AN INTEGRATED BUILDING SYSTEM

by

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1967

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARCHITECTURE

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

September 1969

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June 17, 1969

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Dear Dean Anderson,

In partial fulfillment of the requirements for the degree of Master of Architecture, I hereby submit this thesis entitled "An Integrated Building System".

Respectfully,

Kris Oscar Eggen

ABSTRACT OF THESIS: AN INTEGRATED BUILDING SYSTEM

Kris Oscar Eggen

Submitted to the Department of Architecture on June 17, 1969, in partial fulfillment of the requirements for the degree of Master of Architecture.

The objective of this study was to develop a building system based on modern technology and construction techniques which would incorporate spatial and circulation systems with the systems of structure and environmental control to produce an integrated network of buildings as systems.

The study began with investigation of functional requirements for a specific building type and with a general study of structural and mechanical systems and construction techniques. From these studies criteria were established for the design of a system which would accomodate the requirements of all of these sub-systems in an efficient and economical manner. The emphasis of the design search was directed toward a system which would provide flexibility in determining the location of the building perimeter.

Essentially because of the flexibility needed in the increment of expansion perpendicular to the direction of circulation and the equally important mechanical zoning requirements, a 2-way structural system was developed. The system achieves a 12' increment of expansion by using a square bay with columns located at the midpoints of each side and through utilization of a cantilevered column capital system. The building perimeter can occur either at the column line or at a line 12' from the column line supported by cantilevered arms from alternate columns. The system is constructed primarily of 1-way elements in order to simplify the erection procedure.

Although it presents some hypothetical problems in spatial planning, the system does solve for all of the important pre-determined criteria.

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The author wishes to thank the following people, whose assistance and advice have contributed greatly to the completion of this thesis:

Prof. Waclaw P. Zalewski
Professor of Architecture
Massachusetts Institute of Technology

Assoc. Prof. Yusing Y. Jung
Professor of Architecture
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TABLE OF CONTENTS

TABLE OF DIAGRAMS AND PHOTOGRAPHS

INTRODUCTION

The object of this study is the development of a building system based on modern construction techniques which would achieve a successful integration of environmental services and structural elements with systems of circulation and spatial modulation and to relate these elements to a system of growth and change.

The current and anticipated need for buildings with spatial flexibility, in which the ability to change and grow in a logical and controlled manner is a design criteria, has established the need to study total systems integration in an architectural context. Use of the potential of modern technology for fabrication and assembly in order to meet a set of conditions which are only generally defined will in the future become a more and more common problem. The premise that the design of an integrated building system was possible by first examining the requirements and criteria of the component sub-systems was accepted and initial research was begun with the simultaneous study of mechanical and structural systems within the parameters of a specific range of functions.

This involved a review of the research and projects completed by students following this program at M. I. T. in the past, a review of current projects and work being done in offices here and abroad, and a study of pure structural and mechanical principles. An investigation of factory techniques for pre-fabrication and erection was also undertaken at this time to help establish the possibilities open in terms of building construction.

Before further research could be done the systems of spatial planning and circulation had to be defined. The design approach has been essentially to establish a general direction by choosing a particular range of functions—a specific building type—and to then explore as many alternatives as possible within each of the disciplines affecting

the final building system in this light.
Once the requirements of the general building type were established, the specific structural and mechanical problems became the primary foci of the study. The investigation of structure, environmental control, planning and construction technique eventually led to a pattern of systems overlays. Making these meet and accomodate each other efficiently in the form of a three-dimensional system for building is the major problem to be solved in systems integration.

The technology of assembly is considered to be at least as important as the technology of prefabrication. The specific objective in terms of construction technique was to design a system which minimizes construction difficulties by eliminating such factors as temporary scaffolding and complicated on-site connections. This further implied a study of materials fabrication and structural detailing, which became parallel studies.

The specific problem of expansion and variation are of particular importance in a study of this type. The final solution would have to be one that in terms of expansion and variation would accomodate all pre-established conditions: in particular this was seen as the problem of precise location of the perimeter of the building, as determined by functional requirements, in respect to internal circulation. The initial analysis of function and circulation within the selected general building type established the increments within which need for variation and growth are likely to occur and this increment became an important criteria in the development of the structural geometry.

The final product of such a study would be a system for building with an integration of primarily structural and mechanical elements that are capable of manipulation and change within the established limits. Physically this means designing both the structural and mechanical systems so that they are mutually compatible and so that together they satisfy other requirements of the building which might relate to the pre-determined systems of circulation, zoning of environmental control, partitioning, acoustical control and parking among the more obvious.

WORKING ASSUMPTIONS

It was initially accepted that the search was for a system of mutually accomodating sub-systems which would result in a three-dimensional integration of the component systems but which would not necessarily imply a single integrated component.

Because this study is part of a continuing research program, pre-cast concrete was accepted as the building material. The advantages of concrete are economy in cost of material (depending somewhat upon repetition in the use of formwork) and the fact that the material is fireproof (thus avoiding many peripheral problems not directly related to systems integration), as well as the fact that the structural elements could be a finished material which could be important if the structure is ultimately to be exposed.

The advantages of pre-cast concrete over cast-in-place concrete are the degree of quality control possible with factory produced elements and elimination of loss of time during the on-site construction process because of curing or steel fabrication. With proper design, costly connection details involving on-site labor can be avoided, and rapid erection, with minimum interference from weather, also reduces labor costs.

Two other goals were established; one the achievement of a uniform structural depth to minimize partitioning problems and to give maximum planning flexibility, and, two, a solutioning involving no scaffolding or temporary construction again in order to cut on-site labor costs and waste of materials and to speed the erection process.

Both the Uniform and National Building Codes were consulted to determine structural and planning requirements.

BUILDING TYPE

Before the building systems research could begin the parameters of the building functions had to be established and the resulting requirements determined. A medical research and teaching facility was chosen because of the combination of heavy mechanical requirements involved and because of the varied planning considerations involved.

The building type is conceived of primarily as providing the laboratory space, teaching facilities, offices and clinical spaces needed by major teaching hospitals and medical research facilities as they grow and as their various departments, services and professional staffs expand. The resulting buildings would be limited in overall size and would rarely, even in an entirely new facility, cover more than one square block. The fact that the floor area - to - perimeter ratio would be greater than in many of the projects completed in the past in this study helped set the direction toward concern with flexibility in setting the perimeter/circulation relationships. In general the ultimate building size indicated that a smaller structural bay might well be possible since bio-medical and research facilities in general do not require large, continuous floor areas.

The functions to be accomodated were classified into three general types:

1. Research Laboratories; graduate and undergraduate instructional labs and medical testing labs as well as pure research labs. These would serve all of the medically oriented sciences such as Biochemistry, Audiology, Biophysics, Physiology, Bacteriology, Genetics, Medicine, Preventative

Medicine, Pathology, Pharmacology and Radiology.

2. General Teaching Facilities; for students in medicine, pre-medicine, nursing and dentistry. This would include teaching of Microbiology, Entomology, Anatomy, Botany, Zoology and Plant and Animal Physiology in addition to the above disciplines.

3. Out-Patient related Teaching and Clinical facilities.

Thus the building system must accomodate the full range of medical activities as well as teaching and research facilities. Because of the time limitations this study was quite brief, but several planning requirements, both in dimension and organizational patterns, and the mechanical requirements were established as a basis for further design.

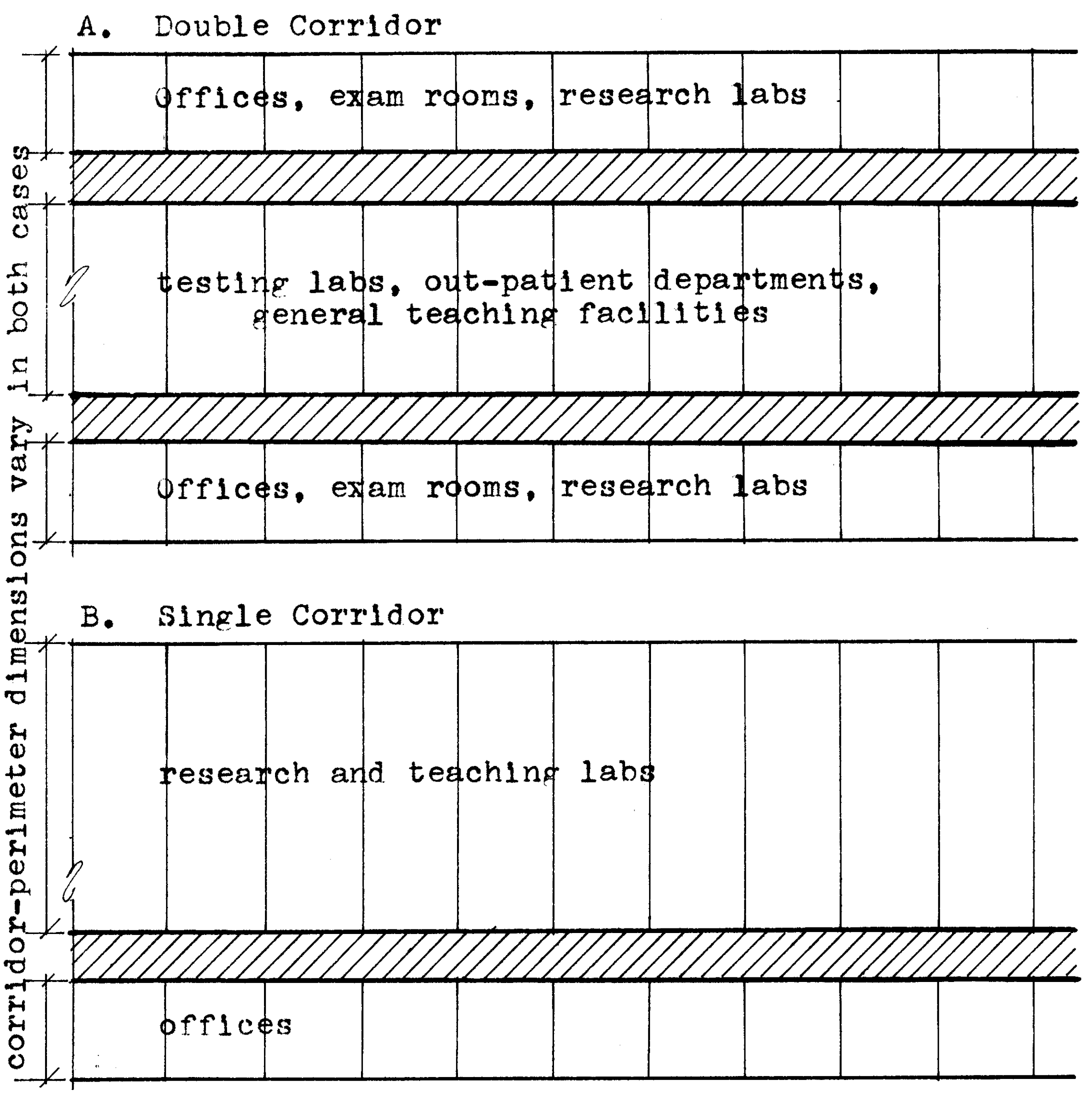
CIRCULATION

Circulation patterns for research/medical buildings generally followed one or two types; a double corridor, with exits, services, storage, and highly used labs and teaching areas between them and general laboratories and offices to the outside (this pattern also occurs in out-patient clinical areas, where the support facilities and testing labs were in the center with examining rooms and private offices on the exterior), and, secondly, a single corridor system with offices on one side and labs on the other. Diagram 1 on the following page shows the principal circulation/assigned space relationships involved.

