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A Case Study in Light Industrial Buildings

Michael L. Norton

A CASE STUDY IN LIGHT INDUSTRIAL BUILDINGS - NORTON

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By

Michael L. Norton

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CHAPTER I

ANALYSIS AND SYNTHESIS

Introduction

The title of this thesis is "A Case Study in Light Industrial Buildings." After research in this area I am more convinced than ever that such a study is needed. The single building that represents most of today's monuments is no longer solving the problem that arises in a complex society. We as architects are no longer as naive to think that form alone can solve the challenges of the 21st century. A philosopher a few years ago said we were in an era of analysis and that the next era would be that of suspended judgement. These qualities of analysis and synthesis have been employed by architects for some time, but usually by a single person acting alone and acting on a single isolated building. It worked then; it does not work now. No longer can design be limited to one individual's intuition and experience. What is needed is a closer look at the organization or structure inherent in types of buildings and complexes of buildings. This structure in context with goals, constraints, and trends should evolve into an architecture that is not only unique but that solves the problems.

This particular case study deals only with a small part of architecture, that of Light Manufacturing Industrial Buildings. My intent is to provide guide lines for architects as well as management in determining basic organization in plant layout and a methodology within which a more detailed

study can be made. This case study is in no way complete or the end answer to all problems that may arise. I have focused on industrial buildings because in an expanding economy where change is predominant, the building type is a function of this change and, secondly, because of a strong tie to a much-needed "American Architecture." I have also tried to concern myself with those things that influence an architectural solution, namely functional, spacial, and physical systems.

Goals

"As every businessman knows, the decision to build a new factory or modernize an old one is no longer the prerogative of one man. Nowadays, the entire management team must buckle down to a lengthy study of markets, raw materials, transportation, and machinery. All of the team's decisions are weighted against one predominant goal."[1] "The typical industrial project is a plant for the efficient production of finished or partly finished goods."[2]

Classification

Industrial Buildings are grouped into three types. These plant classifications are according to character of products manufactured.

Light Manufacturing:	Textiles Paper Books Glass products Pottery

	Metalware Canning Food processing Bakery goods Garments Shoes Furniture Boxes and containers Pharmaceuticals Electronic equipment Hardware Tools, etc.
Heavy Manufacturing:	Automobiles Aluminum Aircraft Building equipment and components Railway engines and cars Machinery of all types, etc.
Noxious Manufacturing:	Chemicals Petroleum products Steel, etc.[3]

In terms of architecture, the three previously stated break-downs can be classificated as: buildings as machines and buildings as space providers. Most of the heavy manufacturing and noxious manufacturing falls into "buildings as machines" and are therefore not suited for a case study of this sort. A building as a machine basically means a shelter from the elements as applied to a certain machine/or machines and conforms directly to that machine, the body of a car or the storage of grain in an elevator, or a similar example. In industry the most familiar example is that of petroleum products.

Opposite to that of machine housing is space providing. Light industry falls into this classification as a variety of functions happen including the right proportion of both men and machines. As this category fits a great variety of different manufacturing processes, it is well suited for a case study.

Automation

Automation, in the past few years, has been an important issue, with its impact on architecture. Some forecast total automation. If this were so it would take the industrial building out of the architectural field and into an engineering problem as it would eliminate the human factor--the factor that now separates the two fields. The concept of buildings as machines isn't something new as for years many industrial types have been enclosing machines in containers conforming to the machine process, i.e., petroleum plants in which all but a few offices have been left "to stand out in the rain."

Arthur Brown of A. D. Little, Inc., maintains that if automation were to reach its logical conclusion, a building to protect the occupants might not be necessary. A machine/or machines would house themselves and maintenance workers would then carry along their own plastic skins, just as they can carry along their own lights, as factories would have no need for permanent lighting.[4]

Despite some science fiction forecasting, it appears that automation is simply another tool in production line methods and that the total machine is still some time off. Today, as one author, James Bright, notes, "automation means doing things notably more automatically than customary; this turns out to mean radically differing stages of advancement among different automating industries and even among different processes within the same industry."[5]

This "notably more automated" has had its emerging effect on factory design. In terms of space, automation acts to decrease the size of plants as automation means fewer machines, not more.[6] This fact along with increasing scarcity of land means that, although plants will continue to grow, their growth will be at a decreasing rate at least with regard to square footage.

One of the first items to experience a higher degree of automation will be that of warehouses. "In time 80% complete automation in distribution warehouses will be the rule. Goods will be handled by machines activated by magnetized tape. Machines will detect odors, read numbers, appreciate dimensions, work in the dark of one story warehouses of towering height, without floors."[7]

Production Lines

The production line today is where a manufacturer makes or loses his profit. For this reason a great deal of

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Production Lines

The production line today is where a manufacturer makes or [illegible] big profits. But they require a great deal of time and money is invested into their layout. Analysis is made of products to be manufactured, machines for different tasks are studied, time-motion studies are made, material handling is carefully looked at, all to insure the smoothest and most economical manufacturing process possible. This is then put from a two dimentional proposal into a three dimension reality. And this is where an architect becomes valuable.

Most authorities in production line design agree that the building should fit the process involved. This thinking works well for manufactured items that experience little or no customer demand for change. An example of such an industry is that of the steel producer. However, in processes which incur a great deal of change, manufacturers may find that too close a fit between production line and building is somewhat disadvantageous. If the product changes and subsequently the machines become obsolete, so does the plant.

Manufacturing of today is producing an unprecedented array of industrial hardware. The trend for more products and a greater diversity of them will continue into the future. Product watchers in the 1950's were astonished by the rise of new products and many disbelieved that the market could increase; many were convinced that a point of saturation had been reached. This was when the GNP was 285 billion.[8] Today it is at 759 billion and still increasing.[9] One Detroit truck manufacturer now offers 13 billion possible combinations, or enough to keep the company in production for hundreds of

centuries without building two identical vehicles.[10] To keep up with this type of demand the production line must remain in constant change. This is demonstrated by an investment in the past decade of $140 billion for new machinery, which in turn yielded a 30% increase in productivity.[11] Since manufacturing is extremely competitive, new machinery may make the difference in sales. Management consultant, Bernard J. Muller-Thym, stated: "A businessman who bought a machine tool three years ago is at the mercy of a competitor who buys one this year. With 60% of all U.S. machine tools at least a decade old and with management anxious to boost productivity and profits, the machine tool makers are staging quite a donnybrook themselves over this $900 million market."[12]

This then means, in terms of architecture, that plants in the future must accommodate new lines of production in a way that is tuned toward dynamic, not static, situations. The building must adapt to flexibility or even movability in order to accommodate shifts in demands.

Plans

Industrial plans are made up of several dependent parts. Functionally these parts all work together to achieve a common goal. The generally accepted breakdown according to function is: assembly, storage, offices, labs, service and employee facilities. The plan of most light manufacturing areas is usually a collection of large unobstructed regular bays combined to form a rectangular space. The particular production

line employed dictates the over-all size. There is not a maximum or minimum size; however in April of 1954 "the Society of Industrial Realtors, a division of the National Association of Real Estate Boards, surveyed the national market for industrial buildings and sites. Their findings revealed certain strong owner preferences which show how economic and social pressures can affect industrial building design and demonstrated a steady demand for good industrial location coupled with a growing scarcity of prime industrial land.

"The market for industrial sites showed an increased dollar volume of sales and price increases ranging from 10 to 20 per cent. As to type of building, a continuing heavy demand for one-story buildings existed, as compared with multi-story buildings which are beginning to drag on the market, with more offered for sale, fewer buyers and weak prices."[13]

Another trend was discovered. "More small plants (less than 50,000 sq. ft.) were being bought than larger structures (over 50,000 sq. ft.) although only a slight change in prices for either was noted."[14]

Next, and probably most closely related to assembly is the function of storage. Storage areas are as widely different as the products they store--furniture to vitamin pills; however, several common features can be seen. "Square storage buildings are generally preferred as they

provide a shorter perimeter and less wall is needed for a given footage, but more important than any saving in building cost is the low cost in handling when a storage area is well proportioned."[15] The cost of the building for storage space is about 80-90% of the total cost for that space; in contrast the cost of the building for the assembly area runs 30% or less in total cost for that space.[16] Since storage and assembly form a close relationship to one another, it is imperative to have a good fit. This good fit would be handled according to production line needs if it were not for shipping. Factories may or may not need rail access, however for resale reasons or for changes in delivery procedure because of product change, rail access is highly recommended. Rail and trucking, in a lesser degree, are linear in nature. This then implies that storage be grouped in a linear way, serving delivery on one side and assembly on the other. In some industries a great variety of raw materials are used in order to produce a finished product. Input storage in this case would need more space than would output storage as the difference in bulk would be noticeable. Still other manufacturers state a preference for rapid input and output with very little space alloted for storage.

"On the other hand, warehousing, both for materials coming in and those going out, is apt to be considerably larger and more dramatic than in older plants. For instance, automated bakeries, feed plants, and the like convert from handling their raw materials in bags to handling them in bulk. Flour

arrives in huge bulk shipments to go straight from storage into conveyors, and thus one of the first automated bakeries has storage silos 90 ft. high for its ingredients.

"At the output end of an automated plant, little storage should be needed, at least in theory. The products ought to be shipped off almost as they come from the line. This is what high-production plants aim at, but it is more easily said than done; for it requires fantastic dove-tailing of production schedules with customer requirements."[17]

In terms of rail and truck delivery, dock heights are important. Heights of over the road trucks may vary as much as 2 ft. between the highest and lowest. It is impossible to adjust for all. Nor is there any way to predict the height that suits most. In adjusting for height, full and empty loads must also be taken into account. Ramping slightly up into any vehicle is preferable. The same thing applies to rails, ramping up is preferred because of space needs for lift trucks and other handling of materials. Another reason for up-ramping and consequently low docks is that railroad cars differ in floor heights and door swings. In refrigerator cars, for example, the doors swing out and may impair loading conditions. For this same reason the distance from the center of the rails to the dock is usually 9 feet or more. The gap remaining between car and dock is then nearly 4 feet, which can be bridged without much difficulty.[18]

Next, functionally, are the administrative spaces. Since little change occurs within an office, fixed space requirements may be set.

Closely related to office space in the functional breakdown is laboratories. Laboratories for manufacturing are usually rectangular in shape and range in size from 19 ft. to 28 ft. long and around 9 ft. in width. These vary of course, due to use, but generally run in the above mentioned range. Layout is usually set up on a modular unit so as to facilitate expansion to 18 ft. by 28 ft. bays, a multiple of the modular unit.[19]

Service areas lend themselves directly to total numbers of employees and total square feet. Such facilities included maintenance areas, toilets, and cafeteria kitchens. Each should be arranged according to demands placed upon them.

Employees' facilities function similarly. Although a cafeteria is not a must, many owners find them advantageous. Employee morale may increase as well as productivity. Some considerations are: distance from work area, which should be away from work and noise but should not consume too much time in transit; piped music, which has worked in many cases; and pleasant surroundings. Employee entrances are recommended but not a must. Off-time spaces, lockers, and adequate toilet rooms are also desirable.[20]

Flexibility

Flexibility differs from expansion. Expansion is the process of growth whereas flexibility is the process of internal change. Until recently factories remained relatively static. The emphasis was on producing more of one item at less cost than its competitor. "Today's economy is no longer based on increased production of the same item but on production of items that constantly change."[21] "Any management complacent enough to sit around in a euphoric mood after the construction of a new plant is heading for trouble. 'The moment the facilities are exactly what you need', points out Vice President Joseph M. Kuben of the management consultant firm, Booz Allen & Hamilton, 'that moment signals the beginning of the decline of enterprise'."[22] "One recent Booz Allen study revealed that half of all new products are commercial failures while the average life of the surviving successful product is two years."[23] The savings resulting from greater productivity, fewer rejects, smaller space requirements, higher precision and quality are of such a magnitude that installation of new techniques and systems, however great the initial cost, is well worthwhile.

Management consultant Bernard J. Muller-Thym had this to say about flexibility: "What is new within our grasp is a kind of productive capability that is alive with intelligence, alive with information so that at its maximum it is completely flexible; one could completely reorganize the plant from hour

to hour if one wished to do so . . ."[24] If this thinking continues, and there seems little doubt, then the major architectural contribution to this change will be that of flexible building types. This means providing structural and mechanical systems that can undergo change and still function correctly both physically and esthetically.

Expansion

Expansion as well as contraction is predominant in plant layout. Physical growth may make, as was stated in the section on flexibility, the difference in success of one manufacturer over another. Adequate planning in advance is a necessity. "The consequences of building without such a plan can be as severe as forgetting to provide a general with a foot soldier."[25] One of the better architectural solutions has been that of modular design. Through a repetition of units which adapt themselves to extensions, a factory can be made to shift with a great deal of ease. The modular unit is also adaptable to technological construction and mass production.

