

TOWARD A NEW ARCHITECTURE FOR INDUSTRY.

by

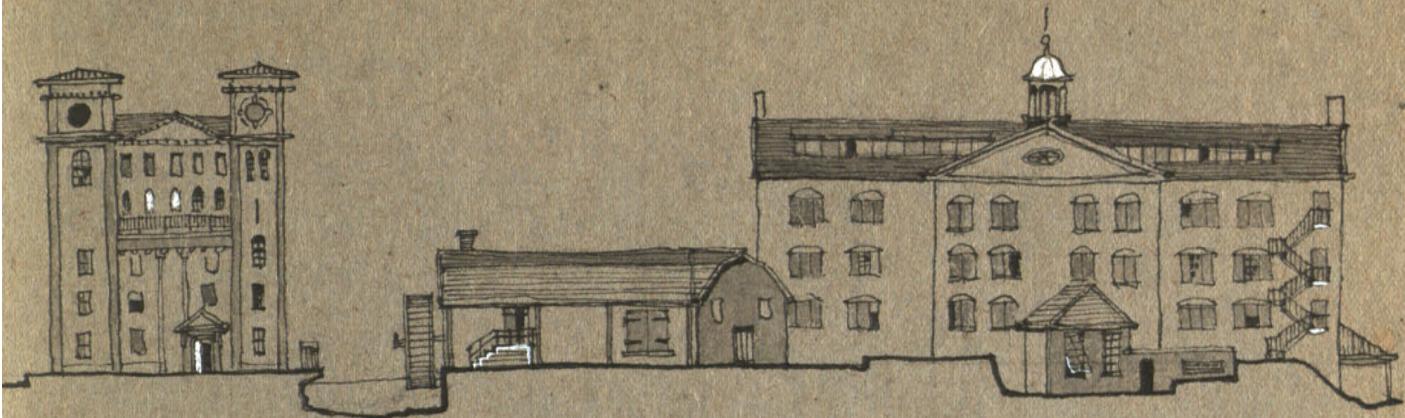
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Submitted in partial fulfillment of
the requirements for the degree of
Master in Architecture at the
Massachusetts Institute of Technology.

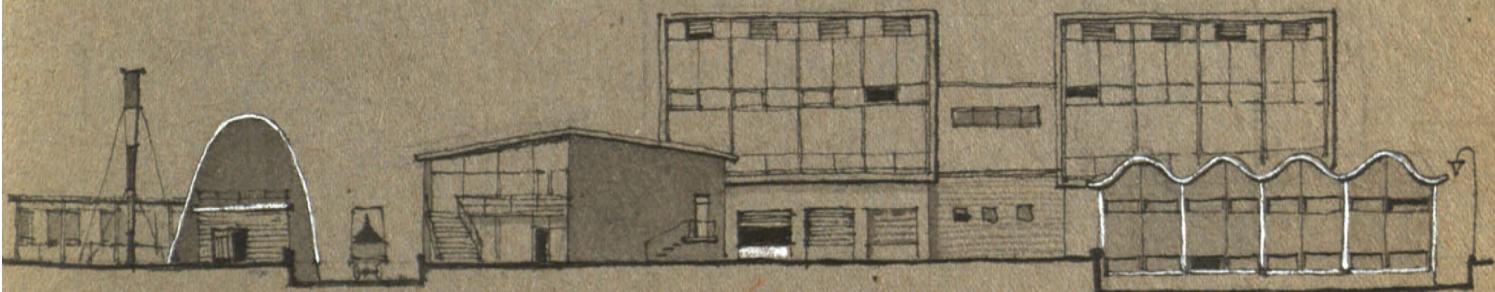
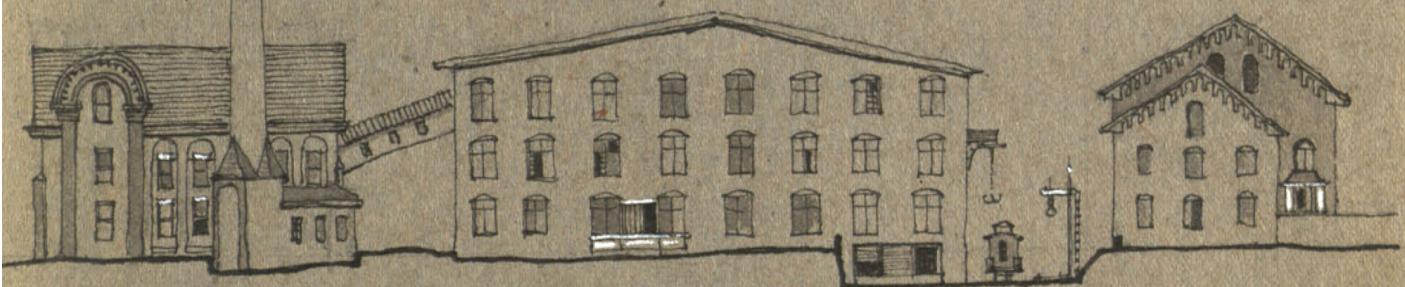
—
N. Keith Scott.
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toward a new architecture

for **INDUSTRY**



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P. 89

c/o Department of Architecture,
Massachusetts Institute of Technology
Cambridge, Massachusetts.

11th January, 1955.

Dean Pietro Belluschi,
School of Architecture and Planning,
Massachusetts Institute of Technology,
Cambridge, Massachusetts.

Dear Dean Belluschi:

In partial fulfillment of the requirements for the degree
of Master in Architecture, I herewith submit the thesis
entitled "Toward a New Architecture for Industry".

Sincerely yours,

N. Keith Scott.

ACKNOWLEDGEMENT

I would like to place on record my appreciation to the staff at the Massachusetts Institute of Technology, for their guidance in the preparation of this thesis. In particular I wish to thank:

Prof. L. B. Anderson
Prof. K. A. Lynch
Dr. W. L. Pierson
Prof. Powell
Prof. E. R. Schwarz
Prof. L. Rodwin

TABLE OF CONTENTS

Preface.	1
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PART ONE : OVERALL LOCATIONAL AND DESIGN CRITERIA.

Chapter 1.

The Influence of Transport.	25
The Influence of Labor and Power Availability.	32
The Influence of Climate.	37

Chapter 2.

Choosing a Site.	41
a) The Community.	44
b) Labor.	44
c) Markets.	45
d) Transportation Services.	45
e) Site Statistics.	46
Choosing an existing plant.	47
Available Factory Building: Information Sheet.	48-49

Chapter 3.

The Industrial District.	50
Design Considerations in Industrial Districts.	55
Three Examples of Industrial Estate Development.	59
1) Clearing.	59
2) Boston.	63
3) Dallas.	64

Chapter 4.

Factory Planning.	66
The Analysis	70
Changes to an Existing Factory.	72
The Growth of Specialization and the Influence of Time Motion Study.	76
Design for Straight Line Production.	79
Design for Machine Line Production.	81
Materials Handling Equipment and Methods.	83
Planning the Administration Block.	86
NOTES ON PART ONE.	93

PART TWO : CONSTRUCTION AND DETAILED DESIGN CONSIDERATIONS.

Chapter 1.

Single versus multi-storey structures.	98
Lighted versus windowless plants.	100

Chapter 2.

Bay Sizes.	104
Steel or Reinforced Concrete.	106
Roof Construction.	114
Walls.	121
Floors.	127

Chapter 3.

Lighting.	129
-----------	-----

Color.	136
<u>Chapter 4.</u>	
Ventilation.	144
Heating.	145
Services.	147
Industrial Accidents.	149
NOTES ON PART TWO.	153

PART THREE : THE VISUAL ASPECT OF THE FACTORY.