MODULE

As previously mentioned the scale of the project indicated that a relatively small bay size might be utilized. In general, 10 types of spaces were defined which were used to determine the final

Dia. 1., Circulation/Assigned Space Relationships



planning module and bay size. The larger spaces included, however, would only occassionally be needed, and the incidence of such situations is not such that they should be allowed to establish criteria for the far greater building areas involved in more typical functional requirements. The basic types of spaces are:

1. Non-Technical Instructional Spaces.
   a. Seminar Rooms
   b. Lecture Rooms
   c. Large Lecture Rooms

2. Special Non-Technical Instructional Areas.
   a. Auditorium
   b. Library
   c. Exhibition Areas

3. Technical Instructional Spaces.
   a. Teaching Laboratories
   b. Amphitheaters

4. Laboratory Facilities (Research Oriented).
   a. Private or Semi-Private Labs
   b. Group Research Labs
   c. Testing and Out-Patient Oriented Research Labs.

5. Private Offices.

6. Public Waiting, Reception, Examination and Treatment Facilities.

7. Service, Supply and Equipment and Materials Storage Facilities.

8. Circulation.

9. Maintenance Services.

10. Parking.

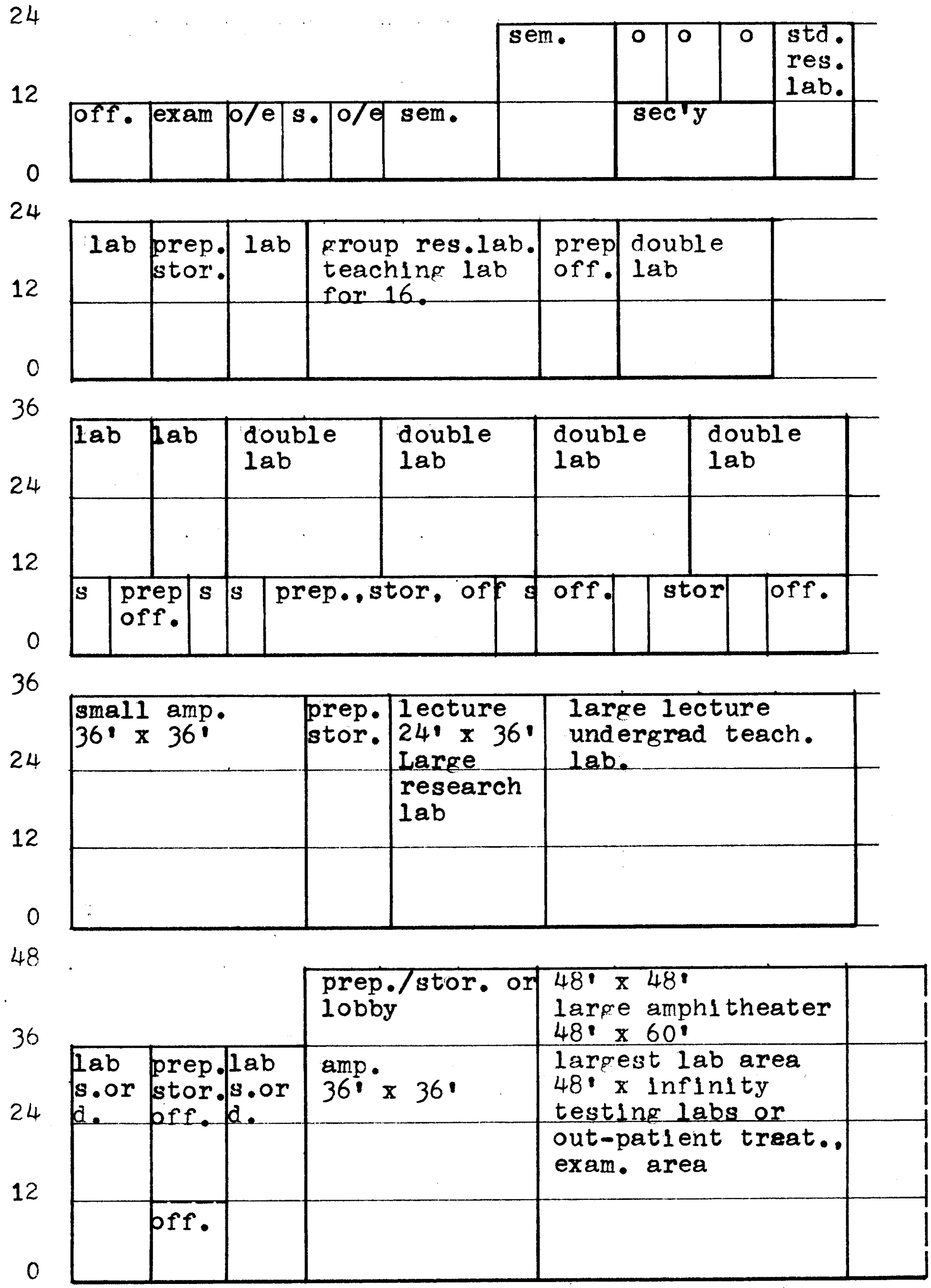
Diagram 2 on the following page indicates the dimensions and planning considerations involved in the most common of these spaces.

On the basis of a brief investigation into these functional requirements, a base module of 12' x 12' (nominal dimensions) was established for the general building area. This was further broken down into a 6' x 6' planning module (with the alternative of 3' x 6').

EXPANSION AND GEOMETRY

In the context of the functions to be solved for and the circulation patterns which relate these functions, the required increment of growth and variation is seen to be quite small.

Dia. 2., Spatial Requirements



The location of the building perimeter with respect to the circulation system was considered the important variable and, once established, this began to set limitations on the overall geometry and structural system.

Based on the wide variety of spatial sizes and organizations (see diagram 2, previous page) the increment of expansion was established at 12'. That is, given a fixed circulation corridor location, the building perimeter could be located 12', 24', 36', 48', 60', 72', etc., from this corridor. The minimum building might be as little as 48' (or even 36') and the need for various logically supported building depths was deemed more important in the selection of the structural system and overall geometry than was the possibility of large uninterrupted areas of column-free space.

The flexibility in determining this corridor-to-perimeter depth is not critical in the sense that one would ever make an addition to a building in this small increment (although that might be possible). In a building of this scale however, this small increment would give planning flexibility in the initial design process.

The planning direction and the direction of the increment of expansion are generally at 90° to each other, thus indicating that a system that can expand easily in two directions is needed. The limiting dimension in both directions is 12': a 12' laboratory module in the direction of the principal circulation and a 12' expansion module perpendicular to this.

CORES

The general circulation systems suggested a linear, modular core system which could run between parallel corridors or be distributed throughout a structure and which could form composites of any size and makeup including only the elements which are required at a given location. This becomes especially important when considering the variety of building forms possible. A core system which separates all of the major elements into singular entities (fire exits, mechanical spaces, toilets, passenger and freight elevators, etc.) could easily adapt to unusual conditions by including only that part of a "complete" core that was necessary. It might, for example, occur that a fire exit or a mechanical shaft would be needed in an area adequately covered by elevators or toilet facilities occuring elsewhere. A system with variables which impose no limitations on the minimum building variation or on specific configurations which might be required for functional or other reasons would be ideal, and for this reason the core elements were finally conceived of as independent modular entities.

The spacing of fire exits was determined by code and became the initial fixed point of reference in establishing the building footprint, which is a combination of the vertical and horizontal circulation systems within the structural grid. The distance from any point in the floor area served by an exit can be in this particular case no more than 100'. All other elements were eventually grouped at these fixed points and sized according to current practice and recommendations. In general the frequency of the major core locations was determined by (1) fire exits, (2) elevator locations, and (3) toilet locations.

Exit size and location for the general building type were determined on the following basis:

One unit of stair width is 22".
Gross area per occupant = 100 s.f.
Number of occupants per unit of exit width = 60.

On the master grid, using the maximum spacing allowed by the 100' restriction, 36,000 s.f./ 100 s.f. per person = 360 occupants.

This divided by 60 occupants per unit of exit width results in 6 units = 11'. If two exits are provided at each point in this grid, the exit width of each would be 5'-6".

It is admitted however that in a final building design even the exit location would be an add-or-delete item since the final configuration may or may not require exits at all points indicated on the hypothetical master grid.

The final core elements are all designed to fit in a 12' x 24' module. The exception is the vertical mechanical module, which always occurs on the end of cores involving vertical circulation to solve the problem of bypassing voids, or in isolation. This module is 6' x 24'. The fragmented core concept permits adequate coverage throughout any building with these basic elements and minor variations:

1. Fire Exit
2. Mechanical Shaft

3. Passenger Elevators

4. Freight Elevator

5. Variation on elevator elements with Janitorial and Telephone space.

6. Single Module Mens Toilet : 2 WC, 3 Ur and 2 LAV

7. Single Module Womens Toilet: 3 WC, 2 LAV

8. Double Toilet Modules

Photograph 5 illustrates the final core elements.

It is obvious that any additional elements needed can be added within this system depending only on the relationship between the core grouping and circulation.

For purposes of the building footprint and the outline variations indicated, three typical core layouts are also indicated in Photograph 5.
The two linear cores, when utilized in the typical core/circulation diagram (photograph 2), satisfy all requirements for the various functions as specified

by code or indicated in current recommendation and practice.

STRUCTURE

The structural system ultimately had to solve two basic problems:

1. To provide for the previously determined 12' increment of expansion, and
2. To provide a uniform ceiling height for easy partitioning (and adequate acoustic seal).

It was soon determined that a 2-way system would best meet these requirements. Not only did this provide a way to change the circulation and mechanical distribution directions within a building without changing construction, but it allows for the greatest planning flexibility in both directions.

For purposes of economy in erection and to avoid the problems of scaffolding usually associated with 2-way pre-cast systems, the search was directed toward systems which were one-way in erection procedure (and thus probably involvine one-way structural elements). Simplicity of erection, the economy of one-way construction, along with the need for expansion in 12' increments, became additional objectives in the design of the structural system.

The design load was accepted as 100 psf maximum, and it was intended that through variable depth in the floor deck and with steel placement and techniques a system could, without drastic overstructuring, be designed within basic limits to carry from 40 psf (classrooms) to 100 psf (corridors, public rooms). This might result in savings in areas where the functional uses would remain constant.

A 7 story limit on building height was established as being typical in buildings of this type.

Several geometries and systems were investigated primarily with the goal of attaining the expansion increment desired.
As expected the one-way systems were unsuitable because the needed increment of expansion for determining the building perimeter is at 90° to the primary planning module direction and at 90° to the mechanical zoning direction. (This is evident in diagram 2).

A 2-way structural system permits every other system, including the pattern of mechanical distribution, to change direction without structural interferance and also provides greater partitioning flexability.

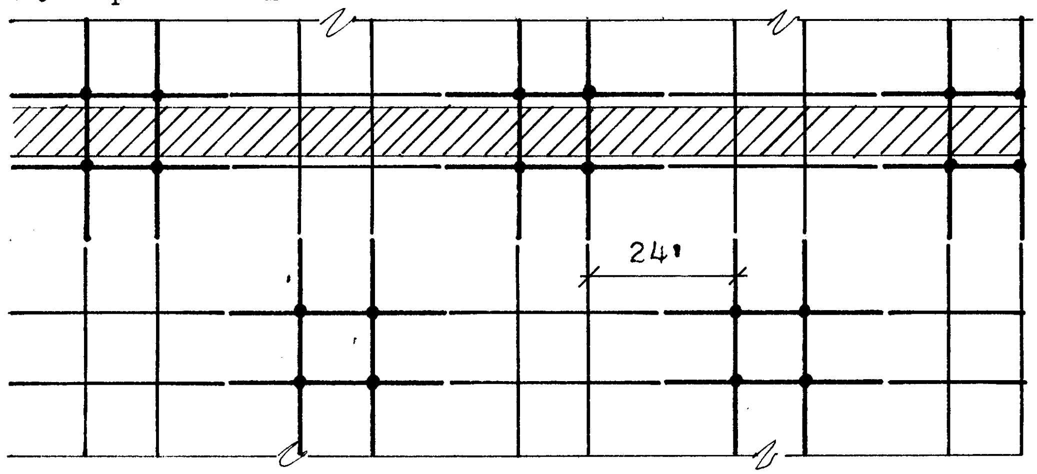
After several systems were investigated, the staggered column geometry with columns at the mid-point of a square structural bay seemed to offer the best resolution of all goals and objectives, being particularily suited to achieving great flexability in determining the "cut-off" point on the building perimeter. This geometry was previously investigated by Michael Gelick in the 1966 research program.