"Unless industrial buildings are designed to provide for optimum capacity with expansion provided by the future erection of one or more complete factories, on the site, the expansion of each department must be considered. All departments will not need equal expansion. However, since new construction is less costly than remodeling, it is wise to

oversize facilities for a reasonable amount of internal growth."[26]

Walls probably contribute most to blocking progress. Donald F. Tappan, structural engineer for Ford Motor Company, warns, "You do not build walls inside a plant--except in areas where you are 99% sure you are not going to change for 10 years."[27] Exterior walls are a must for obvious reasons, and therefore walls that can be disassembled and moved are to an advantage.

Structural

The choice of structure depends on several items. In general there are three major factors governing selection of a structural system: architectural concept, suitability, and economy.[28] The architectural concept will be left until later.

"Economy is one of the most important factors in selecting a structural system. Economy is affected by:

a. Height of building: overall number of stories and floor to ceiling height.

b. Columns: spacing, pattern, size, and shape.

c. Shape in plan: square, round, rectangular, irregular, etc.

d. Wind loads: width to height ratio.

e. Floor area: variation from floor to floor and minimum area.

f. Garaging requirements.

g. Air-rights.

[illegible]

[illegible]

[illegible]

[illegible]

a. [illegible]

b. [illegible]

c. [illegible]

d. [illegible]

e. [illegible]

f. [illegible]

h. Dead weight of structure.

i. Applied loads.

j. Soil conditions.

k. Local conditions - material cost, labor rates, union regulations, codes, etc."[29]

First let's consider height and number of stories. "Management has discerned that while a one story building covers a greater area than almost any other kind of structure, few industrial buildings have greater flexibility."[30] So where flexibility is desired, a one story assembly area becomes an asset. A one story building also suits a majority of light industry, and only in highly technical industries such as electronics does a two story building become more feasible. Actually the more technical a manufacturing process becomes, the more stories are needed.[31]

Height of a particular building also becomes an important structural consideration. "A low ceiling, for example, is now the height of folly. 'A few years back,' says a Philadelphia architect Louis de Moll, 'it was thought that 12 or 14 foot ceilings were sufficient for any factory purpose. Now we are going as high as 20 feet.' This enables management to install overhead conveyors for new products or to make adjustments easily in the advent of new handling methods."[32] Moll continues, "Adding height to a one story building while it is still under construction costs peanuts.

If height has to be added after the roof is on, you pay dollars instead of cents."[33]

Next to be considered is the roof support. In the requirement under economy the second consideration was that of columns. It is the consensus that a column approach is more appropriate than bearing-wall construction. Masonry walls for a long time have been used. In this study, however, masonry is disadvantageous because of its inflexibility, which contrasts to changing production facilities. Also, some extra expense may be seen other than materials due to the high cost of masonry labor. Exterior walls, for obvious reasons, are still needed. Although the use of panels has been limited, it is easy to predict its acceptance; one reason being the development of new and better panels which are low in maintenance, furnish the desired flexibility, and result in economy. More and more emphasis on "industrialized" building components should also add to their extended use. Cranes used in railroads and in the buildings themselves may be employed to handle wall panels. Some of recent development used in industrial walls are: tilt-up reinforced concrete walls which are usually poured in the horizontal position on the ground; pre-stressed and pre-cast reinforced concrete panels; sandwich wall panels with metal or plastic surfaces and insulating core; and new plastic panels.

Spacing of columns is a prime factor in an economical structure. Early factories had relatively small spans which

allowed, or at that time, demanded wood, since cast iron or structural steel was not available. As machines grew, short spans began to hamper the progress. This trend has continued until the present when no one gives a second thought to bays of 40 ft. and larger. As a matter of fact, small bays are more detrimental today than in the past. But the largest bay possible is not a panacea, only a proper balance between ultimate use and present cost will lead to a good fit.

The next consideration is shape and configuration of the plan. This is discussed under the section on plans.

Floor area has little effect on overall cost unless mass production is employed or where profit margin shows gains for more material used. Also, variation in ceiling heights tends to complicate cost.

Wind load, soil conditions, labor rates, air rights and codes are important considerations but are not included in this study because they depend upon local factors.

Suitability is the third factor in the selection of a structural system. This classification may be the final conclusion on structure. Suitability runs in direct conflict with economy. Using economy as a single rule, it is not difficult to choose the least costly building. "A metal prefabricated building is hard to beat."[34] However, as Mr. Ferreri pointed out, many factors concerning suitability enter the picture. Insurance rates, depending upon the degree of fire resistance, can reduce or increase an owner's monthly

expenditures. Some estimate that a good fire rating and consequently low insurance rates will pay back additional construction cost in five to ten years. To demonstrate a specific example, one warehouse building's annual insurance rates were $800 for prefabricated steel, $600 for unlabeled concrete, and $200 for labeled pre-cast concrete, or a savings of $600 annually.[35] These costs are rounded off and are only intended as an example; however, they are taken from a quoted source and an actual building in the Albuquerque area. Since factory construction constitutes only a third of total plant costs, and since some manufacturers store or have in production several times that amount in goods, it may be advisable to consider this point on fire protection in selecting a suitable structure. Heat loss and gain is another factor under suitability. Often monthly heating and cooling costs in insulated buildings may reduce overhead and consequently pay for structures over an extended period of time. Maintenance is a third factor in suitability. Similarly to heat and fire costs, maintenance may also be a deciding factor, with dividends over a length of time.[36]

<u>Mechanical</u>

"Mechanical systems are closely related to location. Local temperature, surrounding buildings, and demand for air conditioning in areas of high summer temperatures all influence types of mechanical systems.

expenditures. Some materials have a good fire rating and consequently low insurance rates will pay back additional construction cost in five to ten years. To demonstrate a specific example, for warehouse buildings, annual insurance rates were $300 for prefabricated steel, $400 for unheated concrete, and $500 for heated pre-cast concrete, or a savings of $100 annually.[29] These costs are rounded off and are only intended as an example; however, they are taken from a quoted source and an actual building in the Albuquerque area. Since factory construction constitutes only a third of total plant costs, and since some manufacturers store, or have in production several times that amount in goods, it may be advisable to consider this point on fire protection in selecting a suitable structure. Heat loss and gain is another factor under suitability. Often costly heating and cooling costs in insulated buildings may reduce overhead and consequently pay for structures over an extended period of time. Maintenance is a third factor in suitability. Similarly to heat and fire costs, maintenance may also be a deciding factor, with dividends over a length of time.[30]

Mechanical

"Mechanical systems are closely related to location. Local temperature, surrounding buildings, and demand for air conditioning in areas of high summer temperatures all influence types of mechanical systems."

"First, let's consider two opposing directions in actual placement of mechanical sources. Many benefits have been found in the concept of a central plant, generating heating energy in the form of hot water or steam, and chilled water, to be distributed throughout the complex. Benefits include economics, performance and aesthetics. A central system is usually compared with a series of individual plants located at each building in the complex. In a central system all boilers, refrigeration equipment and auxiliaries would be housed in one building, with chilled and hot water or steam fed to each building through a network of pipes, running from building to building. With individual plants, the boilers, refrigeration equipment and auxiliaries would naturally be contained within the particular building served, with no piping between buildings.

"Advantages of a central system include:

1. Greater heating flexibility: mechanical equipment space need not be provided in each building for boilers, chillers, and auxiliaries; chimneys, which are a common architectural design problem, need not be provided at each building; cooling towers, often difficult to locate at each building, would be at a central plant.

"2. Reduced costs of fuel and energy: central plants typically consist of several components or modules of equipment, so that only a necessary number of boilers or chillers operate at partial loads. Each of these components operate at an

efficient loading. With a plant at each building, an operation could not be as selectively efficient. The large equipment characteristic of central plants is also generally more efficient than smaller equipment typically installed in individual buildings. More money can be spent for automation controls to improve operations economy at a central plant, than for similar controls at a particular building.

"3. Reduced maintenance costs and better quality of maintenance: central plants require less personnel to operate and maintain equipment than do many individual buildings. Travel between buildings is eliminated and it is to keep the central plant under full time surveillance. Since fewer persons are required for a central plant system and highly trained maintenance men are hard to come by, it is likely that maintenance for the central plant will be superior to that for individual buildings.

"4. Better air pollution control, greater cleanliness, less noise and vibrations: programs for treating the products of combustion for air pollution control can be considered at less cost and greater efficiency in a central plant than in individual buildings. The central plant also concentrates all the equipment in one location where problems of vibrations, noise, and cooling tower spray can be handled efficiently.

"5. Reducing cost of building construction for equipment room space: total space required to house the central heating and cooling equipment will be less than the total of all the

space required for all the individual plants at each building. Centralization also eliminates the cost and structural problems of supporting cooling towers on building roofs.

"6. Since the central plant is built up of modules of equipment, the overall performance and dependability of central heating and cooling systems will be superior to that of individual plants. It is more economical to provide stand-by equipment in a central plant than to provide stand-by repeatedly at each building with expensive duplication. The constant surveillance and better maintenance possibility at the central plant also reduces the likelihood of a breakdown.

"7. Once the central system has been established, the cost of connecting additional buildings is reduced. Cost savings generated by the plant in the early stages tend to grow as the system grows.

"8. The central plant greatly simplifies installation or modernization of environmental control in adjacent existing buildings. Older buildings normally have neither the space nor the structural capability to accommodate heavy, vibrating equipment and cooling towers. One need only connect an additional building to the piping network.

"9. Lower total installed capacity: the central plant takes advantage of the fact that peak demands for heating or cooling for individual buildings do not occur simultaneously. This diversity in demand usually grows as the number of different buildings in the system increases. The result is a

lower installed capacity than the sum of the many individual plants.

"For the central system to justify itself, there must be a fairly high demand of heating and cooling per linear foot of piping distribution emanating from the central plant. Underground piping is costly and the connected load per linear foot must be higher if the cost of piping distribution is higher.

"Where buildings are separated by great distances a careful study is needed. Large distances between buildings create the problem of heat loss or gain from piping and high pumping costs which tend to lower efficiency. The cost of the initial stage might impose on the project too great of a financial burden.

"Conveying energy throughout a multi-building complex has many alternatives. A basic objective is to carry energy at a high potential, such as high pressure steam or high temperature hot water. This minimizes the quantity flow and hence pipe sizes and attendant costs. Other objectives are long life, resistance to corrosion, accessibility, allowance for expansion and contraction, low thermal losses, and cost.

"High pressure steam and high temperature hot water are often compared for conveying heating energy. High temperature hot water is the more recent but requires costly fittings, valves, joints, and pumps. These, however, are often justified to obtain flexibility, more accurate control, smaller pipe

[illegible]

[illegible]

[illegible]

[illegible]

sizes, less maintenance, and greater storage capacity. High temperature water piping has few limitations on pitch of pipe and can follow grade contours. Steam piping must have a constant pitch with traps at all abrupt changes in elevation. Generally this results in more costly excavation and trenching. High temperature water systems require much less make up water and do not have such maintenance problems as leaky traps, corroded pipes and clogged strainers characteristic of steam systems.

"Chilled water piping is typically larger than high temperature water piping, since the temperature difference between the environment and the water is not as great and more flow is required. In central chilled water systems it is wise to take advantage of as big a temperature rise between supply and return water as possible to minimize the flow--hence pipe sizes and pumping costs."[37]

FOOTNOTES

[1]"Dividends from Design," Dun's Review and Modern Industry, March, 1964, p. 117.

[2]Clinton H. Cogwill, "Industrial Buildings, Part 1," Journal of the American Institute of Architects, November, 1960, p. 93.

[3]Ibid.

[4]"These Trends May Reshape Factory Design," Architectural Forum, April, 1962, p. 86.

[5]Ibid.

[6]Ibid.

[7]Buildings for Industry (New York: F. W. Dodge Co., 1957), p. 56.

[8]Luman H. Long, The World Almanac, 1967 (New York: Newspaper Enterprise Ass'n. Inc., 1966), p. 169.

[9]Ibid.

[10]"Dividends from Design," Dun's Review and Modern Industry, March, 1964, p. 119.

[11]Ibid.

[12]Ibid., p. 120.

[13]Buildings for Industry (New York: F. W. Dodge Co., 1957), p. 5.

[14]Ibid.

[15]Ibid., p. 55.

[16]Ibid.

[17]"These Trends May Reshape Factory Design," Architectural Forum, April, 1962, p. 86.

[18]Buildings for Industry (New York: F. W. Dodge Co., 1957), p. 56.

[19]Interview with Richard Wiedersum, March 15, 1967.