Recommendations and Conclusion.	158
NOTES ON PART THREE.	195
APPENDIX 1. A Historical Outline of Mill Architecture in the U.S.A.	197
Notes on Appendix 1.	223
APPENDIX 2. Principle Types of Factory Construction in Trading Estates.	225
APPENDIX 3. Some Design Criteria for Railroad Layout in Industrial Districts.	227
Notes on Appendix 3.	231
APPENDIX 4. Basic Time-Motion Principles.	233
Notes on Appendix 4.	235

APPENDIX 5. Presenting the Scheme.	236
Note on Appendix 5.	240
APPENDIX 6. A Check List of Design Consideration.	241
Note on Appendix 6.	245
• • •	
BIBLIOGRAPHY. Original Sources.	246
Secondary Sources.	253
• • •	

TOWARD AN ARCHITECTURE FOR INDUSTRY

Preface:

I believe that the documentation of all true research towards a given facet of knowledge should be conceived as but an interim report. To presume that it is more, not only closes the author's mind to further study and analysis, but presumes upon a judgement which can only be arrived at by later authorities, who, in the light of subsequent events may decide that a particular point was the apex or consummation of a certain avenue of investigation.

I approach the task of presenting this study with the firm conviction that I cannot hope to do more than produce what could be called a preliminary dissertation, or the drawing together of a hitherto rather unrelated mass of data on a very complicated subject.. That certain aspects of this data have been drawn together before I do not deny, but my thesis rests on the assertion that the data has not been correctly orientated, and I hope to show that the architectural profession has a vital part to play in the evolution of an architecture for industry which can take its rightful place as an integral part of modern civilization.

I stoutly maintain that the architect does not at the moment play his rightful part in this respect. It is common ground that during the stylistic confusion of the 19th Century, the architect ceded to the engineer his birth-right of leading man safely through the uncharted esthetic wilderness of the Industrial Revolution. That this was a visual catastrophe from which we are still trying to recover is also self evident to the most casual and disinterested visitor to any industrial community, and it is to this problem of recovery that I as an architect feel persuaded to address myself. I am convinced that, having lost the initial opportunity to establish himself as the logical practitioner to whom the manufacturer should have recourse when considering an industrial undertaking, the architect should do everything in his power to equip himself to seize the opportunity and shoulder the responsibility which is presenting itself a second time in the form of the widespread trend towards decentralization - about which much will be said both from an economic and visual standpoint.

With my specialized training and esthetic outlook I had rather tended to take it for granted that the architect should be the obvious professional man for the onerous task of bringing into factory design some of the visual qualities that we have not been privileged to see since the old days.

Georgian mills of the late 18th and early 19th Century. It has been put to me, however, that I should first establish the fact that improvements are needed, and secondly show that the architect is really the man to do the job of re-discovering esthetic standards.

It is not my intention to dwell on the first requirement, for as I suggested at the beginning, anyone who cannot see that something has gone drastically wrong, with our cities, and more particularly with the industrial complexes within their bounds, is esthetically blind, and we have no common grounds upon which to build up a discussion of any sort.

The second point is worthy of deeper consideration. To answer it one could ask the question "wherein lies the fault of which we complain?" A superficial study will soon demonstrate that the technological advances made in industrial plants within the last 20 years have been little short of phenomenal. Time and Motion Study has become a specialized science, mechanical handling equipment has developed apace; efficiency has become the watchword, and economy and directness of structural techniques has become the order of the day. How is it, therefore, that the visual aspect of our factories is no more satisfying today (in the main), than it was 50 years ago? I submit that it is because none

of the branches of engineering which are concerned in the above sciences have the smallest training in abstract visual qualities, and that true beauty can therefore only appear in their work as a fortuitous byproduct of the main stream of their studies.

Throughout five years of study, the architect is trained to ask himself in every act of creative work, "What is this going to look like, will it satisfy mens' need for a beautiful environment, and will it be a perfect expression of the civilization in which we live?". These questions are not basic to the professions which have had control of the design of our industrial zones and plants, and to me it is small wonder that they fall far short of the adequate expression of our age for which we are striving. I think it unjust to expect this to be so, and my only contention is that men equipped to assess esthetic standards should work hand in glove with those who are trained in the sciences, and who are equally indispensable to the production of a balanced scheme which contributes fully to all man's requirements.

Now it may be further asked: Granted that the architect is capable of designing a beautiful factory, but what good is this to the manufacturer; what will this mean in terms of economy; can you convince the hardbitten manager

that good architecture means good business?

These questions are frequently asked the architect, and one gets weary of having to point out that good design does not (or should not) cost more than poor architecture - for this is the implicit assumption behind this battery of questions. This has been proved most effectively in England during these post-war years, when money has been scarce and a huge housing and school-building program was required to be undertaken. Under these conditions excellent schools have been produced - at a cost considered to be quite untenable when the project was embarked upon.

Is good architecture good business? This can be answered with an unequivocal "Yes", and for support of this, one has only to consider great concerns such as "Johnson and Johnson" who would not consider building any of their huge cosmetic and toilet plants without the skilled esthetic services of an architect. Great industrial districts like Clearing, have an architect as their chief of design. The reason for this change of heart in the industrialist is not far to seek. New factories are being built on the periphery of cities, contiguous to main roads, and it has been realized that a good looking plant has a huge sales appeal and acts as free, permanent advertisement to the thousands who pass each day.

It has also been rather belatedly realized that the fellow best equipped to produce a beautiful building is the one who has devoted his life to a search for beauty as it is expressed three dimensionally in architectural practice.

It may further be demonstrated to the still incredulous manufacturer that this concern over esthetic qualities not only gives his plant 'sales appeal', but also contributes in a very real way to the production figures within its walls. The field of color psychology is one that is becoming well written up, and it is generally conceded to be a positive aid to employee contentment (although there is much charlatanry in many authors who profess to have expert knowledge), and new lighting techniques are known to materially assist in speeding production. There is much more to be learnt in these two spheres of study, and in particular, research is urgently needed concerning the interplay of light on colour, and this is the immediate concern of basic research which is being carried out in the newly set up lighting laboratory at the Massachusetts Institute of Technology. I submit that the best results in terms of visual relationships can be got from these studies by the architect, with his sensitive appreciation of the fundamental concepts behind the perennial search for absolute beauty.

Another avenue for the special talents of the architect is surely in that of applied psychology. Over the years since the early 1920's, sociologists and psychologists have been coming up with new theories of employee - management relationships, which have doubtless dumbfounded many of the old school industrialists. (My own father is of this generation, and he tends to be openly scornful of the more extreme of these theories - although he is one of the pioneers of trainee education in Lancashire, and very sympathetic to machine redeployment.) In England there appears to be no architect sufficiently in an industrialist's confidence to try out these theories,-which would have to be very sensitively applied if many of them are to work in reality. An example of this new approach is to have workers enter the plant by the same entrance as the management - instead of through a side gate or watch-house with its often poky air of utility and even suspicion. This measure, under test, has shown that workers instinctively begin to arrive at work with a neater, tidier appearance; with clean shoes for the carefully polished floor, or even carpet they must cross in the plant lobby Again I submit that the architect is the man who, by training, is equipped to tackle the job with the greatest chance of success, and who carries with him the greatest potential for getting the best out of these new design opportunities.

I would like to make three points which will enable the reader to appreciate my outlook to the subject as a whole and the standpoint from which I will tend to look at certain aspects of the problem. The first is that I have been brought up in England where, until 12 months ago I had resided, influenced by the island's economy and way of life. Further, and more important, I was reared in the heart of the Lancashire textile industry, and have known intimately its problems through personal family connections. My father is a textile weaving manager and throughout my life I have been a constant visitor to his and other mills in the area.

The second point is that I undertook a historical study of the architectural development of textile mills in Lancashire for a thesis which was presented for the degree of Master of Arts~~date~~ Liverpool University in 1951. This study convinced me that if the contemporary architect is to make any real contribution to the industrial rehousing program, he must first be willing to explore the 'raison d'etre' of the present situation, and to familiarize himself with the industry's problems before attempting to present managements with a solution.

