


BUILDING SYSTEM NO. 420
by
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B.S., B. Arch. Rensselaer Polytechnic Institute
1971
SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF
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June, 1975

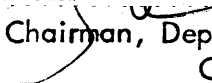
Signature of Author

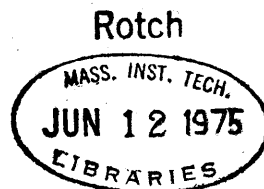
 Department of Architecture
May 9, 1975

Certified by.....

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Thesis Supervisor

Accepted by.....

 Chairman, Departmental
Committee



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SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE ON 9 MAY 1975, IN PARTIAL FULFILLMENT
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This thesis shows a structural steel building system with non-structural panel infills of walls and floors for low-rise housing. It shows the structural system and its components, the mechanical systems appropriate to it, various possible unit plans for apartments and townhouses (or duplex apartments), and site plans showing actual buildings and the different ways in which they can be used. The apartment buildings are low-rise, small-scale units intended for non-urban sites and the townhouses (duplex units) for the same and possibly even less dense situations.

Thesis Supervisor: Eduardo Catalano
Title: Professor of Architecture

TABLE OF CONTENTS

	page
TITLE PAGE	1
TABLE OF CONTENTS	2
INTRODUCTION	3
STRUCTURAL/COMPONENTS	6
Structural System	7
Details	13
Kitchens/Baths	20
MECHANICAL	22
Heat Loss Calculations	24
Plumbing	27
Hot Water Heat	29
Fan Coil Units	30
Electrical	32
UNIT PLANS	33
Apartments	35
Townhouses	42
SITE PLANNING	55
CONCLUSION	69
PHOTOGRAPHS	70

INTRODUCTION

INTRODUCTION

The basic intention of this building system is to provide an amenable living space with a simple, easily understood (both in concept and constructability) and economically feasible assemblage. It is not meant to be an aardvark in terms of marketability or methodology; all phases should be an orderly assemblage of correlated members which are currently acceptable in ideology and actual content to standard methods of production, construction, marketing, and appeal. There is a concern shown for adaptability and versatility in that many kinds of designs and living situations can be accommodated with this system including apartment complexes, condominiums and/or rental units, townhouses and single-family detached houses, but it is not meant to be used for high-rise, very high density or ultra-urban situations. Each unit including apartments, can be, though not necessarily will be, self-sufficient in terms of mechanical systems; this gives the builder/owner a choice of whether or not to use central or owner-paid utilities. It also makes condominium construction and marketability greater and allows rental apartment units to be later adapted to condominium use. There is also a concern shown for energy consumption as people tend to be much more conscientious about using less energy if they must absorb the cost. Each unit can be individually metered and operated as the tenant desires, but the availability and desirability of using central HVAC systems in certain cases, especially apartment complexes, is also present. Another factor is the climatic conditions in which the buildings are placed; this

determines the necessity for AC, amount/deviation of use and therefore the most desirable unit type in terms of efficiency and cost. The economic level of tenant/owners also affects the type of system(s) which are available to them; the higher the cost of the unit, the more sophisticated the equipment and functioning must be.

This building system demands no high-capital-input in tooling-up the factory. Although most of the system is factory-produced, none of the components require heavy expensive equipment for their manufacture; rather, they rely rather heavily on an orderly process of labor, the use of jigs and hand tools, mass production and storage. Some, but not all, of the stored components must be weather-protected (kits, baths, stairs, etc.) which requires a large indoor area.

Because this system is not completely factory-produced, it provides some jobs for the community in which it is to be built. This is important for acceptability by the community, which is a problem for "systems" buildings because they tend to be foreign to the community and there is little effort to accommodate local needs and desires. To finish one of these buildings would require local carpenters, concrete workers or masons, roofers, dry-wallers, painters and plumbers, and would not be erected so quickly as to give no time for the community to accustom itself to it (as they can with stick-built construction) and see that it is not alien or freakish.

CODE INFO.

It is hoped that the construction and character of the buildings resulting from the use of this system will fulfill multifarious human needs. The primary market at which it is aimed is North American middle to upper-middle class and family-oriented. The basic provision for these people is shelter, protection from weather and other adverse elements. More than that, it is also meant to provide a home and a beneficent environment to the extent that architecture is able to provide or aid in the establishment of these things. The scale is kept to three stories, maximum, because it is felt that people, especially families and children, can better relate to a smaller scale and are more psychologically comfortable at this level. There is a unity at the street and community level brought about by the use of the same materials in such things as siding, windows, roof, and walkways. There is also diversity at this scale as the units are not all the same, exterior spaces vary greatly and such elements as entries, decks, plantings, and fences tend to be individualized rather quickly by the owners. Orientation of the units is extremely important and should be carefully considered on any real site plan. Outdoor areas, spaces between buildings, and the sequence of spaces leading to buildings should all relate to the scale of the area and the appropriate function of that area. Especially spaces leading to entries should help break down the scale and provide a psychological as well as a physical transition between outside and inside.

Use Group L-2 and L-3, noncombustible unprotected Type 2 construction.

HEIGHT LIMITATION - 3 floors or 40'-0"

AREA LIMITATION - 9,600 sq. ft./floor

VENTILATION: Toilet rooms: ext. window of 3'-0" sq. ft. area or mech. vent. 24 cu. ft./min.; common hallways: windows to ext. or mech. vent systems.

EXITWAYS: 25 people per unit width of exitway enclosure (22") but min. 44" stair and 32" door; at least one enclosed interior stair with access length not more than 50'-0"; all non-combustible construction.

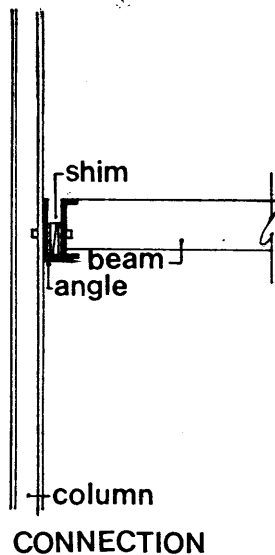
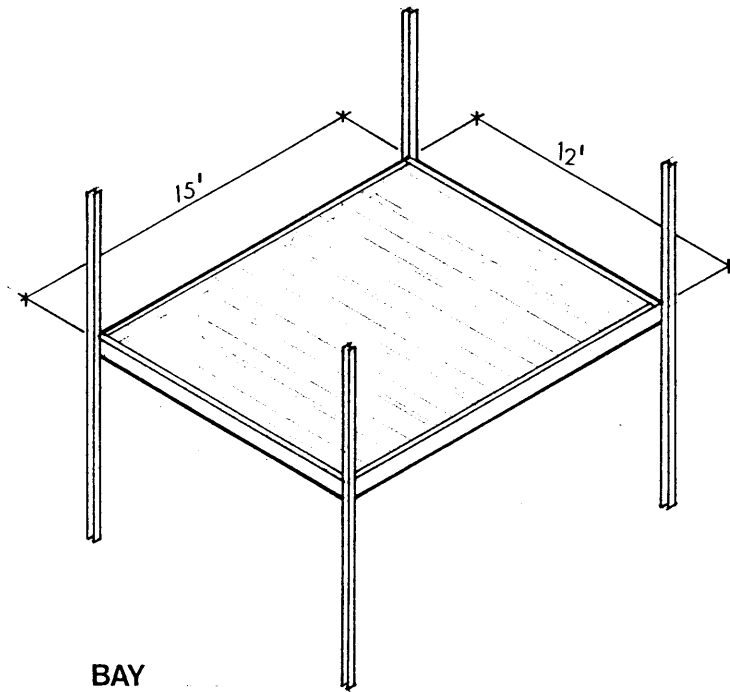
FIRE:

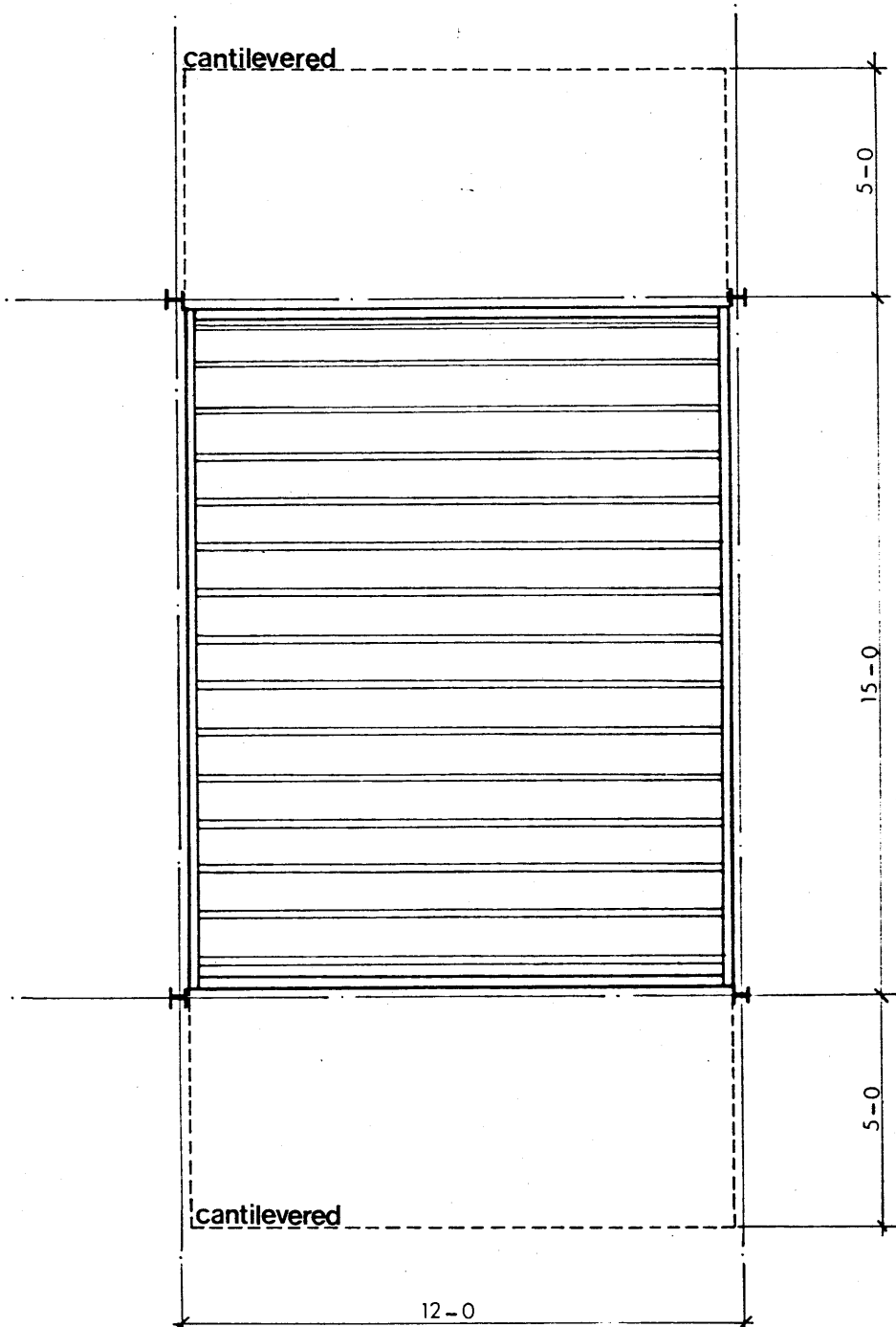
<u>member</u>	<u>provided</u>	<u>required rating</u>
exit halls and stairs	2	2 hrs.
vertical separation of tenant spaces	3/4	0 hrs.
columns	3/4	0 hrs.
roof	3/4	0 hrs.
vertical shafts (common)	2	2 hrs.

STRUCTURE / COMPONENTS

SYSTEM

The actual building system consists of a steel frame rigidized by floor panels with wall panel infills. The steel frame is made up of 4" H-columns 2 or 3 stories high (full height of the building) with beams in two directions which form the edges of the floor panel. The remainder of the floor panel is 6" deep metal decking which spans 12' and is covered with 3/4" fire-retardant plywood. The connection of the beams to the columns is the same in both directions and is a bolted connection at the corner of the column to a plate welded to the column and bolted through the edge beam. The wall panels are metal studs covered on the exterior with 3/4" textured plywood and vapor barrier and on the interior with 1/2" rigid insulation (blanket insulation between studs may be added for cold climates). Half-inch gypsum wallboard is added on-site as the interior finish. The ceilings (GWB) and finish floors (carpet, wood, tile, etc.) are also done on-site. There is a wind-bracing element of heavy-gauge steel shipped in the corners of the wall panels to be connected to the column and bottom of edge beam on-site. The wall panels themselves are bolted to the edge beams of the floor panels through an angle which runs the full length of the panel top and bottom.





COLUMN:

- WEIGHT: 75 lbs./ft² dead load + live load.
- AREA: 12'-0" x 15'-0" = 180 sq. ft. @ 75 lbs./ft² = 13,500 lbs.
- HEIGHT: One column supports 3 floors, @ 8'-0" unsupported length; 13,500 x 3 = 40.5 kips.
- CHOICE: 4" x 4" misc. section @ 13 lbs./ft. effective klr ratio 9'-0" can support 42 kips.

DECKING:

Max. allowable deflection is L/30 or 12'/30 or 2/5", span 12'-0"

CHOICE: 6" deep non-acoustical roof deck, 20 gage, 57 lbs./sq. ft., spans 23'-1"

$$E = 29 \times 10^6 \text{ PSI}$$

$$I = 9.82 \text{ in}^4$$

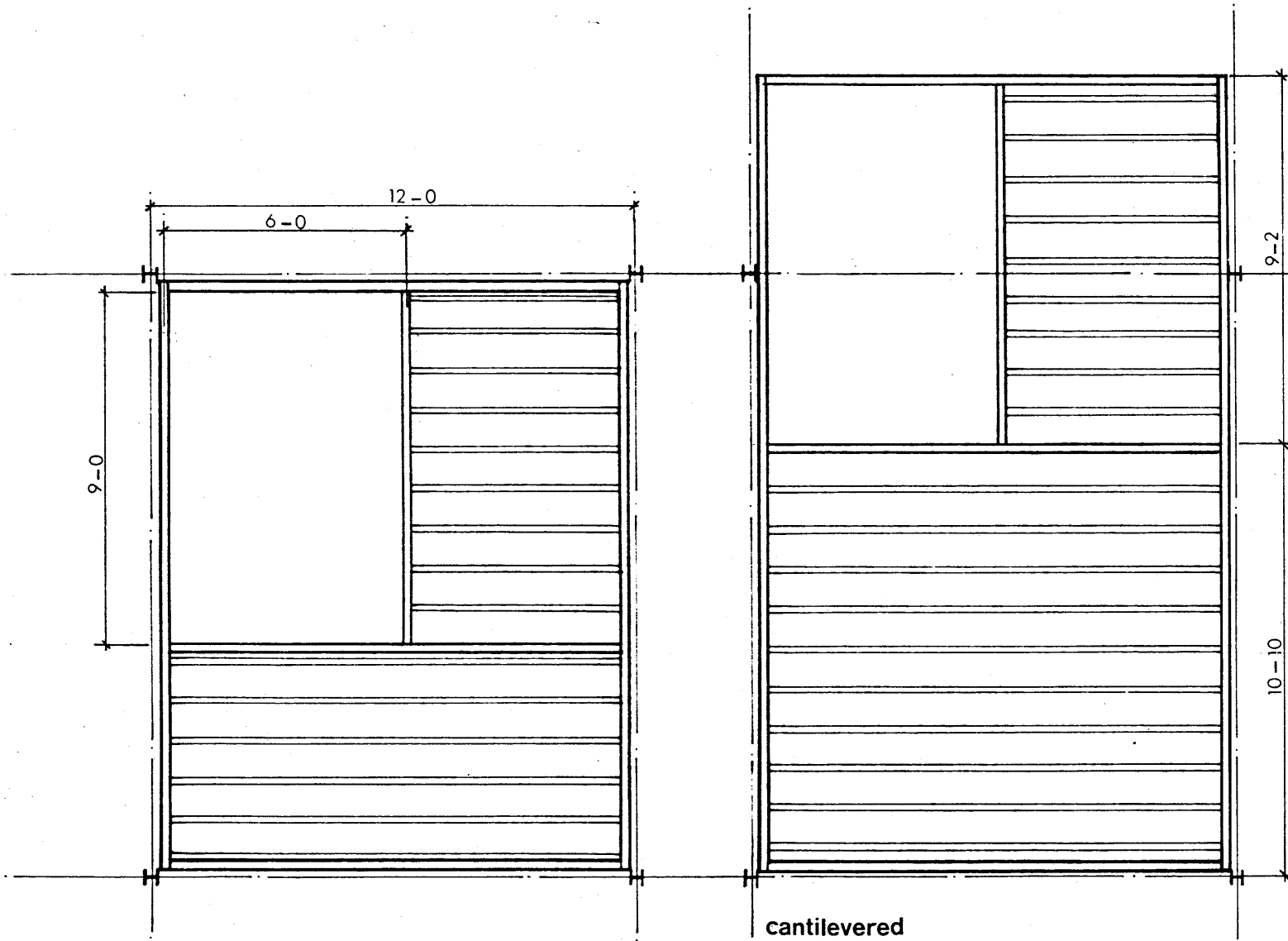
Deflection (critical design factor):

$$d = \frac{5WL^4}{384EI}$$

$$d = \frac{5 \times 75 \text{ lbs./ft}^2 \times 12'^4}{384 \times (29 \times 10^6) \times 144 \times 9.82}$$

$$d = .005 \text{ IN.}$$

STRUCTURAL BAY



EDGE BEAM:

SECTION MODULUS
CALCULATION:

$$75 \text{ lbs./ft}^2 \times 6' \text{ (length)} \\ = 450 \text{ lbs./lin. ft.}$$

Free supported

$$M = WL^2/8$$

$$M = 450 \times 15^2/8$$

$$M = 150k\text{-in.}$$

$$S = M/f \text{ allowable}$$

$$S = 150/24 = 6.25 \text{ in}^3$$

CHOICE:

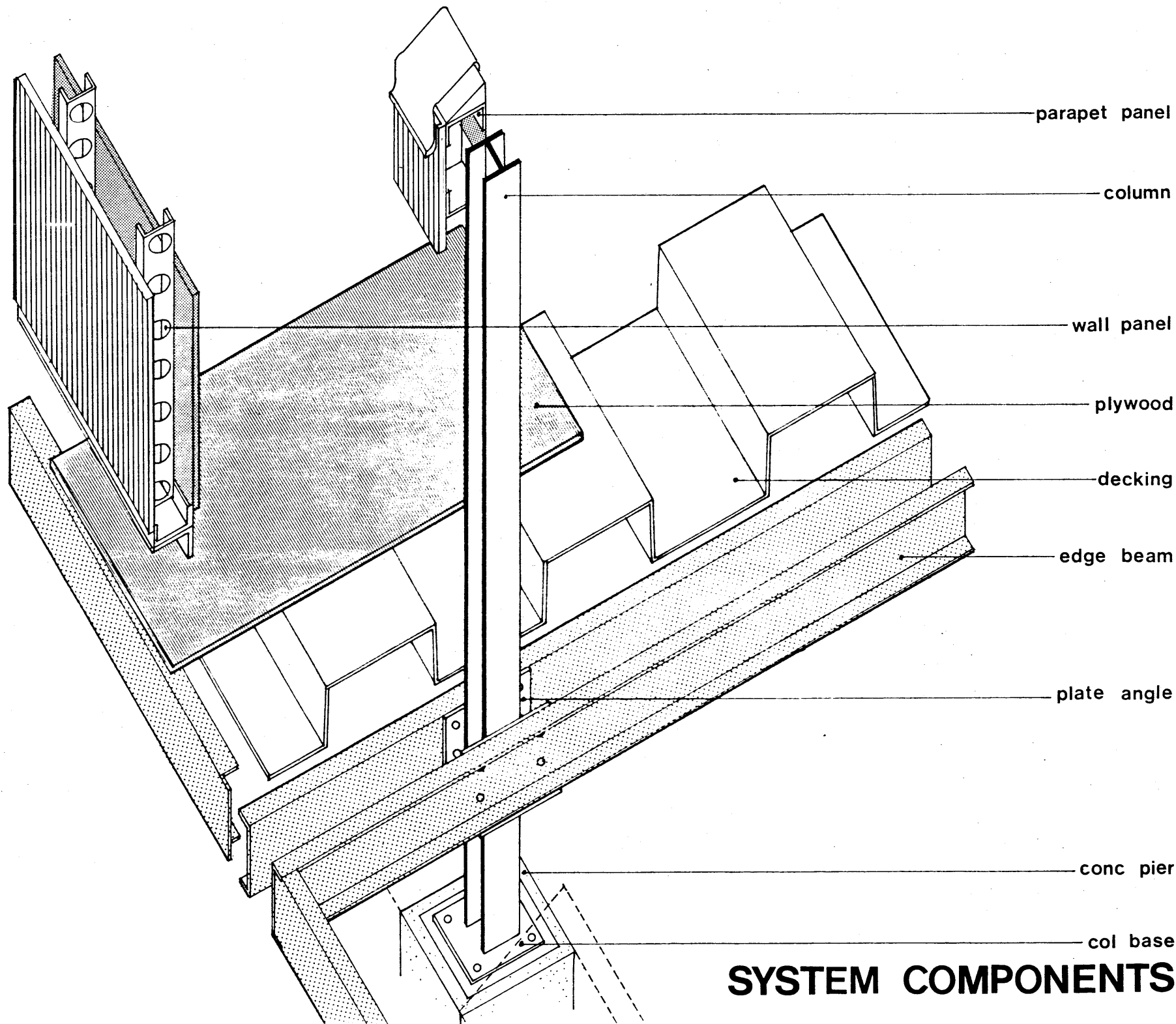
Section of 7" x 2 1/8"
has S of 6.9 in³

FOR INTERIOR BEAMS:

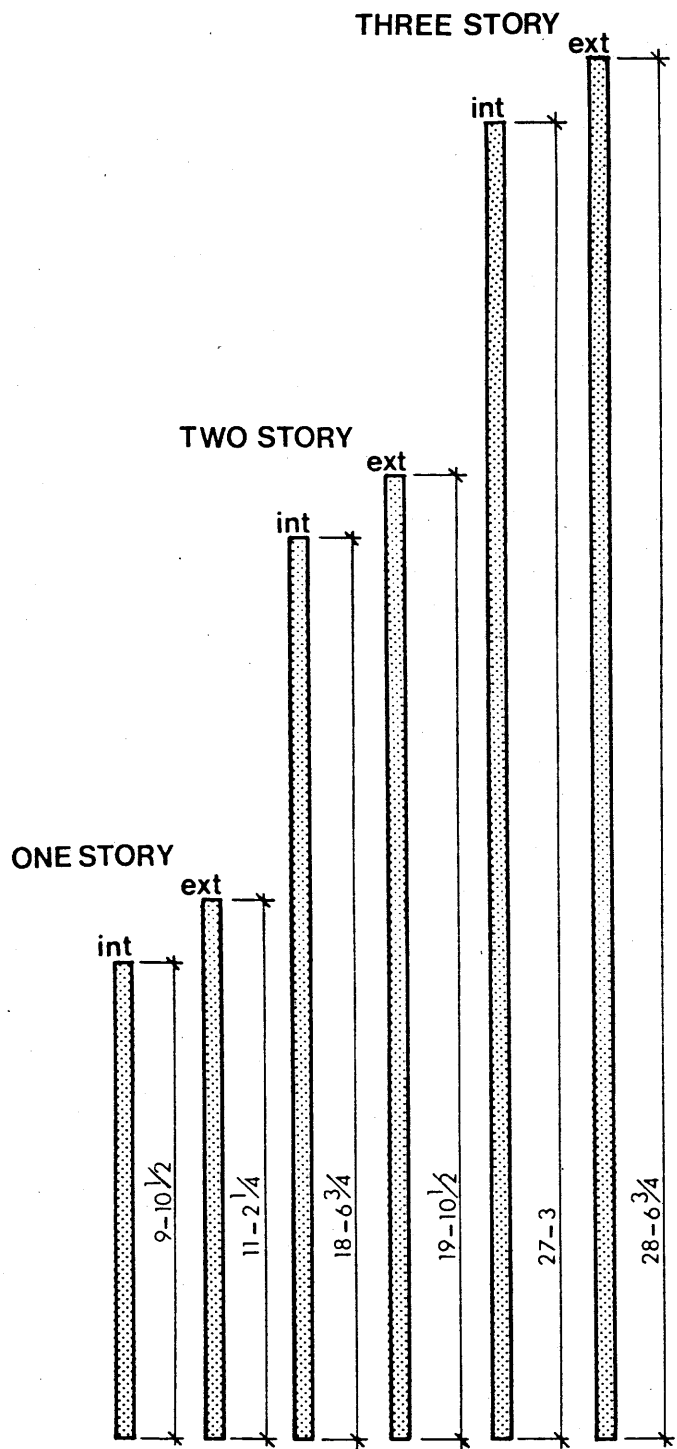
$$6" \times 2"$$

$$S = 6.00$$

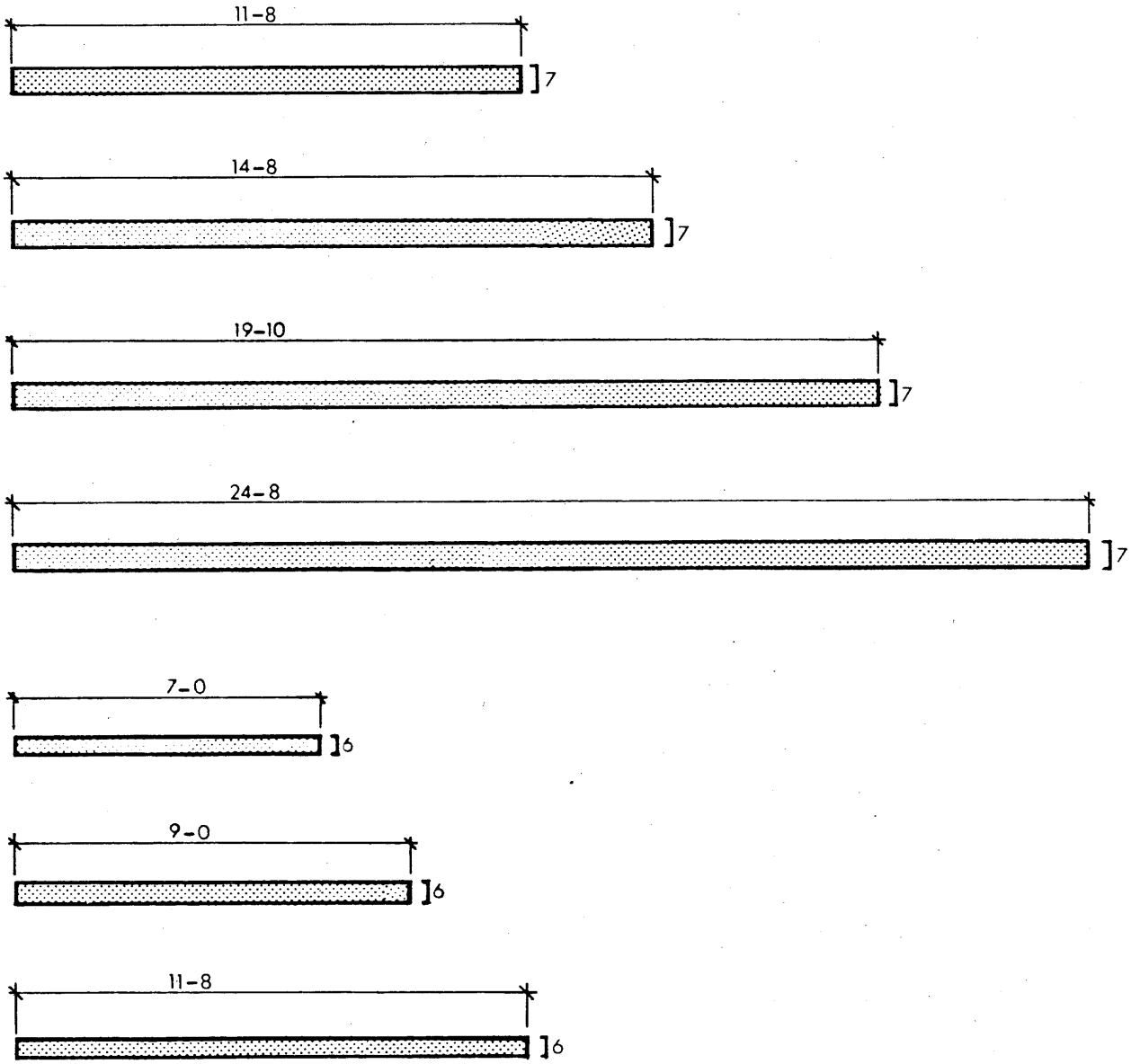
STAIR OPENINGS



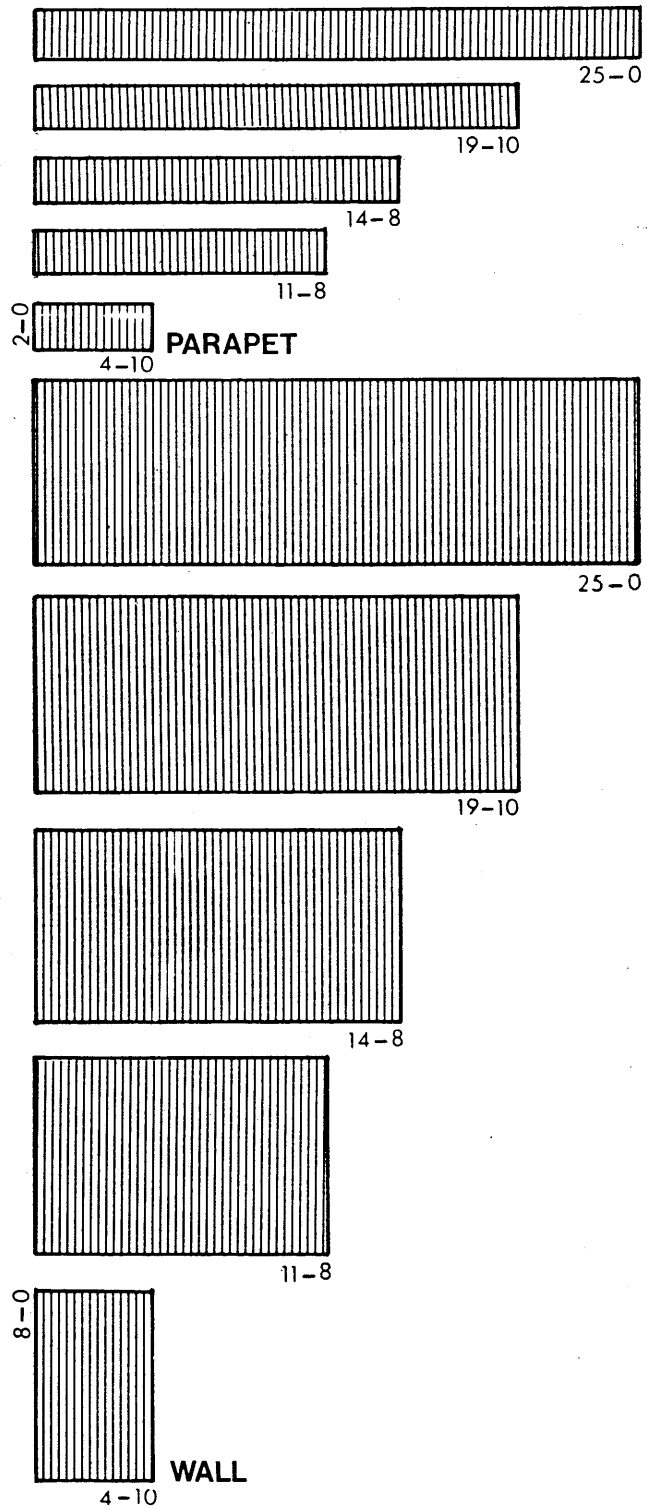
SYSTEM COMPONENTS



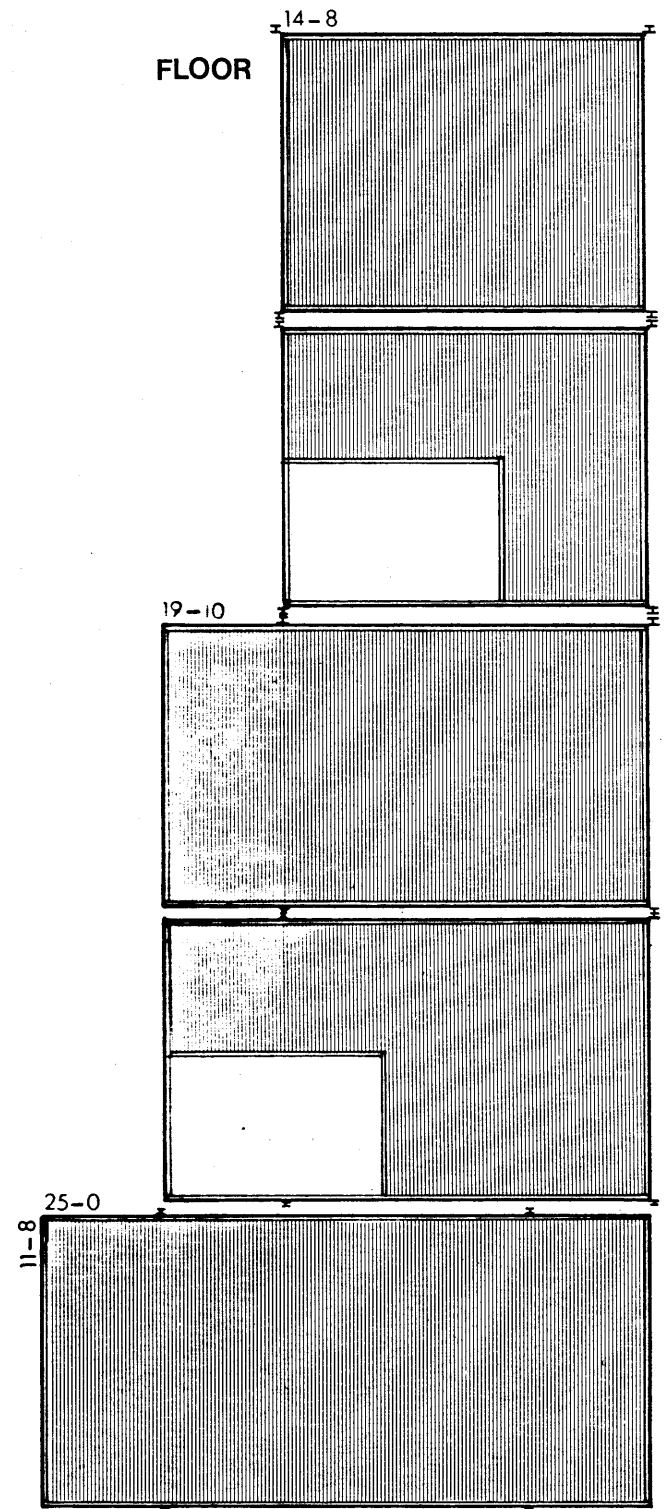
COLUMNS

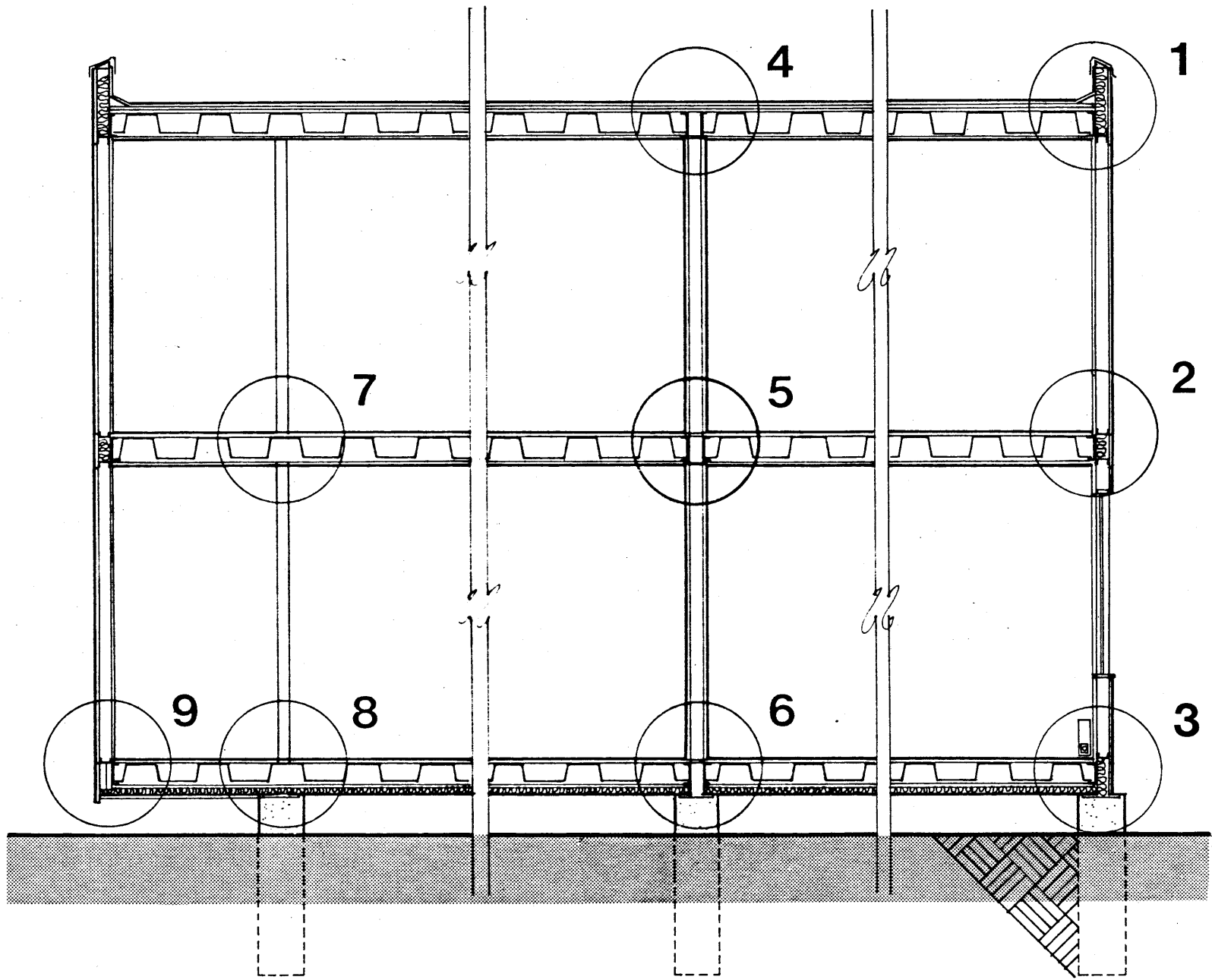


BEAMS



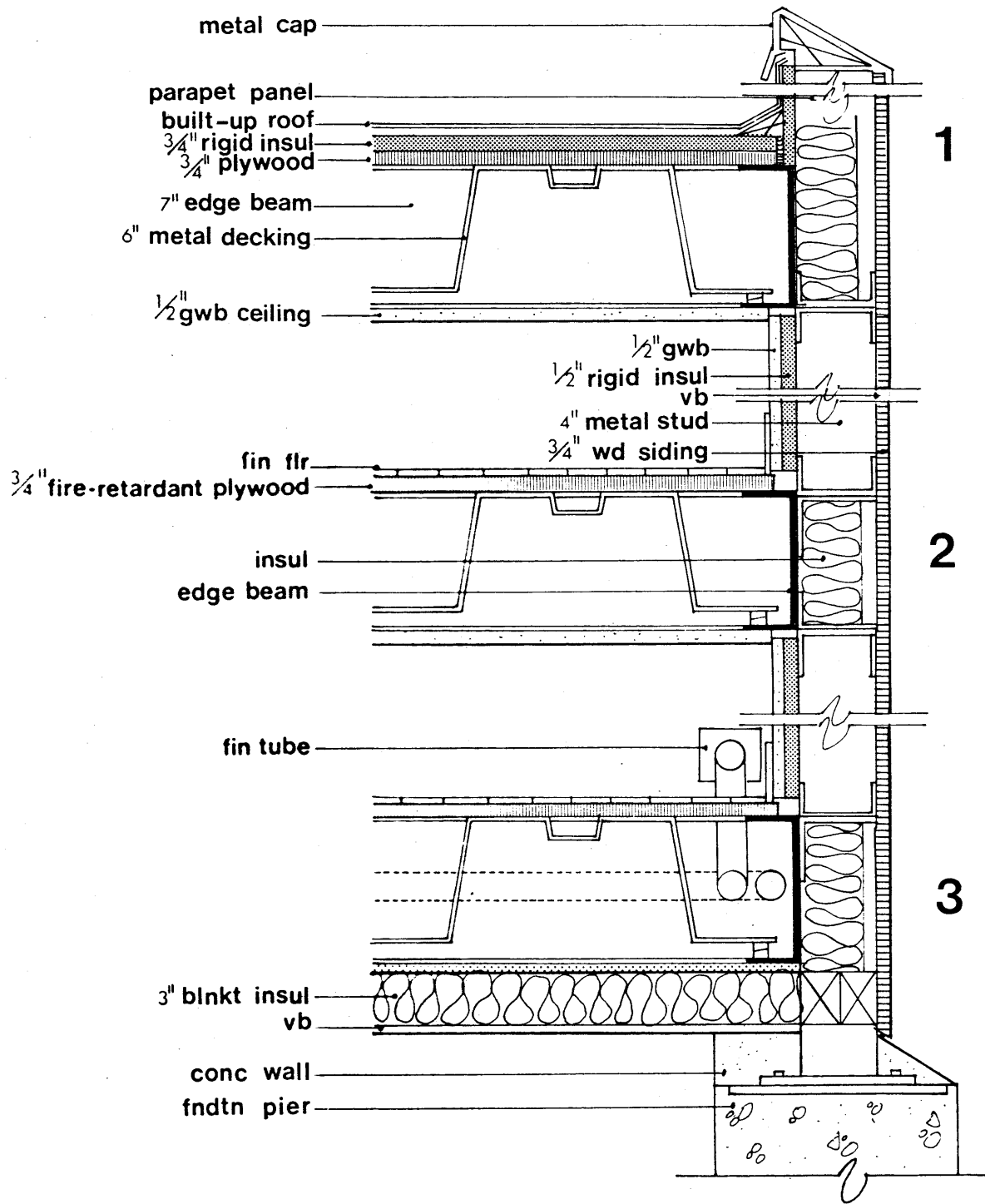
PANELS





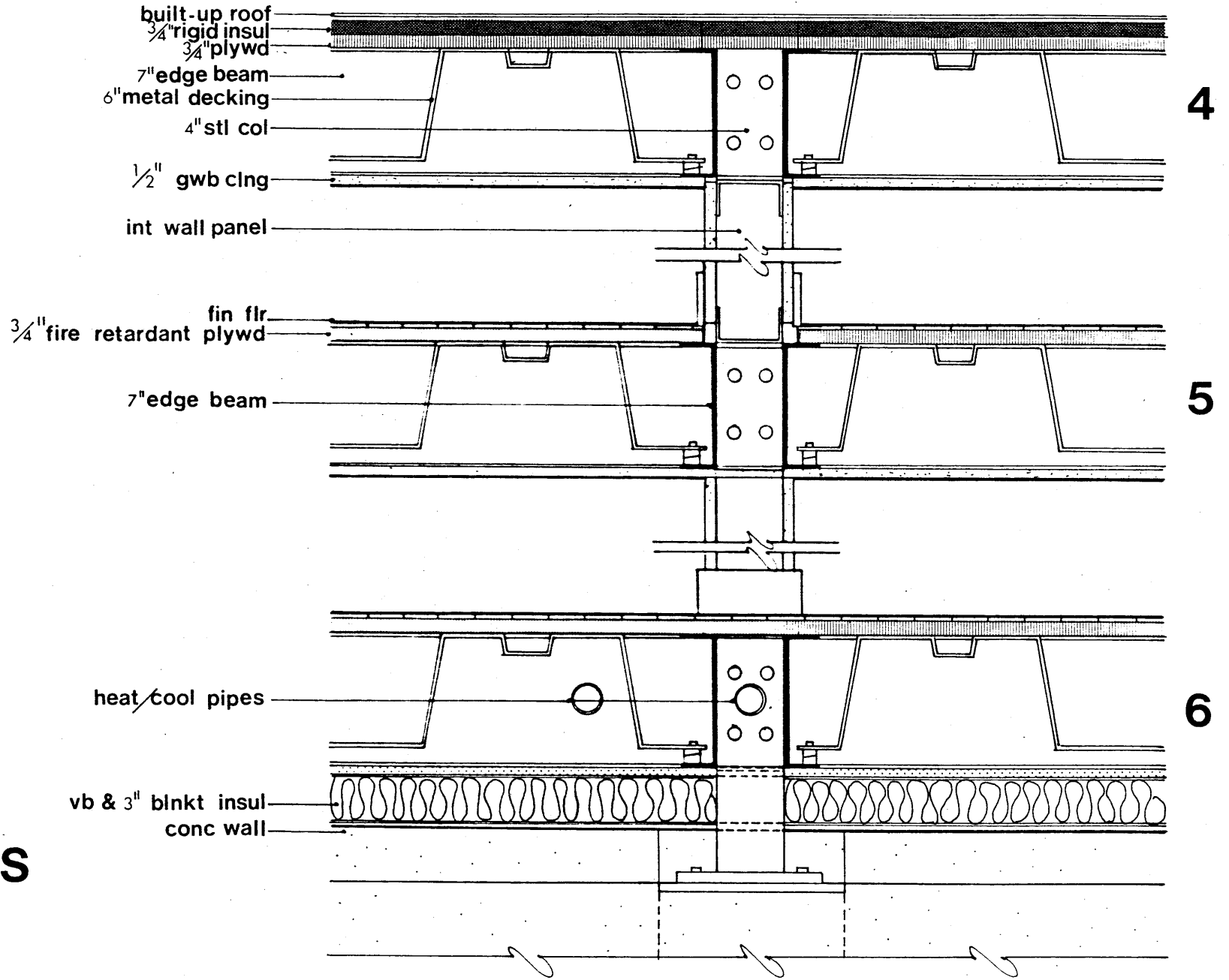
$\frac{1}{4}'' = 1'-0''$

DETAIL REFERENCE



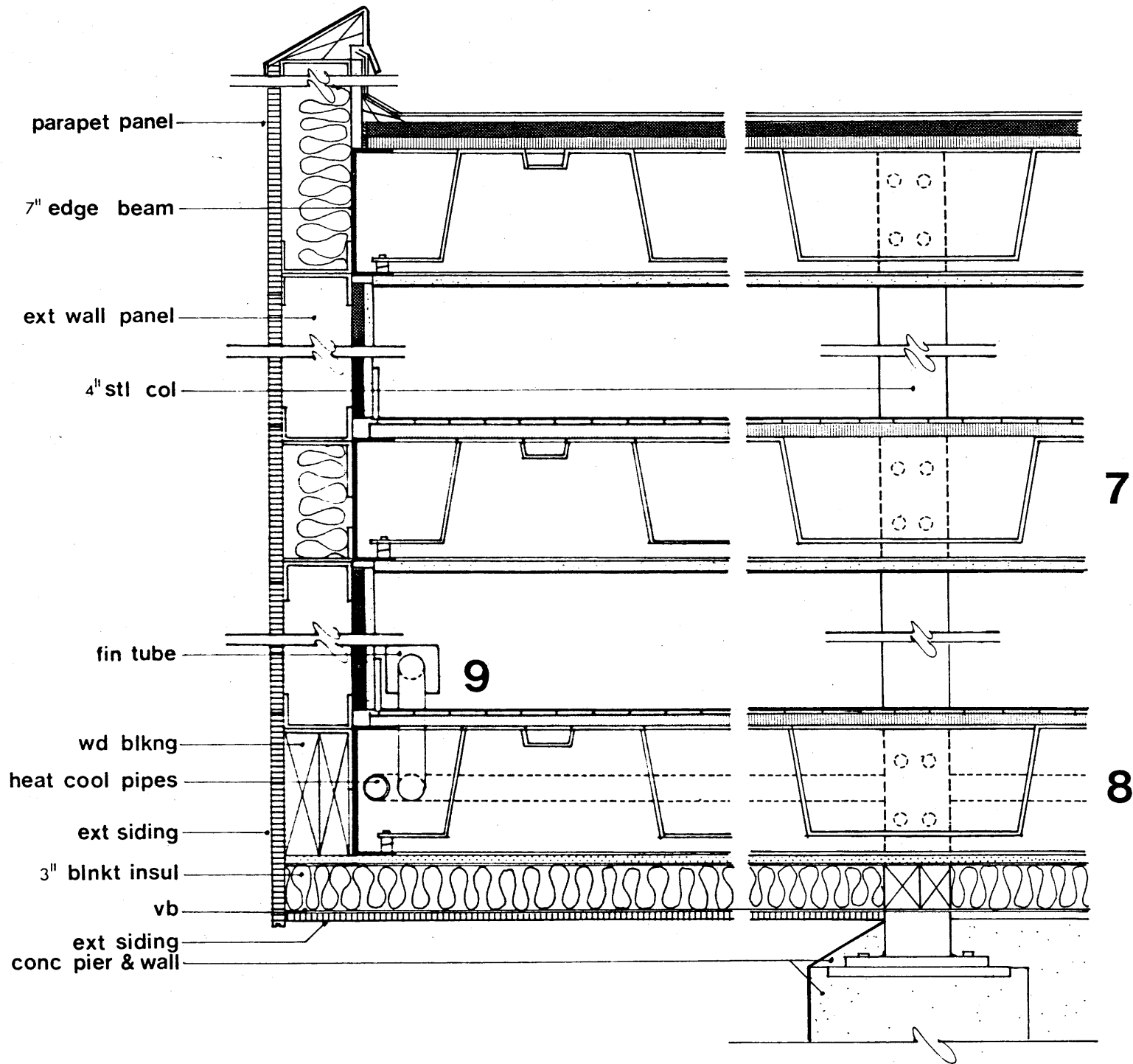
DETAILS

1-1/2" = 1'-0"



DETAILS

1 1/2" = 1'-0"

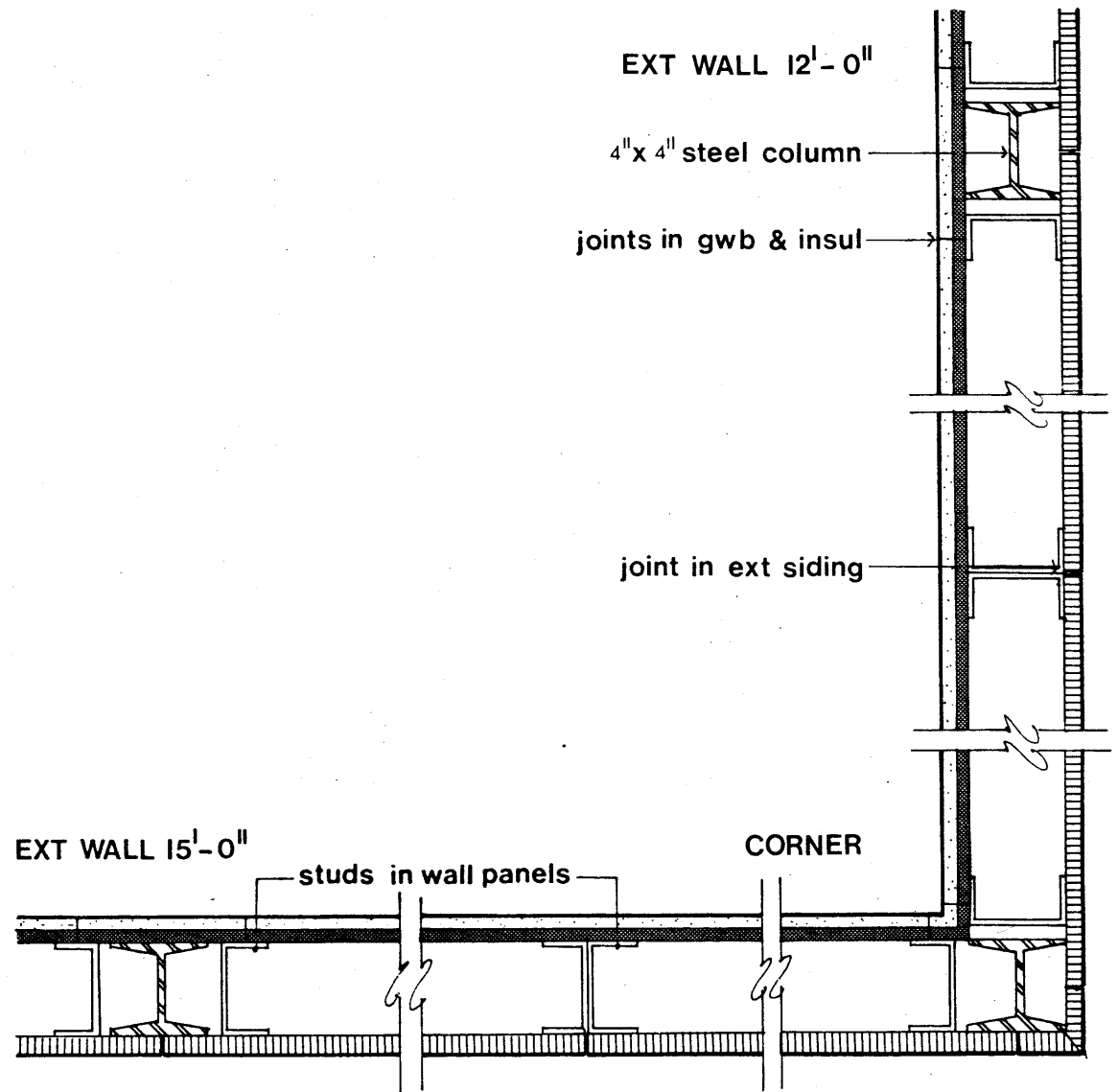


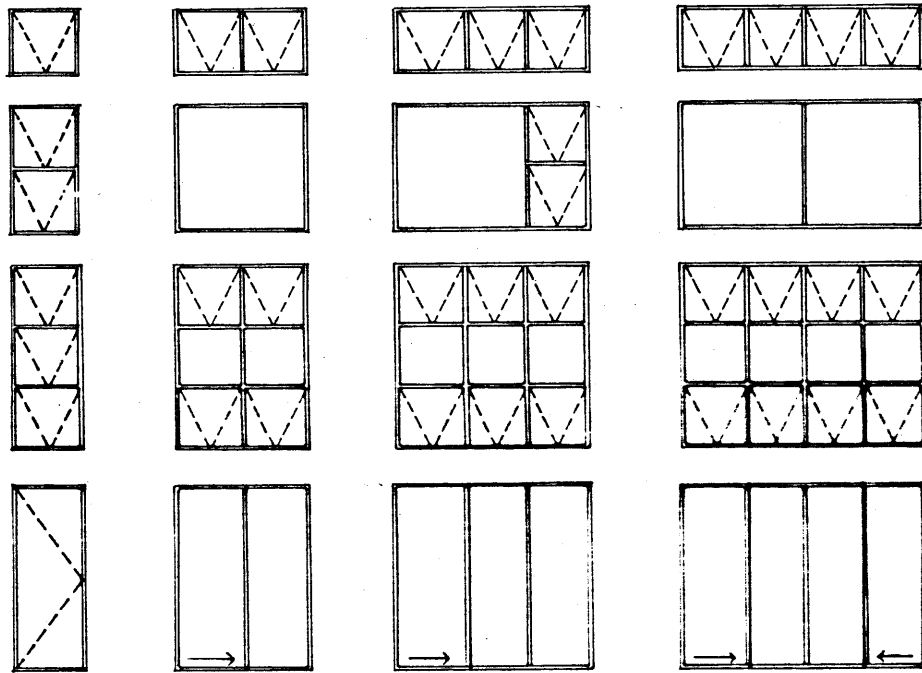
DETAILS

1 1/2" = 1'-0"

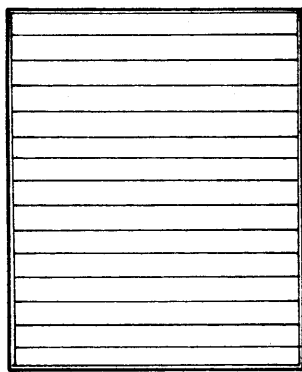
PLAN at COLUMNS

$1\frac{1}{2}'' = 1'-0''$

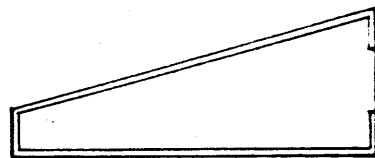




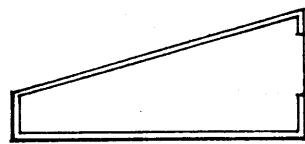
WINDOWS



plan

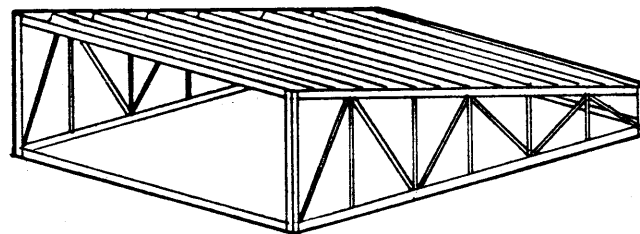


15-0

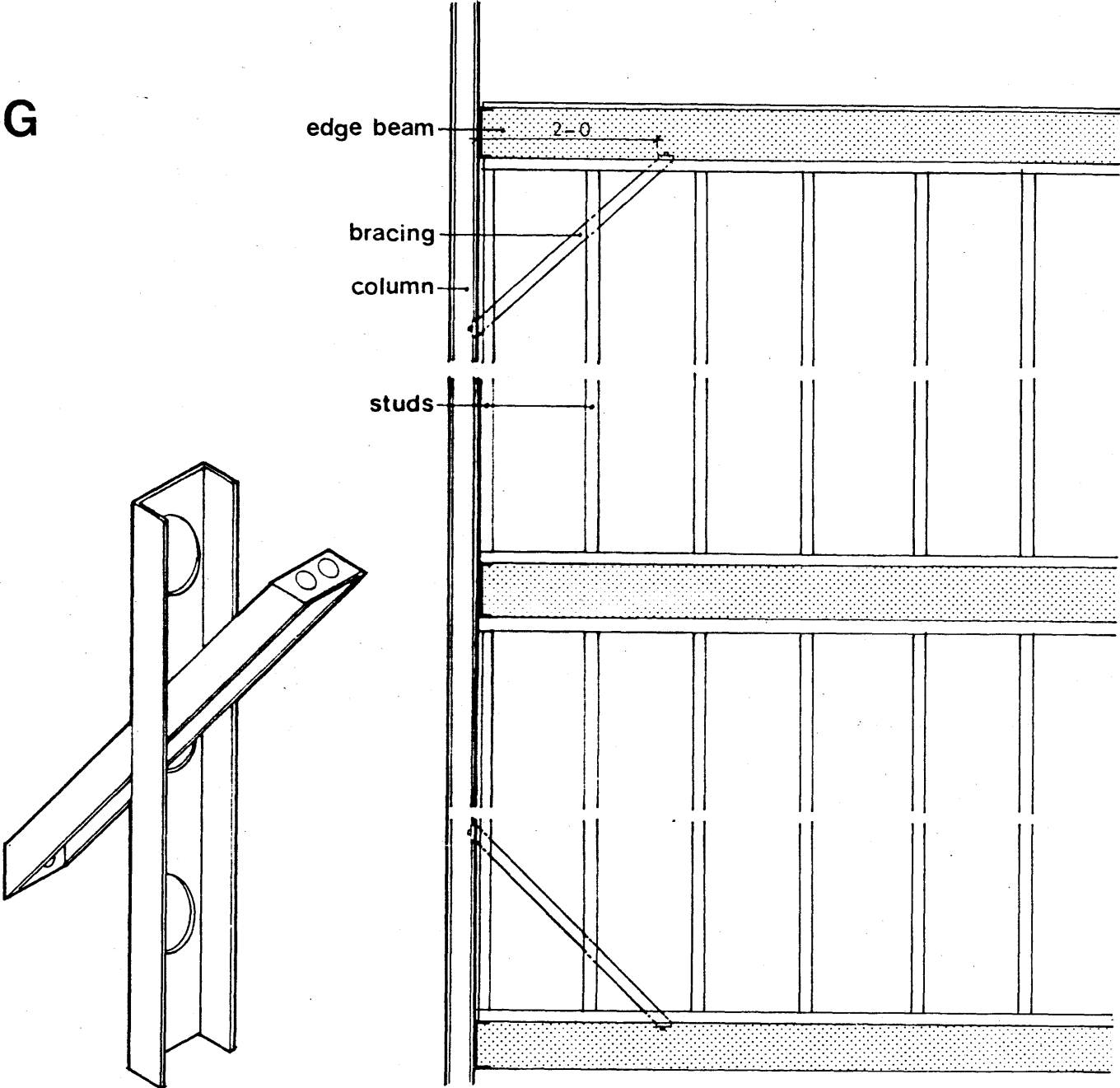


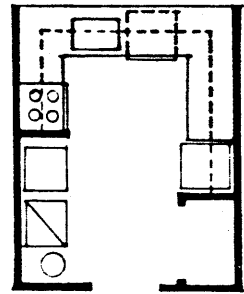
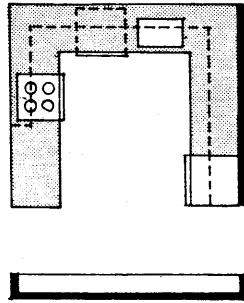
12-0

PITCHED ROOFS

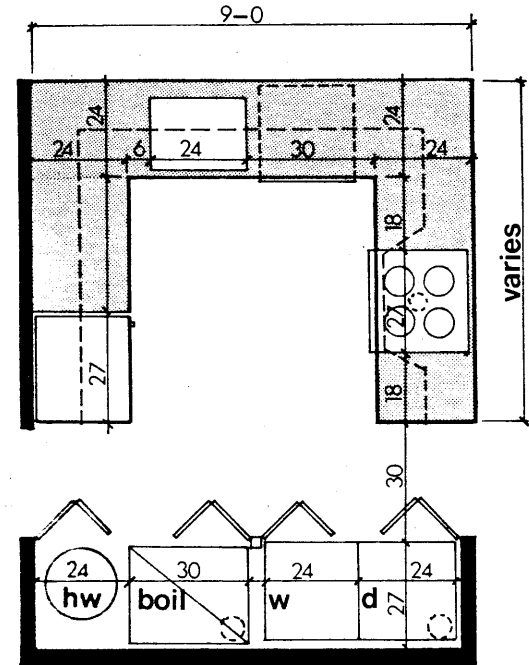
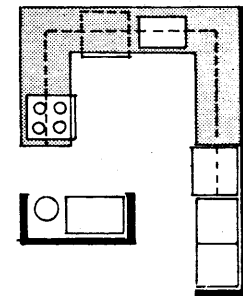
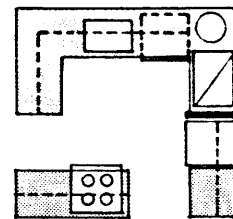
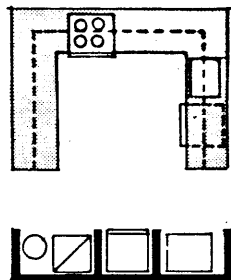