[20]Cogwill, op. cit., p. 95.

[21]"Dividends from Design," Dun's Review and Modern Industry, March, 1964, p. 118.

[22]Ibid.

[23]Ibid.

[24]Buildings for Industry (New York: F. W. Dodge Co., 1957), p. 55.

[25]"The Perfect Plant," Dun's Review and Modern Industry, March, 1963, p. 190.

[26]Cogwill, op. cit., p. 98.

[27]"Dividends from Design," Dun's Review and Modern Industry, March, 1964, p. 118.

[28]Nicholas Farkas, "Selecting a Framing System," Architectural and Engineering News, September, 1966, p. 24.

[29]Ibid.

[30]"The Perfect Plant," Dun's Review and Modern Industry, March, 1963, p. 189.

[31]Ibid., p. 192.

[32]Ibid., p. 186.

[33]Ibid.

[34] Interview with Ron Ferreri, Pres., Prestressed Concrete Products, Inc., March 20, 1967.

[35] Ibid.

[36] Ibid.

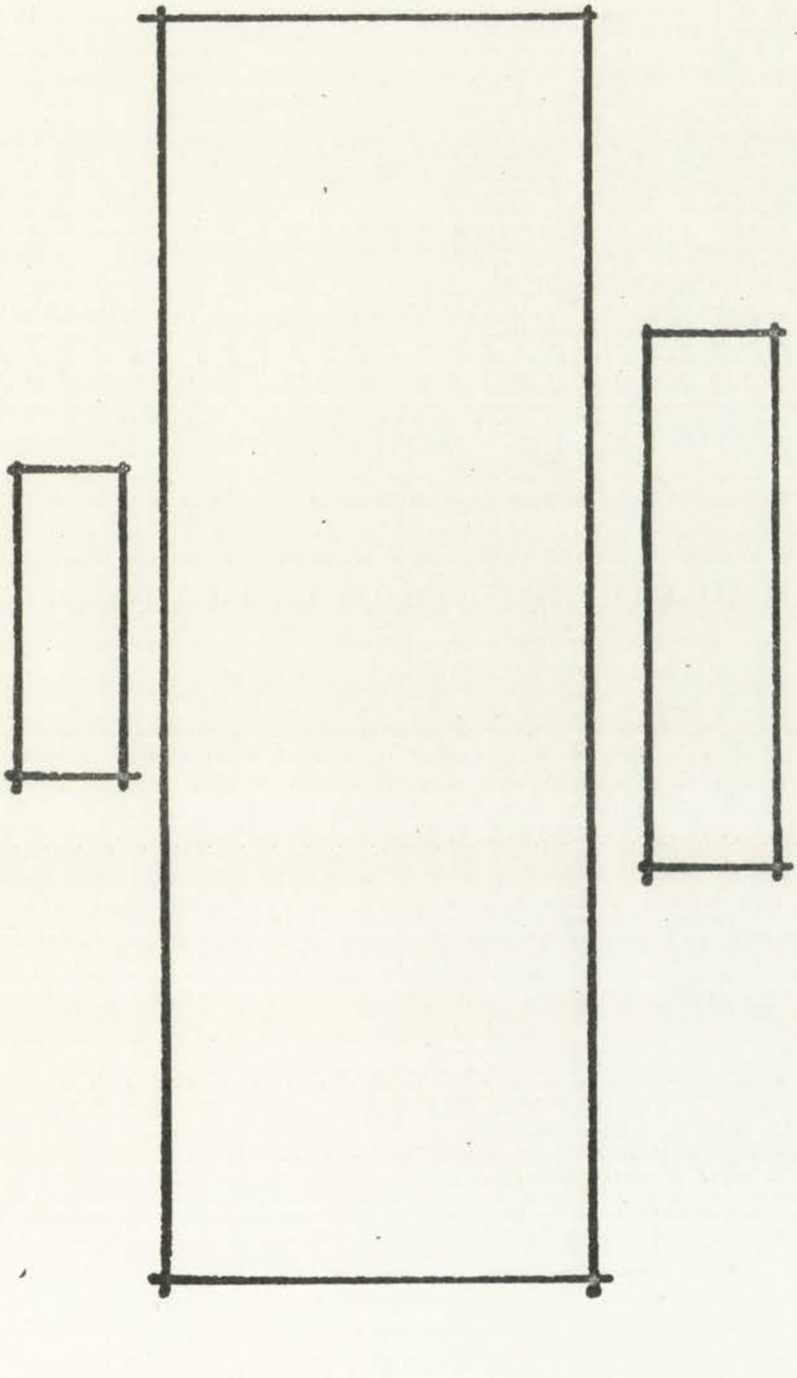
[37] Norman D. Kurtz, "Servicing the Complex," Architectural and Engineering News, June, 1966, pp. 56-65.

CHAPTER II

SPACIAL ARRANGEMENTS

Mass Model

The following four schemes demonstrate several diverse ways in which the various functions and their requirements can be arranged in space. This is not to say that the schemes shown represent all possibilities. I do feel that those shown consist of the main spacial organizations. Of the four schemes, I have chosen number four as I feel it satisfies most of the requirements in the best way. The development of scheme number four is found in Chapter IV, where exact requirements and local conditions are brought in to test its validity.

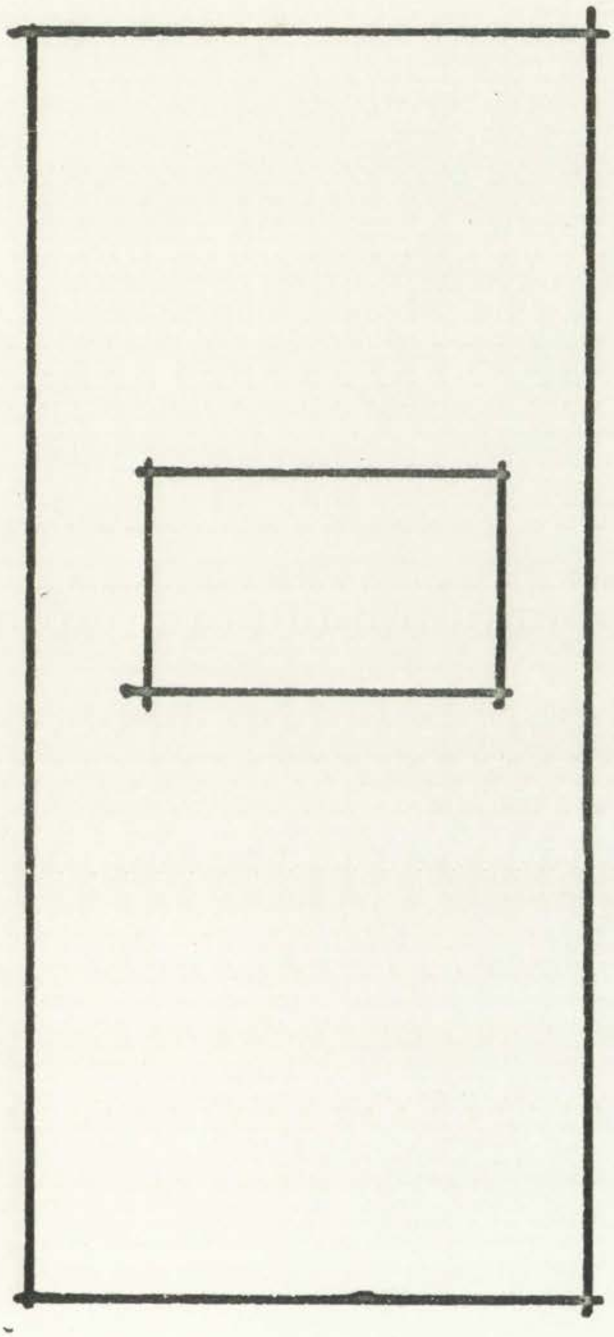


1.

Scheme Number One

Description: In this plan the assembly area is centrally located with administration bounding one side and input and output storage on the other. This arrangement is prevalent in many of today's factories.

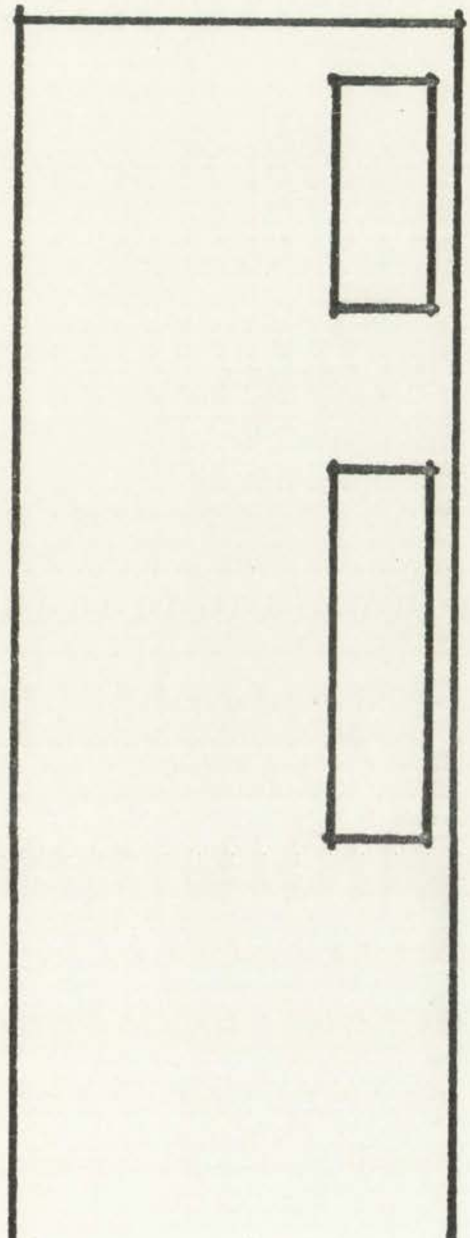
Critique: The initial flexibility is good, however expansion can be accommodated only in two directions which will eventually limit the degree of interior arrangement. Delivery can be handled by rail and truck, but study is needed to accommodate both at one time. Storage can be expanded linearly and vertically. The administration has easy access to public as well as personnel.



Scheme Number Two

Description: In this scheme the laboratory, offices, and storage areas are located centrally with assembly areas located peripherally.

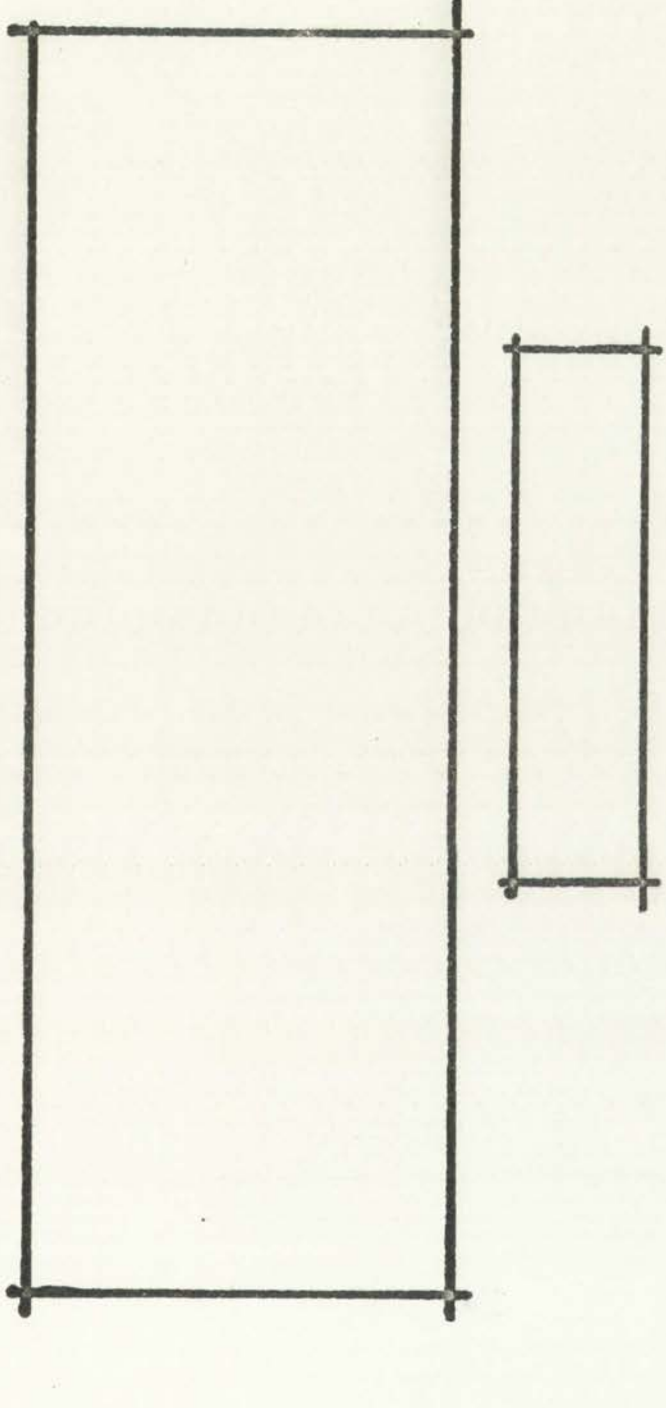
Critique: A spacial arrangement like this affords the maximum expansion and at the same time minimum flexibility. Delivery is difficult as goods must be hauled a great distance and must pass through the process to storage areas. Storage can expand only vertically and may not satisfy all manufacturing processes. Administration has good relation to the factory but poor access to public and poor visual surrounding for employee areas.