In the course of my previous study, I made personal visits to over seventy mills, and while I was impressed with the courtesy and interest with which my project was greeted, I could not avoid sensing the cautious reticence which met my theories of architect designed

structures. The architect, at least in England, has still to break down the formidable prejudice against his services which is his unhappy legacy from the 19th Century. Isolated cases have recently appeared in England which indicate that at last manufacturers are willing to avail themselves of the unique talents that the properly equipped architect can bring to bear upon his problem. In America I am happy to note that the process is in a much more advanced state, due firstly to the less rigid post war economy, (allowing a great volume of work to be carried out), and secondly, a point to which I have already referred, to the marked tendency to decentralization and suburban, rather than urban sites, thus affording managements the opportunity to advertise the excellence of their product through the merit of their well designed factory.

The third point stems directly from the second, and concerns the long term plans that I have made for combining the researches I have made for the Liverpool thesis and the present work. When I embarked upon the M.A. Degree at Liverpool, my aim was to try and present some serious thoughts on the prospect which lies ahead for the architect in the realm of industry. This idea was quickly disposed of by the authorities, who quite rightly maintained that the time for prophesy would arrive when I knew what I was talking about in the first place.

I therefore undertook a detailed historical analysis with a view to understanding the 'why' of the present situation. This done I felt free to look more closely at the current work, and in preparing this dissertation for the Massachusetts Institute of Technology, I have tried to equip myself more fully for the task of compiling a book for publication on the subject of industrial architecture. This final culmination to these studies is my long term aim, and it is my sincere hope that this present study will be considered merely as part of a much larger work, and that the many gaps in the continuity will be looked upon in this light.

Furthermore, the duration and financial limitations of my stay in the U.S.A. have made it impossible for me to do any but the most flimsy field research at the time of writing. Before returning to England I hope to make a tour of many of the more famous contemporary examples of industrial architecture in America, but I wish it to be understood that I have had no chance to personally appraise the plants I comment upon, and my knowledge is derived entirely from current literature. This field survey, is, I believe, of paramount importance to the value of my stay here, and much of what I learn in the course of the tour will, I hope, be incorporated in the final work for publication.

These three points, then, will condition my whole approach to this study, and I hope that in the foregoing paragraphs I have established a firm case for my contention that the architect is in a vital position to make a positive contribution towards the creation of an industrial architecture, and that the time is now ripe for that contribution to be made if the suburban townscape is not to suffer the same fate as did the strictly urban development of the last 100 years.

The problem would appear to be one of deciding how best this contribution can be made; how the architects can marshall the many talents of the technical specialists concerned with industrial undertakings, and produce a structure which is more than a 'machine for working in'. From the many sources I have referred to, I failed to find an author who made a deliberate effort to relate the fundamental factors of utility and technology to the overall problem of the erection of structures in which man can amenably spend one half of his wakeful days in the production of goods in the least possible time, through the shortest possible route. Over a period of the last three years I have tried to equip myself for this task, and this study may be considered a dissertation on how I feel the architect can prepare himself for the practice of industrial architecture, by listing and

discussing the main sphere of research he will have to explore - beyond and above what he might reasonably be expected to have studied in his normal training. To do this I feel I cannot do better than follow such a course myself and consider American industrial architecture from the standpoint of one who is already an architect but wishes to acquaint himself with the specialized problems with which he will be confronted when actually in practice and advising clients on the design and erection of industrial structures.

I am convinced that this is the correct attitude towards a work of this nature. A thorough, informative analysis is the only method which can produce a study which is any good to the profession. Too, often, when confronted with a job, the architect will flee to a library for information on the technical problems connected with his new commission, only to discover that if there is anything at all on the subject it is often of the most superficial nature, and consists of nothing more than a brief pot-pourri of some recent buildings of the same class, and the limit of the research possibilities is reached when he has acquainted himself with some large, beautiful photos taken on a cloudy day with a red filter.

I believe it is not mere chance, or a fortuitous coincidence, that the general level of hospital and school

design has climbed to such a high level since the war. On these subjects there is a wealth of technical data, and the architect can certainly not complain of lack of information, - even though it be somewhat scattered, - and a little study will reveal all the basic information required concerning technological requirements, recent trends and developments, and the reasons behind the current evolutionary pattern in the design of contemporary structures. Having set forth this statement of certain convictions which appear to me basic and valid for the type of work I wish to do, I will conclude this Preface with a description of the format within the following pages, and some comments on the particular aims in each section.

The First Part of the study analyzed the various factors which are an indispensable part of any industrial undertaking, and a knowledge of which is important to the industrial architect. The first step in the process of erecting a new factory is plant location, and the architect may be called upon as a consultant in this respect. He should therefore have within his knowledge the guiding principles behind plant location so that he may talk informedly with experts in the field. Some of the influences on location are basic and should be well understood; many considerations may be critical in determining the eventual location, and knowledge of their importance can avoid prime selection errors.

The area having been chosen, there comes the question of site selection, - one which the architect may have much cause to regret if he chooses unwisely through lack of knowledge. He must learn to resist the temptation to build on a superficially fine site when other factors are more important, and it is only through knowledge of the relative importance of many factors concerned that wise decisions can be made. It is at this stage that the decision must sometimes be taken to build in a trading estate. The architect must realize that these zoned areas are not the panacea for all ills, and he must know the factors which militate against its many advantages. These principles of site selection will be discussed.

The study of the broader aspects of industrial location is a highly specialized field and one in which the architect cannot hope to become more than 'well informed', (the present study takes it as far as I consider the average architect need go), but site selection is very much more his responsibility, and the final step, the erection of the building, is one in which he should be constantly trying to increase his knowledge.

This will form the first section of Part One, and considerable attention will be paid to the various aspects of factory design. First under this heading comes factory

layout with an analysis of the purpose of production flow studies and the value of 'time, motion' research. This leads naturally into the fundamental principles of plant layout and a discussion of modern materials handling, the mechanization of which has revolutionized plant layout in the last 30 years.

In Part Two we move from these basic studies and begin to think about structure. Here, great strides have been made in freeing the floor space of columns, but the architect must be able to judge when free floor space is not the prime factor, and when economy, or lighting or other features are of more importance. The great trend towards expandability and salvageability of structure is one which the designer must study. The panel wall has still to be exploited to the full in this respect, and this and the structural aspects of walls, floors and roofs, mechanical services and the practical and esthetic advantages of a correct approach to color and lighting are the main burden of this Part.

Lastly I hope to discuss a little mentioned topic; the esthetic considerations of mill design. Little has been written on the psychological effect of pleasing elevations, elegant entrance ways, amenable working conditions, effective landscaping and well laid out approaches. Enough has

been said however, to convince one of the material benefits to be derived from consideration of these things, both in increased productivity and low labor turnover figures. There are several plants now in operation in the U.S.A. which seem to me to bear some or all of these points in mind in their construction, and to close the work I would like to refer to some of these by diagram or photograph.

During my studies in preparation for this thesis, I came across much material, which, while not relevant to the main topic, has direct or indirect bearing on industrial architecture. In view of its associated interest and future value to my studies, it was agreed to relegate this data to a series of Appendices rather than omit it altogether and so possibly waste much useful information.

The first of these Appendices is an historical survey of mill architecture. It was invaluable to the author as a groundwork for an understanding of the American industrial scene, for there are several important differences between early English and American mill structures. Since I have already done a detailed study of the historical aspect in England, and as I have only one study year in the U.S.A., I have not attempted a comprehensive retrospective study in order that I might concentrate upon the contemporary scene. The remaining Appendices are self explanatory and need no elaboration.