WIND BRACING



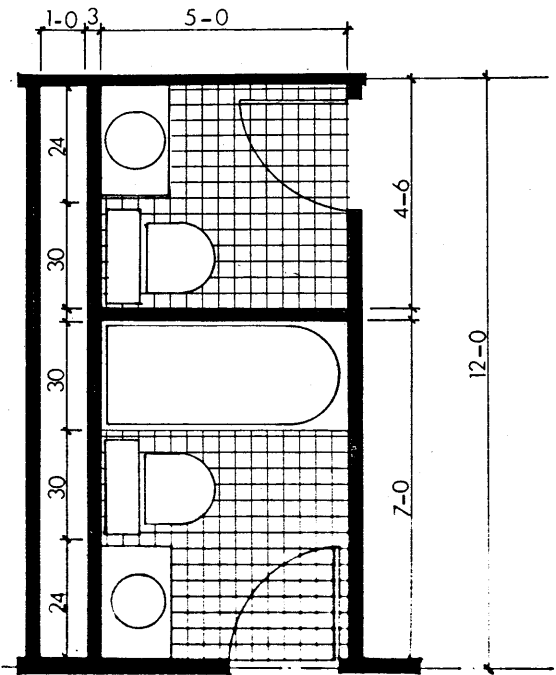


VARIATIONS

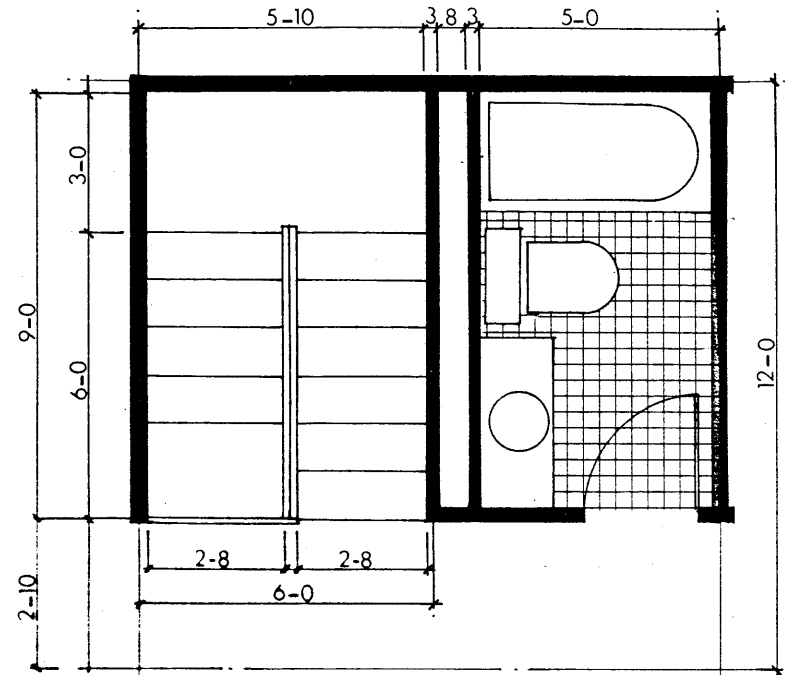


BASIC KITCHEN & UTILITY CLOSET

KITCHENS

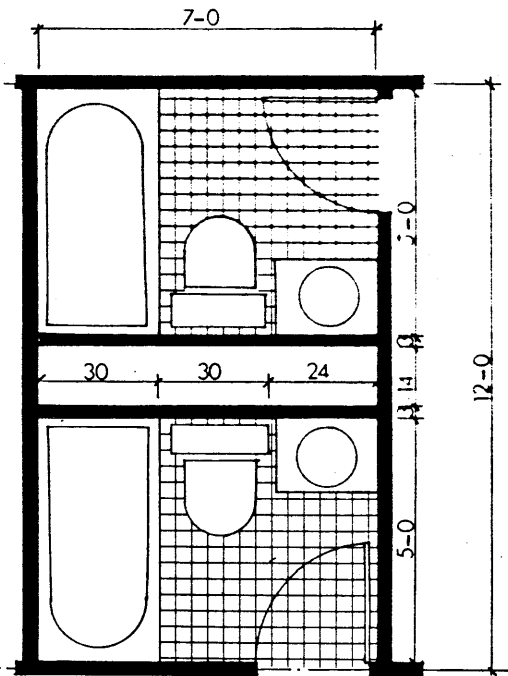


FULL & HALF BATH

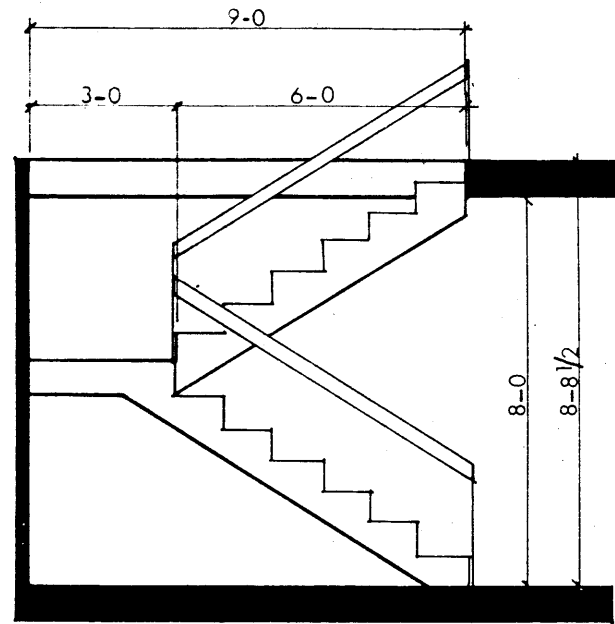


STAIR & BATH

BATHS & STAIR



TWO FULL BATHS



STAIR

FACTORY WORK

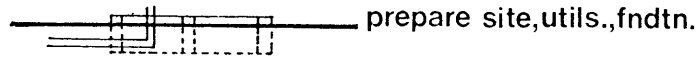
- Cut steel frame members
- Weld and drill for connections
- Fabricate floor panels
- Weld Edge Beams
 - Attach decking
 - Lay on plywood
 - Lay in pipest wiring
 - Insulate/waterproof if necessary
- Fabricate wall panels
 - Stud frame
 - Put on ext. siding and VB
 - Lay in wiring and wind bracing
 - Put in windows
 - Put insul. on int.
 - Attach angles top and bottom
- Fabricate kitchens, baths, closets in boxes for shipment
- Pack for transport

ON-SITE WORK

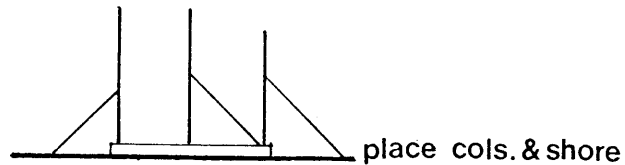
- Prepare site and utilities
- Pour foundation
- Erect columns and shore
- Connect first floor panels
- Set in kitchens, baths, stairs, closets, and utility closets, and int. wall panels
- Connect second floor panels
- Set in ext. wall panels and connect to edge beams
- Connect wind bracing
- Repeat for second and third floors
- Connect all utilities to main
- Connect all wiring, plumbing, and HVAC equip.
- Apply gypsum wallboard to walls and ceilings
- Lay finish floors
- Finish underside of cantilevers
- Finish ext. panels with insul. and siding
- Connect parapets and finish flues and vents
- Apply built-up roof
- Install entries and decks
- Paint
- Test all systems
- Landscape

MECHANICAL

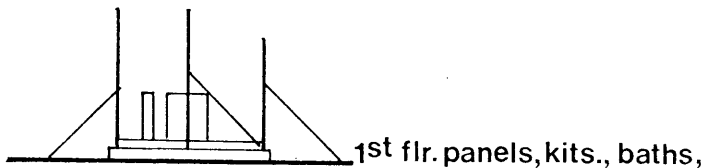
CONST SEQUENCE



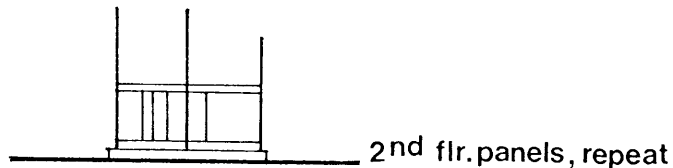
prepare site,utils.,fndtn.



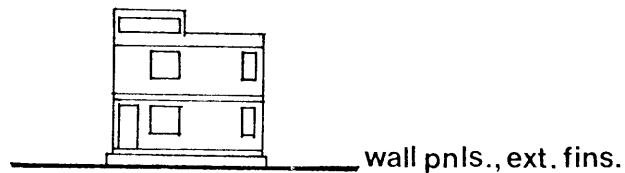
place cols. & shore



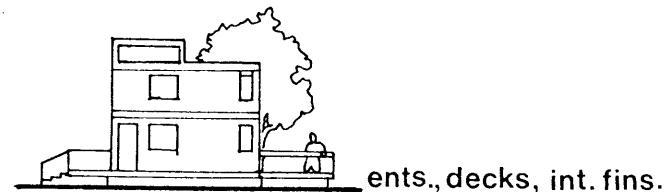
1st flr. panels,kits., baths,



2nd flr. panels, repeat



wall pnls., ext. fins.



ents., decks, int. fins.

MECHANICAL

The mechanical system(s) which (are) integrated into the structural system are all hydronic as the structural system is not designed for ductwork. For cold climates or lower income levels, the system consists of hot-water baseboard heating units and through-the-wall room/area electric air conditioners. There is space for a boiler to supply the heat in each unit or connection to a central system is possible. The AC units fit under the windows in the space they are to occupy and have a grille on the exterior wall through which they draw air. For warmer climates and higher income levels there is provision for a fan-coil HVAC system. These units are individually sized to the space they are to heat/cool, and may be connected to a boiler within the unit but would be more efficient if connected to a central boiler and central chiller, and both options are provided. The mechanical equipment is shipped in a factory-made utility closet and connected on-site. The plumbing and piping for the HVAC may be all done on-site or could be roughed-in in the factory. Also included in the utility closet and shipped complete to the site are the water heater, main electrical box, washer-dryer (most units) either stacking or side-by-side and vents for the boiler and dryer. The utility connections are made on-site to this component.

The other components which are fabricated in the factory and shipped complete to the site beside the utility closet are the baths, kitchens, stairs, closets, entries, and decks (the latter two not delineated here).

HEAT LOSS CALCULATIONS

SPACE	ITEM	AREA	U-VALUE	Δt	HEAT LOSS BTU/HR.
LIVING	WALL	580	.061	70°	2500
	ROOF	160	.12	70°	1350
	GLASS	100	.78	70°	5550
	EDGE	34 x 36	btu/ft.		1225
	FLOOR	250	2btu/sq. ft.		500
	INFIL.	5800 x	.98 x	70°	7300
	Subtotal				18,375
DINING	WALL	146	.061	70°	623
	ROOF	0			0
	GLASS	70 sq. ft.	.78	70°	3812
	EDGE	24 ft. x	36 btu/ft.		864
	FLOOR	140 sq. ft. x	2 btu/ft.		280
	INFIL.	1944 x	.98 x	70°	2450
	Subtotal				8029
KITCHEN	WALL	100	.061	70°	430
	ROOF	0			0
	GLASS	5	.78	70°	253
	EDGE	12 ft. x	36 btu/ft.		432
	FLOOR	130	2 btu/sq. ft.		260
	INFIL.	1296	.018	70°	2450
	Subtotal				3825
STAIR	WALL	324	.061	70°	1384
	ROOF	72	.12	70°	60
	GLASS	0	2		144
	EDGE	18 ft.	36		648
	FLOOR	72	2		0
	INFIL.	1300	.018	70°	1638
	Subtotal				3874

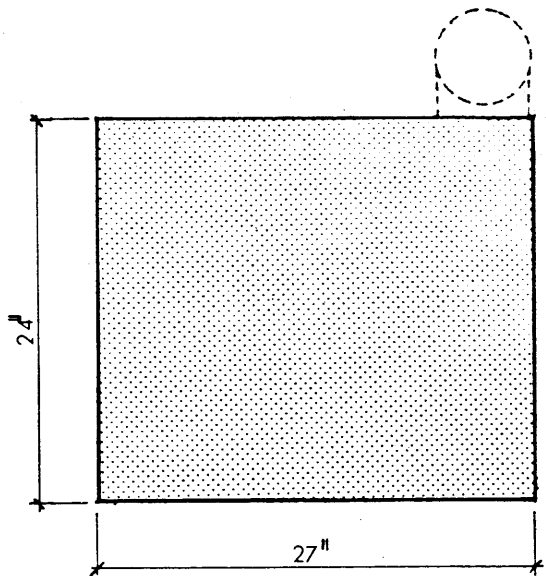
SPACE	ITEM	AREA	U-VALUE	Δt	HEAT LOSS BTU/HR.
FOYER	WALL	180	.061	70°	612
	GLASS	10	.78	70°	378
	EDGE	20	36 btu/ft.		720
	FLOOR	64	2 btu/sq. ft.		128
	INFIL.	576	.018	70°	1088
	DOOR	20		70°	505
	Subtotal				3431
BDRM. 1	WALL	270	.061	68°	1130
	GLASS	20	.78	68°	1060
	EDGE	33	36 btu/ft.	68°	1108
	FLOOR	0			0
	INFIL.	1944	.018	68°	3570
	ROOF	216	.12	68°	1770
	Subtotal				8720
BDRM. 2	WALL	255	.061	68°	1070
	GLASS	15	.78	68°	795
	EDGE	30	36 btu/ft.		1080
	FLOOR	0			0
	INFIL.	1944	.018	68°	3570
	ROOF	266	.12	68°	2180
	Subtotal				8695
BATH	WALL	68	.061	70°	290
	GLASS	5	.78	70°	270
	EDGE	8	36 btu/ft.		288
	FLOOR	0			0
	INFIL.	648	.018	70°	1225
	ROOF	72	.12	70°	605
	Subtotal				2678

SPACE	ITEM	AREA	U-VALUE	Δt	HEAT LOSS BTU/HR.
CORRIDOR	WALL	27	.061	68°	115
	GLASS	25	.78	68°	1675
	EDGE	3	36 btu/ft.		108
	FLOOR	0			0
	INFIL.	540	.018	68°	995
	ROOF	45	.12	68°	370
	Subtotal				
TOTAL					58,890

$58,890 \times 1.6 = 94,224$ BTU/HR. BOILER

AREA: 4.5 SQ. FT.

FLUE SIZE: 6-7" DIAMETER



RADIATORS BASEBOARD LENGTH:

LIVING ROOM:

Heat loss 18,375 @ 1540 btu/ft. = 11.8 lin. ft.

DINING:

8029 @ 1540 = 5.2 lin. ft.

BATH:

2678 @ 1540 = 1.7 lin. ft.

KITCHEN:

3825 @ 1540 = 2.4 lin. ft.

CORRIDOR:

3263 @ 1540 = 2.1 lin. ft.

STAIR:

3874 @ 1540 = 2.5 lin. ft.

FOYER:

3431 @ 1540 = 2.2 lin. ft.

BDRM. 1:

8720 @ 1540 = 5.7 lin. ft.

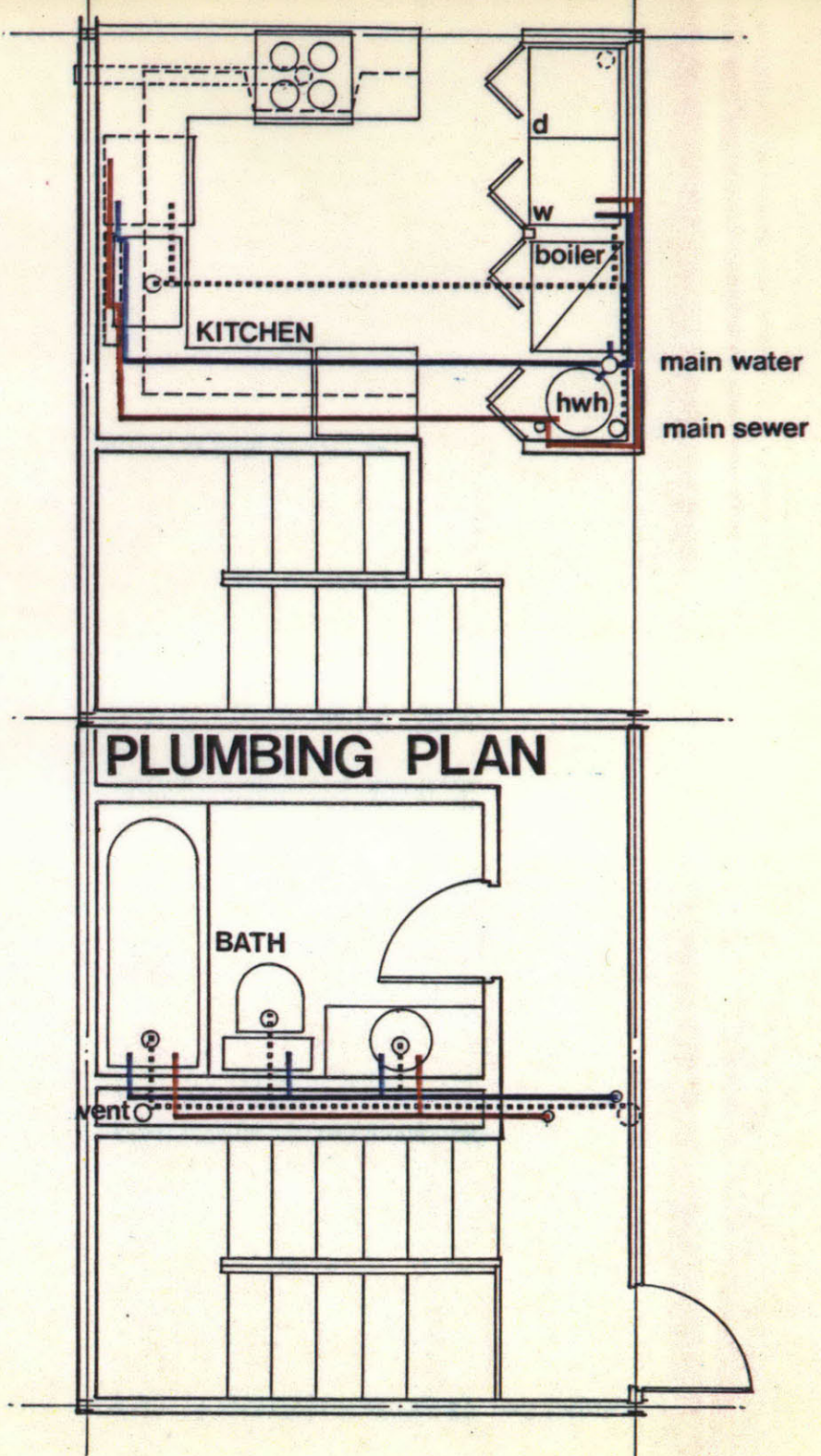
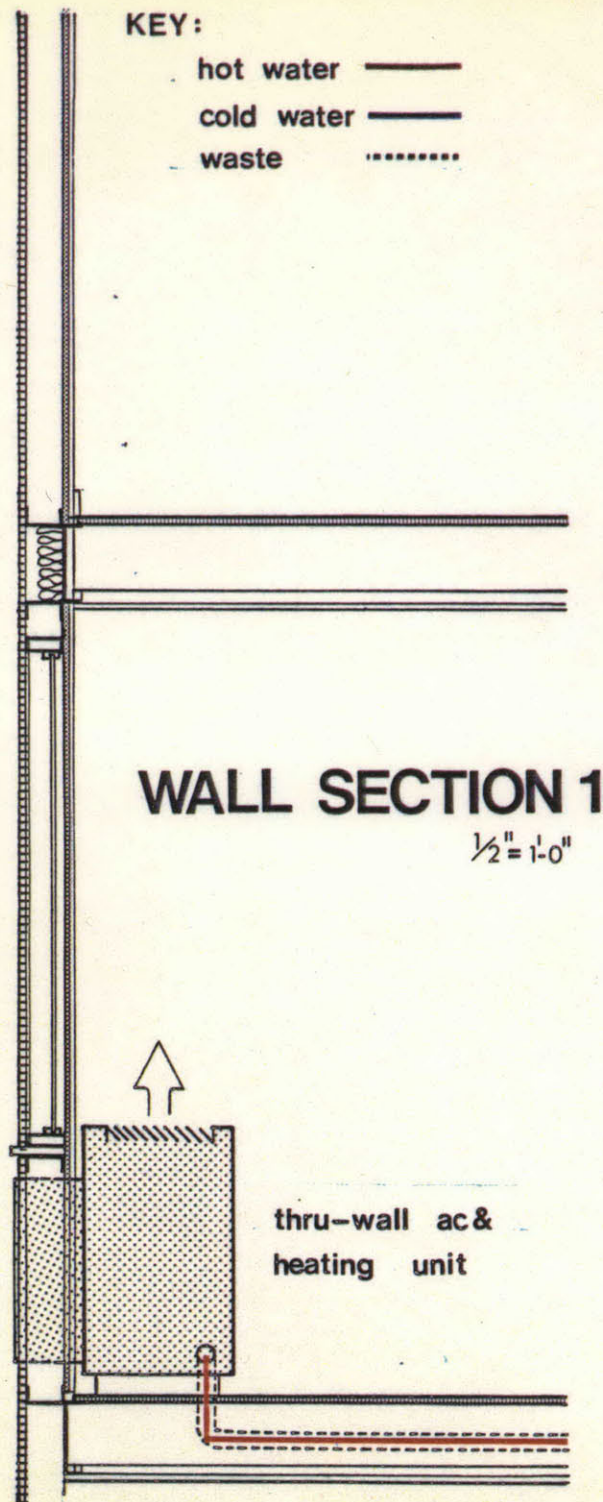
BDRM. 2:

8695 @ 1540 = 5.6 lin. ft.

TOTAL FOR HOUSE: 39.2 lin. ft.

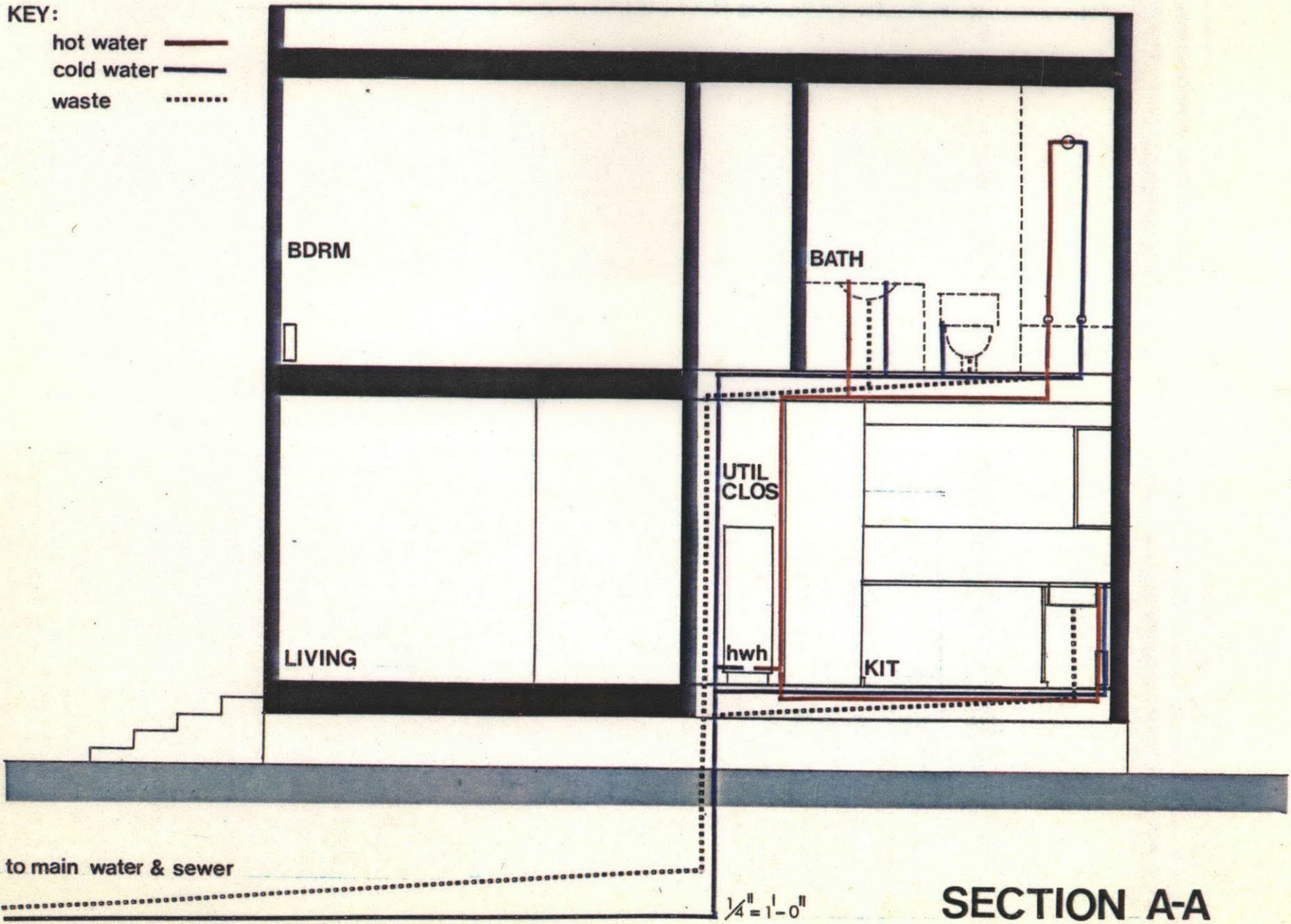
KEY:

- hot water ———
- cold water ———
- waste ·····



KEY:

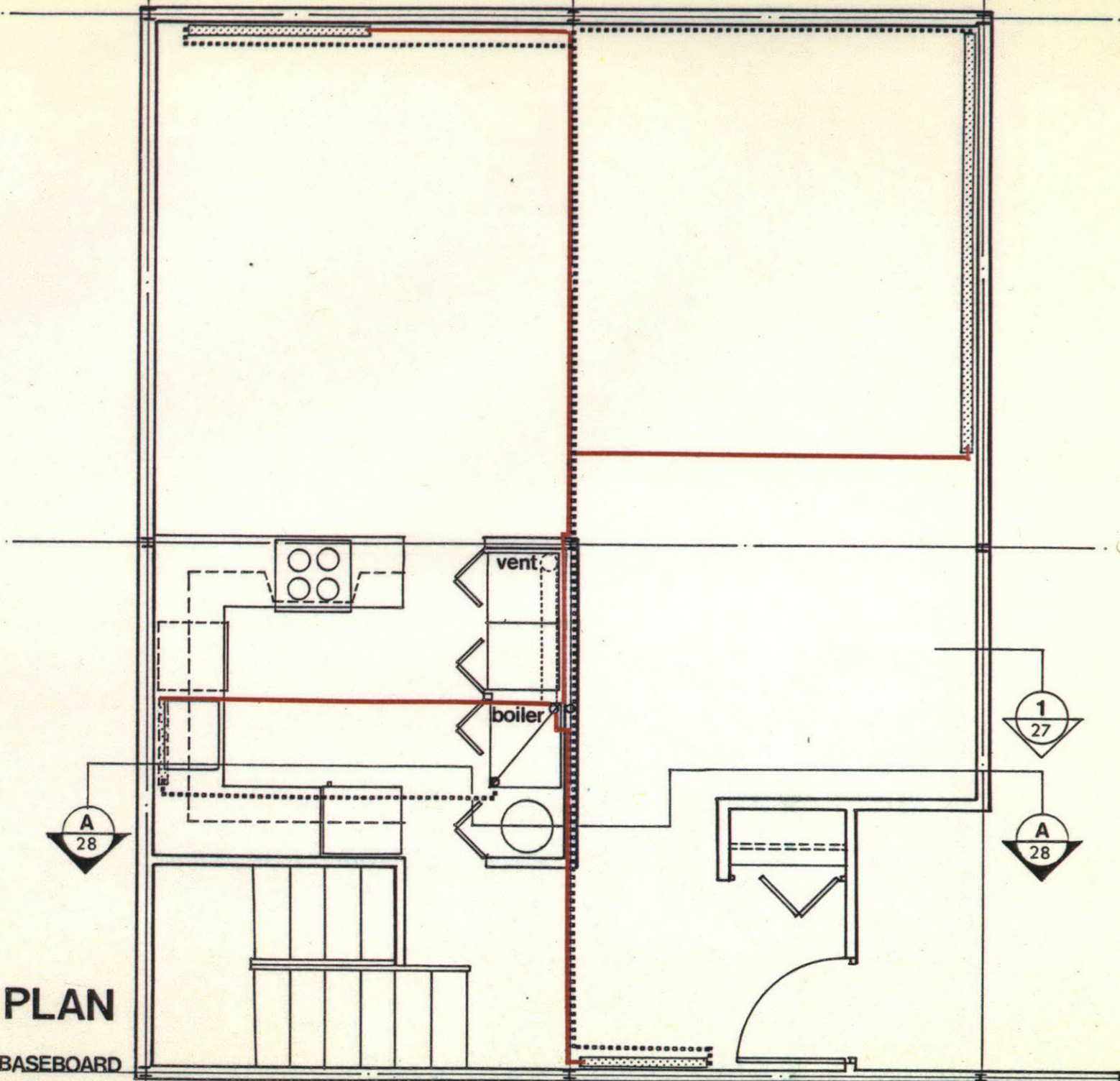
- hot water ———
- cold water ———
- waste ·····