Scheme Number Three

Description: The assembly area is on the ground floor with all support facilities on the second floor.

Critique: Expansion is excellent in four directions with the only limitation in the vertical direction under the administration and storage. If a great deal of storage is required, vertical growth may be eliminated altogether. Flexibility is very good. Storage may expand in four directions as well as vertically, however access to the ground may cause some difficulty. Delivery of goods is very good as storage of any material can be directly over the area needing that good. Over the head material storage, however, causes a waste of space and a more costly structure. The expansion of the administration area is good but may restrict storage growth. Public access is poor in cases of growth and employee areas are poor for mechanical and visual reasons.



Scheme Number Four

Description: All support facilities are located on one side and all manufacturing areas adjoin on the other.

Critique: Expansion is very good. Flexibility is also very good, however some problems may develop in storage as changesin machines make different demands on storage. Delivery is good but only one delivery can be handled at a time causing delay in materials. Storage can expand in two directions--vertically and linearly, but this is restricted somewhat by the factory and to the public, but at the same time may conflict with delivery processes.

CHAPTER III

PROGRAMS OF LIGHT MANUFACTURING PROCESSES

Introduction

The following pages give specific area and flow requirements for three light manufacturing processes: air line flight bag assembly; Levis Strauss Co., clothing manufacturing; and Gulton Industries, Data Systems Division. These examples are not all-inclusive, however, they do give a practical base for a more complete study.

Program of a Light Manufacturing Process--An Air Line Flight Bag Maker

I have taken this program of an air line flight bag maker, which was analyzed by Richard Muther in the June 1966 issue of Architectural Record. This information follows on the next pages.

	square feet
1. ASSEMBLY	
Cutting	1600
Silk Screen	2100
Sub-Assembly	800
Final Assembly	5400
Inspect. (incl. pack)	1700
2. MATERIALS	
Receiving & Shipping	2550
Material Storage	1650
Finished Storage	2500
Dark Room	400
Art Room & Design	500
3. ADMINISTRATION	
Office	2300
Maintenance	550
Rest Rooms	700
Lunch Room	1650

layouts, which are then evaluated according to a numerical system, and the best one selected.

"The example shown here is for a layout by product that is fitted into an existing rectangular space. The product is an air line carry-on bag, and the necessary flow of materials is shown in the diagram above. Such flow diagrams are quite familiar, but the relationship matrix next to it represents a valuable new technique for correlating production flow with the other functions of the factory. All activities taking place in the building are identified and listed, the production line in this case being represented by items three and four on the chart. The degree of relationship is then posted using a scale of six places ranging from absolutely necessary to undesirable. There is also room for a numerical code showing the reason for the relationship.

"The chart can then be translated into a relationship diagram. The operations continue to have the same identifying numbers that they have had on the chart, and they are now given a symbol, such as a circle, or a triangle, following a standard method of differentiating the type of activity represented. The number of lines connecting various items indicates how important the relationship between them is to the production process. Note, for example, that operation two (silk screening) and operation three (sub-assembly) do not connect, but they both relate equally strongly to step four (the final assembly process).

[illegible]

[illegible]

[illegible]

[illegible]

is shown in [illegible]

[illegible]

[illegible]

place in the [illegible]

[illegible]

[illegible]

[illegible]

This simple and rational method for planning the layout of industrial buildings was developed by Richard Muther, an industrial engineer and management consultant, and his associate, John D. Wheeler. It provides a way of analyzing the space requirements for different kinds of manufacturing processes, and it may also suggest an approach to other kinds of design problems.

The following quoted information has been taken directly from "Industrial Buildings," Architectural Record, June, 1966.[1]

"The entire layout process is diagrammed above left. It begins with an analysis of the type and number of products (P) and the quantities (Q) in which each product is to be manufactured. In general, a small number of items produced in large quantities calls for production lines, or layout by product. When there are many items, and they are produced in small quantities, it will be more efficient to lay out the plant according to processes of forming or treating, or by fixed assembly locations, called layout by process.

"A consideration of the movement of materials and the necessary relationships between various manufacturing activities produces a flow-activity relationship diagram. When the space requirements are added, a space-relationship diagram results. This diagram can be turned into a number of different

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[1] "Industrial Buildings," Architectural Record, Vol. 139, June, 1966, pages 178-181.

"The diagram looks complicated, but it is actually relatively easy to construct, if it is built up sequentially. The first step is to diagram the strongest relationships--those indicated by four lines--because it is obviously most important that they should be closely associated with each other. When a satisfactory relationship of the four-line connections has been established, the three-lines can be considered, and so on.

"At this time, it is time to add the actual space requirements to the relationship diagram. Muther's method makes use of a chart that shows not only the areas needed for each operation but many other characteristics of the space as well, including clearance, loading conditions, and mechanical services. These requirements are then combined with the relationship diagram, and adjusted and rearranged to include modifying considerations. The ideal diagram is clearly capable of describing three or four likely solutions. All of them should be drawn, and then evaluated by an ingenious system that Muther has devised.

"The considerations by which the layout will be evaluated are listed on a special evaluation chart. In the example illustrated above, six criteria are shown. The relative importance of each criterion is then established by a numerical rating system on some agreed upon scale, such as one to ten. In the example, flow of materials and handling economy is assigned more importance than cost considerations, labeled "least investment." Least investment, however, is given more

importance than flexibility or ease of expansion.

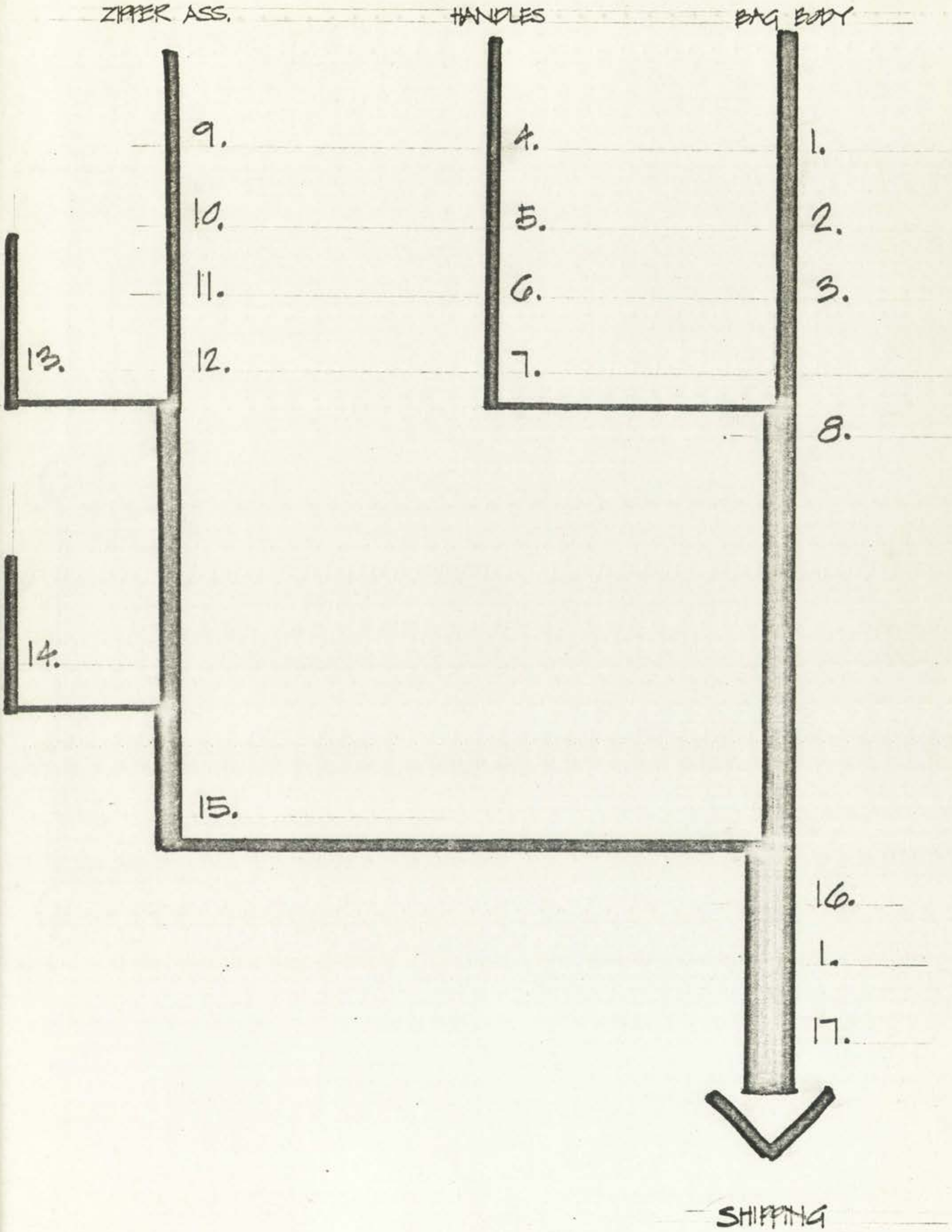
"Each of the columns A, B, and C, represent a different layout. Each layout is evaluated on a five place scale, A, E, I, O and U. The vowel letters are chosen because they are easily remembered, but they each stand for a somewhat contrived description. A is almost perfect, E is exceptionally good, I stands for important results, and O for ordinary results. A U rating is unsatisfactory. Layout A, for example, is rated E for flow of materials and I for least investment, whereas layout B receives A for flow of materials and E for least investment.

"When all the people involved in the evaluation have agreed upon weights and ratings for each layout, the evaluation is really complete. It only remains to compute the score each layout has received. Up to this point, the ratings have been in letters, mostly to prevent the results from being calculated prematurely. Now, each letter is given a numerical value: A = 4, E = 3, I = 2, O = 1, and U = 0. The rating is then multiplied by the weight and set down on the chart. For example, layout A receives 30 (10 x 3) points for flow of materials and 16 (8 x 2) points for least investment.