I hope to show in this dissertation that we are arriving at an increased awareness of the importance of well designed plants, and that it is the architect who is leading the way back to a sensitive expression of this tremendously important facet of 20th Century life. If this argument fails to carry conviction, I at least hope to persuade the reader, and the architect in particular, that the struggle to evolve an architecture for industry is worthy of his deepest study; that far from being a junior engineering draftsman's job, the expression of our industrial age demands the utmost skill and ingenuity.

PART ONE

OVERALL LOCATIONAL AND DESIGN CRITERIA

PART ONE

OVERALL LOCATIONAL AND DESIGN CRITERIA

Chapter 1Choosing a Regional Location : The Problem.

As I said in the preface to this work, the first possible contact the architect can have, as a practitioner, to industrial architecture is in plant location.

Plant location is a very complex study, and I feel that since there are many scholars in this field who devote their exclusive attention to its problems, there is no need for the architect himself to make exhaustive researches, and take valuable time from considerations he is by training more competent to pursue.

This brings me to the first important point I wish to make in this chapter, namely that plant location IS a complicated subject and one which is constantly engaging the attention of scholars, since the contemporary pattern of life is fluid to the point where it makes the task of reducing the subject to some well defined statement extremely difficult and dangerous. Stated in this way, the above assertion seems

perhaps selfevident, and so indeed it should be. The fact is, however, that past experience has conclusively shown a prevalent unawareness of the pitfalls awaiting the unwary industrialist and his advisers, and a very high percentage of industrial failures can be attributed to faulty site location.

I wish to make it clear at this point that we are discussing plant location in the widest possible terms. That is, the problem of what section of the country, or of the state, shall the client build. This is distinct from considerations of detailed site location within the chosen area or problems of site planning, which we shall discuss in detail later.

The architect should therefore be aware of the problem in the first place, and then be conscious of his basic inability to be an expert in the field, - unless he foregoes his profession to become one. In this initial stage it would seem that there are two ways in which the architect can equip himself to be of real service to his client. The first is to acquaint himself with the names and reputations of men who are acknowledged experts in the field and to whom he can direct his client for competent advice. America is fortunate in this respect. There are a number of firms, individuals and agencies which are

available to manufacturers for advice on plant location. This is not the place to list these sources, and it is sufficient for our purpose to note their existence and wide experience.

The second area of research is more specific. The architect can apply himself to acquiring some basic knowledge of the principles involved in site location, so that he may intelligently discuss its problems with acknowledged experts; for it is a fact that if two intelligent persons are presented with the same facts, they are both likely to make invaluable contributions to its solution - even if one is much more skilled and experienced in the field than the other. It is at this point that our detailed research can begin, and as it progresses I feel it will be of interest to introduce something of the British approach to the problem, so that together, the conditions in the two countries can compliment each other, and where they differ, the comparison will serve to clarify the point. Our aim in the next few pages can therefore be said to be one of giving basic information supplemented by a few facts and figures to give point to the discussion.

• • •

"Theoretically the most favorable location of a plant is that spot where, in consideration of the business as a whole, the total cost of producing and delivering goods to all the customers is the lowest."¹

This statement can serve as our text and a broad check against which we may test any theories of location which may arise. The broadest question which one can be asked regarding plant location is - "Which part of the country will most suit my purpose?". The first prerequisite demanded of the consultant when studying this problem is the ability to take a completely dispassionate view of the factors for or against a particular locality. He can be of valuable service to the client in this respect, for the industrialist is very likely to have some strong sentimental attachment to the location he has occupied for several decades, and may be therefore biased in his thinking. The markets which were the reason for the original location may, on analysis, be showing signs of movement, and the consultant should therefore start by making a chronological history of the plant showing 5 year intervals for the growth of the company, increase in staff, alteration of taxes, of rates, additions to floor space, labor costs and difficulties, maintenance costs, etc.

Such information will help the management to see clearly the pros and cons involved in either moving to a different location or even starting up an entirely new

industry. A typical example of the value of such a study would illustrate to the manufacturer how much freight adsorption is necessary to equalize a competitor's more favorable position. Most managers are quite uninformed on this vital point and it is very important to show the difference between production and distributive costs.

Industries differ widely in the relation between these costs. For example, textiles average distribution costs account for only 9.2% of the total manufacturing costs, but in other fields distribution is most important, e.g. 25% in machinery, 31.6% in confectionary and beverages, 33.1% in furniture, 38.6% in paints and varnishes, and 38.8% in drugs and toilet goods.²

The first essential, therefore, is to determine the type of goods to be manufactured, and the disposition of the intended market. A large map may be prepared showing the extent of the market, the location of competitors, distribution facilities and the accessibility of raw materials, so that new plant facilities may be established at a point where a definite freight advantage can ensure control of a substantial market, and where a good competitive position can be maintained in important adjoining market areas.

Generally speaking, the extractive industries are best located at the source of the raw material. This obviously

applies to the mining industries, since the final weight of the finished material or mineral is far less than the excavated ore. If a pure or undiluted material is used in manufactured articles without loss of weight, then the plant can be sited at the source, at the market, or at any point in between, depending on other governing factors. Again, if a ubiquity is used, the location should be at the market since the material is universally available.

The above paragraph indicates that the aim is always to locate industry where there is the lowest transportation cost, but the picture is more complex than it would seem, and so many factors militate against a simple solution. Traditionally, plants were located near the raw materials, so that such trades as the leather and tanning were settled in the State of Massachusetts where there is the bark of the oak and the hemlock for tanning. Today, however, transport is much improved and the attraction of good labor and steady markets is very influential, so that only the heavy extractive industries, and those which use bulky or perishable raw materials remain at the source. Saw mills, papermills, cotton gins, beet sugar refineries, food packing and dairy products are some of the most important industries in this latter class.

An excellent way of determining the relative merits of two or more locations is to set up a comparative

analysis such as the one reproduced below. In this example, A and B are the locations, the market is assumed to be the same destination, and the sources of the raw materials are limited to those shown. The production costs are assumed to be equal.

<u>Commodity Raw Material.</u>	<u>Total Annual Wt. in lbs.</u>	<u>Carload Rate in ¢/100 lbs.</u>		<u>Total Freight Costs</u>	
		A	B	A	B
1	16,000,000	225	170	\$360,000	\$272,000
2	9,000,000	350	100	315,000	90,000
3	4,000,000	60	30	24,000	12,000
4	2,000,000	240	180	48,000	36,000
Finished Products	25,000,000	300	500	<u>750,000</u>	<u>1,250,000</u>
				<u>\$1,497,000</u>	<u>\$1,660,000</u>

A differential is shown in favor of A; \$163,000.³

It can be deduced from this example that point B is too close to the raw material source and too far from the market, and the example illustrates the importance of setting up such a comparison before deciding on the relative merits of two or more possible locations. It also shows the research which must be done on the raw material, for not only must the location be determined, but also its availability price, the terms of sale, and the freight rates to the site.

The Influence of Transport.

We can now examine in more detail the individual elements which go to make up the total picture, and which must be understood before the location can be decided, but I wish to reiterate my belief that only the broadest outline of this field can be grasped by the architect, and I include in the following discussion only such information as I feel the architect should have at his command.

Transport is without doubt a most critical factor, and is the key to all economic progress. Statistics show that virtually every new industrial enterprise is located on or within easy reach of an established transportation route. Access to some sort of communication artery is imperative, and here the influence of topography can have a most marked effect upon transport. There is an area in Tennessee, for instance, which has no railway within an area of 70 miles by 90 miles, and it is obvious that a factor such as this would seriously condition any decision to build there no matter how favorable the markets or the availability of the raw material.

In America, the fact that one is on a railroad or highway does not ensure perfect or even adequate transport-

ation. The country is so vast that the railway system, for instance, is cut up into many companies and the various topographical features form barriers to transport so that one or both of these factors may result in enforced transfer from car to car. This adds considerably to the cost and the architect should be at pains to study the operating areas of the various companies to be sure of their operative limits. One can well imagine how the location of a mill could be decided by the fact that a river constituted the limits of one company's territory. Depending upon the direction of the market, etc. the location would then be preferable on the one bank even if many other lesser advantages would seem to indicate the contrary. This is an example of how a little research can save hundreds of thousands of dollars.

