

A CASE STUDY OF COMPUTER USE IN ARCHITECTURE AT V.P.I.

by

Michael Raymond Majewski

Thesis submitted to the Faculty of the  
Virginia Polytechnic Institute and State University  
in partial fulfillment of the requirements for the degree of  
MASTER OF ARCHITECTURE

APPROVED:

---

J. Wade, Chairman

---

G. Hunt

---

R. Schubert

August, 1982  
Blacksburg, Virginia

TO MY WIFE, CATHY  
THANK YOU FOR YOUR LOVE, PATIENCE AND UNDERSTANDING  
AEO

## TABLE OF CONTENTS

Introduction.....	1
The Design Project.....	3
Site Description.....	4
Design Concept.....	5
Building Program.....	6
Building Design Description.....	7
Basic Physical Information Concerning the Library.....	12
Proposed Building Materials and Structural Systems.....	13
Use of the Computer to Represent the Project Building.....	15
Logic and Method of Input.....	15
Method of Measurement.....	17
Entering Building Parts.....	18
Syntax of Operation.....	24
Initial Mapping of the Building Elements.....	25
Conversion to Three Dimensions.....	27
Constructing Walls and Openings.....	28
Fig. 1, Three Dimensional Coordinate System.....	29
Fig. 2, Construction of a Door Within A Wall.....	32
Fig. 3, Construction of a Window Within A Wall.....	35
Fig. 3 cont., Combined Walls.....	36
Fig. 3 cont., Combined Openings.....	37
Fig. 3 cont., Composite of Walls and Openings.....	38
Constructing Floors and Stairs.....	39
Fig. 4, Construction of a Floor Slab.....	41
Fig. 5, Illustration of Stair Construction.....	45
Fig. 5 cont., Composite of Floors and Stairs.....	46
Constructing Askew Planes.....	47
Fig. 6, Tilting the Elevation to Construct Spaceframe...	48
Fig. 7, Construction of Spaceframe.....	54
Fig. 7 cont., Positioning the Spaceframe.....	55
Constructing a Circular Form.....	56
Fig. 8, Construction of a Circular Form.....	59
Final Perspective Representation of the Building.....	60
Syntax Conclusion.....	62
Observations and Conclusions.....	63
Suggestions for Further Research.....	67
Summary.....	71
Bibliography.....	73
Appendix 1, A Glossary of Terms Used.....	74
Appendix 2, Functions Used to Implement Thesis.....	76
Appendix 3, Final Drawings Generated by the Computer.....	83

Vita.....138

## INTRODUCTION

This thesis project was initiated for two very different reasons. The first reason was the continued practice and experience of the traditional abilities and methods of working incorporated by an architect. To accomplish this goal, a design project was proposed and initiated. This project fulfilled my personal needs to continue in the practice of design. The project also was incorporated to be used in the research portion of the thesis. The research portion involved the adoption and use of the design project in relation to computer use, in particular the graphic abilities of the computer.

My personal experience in computer use is limited to one year of use. The language used in the incorporation of the thesis is APL.

The choice of this thesis was to gain personal practical experience by use of the computer and its relation to architecture. This was attempted by using systems or programs already developed for computer use in architecture as well as developing a methodology which would pertain to the thesis project.

Systems I have experimented with in computer use have been developed by Professor John Wade. These systems are

zdraw which is a two dimensional drawing system and a system of unit figures which are manipulated to make three dimensional representations.

The system or method used in the final implementation of this thesis was developed expressly for this project. The method is outlined in the following pages. The method incorporates elements of both the two and three dimensional systems. It was necessary to develop this method because no one system gave the versatility that was necessary for the project.

It is the hope that the documentation of this thesis will give a base or raise additional questions for further exploration into the subject of computer use in architecture.

## THE DESIGN PROJECT

The design project was chosen for numerous reasons. The project had to deal with a certain amount of complexity or more simply stated a project with a series of specialized spaces. This was chosen so that the computer may be more stringently tested on a building that may not necessarily adhere to strict geometric physical bounds or a strict geometric structural system. The project location was chosen to be an area in Blacksburg Virginia. The site chosen was cleared of all existing structures.

The site location was chosen purely for convenience. Since this project is hypothetical and is used as a catalyst in the research of computer use this was reasoned to be valid.

The final reason for the project selection was to increase my personal experience with a building type that I have had little experience designing.

It is important to note that the design project was not intended to be a completed architectural project. It was meant to be only a design exercise that could be incorporated with a research project.

#### SITE DESCRIPTION

The project site is located on the northwest corner of Draper Road and Clay Street in Blacksburg. It is the present site of the Blacksburg Public Library.

This site may be considered the boundary between Residential Blacksburg and Commercial Blacksburg in this area of town.

Across Clay Street, to the north, is a small parklet, to the northwest is the Blacksburg Municipal Building. Northeast of the site is the newly constructed Blacksburg Police station. Directly west of the site is a small shopping center and office building. Residences are on the south and east sides.

The site itself consists of a slope falling gently to the north. The site is approximately 180 feet square and is bounded on three sides by public roadways.



## DESIGN CONCEPT

The building type chosen is a library. The structure is to service the town of Blacksburg, Virginia as a branch library of the Montgomery County library system. The existing library building was used as the basis for the new building program with additional facilities and space requirements determined through interviews with library employees and personal observations. For more information consult the building program.

The main concept of the building was inspired by the idea of books, how they are stored and how a person uses books. This concept led to an exploration of different ways to store books and how this storage effects the traffic and use patterns of people in the library.

Another aspect added to the program was that of an area in the library which would serve as public space for activities slightly or not at all related to the use of books. It is my belief that in this case, because of the two very different above mentioned uses, the library building should physically express these two uses. It was this belief that led to the final design scheme of the library building.

BUILDING PROGRAM

area	not to exceed present library area or 15,000 sf
volume capacity	40,000
linear shelf space	at least 6,500 lf

FACILITIES TO BE INCLUDED IN THE LIBRARY BUILDING

reading and studing areas  
audio/visual area  
children's library  
control desk placed near main entrance  
area for reference and card catalog  
public meeting room to seat at least 100 people  
office space for library staff  
staff lounge  
work room  
public rest rooms  
receiving entrance

## BUILDING DESIGN DESCRIPTION

Very early in the design phase it was decided to use the idea of wall as the physical element to express the presense of books in the library. Later in the design process, it was found not to be practical to use one wall as the storage element of books. This became necessary because of the large number of books needed to be accommodated in the short linear space the site had to offer. This idea of a wall-like space then transformed into the area of circulation within the building. This circulation space became the main area of access within the building servicing both books and the adjacent areas designated for reading and research.

The main feature of the building is a high narrow wall-like space which encloses three levels of access corridors. The walls which enclose this access area move uninterrupted through both the inside and outside of the building. On the outside of the building, with only a few exceptions, the walls contain no openings. On the inside of the building, however, the walls are honeycombed with many openings and arcades. This enclosure is the dominate element in the building and acts as a division line between book storage and book use.

The circulation space services book alcoves on the

south side. These book alcoves rise uninterrupted the three levels of the building with only the ceiling height becoming greater on the upper levels.

In contrast, the north side of the building which houses the reading rooms is varied in form. The larger reading rooms are on the bottom floor with the second level containing smaller, more private reading rooms. The third floor contains no reading rooms. Reading area is accommodated on the third floor by means of small balconies that jut from the wall over the large reading room on the first floor. These balconies can be installed with private desks.

Additional spaces on the north side of the building are a children's library and audio/visual room on the first floor and a control area for the library staff at entrance level.

The entrance level services the control area as well as the card catalog room and public rest rooms on the building's south side.

In addition to the library area of the building there is also a special activities area. The use differences of the library area from this area caused the design of this section of the building to become a separate wing. This

eliminated any problems that might arise from use of the two areas at the same time. It also solves the problem of security in the library when activities are occurring during hours that the library area is not open to the public.

The special activity wing is located immediately west and askew to the library wing. The angle of orientation developed from the building's orientation and position on the site. The activity wing runs parallel to Draper Road which makes a slight shift from the regular grid pattern of the town. The library wing's position is determined by its relation to the view of the park across Clay Street, the attempt to be parallel to the slope of the site and its directional relationship to the police station and municipal building. Both wings have an individual outside entrance.

Contained within the special activity wing is a meeting room for special groups and speakers. This room is to have movable seating. The seating area is terraced toward a small stage. Each terrace is planned to be wide enough to accomodate two rows of seats or tables and chairs for conferences or workshops. Also within the meeting room is a projection booth, storage for portable tables and chairs and a stage that may be used for very small community theatrical productions or recitals.

The lobby acts both as an entrance to the wing and as

an area for gatherings of people using the meeting room. It is large enough to accomodate tables for refreshments and is adjacent to the kitchen and public rest rooms.

The remaining area in the activity wing houses staff offices, a lounge, a work area and receiving dock. These areas do not directly relate to the library but are all support facilities and are therefore located in this wing.

The joint of the two wings evolved from the askew angle at which the the two wings meet. This angle has nothing in common with the geometry of the two wings and was therefore treated as a separate entity. This area serves as the entrance to both wings. The joint is evolved from a circular extrusion at one end of the circulation wall of the library wing. The original concept of the joint developed from relationships similar to those found in the human body, for example, a ball and socket. This type of joint functions for any angle. The circular space also functions as a good entrance into the two wings. This area is the only place in the building constructed in this circular geometry and therefore calls special attention to itself. Another aspect of the circular joint is that it is not covered. This acts as a transition between outside to inside.

The final computer produced drawings illustrating the

design can be found in Appendix 3.

BASIC PHYSICAL INFORMATION CONCERNING THE LIBRARY

ROOM/ROOMS	AREA
reading area total	1,900 sf
book storage total	1,866 sf
children's library	880 sf
card catalog	234 sf
audio/visual room	224 sf
meeting room	1,608 sf
staff work space total	700 sf
lobby	720 sf
mechanical room	540 sf

The above room classifications do not include public rest rooms, circulation spaces, stairs, closets and risers.

total area	12,500 sf
total shelf space	7,000 lf
total volume capacity	40,000
meeting room capacity	136



## PROPOSED BUILDING MATERIALS AND STRUCTURAL SYSTEMS

References to structural systems and building materials made in this section do not reflect the completed building. These references are made only because the ones that are mentioned influence the design and aesthetic of the project. I therefore have included them so that a better picture of the building can be established.

The entire wall area of the building is to be built of standard common concrete block. In all cases the standard concrete block walls are to be surface treated with stucco on the outside and standard drywall on the inside. The exceptions to this are the walls enclosing the access corridors of the library wing and the walls of the entrance arcade or the joint of the two wings. These walls are to be constructed of fluted concrete block. The fluted block walls are to remain their original texture. The fluted concrete block is to be the same color as the finish stucco.

The entire building is of bearing wall construction. The floor and roof system in the library should be prefabricated hollow core concrete slabs with a concrete topping.

The first floor of the library and the activity wing are slab on grade. The roof system of the activity wing is

to be a concrete topping over a corrugated metal roof deck supported by steel joists.

The space frame over the large central area of the library wing is to be constructed of tubular steel and sheathed in clear glass.

## USE OF THE COMPUTER TO REPRESENT THE PROJECT BUILDING

The following sections outline the the final method chosen to input information about the project building into the computer. An attempt was made to outline this procedure precisely so that the method could be incorporated to any building of the type used for this thesis. In this project the building type is meant to describe the complexity of the building and not the building use.

### LOGIC AND METHOD OF INPUT

Using a computer to represent a three dimensional form such as a building requires a good deal of organization and understanding of both the building and the machine on the part of the user. The method outlined here is just one example of using the computer as a tool in architecture.

This method or logic was chosen as the simpliest way to get the greatest diversity of use from the information placed in the machine. This method was also chosen because it allows some variation in use and is easily understandable to someone like myself with limited experience in computer use.

Factors which affected the choice of this method are:

- the design of the building is asymmetrical
- the structural system sizes are not the same throughout
- windows, doors and other openings are not in a regular pattern
- floor sizes and configurations differ from one floor to another
- wall heights differ throughout the building

These factors may be considered the overall character of the building or building type. It was this building character which determined the method by which information was entered into the machine. A building of different character may dictate an entirely different way of entering information.

The method used to input basic building information was through the use of the crosshairs on the tektronix graphic terminals. This method is beneficial because the user is able to see graphically every step of the input process.

A negative aspect to crosshair use is that the points and lines constructed by the crosshairs are not entirely accurate or exactly in the position wanted. The accuracy that can be gained with the crosshair depends on the patience of the user and the amount of vibration in the crosshairs which differs among terminals.

To correct this problem of inaccuracy required the use

of an adjust function. This function rounds each entered value to the nearest integer value specified as the left argument of the adjust function.

It was also easier to work with the crosshairs at a large scale and then scale the drawing down after information was entered.

#### METHOD OF MEASUREMENT

Before entering information into the computer it had to be determined on what unit of measurement this information was to be based. The building measurements or true life measurements had to relate proportionally to screen units. One screen unit is approximately  $1/126$  inch. It was decided to use a measuring unit that was found throughout the building. This unit is a standard concrete block with mortar joint or 16 inches long 8 inches deep and 8 inches high. Earlier in the design process it was decided to use concrete block as a building material and therefore all wall openings and ceiling heights adhere to an 8 inch interval. This makes this measurement system more desirable than constant conversion to feet and inches.

## ENTERING BUILDING PARTS

The following method of entering building parts was used throughout the construction of the three dimensional representation of the library. The final result was a line drawing of all parts which could be manipulated into any position and scaled to any size for examination and documentation of the design project.

It was beneficial to construct groups of the larger parts of the building representation first. These could then be displayed to help with the input of the smaller parts. Examples of large parts are plans or floors and/or major walls or openings.

For the most part this representation was based on the building plan. This method could easily be adopted to a building generated from a section simply by following the same format and then rotating into the correct position.

Organizing groups of building parts that have something in common was found to be the best way to construct the three dimensional representation. Doors of standard or the same height, for instance, were grouped together so they could all be acted upon in one process.

For example, the doors on the first floor of the library are all 6 feet 8 inches high but of different depth

and length. To represent these a map or plan was constructed of the door lintels using the crosshairs. The map corresponds to the door length and depth. This map was then aligned and scaled to the plan of the first floor. The map was translated up in space 40 units which corresponds to 6 feet 8 inches in the measurement system chosen. A line function was then called to connect the lintel with the plan and a three dimensional representation was made of the doors. This representation shows plan, lintel and jamb.

Windows were constructed in a similar fashion. A map of the lintel was drawn. The map was translated into space twice, once to define the lintel and once to define the sill. The line function was then used to connect the two.

Walls were constructed in much the same way as openings. The construction of walls required a map of the wall top or parapet. The wall top was then translated in space to its uppermost position and the line function called to connect the corners of the wall to the corresponding corner points on the plan.

Some walls, however, created a very different problem. These walls were those whose corners do not connect to the same plan. For instance, a wall climbing a slope that meets the first floor on the downward side of the slope and meets the third floor on the upward side. The wall also has a

level horizontal map. If the line function were called to give the height of the wall at the first floor, a line would also be constructed to the first floor elevation at the point where it was to meet the third floor elevation. This problem was solved by either constructing the map in two sections or dividing it in half and performing the line operations separately on each section before the wall was reassembled.

Floors and ceilings were envisioned as slabs floating in space. The map of the floor or ceiling consists of the horizontal line that a floor or ceiling intersects a wall. In most cases except in a balcony or cantilever this line will always fall within the interior of the wall on the plan. After the map is constructed, it is then translated into space twice, once to represent the floor and once to represent the ceiling below. The line function is called to then define the thickness with vertical lines.

To this point the construction of parts has dealt only with horizontal and vertical planes and openings within these planes. The problem of constructing a plane that is askew to the vertical and horizontal planes is now addressed. The library project used for this case study has as one of its elements a large space frame that is at a 45 degree angle to the vertical walls. The representation of



this space frame required additional steps in the construction process.

It was found that the space frame could be initially constructed in two different ways. The first way was that of determining the basic or smallest unit. This unit could be represented as a small pyramid with 8 line segments, each segment defining an edge of the pyramid or one member in the space frame. After the initial unit is constructed it is then repeated and translated the required number of times to form the space frame representation. This representation is then rotated and moved to its appropriate position. This method is probably the easiest to construct but will have much redundancy of line segments. This redundancy occurs when two units are translated and drawn next to one another and line segments overlap. The problems that may occur from this redundancy of line segments is the amount of time required to draw the entire representation and the amount of storage required if the representation is stored as a variable. A way to solve the storage problem is to store the initial beginning or unit figure and write a niladic function that will reconstruct the representation each time it is called. There is still a danger, however, of getting a full or overloaded work space.

The alternative to the basic figure method is to

construct the space frame as two grids, planes parallel to one another. These grids can be easily constructed with the crosshairs. The grids cannot, however, be constructed on the plan since this would give a foreshortened view of the grid because of its angle. For the library project the grids were constructed with the crosshairs by first rotating a view of the elevation down 45 degrees so that the plane of the space frame was parallel with the screen front. A smaller unit figure can then be called as above. This figure represents only those line segments found between the two planes or 4 line segments. The redundancy is now eliminated. The results of the two methods will give the same representation.

Steps and staircases could be constructed from the plan as were the walls and floors. This was found, however, to be unnecessarily time consuming since each step had to be translated up or down individually in space. A much faster and more accurate method with crosshair use was to display an elevation or section of a wall near or connecting to the stair. A profile or section of the entire staircase was then constructed. This profile was then extruded to the width of the staircase using the line function and then rotated and translated into position. Another beneficial method to construct stairs was by constructing the steps as if they were small floor segments. One segment can be

constructed then repeated and translated to the position of the remaining steps in the staircase. Each of these segments can then be translated and extruded into position much like the method of constructing floor slabs.

## SYNTAX OF OPERATION

This section will deal with the actual syntax used to construct the project building. In order for this syntax to be used, it is necessary that the functions and variables found in Appendix 2 be loaded into the workspace being used.

The syntax will follow the order of construction that was used to represent the library project. This order need not be followed exactly but will and should change depending upon the building type being represented.

Throughout the construction of the representation it is important to remember whether the point or line set being constructed is in two or three dimensions. This factor in most cases will influence the function used for manipulation. The method begins by constructing maps in two dimensions and then converting these maps into three dimensions.

The terms used are defined in a glossary in Appendix 1

All function and constant variable names will be represented in upper case letters.

## INITIAL MAPPING OF THE BUILDING ELEMENTS

After a system of measurement has been chosen that will easily relate to the project building activate the crosshairs.

Activating the crosshairs is accomplished by using the function CURSR. The function CURSR contains one right argument. The argument determines the spacing of the guide points on the X and Y axis. It is a good idea that after initial experimentation, the work done with CURSR be assigned to a variable for storing. The proper syntax for this operation is shown below.

```
variable name←CURSR point spacing
```

When CURSR is activated the crosshairs should be displayed with the X and Y axis shown as a series of points. The crosshairs are manipulated with the two dials on the right side of the keyboard. To draw with CURSR, position the intersection of the crosshairs to the first position that is desired. Depress key S. This action will initiate the point set and display a point. To draw a line, position the crosshairs to the next position and depress key D. If a break is desired between two points, position the crosshairs

and depress key B. This action will cause a break in the point set and display a point instead of a line. To cause the point set to end, when finished with a section, depress key Q. Erasing can be done only on the last point or line entered. To erase, depress key E before repositioning the crosshairs.

KEY	RESULT
S	start or begin
B	break between two points
D	construct a line segment between two points
E	erase last point or line before repositioning crosshairs
Q	end point set

If an examination of the point set is desired simply type the variable name and return. The point set that is displayed is n rows by 3 columns. The first column is a code column, -1 corresponding to start, 1 corresponding to a line segment and 0 corresponding to a break. The last two columns correspond to X and Y values of the point respectively.

In order to display the drawing on the screen again the function REDRAW is used. REDRAW has one right argument which is the variable name.

REDRAW variable name

This process should be continued to construct all maps. Experience using this mapping system has shown that it is a good idea to construct a few maps at one time and then check them in 3 dimensions. This is to be sure the maps are representing the areas wanted properly.

#### CONVERSION TO 3 DIMENSIONS

After the maps have been constructed and stored as variable names they are ready to be made into a three dimensional representation.

The first step involves converting the 3 column point set into a 4 column line set so they can be used in other functions. This is accomplished by the use of the function CONFORM. CONFORM has one right argument, the variable name of the map.

```
map name←CONFORM map name
```

The result of this operation is a 4 column line set corresponding to the first point and the second point of each line in each row or X Y X Y.

The line set is now in the proper form to be manipulated into three dimensions.

#### CONSTRUCTING WALLS AND OPENINGS

Before the manipulation is performed on the maps it must be determined where in space the maps are to be positioned. In the coordinate system used the two dimensional maps always have a 0 height or Z value. This coordinate system places positive Z values in the down direction and negative Z values in the up direction from the map. If, for instance a door is represented that will stand above the plan in space, a negative value must be used.

Figure 1, on the preceding page shows the relationship of the three dimensional coordinate system used.



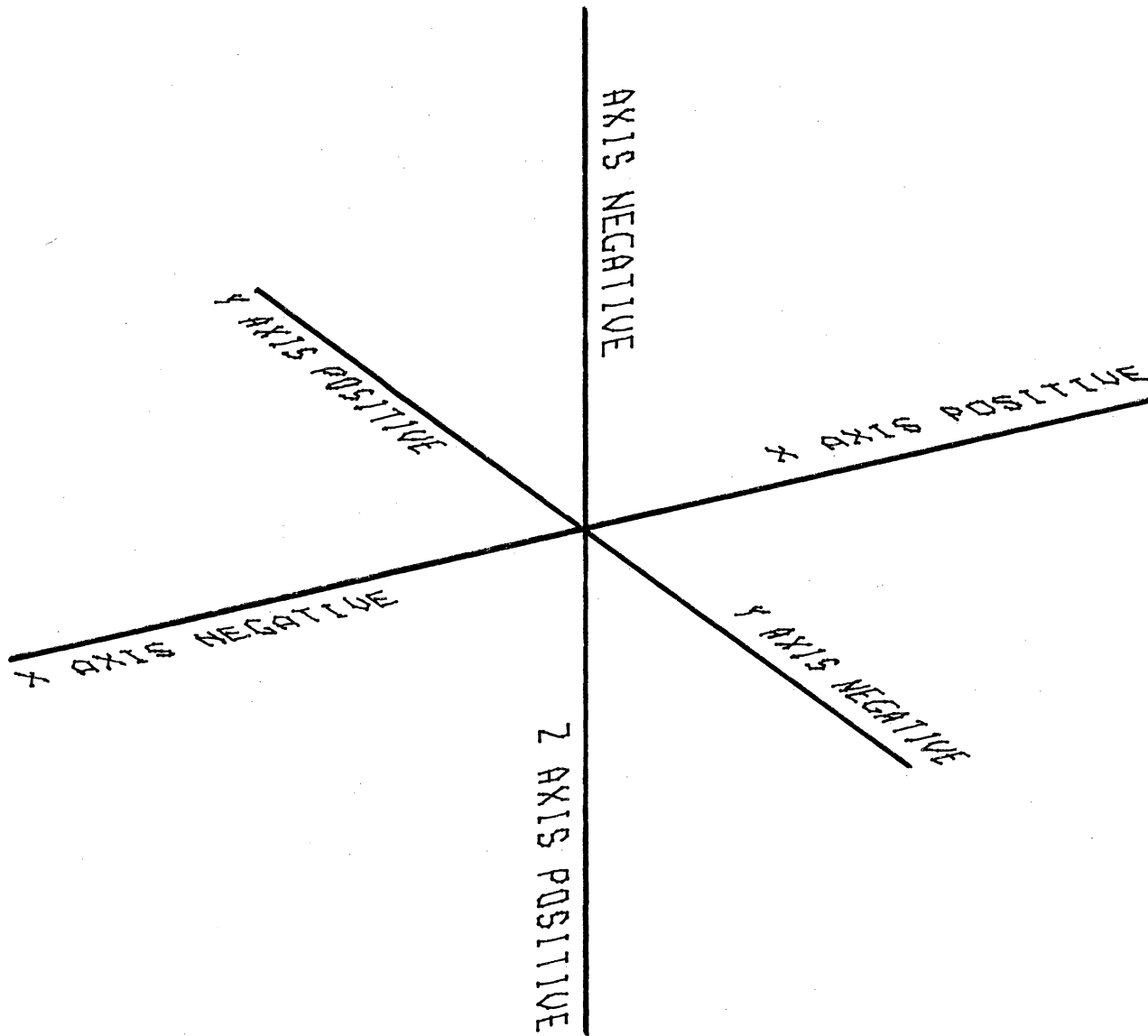


FIG. 1 THREE DIMENSIONAL COORDINATE SYSTEM

The operation of making a map into a three dimensional representation is a basic extrusion operation. The syntax involves the use of a translate function, an identity matrix and an extrusion and conforming function.

