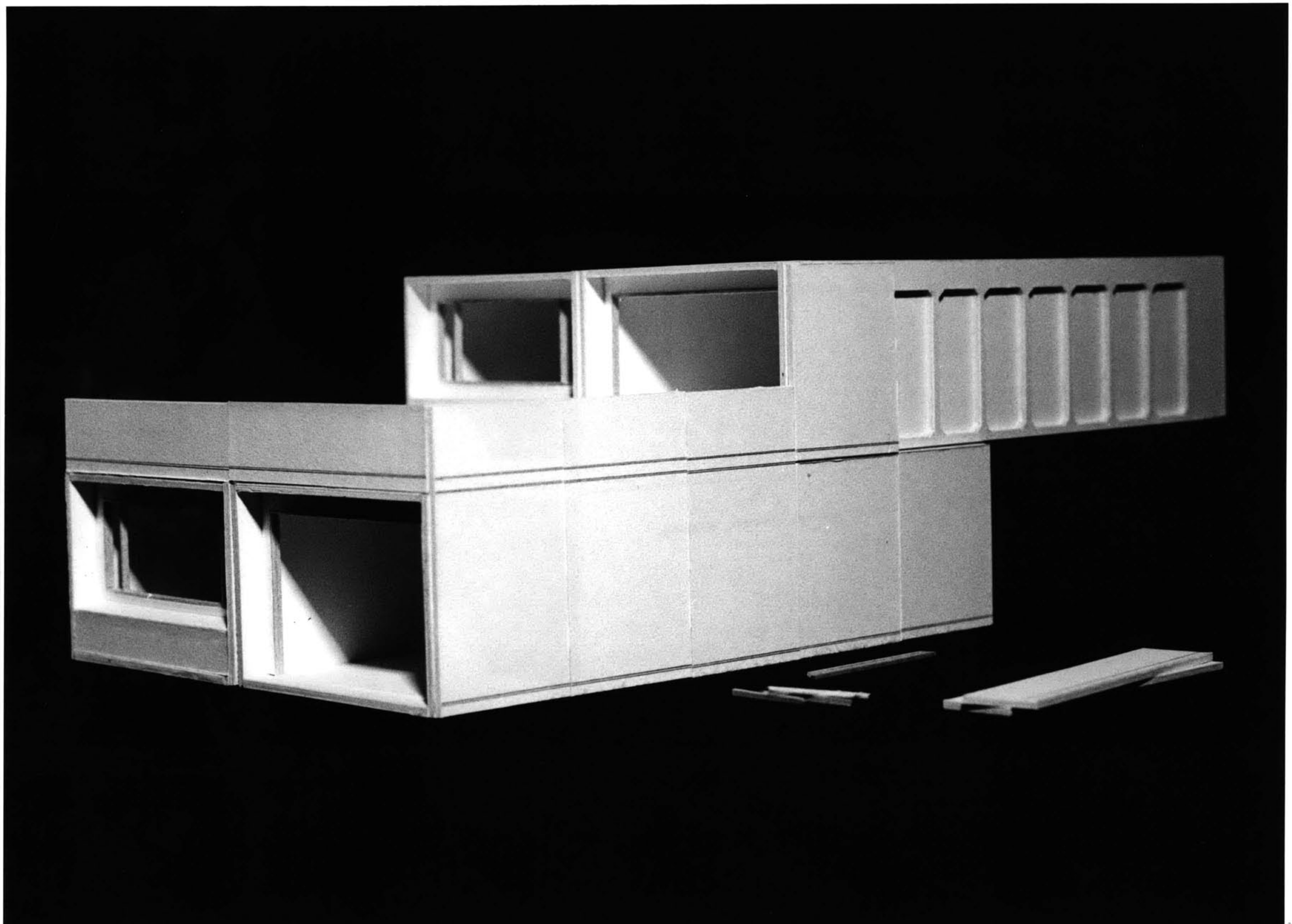


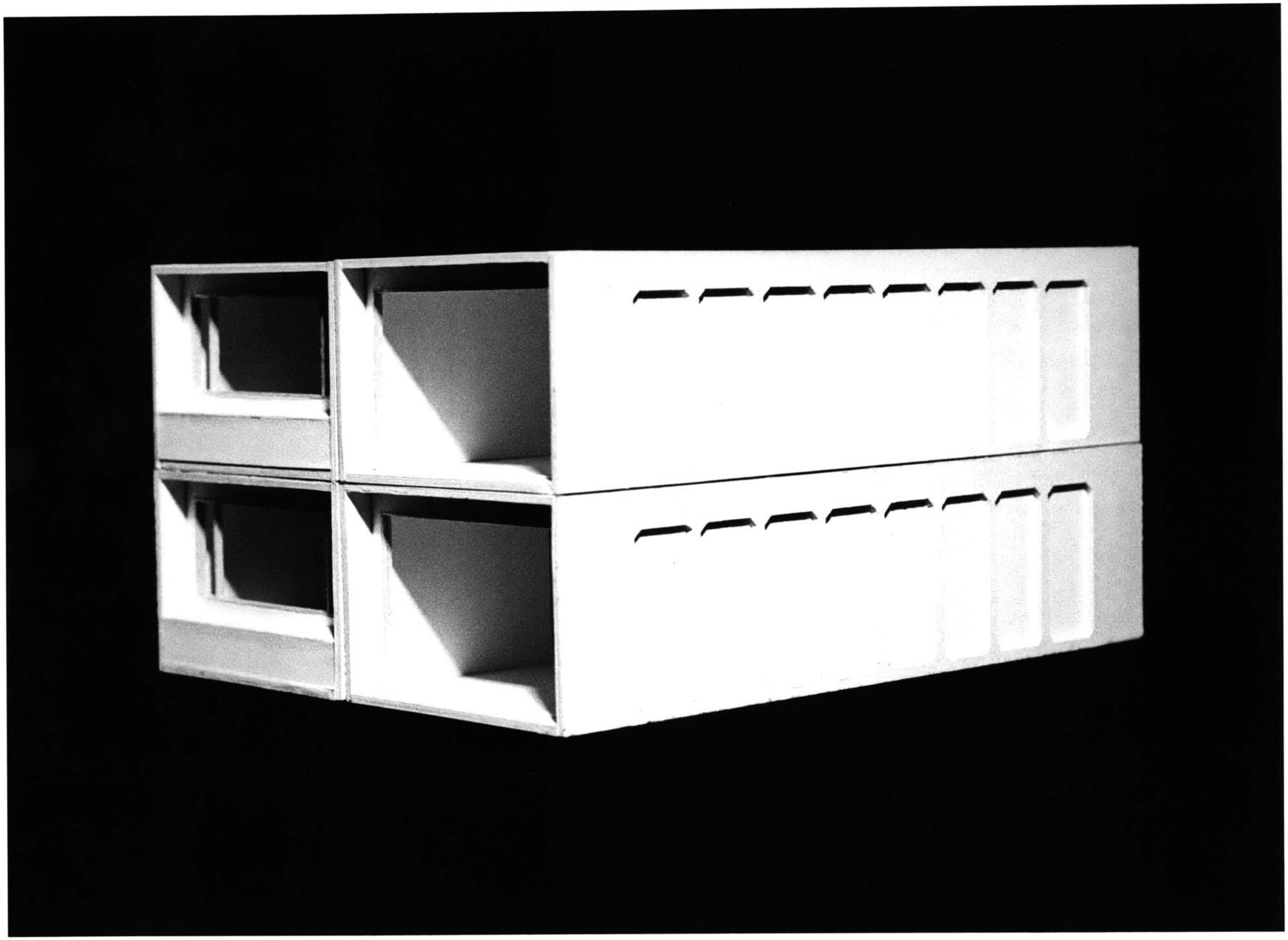


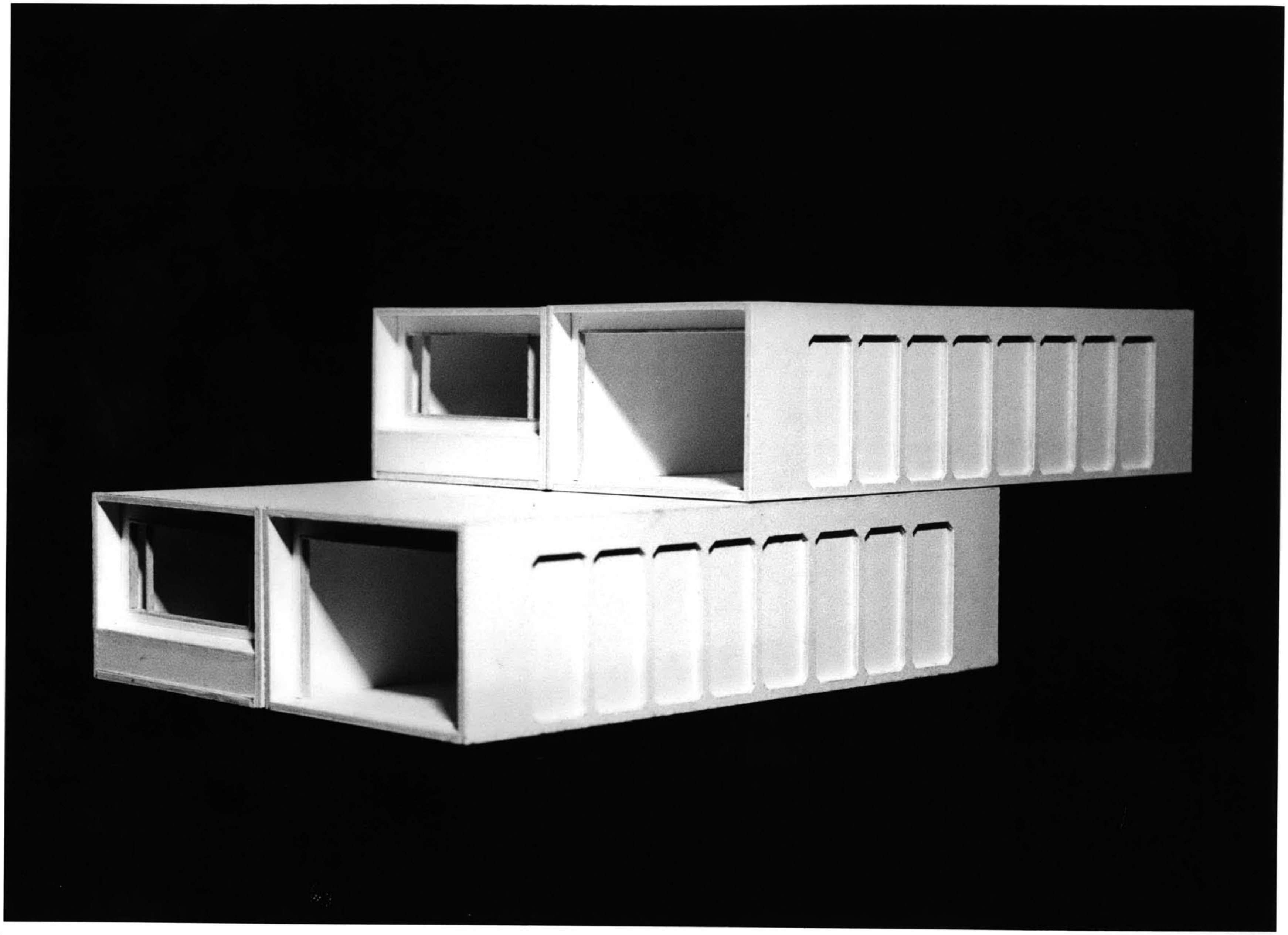


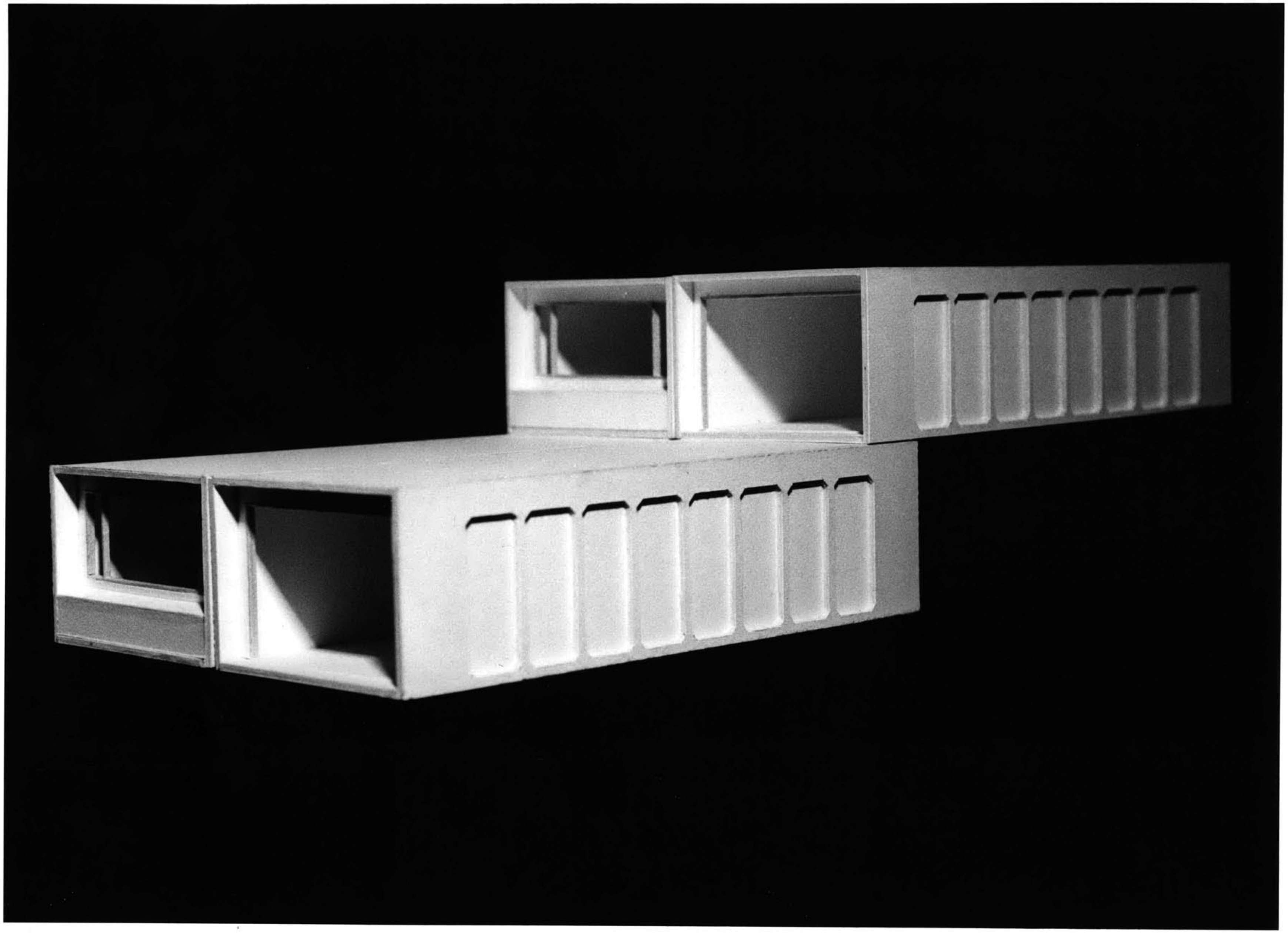