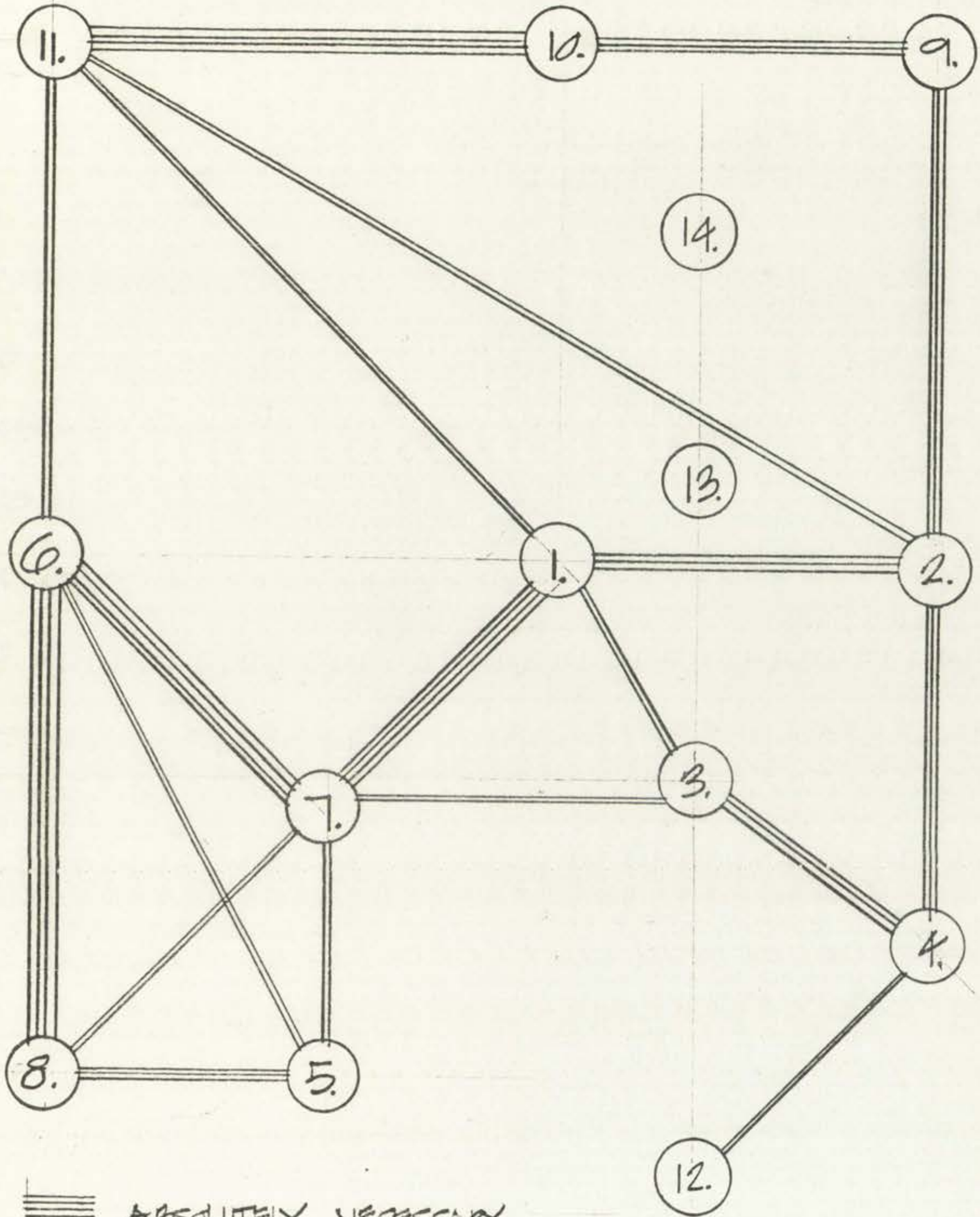
"As the highest numerical score is received by layout B, it is clearly the best alternative by the standards used in the evaluation, and it is the one shown on the final plan above.

"The design of an effective plant layout is thus seen to be a problem that can be defined and made to respond to

analysis. It is by no means the mysterious process, based solely upon "know how," that it is sometimes made to appear. The example illustrated is naturally a simple one, and plant layout is a sufficiently complicated specialty to be a professional discipline in its own right; but the points in the process where space-relationship problems appear could profitably involve the services of an architect, who could work through the problem with an industrial engineer."



OPERATION PROCESS CHART *



ABSOLUTELY NECESSARY
ESPECIALLY IMPORTANT
IMPORTANT

RELATIONSHIP DIAGRAM [MAJOR]*

EVALUATING ALTERNATIVES *

	WT.	A	B	C
LOW OF MATERIALS	10	E 30	A 40	I 20
ASE OF SUPERVISION	5	I 10	E 15	O 5
LEXIBILITY	4	O 4	A 16	A 16
ONVENIENCE OF PERSONAL	6	E 18	I 12	E 18
EAST INVESTMENT	8	I 16	E 24	O 8
ASE OF EXPANSION	5	O 5	E 15	A 20
		83	122	87

Program of a Light Manufacturing Process--Levi Strauss

The Levi Strauss Co., now operating in Albuquerque, requires a straight line assembly which is now in the configuration of a " " pattern. Very little storage is needed as the plant ships out finished goods immediately. The bulk of storage is needed in input of materials.

The following are area requirements:

	square feet
1. ASSEMBLY	31,320
2. MATERIALS	14,000
3. ADMINISTRATION	
Offices	720
Conference	300
Lobby	300
Lunch Room	900
Restrooms	400
Maintenance	200
Mechanical	200

Program of a Light Manufacturing Process--Gulton Industries, Data Systems Division

The following information has been taken directly from the public relations information sheet distributed by Gulton Industries, Data Systems Division:

"GENERAL DESCRIPTION

Data Systems, a division of Gulton Industries, Inc., located in Albuquerque, New Mexico is highly experienced in the design, development and manufacture of digital systems capable of meeting the stringent electrical, mechanical, and environmental requirements of military and aerospace applications.

"The ten year history of Data Systems' accomplishments include successful deliveries of digital systems for such programs as the Sergeant Missile, Redstone, Blue Scout, Advanced Polaris, Apollo, Gemini, Saturn, Nimbus, Orbiting Solar Observatory (OSO), Scout, Vela High Altitude Program, SD-5, TF2, Titan III Missile Guidance Checkout and Stratoscope II High Altitude Balloon Program. These systems were developed under contract with the Army, Navy, Air Force, NASA, the AEC, various integrated contractors, a number of college and university affiliated laboratories, and most of the nation's top prime contractors.

"The Data Systems Division is primarily involved in the design, development and manufacture of digital electronic systems and equipment as applied to instrumentation problems. These applications range from miniaturized high environment spaceborne packages to large complex ground station systems used at launch pad facilities. Data Systems has been involved in activities at both extremes.

"Specifically the engineering endeavor of Data Systems is pronounced in the following area:

1. PCM Telemetry Systems
2. Airborne Timers, Programmers and Sequencers
3. Command and Control Systems
4. Data Acquisition Systems
5. Digital Transducers
6. Memory Products

"In 1956, the Data Systems Division was established under the name of CG Electronics for the purpose of pioneering the application of digital techniques to instrumentation problems. It was specifically assigned the task of creating a line of digital acquisition and handling devices.

"A landmark was established in 1958 with the design, development and manufacture of the first standard missile-borne PCM Telemetry Encoder to be installed for a missile program (Sergeant). Since that time, the Division has continued to advance in the field of digital technology, improve and institute the latest production techniques and provide to the Government and industry the highest quality equipment possible.

"In order to provide a broader range of technical and fabrication capabilities, a consolidation of activities of the Computer Systems Division of Gulton Industries, formerly of Pompano Beach, Florida and the CG Electronics Division took place in mid 1966. The result of this consolidation is now known as the Data Systems Division.

"Engineering design and development has enabled Data Systems to enhance its position among the leaders in the digital field. The engineering talent of this division is heavily concentrated on the application of digital techniques to data acquisition, handling, logging, transmission, and reduction.

"Competent engineering and technically qualified design are not the sole ingredients for reliable and workable systems; manufacturing integrity and ability as well as adequate quality control must also be included. An example of the qualifications of Data Systems in this area is its capability of inspecting and manufacturing in accordance with the requirements of NPC 200-3 and NPC 200-4 respectively. The Data Systems Division has had considerable experience under both specifications.

"In accordance with NPC 200-4, Data Systems presently has two Category II instructors, 90% of all presently employed assemblers are certified to Category III and 60% of all presently employed inspectors are Category III as certified

by NASA. In addition, 100% of all the plastics technicians are certified to NASA specifications. Training and certification schools are regularly held in-plant. The Quality Control Program at this division is based on MIL-Q-9858 and has been reviewed and countersigned by the USAF. This program has been updated to meet the specific quality requirements of NASA's NPC 200-2."

"DIVISION ORGANIZATION

The engineering operation at the Data Systems Division of Gulton Industries was established in 1958 with the express purpose of pioneering in the application of digital techniques to instrumentation problems. Gulton Industries, after attaining considerable stature as a designer and manufacturer of sensing elements and transducers, recognized the advantages to be gained by offering to industry complete instrumentation systems. As part of this program, the Data Systems Division was assigned the task of creating a line of digital data acquisition and handling devices.

"The engineering department employs 50 individuals of which 29 are engineers with several holding advanced degrees. This group has experienced little turnover and has achieved the stability and teamwork so necessary for successful accomplishment of customer projects. The record which this group has established with respect to delivery, equipment performance and customer satisfaction is one which all of

Gulton is justifiably proud. Since its inception, this group has successfully completed every contract which it has been awarded; a statement which many of our competitors in the digital field cannot make.

"All engineers are cleared to the "Secret" level through the Department of the Navy.

"At the present, 220 people are employed at the Data Systems Division."

Area requirements for Gulton Industries are as follows:

	square feet
1. ASSEMBLY	24,500
2. MATERIAL	1,500
3. ADMINISTRATION	
Offices	4,300
Lobby	300
Business	1,000
Conference	1,000
Lunch Room	1,200
Special	1,600
Mechanical	300
Janitor	100
Maintenance	500
Restrooms	1,000
4. LABORATORY (deleted)	9,000

"Of the manufacturing area, 3,600 square feet is designated as a classified area and is qualified to AEC "Q" Secret level. Another 3,300 square feet encompasses a class 100 laminar crossflow clean room which meets all of the requirements and specifications of Federal Standard No. 209. The clean room adequately accommodates 70 assembly workers and is designed with the capability of being expanded another 2,200 square feet for accommodating a total of 120 assembly workers. The design provides for the expansion without deterioration of the clean room classification."[1]

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[1]Quoted directly from the public relations information sheet distributed by Gulton Industries, Data Systems Division.

CHAPTER IV

GRAPHICS

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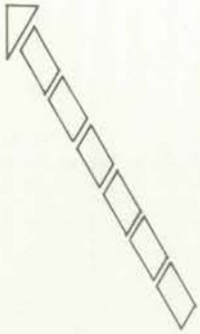
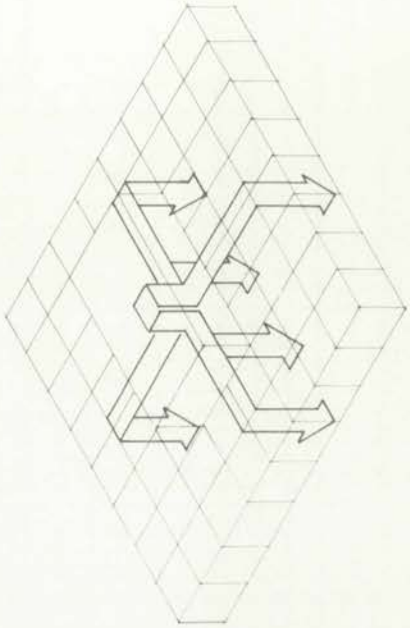
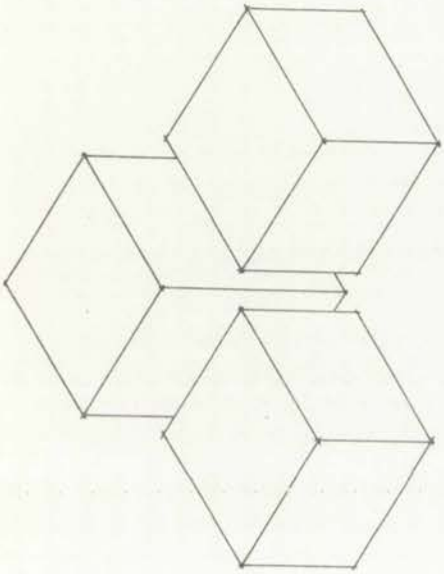
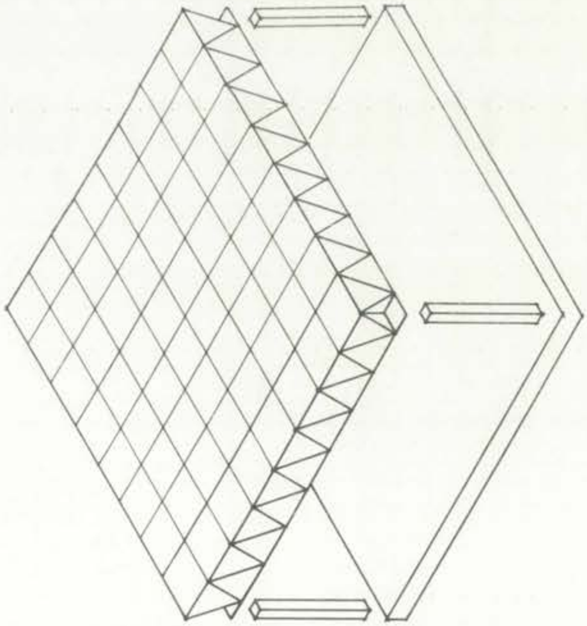
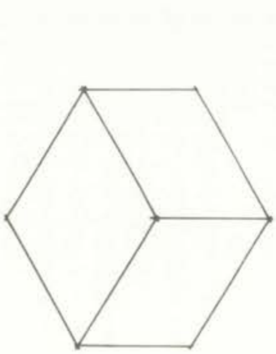