This operation will represent a door or wall segment in which the Z value or height will equal the line segments drawn on the side of the representation. In other words the representation will show the map connected to the plan.

3D rep.←(0 0 height TR3 ID3)MD3 side length 1 LINES map name

height	Z value
TR3	translation function
ID3	3 dimensional identity matrix
MD3	conforming function
side length	length or height of the sides or the connecting lines
1	argument to draw connecting side lines
LINES	extrusion function

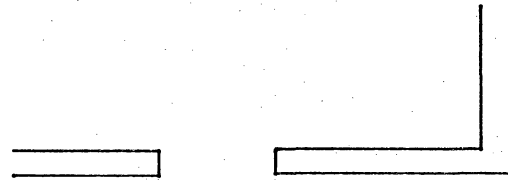
In order to draw this representation to check if all the coordinates are positioned requires the use of a rotation and translation. To simplify this operation a special function called ISO was written to give an isometric-like view of the representation.

To activate the drawing capability of the terminal type ADS and return. The machine will respond displaying a number 2. The syntax for drawing this isometric follows.

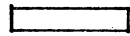
2DS ISO 3D rep.

2DS	drawing function of the terminal
ISO	isometric function
3D rep.	new 3 dimensional variable created in the step above

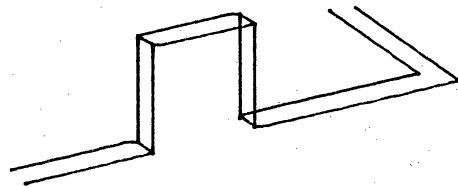
Figure 2, on the preceding page illustrates the construction of a door within a wall.



PLAN OF DOOR



PLAN OF DOOR LINTEL



DOOR AND PLAN IN ISOMETRIC

FIG. 2 THE CONSTRUCTION OF A DOOR  
WITHIN A WALL

To construct a three dimensional representation of an opening such as a window a variation on the above operation is preformed. This operation must be preformed in two steps.

The first step in construction of a window is to locate the window top or the map of the window lintel. This is done as in the above step to construct openings that meet the floor. The exception being that the distance translated in the Z direction does not equal the distance of the line segment constructed to represent the window side.

The second step in this process is to construct the window sill. This is accomplished by translating the map of the window into the lower position or the position where the side lines end.

When these two processes are executed and assigned variable names they can then be catenated in the first dimension to each other and reassigned a new variable name.

3D rep.A←(0 0 height TR3 ID3)MD3 side length 1 LINES map name

height	Z value
TR3	translating function
ID3	3 dimensional identity matrix
MD3	conforming function
side length	length or height of the sides or the connecting lines
1	argument to draw connecting side lines
LINES	extrusion function

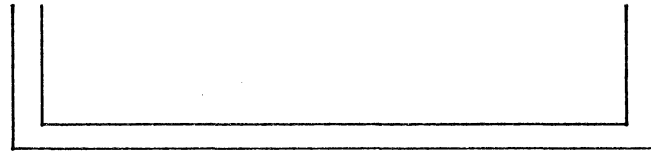
3D rep.B←(0 0 height TR3 ID3)MD3 1 1 0 1 1 0\ map name

height	Z value
TR3	translating function
ID3	3 dimensional identity matrix
MD3	conforming function
1 1 0 1 1 0\	converts 2 dimensional map to 3 dimensions

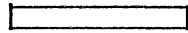
3D rep.←3D rep.A,[1] 3D rep.B

Figure 3, on the preceding page illustrates the construction of a window within a wall.

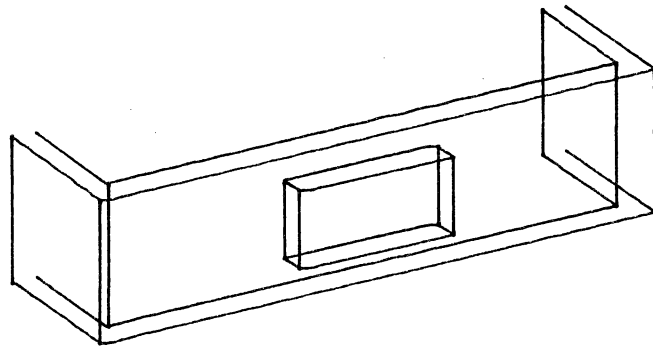
The following pages illustrate combined walls, combined openings and a composite of walls and openings.



PLAN OF WALL



MAP OF WINDOW



WINDOW AND WALL IN ISOMETRIC

FIG. 3 THE CONSTRUCTION OF A WINDOW  
WITHIN A WALL

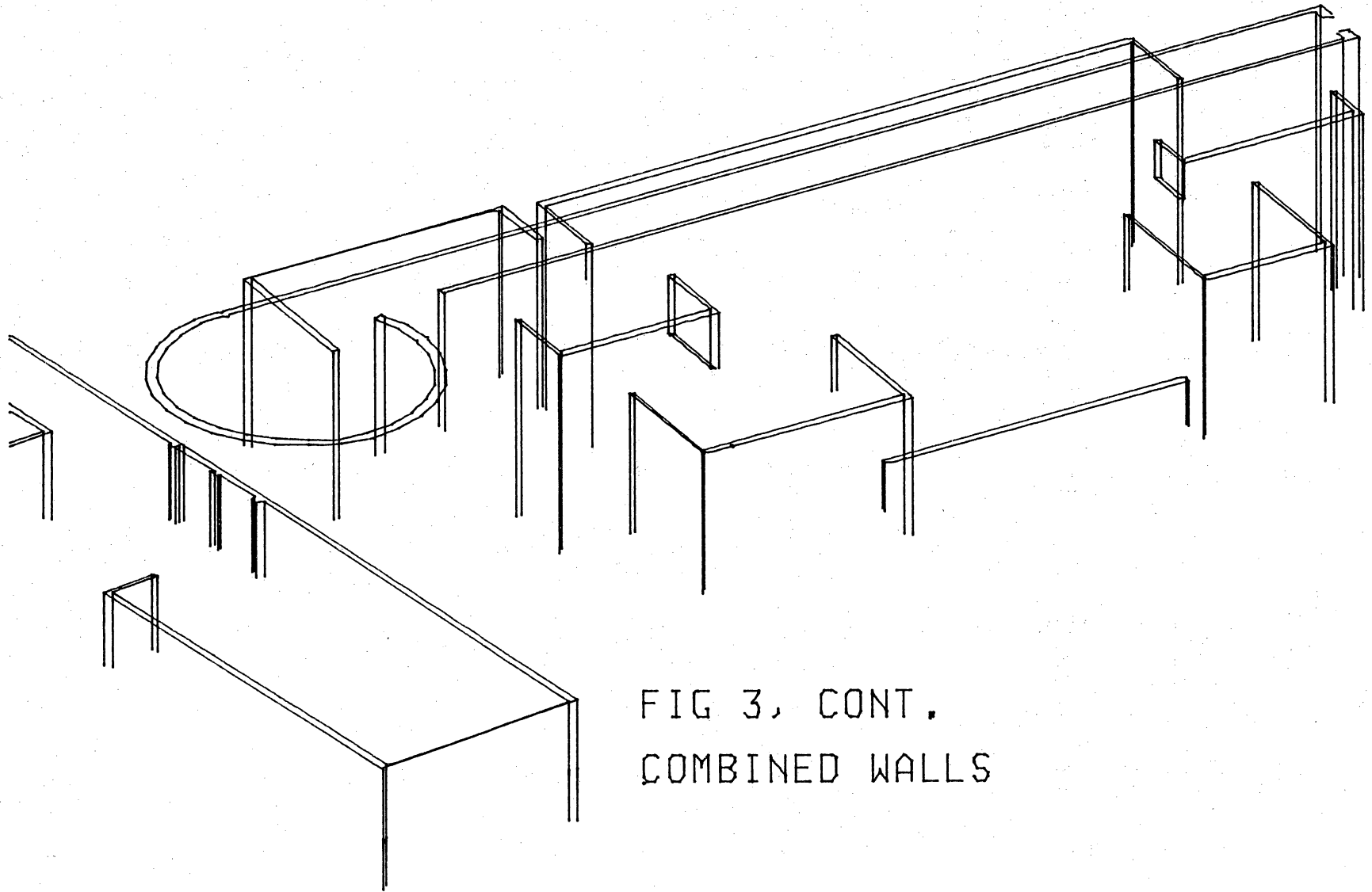


FIG 3, CONT.  
COMBINED WALLS



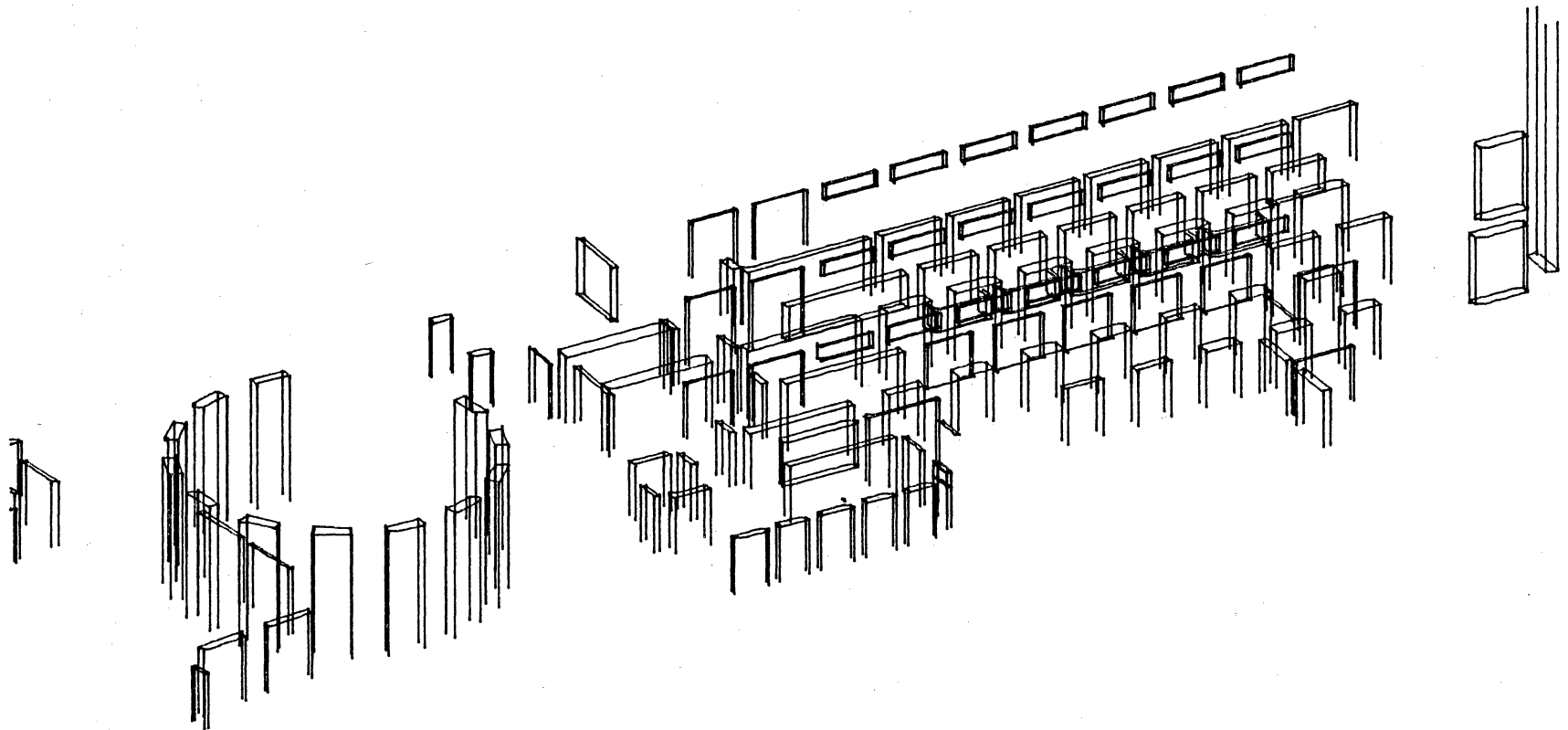
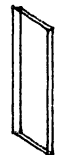


FIG 3, CONT.  
COMBINED OPENINGS



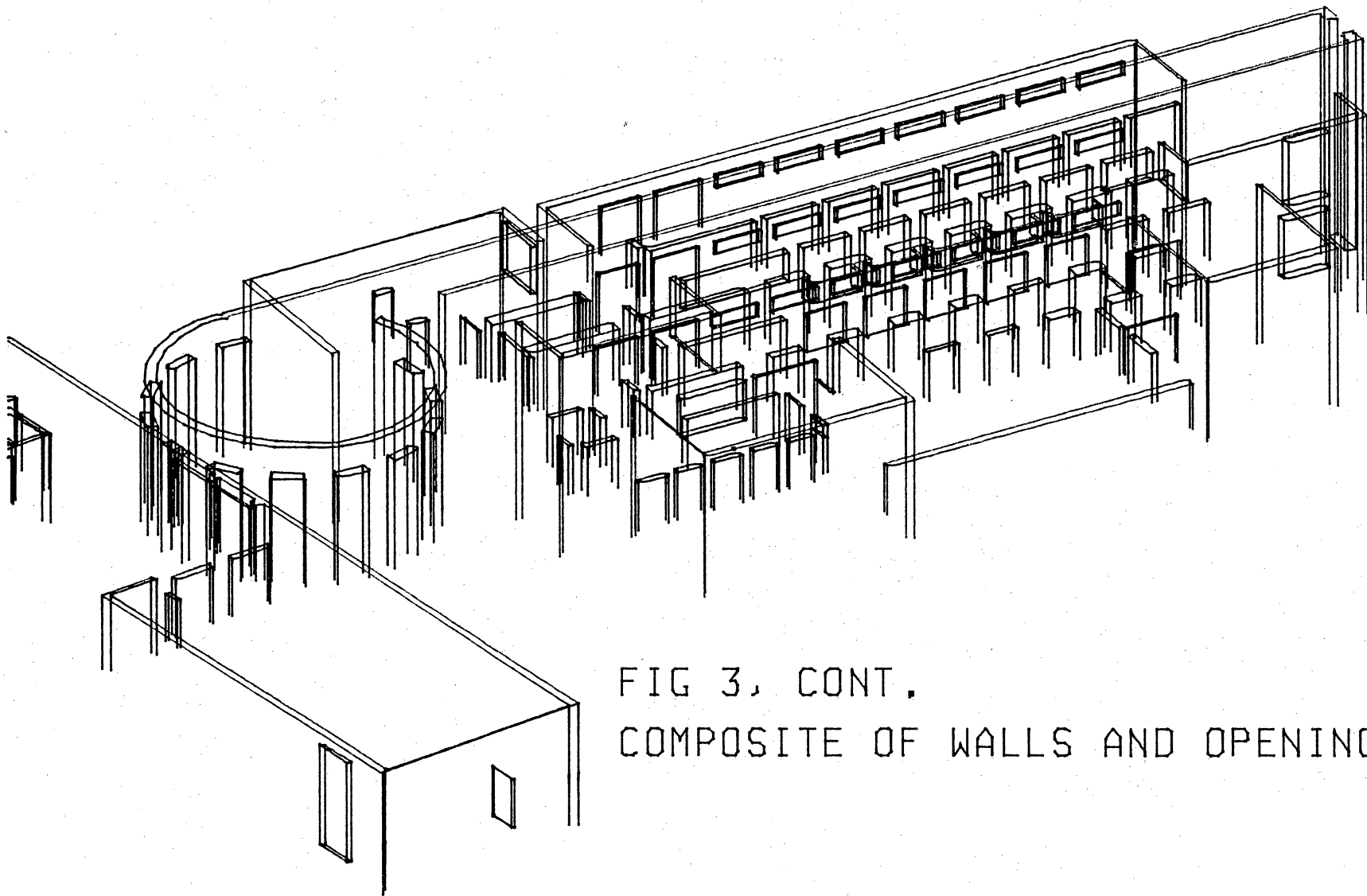


FIG 3, CONT.  
COMPOSITE OF WALLS AND OPENINGS

## CONSTRUCTING FLOORS AND STAIRS

The construction of floors and stairs were treated in a similar manner to each other. The map of a floor is the horizontal line at which the floor meets the wall. This map can then be used to construct a representation of a slab floating in space.

A map of the floor can be entered with the crosshairs by using a floor plan as a guide. The map of the floor will be similar to the floor plan but will have some differences. It is important that the user have the ability to visualize the relation of map to floor plan before the information is entered.

After the map has been constructed and stored as a variable it can then be constructed three dimensionally in a method similar to constructing doors and windows. This process, like that of constructing a window occurs in two parts.

The first part of the process involves extruding the map into space to the floor elevation. The second part extrudes the map again into space this time giving it the elevation of the ceiling directly below the floor being represented. The LINE function is called in this step to give the slab thickness.

floor A←(0 0 height TR3 ID3)MD3 1 1 0 1 1 0\map name

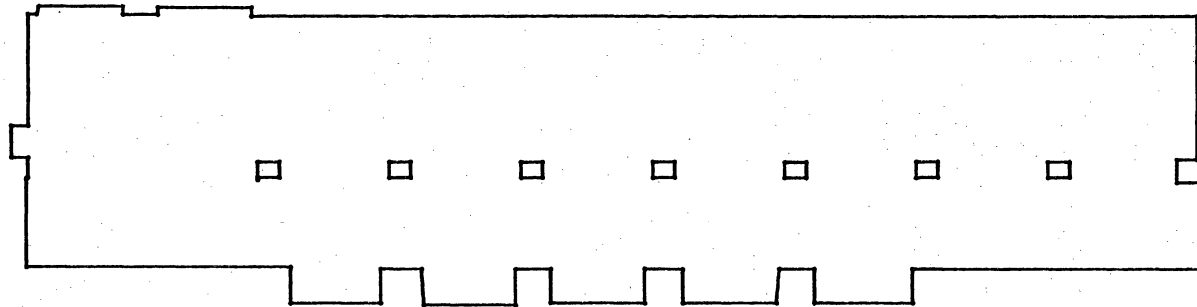
height	elevation of the floor
TR3	translating function
ID3	3 dimensional identity matrix
MD3	conforming function
1 1 0 1 1 0\	converts 2 dimensional map to 3 dimensions

floor B←(0 0 height TR3 ID3)MD3 side length 1 LINES map name

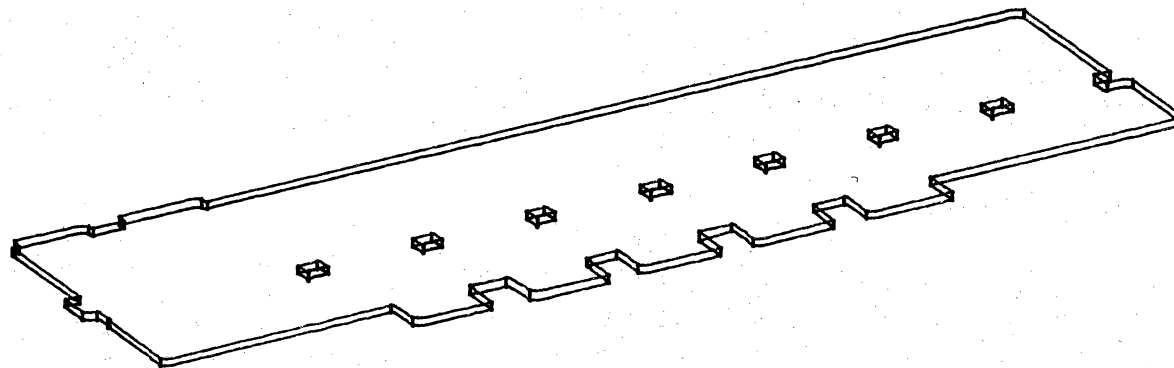
height	elevation of the ceiling immediately below floor
TR3	translating function
ID3	3 dimensional identity matrix
MD3	conforming function
side length	depth of slab
1	argument to draw connecting lines
LINES	extrusion function

When both of these operations are completed they can then be catenated together and stored as one variable name to represent a floor slab.

Figure 4, on the preceding page represents the construction of a floor slab.



MAP OF FLOOR



ISOMETRIC OF COMPLETED FLOOR SLAB

FIG. 4 THE CONSTRUCTION OF A FLOOR SLAB

The construction of steps was thought of as many small floor slabs placed side by side with the thickness of each slab determining the elevation of the adjacent slab.

A two dimensional map of one step was constructed using the crosshairs. This step was located at the top of the staircase so that only positive numbers were required to translate each step down. This was done for ease of typing. A variable was then entered establishing the elevation of the first step.

```
step1←(0 0 height TR3 ID3)MD3 1 1 0 1 1 0\map name
```

height	elevation
TR3	translating function
ID3	3 dimensional identity matrix
MD3	conforming function
1 1 0 1 1 0\	converts 2 dimensional map to 3 dimensions

With the first step now located it was now very easy to locate the rest of the steps based on their relation to the first step.

```
step2←Xmove Ymove Zmove LTRL step1
```

Xmove	move on the X axis
Ymove	move on the Y axis
Zmove	move on the Z axis
LTRL	translating function

This process is repeated for each step. Each step is

assigned to a different variable name. When the process is complete all these variables can be catenated together to form the entire top run of the staircase.

Giving the steps depth involves repeating the above process and calling the LINE function in the initial variable.

```
step1 ← (0 0 height TR3 ID3)MD3 depth 1 LINES map name
```

height	elevation of the step under the step slab
LTRL	translating function
depth	the stair slab thickness
1	default to draw connecting lines
LINES	extrusion function

The remaining steps can then be constructed in exactly the same method as the second step in constructing the step runs. These can then be catenated together to form the bottom half of the staircase.

The entire staircase can then be constructed by catenating the top half to the bottom half.

When the stairway is complete it can be translated into any position and repeated as many times as needed to show all staircases in the representation.

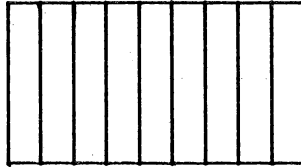
Figure 5, on the preceding page illustrates this method of constructing stairs.

The additional illustration represents a composite of floors and stairs.