Several bay sizes and structural configurations were examined (see diagram 3 on the following page).

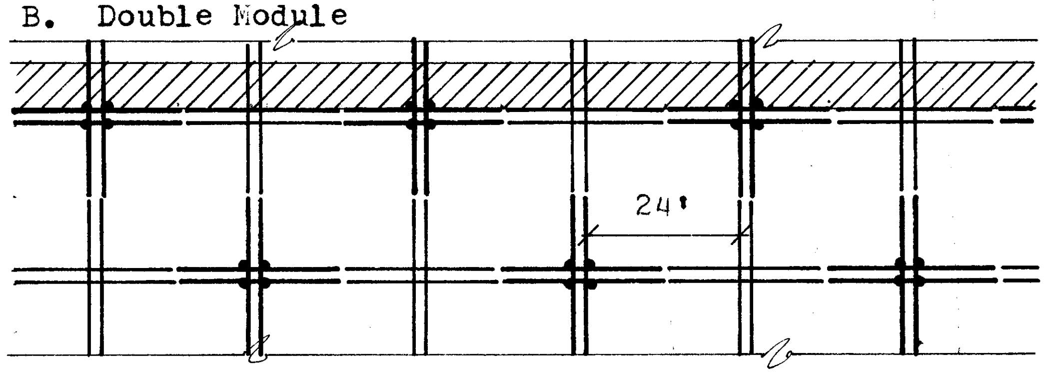
A. was at first examined because the maximum column-free spaces were quite large (60' x 60'), because there would be no problems in parking, and because this bay size would accomodate even the largest programmed function. The primary mechanical distribution was directed along the 12' wide modules created by the spread columns. This system was found unacceptable because of the column placement, which consisted of 4 columns in a 12' x 12' square (related to both vertical and horizontal mechanical distribution), and because of the creation of the resulting special module which limited planning flexibility. In particular the circulation patterns were severely limited and very rigid. There were in addition structural problems in achieving certain

Dia. 3., Development of Structural Bay

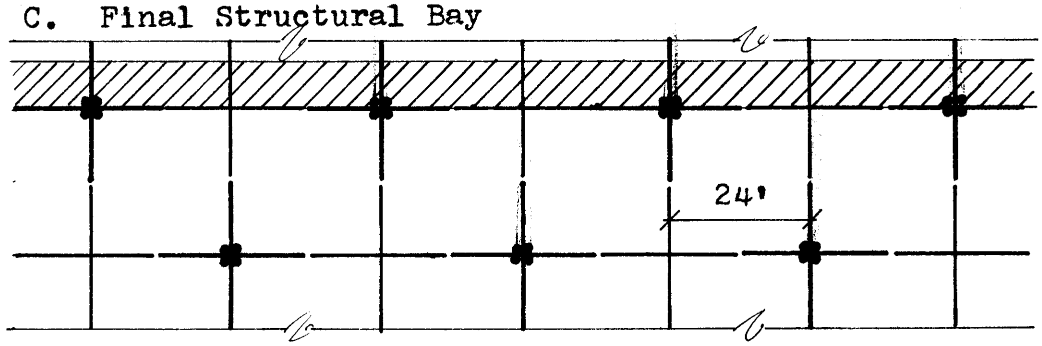
A. Spread Column



B. Double Module



C. Final Structural Bay

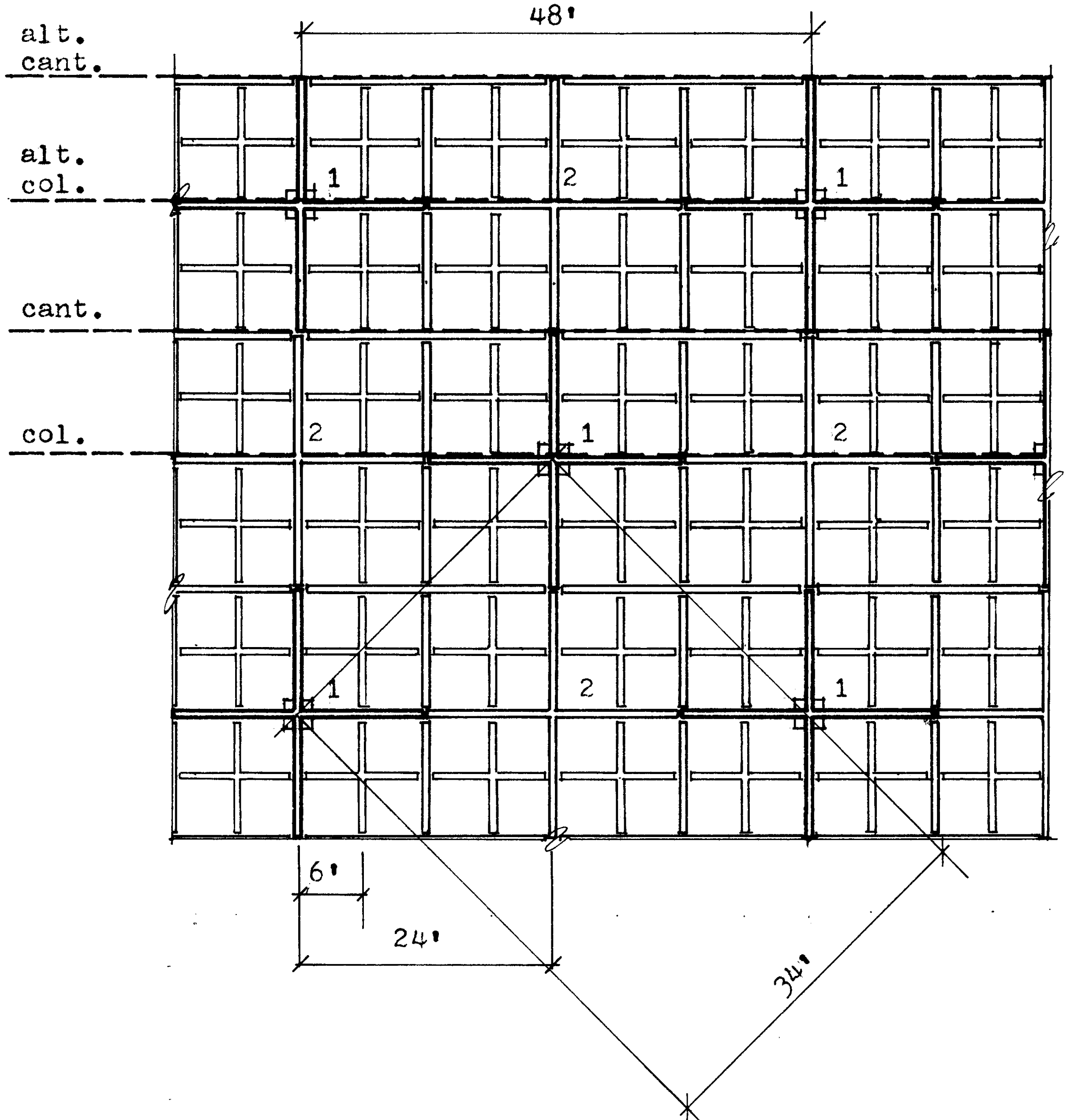


corner conditions because of the large cantilevers, and with some edge conditions the second row of columns would fall 12' behind the building perimeter and would interfere with planning.

B., a double module, was also investigated. This had the advantage of providing a location between the double primary girders for any post-tensioning that would be needed for minor members and it provided a specific module for both mechanical cores and major horizontal mechanical runs, but it presented difficulties in continuous planning with a 1-2-2-1-2-2-1 modular progression and for this reason was abandoned. The double module presented problems in core planning as well. If the cores were to be made up of modular elements the smaller structural module, occuring regularily, would break this progression with an essentially unusable space.

The final solution, C., utilizes a single cantilevered girder from columns occuring at the mid-points of a 48' x 48' structural bay (see diagram 4 on the following page).

Dia., 4. Structural System



1. Column with cantilevered capital girder elements
2. Suspended girder elements

The column spacing on a rectangular grid, at 45° to the planning and structural grids, is thus 34' o.c. in each direction. The system supports the required building depths either at the column line or 12' beyond the column line on the cantilevered arms from alternate columns. (See diagram 4). Spaces larger than 48' x 48' would be realized with a separate structural system, although the system developed can provide a void to any 6' increment in either direction for these functions to occupy. Column-free spaces of 24' x infinity are possible on the planning grid in either direction. This bay size and geometry permitted all planning and expansion increments to occur without special conditions.

The basic module created by primary structure is 24' x 24', and all major members forming this are post-tensioned to overcome special edge conditions and to provide for general structural continuity.

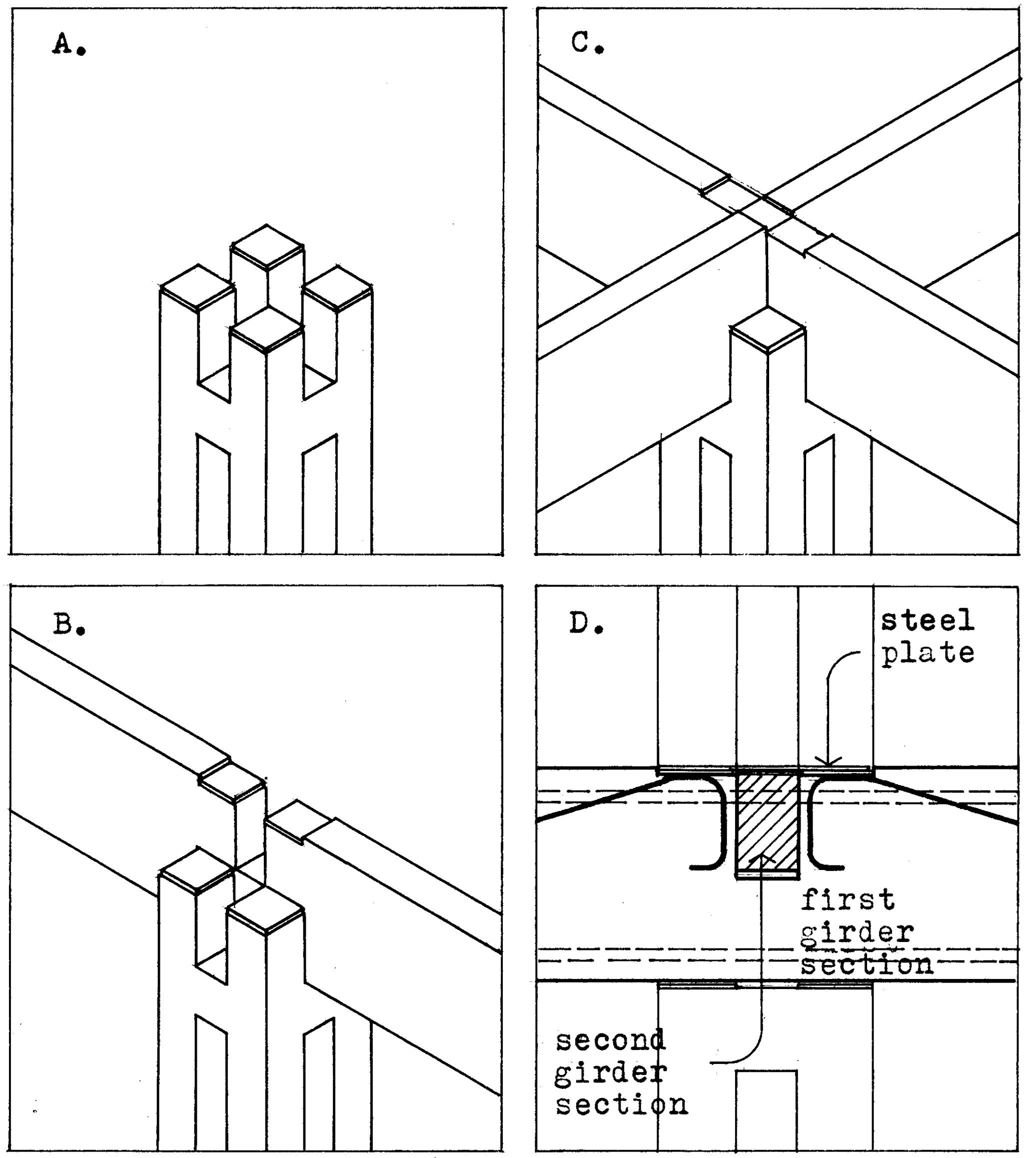
CONSTRUCTION SEQUENCE

The basic element conceptually consists of a column with 2 one-way girders placed on it at right angles to each other to form a column capital with cantilevered arms of 12' (see photograph 10).