To mitigate the excessive cost of transfer, two rating systems are in operation for freight. The first is known as Car Load (C.L.) which represents a full car load of products which is never transferred from that particular truck regardless of operating boundaries; it is interchangeable all over the country, and results in a considerable saving. The second rate is known as Less Than Car Load, (L.C.L.) which is the ordinary condition in which many different manufacturers products are in the same van allocated for different destinations. Here, of course, handling raises

the cost appreciably, since in a journey cross-country, a given product can be handled several times. This has led to the introduction of a special 'middle man' known as a freight forwarder, or a car loading company which is completely equipped for the job, and is capable of showing a reduction in cost.

One of the most challenging design problems today arises from the rapid development of road haulage, and it certainly constitutes the greatest threat to the railroad in that, for many classes of goods, it is cheaper to deliver by road. Road transport offers the great advantage that, given reasonably careful routing, a product need have no more handling than is necessary to load it onto the truck at the factory, and unload it at the destination. Even with the C.L. ratings on the railroad it is still usually necessary to take goods from the factory to the goods yard and then later from the train to the final destination - that is unless both origin and destination are fortunate enough to be in direct communication with the railway.

There are certain cases where this is possible, and the resultant savings are most impressive.⁴ One such example is the whole extractive industry where both origin and dest-

ination are frequently on a direct railroad. In these cases road transport can never compete, because not only is rail quicker, but one trainload can carry as much as a whole fleet of trucks with their attendant costs in both materials and manpower.

Road transport has also encouraged the development of Truck Load and Less Than Truck Load carriage, although the service is not yet complete or uniformly distributed throughout the country. This means care in plant location , and the consultant should check the latest position before reaching any final locational decisions. Where the service is well established, however, there is intense competition, but the system differs from railway operations in that truck routes ignore sectional boundaries and follow the flow of interterritorial traffic.

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Waterways are a much more important factor in plant location than is generally realized. A vast amount of freight is carried by river and canal in the U.S.A., and it is a very economical form of transport if other factors permit siting a factory near its sphere of influence.

The most important river artery in the U.S.A. is the Mississippi, which has a navigable depth of 9 feet from Baton Rouge to Minneapolis; during which distance a boat is lifted through 26 locks and dams. The Illinios

Waterway connects the Mississippi with Lake Michigan and is a further 327 miles long. Again from the Mississippi, at Cairo, forks the Ohio River, and this forms a navigable waterway 981 miles eastwards to Pittsburgh. There are many improvements afoot to make these cheap forms of transport even more efficient, and the latest development allows a tow of 20 barges carrying 20,000 tons of freight which is the equal of 400 carloads or 4 full trainloads.

To help promote river traffic, the Federal Barge Lines compete at a loss on the Mississippi. This gesture has also the effect of helping develop backward areas, and stimulating the invention of new waterway techniques - a process which came to a standstill in the early 20th Century due to the vast, and overwhelming challenge from the railroad and later from road transport.

The presence of the Great Lakes means that a further 1,500 miles of navigable water is available to the great industrial north-eastern sector of the U.S.A. and at the moment it is the longest navigable inland waterway in the world. It is ice free for $7\frac{1}{2}$ months of the year, and it carries 85% of all the iron ore in the U.S. quite apart from a huge traffic in coal, stone and grain. I say "at the moment" for as everyone knows, the U.S. Government has recently ratified a Bill which permits the construction of

the much-mooted St Lawrence Seaway, and ensures U.S. participation in the enterprise. After 20 long years of wrangling, therefore, a project which was obviously of great economic benefit to mankind in general has been sanctioned, and the repercussions of this waterway will be felt the world over. It is obviously of great value to the Canadians, and it will bring added importance and wealth to Chicago, Detroit, etc., for it makes every inlet and settlement on both sides of the 5 lakes a potential seaport. This is a fact that financiers have not been slow to appreciate for they have been buying up huge tracts of currently almost worthless Canadian land along the lakesides, speculating on the reasonable hope that in years to come it will increase in value and may well become priceless.

I have dealt with the St. Lawrence Seaway and the Great Lake Region at some length, because not only do I know its possibilities to be very great (with the progress of the new canal having a profound effect on industrial location), but also because I feel that it is with such developments as these that the industrial architect must keep in constant touch, for a knowledge of them and up-to-date reports on their progress can be a valuable pointer to correct orientation of a new industrial enterprise.

We can see therefore, that the water transport of industrial goods is a highly beneficial method of conveyance, and despite its lack of speed, highly valued manufactured goods prefer this method.⁵ Such items as heavy machinery which would be cumbersome on road or rail are obvious examples of the advantage of water carriage, because river barges can carry bulk goods at low cost and typical loadings are anything from 300 to 500 tons.

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The possibility of air freight is a relatively recent development, but for certain classes of goods it has already become an imperative adjunct to their choice of site. While it is true that comparatively few industries transfer the bulk of their freight by air, it is interesting to note why the minority do.

The overriding factor is, of course, speed and the advantages which accrue from it. The transfer of wearing apparel by air, for instance, permits low inventories, "feeler" sales, and the possibility of meeting seasonal demands: the phonograph record trade can rush supplies to meet unexpected demands, television and auto part manufacturers can fly parts to distributors, permitting them to keep low stocks and so

avoid being caught with obsolete parts. Flowers, vegetables, livestock can all be advantageously shipped by air and all claim the advantages of less capital requirements, less warehousing, lower operational costs, lower shipping weights, less insurance, less pilferage and less commodity deterioration.

The length of haul is very important, for it can be shown that the longer the haul, the more economical the air freight. Road haulage can do distances of 300-500 miles overnight so that distances over these figures should be aimed at. Indeed in 1951 the figure for trunk lines was 628 miles and 1462 miles for all-cargo carriers.⁶ Even so, air freight can only compete with Less Than Carload Traffic and the very expensive railway express. These last two transport systems have already felt the severe competition of the air carriers; a competition which will grow ever more formidable as a really efficient basic freight plane is developed.⁷

The Influence of Labor and Power Availability

Owing to the ever increasing mechanization of plants, labor is less of a problem than it was in the early 20th Century, but for skilled work, labor is still sometimes the greatest single influence in locating a factory. It may be said that in large cities there exists an adequate work pool of employees who are accustomed to factory life

and familiar with machine employment, and who can easily
be replaced.⁸ On the other hand, small towns should not be overlooked purely on these grounds, for their workers are less likely to seek other jobs, since they are generally more stable and have fewer social distractions: furthermore, such a location usually involves a lesser commuting distance, and this brings in its wake happier and more productive employees. It may be seen therefore that these two opinions may each be valid for different circumstances, and that the guidance given in any written work must of necessity be most general. It also stresses the importance of a detailed sociological research to ascertain the facts, and it is upon these facts alone that a decision can be reached. Such labor problems are not within the scope of this thesis nor do I consider them to be within the scope of the architect, but he should be aware of their importance and realise the fact that "labor cost is a vital percentage factor in total delivered-to-customer cost of a given product, the community finally chosen will exert tremendous influence on the competitive position of the new plant."⁹

A typical example of the influence of labor on an industry is in the textile trade and although it is true that New England has lost a lot of its monopoly of the cotton industry, it still has the following advantages which are listed by Knowles and Thomson.¹⁰

1. It still profits from the advantage of an early start and retains those industries that originated there and that continue to work at a profit.
2. It offers the advantage of highly skilled labor much of which cannot be duplicated elsewhere.
3. It provides a good location for industries with products requiring skilled labor, with its high unit value, which is therefore capable of absorbing the high transportation cost to market centers.
4. New England itself is a large market and will therefore retain industries which find markets there,
5. It attracts workers as a recreational area, and provides an amenable climate in which to live.