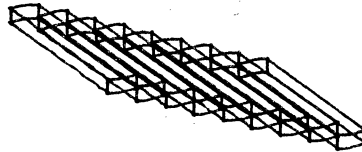




BEGINNING TREAD IN 2 DIMENSIONS



TREAD TRANSLATED INTO STAIR PLAN



ISOMETRIC OF FINISHED EXTRUDED STAIR

FIG. 5 ILLUSTRATION OF STAIR CONSTRUCTION

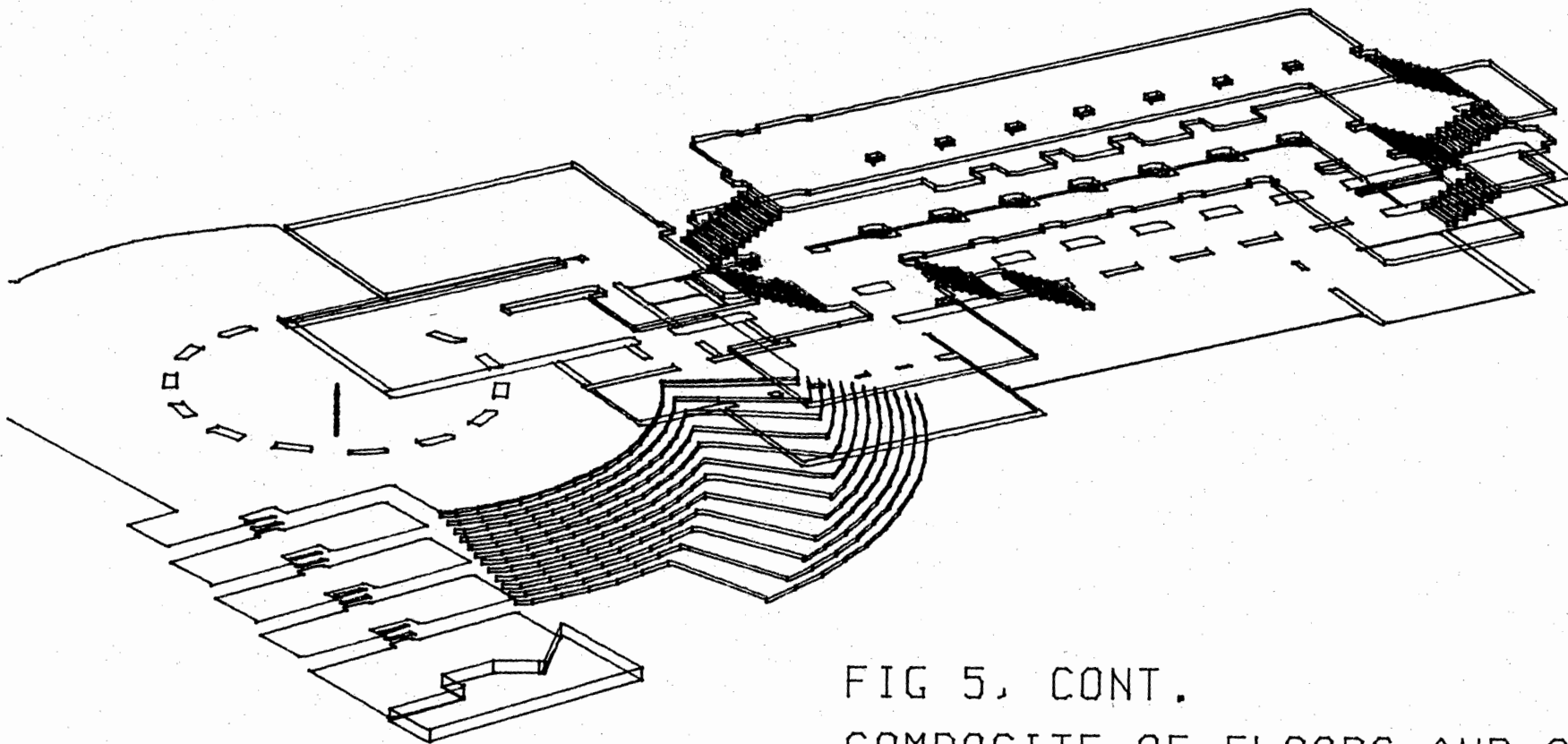


FIG 5, CONT.  
COMPOSITE OF FLOORS AND STAIRS

## CONSTRUCTING ASKEW PLANES

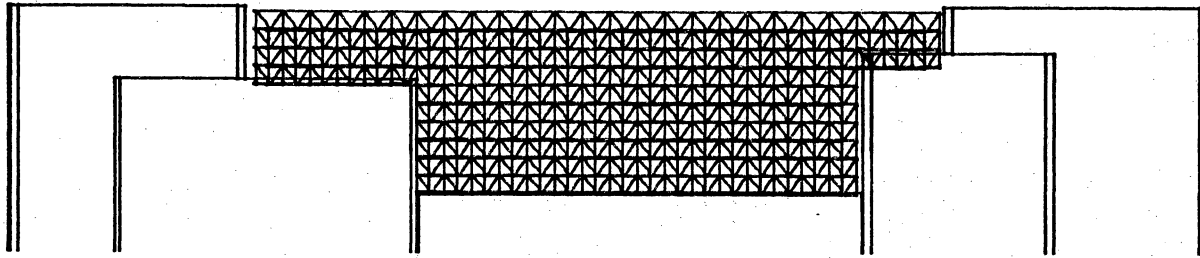
The library project contained as a major visual element a large space frame that is at a 45 degree angle to the vertical walls in the building. In order to construct this plane that is not vertical or horizontal, the following steps in the process were taken.

The first step included the rotation of the entire building elevation down to a 45 degree angle. This operation placed the plane of the space frame parallel with the screen. Because of the large amount of typing involved to preform this operation a function was written to simplify the rotation should it be displayed more than once. The function written was called TILT, the syntax of which follows.

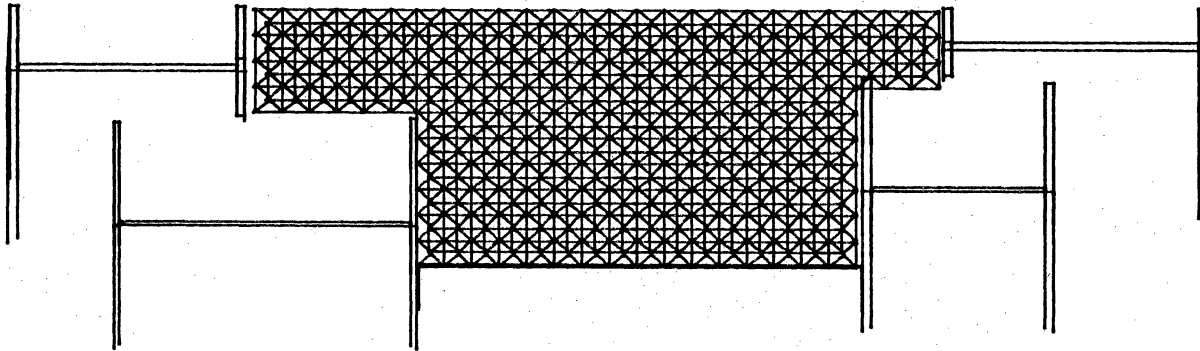
TILT 3D rep. of front elevation

TILT                   function which causes elevation to be  
                          displayed at 45 degrees

Figure 6 on the next page illustrates the move of the elevation in preperation for the construction of the spaceframe.



ELEVATION



ELEVATION TILTED FORWARD

FIG. 6 TILTING THE ELEVATION  
TO CONSTRUCT SPACEFRAME

The actual construction of the space frame was accomplished in two steps. These steps involved the construction of the bottom and top grid patterns and the insertion of the cross members between them.

The first step was to construct a map of the area in which the space frame covered. This was a representation of the plan view of the space frame that was constructed with the crosshairs on the tilted elevation. The map was then stored for use in a latter step.

The grids were constructed by writing a function that produced a texture on the complete screen. This texture consisted of a grid pattern with each unit representing one square in the structural system of the space frame. It is important to note that the grid texture line up with the corresponding sides of the space frame map for accurate representation.

The texture function that was written to generate the grid pattern for the space frame is a niladic function which applies only to this project. It therefore was not included in the documentation.

The grid texture was then clipped by the map to give the proper outer shape of the grid. This clipping process gave as the final result one grid or as used in this study

the top grid, which is the same outer shape as the map.

The second grid or lower grid was constructed by using the upper grid. This grid is one half a grid unit in from the edge of the map. To represent this, the clipping process was used on the first grid.

Two maps were constructed over the first grid. These maps enclosed the areas on the right and left of the initial grid, leaving out one section in the center. After this process was complete the two grid halves were moved to the left and to the right half the distance of a grid square so they would meet. They were then catenated together into one grid and assigned a new variable name. When this first operation was complete, the above clipping operation was again performed this time in the top-bottom dimension.

part1 grid B←KLP grid A

The finished product of these operations gives a representation of two grids, one the size of the map or top grid and one smaller and translated so that the intersection of the grid lines falls in the center of the grid squares of the top grid.

Both grids were then transformed into three dimensions so they could be translated to their appropriate positions.

3D grid ← (0 0 height TR3 ID3)MD3 1 1 0 1 1 0\2D grid

height	Z value of the bottom edge of the spaceframe
TR3	translation function
ID3	3 dimensional matrix
MD3	conforming function
1 1 0 1 1 0\	converts 2 dimensional map to 3 dimensions

The crossbars of the space frame were constructed with one unit figure. This unit figure represents the smallest unit that the crossbars can be divided into. The shape which resulted was an inverted pyramid showing only the edges which meet at the apex and not the base. This shape consisted of four line segments that connected four corner points of the large grid to one point of the smaller grid.

This unit figure was constructed by hand, manually inserting the coordinate points. The coordinates were based on the lower left corner of the upper grid.

The space frame was constructed by writing a function that caused the unit figure to be moved and constructed in the next adjoining square and continued this process until all squares in one row were filled with the unit figure. This row of unit figures was then translated and repeated in the opposite dimension until all squares had a corresponding unit figure.

The group of unit figures in their proper positions was then catenated to the grids. The unit figures were already in three dimensional form.

This entire group of representations was now ready to be translated into their proper positions and rotated.

In order for the figure to be rotated it must be moved onto the X=0 plane. This process is done by using a three dimensional translate function. The position of this can be visually checked by using the ISO function as previously illustrated.

The syntax of the three dimensional move is shown below.

```
grid name←Xmove Ymove Zmove LTRL grid name
```

Xmove	positive or negative values on the X axis
Ymove	positive or negative values on the Y axis
Zmove	positive or negative values on the Z axis
LTRL	translate function

The rotation can now be preformed.

```
variable name←(angle XRT ID3)MD3 variable name
```

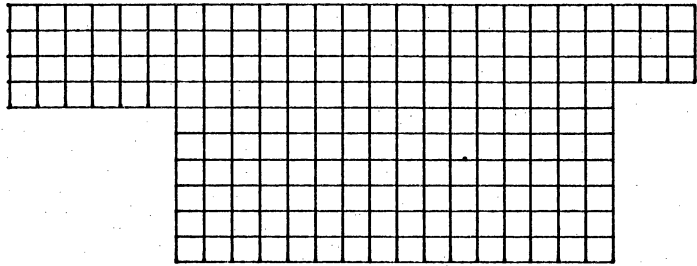
angle	positive or negative angle of rotation in degrees
XRT	function to rotate on the X axis
ID3	identity matrix
MD3	conforming function



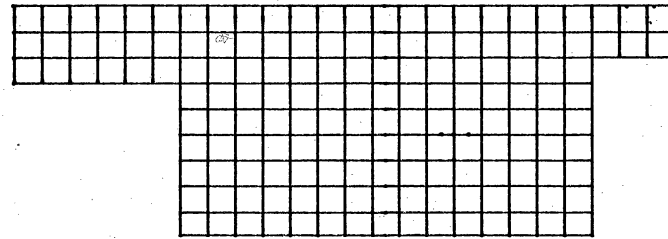
After the rotation process is complete it is now necessary to move the figure back into its desired position. This is done by reversing the above translating process.

The figure is now complete and in its proper position. The figure can now be easily manipulated with the rest of the building representation.

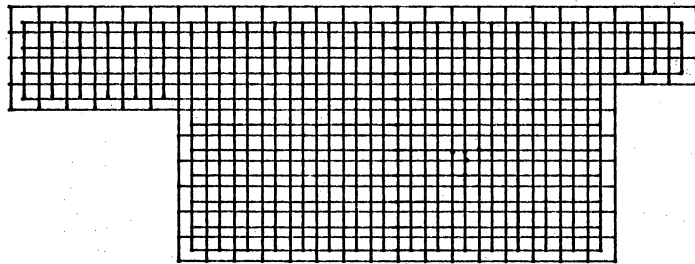
Figure 7, on the preceding pages illustrate the process of constructing the space frame.



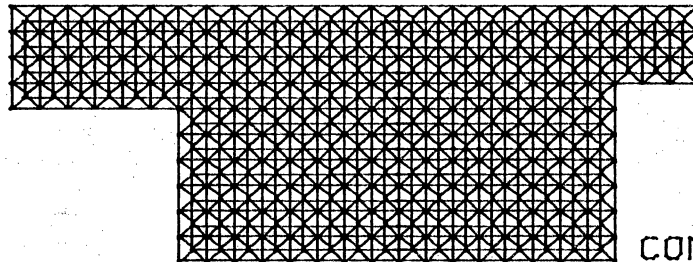
TOP GRID



BOTTOM GRID



GRID COMPOSITE



COMPOSITE SPACEFRAME



UNIT FIGURE



UNIT FIGURE  
ENLARGED BY 4  
AND IN  
ISOMETRIC

FIG. 7 CONSTRUCTION OF SPACEFRAME

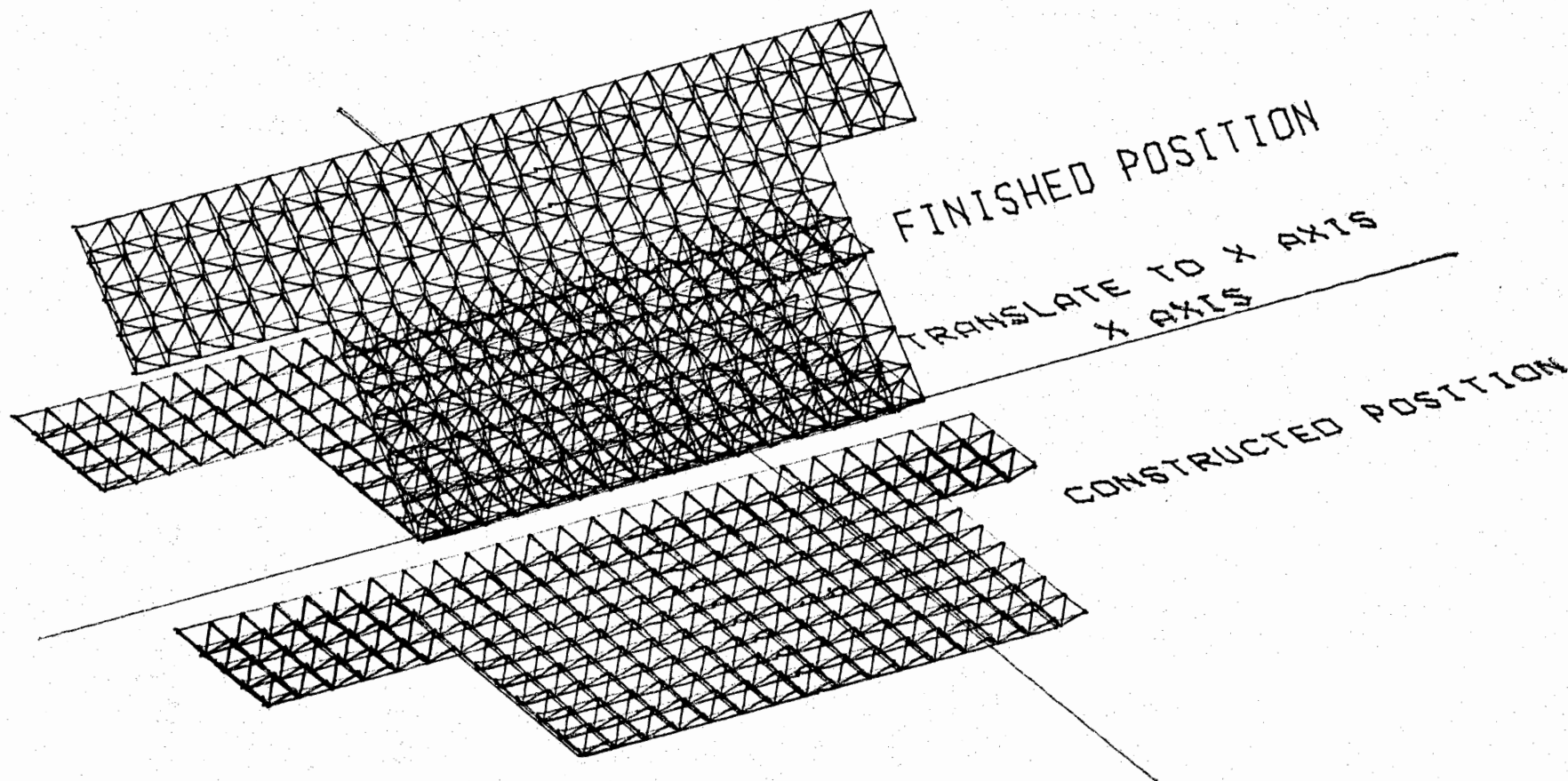


FIG 7, CONT.  
POSITIONING THE SPACEFRAME  
INTO THE FINISHED POSITION

## CONSTRUCTING A CIRCULAR FORM

Located as the entrance and joint to the library project is a circular arcade-like space. The three dimensional construction of this space involved syntax exactly like the construction of the walls and doors found earlier in this section. The difference in procedure used is in the construction of the two dimensional maps used in this space.

The function CURSR does not have the ability to construct curves or curve like shapes. The function POLY was then used to construct this space. POLY has the ability to produce any symmetrical polygon. POLY contains only one right argument. This right argument specifies the number of sides the polygon is to have. The polygon can be scaled by multiplying it by any scaling factor.

The process of using POLY involved making a map for the plan, the lintels to the openings and for the parapet. The polygon used in this study has 28 sides. This was determined from the relationship of openings to piers in the enclosure. Experimentation was done with the polygon and it was found that a multiplication factor of 208 and 192 determined the limits of the outside and the inside of the walls respectively. This resulted in the construction of two circular shapes each with 28 sides and the equivalent

wall thickness between them.

circle ← multiplication factor x POLY number of sides

The circular form of the entrance to the building is not symmetrical. It can be considered as a 3/4 circle. It was then necessary to compress out the unwanted line segments.

POLY gives as a resultant a 2 column matrix, each row corresponding to a point. It was very easy to compress out the unwanted lines through the use of a boolean column. This column which consists of only 0 and 1 was manually constructed. A 0 corresponded to an unwanted point and a 1 corresponded to a wanted point. The boolean column was then catenated to the point set of the polygon. The CONFORM function was then called which compressed out the lines corresponding to 0 and conformed the remaining point set into a line set. It was necessary to repeat this operation for each map needed since each map contained different line segments.

The process of connecting the inside wall limit to the outside wall limit was probably the most complicated section found in the thesis. This connection involved the use of a

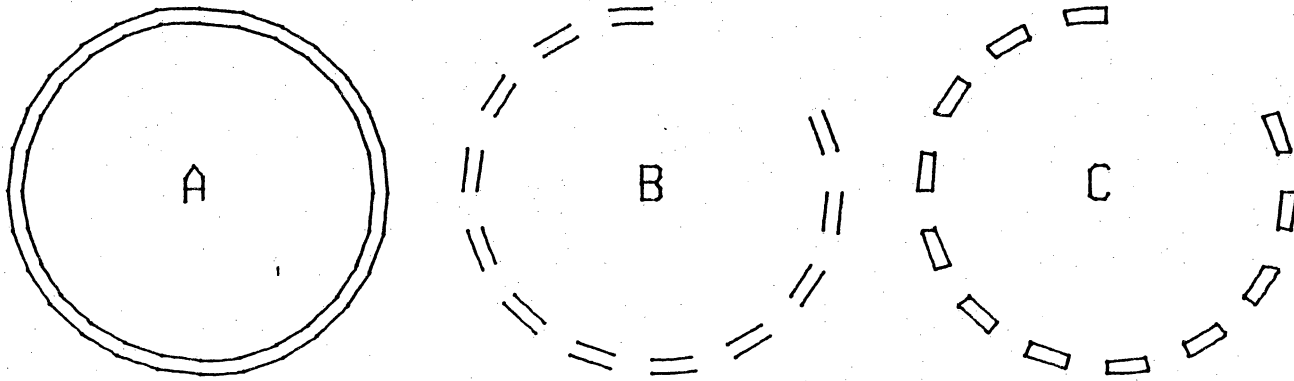
three dimensional array. A three dimensional array being a matrix that contains a layer, rows and columns dimension instead of the standard two dimensional array used throughout that has only a rows and column dimension.

This process was accomplished by reshaping the matrix corresponding to the line set of the circular form to an array having n layers 2 rows and 4 columns. A relationship could then be made between those points on the outside of the circle to those on the inside.

After this new relationship was made the line set was reshaped back into a two dimensional array so that it could be acted upon by the drawing and three dimensional conversion functions.

The construction of the three dimensional form was then constructed in exactly the same method as the walls and openings previously mentioned.

Figure 8, on the next page illustrates the process of constructing the circular form.



A--THE BEGINNING POLYGON

B--POLYGON WITH UNWANTED LINE SEGMENTS  
COMPRESSED OUT

C--THE COMPLETED TWO DIMENSIONAL  
CIRCULAR FORM

FIG. 8 THE CONSTRUCTION OF A TWO DIMENSIONAL  
CIRCULAR FORM

## FINAL PERSPECTIVE REPRESENTATION OF THE BUILDING

The final perspective representation is accomplished with the use of the function PER. PER contains one left argument and one right argument. The left argument is a scaling factor which is used to enlarge the representation after the function result is obtained. The right argument is the final resultant of the LTRL function used to position the point set before the perspective is constructed. LTRL is a translate function written by Professor John Wade and can be found in public library 9 chng cgrp.

It was found that the position of the picture plane was very important for an exact representation. If the picture plane was positioned so that it fell within the building representation uncontrollable bouncing occurred. At the time of the final presentation this problem had not yet been eliminated. Therefore the perspective function only works on those cases that the picture plane falls outside the boundary of the building or the three dimensional representation, limiting the possibilities of interior perspectives.

It was also necessary to use a clipping function for most all of the perspective representations. A simple



function called CLIP was used to clip the screen boundaries.

The syntax for this operation follows.

2DS CLIP scaling factor PER Xmove pic. plane Zmove LTRL pt. set

2DS	function to cause terminal to draw
CLIP	function to clip screen boundaries
scaling factor	multiplication factor
PER	perspective function
Xmove	horizontal move
pic. plane	plane on which the image is constructed
Zmove	vertical move
LTRL	translate function
pt. set	three dimensional point set

## SYNTAX CONCLUSION

The purpose of including this detailed exploration of project syntax is so that a user may use this as a base and modify to suite his individual needs. I must emphasize again that this is only one way in which to enter information concerning a building into the computer. It is encouraged to use this information only as a base for ideas to develop ones own system of logic. This system was found to be the best for my personal use but is based only on my limited experience.

## OBSERVATIONS AND CONCLUSIONS

The intent of this thesis was to establish links from the traditional design process to the use of a computer. Other concerns in this thesis implementation were to gain continued experience for myself in the design process and to sum up my ability both as an architect and as a user of the computer in relation to architecture.

The research portion of this thesis involved two separate operations concerning the computer. The first operation being the actual learning of computer usage and organization of thought in order to deal with the computer. The second operation being the development of a logic or method in order to use a computer successfully with an architectural project.

The method of use that I developed for the implementation of my design project for the computer I found very helpful. This method enabled me to organize and input the building elements in very exact detail. From this initial input process, I was able to show different parts of the building quickly and at many different positions, views and scales. This I considered a great time saver since the quantity of graphic studies available through this method is virtually unlimited. With only the manipulation of the initial information I was able to construct plans,

elevations, sections, isometrics, exploded views and perspectives. These representations would normally take days to construct by hand but the computer can give them at the rate of about one per minute.

In the conclusion of this aspect, the method is very successful in producing finished views of a building after most design decisions have been made. The disadvantage to constructing these views or drawings is that the drawings have an unfinished appearance with all hidden lines visible and the method is unable to make distinctions between differences of shading to accentuate form, light and shadow. These views would be very useful in their accuracy, however, to use as a base in which these elements of shading are added by hand and the hidden lines are removed.

The negative aspect to this method is the amount of time needed to input the initial information. Because of the nature of the method each building element is input separately. I found this necessary, however, because of the form irregularities in the project building. A building with a very regular pattern, for instance could be very quickly entered into the machine simply using the repetition of building elements. Because of this negative aspect of the method, it might become very difficult to change information once it is entered. Therefore I must conclude

that this method is not very practical for the quick changes required in the design process. This conclusion would depend upon the complexity of the building being represented. The method is very flexible in the height dimension. It is not, however, flexible in plan. If changes were to be made in plan it would require the rearrangement or reconstruction of the original maps.

The implementation of this thesis also left me with the problem of the lack of personal experience. It was not until most design decisions about the project building had been made that I felt confident enough in my organization of thought to establish a method for computer use in which to implement the the project building. I found that being more experienced in the traditional design method I could make design decisions more readily and faster by hand. One is always most comfortable with the familiar.

A reservation that I have in using the computer in the design process is: "Might architecture be compromised in favor of computer use?" I firmly believe that architecture in no way should be compromised. This situation could very easily occur because it is much easier to design a building that fits a method of computer use than it is to design a computer method that will incorporate something new or different. I feel that the method developed for this

project examines this issue carefully since the bulk of the method was developed after the design was in its final stages.

In the concluding statement concerning this thesis I found the computer very useful in the implementation of this project. The project made me learn much about the machine, how it functions and how to control and operate it. It also convinced me of its value in the future of the architecture profession. Because the machine requires the entering of information in a very organized and concise manner, it has improved my personal organization habits.

I feel that as a tool in architecture the computer can no longer be ignored. I also feel an obligation that if the computer is to play an important part in the future of the architectural profession we, as architects should learn to utilize it to its best possible potentials. Only through the intellegent and wise use of the machine can we expect to use it to our benefit. In closing it is important to remember that the computer is only a tool, there is no substitute for human creativity.