SECTION A-A

KEY:

supply ———
return ······



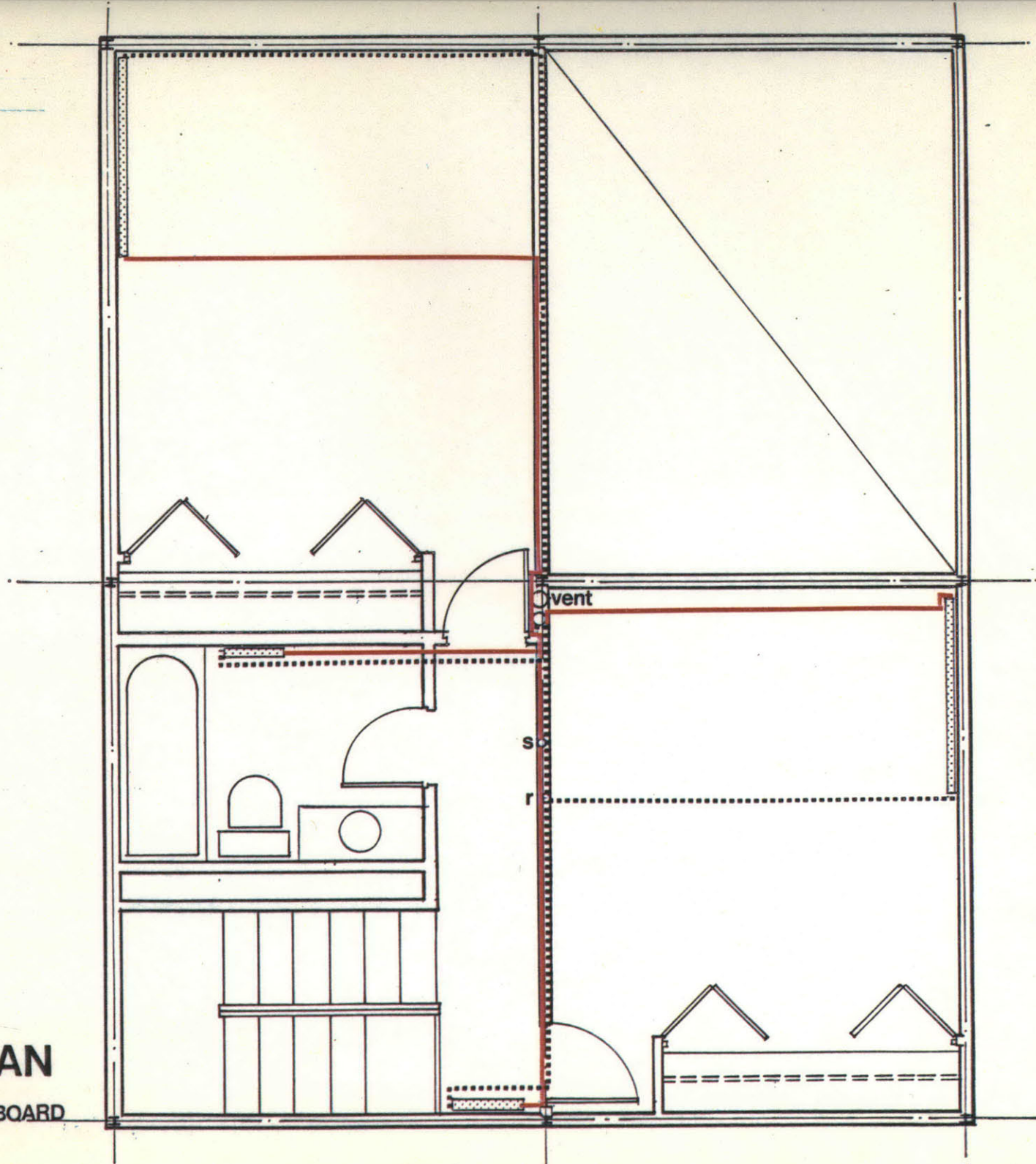
HEATING PLAN

WITH HOT WATER BASEBOARD

KEY:

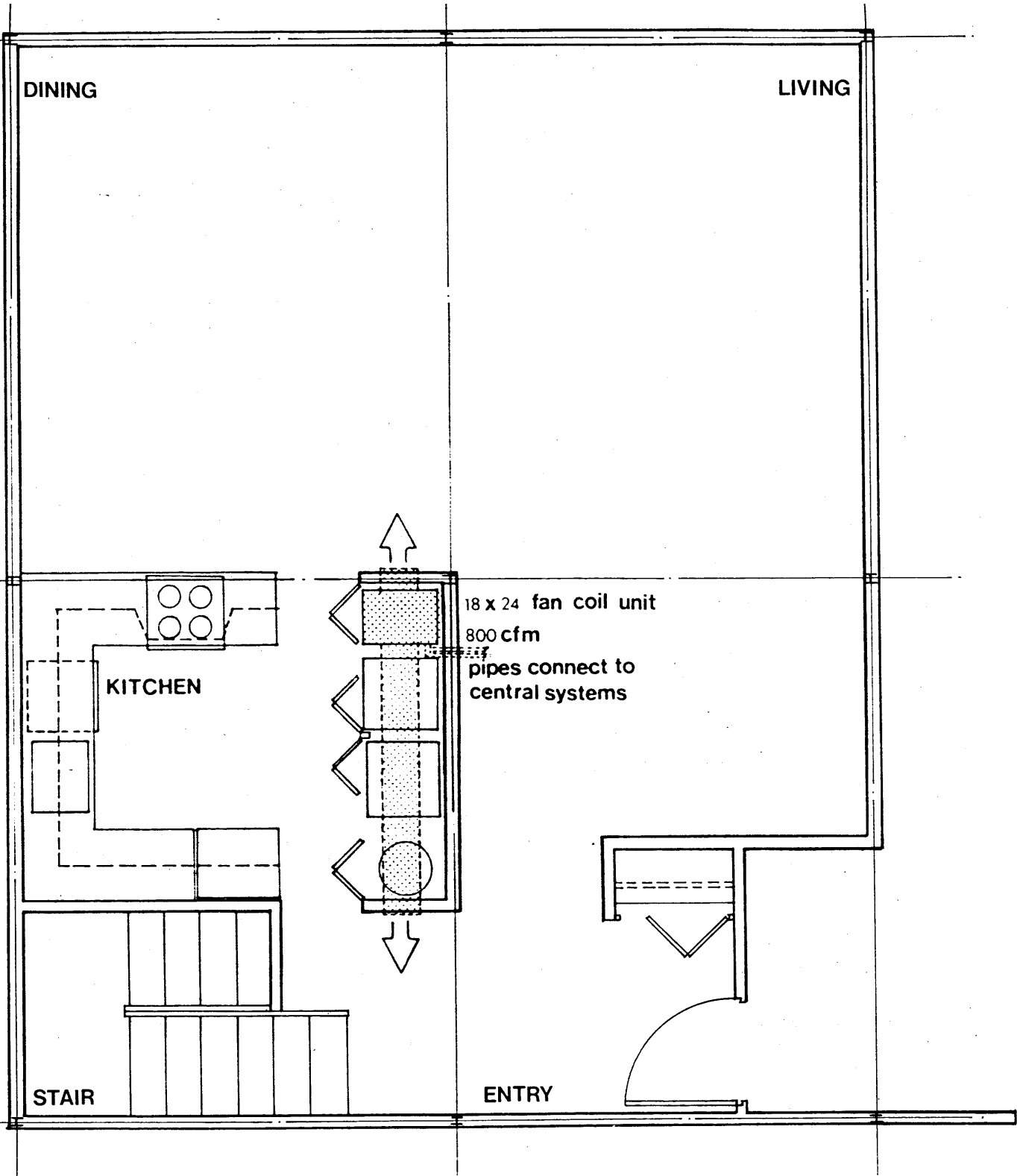
supply ———

return ·····

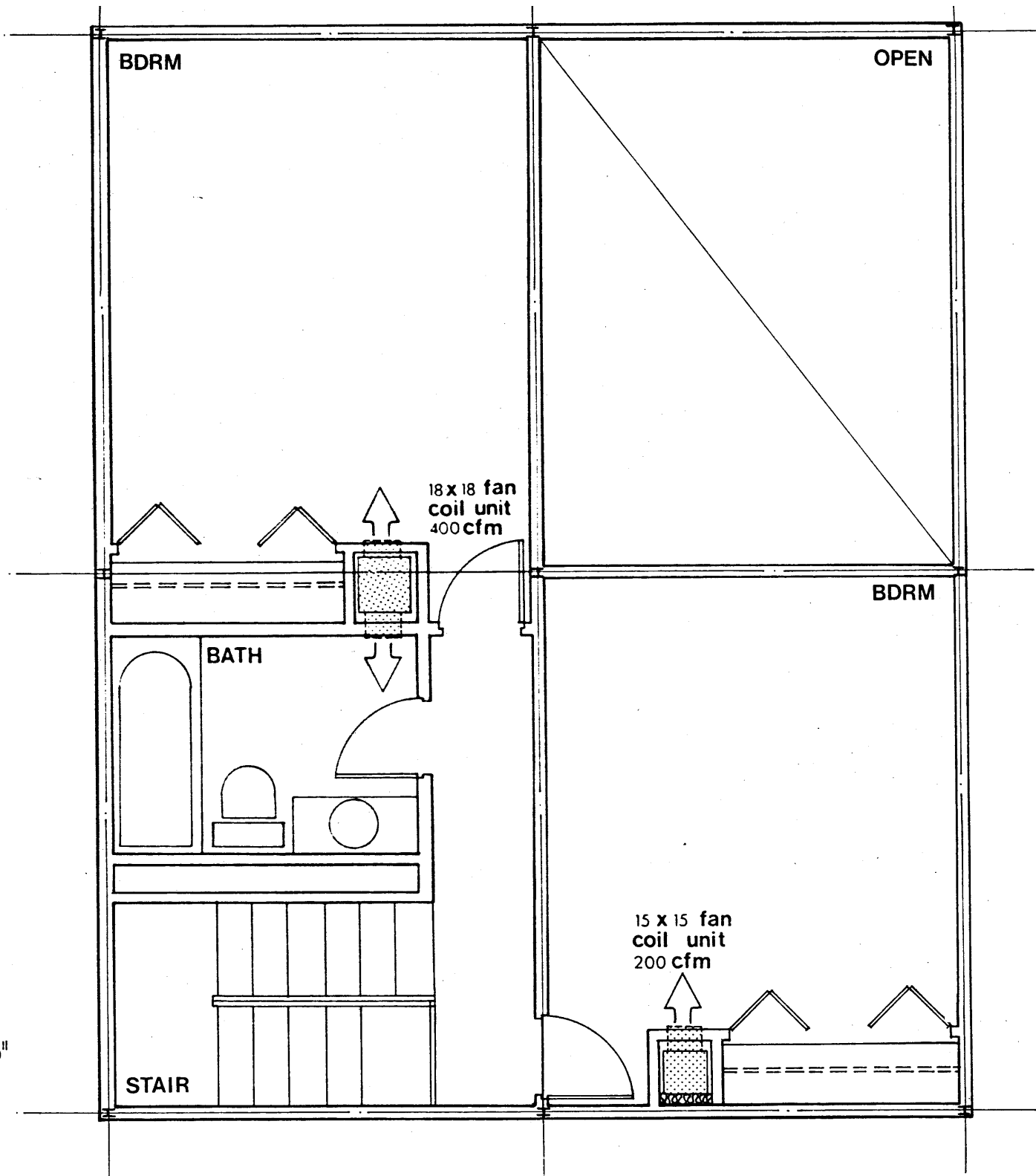


HEATING PLAN

WITH HOT WATER BASEBOARD



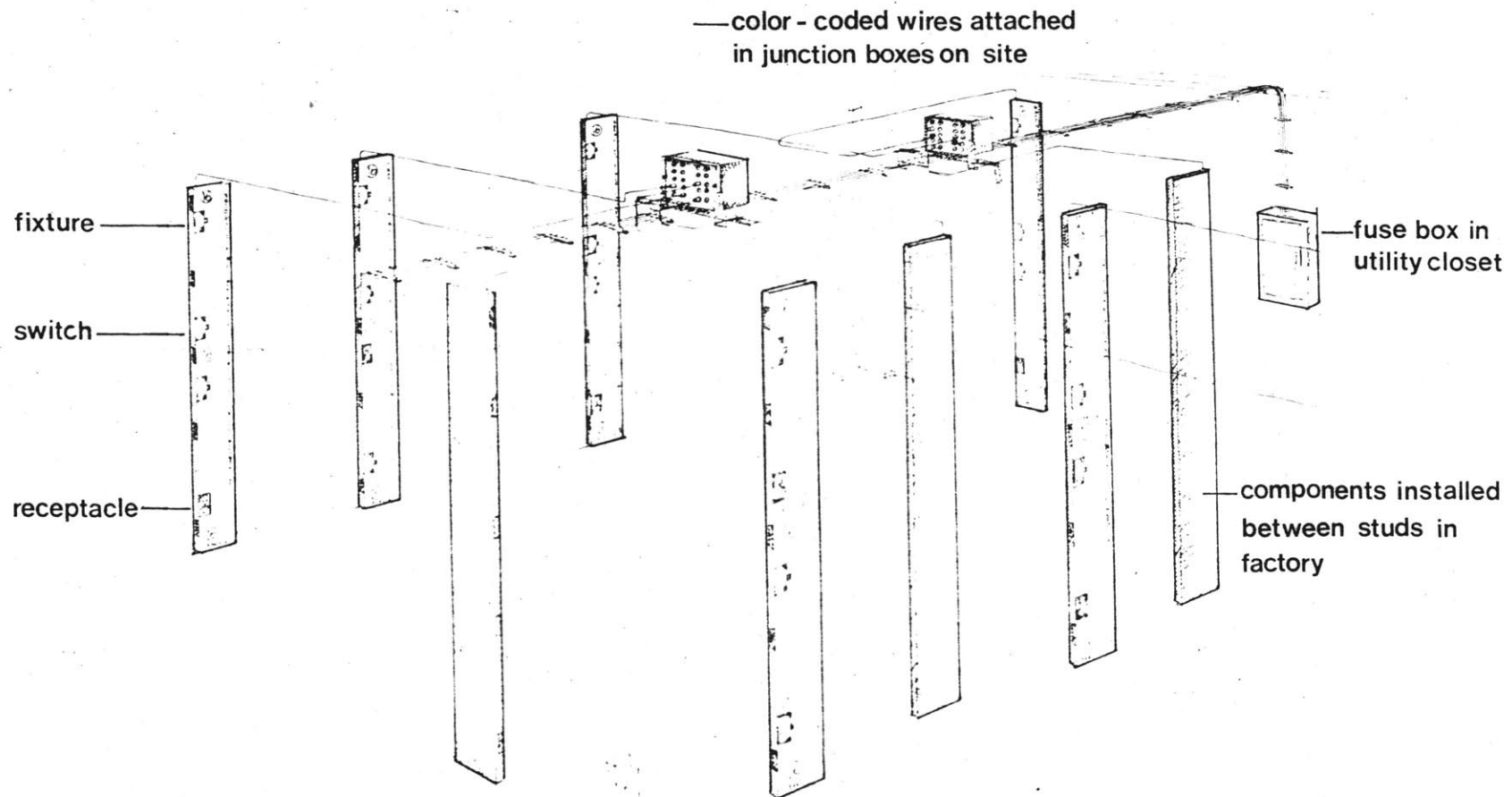
PLAN $\frac{1}{4}''=1'-0''$
WITH FAN COIL UNITS



PLAN

1/4" = 1'-0"

WITH FAN COIL UNITS



PRODUCTION WIRING SYSTEM

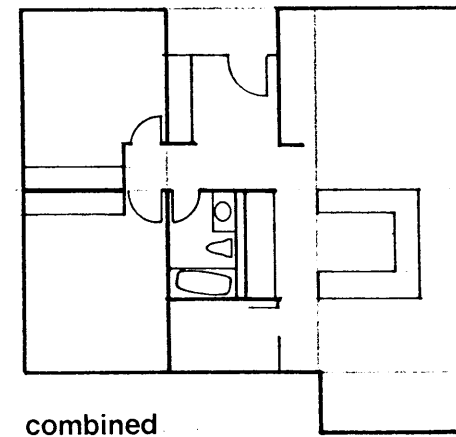
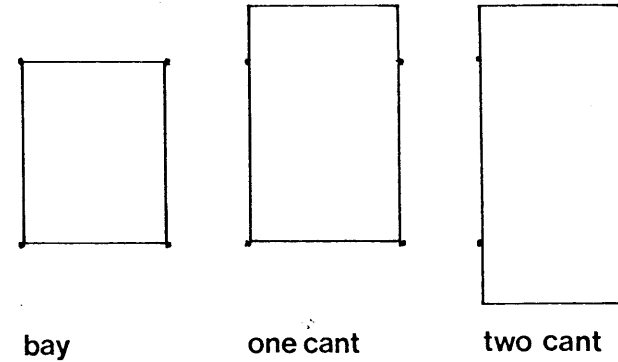
ELECTRICAL

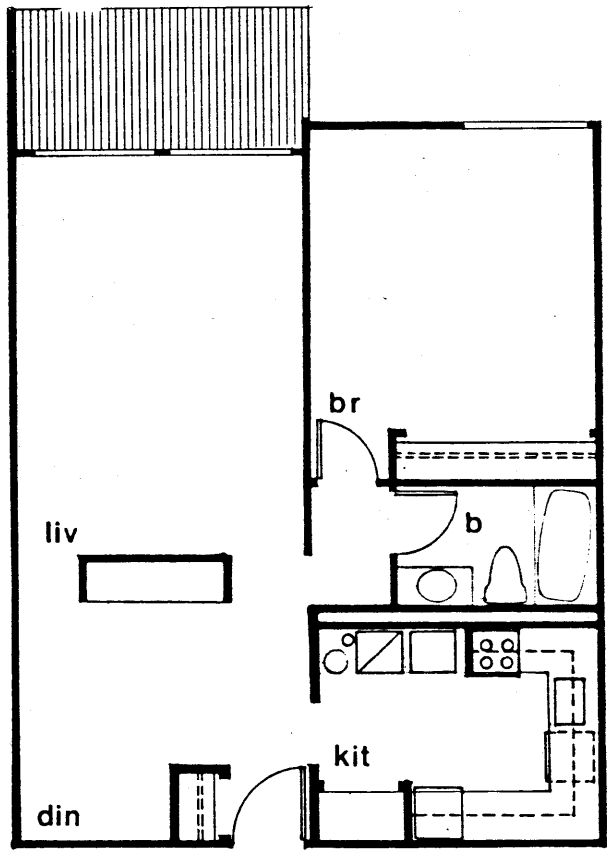
UNIT PLANS

UNIT PLANS

The plans attempt to show some of the ways in which the system may be used to accommodate various living arrangements. The basic planning module is also the structural bay size and is 12'-0" by 15'-0". Utilizing the 5'-0" cantilever at one end gives a 12'-0" x 20'-0" bay, and using the cantilever at both ends gives a 12'-0" by 20'-0" bay. Recessing a wall where decks occur can give variations in length of the bay also.

The smallest unit is studio apartment of 750 sq. ft. and the units increase from there to 1800 sq. ft. for a three-bedroom townhouse. An attempt has been made to give useable and somewhat flexible spaces and to keep the plans from rigidity and formality while still ensuring the necessary privacy. There are many variations and alternate plans of those shown and there are many others possible, but it is intended that the ones shown will give a good cross-section of what can be done with this system.

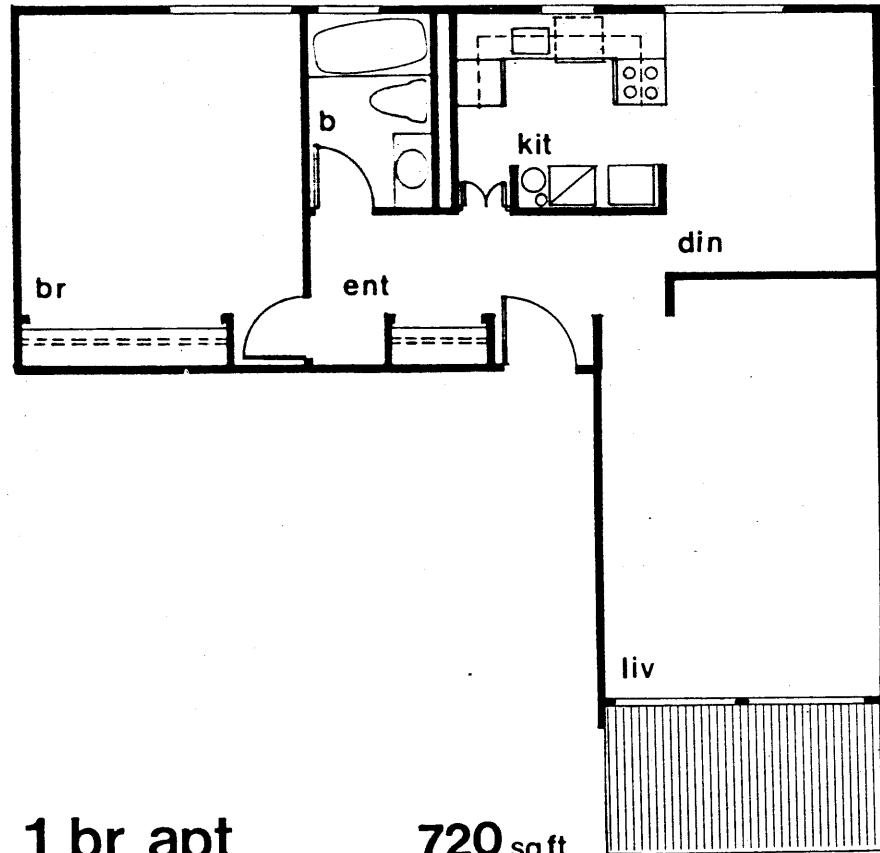




A

studio

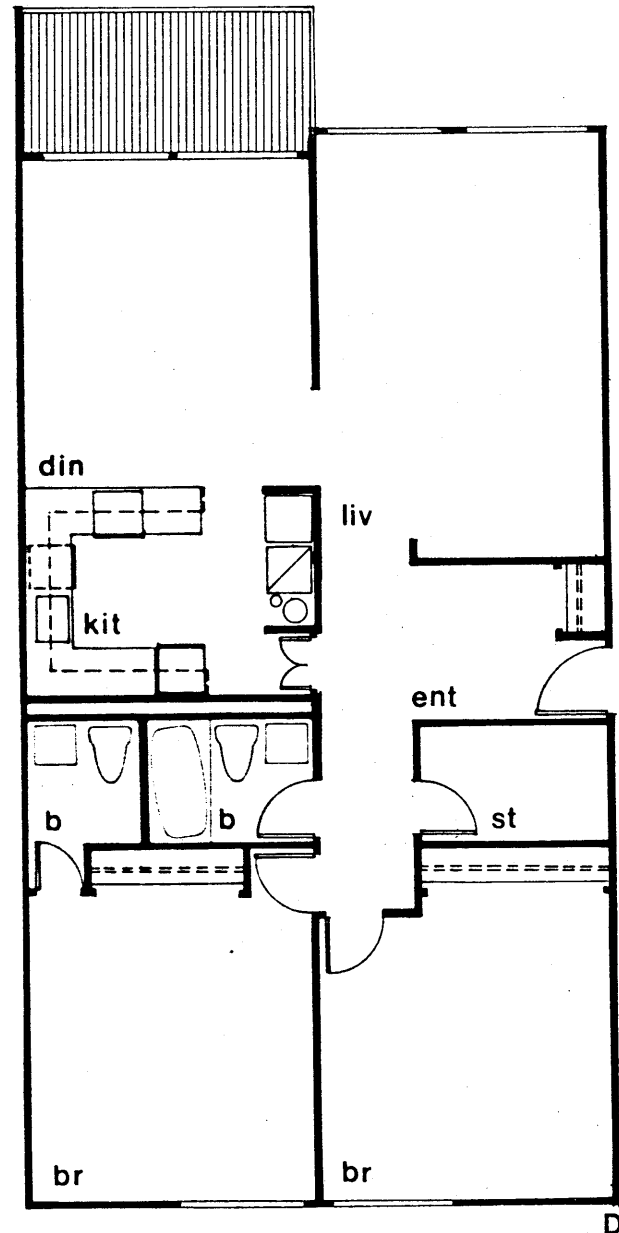
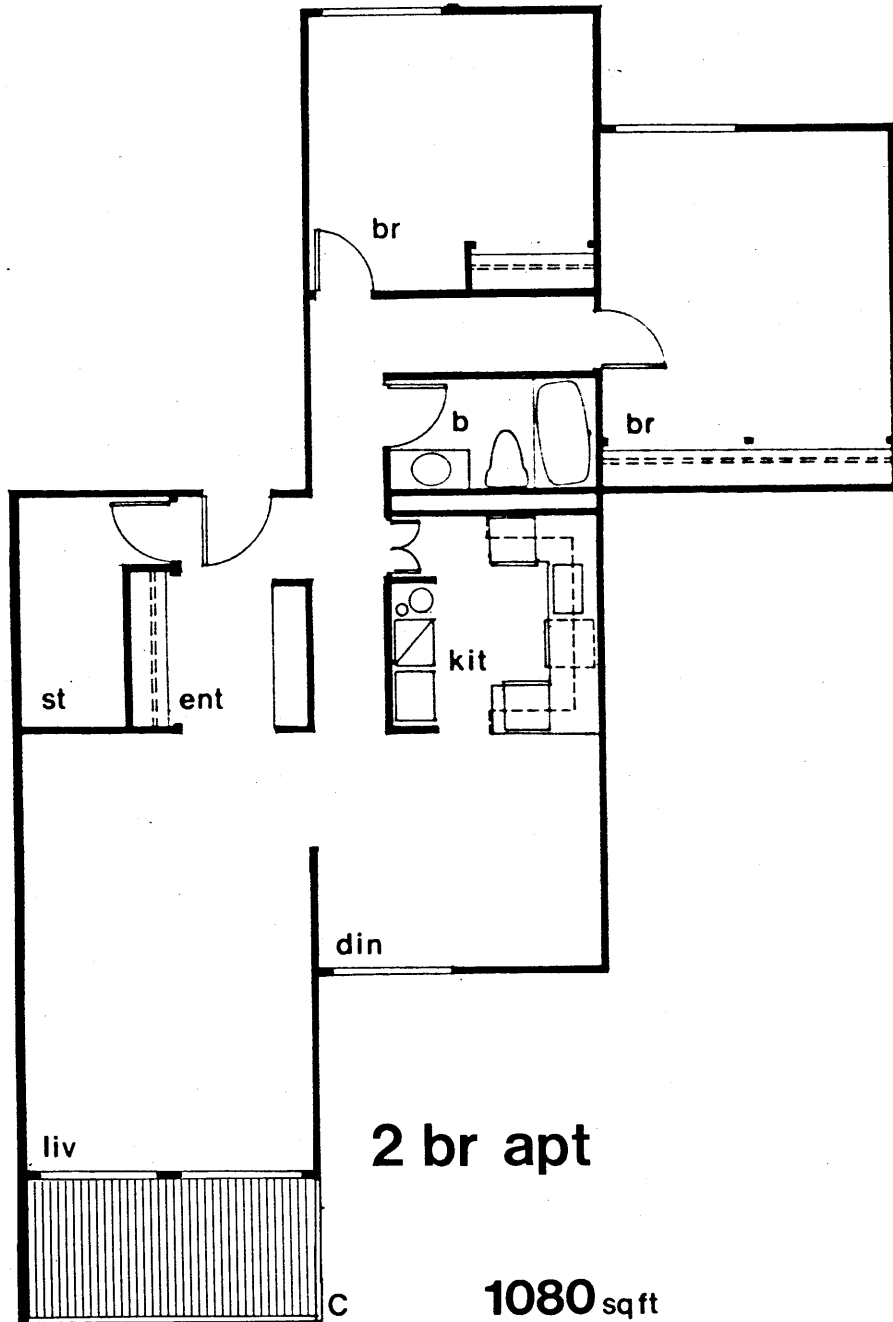
720sq ft