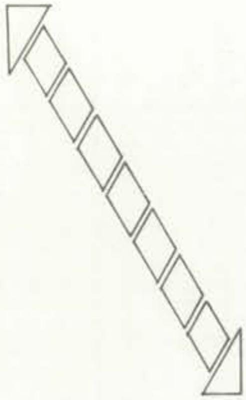

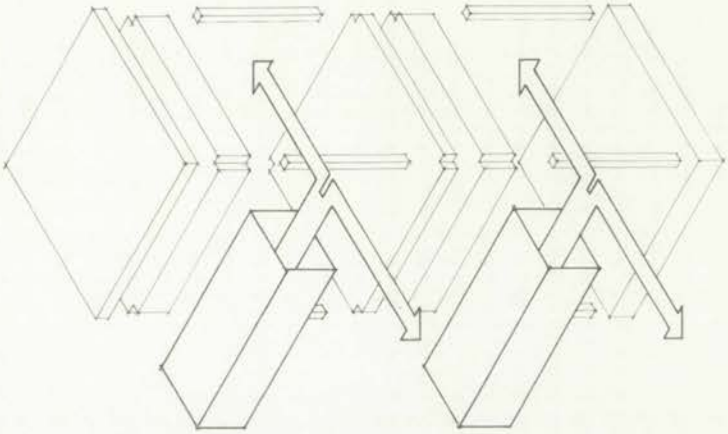

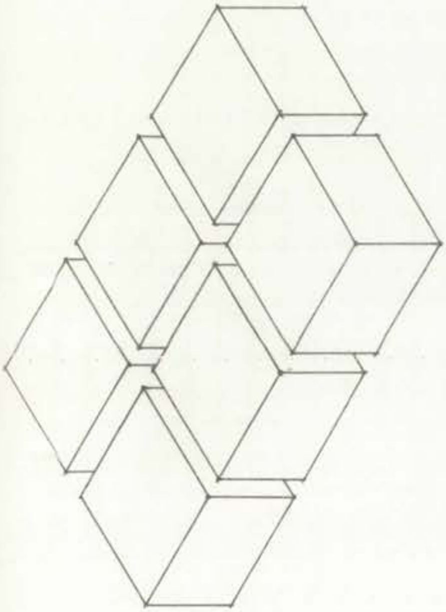

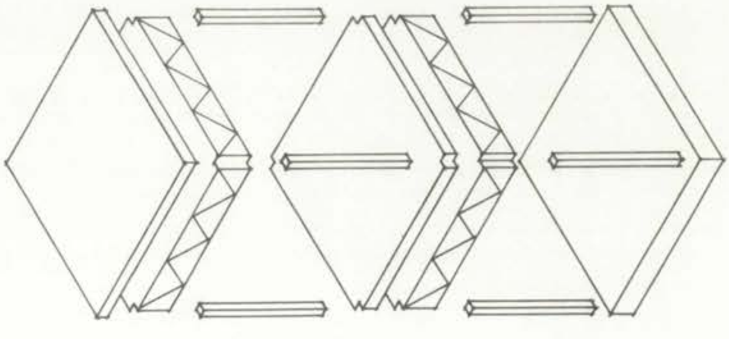

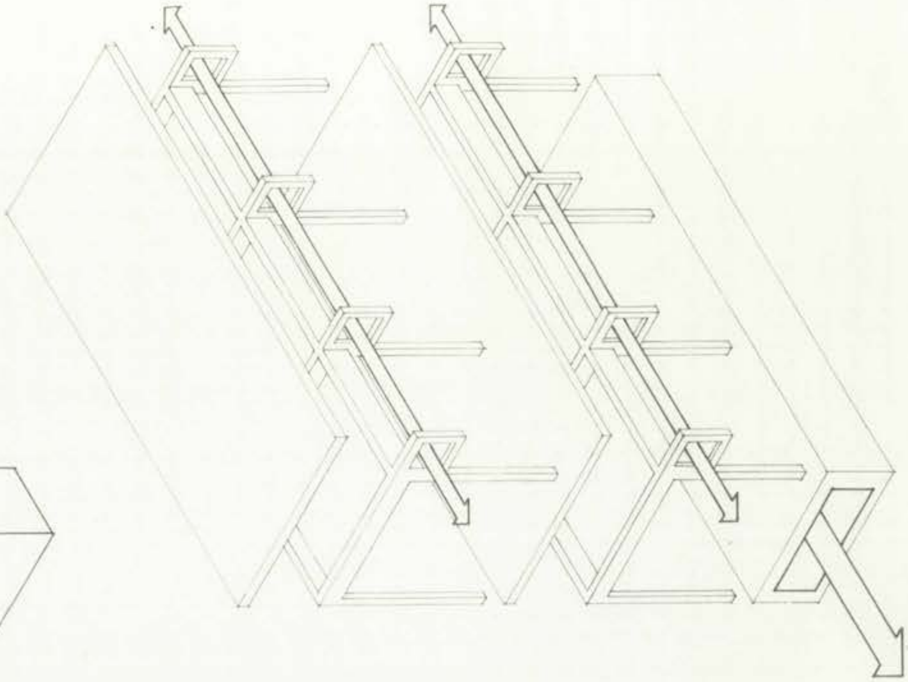

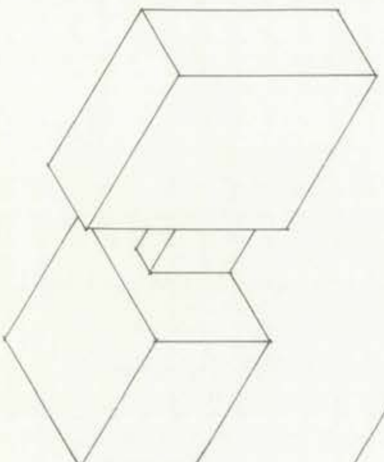