## SUGGESTIONS FOR FURTHER RESEARCH

The topic of computer use in architecture in this thesis has limited itself to only the graphic capabilities of the computer. Other topics concerning the computer could also be readily explored. From research and experience I have learned that some of these topics have been developed and are in present use. These topics, however, are not readily available to the student at V.P.I.

Additional use of the computer in the design process are theorized to provide topic suggestions for future investigation in this subject. For these suggestions certain assumptions concerning the design process cause this process to be broken down into several categories. These categories follow:

- building program
- site selection and orientation
- functional relationships and sizes
- form
- sophisticated graphics
- structural systems
- structuring of standard detail systems
- projected project cost analysis

Using the computer to develop a building program could be very beneficial to the client and the architect. The process most likely used for establishing building programs would be simulation. Simulation is currently used to establish use patterns of persons utilizing a structure.

The question I raise is could simulation also be used to determine durability of materials used in a building. Also how will a building effect its surroundings after it is built. Could computers also project the materials and labor market. All these factors could well effect the design and programming of a building. Knowing these factors before the program and design is begun could lead to a more efficient use of money and materials. It could also lead to better or worse architecture. This depends on the discretion of the architect and the client.

Site selection and orientation analysis by the computer might enable the architect to plan to get the most of what a site has to offer. Issues in this category would include choosing the best solar orientation or natural lighting orientation. Other climatic conditions to be considered are minimizing wind exposure in winter and maximizing and catching summer breezes. Cost benefit analysis could also be addressed in relation to property value, location and pedestrian and vehicular access to the site.

Functional relationships and sizes might be reduced to volumes or numbers that could relate one area of a building to another in the most efficient organization. This might be an extension of the idea of the relationship matrix in which relationships are examined and assigned a value in



hierarchy of importance.

The form of a building might be influenced by the functional relationships determined. They might also be arbitrarily generated by the computer with certain control boundaries. This generation may be an interesting way to begin to develop a building form.

More sophisticated drawing methods could be explored. These methods should remove hidden lines and add shade, shadow and color. All of these capabilities have been developed but are not available at V.P.I. in computer graphics. The capabilities to graphically show texture shade and remove hidden lines have been accomplished at V.P.I. but at a limited scale.

The computer would efficiently be able to determine the best structural system to use in a building. This would not only be in the examination of how a structure will behave and its sizing but also in the efficiency of the structure in construction. It may analyze the availability of the materials in the area, their cost and the ease and amount of labor needed to install the system. It could also determine the practicality of having systems especially made for the job in relation to using standard building products.

The structuring of standard detail packages is

presently in use in most firms. The efficiency as well as the diversity of these packages might very well be increased through computer use.

Cost estimating from personal experience can be very laborious. It is the final cost estimate that usually effects the final outcome of a design project. The reason being that there is no quick and accurate way to determine precise costs during the design process. This unfortunate situation usually results in the project being cut or stripped to the minimum. A computer might easily give a very exact or projected cost of building elements and labor through every phase of the design process. This would eliminate the element of surprise at the end of the project which can sometimes lead to the literal butchering of the project.

## SUMMARY

I would like to state that the implementation of this thesis has given me a much greater understanding of computers and their uses.

I had the opportunity to experiment with a topic that I probably would not have considered before I became involved with computers.

The final results of the thesis in some ways were disappointing to myself. I expected much more in directly involving the computer with the design process. I do feel, however, that the work implemented and the results are far from total failure. This has been a project implemented through experimentation and I know that I have gained much from the experience. I also hope that this documentation may contribute, even in some small way, to the continued research in computer use in architecture at V.P.I.

Before less than one year ago, I knew absolutely nothing about computers and their applications. I can honestly say that I considered them intimidating because they seemed so untouchable.

I now, through use and research, can see that the applications of a computer are virtually limitless. Computer use in the architectural profession is currently in

its infancy. I am excited to speculate what the future may bring in architecture that can only happen with the use of the computer.

I would encourage all architects to experiment with the use of the computer, not purely in relation to a particular task, but to broaden their professional capabilities.

I believe that there are many of us who fear that the computer may one day eliminate the need for architects. This can only happen if we become lazy and allow the machine to generate architecture. We should instead make the computer an active partner giving it the work that we find laborious to free us for more productive activities that only a human is capable.

## BIBLIOGRAPHY

Brawne, Michael, "Libraries, Architecture & Equipment," Praeger Publishers, New York, 1970

Brown, Eleanor Frances, "Modern Branch Libraries & Libraries and their Systems," The Scarecrow Press, Inc., Metuchen, N.J., 1970

Hilker, Helen Anne, "Ten First Street, Southeast; Congress Builds a Library, 1886-1897," Library of Congress, Washington, D.C., 1980

Langmead, Stephen and Beckman Margaret, "New Library Design," Web Offset Publications Ltd., Ontario, Canada, 1970

Metcalf, Keyes D., "library Lighting," The Association of Research Libraries, Washington D.C., 1970

Gilman, Leonard and Rose, Allen J., APL An Interactive Approach, second edition, John Wiley & Sons, New York, 1976

Roth, Harold L., (ed.), "Planning Library Buildings for Service," Proceedings of the Library Buildings and Equipment Institute, Kent State University, American Library Association, Chicago, 1964

Thompson, Godfrey, "Planning and Design of Library Buildings," The Architectural Press, London, 1973

Ward, Herbert F.L.A. and Odd, Sally, (eds.), "Library Buildings," 1970 issue, The Library Association, 1973

## APPENDIX 1, A GLOSSARY OF TERMS USED

This glossary has been compounded in an effort to more clearly explain those terms which the reader may not be familiar with. These terms include those which occur in computer use, the APL computer language and in architecture.

- argument.....A variable term with concrete value.
- bolean.....A vector or matrix of 1 and 0 only, combined. Used in APL as a code to compress out unwanted numbers.
- cartesian coordinate.....Any of three coordinates that locate a point in space and measure its distance along the X, Y or Z axis.
- catenate.....In APL usage, the act of joining.
- conform.....To make similar or identical.
- crosshairs.....Reference lines in a field for marking instrumental axes.
- extrusion.....To undergo shaping three dimensional shaping.
- function.....Any expression which contains a variable term and whose meaning is determined when concrete value of the variable are specified.
- integer.....Any of the natural numbers, the negative of these numbers or zero.
- identity matrix.....In APL, a matrix of numbers used to multiply a function resultant for conforming purposes.
- isometric.....An anonometric projection in which the three spatial axes of the object are represented as equally inclined to the drawing surface and equal distance is drawn as equal on each

axes.

reshape.....In APL, the act of giving new dimensional shape to a vector or matrix of numbers.

syntax.....The arrangement or means of communication with the computer.

three dimensional array..A matrix of numbers in three dimensions, the first dimension being the layer dimension, the second the rows dimension and the third the column dimension.

translate.....A move on the cartesian coordinate system.

true life measurement....Measurement which corresponds to an actual measurement system such as feet and inches.

two dimensional array....A matrix of numbers in two dimensions, the first dimension being the rows dimension and the second the column dimension.

## APPENDIX 2, FUNCTIONS USED TO IMPLEMENT THESIS

The functions listed in this section are those which were written expressly for this research project. These functions for the most part do simple operations on two and three dimensional point and line sets.

The first section shows those functions mentioned in the text and used throughout the study. The second section shows the functions that are subfunctions necessary for the major functions to run.

These functions were written with the assistance of Dean Nueswander who was very helpful as a consultant and who wrote some functions in this section. Some of the other functions in this section were based on functions that he had written and were then used as a base from which to work.

Additional functions used for this study were written by Professor John Wade and are available in public library 9. These functions do not appear in this appendix but are easily loaded from the public library. The sections used from library 9 are listed below. Also found in library 9 is the clipping function, Klp, mentioned in the text.

9 draw 9 auxp 9 chng cgrp



Additional capabilities using two dimensional drawing functions can be found in 9 zdraw. In addition to two dimensional drawing capabilities, zdraw has a text function which was used to annotate the figures illustrated in the text.

```
R←CURSR INT;PAR;PTS;PS
*****USE S TO START OR BEGIN LINESET
*****USE B TO BREAK BETWEEN TWO POINTS
*****USE D TO CONSTRUCT A LINE SEGMENT
*****BETWEEN TWO POINTS
*****USE E TO ERASE LAST POINT OR LINE
*****BEFORE REPOSITIONING CROSSHAIRS
*****USE Q TO END POINT SET
ΔIO← 512 390
1 ΔDR 0,[1.5](-PTS),PTS←0+INT×i⌊390÷INT
1 ΔDR((-PTS),PTS←0+INT×i⌊512÷INT),[1.5] 0
PTS← 0 3 p0
START:PAR←7 ΔDR ''
→(113=1↑PAR)/END
PS←-1,-2↑PAR
→(115=1↑PAR)/DRAW
PS←0,-2↑PAR
→(98=1↑PAR)/DRAW
PS←1,-2↑PAR
→(100=1↑PAR)/DRAW
→(101=1↑PAR)/START
PTS← -1 0 ↓PTS
→START
DRAW:PTS←PTS,[1] PS
→(1=,-1 1 ↑PTS)/3+1↑□LC
1 ΔDR -1 -2 ↑PTS
→START
2 ΔDR -1 4 ↑(,1θ1= 0 -2 ↓PTS)÷(0 1 ↓PTS),1θ 0 1 ↓PTS
→START
END:0pR←PTS
```

```
R←REDRAW W
*****DISPLAYS DRAWING CONSTRUCTED WITH
*****A TWO COLUMN POINT SET AND A CODE
*****COLUMN
2 ΔDR(,1θ1= 0 -2 ↓W)÷(0 1 ↓W),1θ 0 1 ↓W
```

R←DEG XRT W;RA  
A\*\*\*\*\*W: CREATES A 4×4 ROTATION MATRIX FOR A 3D POINTSET.  
A\*\*\*\*\* 'W' IS ALSO A 4×4 MATRIX, EITHER A TRANSFORMATION  
A\*\*\*\*\* OR THE IDENTITY MATRIX(ID3).  
A\*\*\*\*\* 'DEG' IS THE ROTATION MEASURED IN DEGREES CCW ABOUT  
A\*\*\*\*\* THE X-AXIS LOOKING TOWARD -INFINITY.  
A\*\*\*\*\* 'RA' IS THE RADIAN EQUIVALENT OF 'DEG'  
RA←DEG×0.1745329252  
R←W+.x 4 4 ρ(1,4ρ0),(2◦RA),(1◦RA),0,0,(-1◦RA),(2◦RA),(4ρ0),1

R←ISO W;A;B  
A\*\*\*\*\*W: THREE DIMENSIONAL LINE SET  
A\*\*\*\*\*CONSTRUCTS AN ISOMETRIC-LIKE VIEW OF THE THREE  
A\*\*\*\*\*DIMENSIONAL REPRESENTATION  
A←(30 XRT 30 YRT -90 XRT 1 1 -1 SC3 ID3) MD3((1+ρW),3)†W  
B←(30 XRT 30 YRT -90 XRT 1 1 -1 SC3 ID3) MD3((1+ρW),-3)†W  
R← 1 1 0 1 1 0 /A,B

R←A PER W;Z1;Z2;Z3;Z4  
A\*\*\*\*\*A: SCALING FACTOR OF FUNCTION RESULTANT  
A\*\*\*\*\*W: THREE DIMENSIONAL LINE SET AFTER  
A\*\*\*\*\*THE DESIRED TRANLATIONS HAVE BEEN  
A\*\*\*\*\*PERFORMED  
Z1←Z1,Z1← 0 1 0 0 0 0 /W  
Z2←Z2,Z2← 0 0 0 0 1 0 /W  
Z3←(1 0 1 0 0 0 /W)÷Z1  
Z4←(0 0 0 1 0 1 /W)÷Z2  
R←A×(Z3,Z4)

R←CONFORM W;S  
A\*\*\*\*\*W: TWO COLUMN POINT SET WITH  
A\*\*\*\*\*A CODE COLUMN  
A\*\*\*\*\*COMPRESSES OUT UNWANTED LINE  
A\*\*\*\*\*SEGMENTS AND RESHAPES INTO A  
A\*\*\*\*\*FOUR COLUMN LINE SET  
S← 1 1 0 1 1 0 / 1 1 MANIP W  
R←(((1↑ρS)÷2),(-1↑ρS))↑S

R←A MD3 PS;SHP  
A\*\*\*\*\* 'MD3' CONFORMS A POINTSET TO A TRANSFORMATION MATRIX  
A\*\*\*\*\* BY CATENATING A COLUMN OF 1'S TO A 3 COLUMN MATRIX.  
A\*\*\*\*\* IF 'PS' IS PASSED IN AS A LINESET 'MD3' WILL CONVERT  
A\*\*\*\*\* IT TO A POINTSET THEN RETURN IT AS A LINESET.  
A\*\*\*\*\* 'A' IS A 4x4 TRANSFORMATION MATRIX.  
SHP←ρPS  
PS←(((x/ρPS)÷3),3)ρPS  
R←SHPρ 0 -1 ↓(PS,1)+.×A

R←A LINES W;A;B;C;D;E;F  
A\*\*\*\*\*A: SIDE LENGTH AND THE NUMBER  
A\*\*\*\*\*OF LINES WISHED TO CONNECT THE  
A\*\*\*\*\*BUILDING MAP PARTS  
A\*\*\*\*\*W: THREE DIMENSIONAL POINT SET  
A\*\*\*\*\*CONNECTS THE MAPPING ELEMENTS  
A\*\*\*\*\*WITH A VERTICAL LINE  
A←A XTR W  
B←(2,((1↑ρA)÷2),(-1↑ρA))ρA  
C← 2 1 3 ρB  
D←((x/2↑ρ(LON C)),(-1↑ρ(LON C)))ρC  
E← 1 1 1 0 0 0 1 1 1 0 0 0 /D  
F←(((1↑ρF)÷2),6)↑F←A XTR W  
R←F,[1] E

R←A MANIP W;A;B;C;D;E;F;G;H;I;J  
\*\*\*\*\* EXTRUDES LINE SET INTO THREE  
\*\*\*\*\* DIMENSIONS AND THEN ADJUSTS THE  
\*\*\*\*\* RESULT SO THAT IT CAN BE USED  
\*\*\*\*\* IN THE CONFORM FUNCTION  
A←A XTRU 0 1 ↓W  
B←(ρA)ρW  
C←((1↑ρB),((1↑1φρB),1))↑B  
D←C,A  
E← 1 0 0 0 /D  
F← 0 1 1 1 /D  
G←F,1θ[2] F  
H← 0 <sup>-</sup>1 0 ↓G  
I←, 0 <sup>-</sup>1 0 ↓1φ[2] 1=E  
J←((×/<sup>-</sup>1↑ρH),<sup>-</sup>1↑ρH)ρH  
R←I↑J

R←A XTR W;A;B;C  
\*\*\*\*\* PREFORMS THE EXTRUSION OPERATION  
\*\*\*\*\* AND PUTS THE RESULT IN A FORM SO  
\*\*\*\*\* THAT IT CAN BE USED IN PERSPECTIVE  
A←A XTRU((1↑ρW),2)↑W  
B←A XTRU((1↑ρW),<sup>-</sup>2)↑W  
C←A,B  
R←((×/2↑ρC),(<sup>-</sup>1↑ρC))ρC

R←LON PS

\*\*\*\*\* 'LON' CREATES A LINESET FROM A POINTSET. THE  
\*\*\*\*\* LINESET IS CREATED WITH REFERENCE TO THE ROWS  
\*\*\*\*\* RATHER THAN PLANES OR LAYERS.

R← 0 -1 0 ↕PS,1θ[2] PS

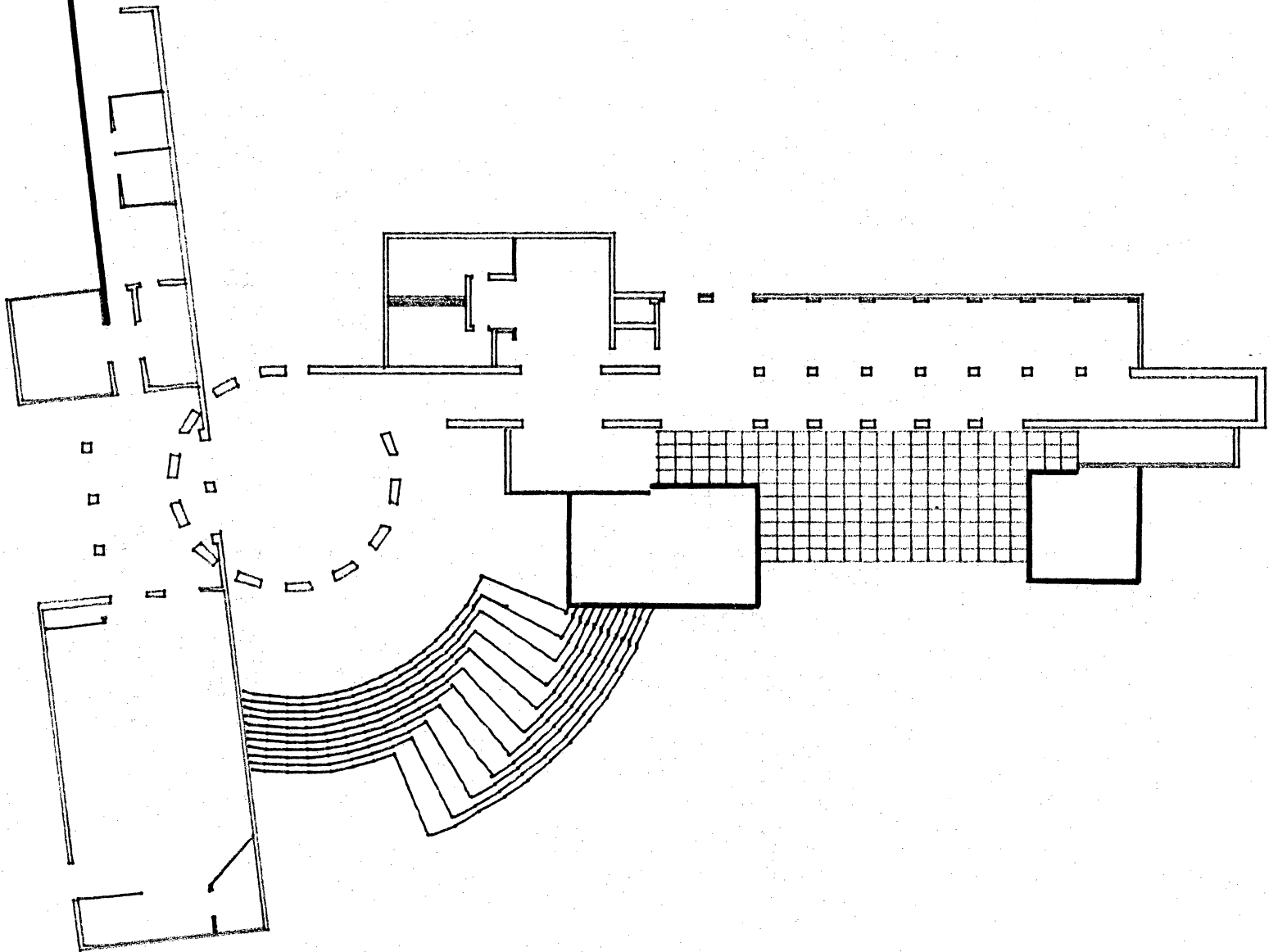
R←DEG YRT W;RA

\*\*\*\*\* CREATES A 4×4 ROTATION MATRIX FOR A 3D POINTSET.  
\*\*\*\*\* 'W' IS ALSO A 4×4 MATRIX, EITHER A TRANSFORMATION  
\*\*\*\*\* OR THE IDENTITY MATRIX(ID3).  
\*\*\*\*\* 'DEG' IS THE ROTATION MEASURED IN DEGREES CCW  
\*\*\*\*\* ABOUT THE Y-AXIS LOOKING TOWARD -INFINITY.  
\*\*\*\*\* 'RA' IS THE RADIAN EQUIVALENT OF 'DEG'.

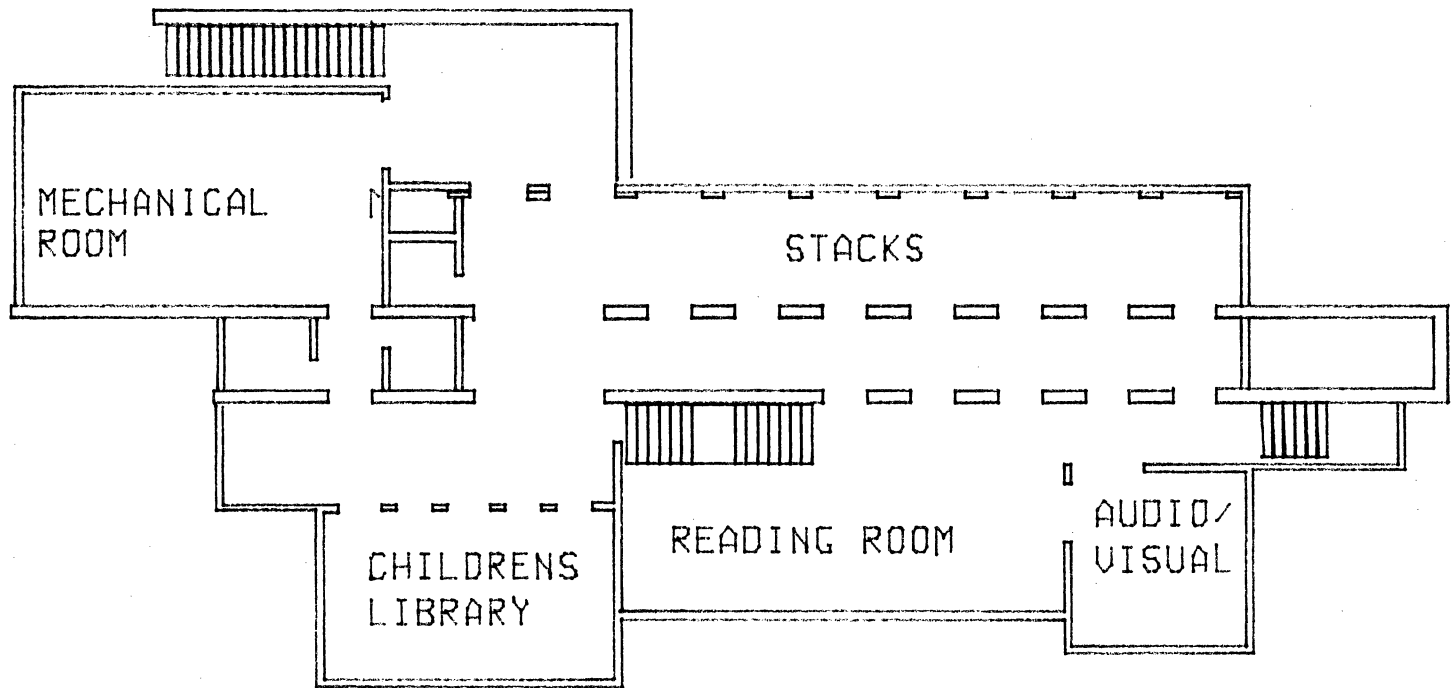
RA←DEG×0.1÷180

R←W+.x 4 4 p(20RA),0,(-10RA),0,0,1,0,0,(10RA),0,(20RA),(4p0),1

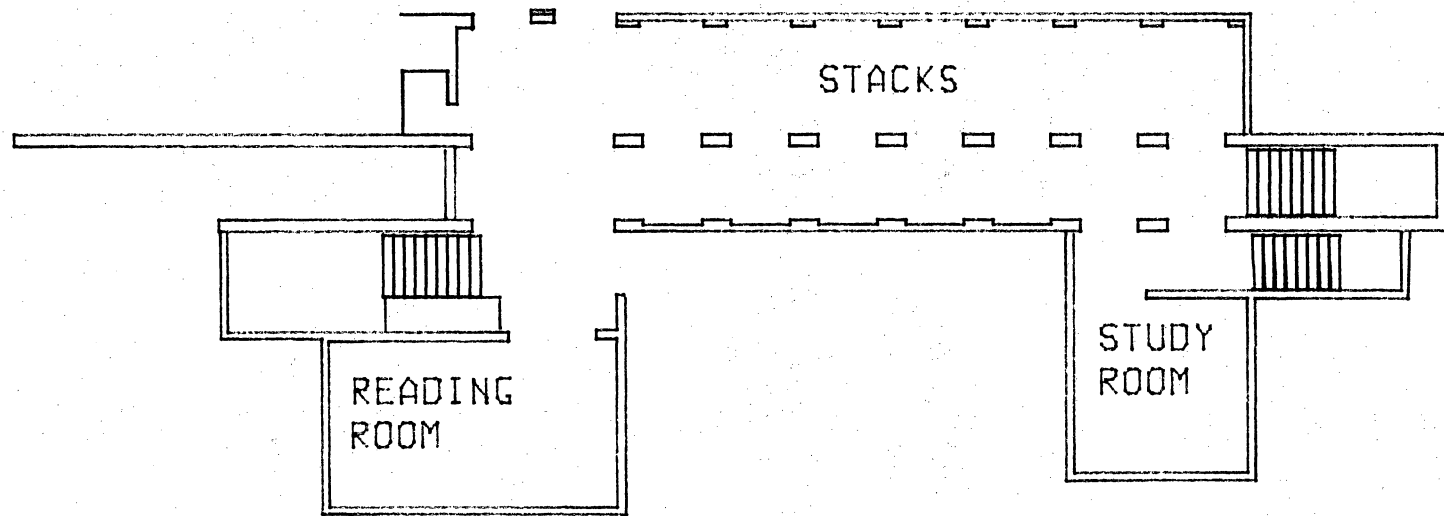
APPENDIX 3, FINAL DRAWINGS GENERATED BY THE COMPUTER