After the column is placed (diagram 5-a on the following page) the first cross-piece is placed and welded (5-b). The second cross-piece is then placed and the tension reinforcing steel in the first element is connected by welding a plate over the second element (5-c and d). The space between the four cantilevered arms of a typical bay is spanned by elements which are the inverse of the column-capital elements thus completing the 24' primary structural grid. The entire erection procedure is seen in photograph 8, keyed as follows:

a.	f.
b.	g.
c.	h.
d.	i.
e.	j.

Dia. 5. Column Capital Sequence



After the suspended sections of the primary structure are placed and welded (photograph 8-e and f), the post-tensioning cables are threaded and the system is grouted and post-tensioned.

The longer of the secondary beams are then placed on the flanges of the primary girders (photograph 8-g) and welded to special plates on the girders. The shorter (6') secondary beams are then placed and welded to complete the structure to a 12' x 12' grid (photograph 8-h).

The final spanning elements are two-way precast cross-shaped pieces which are lowered to rest on the flanges of the primary girders and secondary beams and are welded to the plates prepared for them.

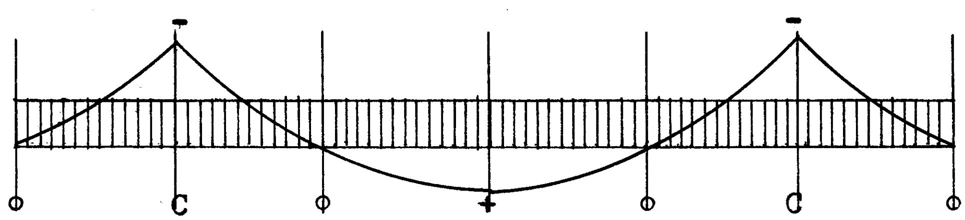
Finally the pre-cast floor slabs, either 6' x 6' or 12' x 12' are placed (photograph 8-j) and a 2"-3" topping is poured which ties the pre-cast slabs together and levels the completed system (see sections on photograph 6). From this point the mechanical elements can be installed and the lighting fixtures, air diffusers and ceiling panels laid in place.

The columns are designed so that either an 8' or 12' ceiling height may be obtained simply by providing stops in the formwork in the proper place during casting. The fact that the column is independent in terms of construction of the horizontal spanning members makes it possible to create voids by discontinuing the horizontal span with no interference or special conditions in the vertical structuring. Vertical continuity is achieved through simple welded connections around metal plates at either end of each column.

All members have openings to permit mechanical distribution and all members are designed with a lower flange to help effect the sealed plenum of the mechanical system and to serve as support for each consecutive element during the construction process. The uniform lower chord provides a structural plane for partitioning (to obtain stability) and acoustical isolation without having to fill odd-shaped holes in the structural members.

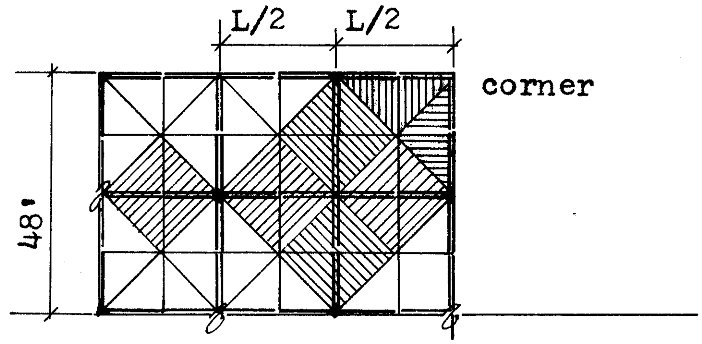
The basic objective of a 2-way structural system with the ease of one-way construction was achieved with this construction technique and through proper detailing of the structural elements.

The structural design was based on the following general moment condition:



A negative moment occurs over the columns and the maximum positive moment at mid-span.

The negative moment at the extreme corner condition was found to be less than the moment at midspan in a normal bay.



At the corner condition L = L/2. Thus:

$$M_{(neg)} = \frac{\frac{P}{2}\,\frac{L}{2}^{2}}{2} = \frac{PL^2}{16}$$

, whereas at mid-span:

$$M_{(neg)} = \frac{PL^2}{12}.$$

Structural design was based on the preceding information and with the general guidance of Prof. Waclaw Zalewski. It was found that the 6' section nearest the column in the primary girder could be left solid for shear resistance with no problems in mechanical distribution.

MECHANICAL

The principle of dual-duct air supply was accepted because of its great flexibility in handling various extreme conditions found in laboratory spaces. This would serve all central areas, and a 4-pipe induction system with convectors would be incorporated for control along the periphery of the building.

2 CFM was accepted as the criteria for air supply volume primarily to provide make-up air for fume hoods and to accomodate the generally heavy demands of this building type. Both Hot and Cold supply ducts were required as well as a general return system and a direct exhaust system.

The concern with mechanical services is limited to the distribution system. General central air-handling equipment was considered outside the scope of the present problem.

In terms of mechanical systems development the first basic decision to be made was whether vertical air handling should be done in the column or at a core location. Given the small spans of the structural system and the relatively shallow structural depth, a column supply system, involving smaller ducts, seemed to be the most obvious solution. In spite of the advantages of column supply in terms of uniform coverage, two factors led to the final selection of core handling. In the first place, in the geometry of the structural bay the columns are in positions where they could interfere with planning flexibility. In some cases complex inter-departmental functions might, in an out-patient testing/treatment area for example, have to be planned around a column location. In a seven story building the column dimension, because of the complexity of the mechanical system and for structural reasons, becomes considerable with column supply and it was desireable to minimize this dimension in order to minimize planning interference.

One problem in the mechanical system involved the relationship of the mechanical space, particularily the space for the major horizontal mechanical runs, to the areas served by it and to circulation. Diagram 6 on the following page shows the various possibilities considered with "D" the final choice.

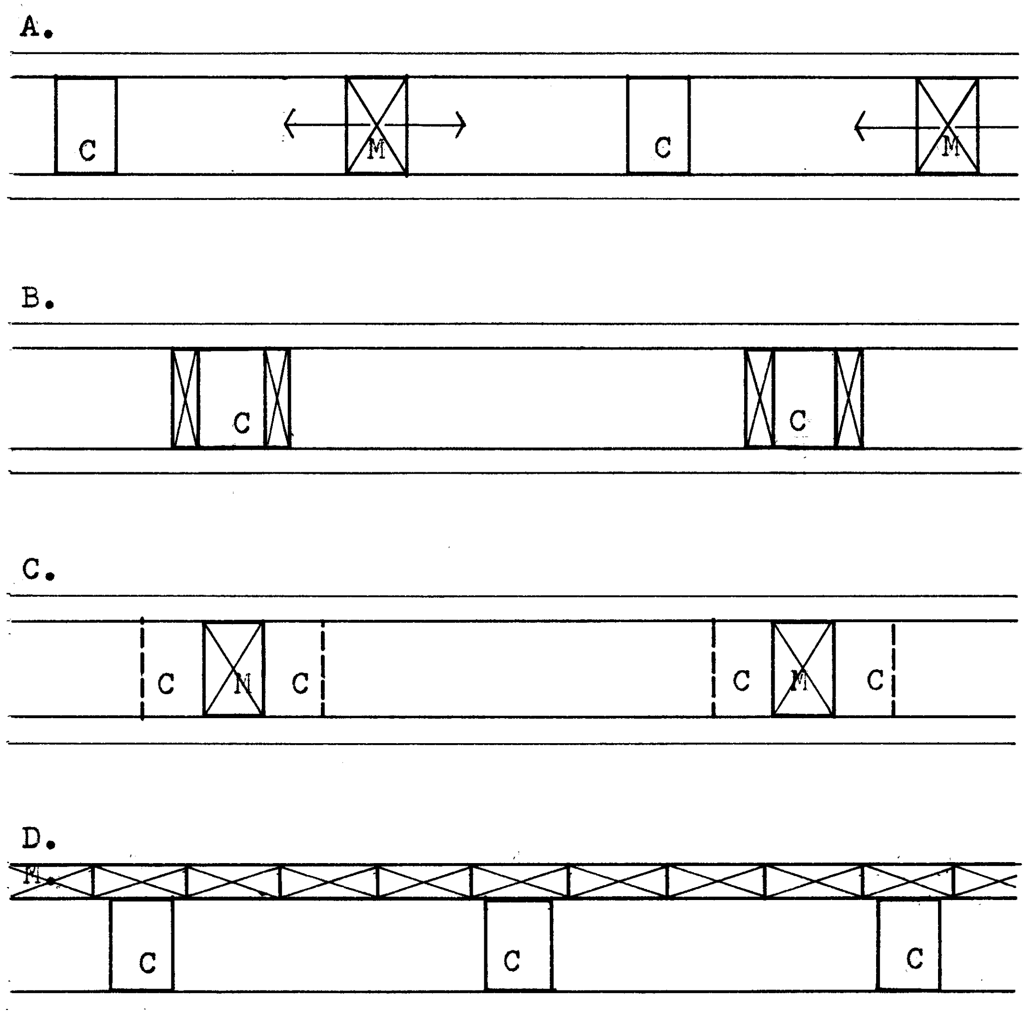
"A" provided excellent accessability to the labs from the mechanical space and could easily provide adequate space for equipment and servicing, but it creates difficulties in planning since no space on the building perimeter can have both natural light and mechanical services.

"B" is a common solution, but it fixes the corridor location permanantly.

"C" is somewhat more flexible in terms of corridor location, but it results in potential separation of the mechanical space from the spaces requiring mechanical services.

"D" gives complete planning freedom because of

Dia. 6, Location of Mechanical Space



vertical separation of the mechanical and planning aspects of the building. The problem within this alternative was to design the complex mechanical system so that it would not require more floor depth than was needed structurally for the spans involved.

The major difficulty encountered in core handling, that of finding sufficient structural depth for the large return ducts and for complex duct overlays, was solved by use of a plenum sealed at the bottom chord of the structure (seen in the sections in photograph 6) and a negative-pressure general return through this plenum to nodes at the cores. Some reduction in the requirements of the return system could be made because of the wide continuous use of the high-speed exhaust in this building type.

Specific areas can be sealed off to omit them from the general return system in cases where dangerous materials might leak into the return system and be recirculated. The various return areas, related to specific pick-up cores, would be sealed in any event to maintain equal pressure within the return system. The sealed plenum becomes in a sense the integrated component of this system.

The high-speed exhaust ducts take the place normally occupied by the general return ducts in the alternating system of S-R-S-R needed to adequately service any given space.

The final solution to the vertical mechanical handling was to use a 6' x 24' mechanical core element that would contain all vertical air ducts as well as vertical piping and electrical conduits.

It was logical from a servicing point of view and in order to achieve the zoning patterns required to run the primary air-distribution and return ducts parallel to the circulation corridors. The basic circulation diagrams indicated that major mechanical runs might follow the central service strip where it existed to the core elements where vertical piping and ducts could be collected centrally on the mechanical floor (probably the basement). The general distribution pattern indicates (in photograph 5) zoning in 12' strips perpendicular to the direction of internal circulation. It can be seen that with this system any 6' x 6' area could theoretically be provided with supply air, general return, and direct exhaust (photograph 5). The maximum area of a single zone (beyond the mixing box) is 576 s.f. (12' x 48'), and the maximum area served by a single mechanical core element is 6812 s.f. (144' x 48') (half of which is served from each side of the girder dividing the core).