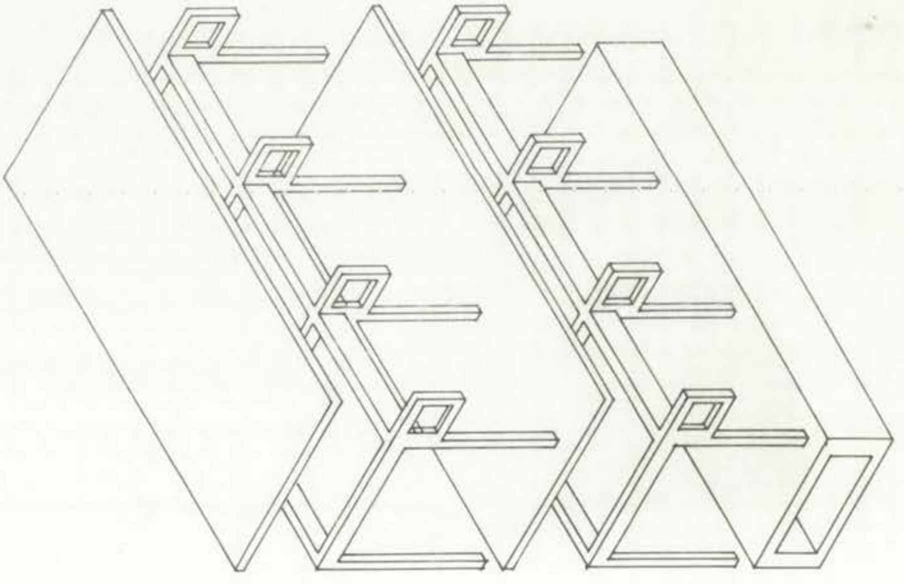

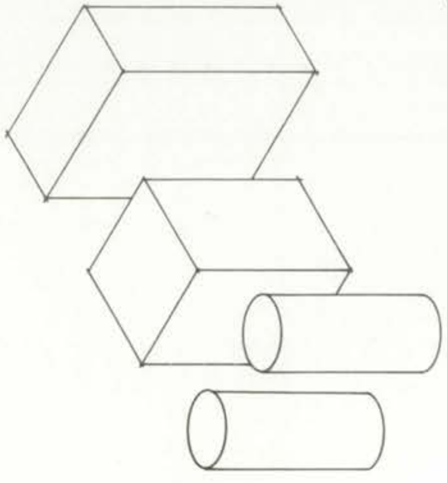

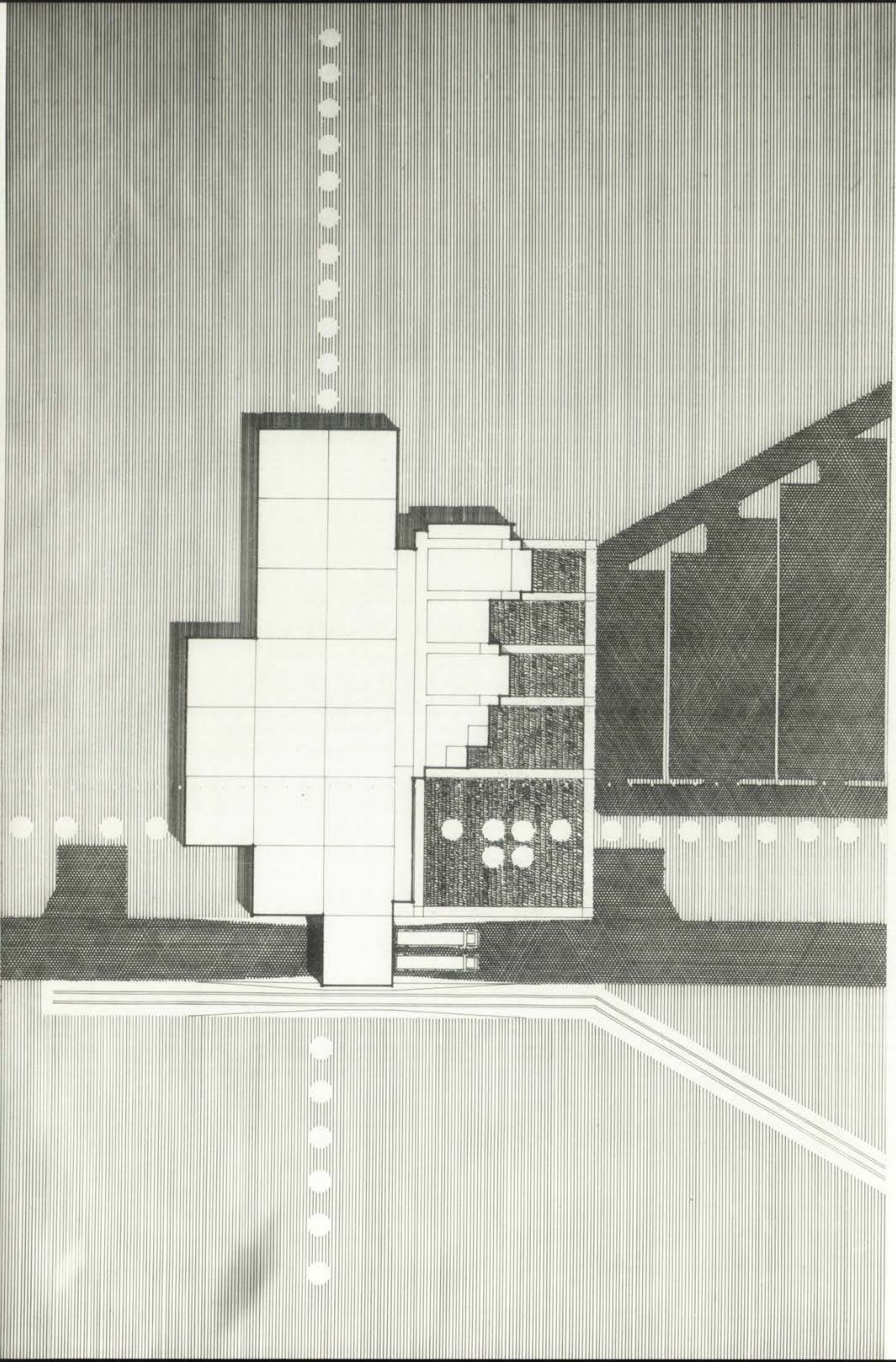

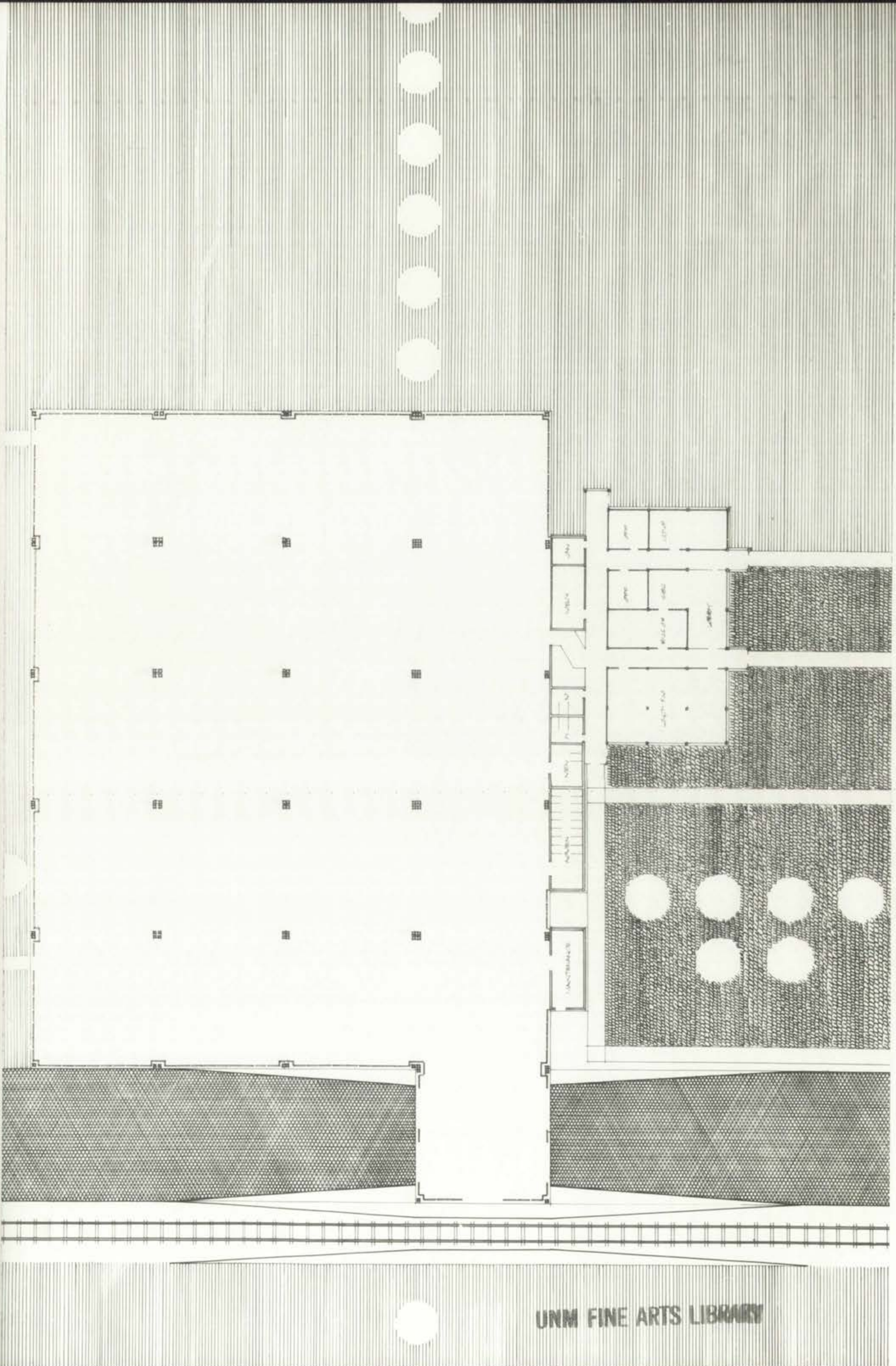

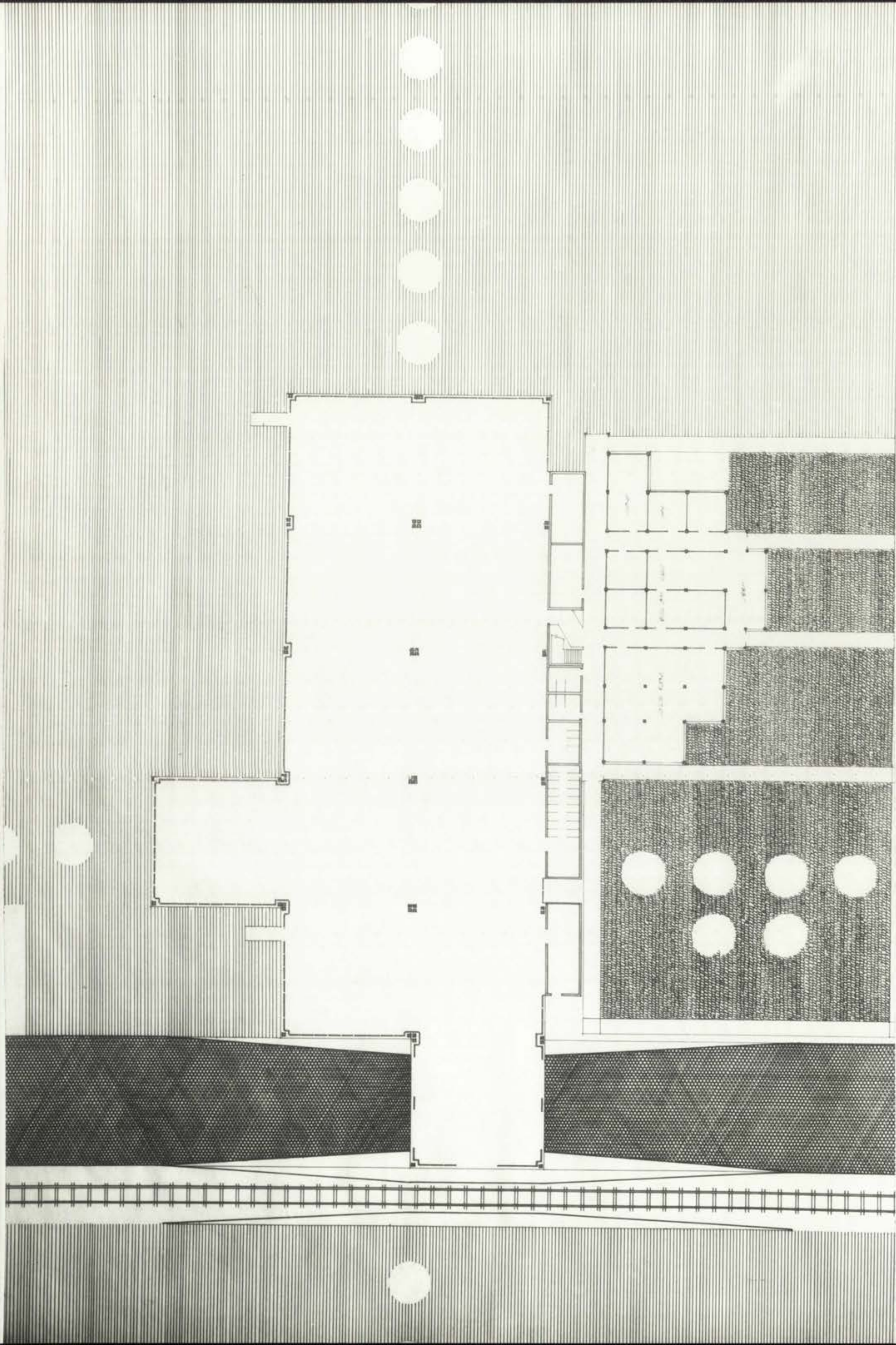

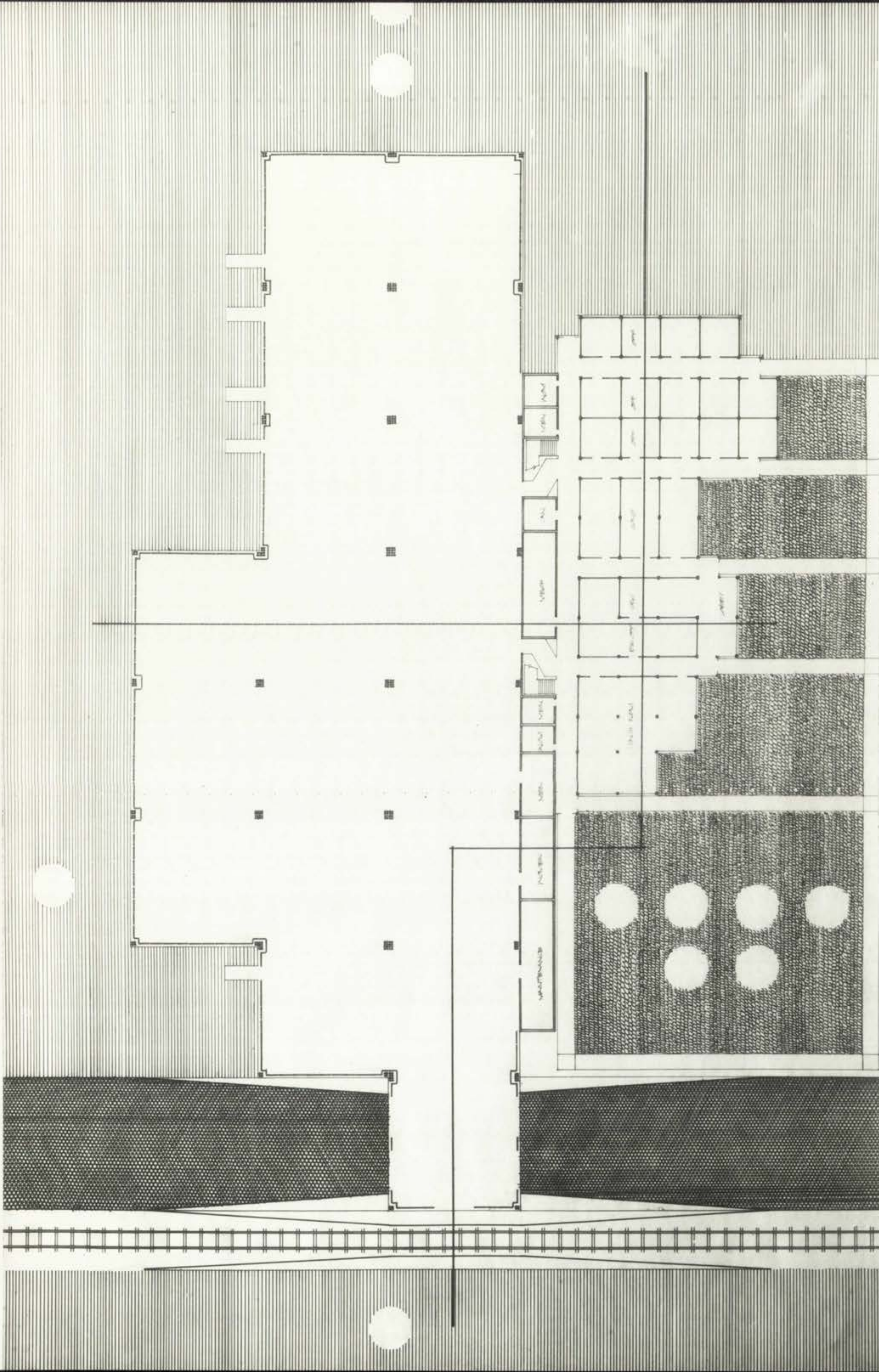