B

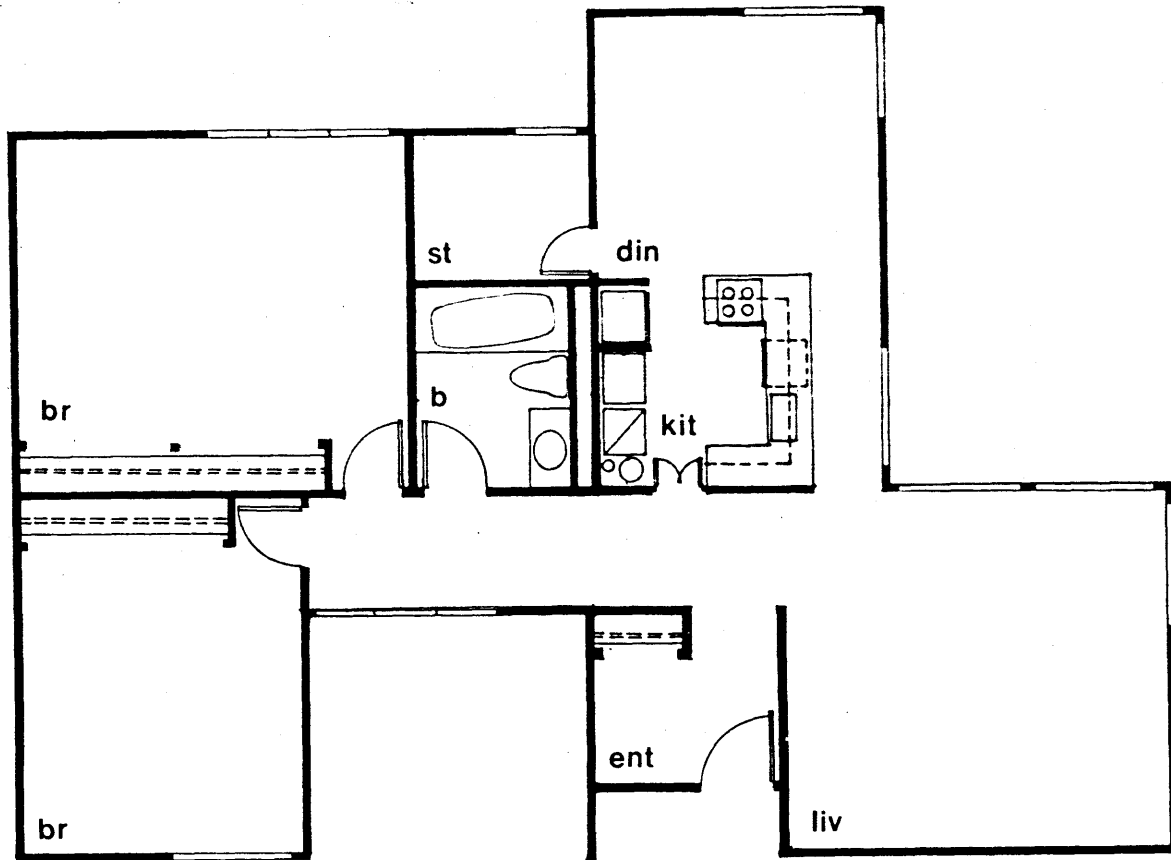
1 br apt

720sq ft



2 br apt

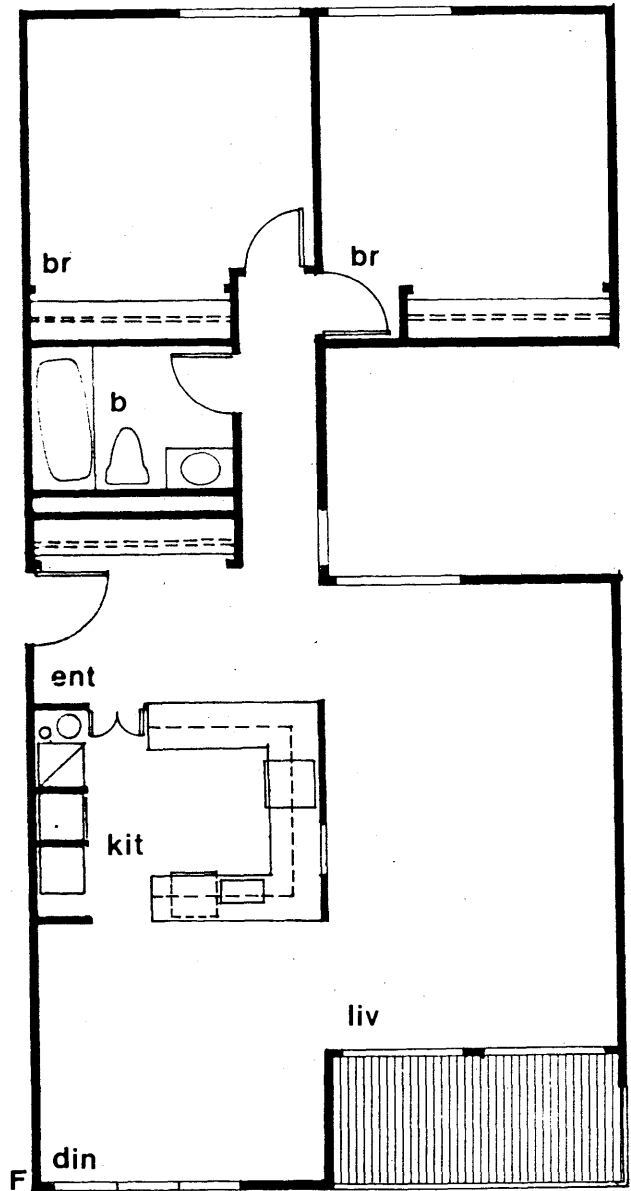
1180_{sq ft}



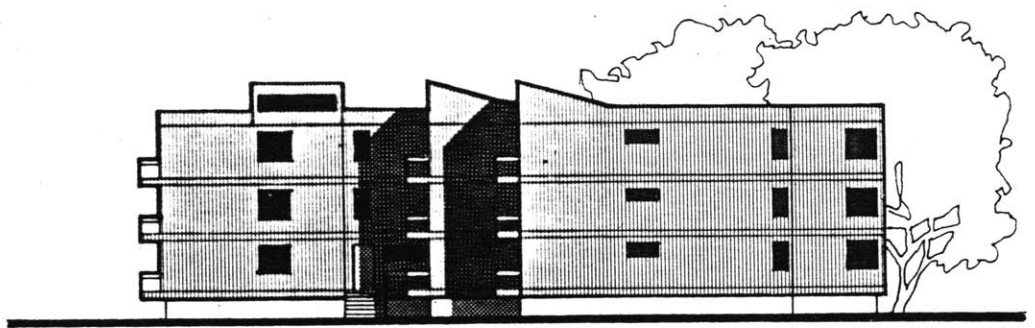
E

2 br apt

1050_{sq ft}



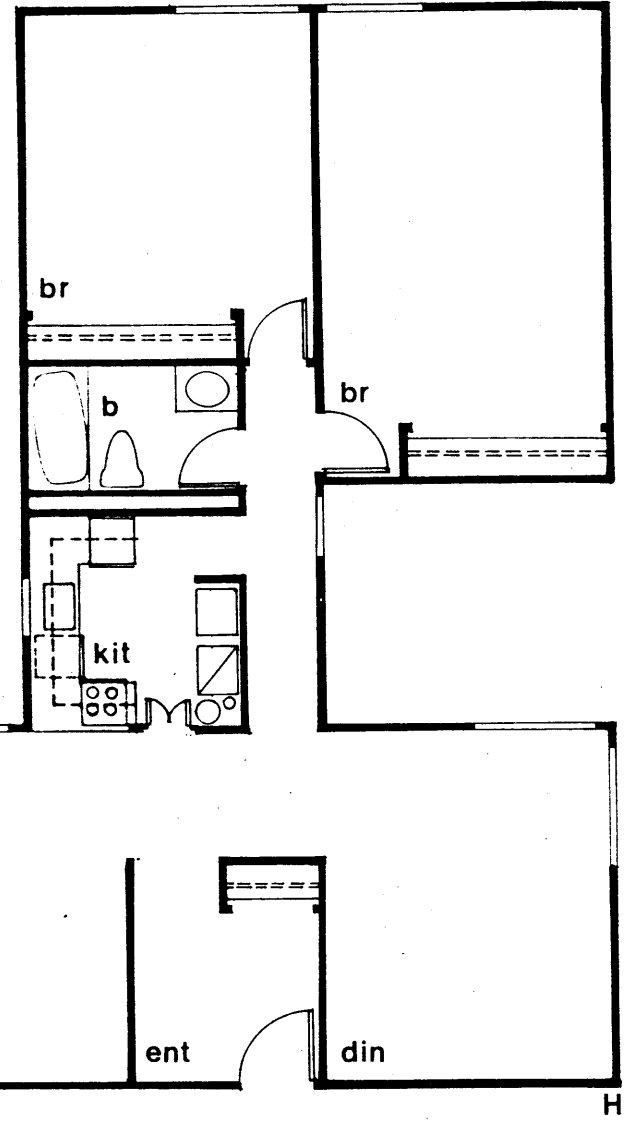
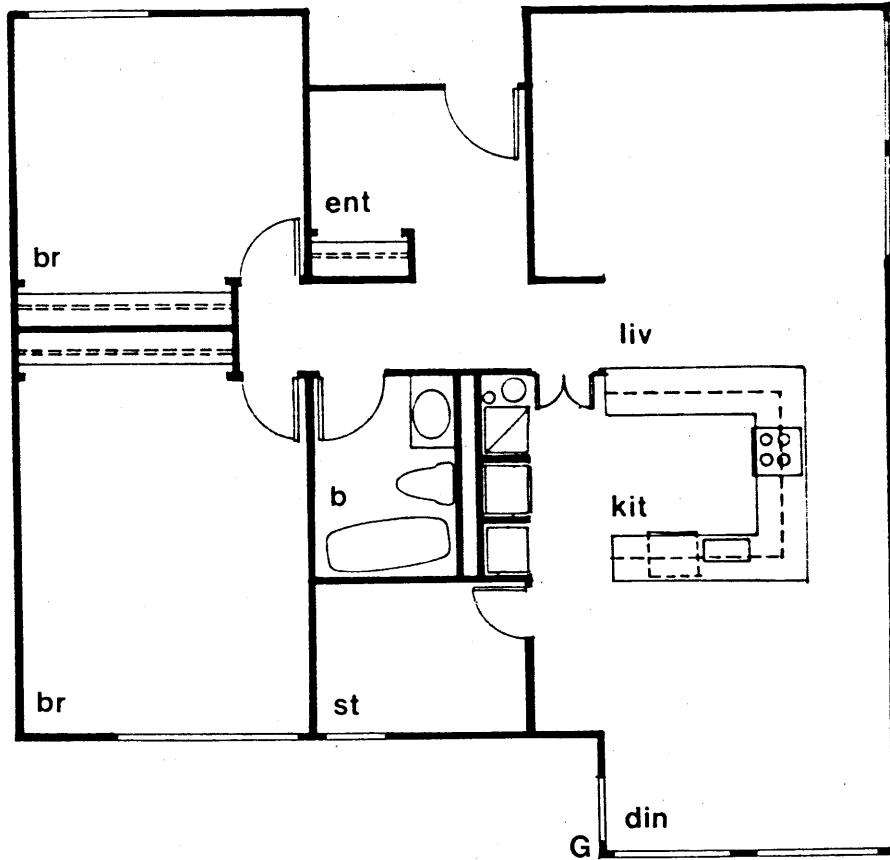
F



apts elevation

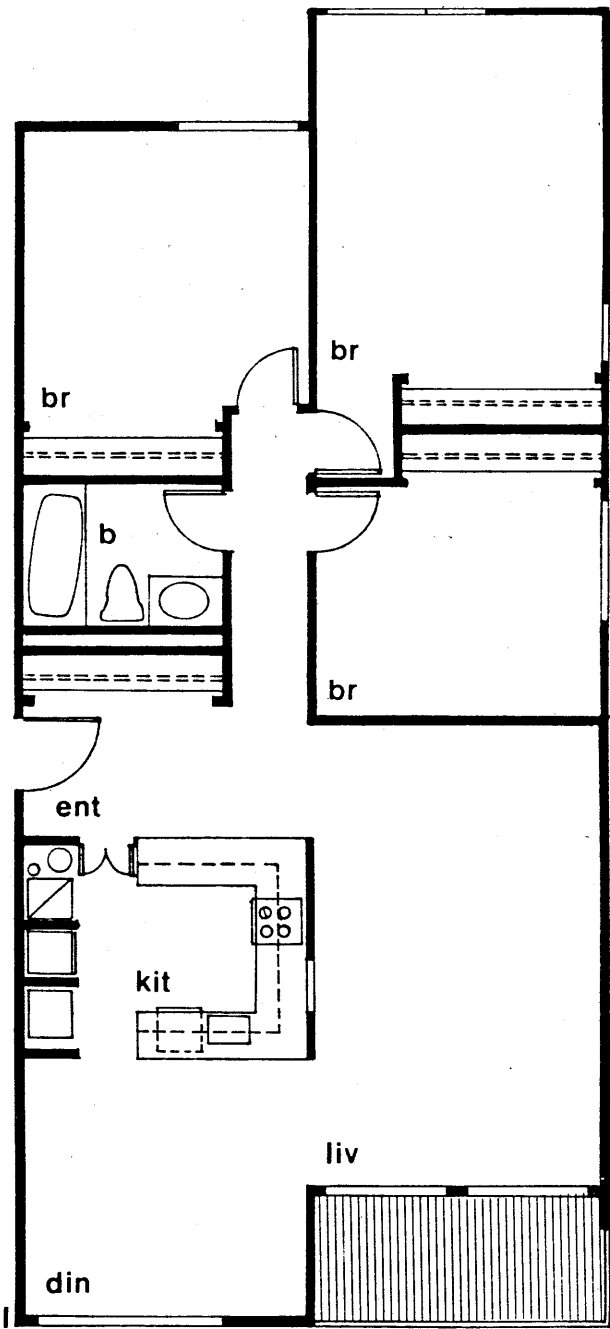
2 br apt

1130_{sqft}



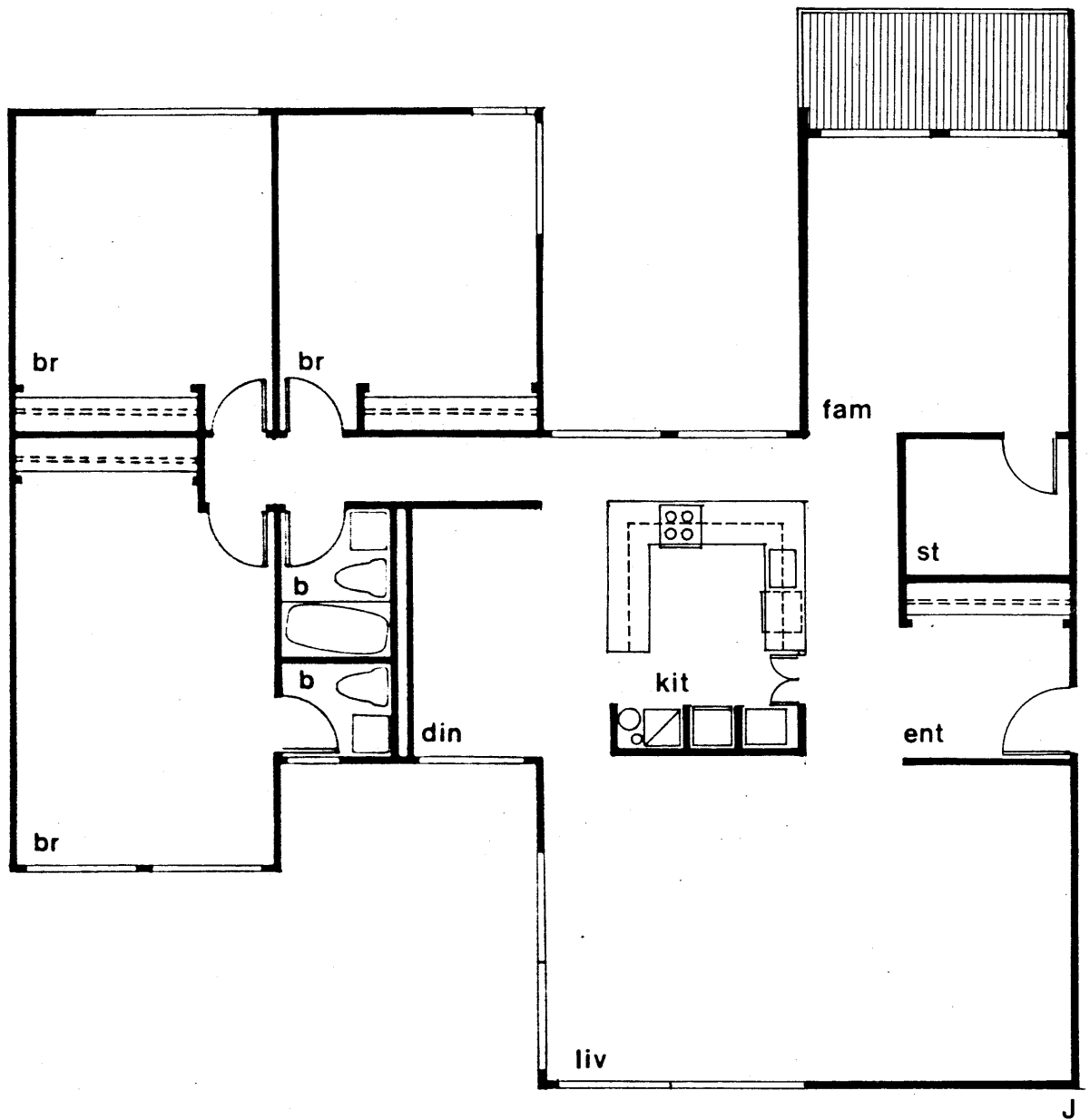
2 br apt

1130_{sqft}



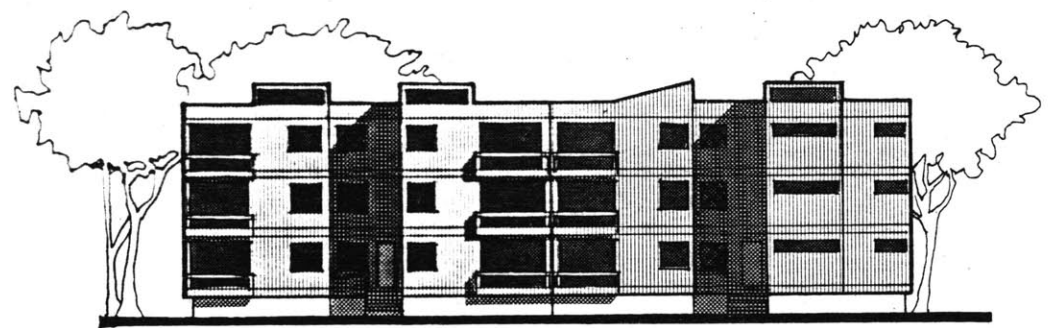
3 br apt

1260sqft

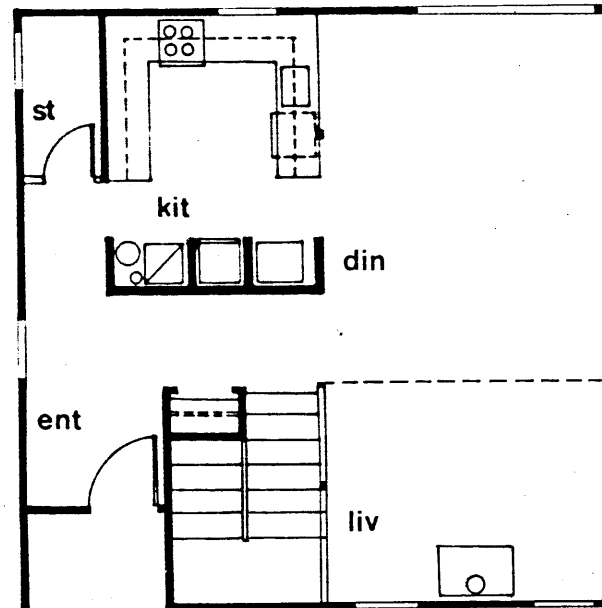
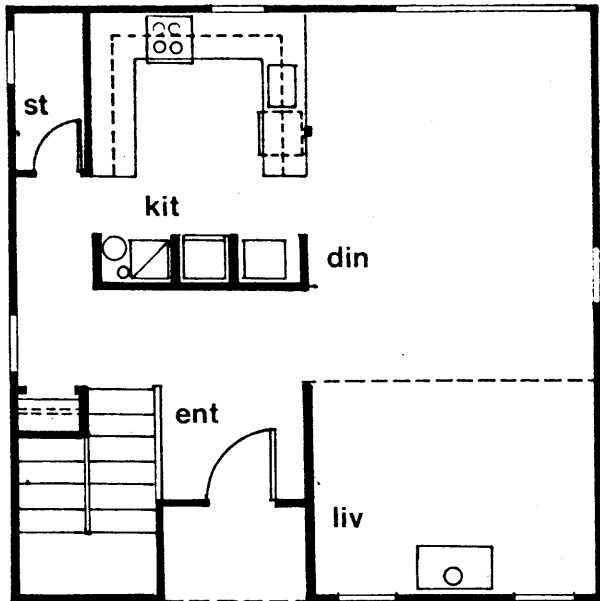
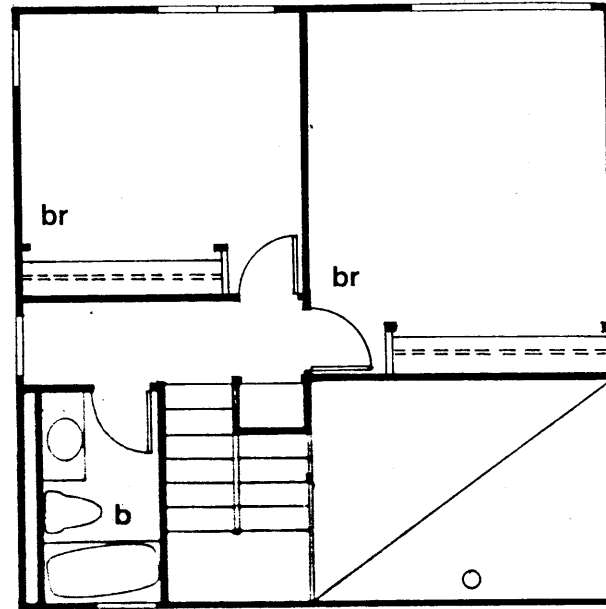
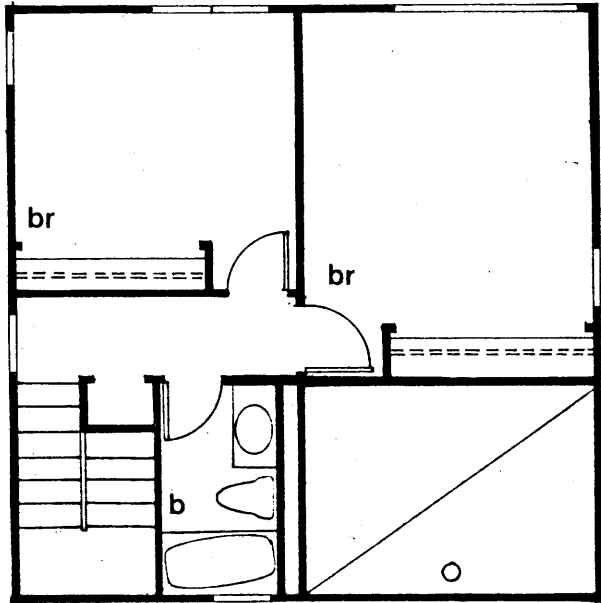


3 br apt

1620sqft

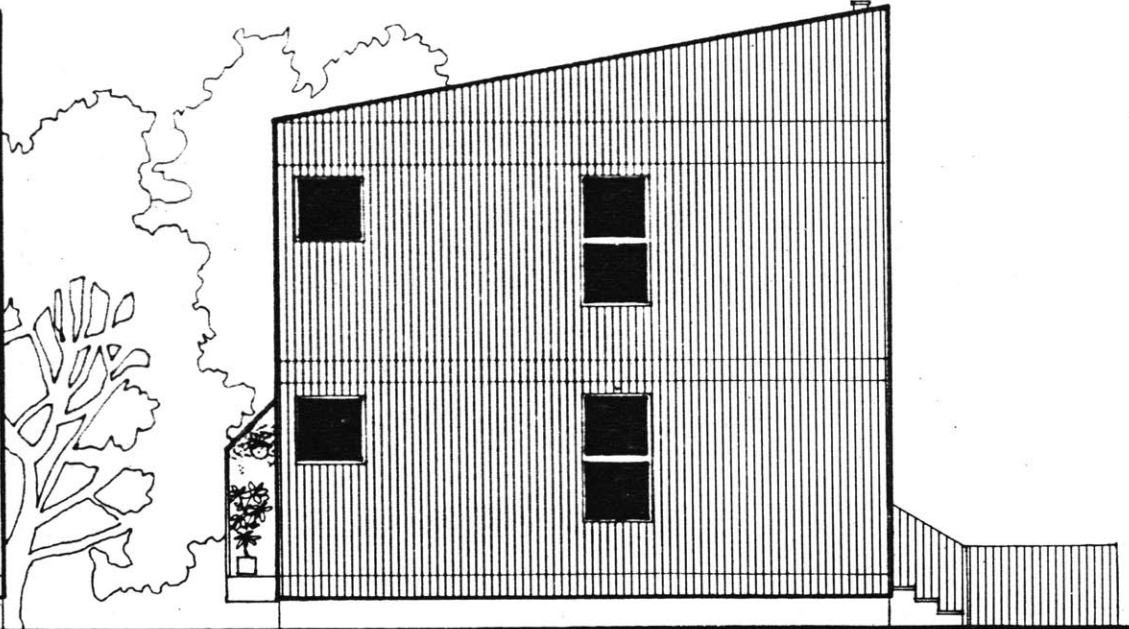
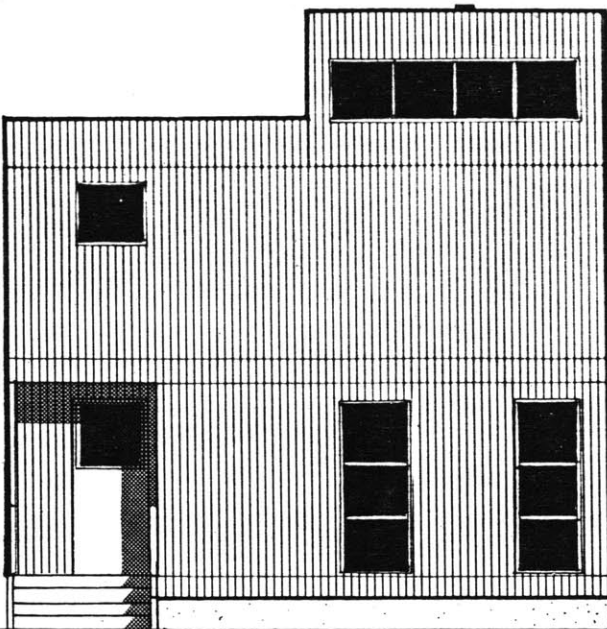
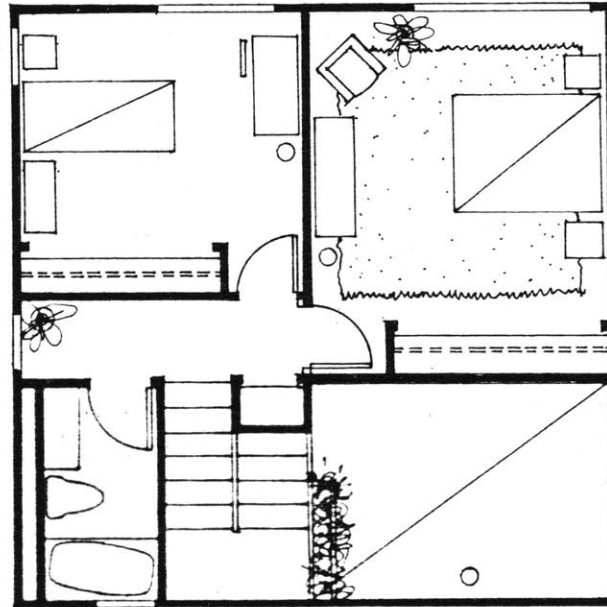
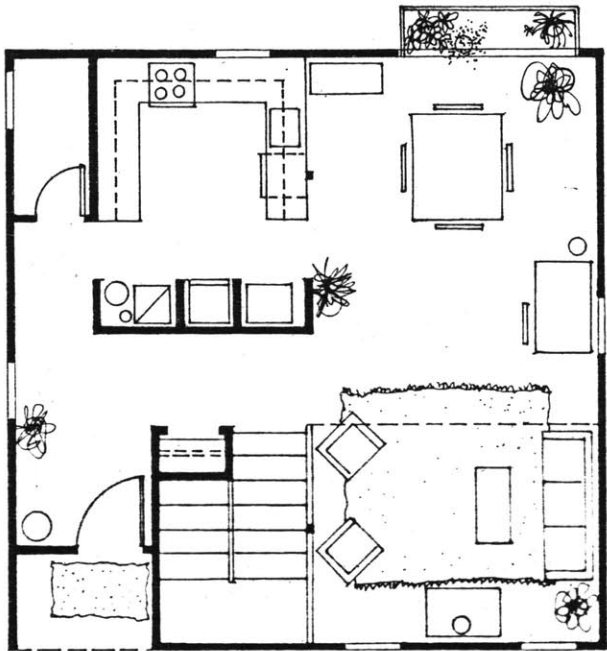