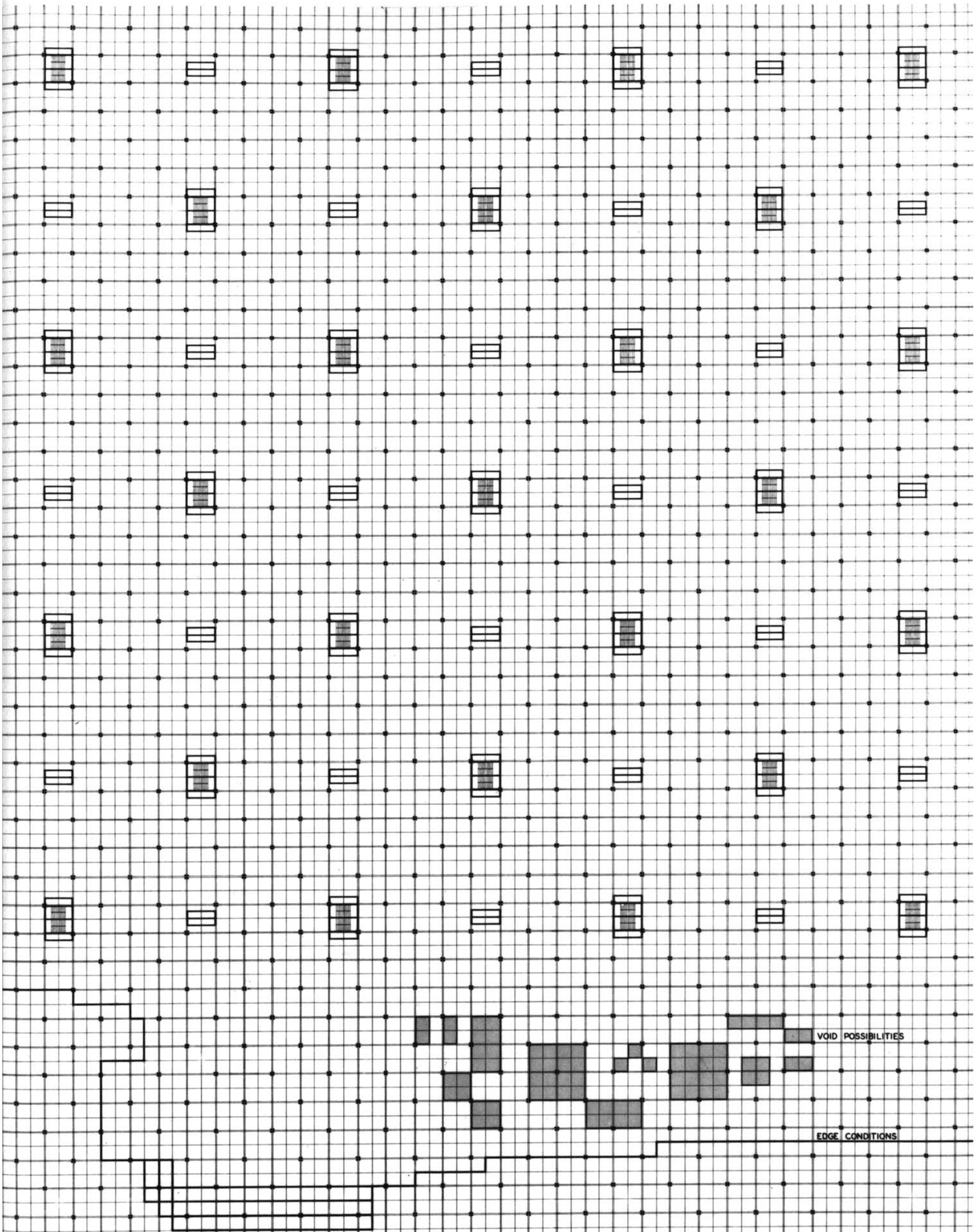
The vertical supply is at 4000 f.p.m.
The primary horizontal ducts for supply, from the vertical ducts to the mixing boxes, is 2500 f.p.m.
The secondary ducts, between the mixing boxes and diffusers are at 700 f.p.m.

SUMMARY

The advantages of the system are that it provides an extremely flexible structural system that can determine the location of the building perimeter in 12' increments even though the structural bay is 48' x 48'. This had been established in the program as the primary objective. The mechanical system provides the complicated services necessary within the very limited structural depth.

The construction technique requires no scaffolding, using for the most part one-way elements and construction to achieve a 2-way structural system.

The disadvantages are that the column locations exclude the possibility of a column-free space greater than 24' x infinity. Although this did not affect the programmed spaces and circulation systems it could be detremental to unforseen planning requirements. The largest unobstructed single space is 48' x 48'.



UILDING FOOTPRINT

10 20 30 40 50 100 200

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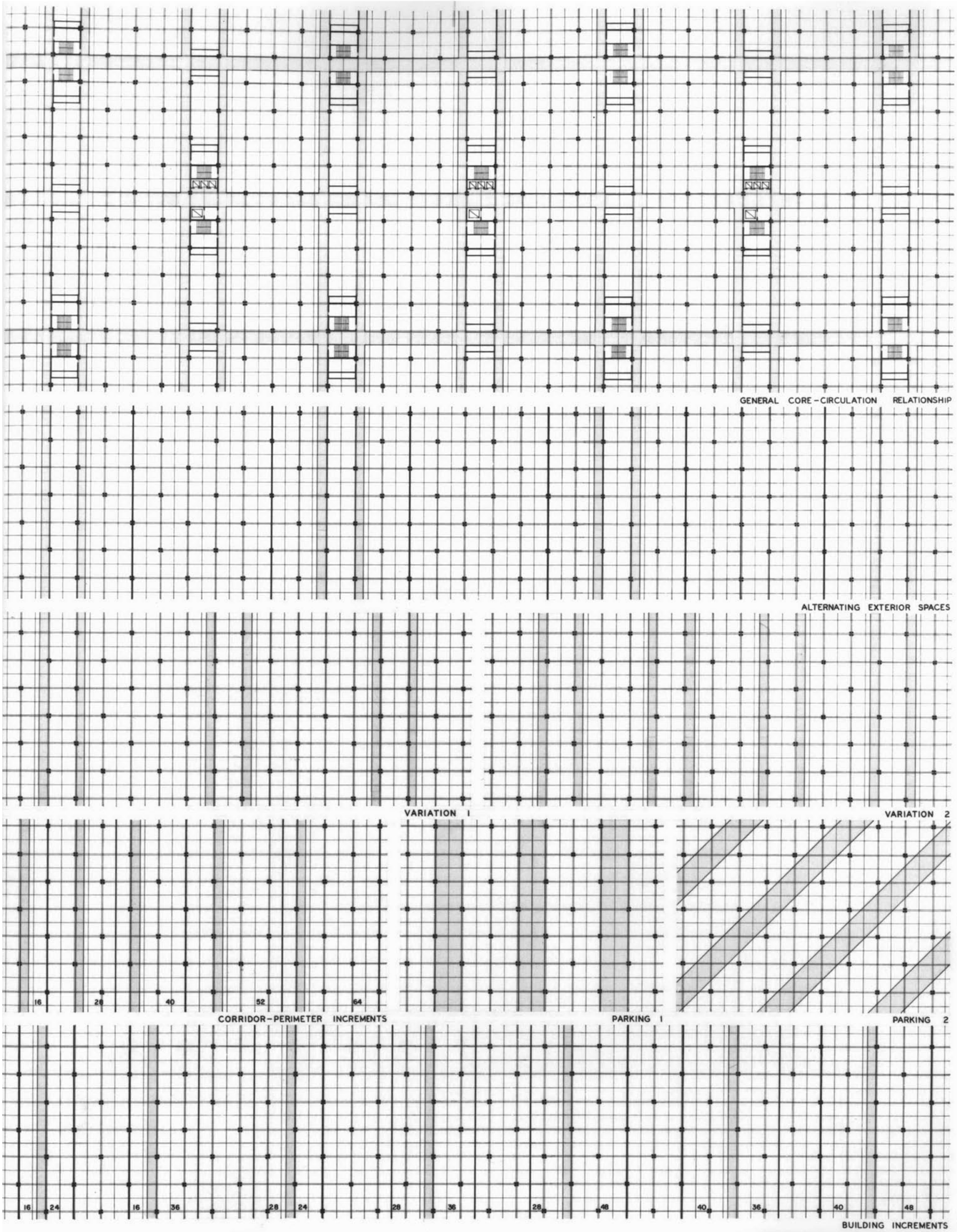
KRIS EGGEN FALL 1967



PLANNING VARIATIONS

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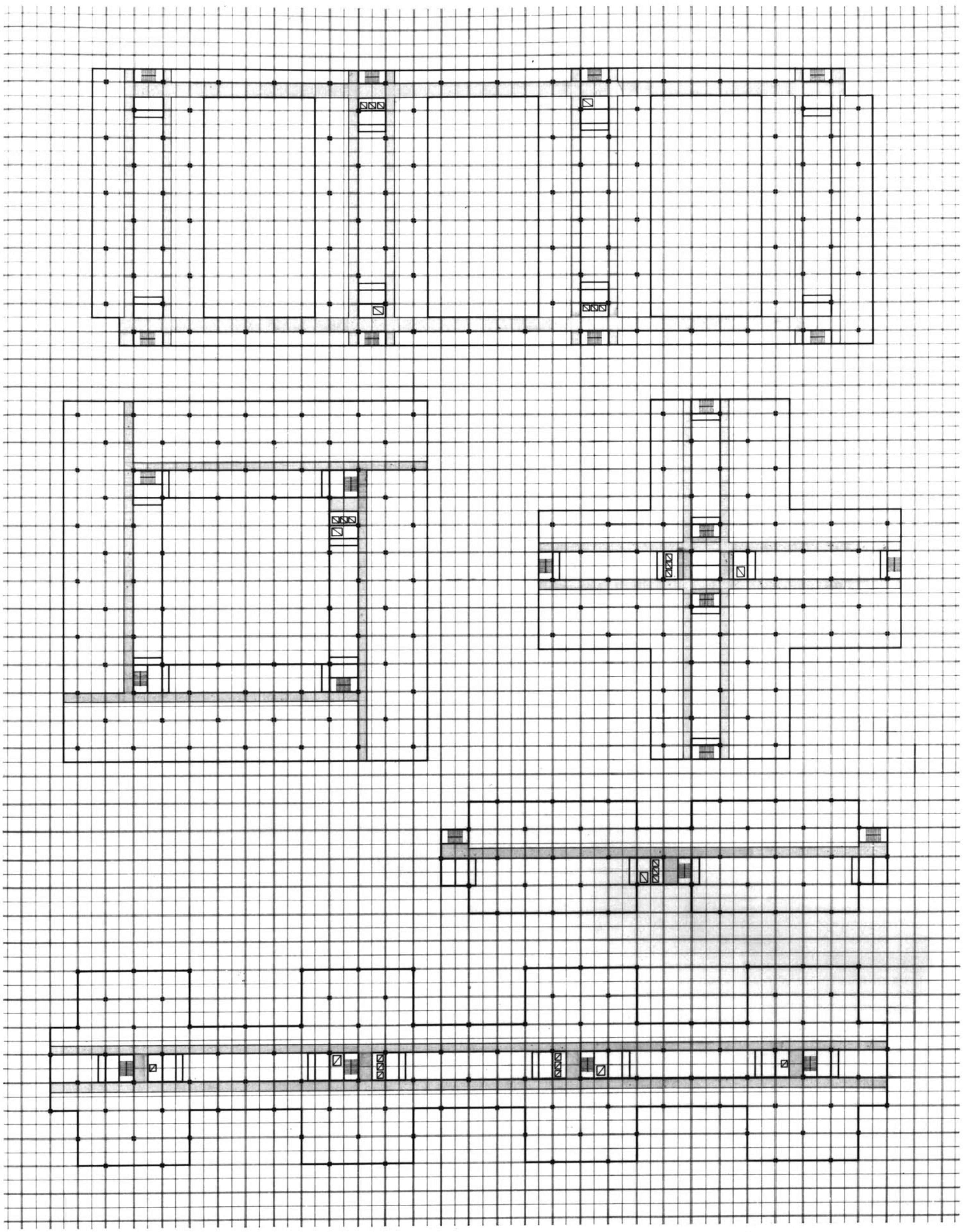