In general then, the architect can become aware of the labor problem by examining statistics or having those statistics professionally analysed to ascertain such things as the present status and trend of the population, the types of labor available for employment in the various trades (and in the proposed one in particular), the current wages paid in competition with like industries in the area, the attitude of the local unions, and the sociological stability of local labor.

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The next general consideration to which we may give attention, is the importance of power resources. In our brief study of the historical development of industry in America, we may see how power was the chief influence overriding all other factors in industrial location.¹¹⁰

Today, water power is no longer such a determining factor for with the development of hydro-electric installations there has resulted a comparative independance, except in the case of the heavy consumer industries such as the electro-metalurgical and electro-chemical groups. Nevertheless the following points should be taken into consideration concerning power availability:

- a) The type of service: 1. Hydro-electric; 2. Steam or other energy.
- b) The reliability of the service and the history of stoppages.
- c) The adequacy of the supply and a further chart indicating any seasonal restrictions.
- d) The kind of power, e.g. phase, cycle and voltage.
- e) The current rates and a graph of their fluctuation.
- f) The availability of off-peak contracts and the possible benefits to be gained thereby.
- g) Fuel adjustments.
- h) Lighting allowances.
- i) Discounts and penalties.

A steady water supply is essential to most industries and care should be taken to ensure both this and an adequate waste disposal system in the area. The water table will be of importance if no direct source, such as a stream, is available and if it is too low some idea of the boring cost should be ascertained.

Disposal of waste can present several difficulties. One of the least appreciated in the past studies is the problem of atmospheric pollution. Most industries are capable of being set in towns, but some, like heavy metal and chemical industries are bad neighbors and care must be taken if one has the task of locating them to the wellbeing of the community. A heavily settled community can involve a considerable amount of expense on the part of the manufacturer if obnoxious gases are to be treated before being dissipated into the air: a country location might avoid this.

Industrial waste can be put into two categories, liquid and solid, the former being the more difficult to deal with. In this case, a public sewer or estuary is essential to ensure complete disposal of the waste, and if a sewer is not already in existence, the building of one can be an extremely costly undertaking if the site is in the

country. Solid waste can usually be dumped, or carted short distances at economical rates and need not therefore be such a critical item.

The Influence of Climate.

Finally, climate can have a deciding influence upon the final decision to site a factory, for it may have a subtle but definite effect on the workers capacity to produce, as anyone who works in Washington D.C. will testify! The productive drive and quickness of the American people as a whole has been attributed to the invigorating nature of the climate and it is interesting to note that the northern section of the continent has produced the greatest technological and industrial enterprise: for confirmation of this one may spin a globe and note the areas on or about the same latitude which have produced the most industrious nations.

Apart from the effect upon the employee, the many different categories of industry sometimes require special climatic conditions. Air pressure, humidity, exposure and average temperature can all play a vital part in decisions to locate a factory, and for historical corroboration one has only to consider the siting of the early textile trade in both England and America. More recently

an aircraft manufacturer chose Tennessee rather than Pennsylvania, because the fine weather in the former state would give more flying days for his tests.¹² Such a consideration could well be the determining factor in the controversial siting of the proposed U.S. Air Academy. At the time of writing it has just been announced that Massachusetts is officially out of the running, and weatherwise, it is astonishing that it was ever considered, since a thoroughly bad winter could seriously curtail all trainee flying for anything up to 6 months in any one year.

The great cotton belt will always be attractive because of its cheap labor. This is not entirely because of the negro population, for it also stems from the warm climate. The heat makes heavy garments unnecessary, and for long periods of the year few clothes are worn, houses are not heated and the cost of living in general is therefore much lower than in the north where heating bills are a major item in winter. Food in the South is also cheaper due to climatic conditions, and the extremely low (or non-existent) frost table, and negligible snow fall makes for lighter, more economical construction, and faster production since no hold-ups for bad weather are experienced.

Wind velocity and prevailing winds may present the planner with ventilating problems and obnoxious gases can be

a serious threat to health if they are blown towards housing settlements. In this matter the U.S. Weather Bureau is most helpful in supplying information and other aspects of climatic conditions.

I think the architect should also be aware of the various official departments carrying information which is available to him at any time. The names in themselves are sufficient to explain their speciality and no more than these will be mentioned here. The Federal Reserve Banks, The Federal Trade Commission, The Interstate Commerce Commission, The U.S. Geological Survey, The U.S. Department of the Interior, and The U.S. Department of Commerce are all official organizations set up for the welfare of the public. Each is a storehouse of vital statistical information and the architect should avail himself of their council.

In conclusion it may be of interest to refer to a table of "Distribution of Location Reasons" compiled by W. F. Lipman in his recent survey of industry in the Boston Metropolitan Area. This table confirms many of the points I have mentioned while omitting other factors.

"DISTRIBUTION OF LOCATION REASONS" *

Compiled by W. F. Lipman, in his recent survey of industry in the Boston Metropolitan Area.

M denotes ordinary manufacturing plants,
D denotes warehouses.

<u>Item.</u>	<u>M</u>	<u>D</u>
Site Advantages.	25	4
Employment factors.	19	2
Conversion to One Storey Operation or other layout leading to improved production.	17	7
Improved Transportation.	16	8
Intangibles. (Architectural and esthetic considerations.)	15	4
Character of Operations.	14	4
Nuisance Factors.	6	1
Management Factors.	4	1
Zoning.	1	-
	117	31

Does the Above Criteria outweigh Financial Consideration?

Yes	16	6
No	6	4

* W. F. Lipman, "The Development of Planned Industrial Districts in the B.M.A." M.C.P. Thesis, M.I.T. Jan., 1954, p.12, Table 5.

"Site Advantages" is a rather vague item and covers many points such as space availability, drainage, power, services, parking etc., and therefore overlaps some of the other reasons. Note the low rating of Zoning.

Chapter 2

Choosing a Site

Having chosen the general area, or section of the country which appears to be most suitable in the light of the above considerations, there remains the task of scouring that region for the 'perfect site' for the plant. Many of the broad considerations recommended in the foregoing chapters still apply and may be used to ascertain a given plot's suitability. However, when one has reached the stage for detailed decision and choosing a particular plot, there are other factors which should be studied.

In America, the most important trend in plant location is the tendency to decentralize, and site factories on the periphery of towns. A decision to built in a town center is therefore one to be taken with caution, and the advantages of a town site, which usually comprise those of a ready-made market, and short commuting distances for employees, should heavily outweigh the many disadvantages in the form of expansion difficulties, high taxes, parking restrictions, difficult access to raw materials and so forth. There are one or two examples of recent factories being built in town centers, but their advent is so rare as to warrant special attention in the technical press.

In country locations, possibly the main temptation to avoid is that of building on a good looking site. In the first place the recent trend to peripheral planning makes sites easy to find, and it is rarely necessary to turn an area down because no suitable plot could be bought or rented. Secondly, the site's position relative to the community and in relation to all the factors we have discussed is of far more importance than purely esthetic or sentimental reasons.

If one is satisfied that the reasons for building near factories manufacturing similar products are valid, and that competition is not too fierce, there may be considerable advantages to be gained from building in close proximity to other mills of the same industry. The chief benefits may be accrued from the pool of skilled labor that such an area produces, and an economy of production which results through specialization. The area becomes known for a particular produce, and much publicity value may be enjoyed from this fact. Furthermore, when an industry becomes particularly prominent in any given area, the principal town in the district often sees fit to include special training facilities for prospective employees in its Technical School. Examples of this may be seen in several New England towns such as New Bedford where the local Technical School teaches textile technology to a very advanced stage.