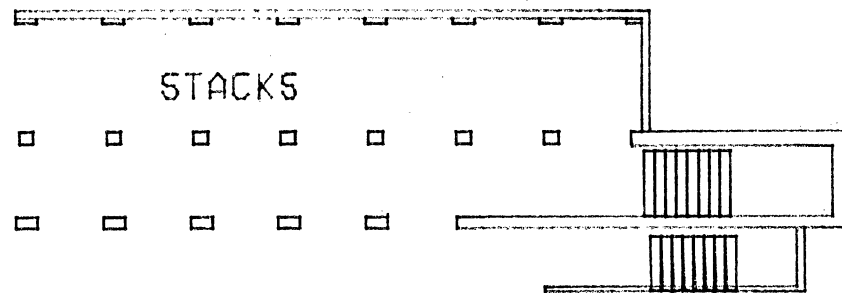
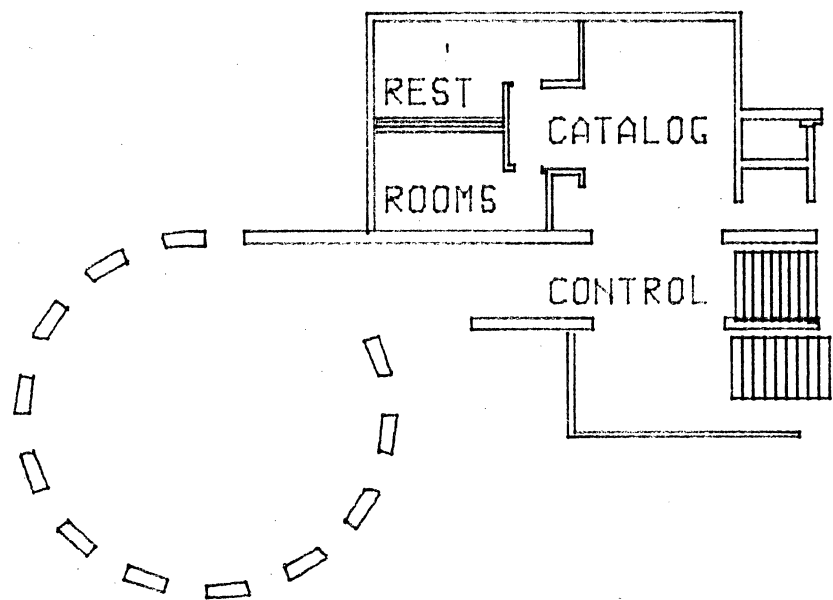