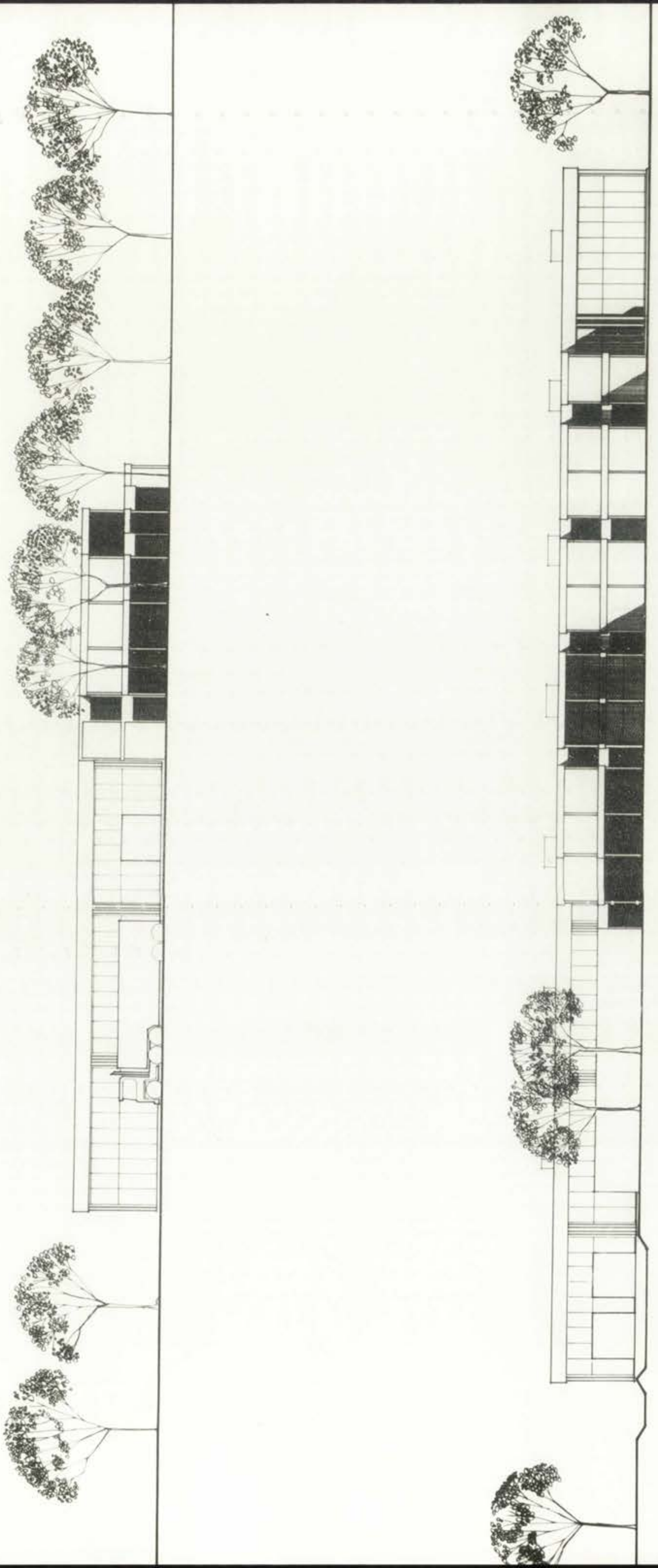

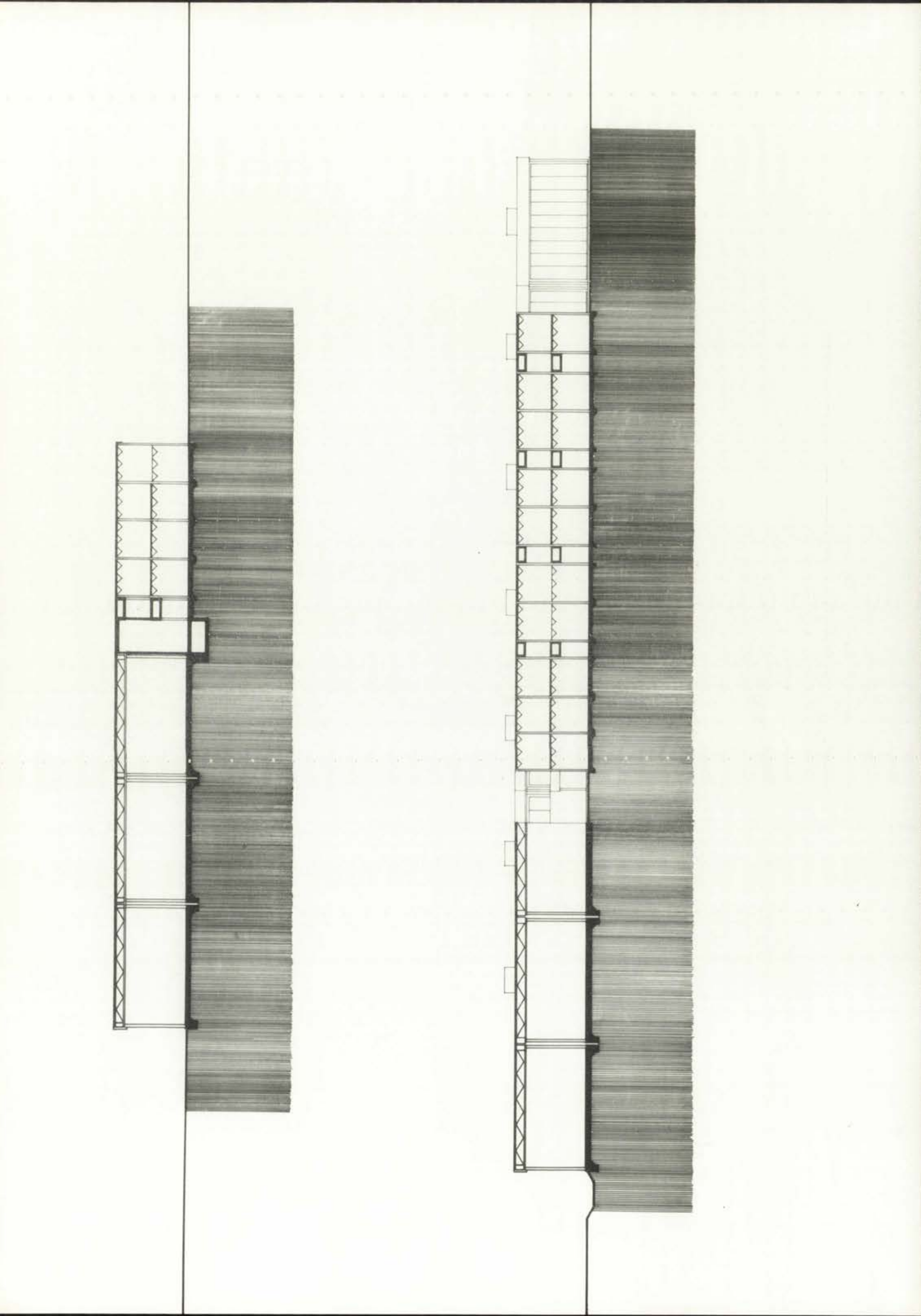

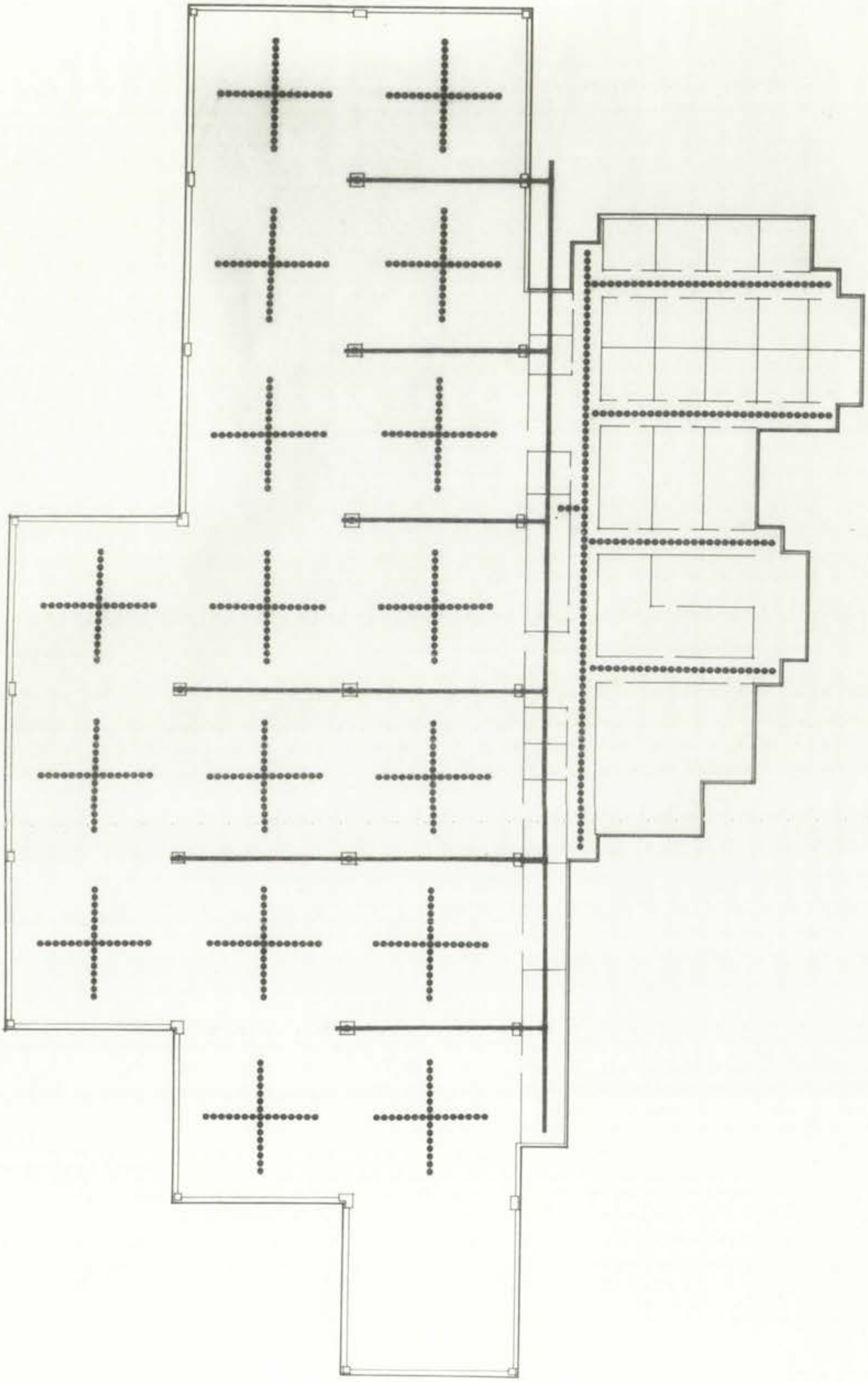

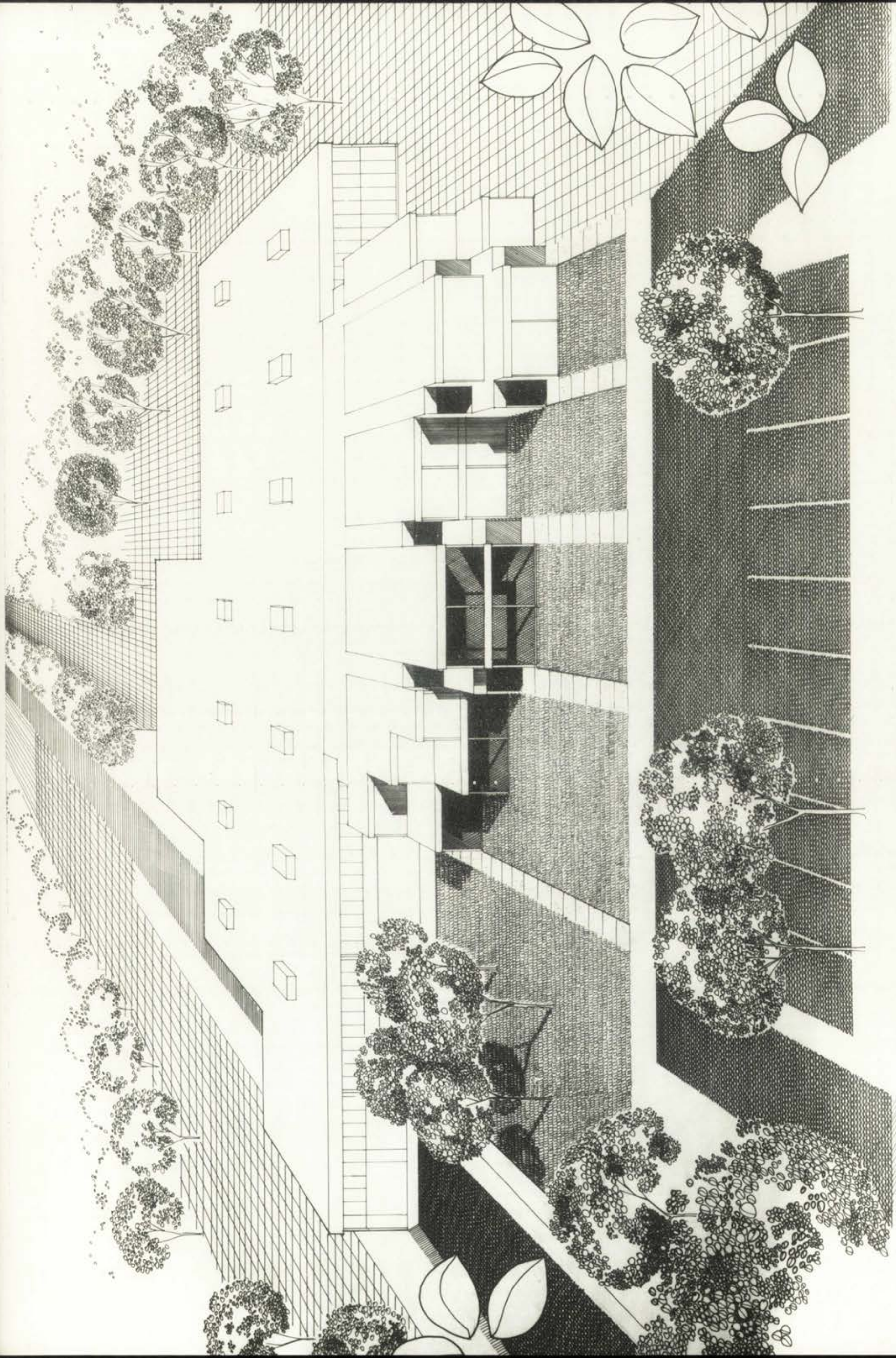

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