Different industries naturally require different basic facilities and different degrees of those facilities, and it may be of use to study a chart such as the one reproduced below which indicates by a system of arbitrary numbers the importance of a given facility to a particular industry. The data is taken from the figures for the U.S. as a whole:

"INDUSTRIAL DEVELOPMENT FOR A COMMUNITY"

Prepared by the Policy-holders Service
Bureau, Metropolitan Life Insurance Co.
New York, 1932.

<u>Reasons</u>	<u>Food Ind.</u>	<u>Textile Ind.</u>	<u>Lumber Ind.</u>	<u>Machin- ery Ind.</u>	<u>Leather Ind.</u>	<u>Chemical Ind.</u>
Markets	1	2	1	1	3	1
Labor	4	1	2	2	1	3
Transportation	3	4	3	3	6	2
Materials	2	6	4	6	4	4
Available buildings	6	3	5	4	2	5
Power & Fuel	7	5	7	8	-	7
Near Related Industry	8	-	8	-	5	8
Living Conditions	5	7	6	7	7	6
Financial Aid	-	8	-	5	8	-

The most accurate way of eliciting the above information about an area is to conduct a community survey. From this one may learn many facts of statistical and psychological importance and in addition to checking them against the above table they may be expected to throw light on some or all of the following topics:¹⁴

a) The Community.

The efficiency and effectiveness of the Local Government and the encouragement it gives to its industry. The conditions that have caused industries to leave the community are important, and the advantages and disadvantages of having local existing industries as near neighbors should be studied. The adequacy of public services apart from the sewer, water and power supply, are of importance and the past record of efficiency of the local fire department and police force should be studied. Living conditions in the area have a considerable effect upon the class and efficiency of the employee and good housing, recreational, school, hospital and church facilities are distinct advantages. The latter consideration is more than usually important if the Roman Catholic faith is predominant in the area.

b) Labor.

This information will merely supplement the

statistics which should have been studied in the more generalized survey of the area, and the local conditions of labor, its status and its trend will be of vital importance.

c) Markets.

Here again the marketing facilities for the goods produced in the factory should have been studied already, and the distance and travelling time weighed against other factors. The local market however, may be of some importance in certain classes of industry, and the nearness of a shopping center will also help the employment of female labor particularly if the location is such that it offers opportunities for noon-hour shopping.

d) Transportation Services.

This item will also have been studied as concerning the factory's raw material, and the accessibility to its market, but for the convenience of employees, railroad services can be of great importance, quite apart from the opportunity to bring freight direct to the factory via the sidings. The trend to decentralization has led to highway locations growing in favor, owing to the very high car ownership in America. A large percentage of the employees come to work in personal or 'pool' cars and many more may use a local bus line. The rapid rise of trucking facilities makes good road access imperative and the disposition of the local

highways should therefore be studied. Water transportation and port facilities have already been mentioned, but the growing air mindedness of American business men and executives makes the consideration of air facilities of some importance. Peripheral planning also sponsors this development and in future years one can visualize helicopter taxi services from local airports to nearby factories and other amenities.¹⁵

e) Site statistics.

The proposed site should be analytically studied and such information as the history of flooding can be of vital importance and a danger not always apparent from a most careful site survey. Borings should always be taken to determine the nature and stability of the soil or rock, and in this latter class the geology of the rocks, their compressive strength and natural weakness or rate of disintegration is necessary for safe structures. Similarly, the local frost depth and water table, which may have seasonal variations, should be ascertained.

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Other check points could make sure the local building code will allow the proposed type of construction; that restrictive covenants and easements do not prevent the maximum use of the property, and if they do, to what extent. In

northern areas the responsibility for snow removal and maintenance of the access roads should be assured, and if the plant is to be erected beyond the city limits, assurance should be sought that the plant will receive full police and fire protection. Open land on two or more sides is very desirable for possible future expansion, and it is generally accepted that an area five times the actual size of a plant is considered a minimum to allow for all requirements.

Choosing an Existing Plant.

Finally in this chapter I would like to mention the case in which the architect is asked to deal either with a derelict factory or asked to convert a going concern to meet the requirements of the new owner. This of course brings the whole problem more specifically into the direct ken of the architect, and with some specialized exceptions he can tackle the job in a normal architectural way. These exceptions in the main concern check points to make sure all the necessary facilities will be available when required, and I intend to do no more than bring attention to them by quoting an excellent check list which can be used for the purpose, and which is reproduced in Knowles and Thomson:¹⁶

AVAILABLE FACTORY BUILDING : INFORMATION SHEET.

Picture of Property

Location: Town: Jacksonville
Street: Williams

Lot No. 270
Plan No. 204

Sale: Yes No
Rent: Yes No
Price: \$ 65,000
Tax Rate: \$ 42.25
Assesment: \$ 55,000
Mortgate: \$ 18,000

Age: 26 years Previous Use: Cotton textiles
Condition: Good. Owner: A.B.C. Realty Co.

Distance from: Boston 40 miles
Portland 70 miles
New York 240 miles
Springfield 140 miles

Property Description:

Name: Rand Mill
Land: 250' x 190'
Building: Main building 75,000 sq.ft.
Other: Garage
Office

Building: Details of Construction.

Type: 3 storey
Construction: Heavy mill, timbers 14" x 14" first floor,
14" x 14" 2nd and 3rd floors: materials, long-leaf pine.
Floors: Area: 25,000 sq.ft. each. Safe load: 175lbs/sq.ft.
Walls: Brick, 2 feet thick on 1st floor, graduating 4"
on each floor, 20" 2nd floor, 16" 3rd floor.

(Available Factory Building: Information Sheet continued:)

Windows: Factory well lighted
Sash material: wood
Condition: fair.
Ceilings: (height to beams)
1st floor: 11' 0"
2nd floor: 10' 6"
3rd floor: 10' 0"
Stairs: Number: 2
Fireproof construction.
Elevators: Number: 1
Fireproof shaft.

Service facilities:

Material handling: No special equipment.

Transportation: Railroad siding: B. & M. R. R.
Length: whole side of building.
Distance from railroad siding: $\frac{1}{4}$ mile.
Trucking: 3 lines.

Water: City supply good.
Ample for process.

Fire Protection: Sprinkler system.
Private hydrants: city supply.

Power: Water power: None.
Steam plant: For heat only.
Gas: Yes.
Public utility: Yes, municipal plant.
Rates: Special contract.

Heat: Steam plant.
Cost estimated: \$1,500 to \$2,000/annum.

Other: Plant yard enclosed.
Fence new.
(and any other physical features of note)

Special Mortgage may be taken over by Purchaser.

Notes: Broker listings etc.
All local brokers.

Date: 18th June, 1954.

Chapter 3

The Industrial District

Up to this point I have dealt with the more general problems of site location since a too specific knowledge is beyond the scope of the average architect. With this background however, we approach problems in which the architect can be expected to be of real assistance in a detailed or particular way, and the first of these can be the increasingly important question: "Should I build in an industrial estate?" The architect should be in a position to set before the client a detailed exposition of the advantages and disadvantages of such a move with particular relation to the industry in question.

The basic idea of the 'trading estate', as it is called in England, was initiated in 1896 at Trafford Park in Lancashire, England, and it was immediately a great success due to the fact that it dealt solely with heavy industry and was admirably situated for transport and had railway service right up to the factory doors. The next one in England was some 30 years later at Slough near London, which dealt mostly with light industry, and it was much better

planned than Trafford Park with a carefully studied road and rail layout.

In the meantime, America had seized the idea and started her pioneer scheme under the leadership of H. D. Isham with the Clearing Industrial District near Chicago. At this time it consisted of only one block, but as we shall see later, it spread rapidly after World War II and is now probably the best known District in the U.S.A. In order to understand the main advantages of this type of development, we can study firstly the principles under which they operate, then the optimum conditions in design and layout and finally it will be useful to examine one or two actual examples in the United States to see how these desiderata fare in practice.