BUILDING VARIATIONS

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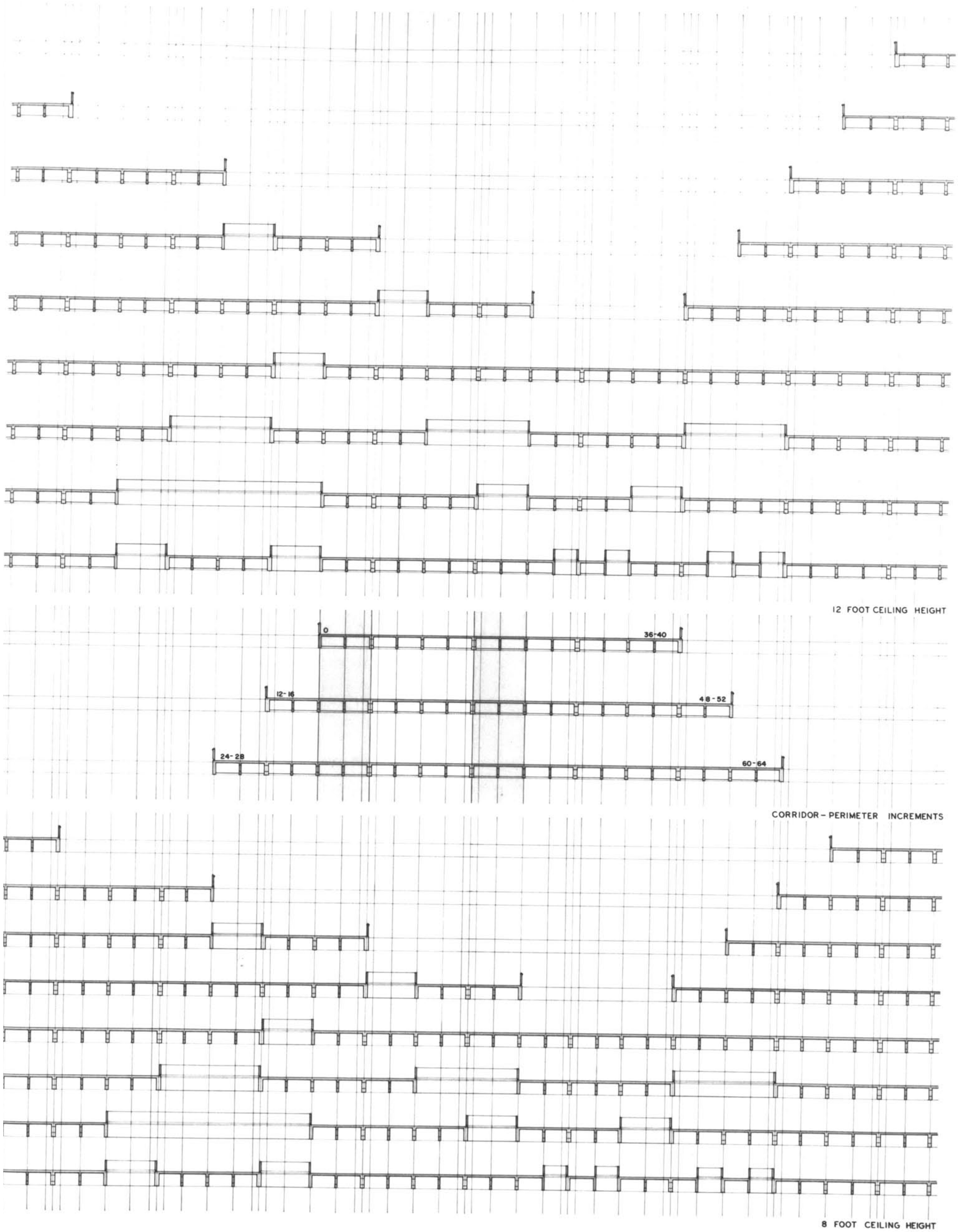

ECTION VARIATIONS

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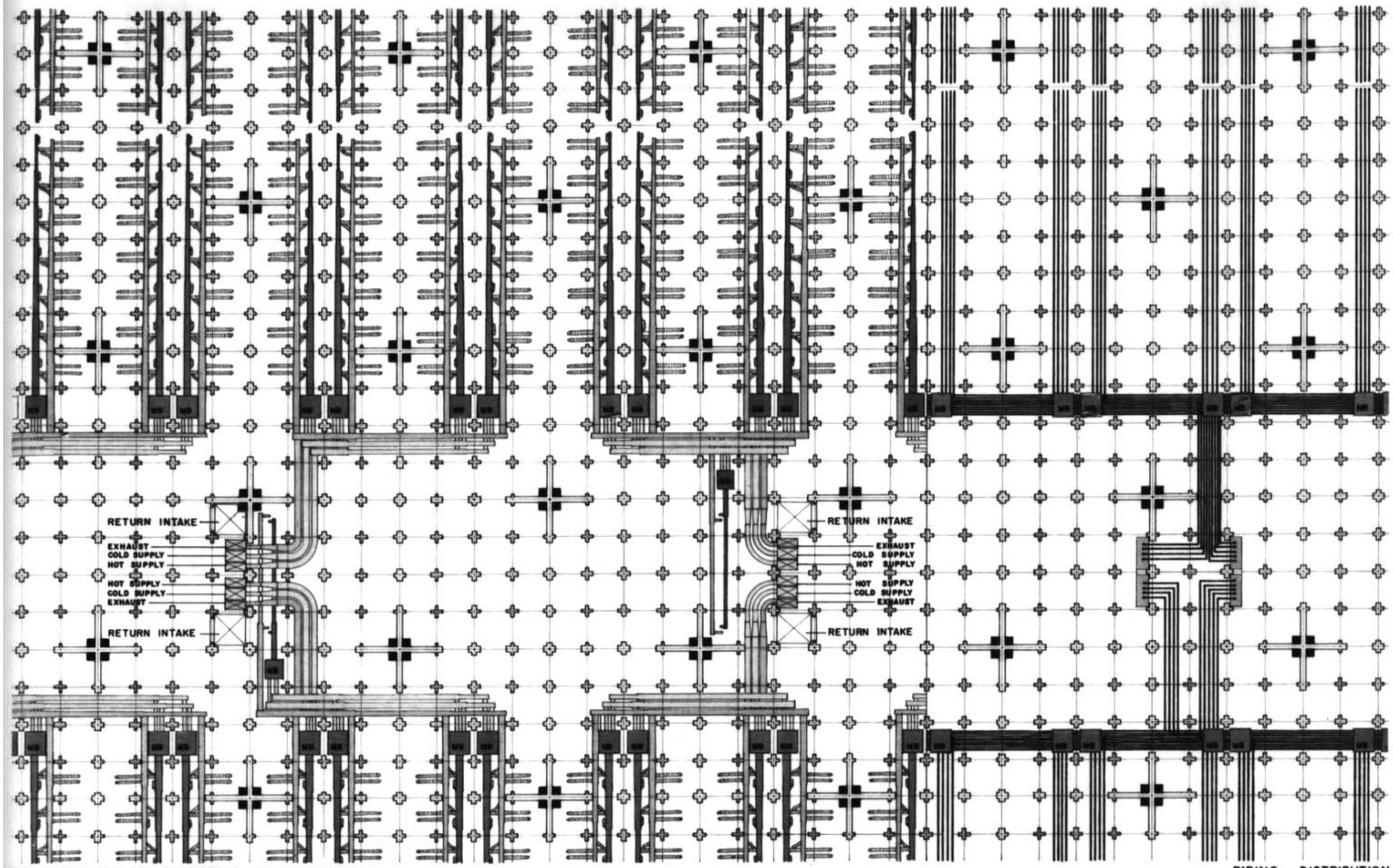
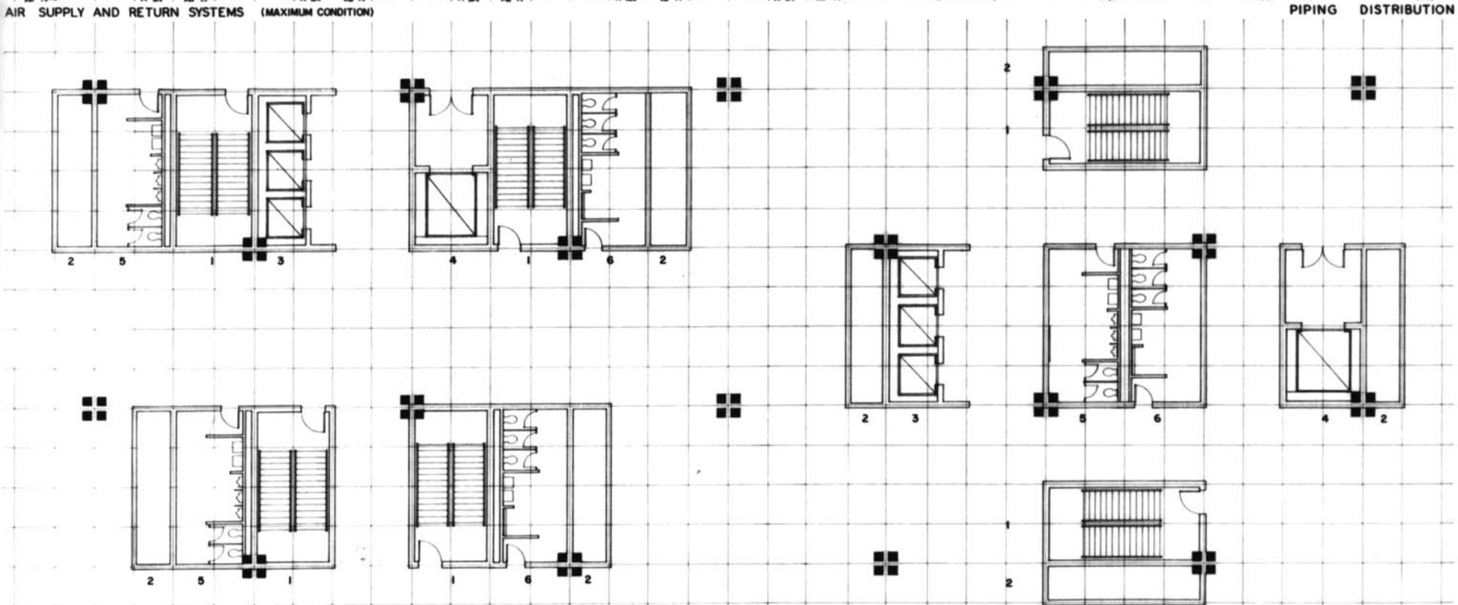
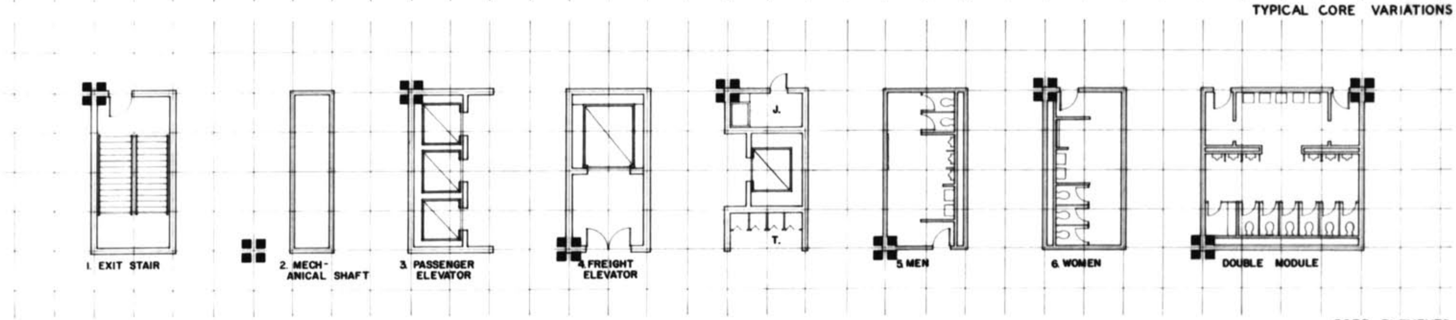