apts elevation



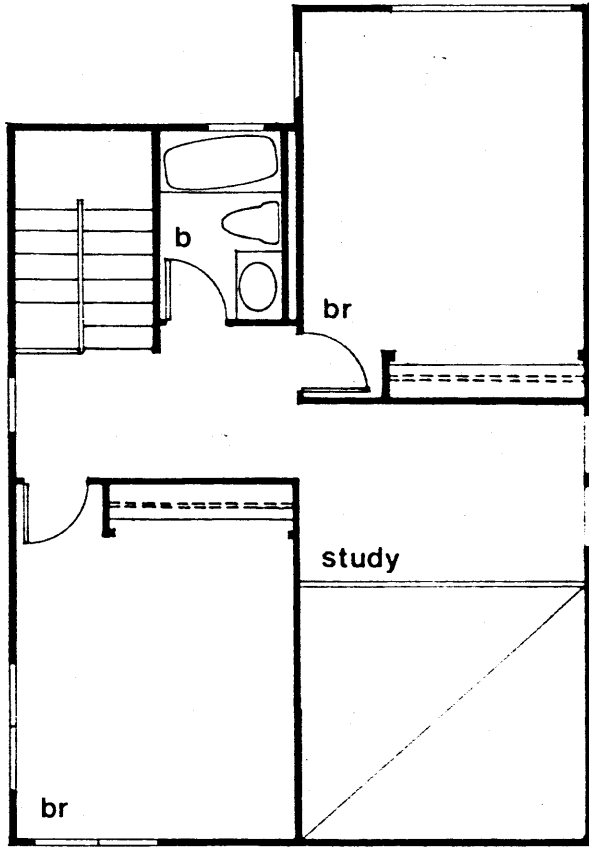
2 br townhouse 1050_{sq ft}

2 br townhouse 1050_{sq ft}

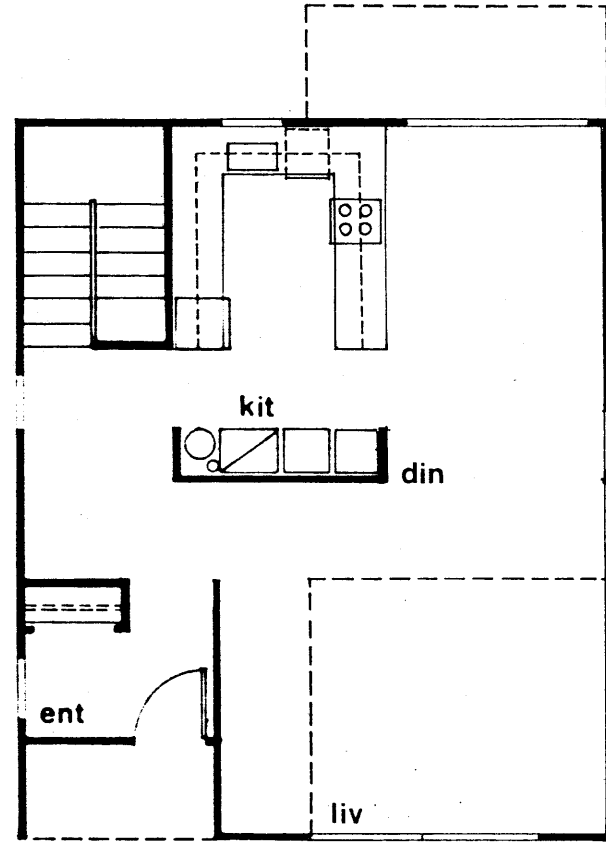


elevations

1/8

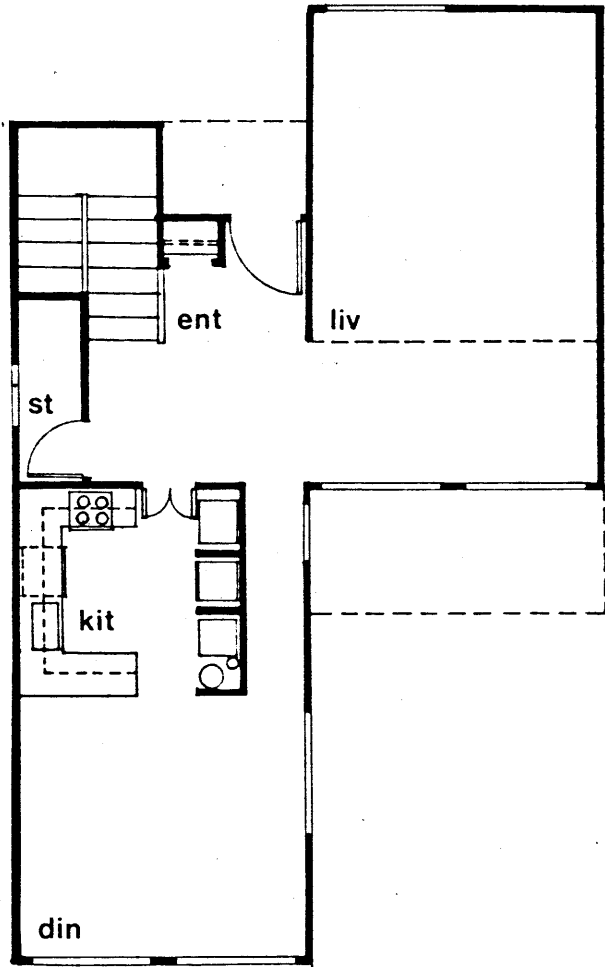


2 br townhouse

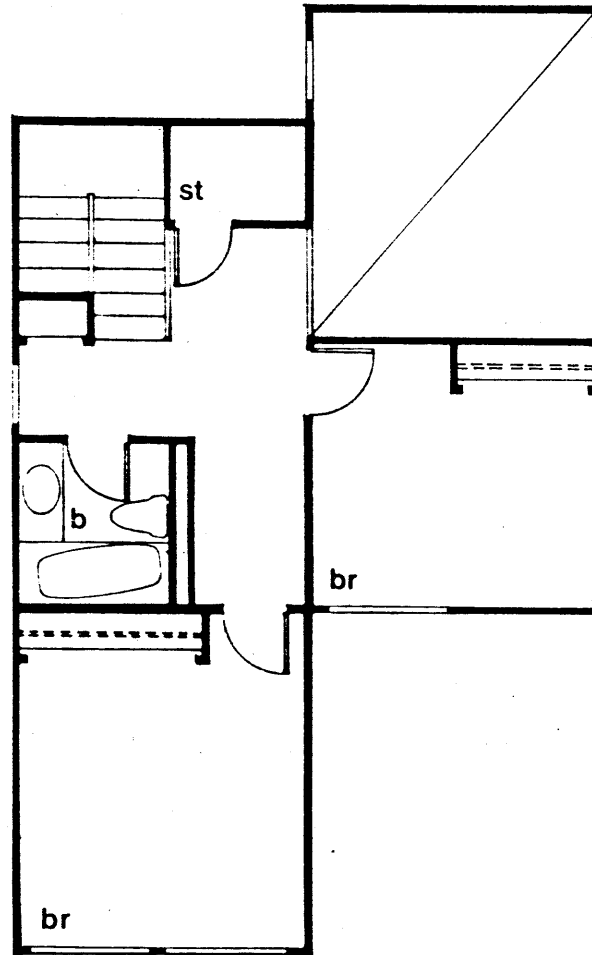


1400sq ft

1/8

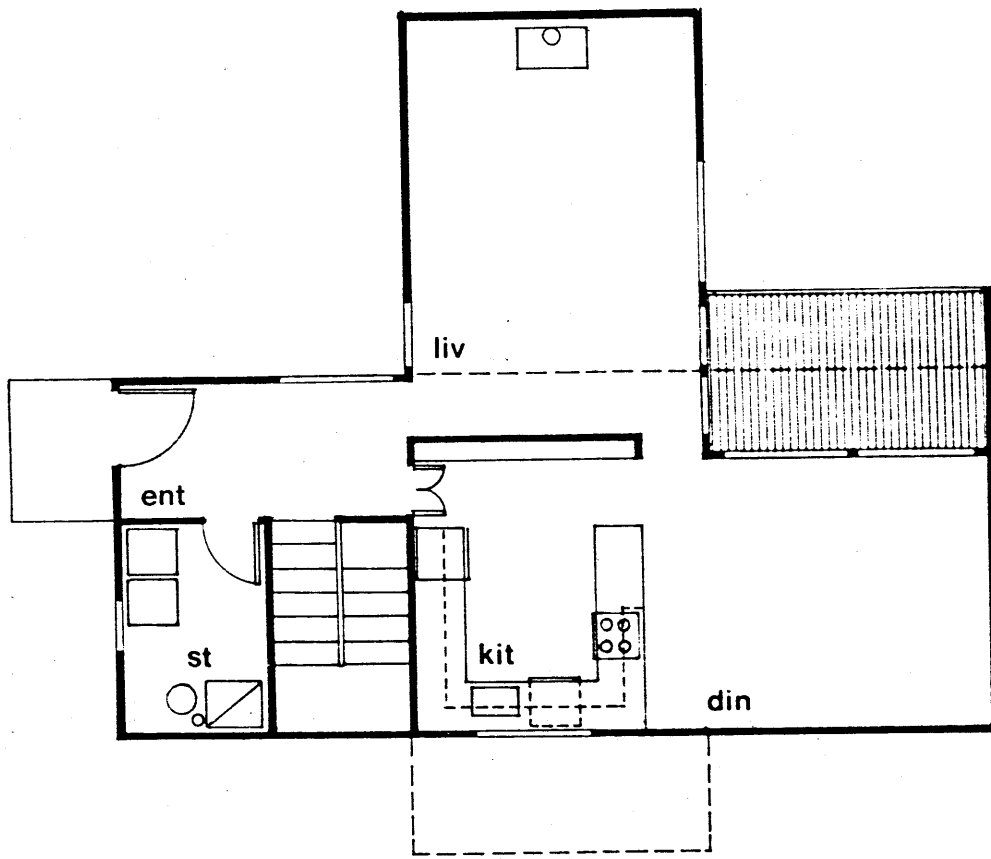


2 br townhouse

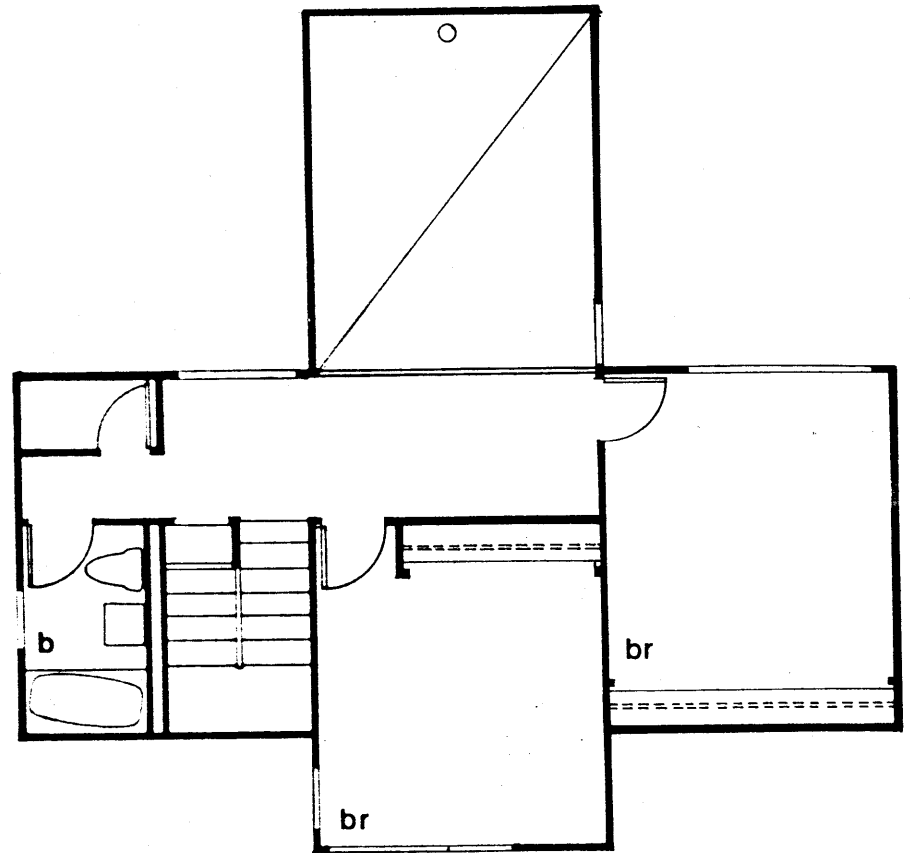


1200 sq ft

1/8

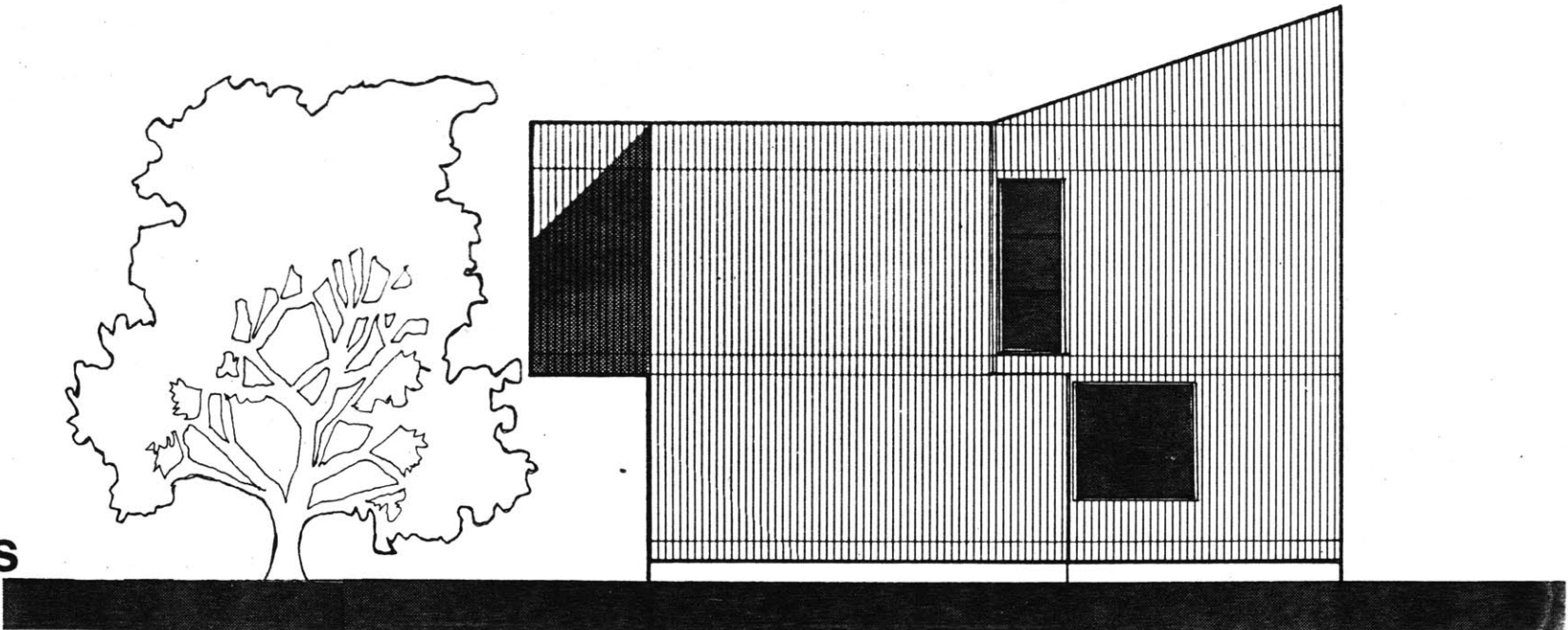
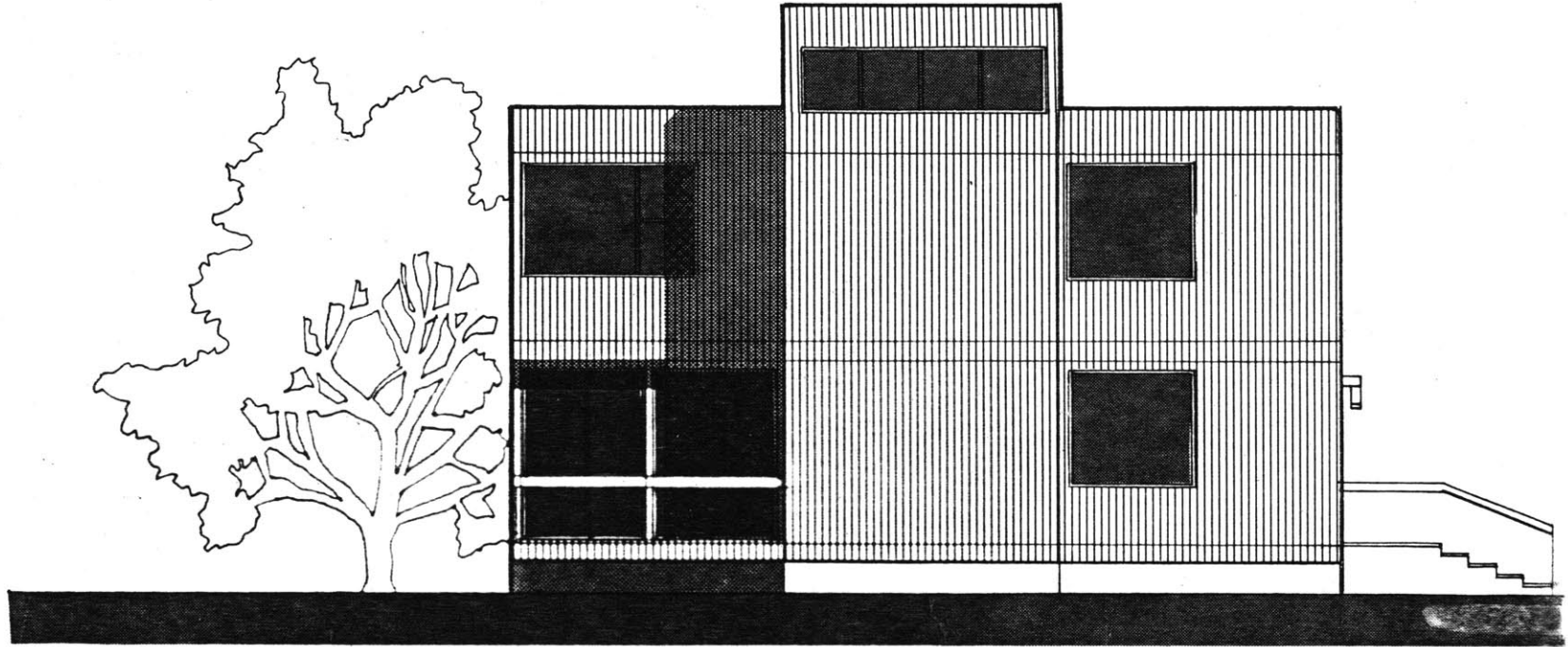