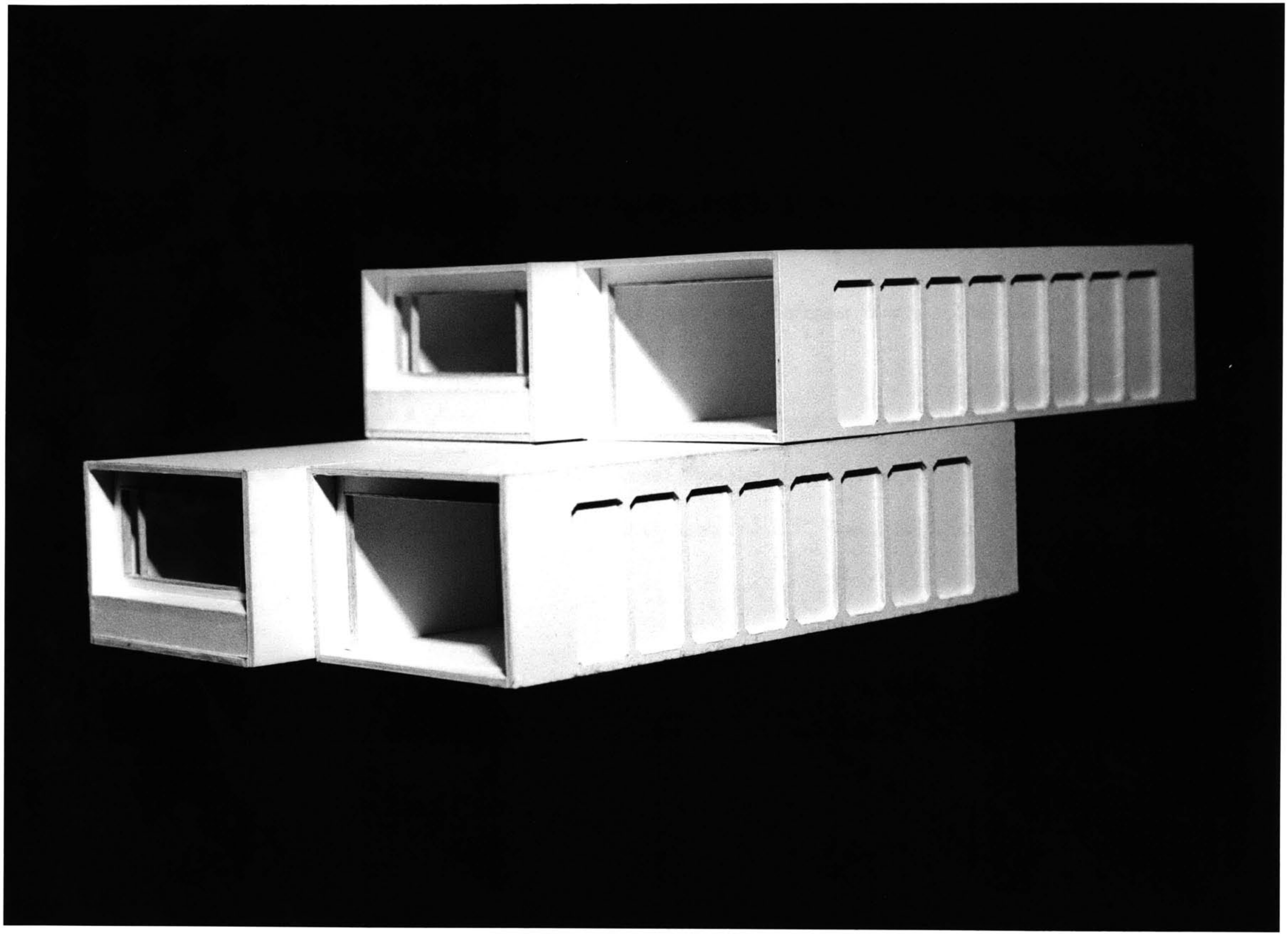












BIBLIOGRAPHY

1. Cornell University, "The New Building Block", Ithaca, New York: Cornell Press, 1969.
2. Dietz and Cutler, Industrialized Building Systems for Housing, M.I.T. Special Summer Session 1969 & 1970. Cambridge, Massachusetts, M.I.T. Press, 1971.
3. M.I.T. 1969 Department of Architecture Research Project with Professor Waclaw Zalewski, "Building on Slopes: An Approach", Limited published report.
4. M.I.T. 1971 Department of Architecture Master's Class with Professor Eduardo F. Catalano, "Housing Systems: Seven Studies for Factory Produced Concrete and Steel Modular Units", Limited published master's thesis, M.I.T.
5. Safdie, Moshe, Beyond Habitat, Cambridge, Massachusetts, M.I.T. Press, 1971.