AIR SUPPLY AND RETURN SYSTEMS (MAXIMUM CONDITION)

PIPING DISTRIBUTION



TYPICAL CORE VARIATIONS



CORE ELEMENTS

MECHANICAL DISTRIBUTION / CORE ELEMENTS

0 5 10 15 20 50

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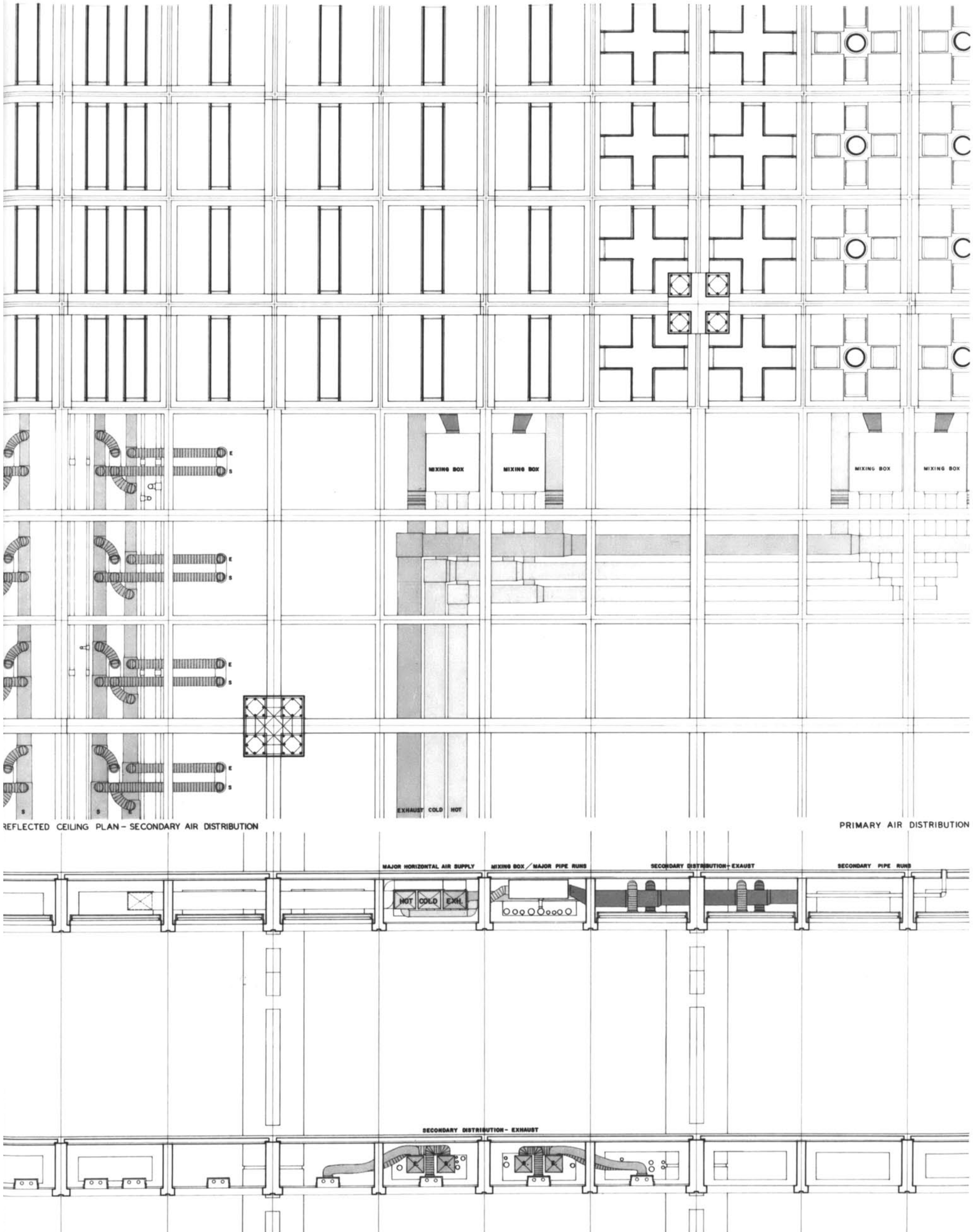

REFLECTED CEILING PLAN- SECONDARY AIR DISTRIBUTION

PRIMARY AIR DISTRIBUTION

SECTIONS

SYSTEMS INTEGRATION

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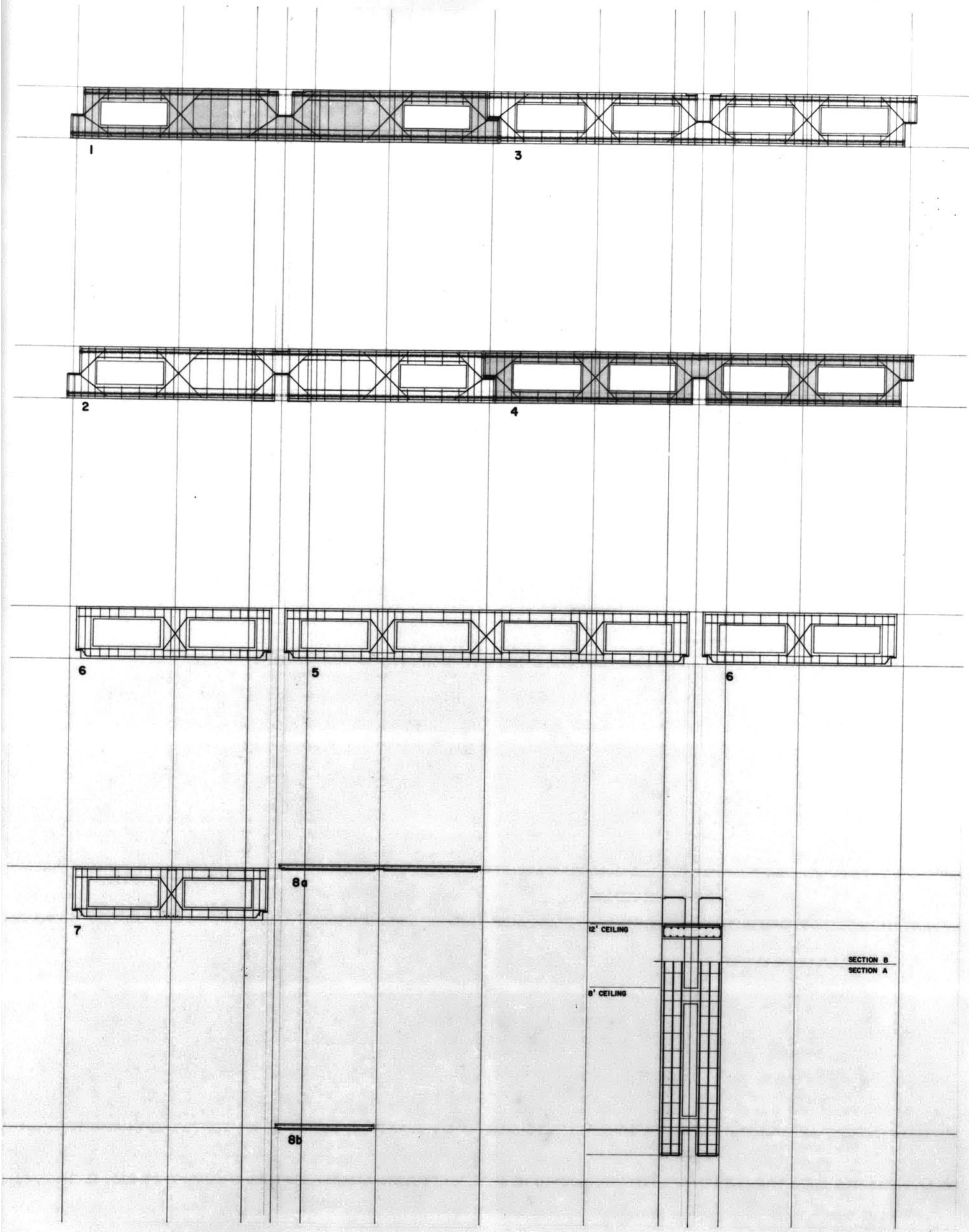

STRUCTURAL ELEMENTS

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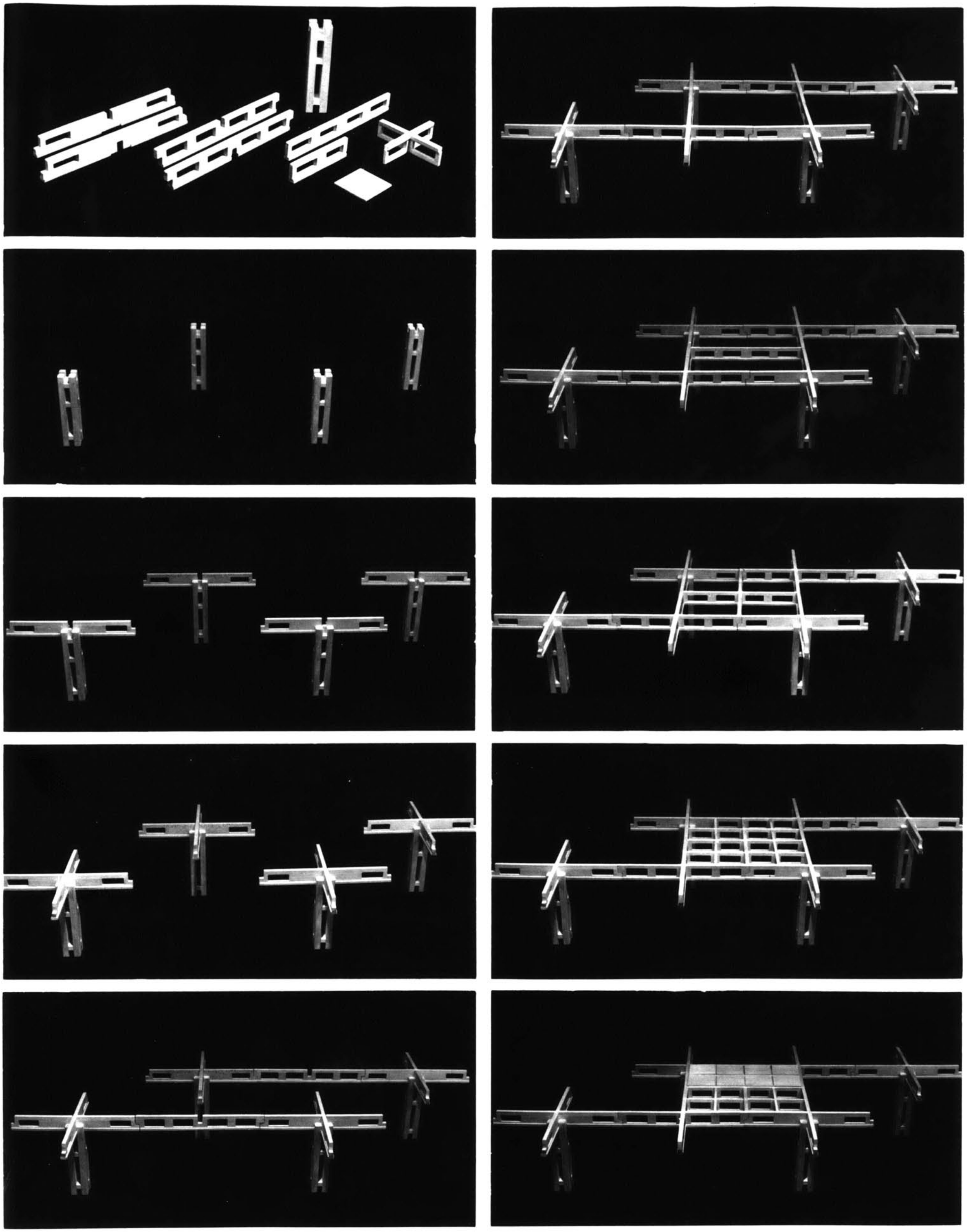