2 br townhouse

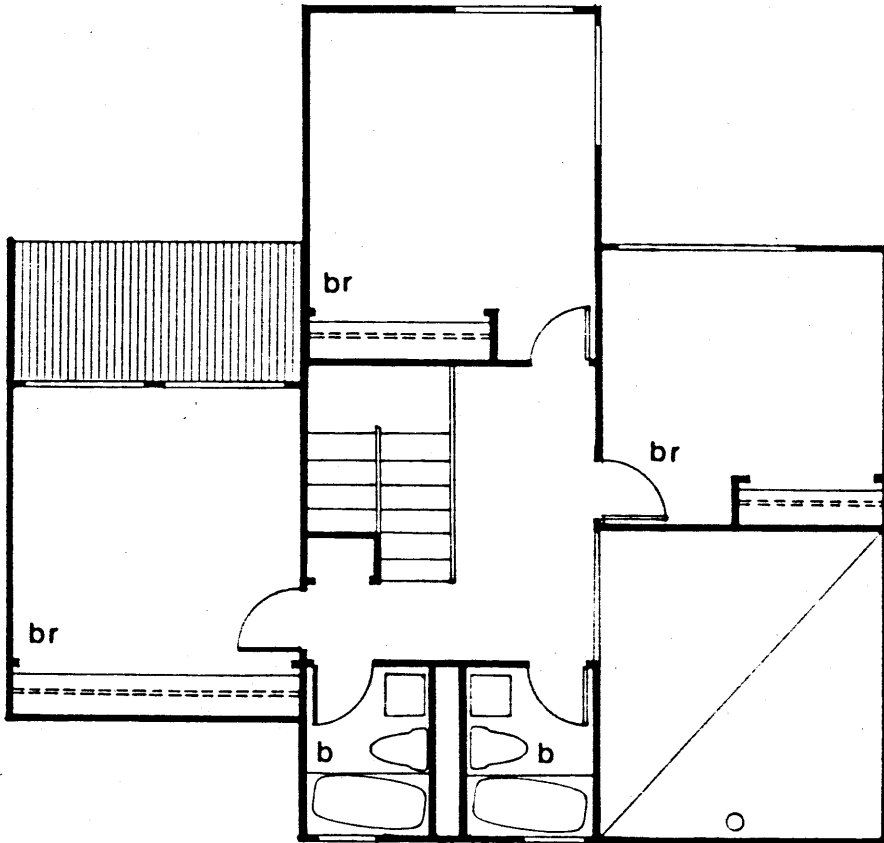


1440 sq ft

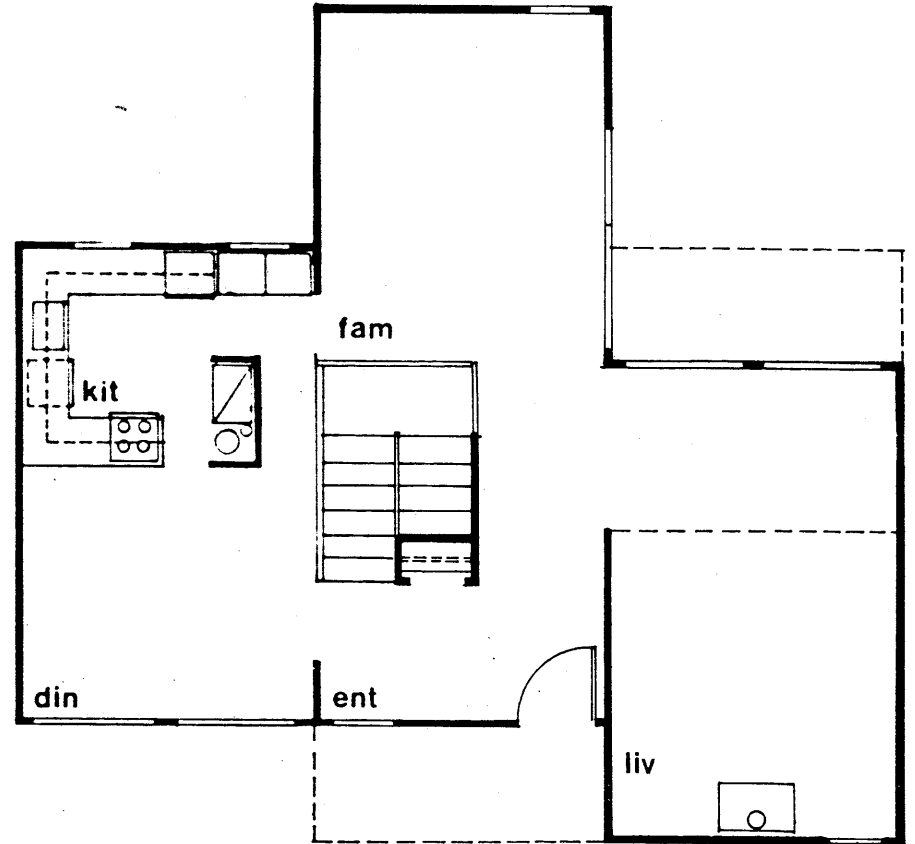
1/8



elevations

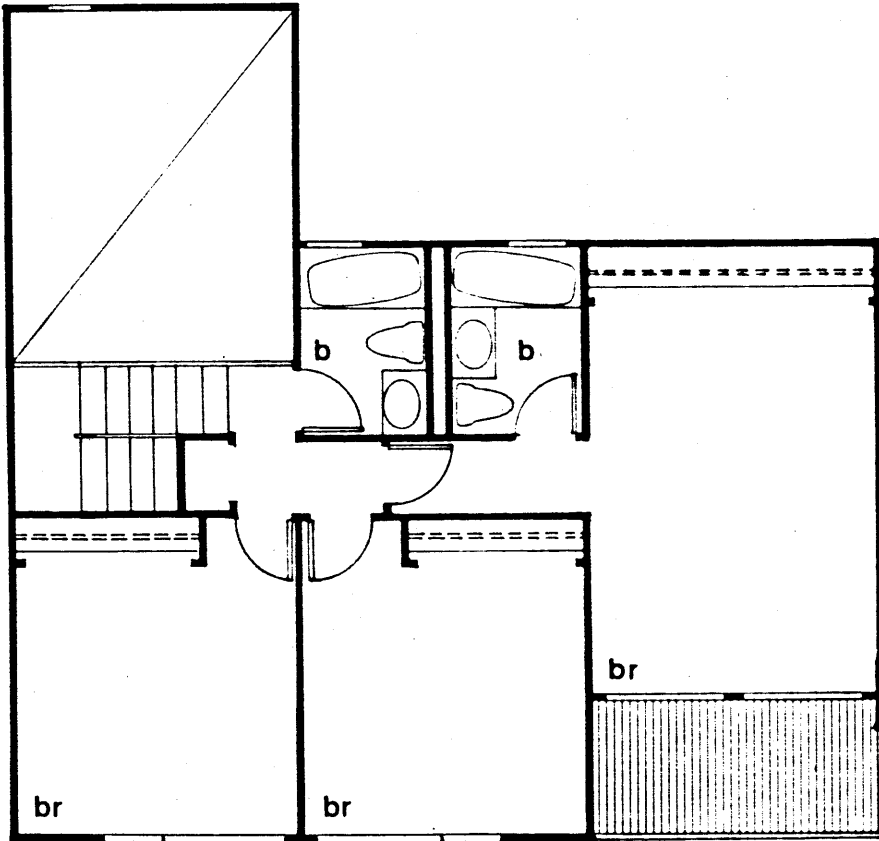


3 br townhouse

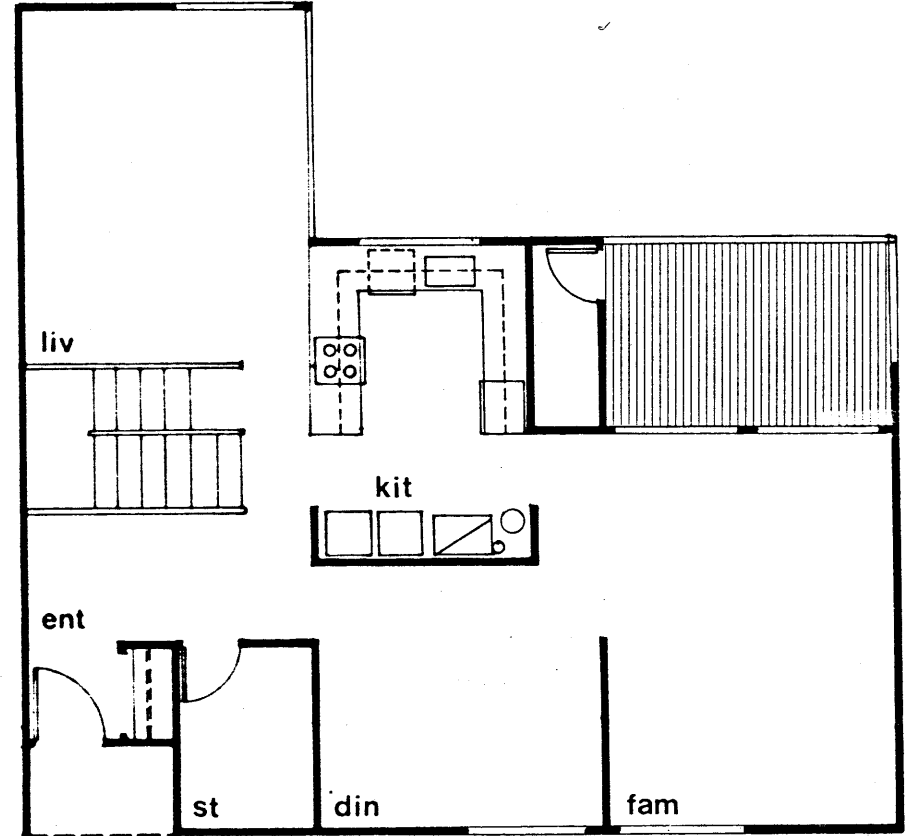


1620 sq ft

1/8

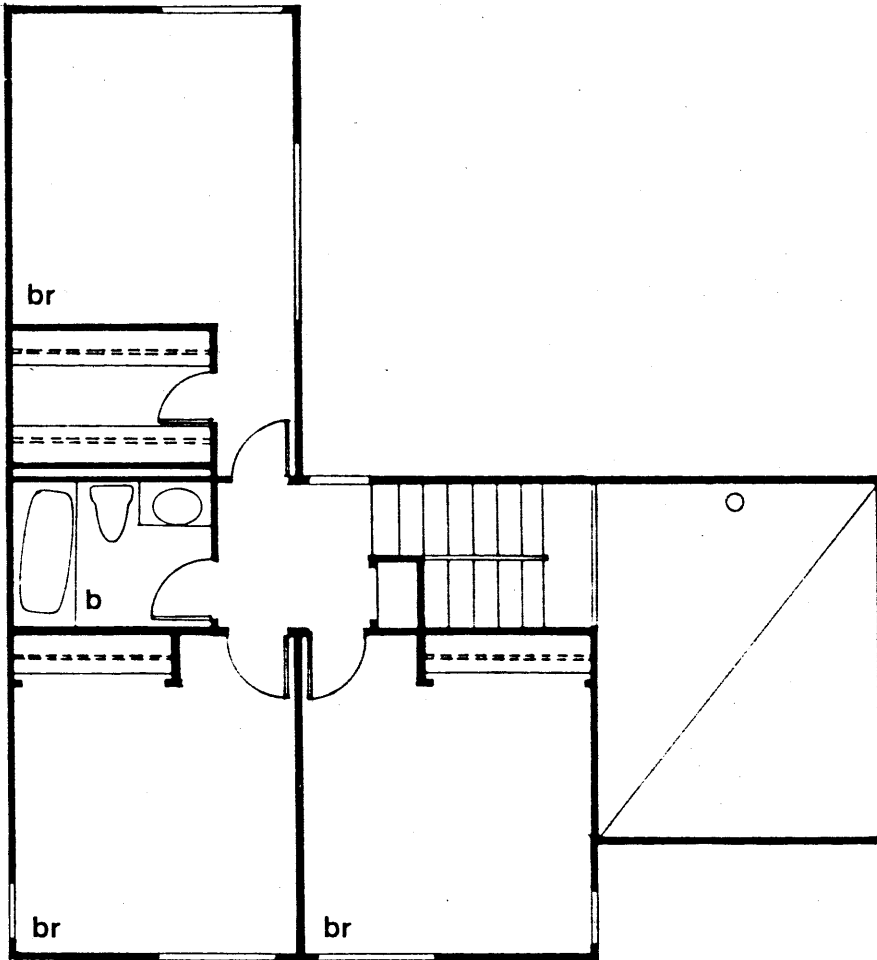


3 br townhouse

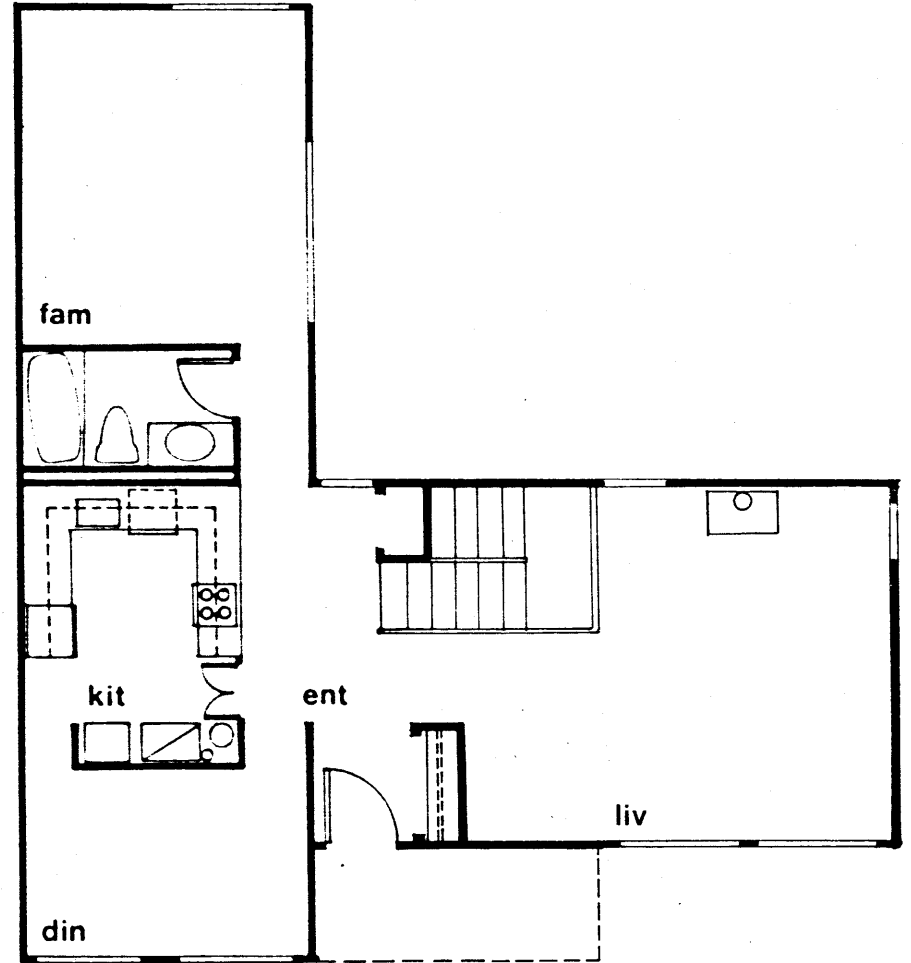


1620 sq ft

1/8

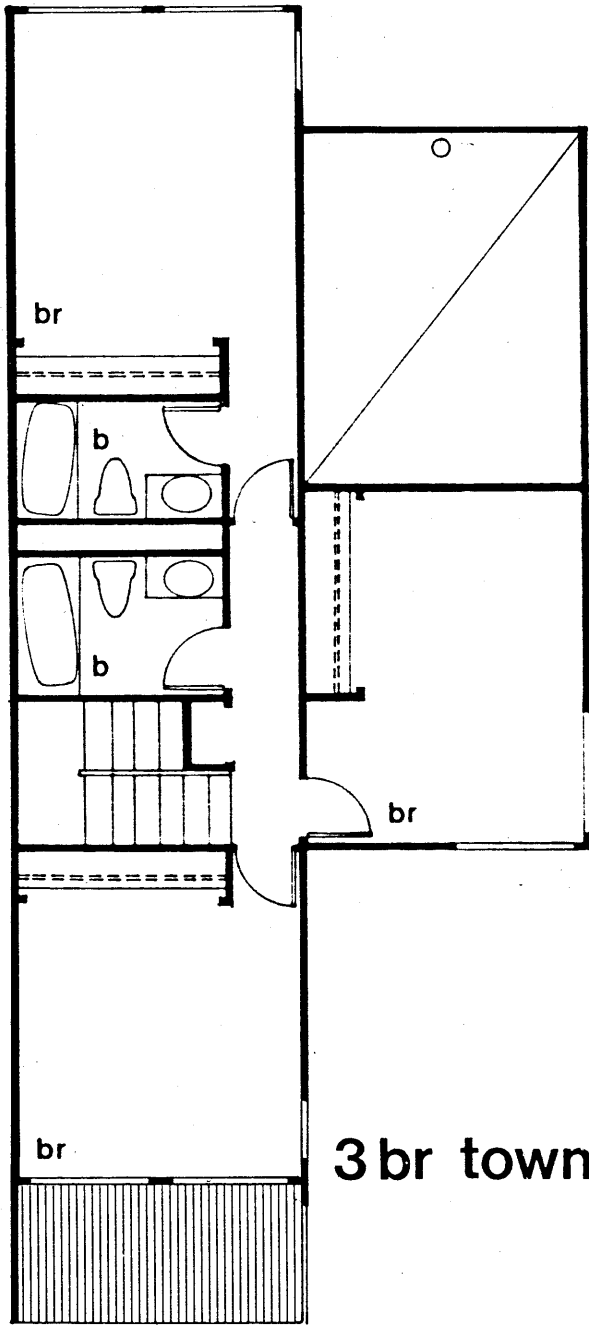


3 br townhouse

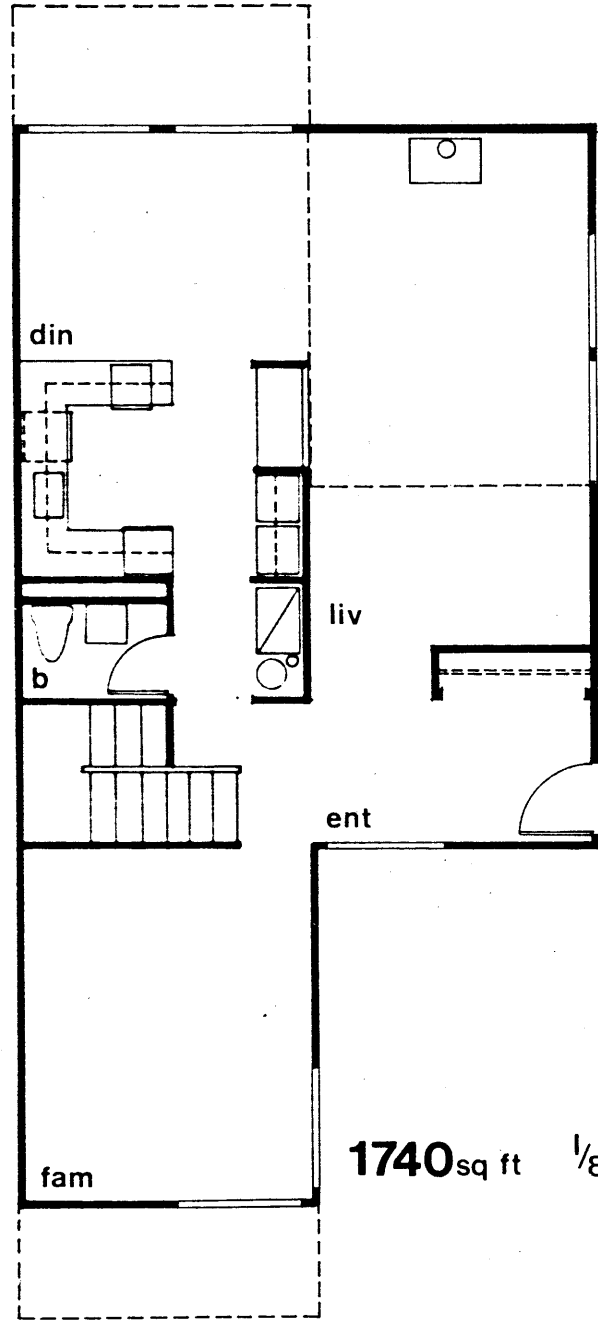


1640sq ft

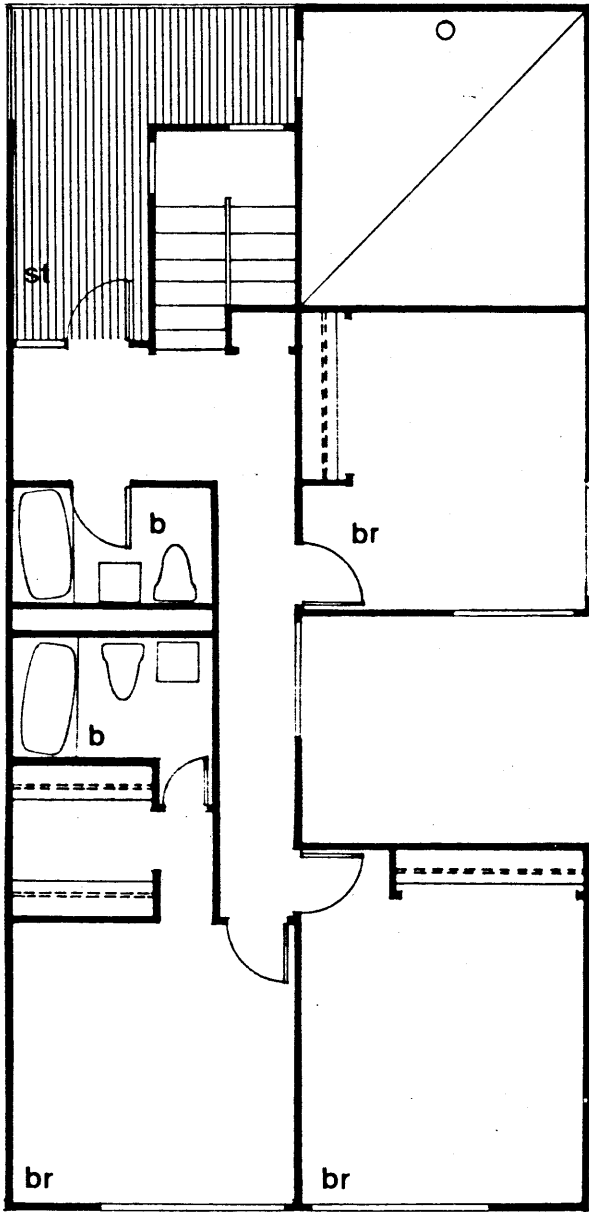
1/8



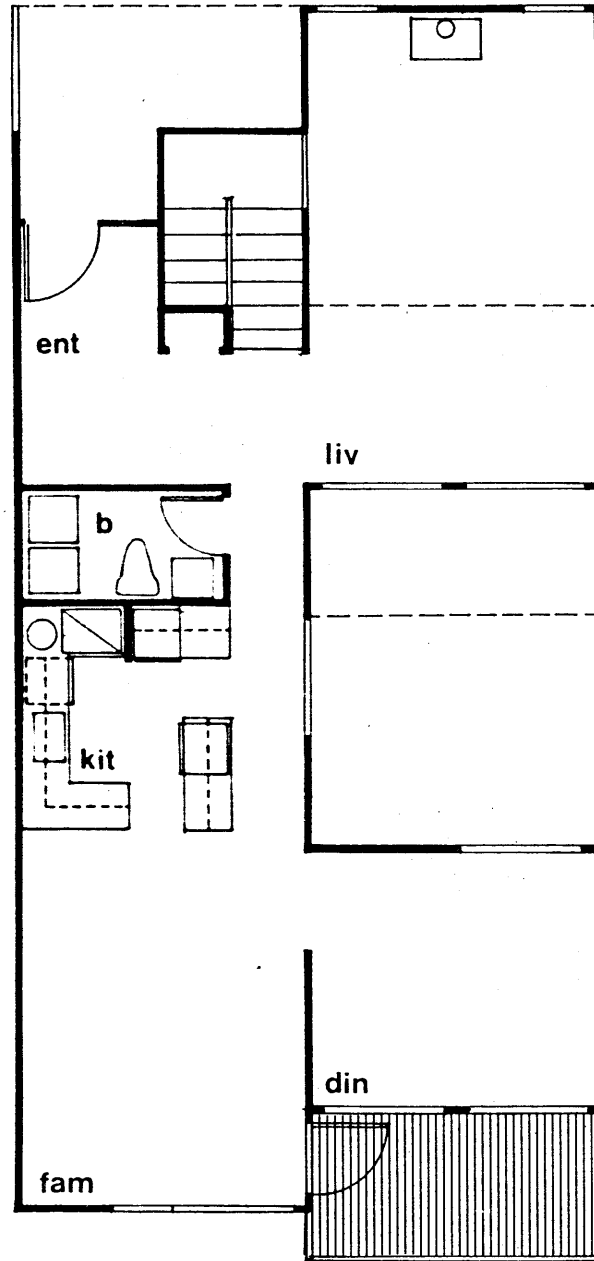
3 br townhouse



1740sq ft 1/8

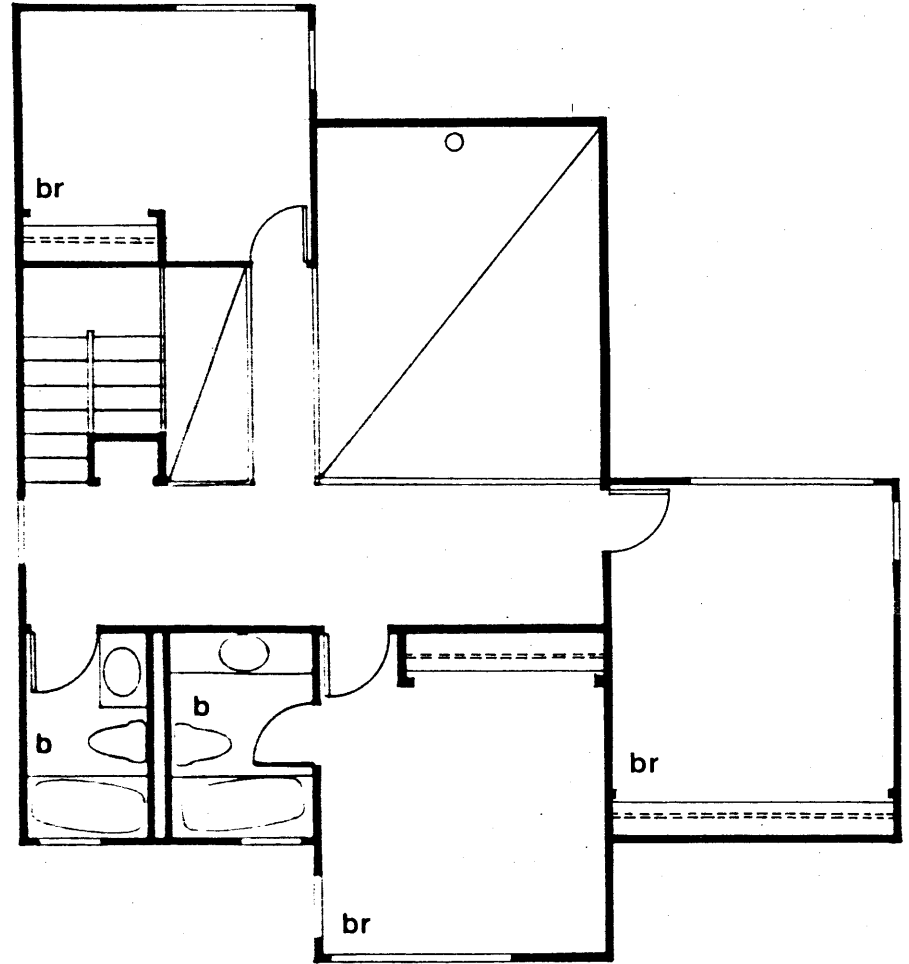
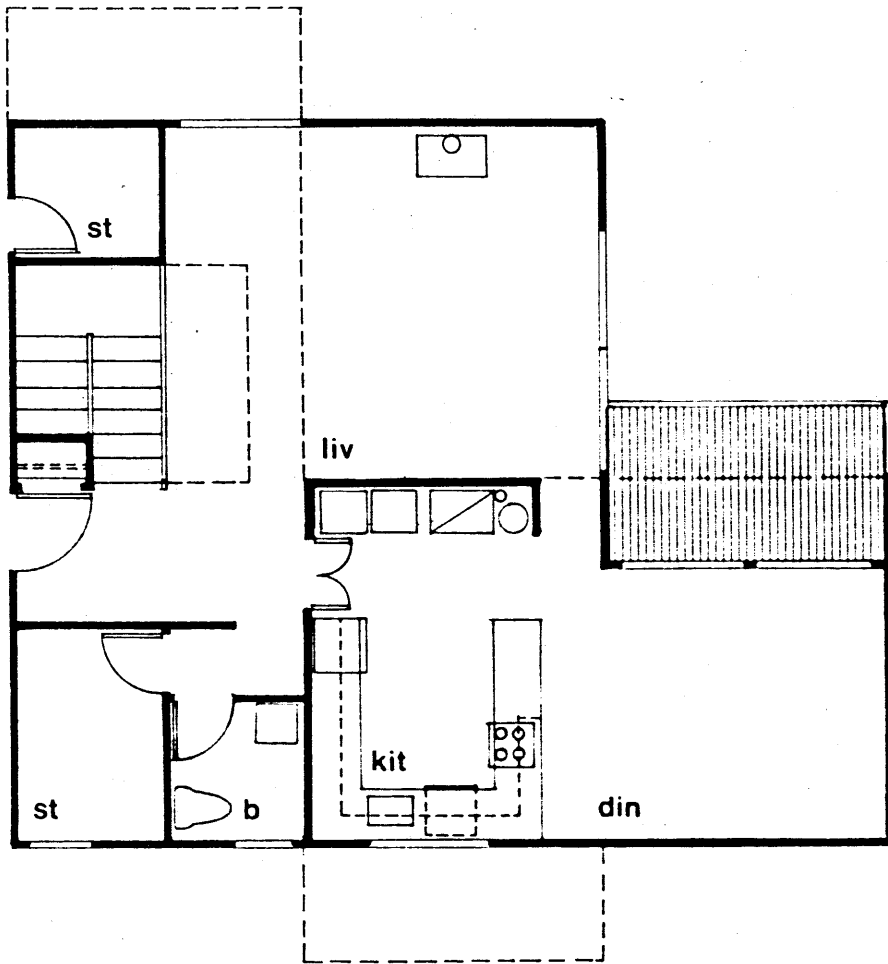


3 br townhouse



1800 sq ft

$\frac{1}{8}$



3 br townhouse

1800sq ft

1/8



elevations

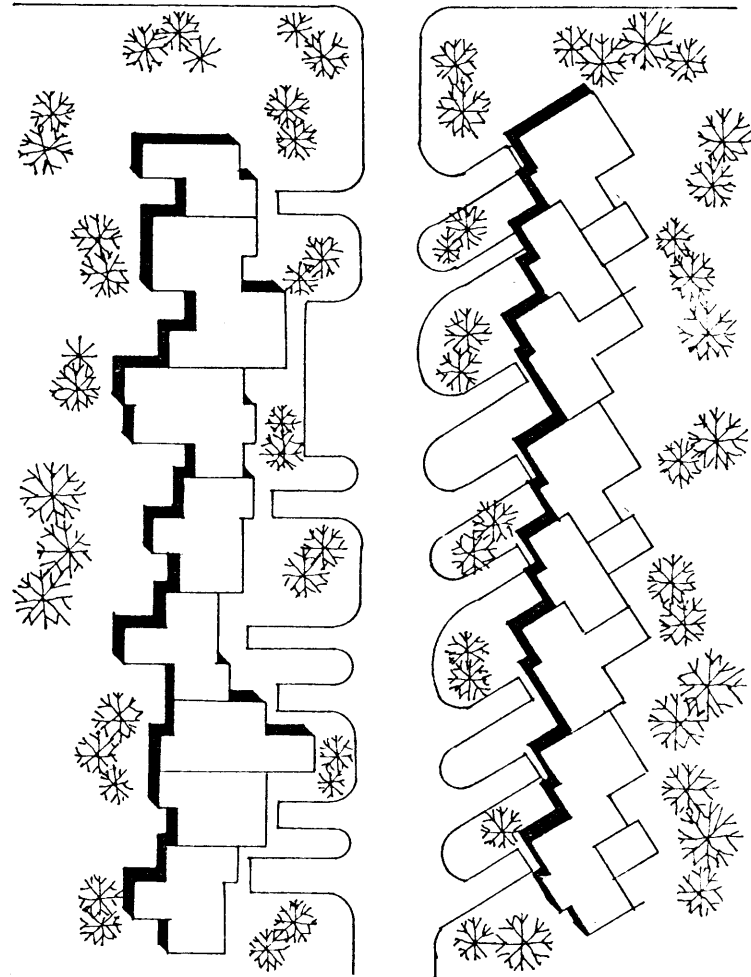
townhouse units

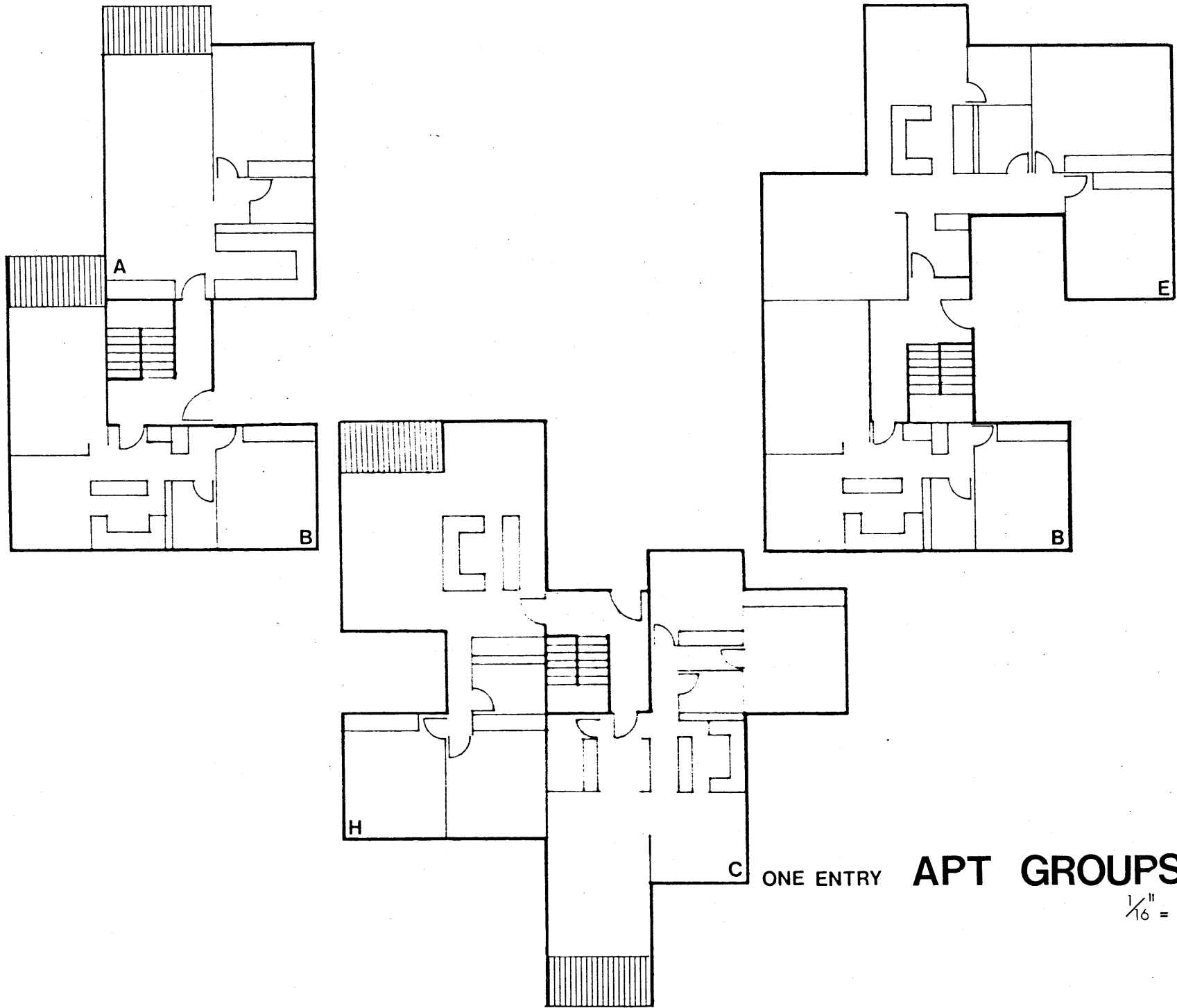
SITE PLANNING

SITE PLANNING

To determine a method for planning, the apartment units were arranged around an entry bay and then the resulting combinations again combined to form buildings. The ones shown are only a few of the endless combination possibilities, and delineate the different forms, entry types, and groupings which may be arrived at using this system.

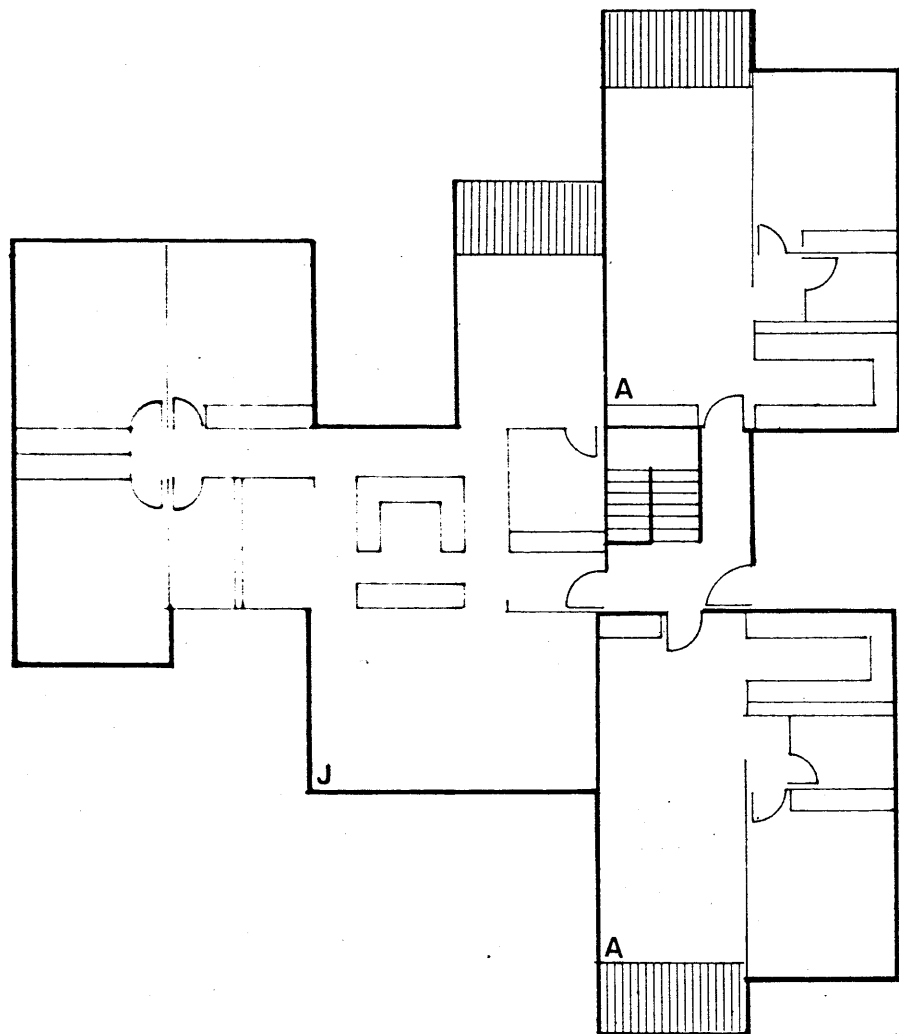
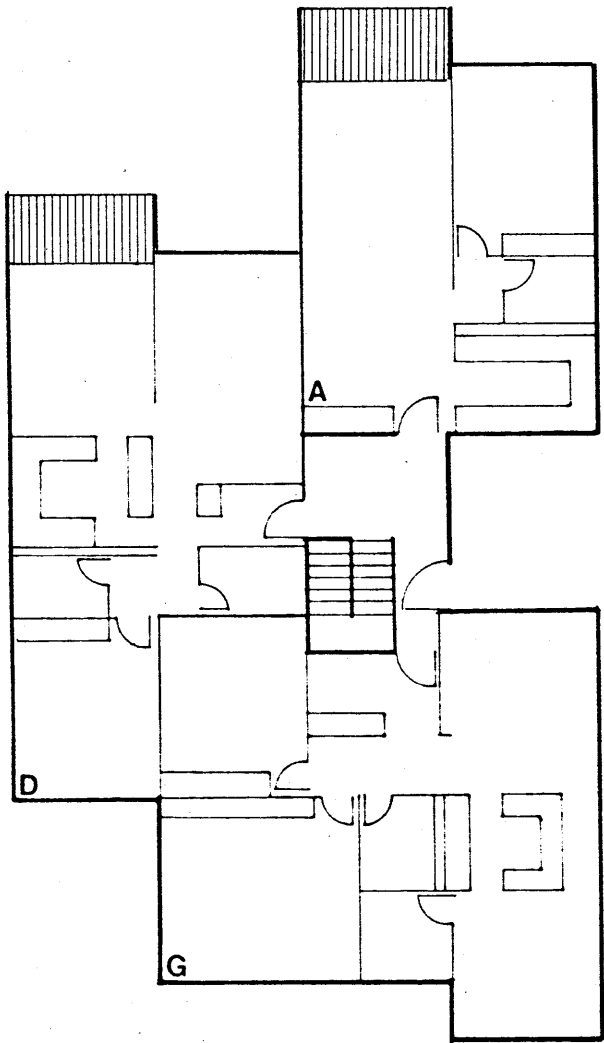
The townhouse units can be arranged side-by-side or on a diagonal, or in combination with apartment units.





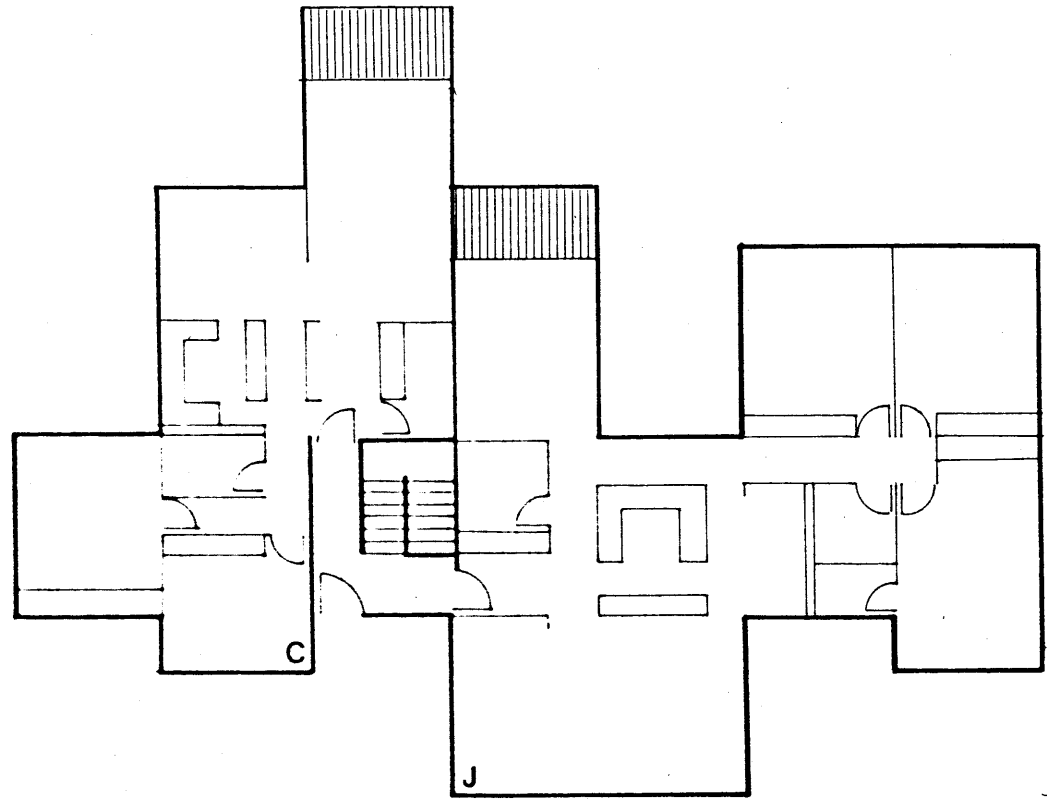
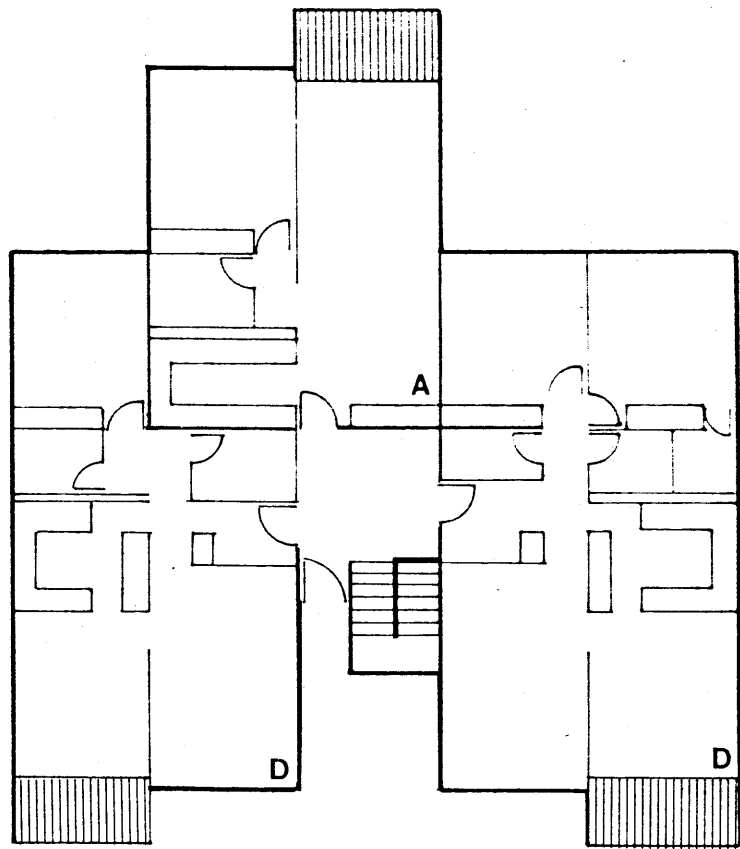
ONE ENTRY **APT GROUPS**

$\frac{1}{16}'' = 1'$

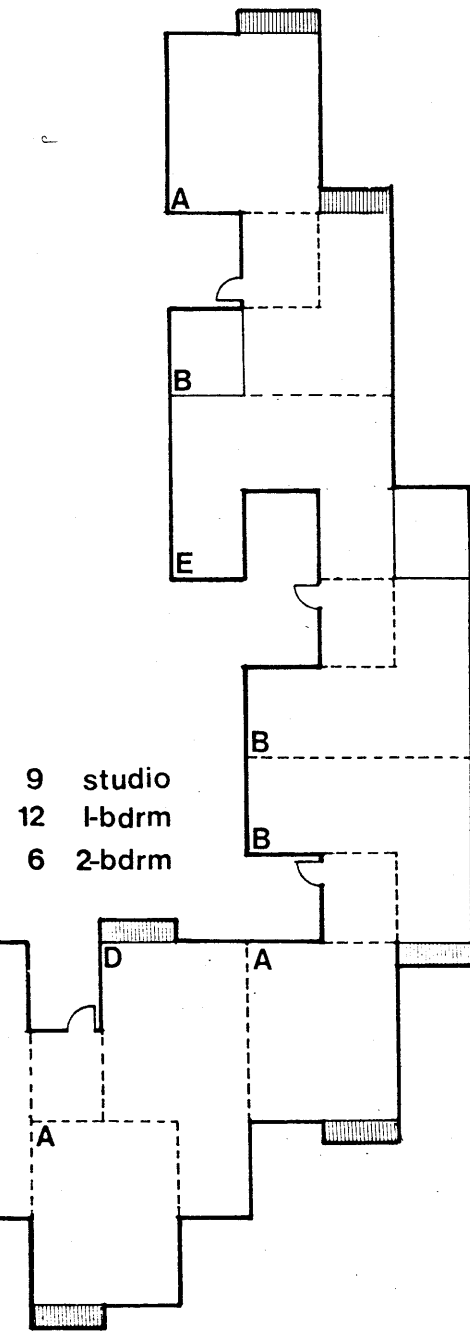
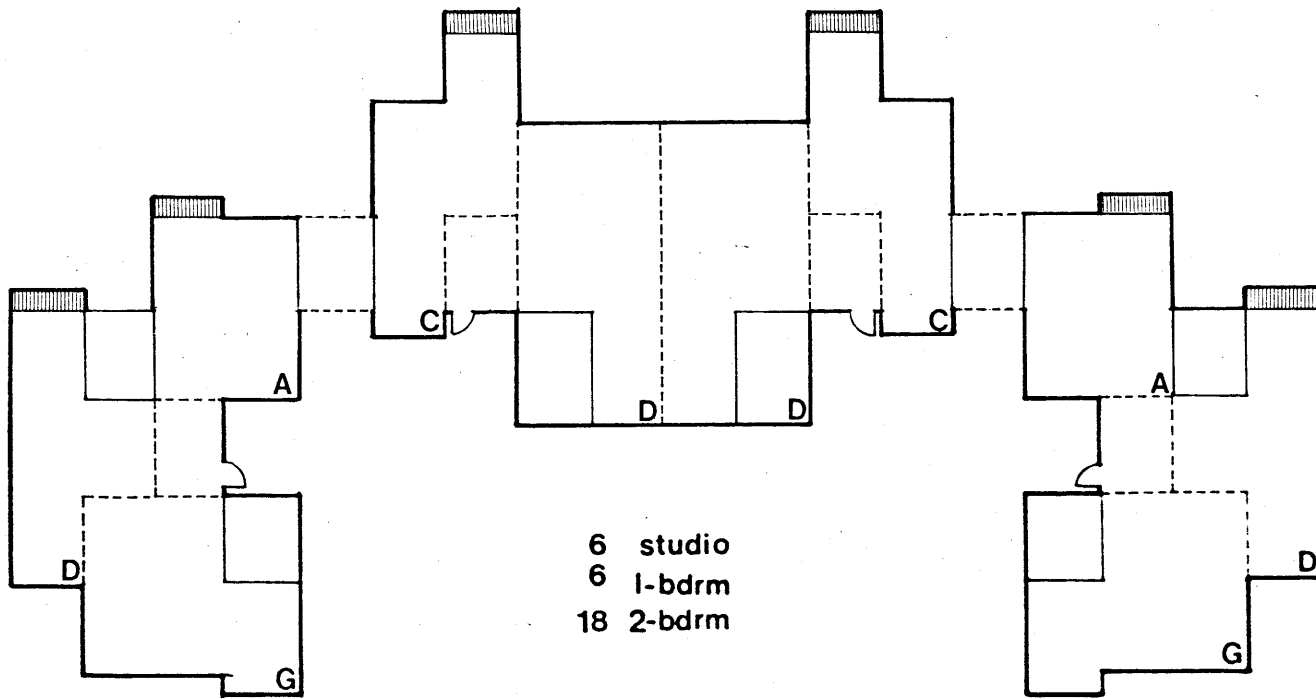


ONE ENTRY APT GROUPS

$\frac{1}{16}'' = 1'$

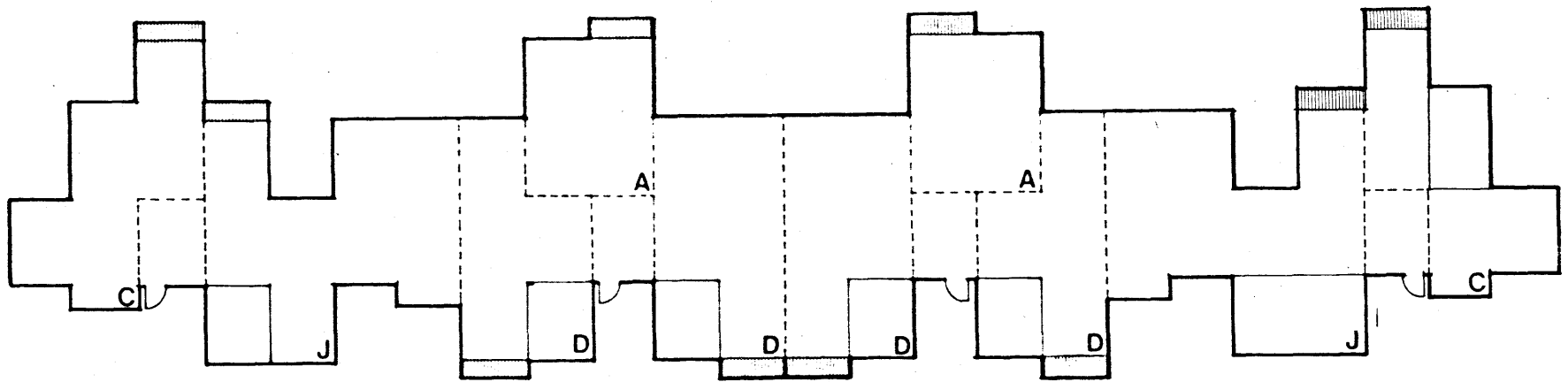


ONE ENTRY **APT GROUPS**
 $\frac{1}{16}'' = 1'$



APT. BLDGS.