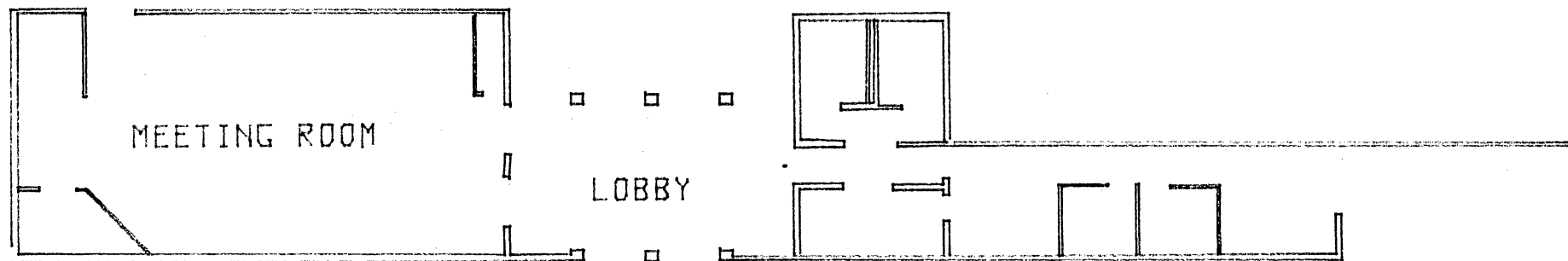
FIRST FLOOR



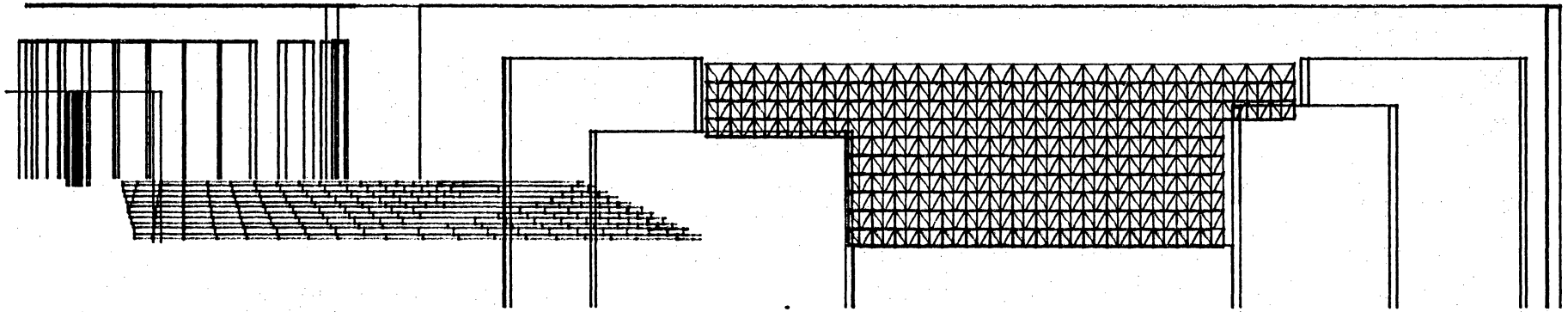
SECOND FLOOR



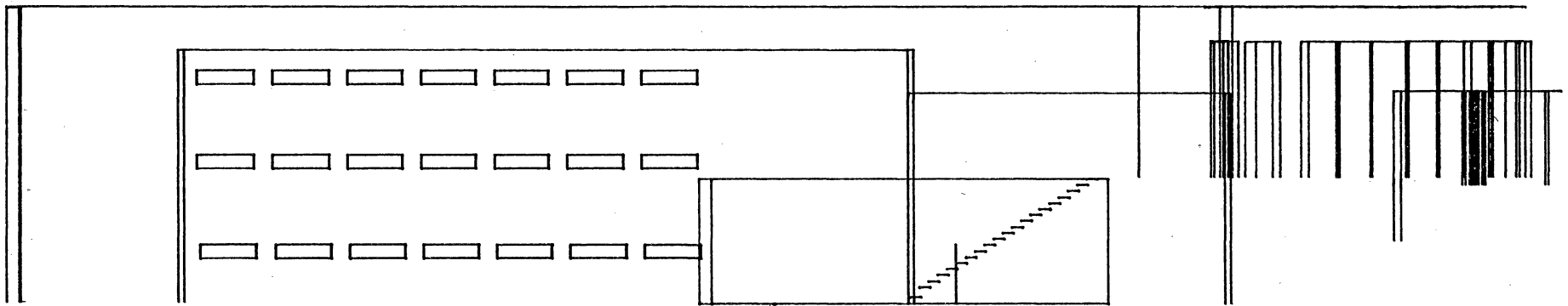
THIRD FLOOR



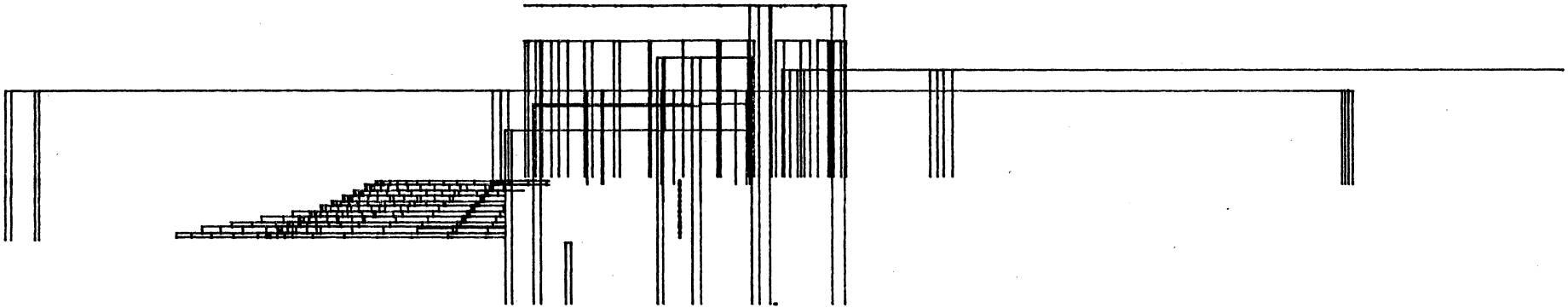
SPECIAL ACTIVITIES WING



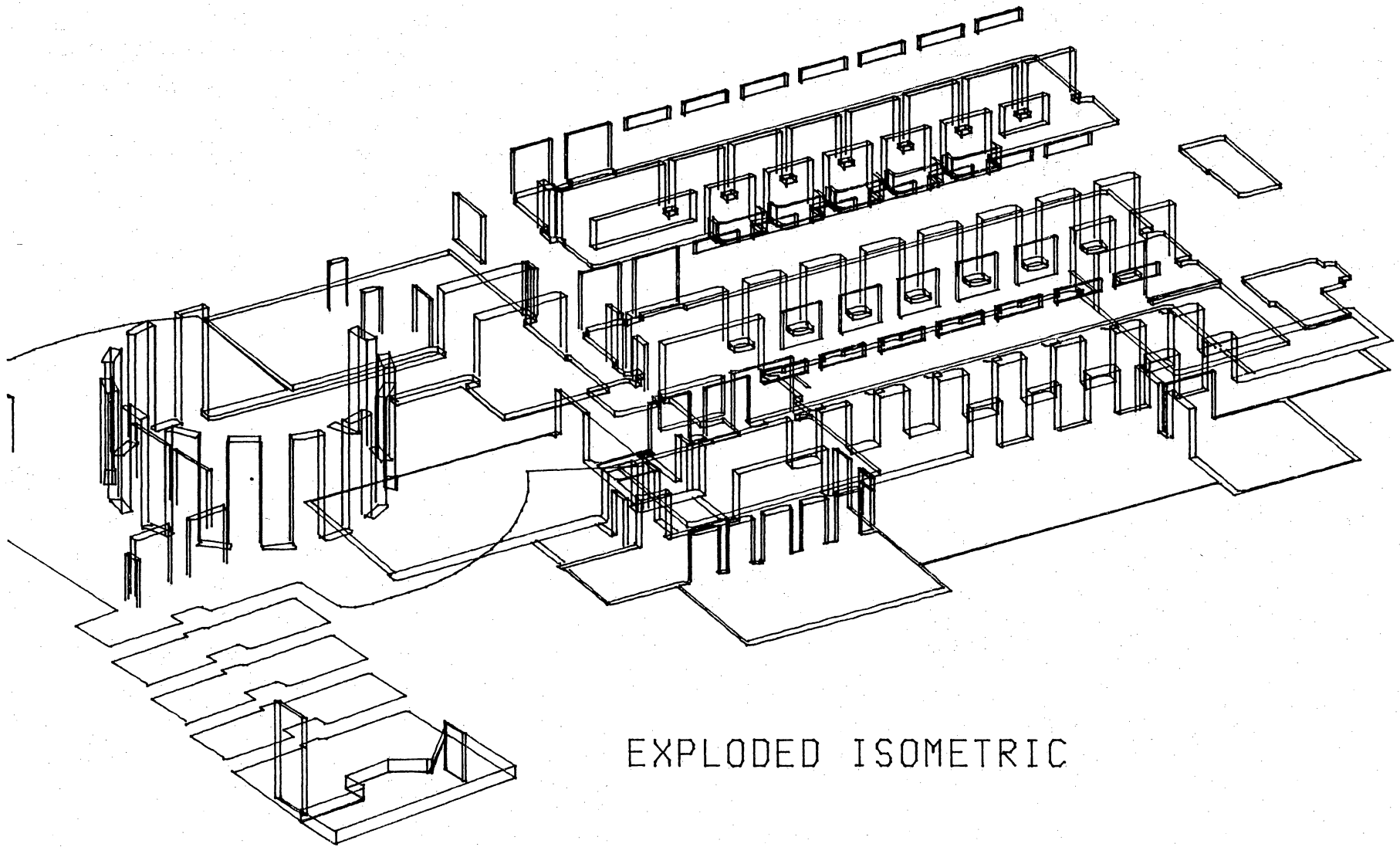
FRONT, NORTH ELEVATION



BACK, SOUTH ELEVATION

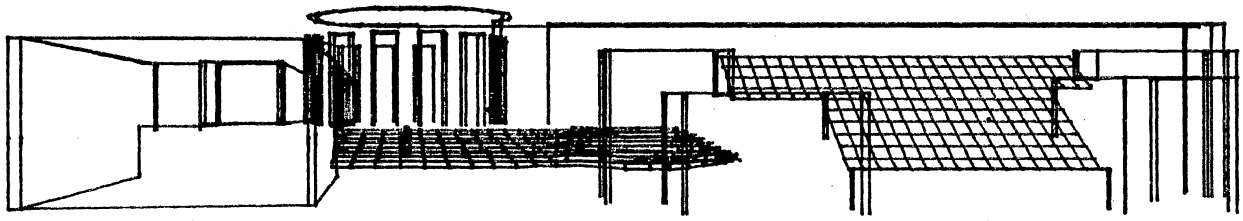


SIDE, WEST ELEVATION

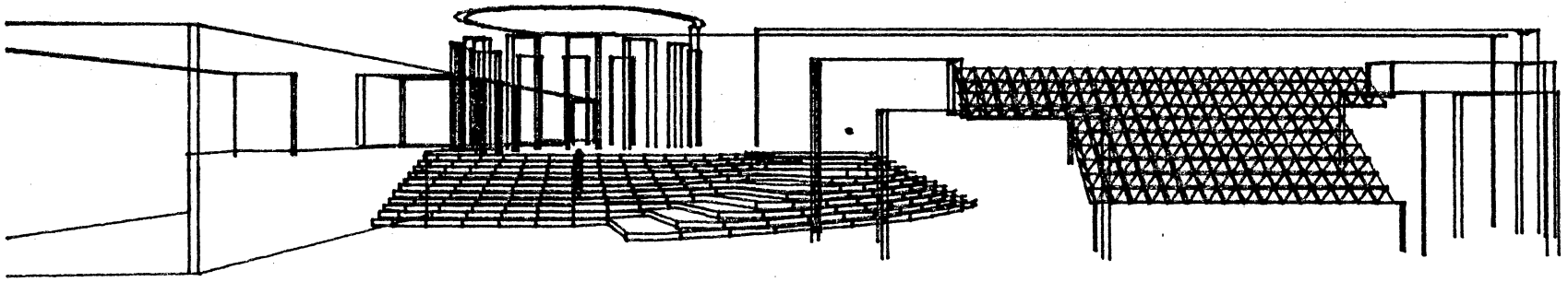


EXPLODED ISOMETRIC

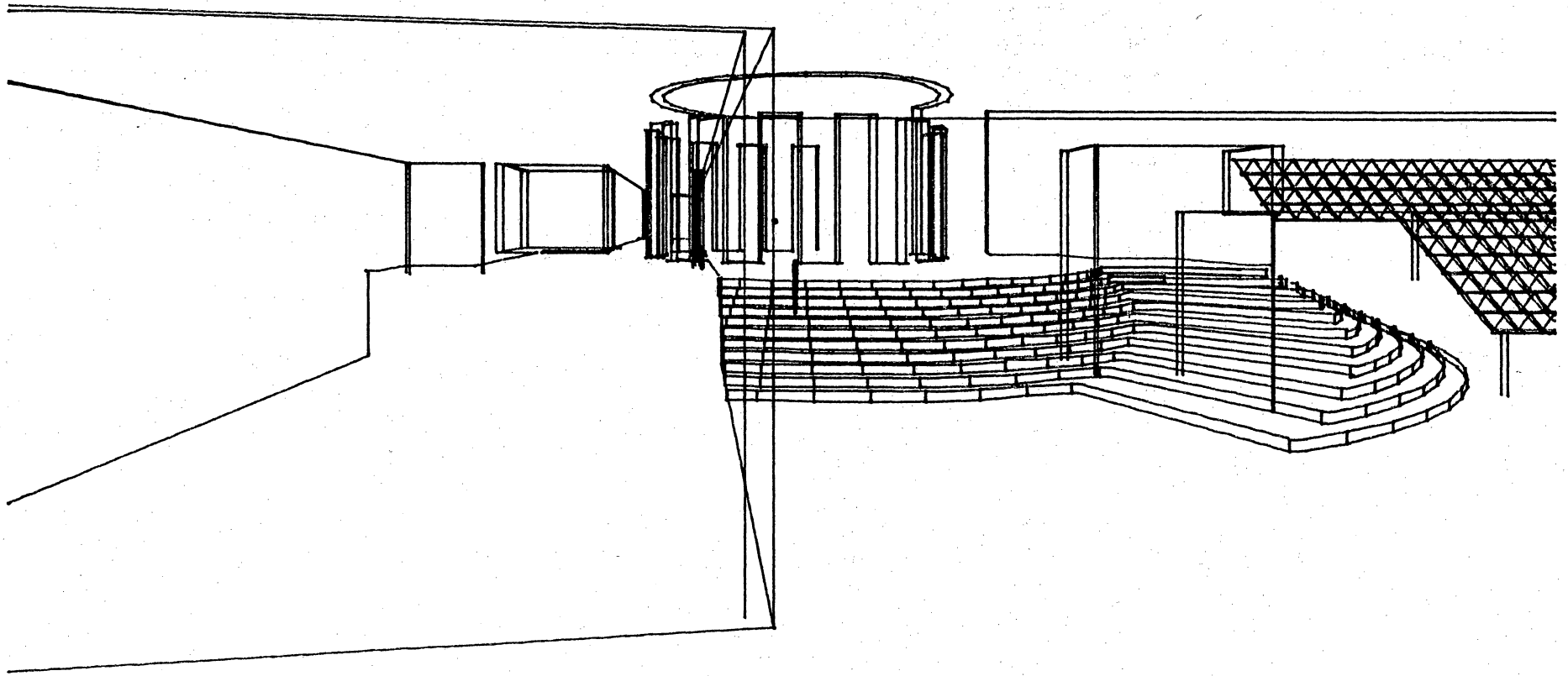




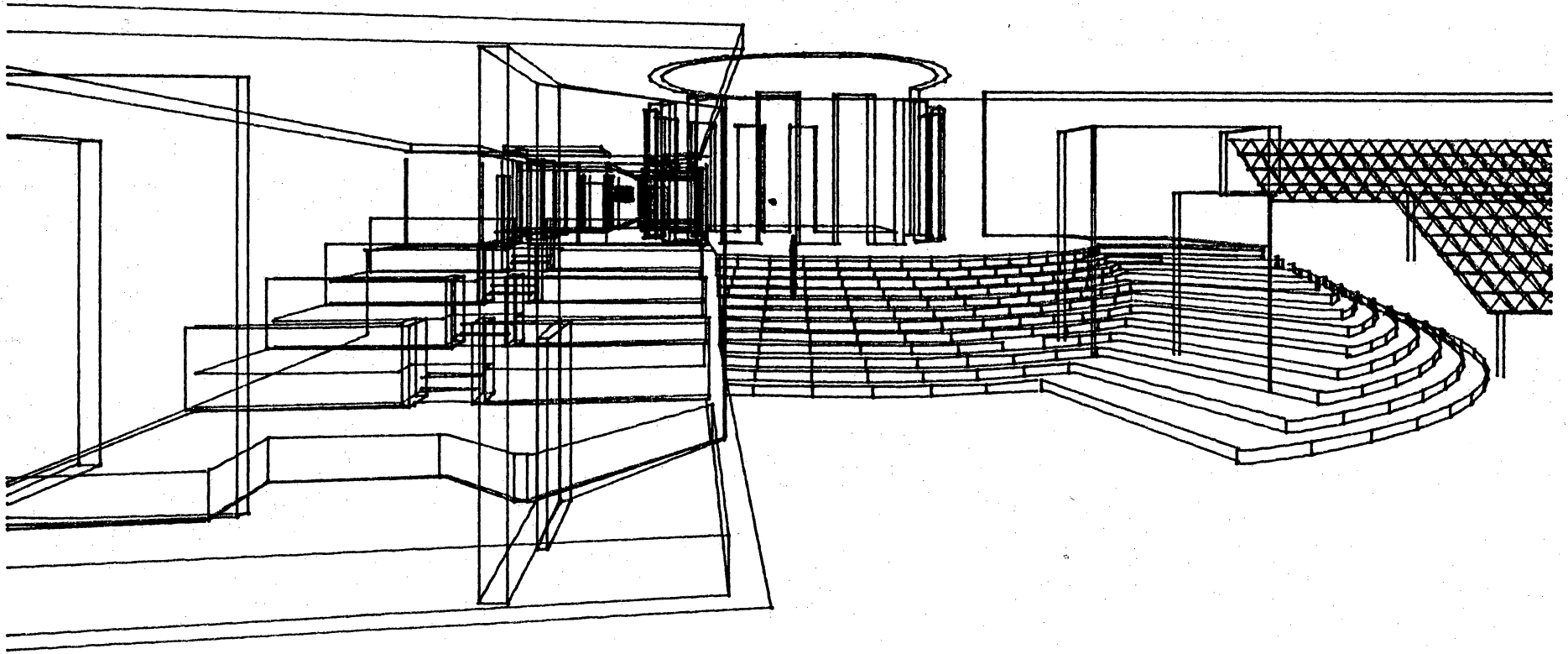






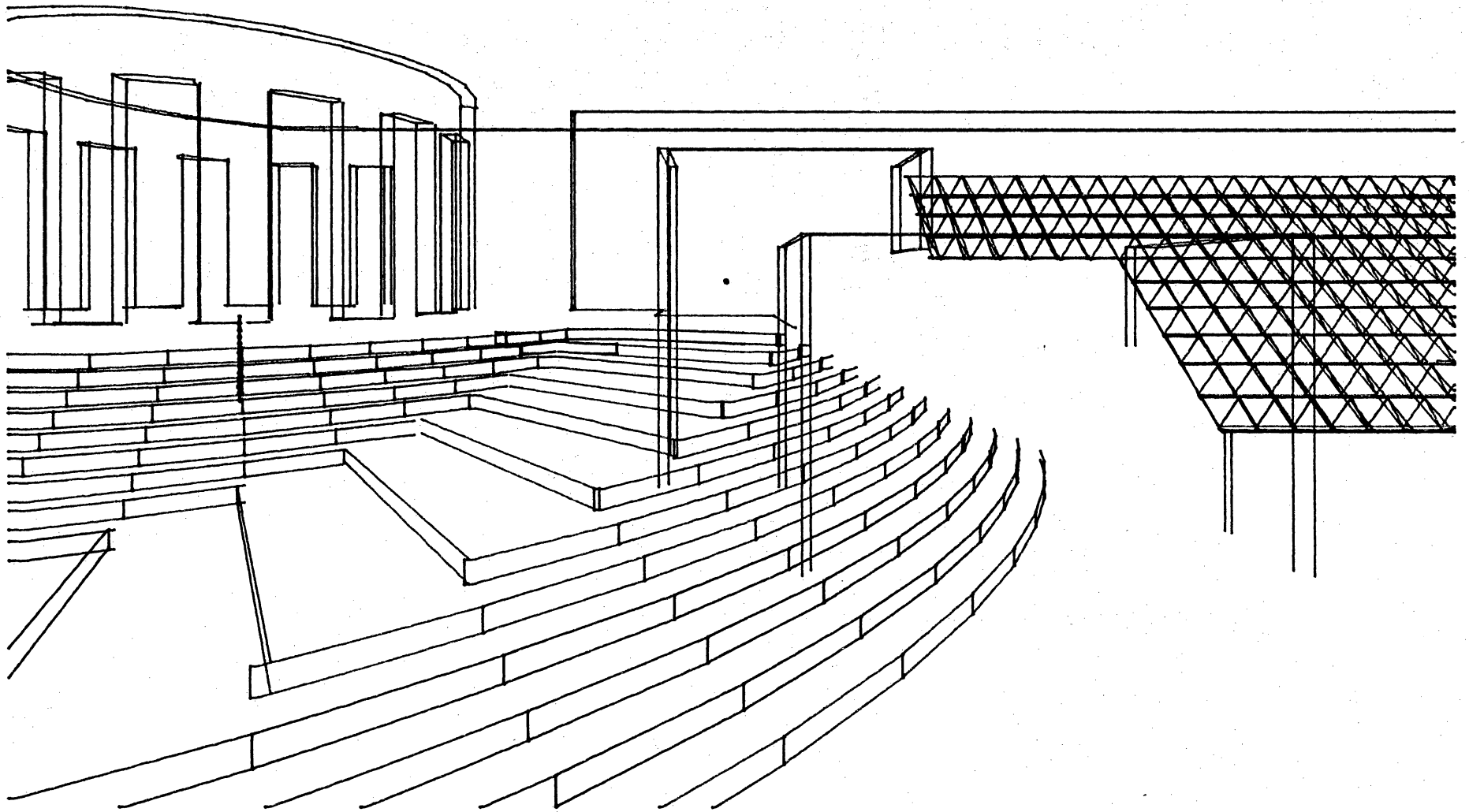




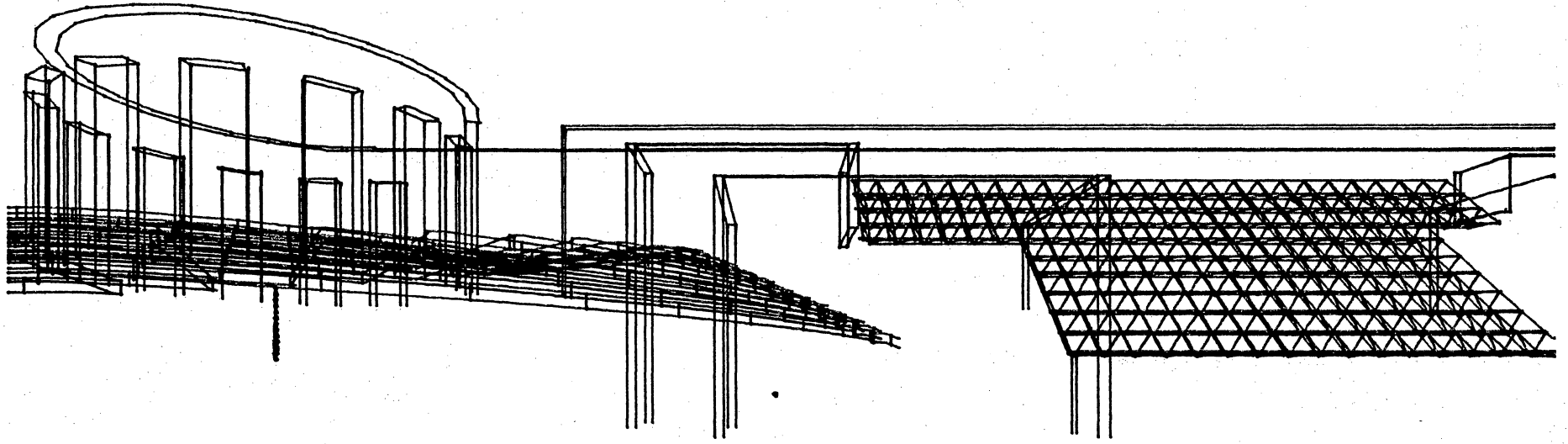




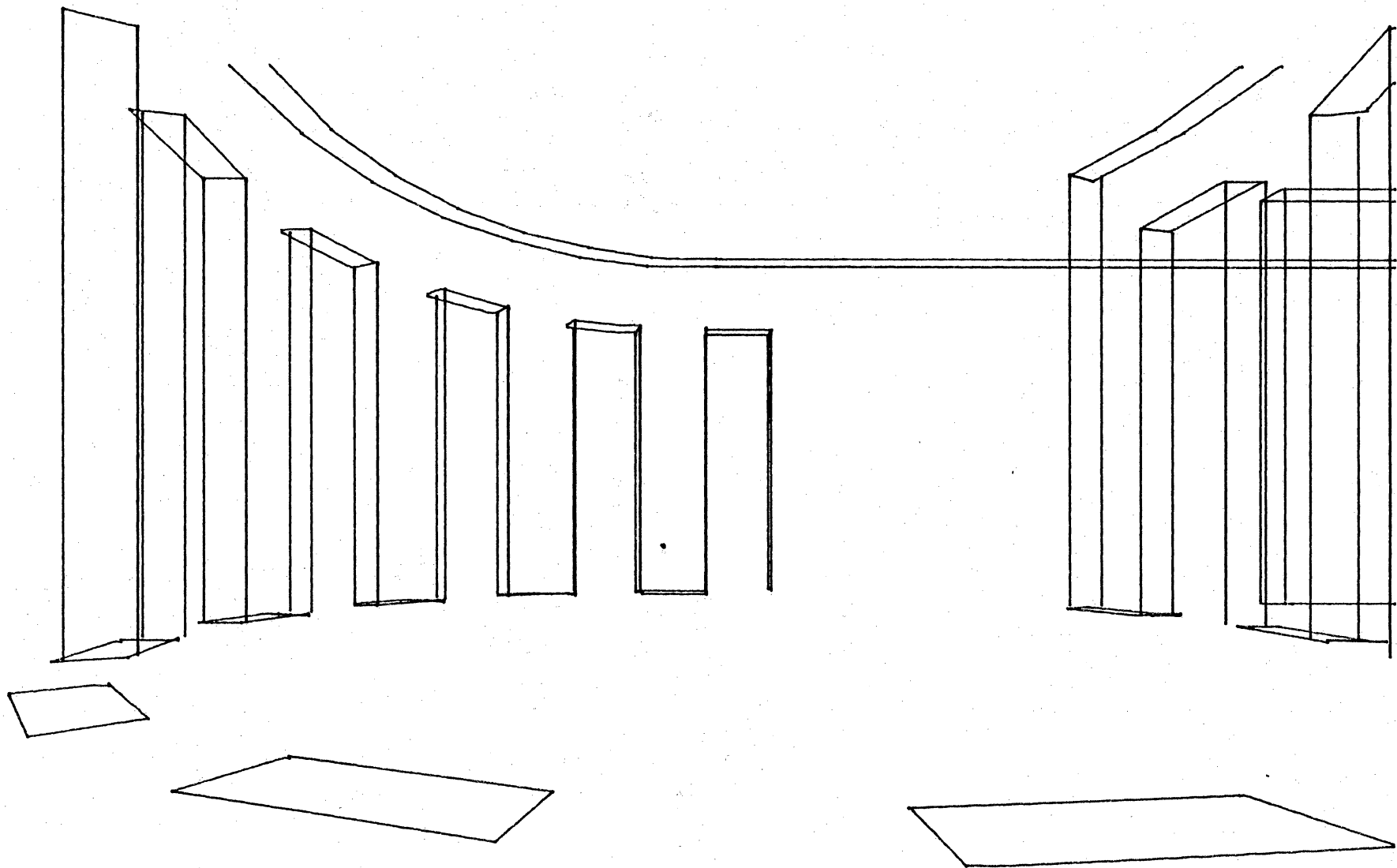




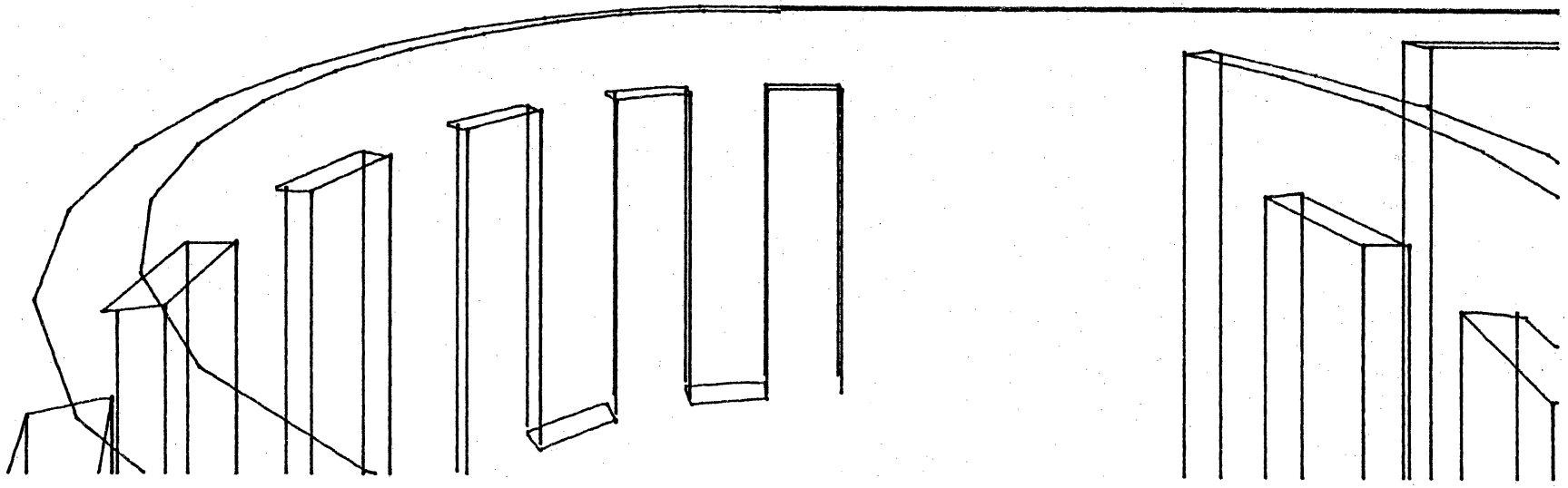


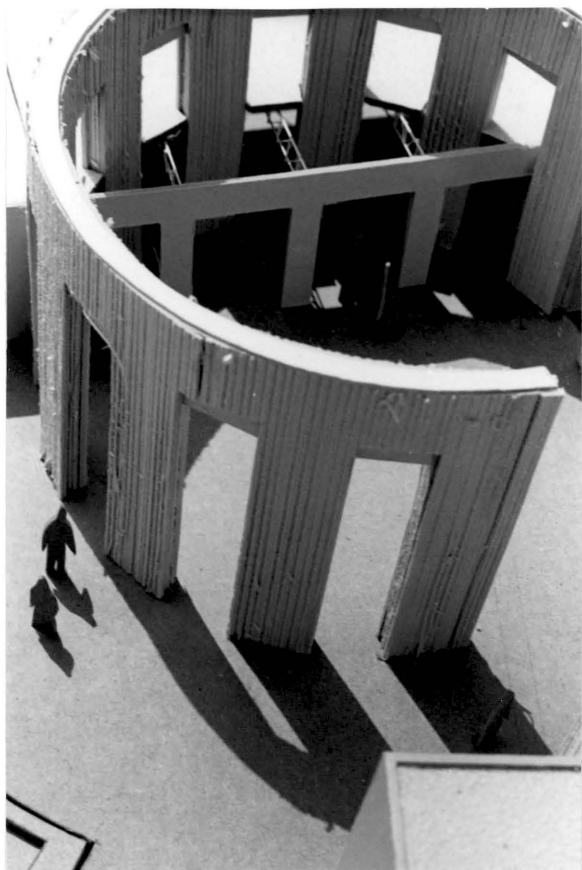




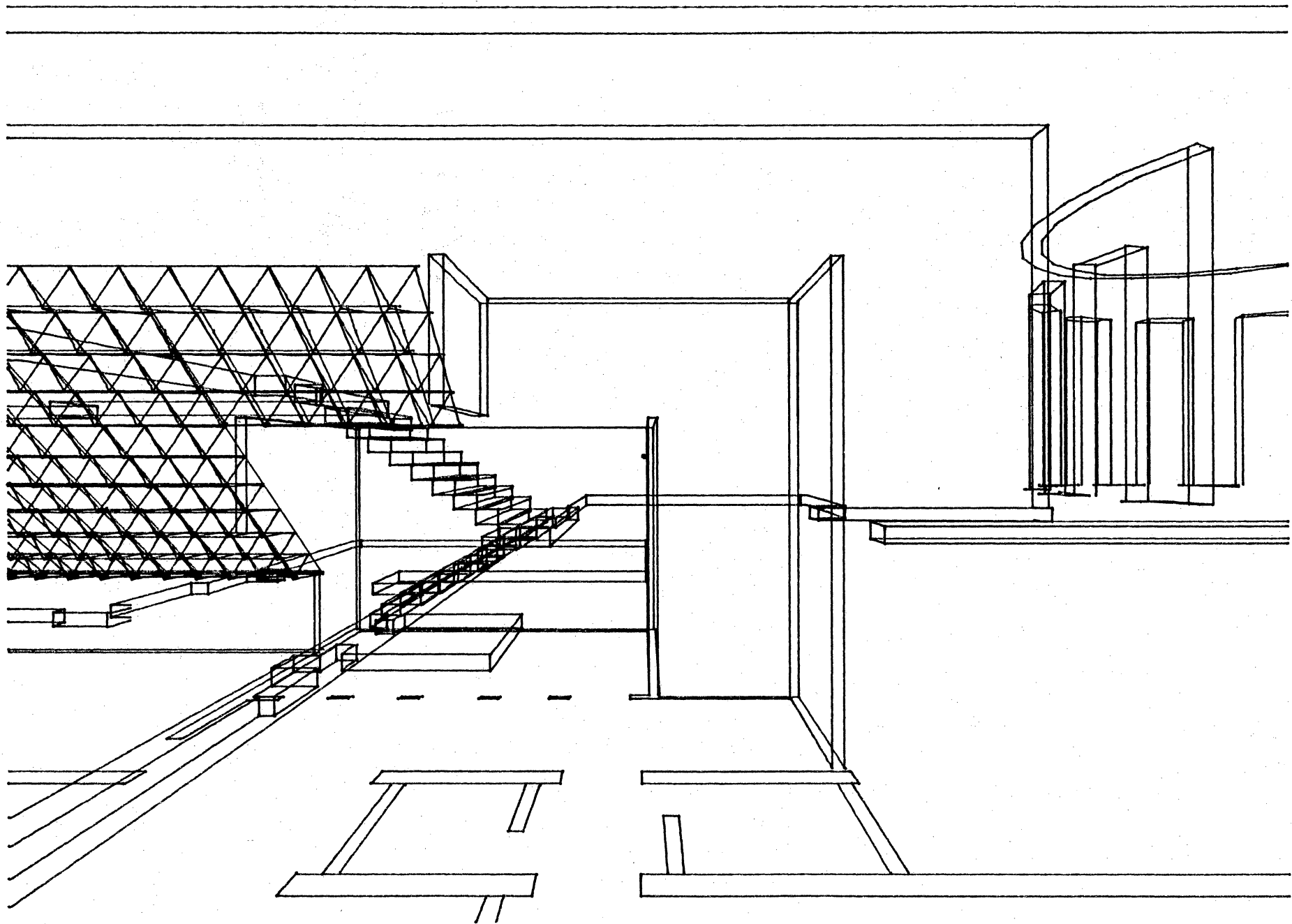




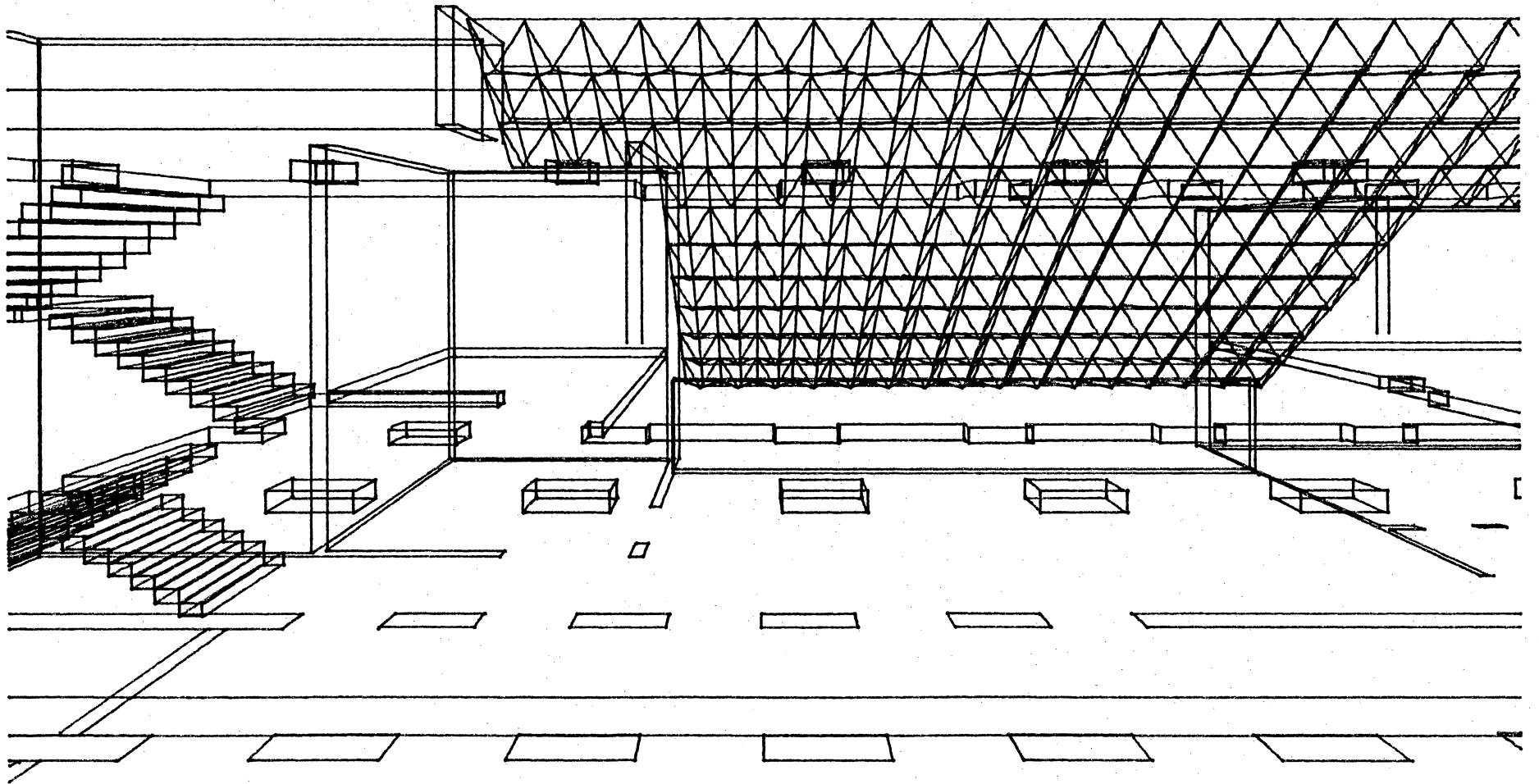


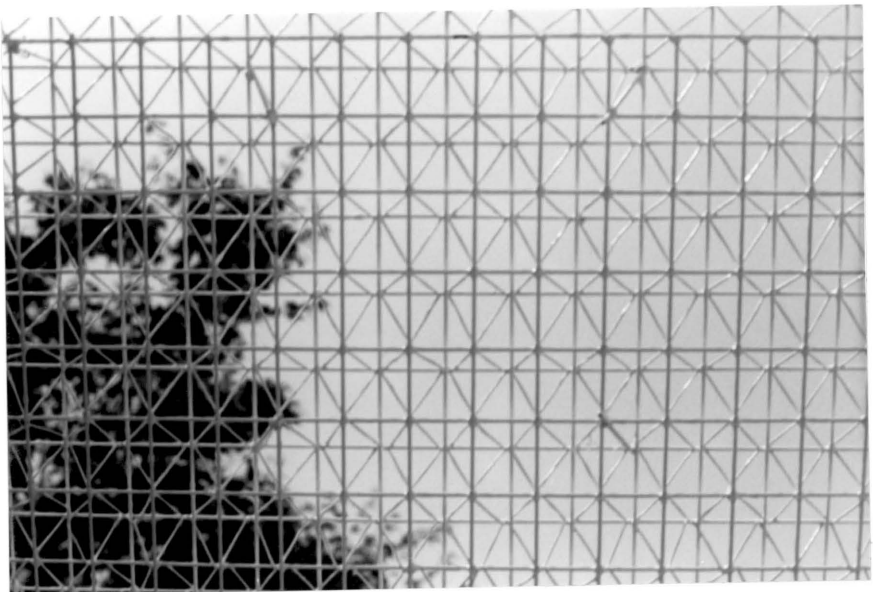


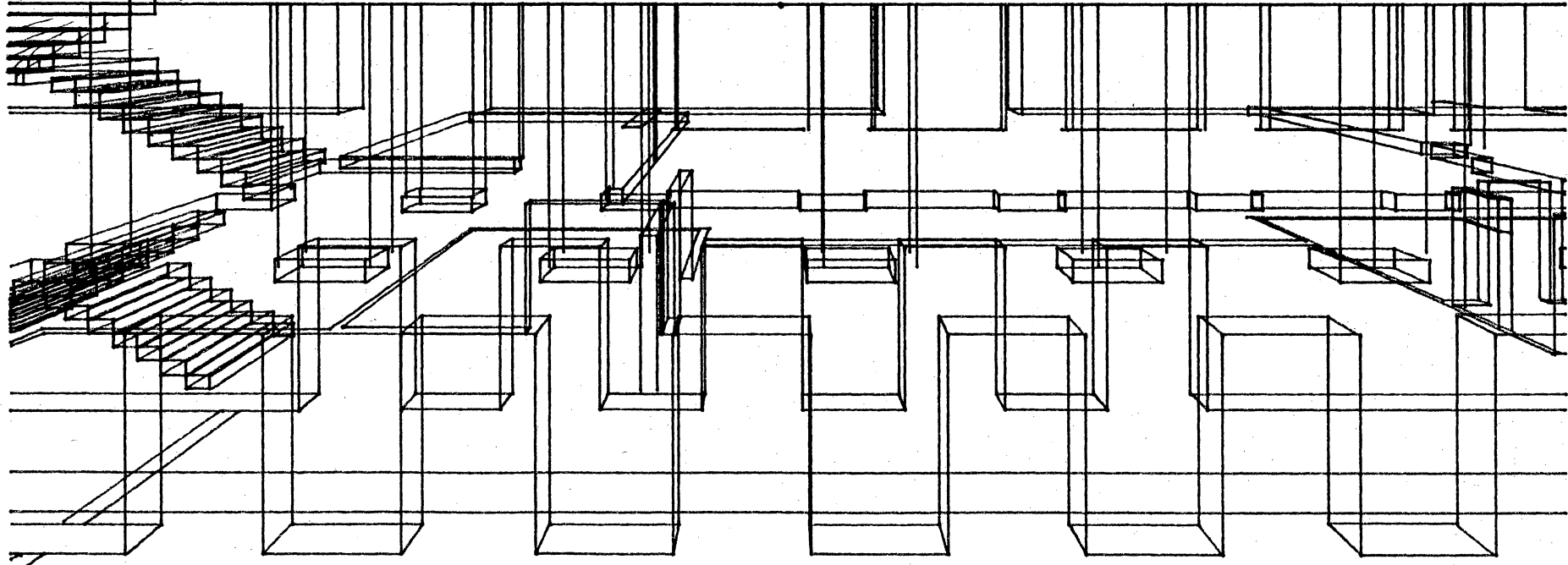
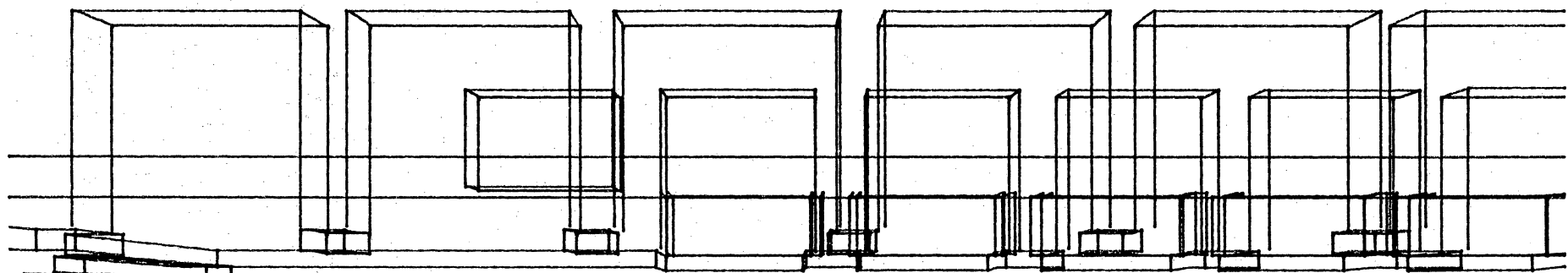
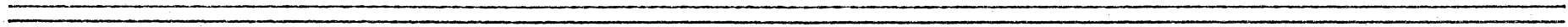
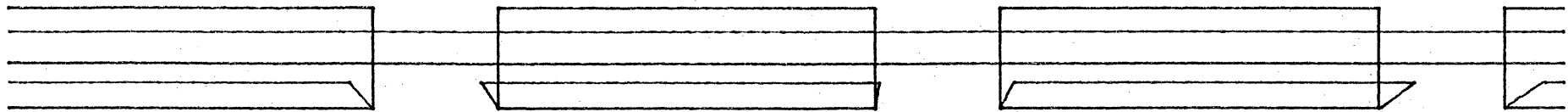