CONSTRUCTION SEQUENCE

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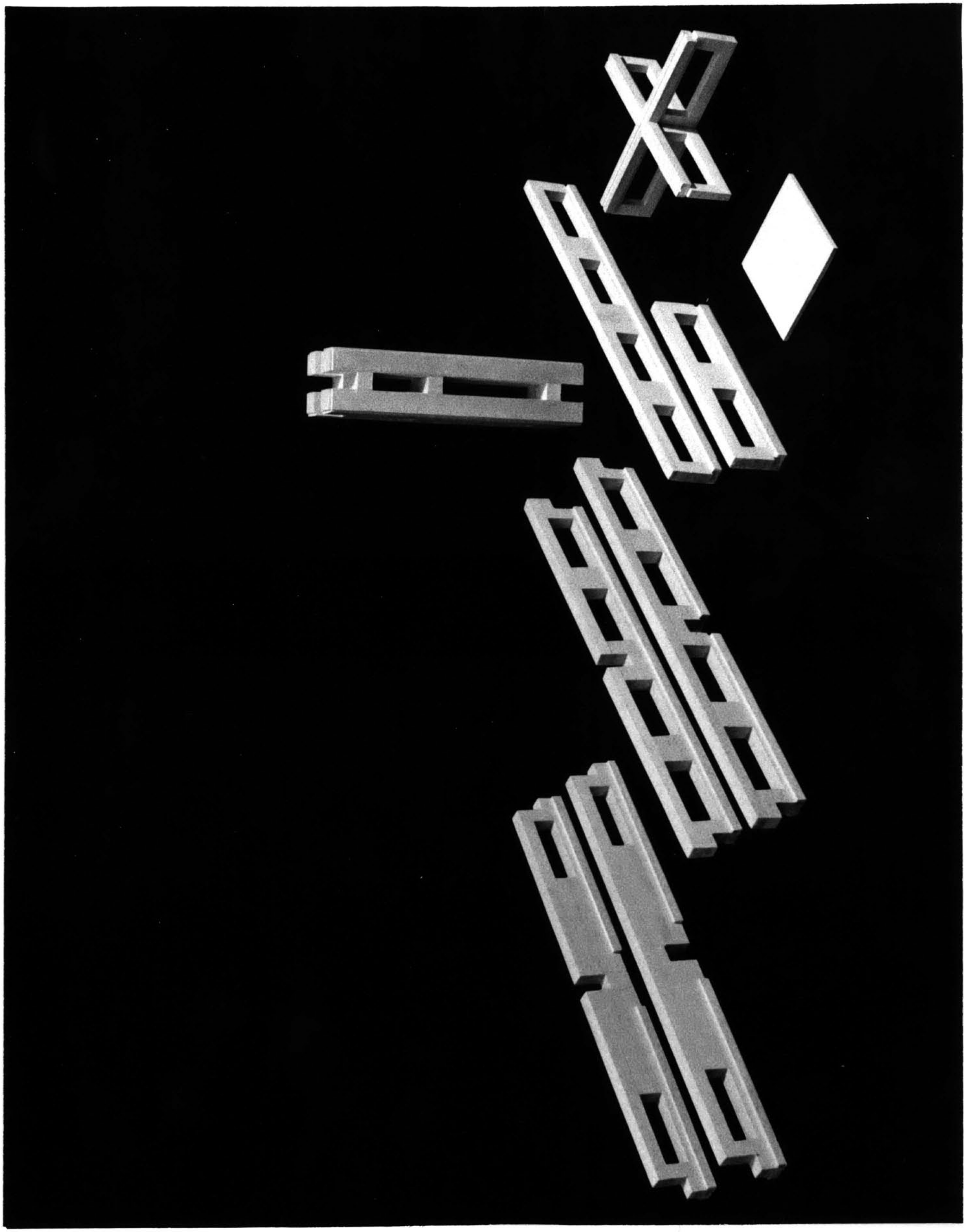
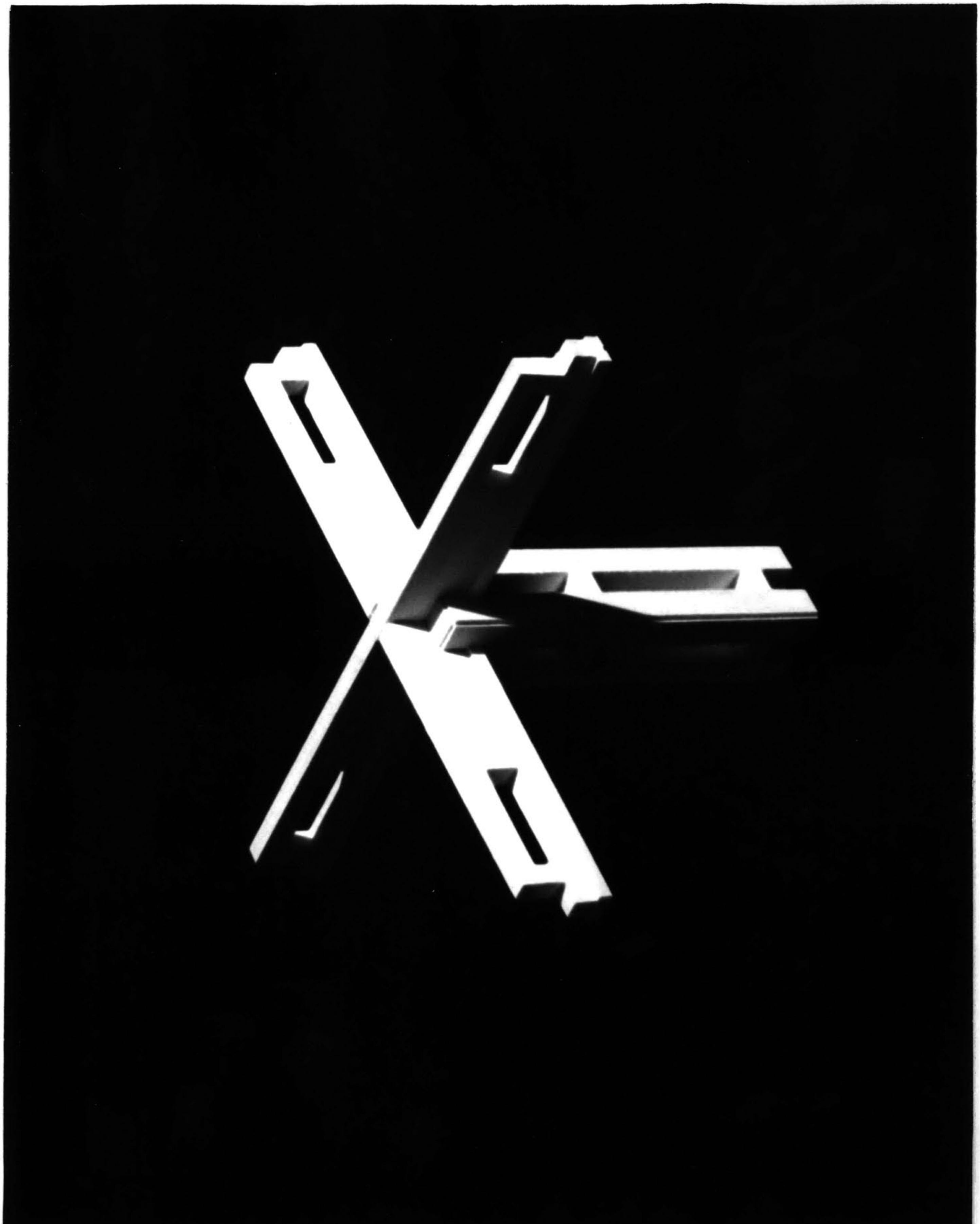


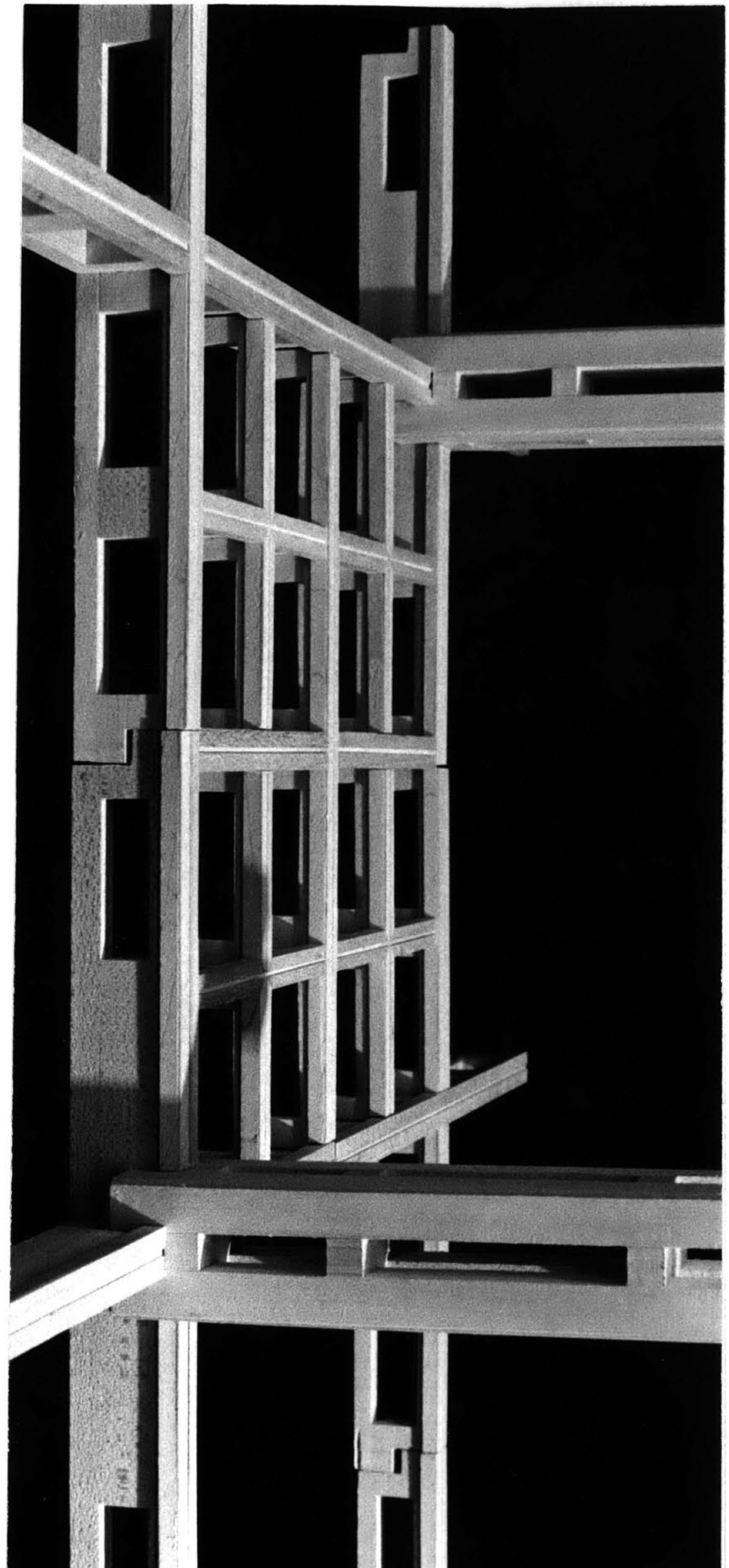
Photograph 9



Photograph 10

Photograph 11

Photograph 12



Photograph 13