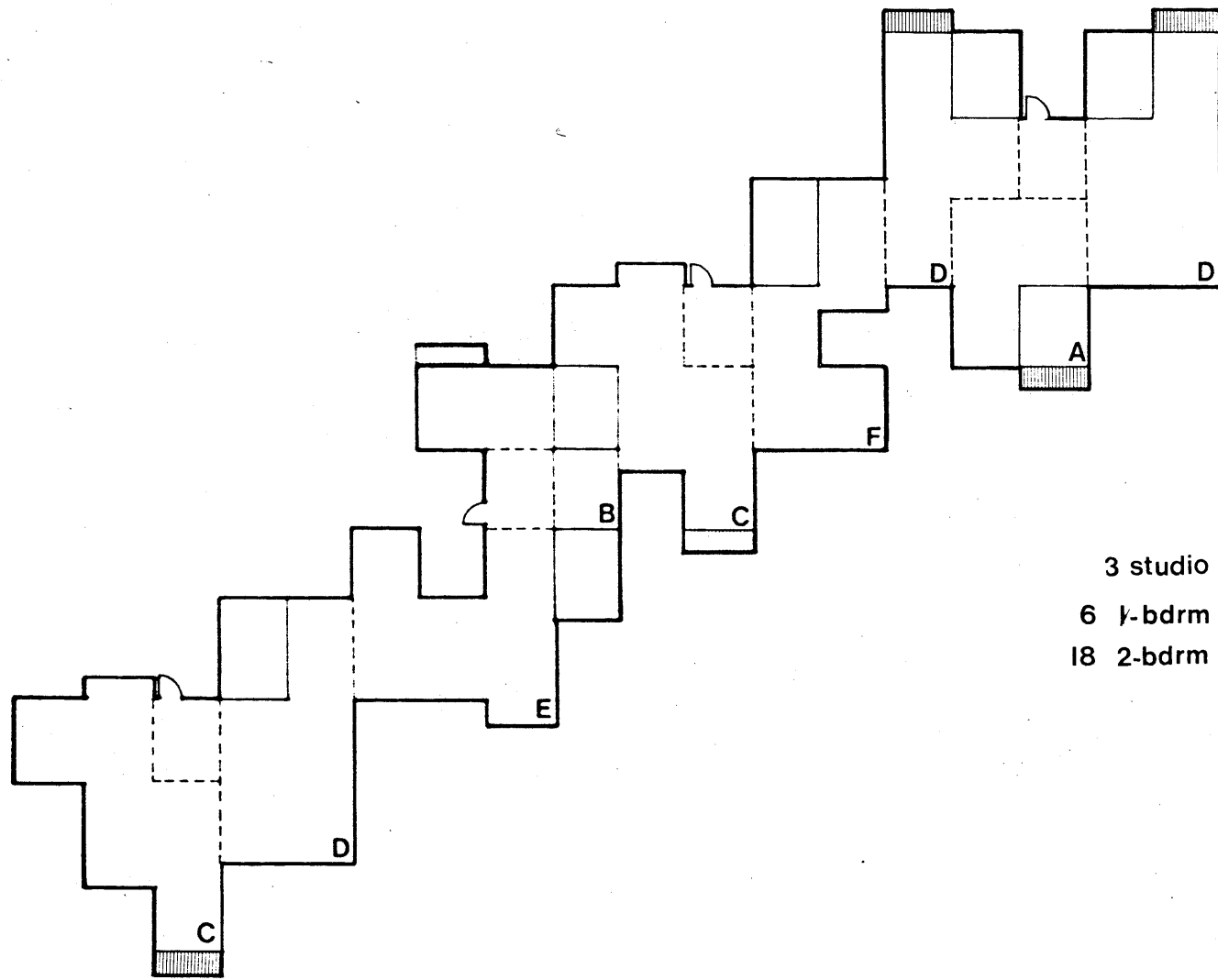
$\frac{1}{32}'' = 1'$



6 studio
 6 1-bdrm
 12 2-bdrm
 6 3-bdrm

1/32" = 1'

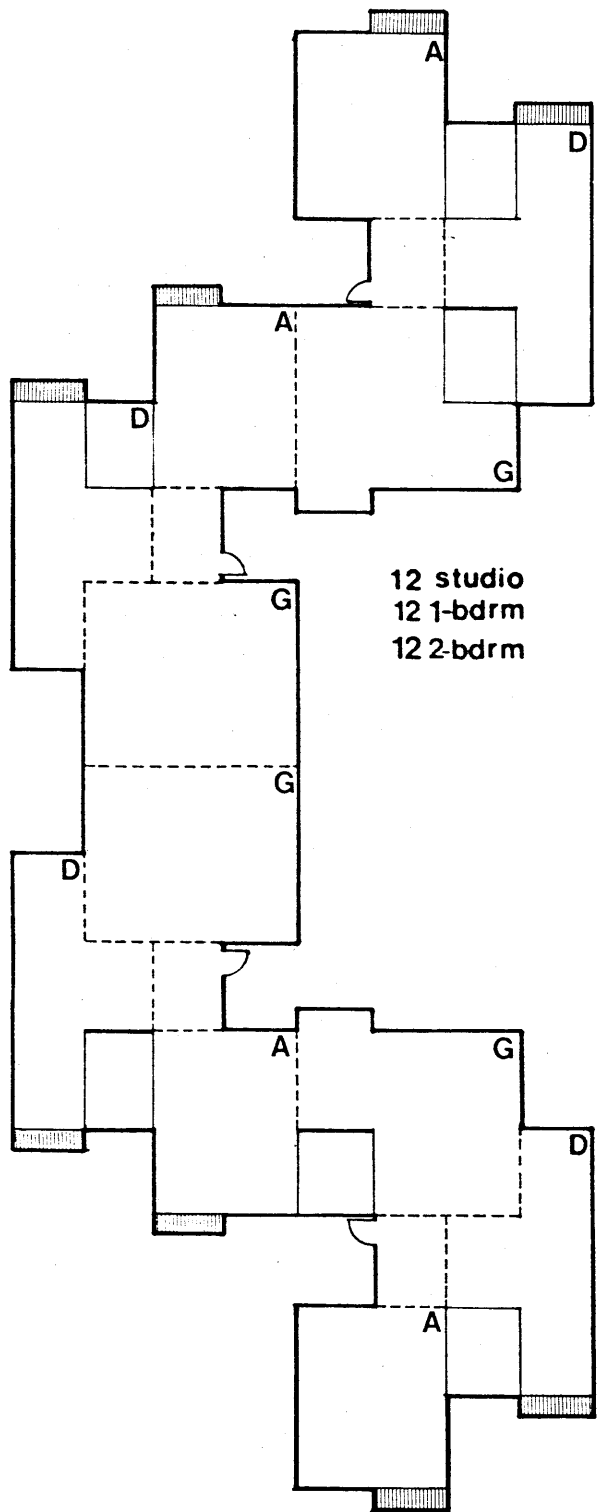
APT. BLDG.



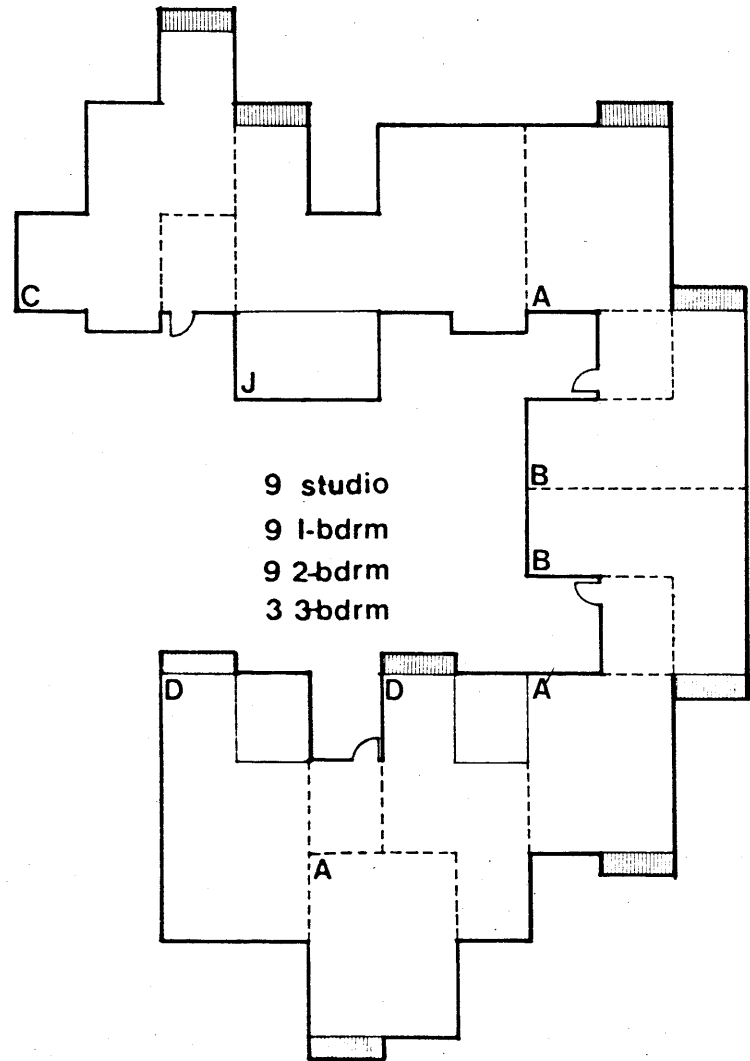
3 studio
 6 1-bdrm
 18 2-bdrm

$\frac{1}{32}'' = 1'$

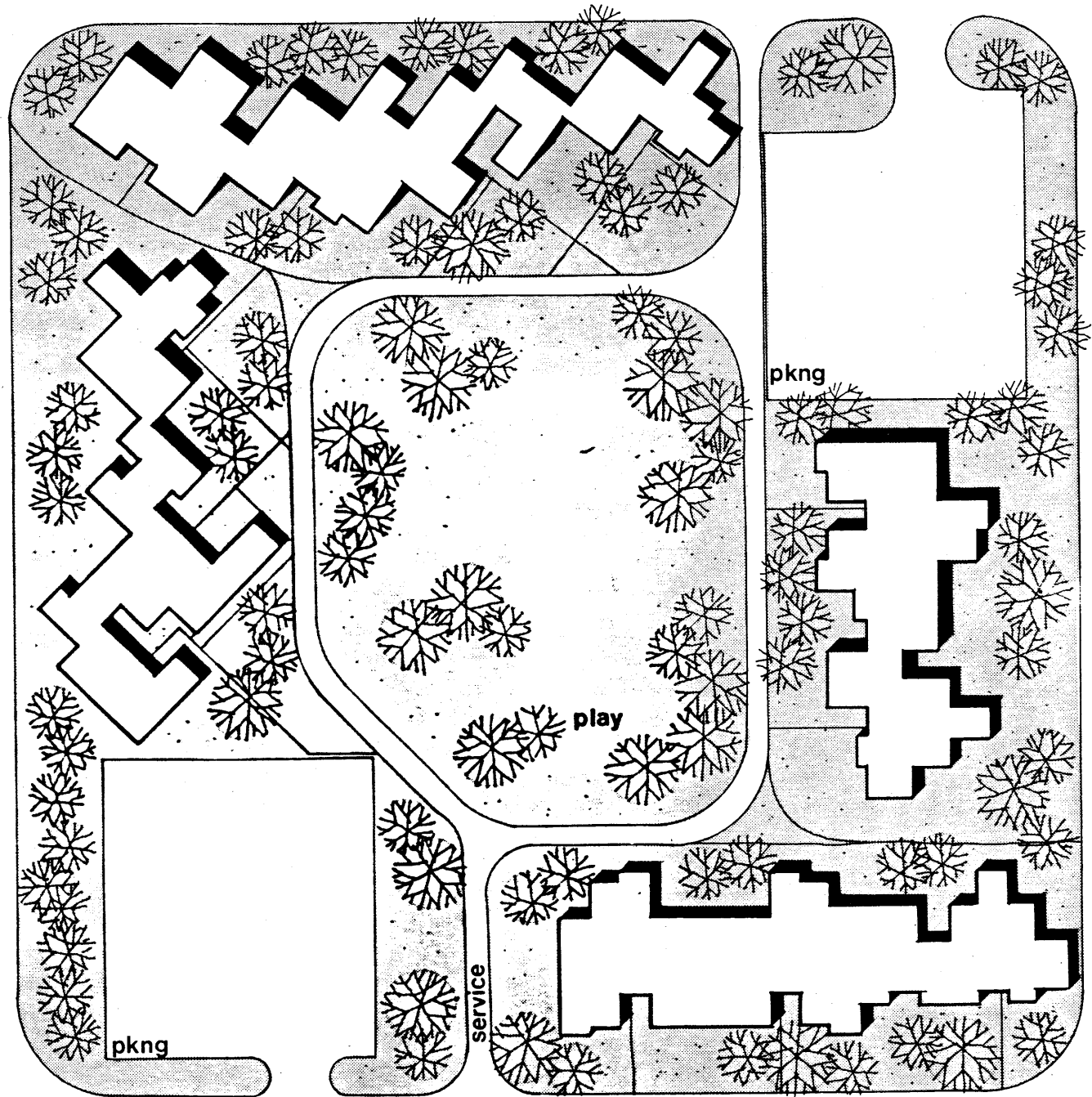
APT. BLDG.



$\frac{1}{32}'' = 1'$

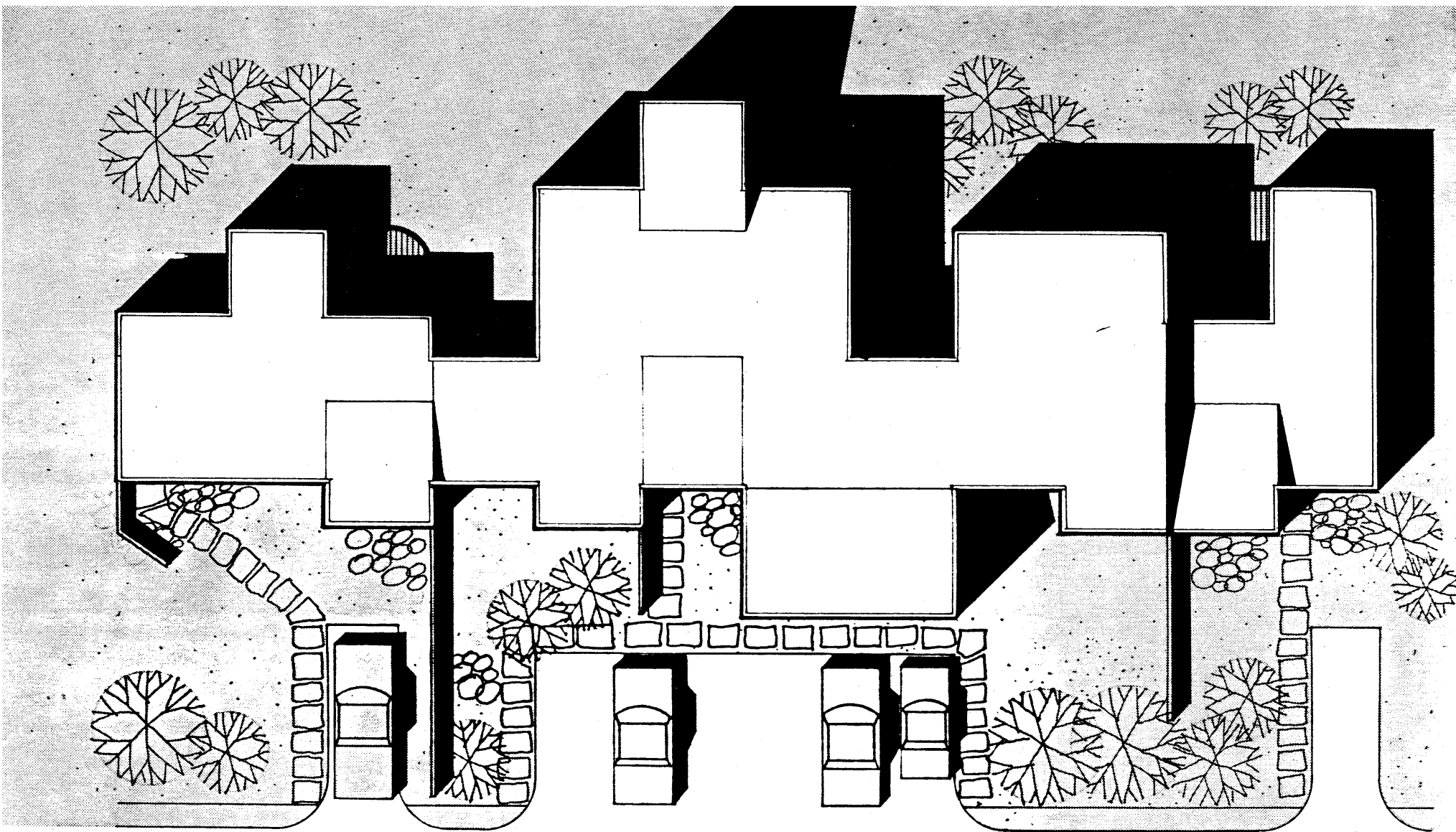


APT. BLDGS.



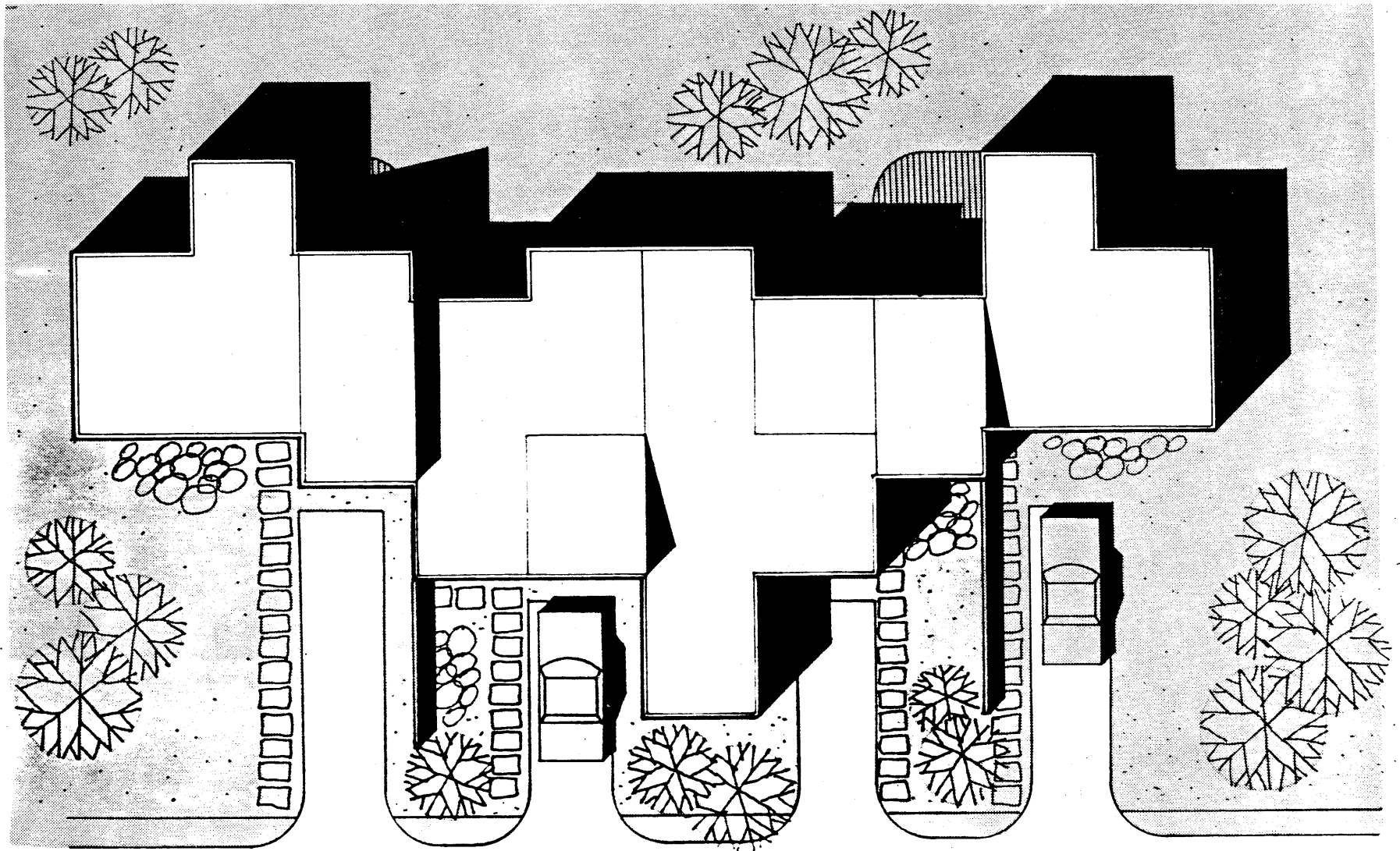
RESIDENTIAL URBAN SITE $\frac{1}{64}'' = 1'$

APTS.



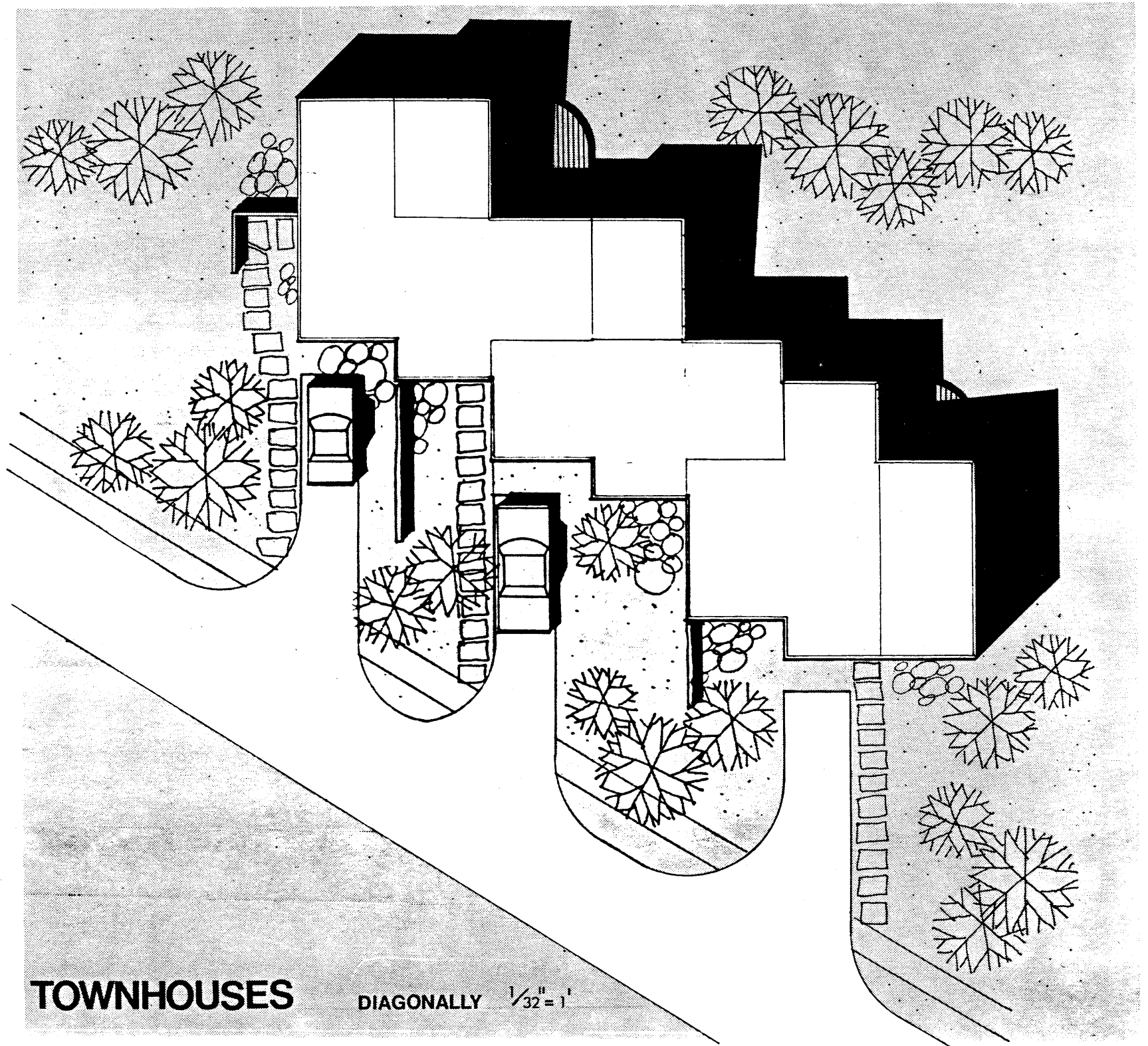
SIDE BY SIDE $\frac{1}{16}''-1'$

TOWNHOUSES & APTS.



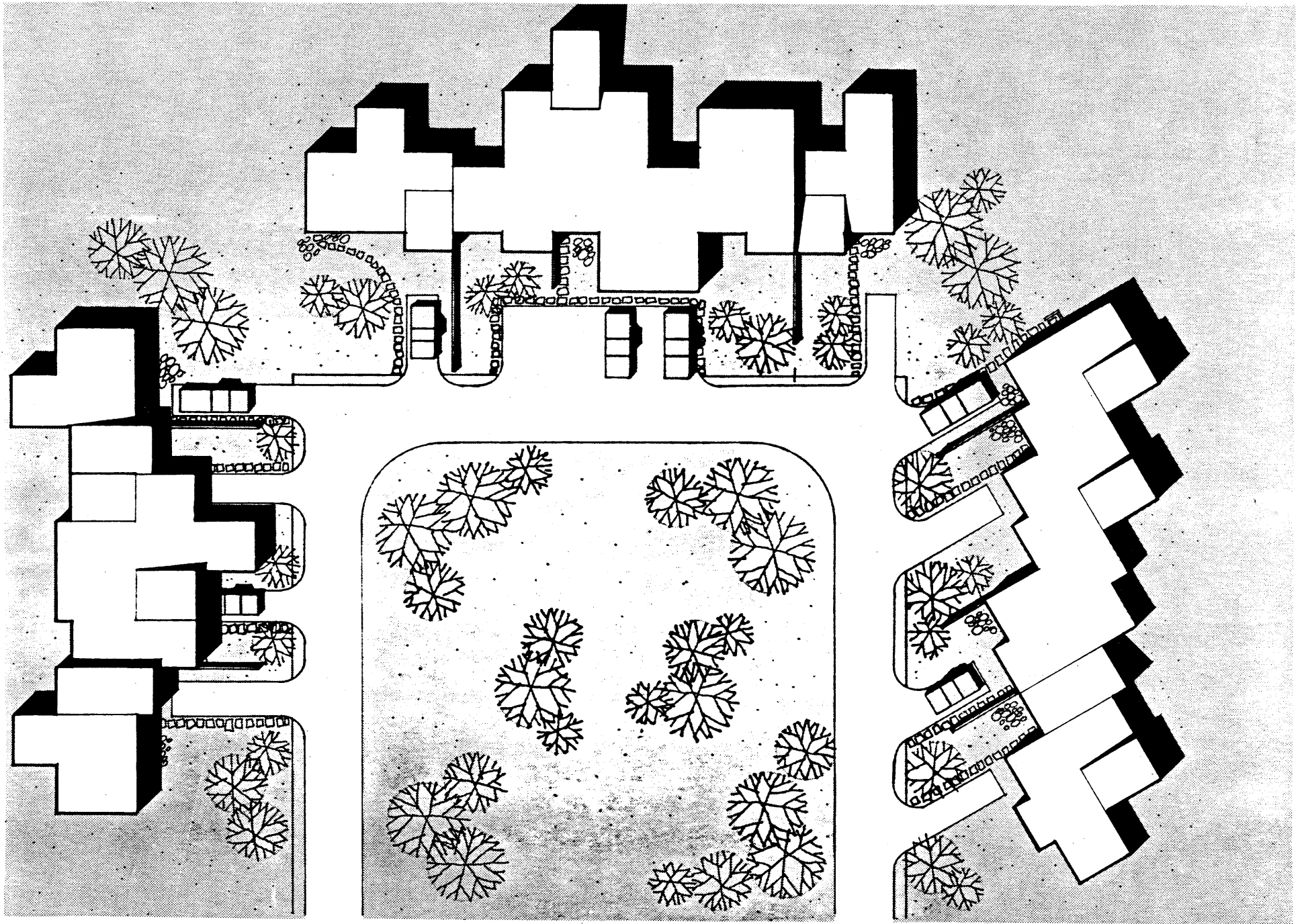
SIDE BY SIDE $\frac{1}{32}'' = 1'$

TOWNHOUSES



TOWNHOUSES

DIAGONALLY $\frac{1}{32}'' = 1'$



U - FORM $\frac{1}{32}'' = 1'$

TOWNHOUSES & APTS.

CONCLUSION

There remains a need for further exploration in the areas of two-way cantilevers that meet to form a 10'-0" bay, and other bay sizes as well. It is difficult to avoid the 12'-0" width of the present bay size and thus rooms become too dimensionally standardized. Details, too, need to be better developed such as lighting, entries, graphics, and planting/paving areas. More comprehensive site planning according to different climatic conditions need to be developed, and outdoor areas put to more use. Other panel types such as metal or sandwich could be studied as well as different stair types which generate strikingly different unit plans. This study is but a beginning and encompasses most aspects of which it was intended to cover, but opens up even more possibilities and potentialities.