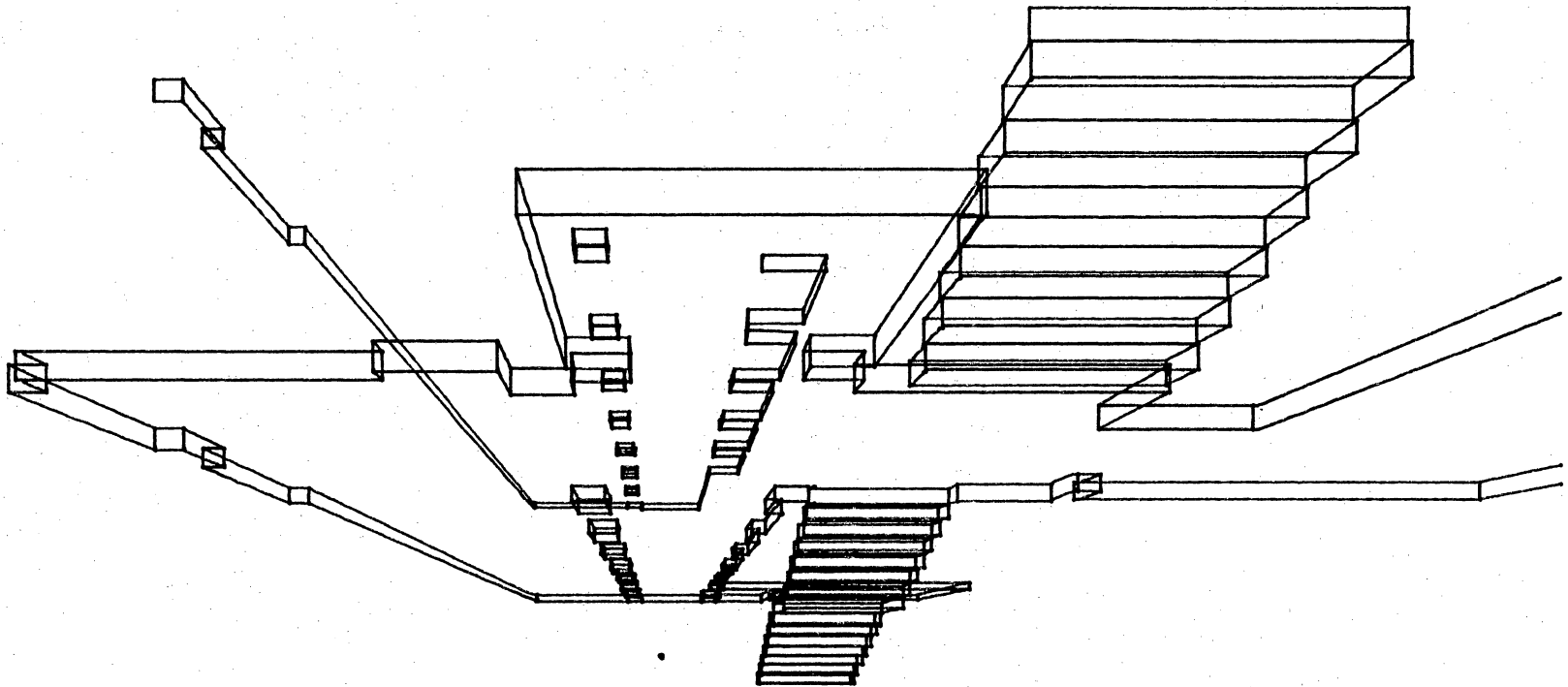






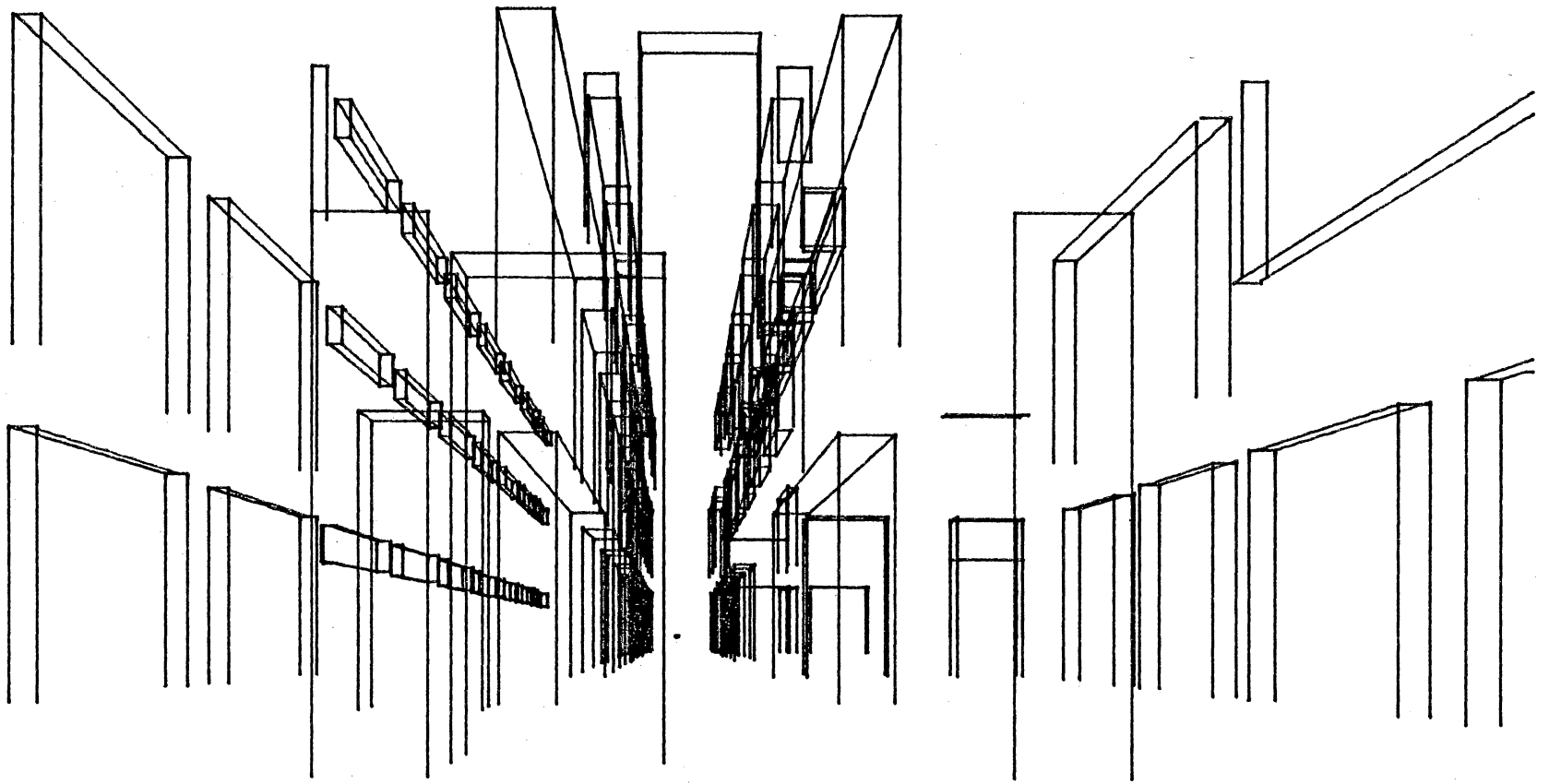




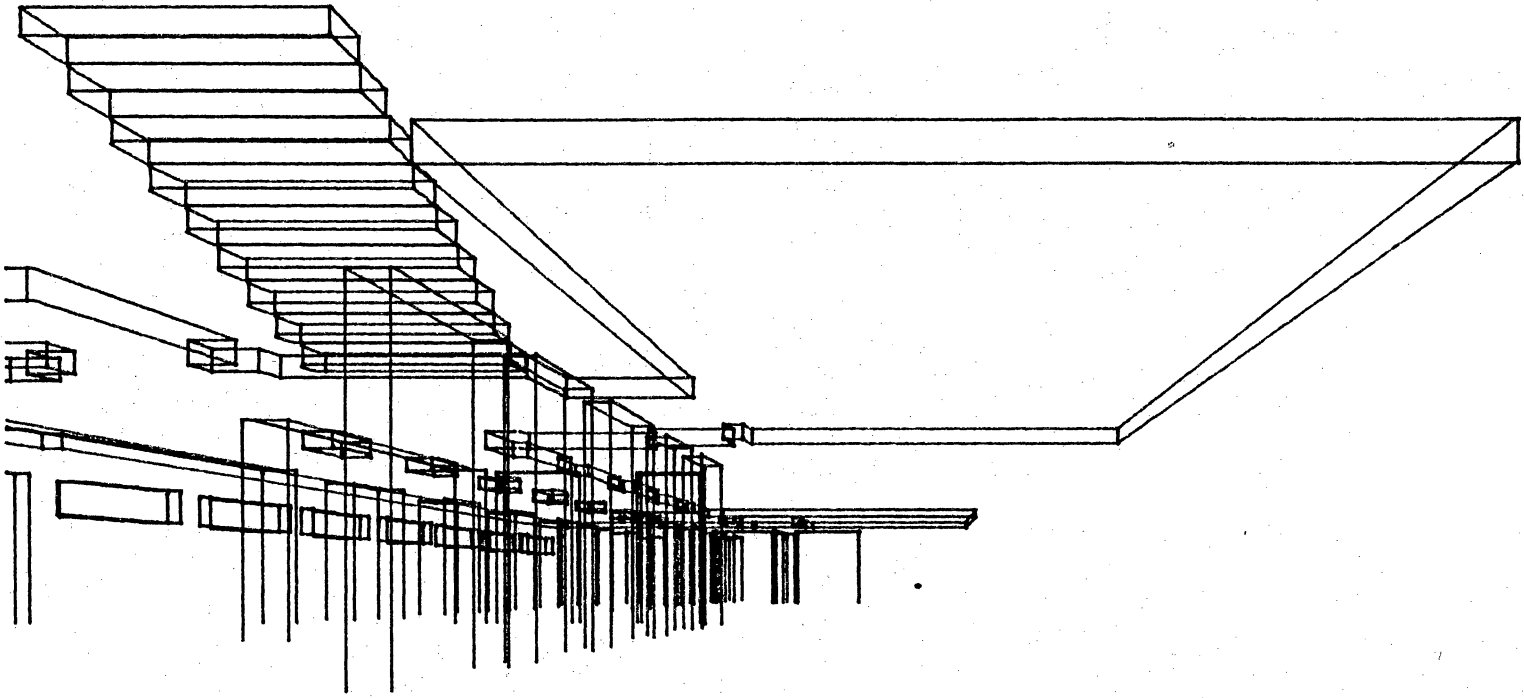




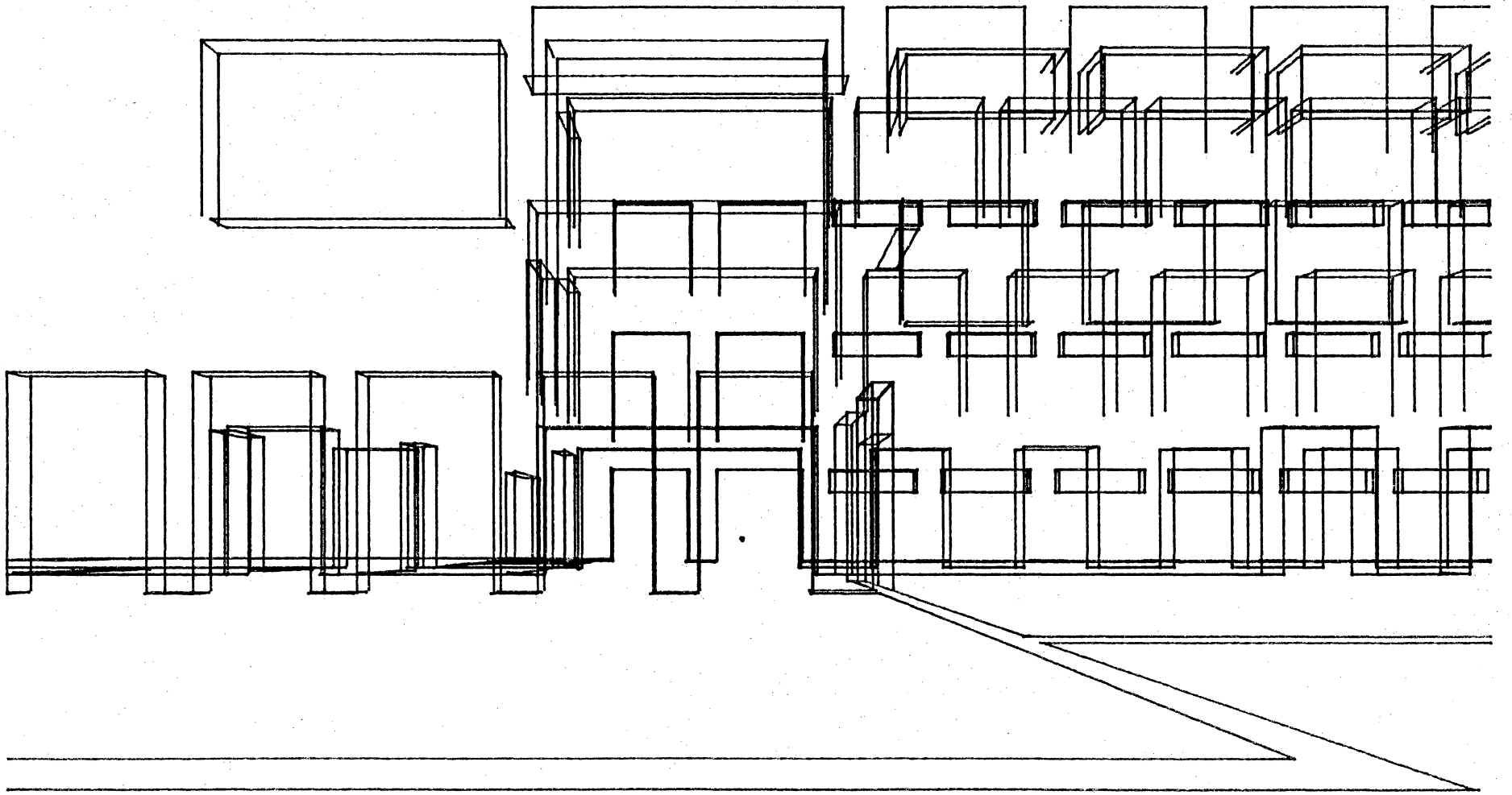




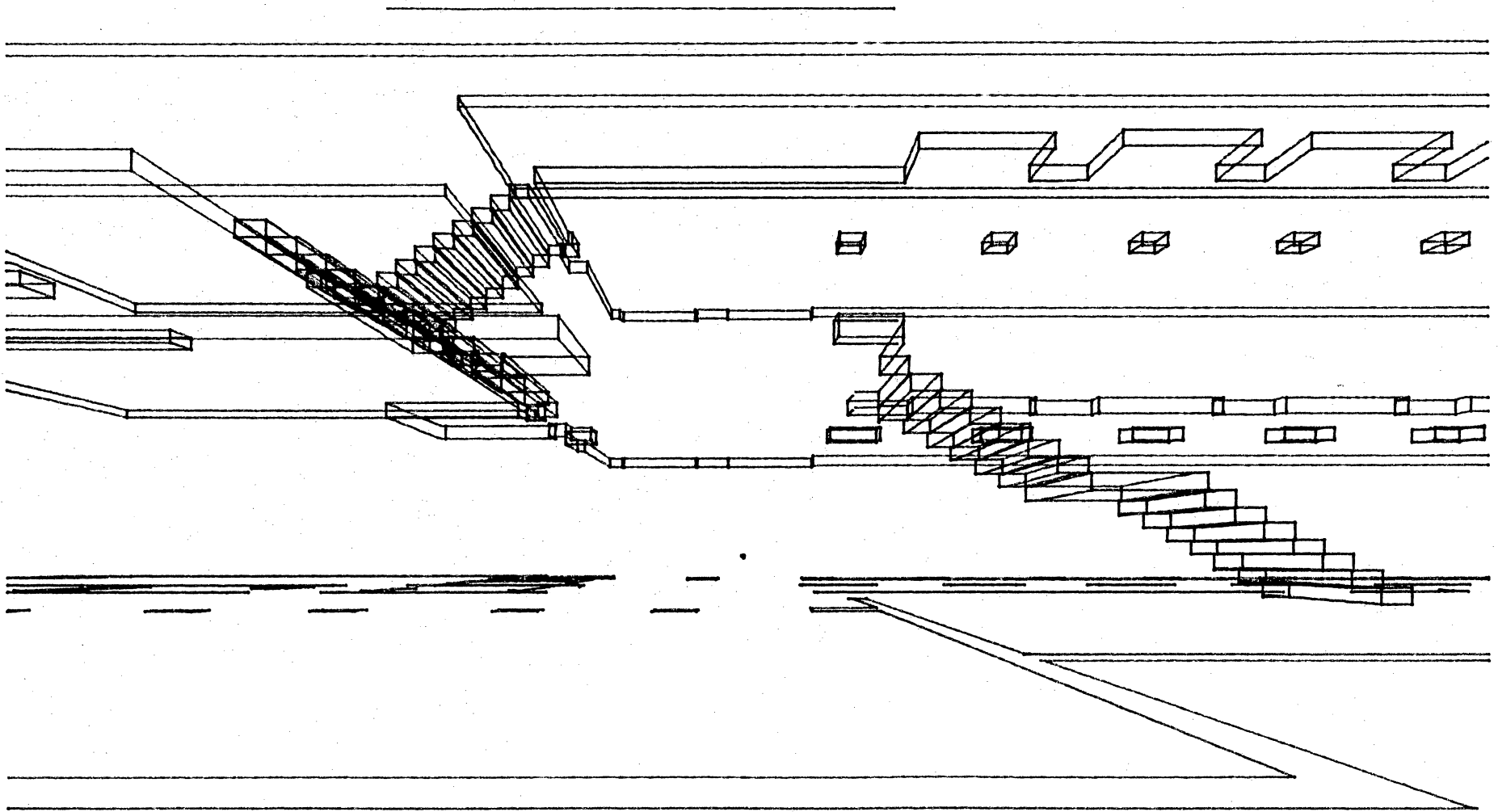


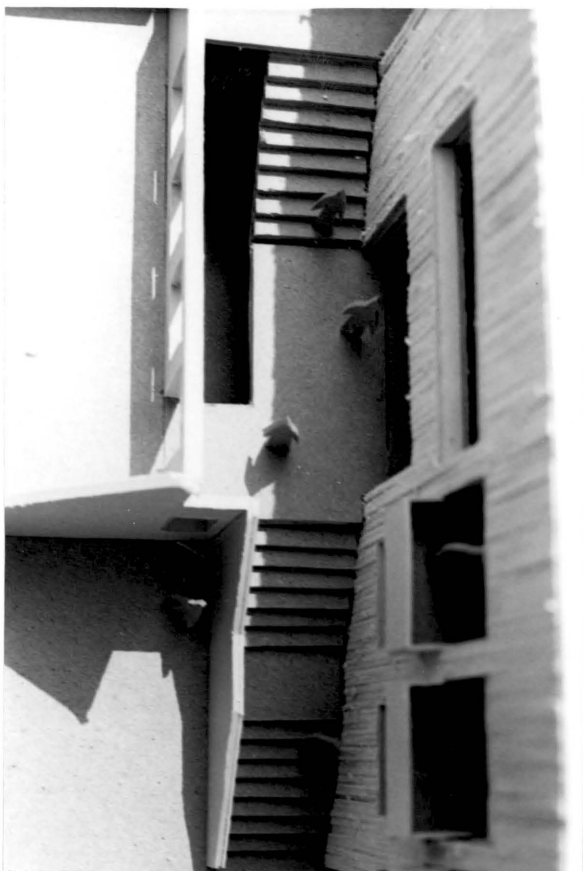




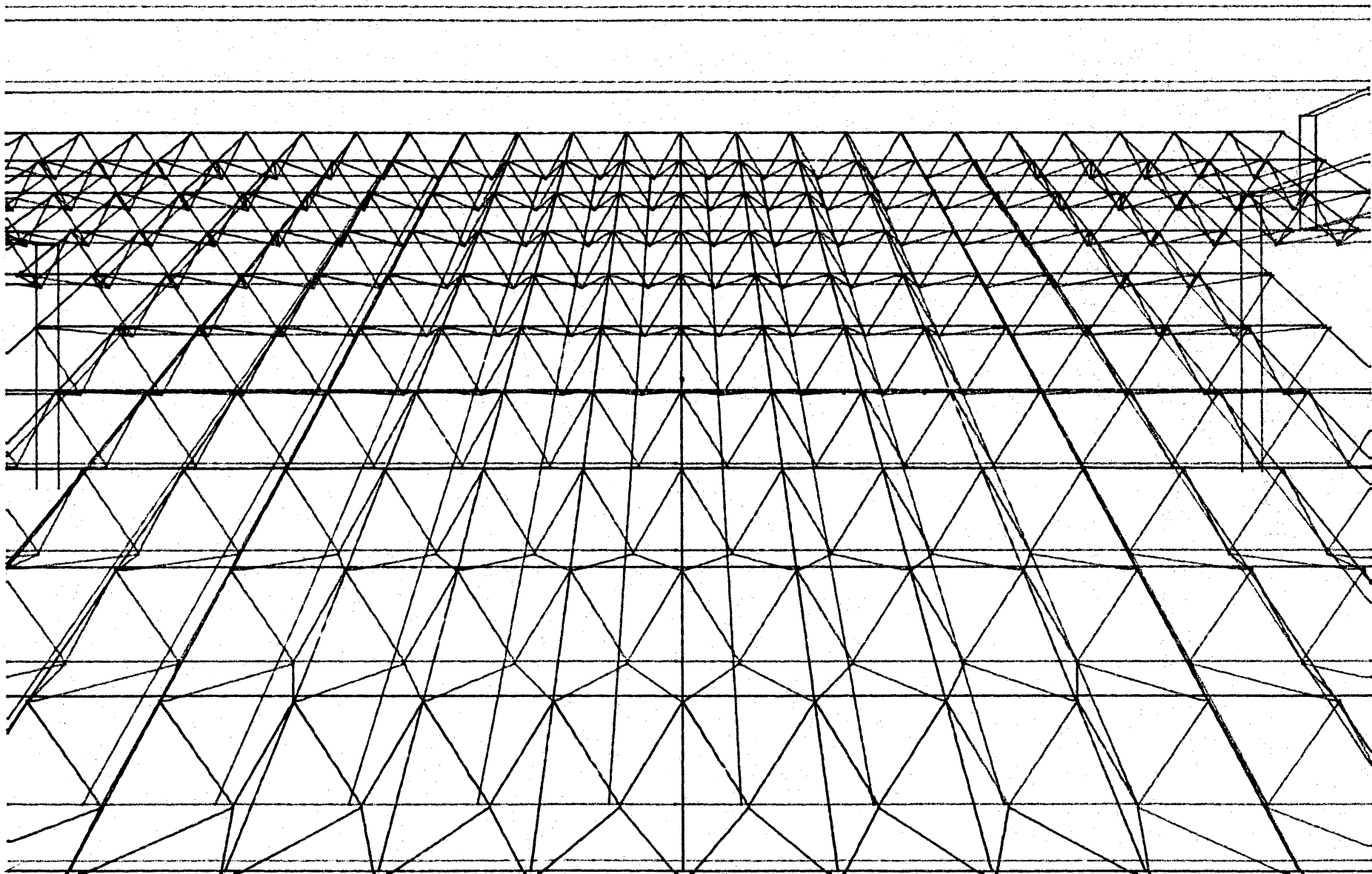




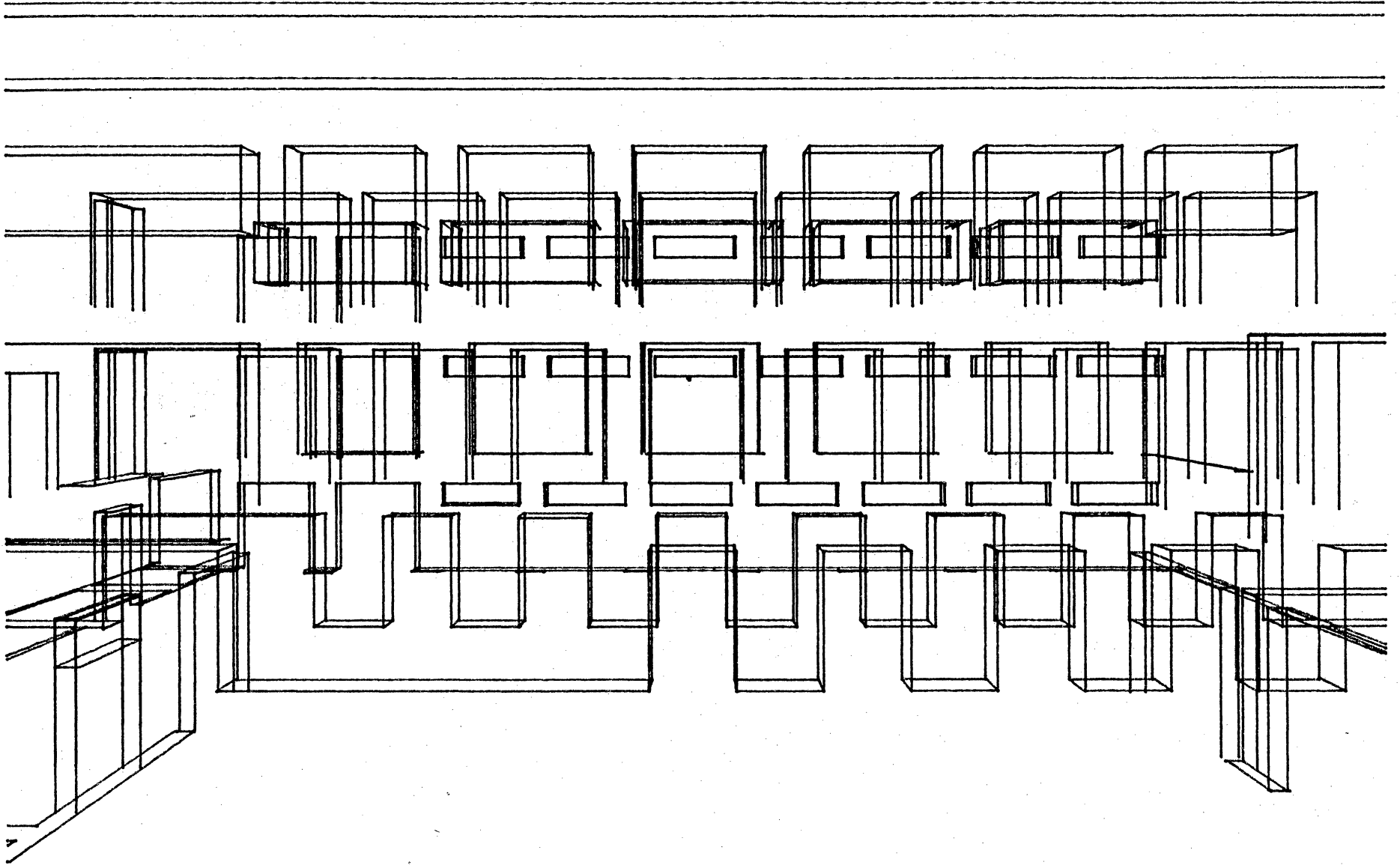


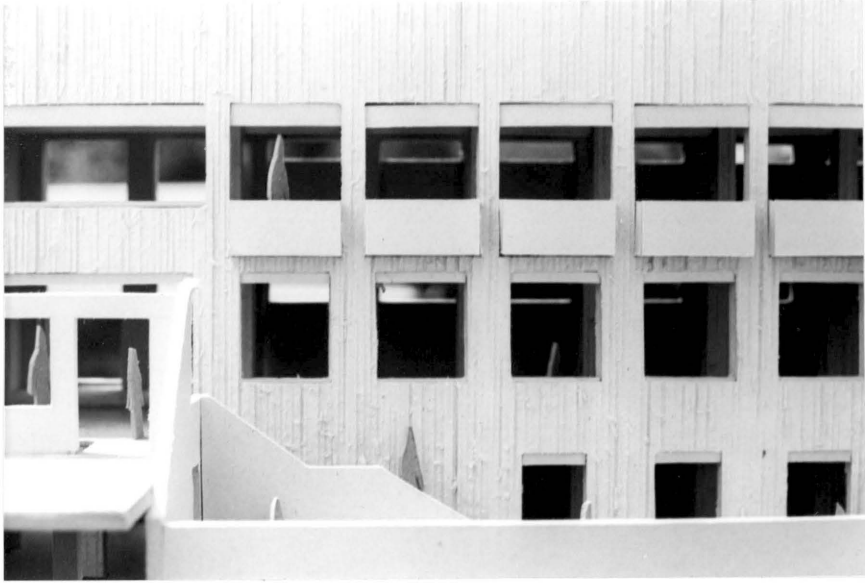


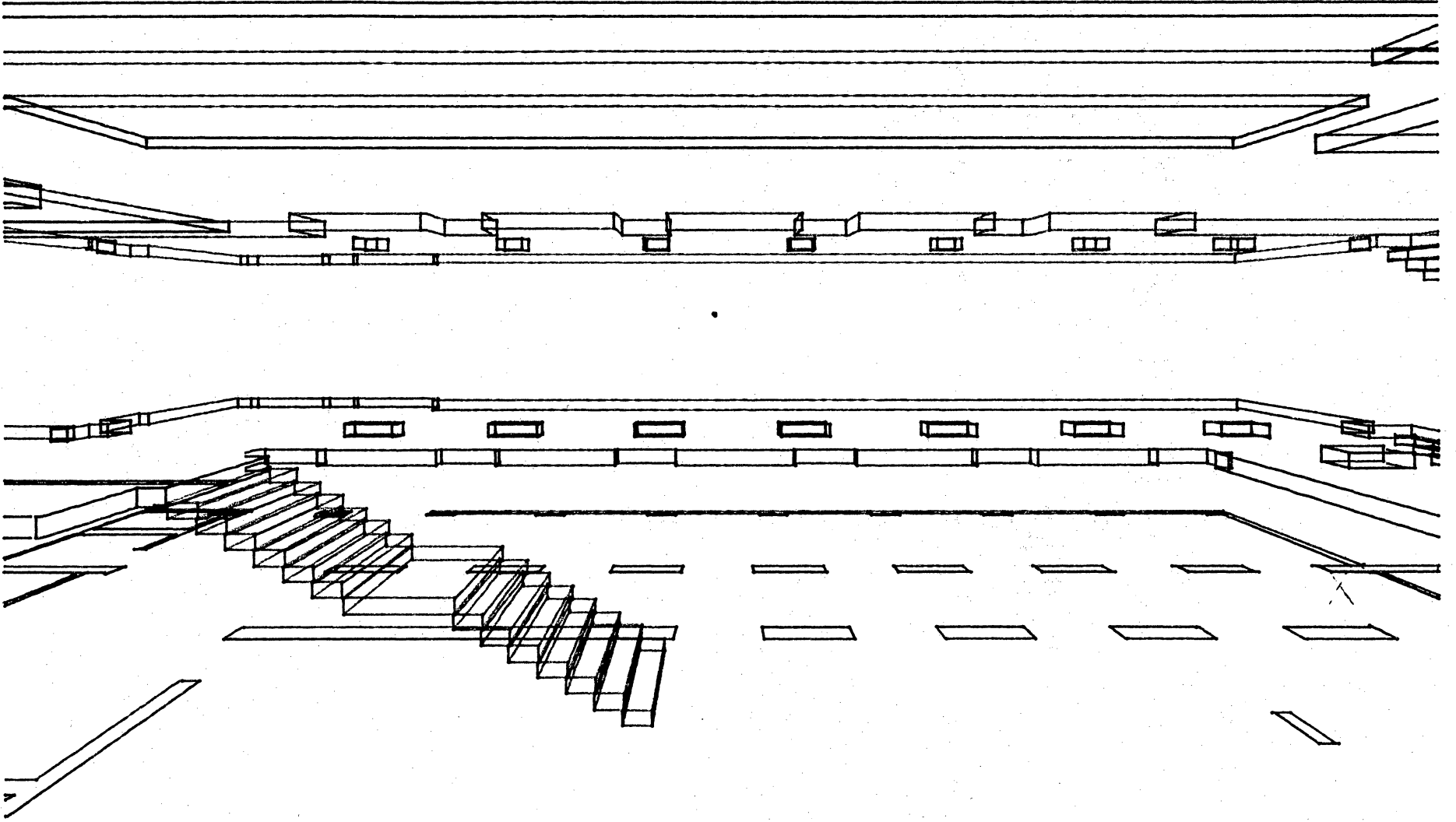




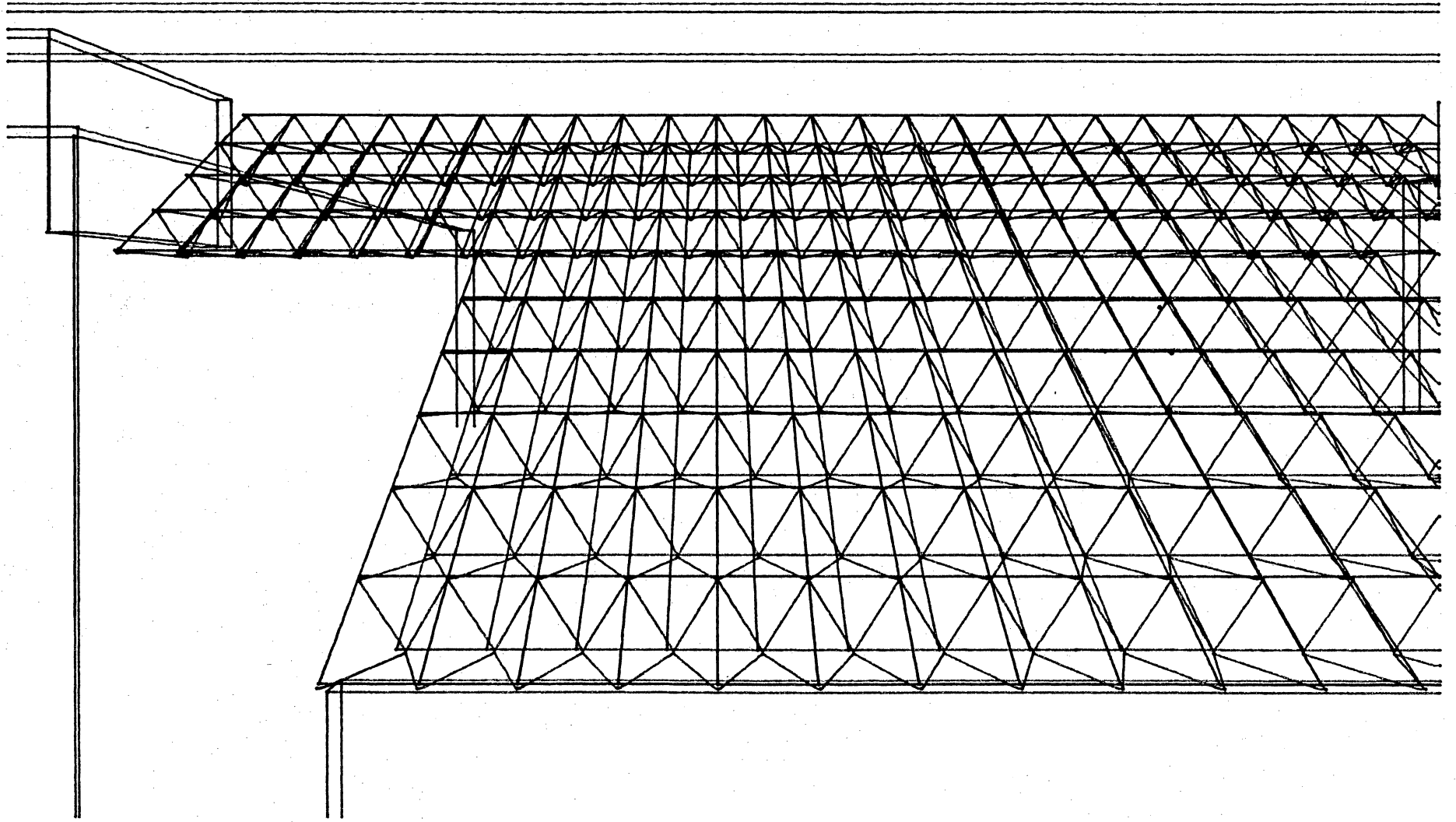






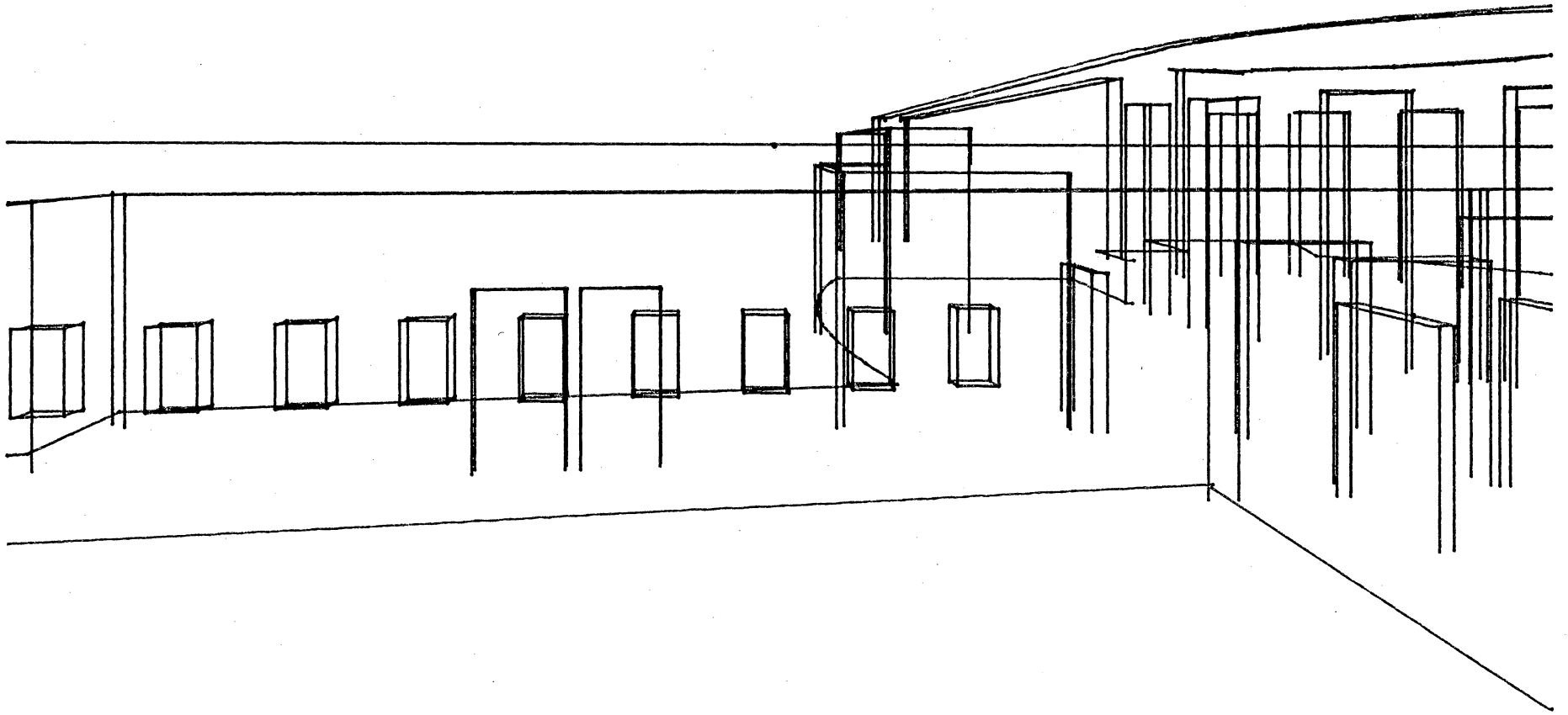




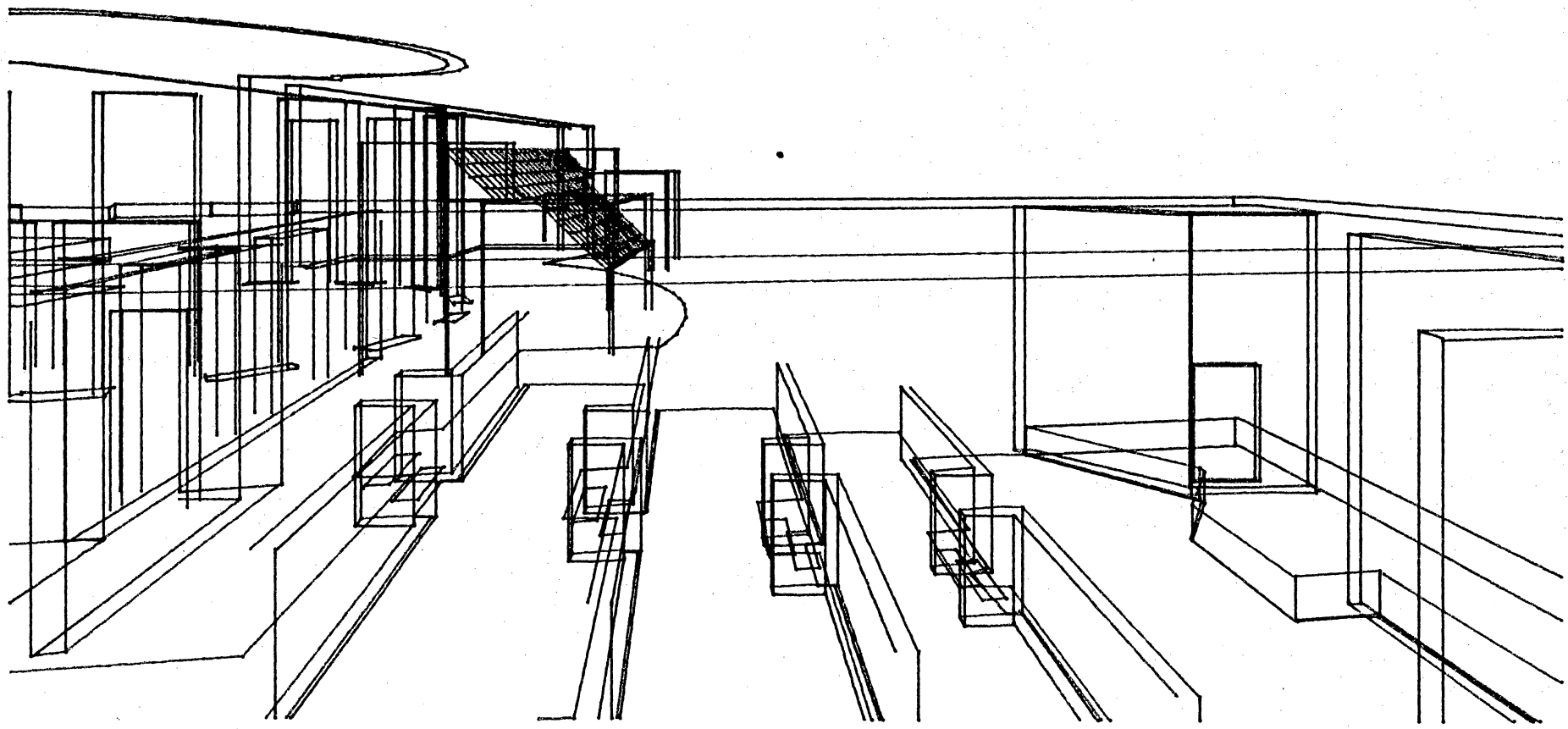


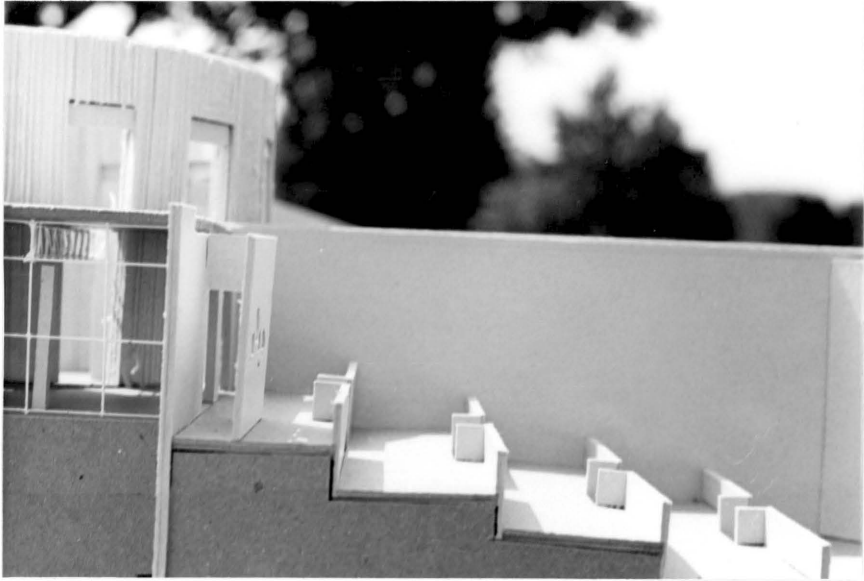


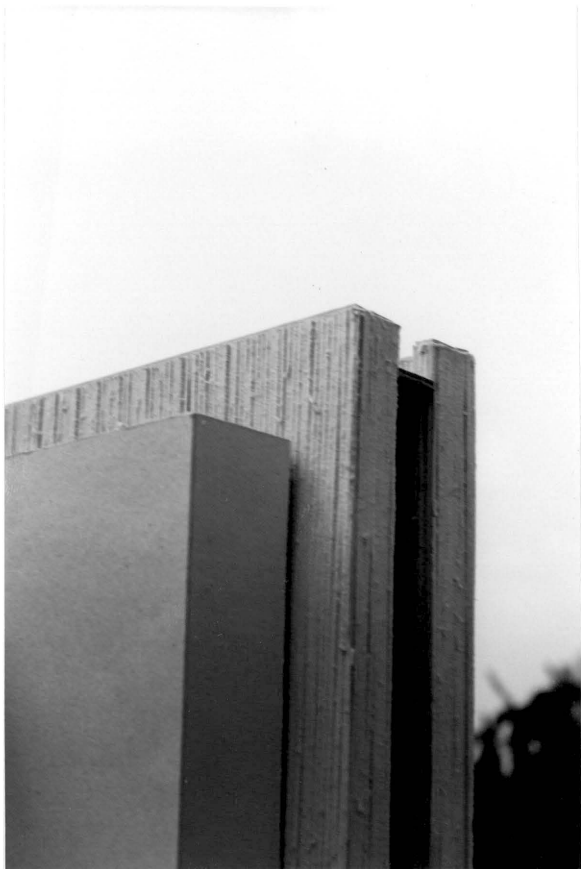












**The vita has been removed from  
the scanned document**

A CASE STUDY OF COMPUTER USE IN ARCHITECTURE AT V.P.I.

by

Michael Raymond Majewski

(ABSTRACT)

The use of the computer as it could relate to architecture was examined. The use was limited for the purposes of this thesis to graphic capabilities of the computer.

The method used to implement this case study was to establish a design project. The project was then used as a catalyst for adapting the visual implementation of the design project to the computer.

An examination of the methodology and the syntax used in the thesis is included. Also included is a description of the design project, the final graphic representations of the design project, topics suggested for further research that were generated by the thesis and documentation of the functions used in the study.