The popularity of the Industrial District is shown by the fact that the Urban Land Institute currently lists over 100 of them in the United States, and we may well start by quoting Mr Mowbray of the U.L.I. who says that an Industrial District is "a suitably located tract of land subdivided and promoted for industrial use by a sponsoring, managerial organization."¹⁷ The main services performed for the industrialist by a District may be summed up as follows:-

1. The sites are pre-selected and are assured to be at least

in favorable relation to surrounding markets.

2. The District contacts local taxing and zoning authorities and bids powerfully for the best terms and smooths out many official snags which may arise. The District's management will soon become experienced in this matter and can perform these services to the best advantage with the incoming plant's interests at heart.

3. It ascertains the availability of suitable labor, the transportation of the same, highway, railroad or water accessibility, switching facilities, low freight rates, and market access. These are all vital factors in the choice of an estate, for the sheer size of such an industrial community can influence the trend of markets and transport facilities in a way that a single factory could never hope to do.

4. It assists in financing if this is required.

5. The District authorities plan the whole area to ensure the correct relation of the plant to highways, railroad sidings, parking and future expansion.

6. The estate furnishes streets, water connections, sewers, and power, but usually makes provision only for their eventual development by the tenant. In addition, restaurants, medical centers and recreation rooms may be built for the

estate as a whole, so relieving the individual industries of the cost of these expensive items.

7. Some Districts, such as the Clearing District, design and construct the plant for the manufacturer.

8. It ensures a mixed expansion, together with convertability and exchangeability of plant.

9. The Industrial District protects each manufacturer against bad neighbors, a feature which can be an intolerable nuisance in a completely free industrial community.

The most typical District is set up by a Real Estate operator, but some are subsidized and set up at cost, or even at a loss by the local Chamber of Commerce, municipalities or railroads; the former two want to increase municipal tax and employment, and the latter hopes to increase traffic. If the plot is under lease these are gradually replaced by sales, but whether lease or sale, the conditions are strictly controlled by covenants or perpetuating building controls.

Plot sizes should be controlled for maximum size and experience has shown that the railroad sponsored estates permit the biggest sites. Such a situation is seen at the railway sponsored Roosevelt Field where the plot limit is 500,000 sq ft in contrast to the average upper limit of about

70,000 sq ft. This limit is subject to constant and increasing change and the Clearing District now averages between 50,000 and 60,000 sq ft, which is an increase of 1,000 sq ft per year over the last 20 years.

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The most favorable and popular location for industrial estates is a peripheral site, but care is taken to build within the urban distribution area. This means that the estate is within central express and pickup districts where rates are already low or where a powerful district might itself succeed in lowering existing rates. This has already happened at Chicago where the Clearing District extends 18 miles beyond the city. Nearness to a large urban conurbation also means that the site is contained within the local switching district of at least one railroad, and preferably in a terminal district, so that rates will not exceed those in adjacent metropolitan areas, - especially rates on Less-than-Carload lots, which is an important factor to small plants or factories manufacturing small bulk goods. The peripheral site should of course have good highway access and frequent rail service for workers.

One of the main attractions of a peripheral site, is the low land cost for contemporary one-storey plants which consume large areas of ground. For instance, Clearing Industrial District can still sell land for between 50 and 60 cents per sq ft, whereas a favorable location on Long Island,

New York, would cost at least \$12 per sq ft.

A central location is usually fraught with difficulties, but it may be preferable for certain industries who find it imperative to keep in close touch with the market. Prices are usually very high however, and difficulties of assembly, poor off-street parking and loading facilities etc. make the efficient organization of such a location very difficult to attain. In exceptional circumstances such as the recent projects in Dallas and Kansas, flood control projects have made it possible to build on downtown swamp areas which were formerly useless marshy acres and an eyesore.

Rural locations such as the Pennsylvania Salt Manufacturing Companies District in west Kentucky, is still more exceptional, and the only justification for such a location is that it is close to the raw materials of factories likely to desire a site in this area, and because the low cost of electric power, transportation and nearness to industries using the product in their own processes warrants such a location. The main difficulty is the labor problem which can be almost insuperable.

Design Considerations in Industrial Districts.

Employee transport into industrial estates, and indeed to all large plant groups demands more study and action.

The tremendous growth in the popularity of the motor car, and the increase in the standard of living, makes the problem of handling large volumes of traffic converging upon one area very difficult to control. In American factories at the moment, 77% of the personnel come to work by car, and at a huge District like Clearing, only 5,000 out of the total labor force of 24,000 come on the streetcar, while 17,000 come in private automobiles: these figures give a very high proportion of 1.7 persons per car.¹⁸ This rather frightening fact has led many managements to encourage "car pools" of workers, and it can be economically very effective from the workers' standpoint, and considerably reduces the car density both on the highway and in the parking facility. The introduction of shift work does nothing to solve this problem, because car parks for the two shifts must be provided to take care of the peak situation.¹⁹

The presence of the factory always tends to produce blockages owing to the deceleration of large volumes of cars, and for this reason deceleration lanes are imperative if a cloverleaf cannot be included because of land shortage or cost. Buses are no help in this situation because they become as jammed as the cars and average about 8 miles an hour in congested areas.²⁰

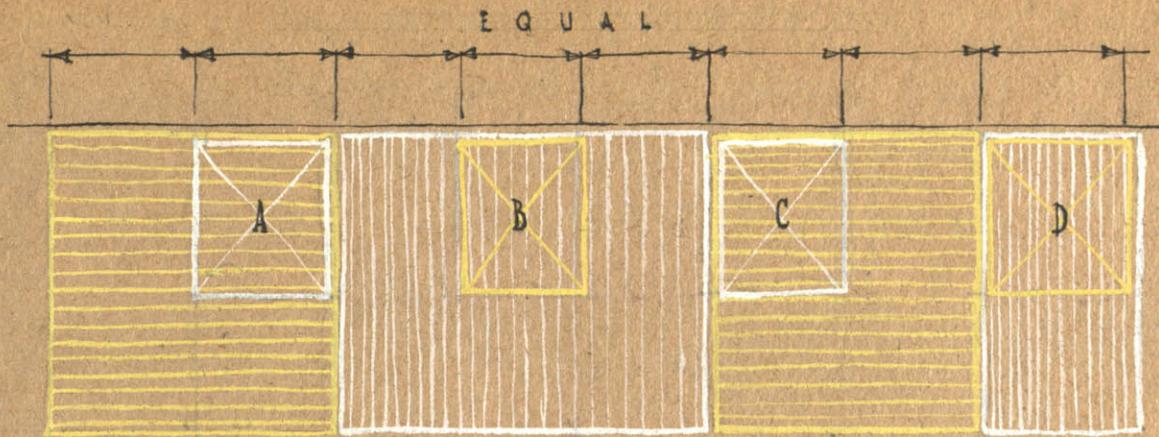
For all industrial estates, flat sites are the easiest to arrange, and a minimum size for a profitable operation is regarded as 80 acres. The maximum depends on the size of individual plants, and whether predominantly heavy or light industrial manufacturers will be attracted to the area, but 150 acres is regarded as the top limit if the factories average 50,000 sq ft.²¹ The lot size depends upon the plant but a 30% to 60% coverage should be the maximum. The road design will naturally be dominated by individual sites, but principal and secondary roads should be wide enough to deal with all traffic and should give a good setting to factories which face them. The roads in the Team Valley and Treforest trading estates in England have main road widths of 180 feet and 160 feet respectively. In these estates the average plot depth is from 500 feet to 650 feet and twice this distance is allowed between cross-roads.²²

If a railroad is incorporated in the estate, the distance from the street to the railroad siding should be at least 200 feet and not more than 500 feet. The shapes of the lots should be variable and maximum flexibility can be obtained when the railway enters an estate block at an angle, so making the area easily divisible into various sizes.

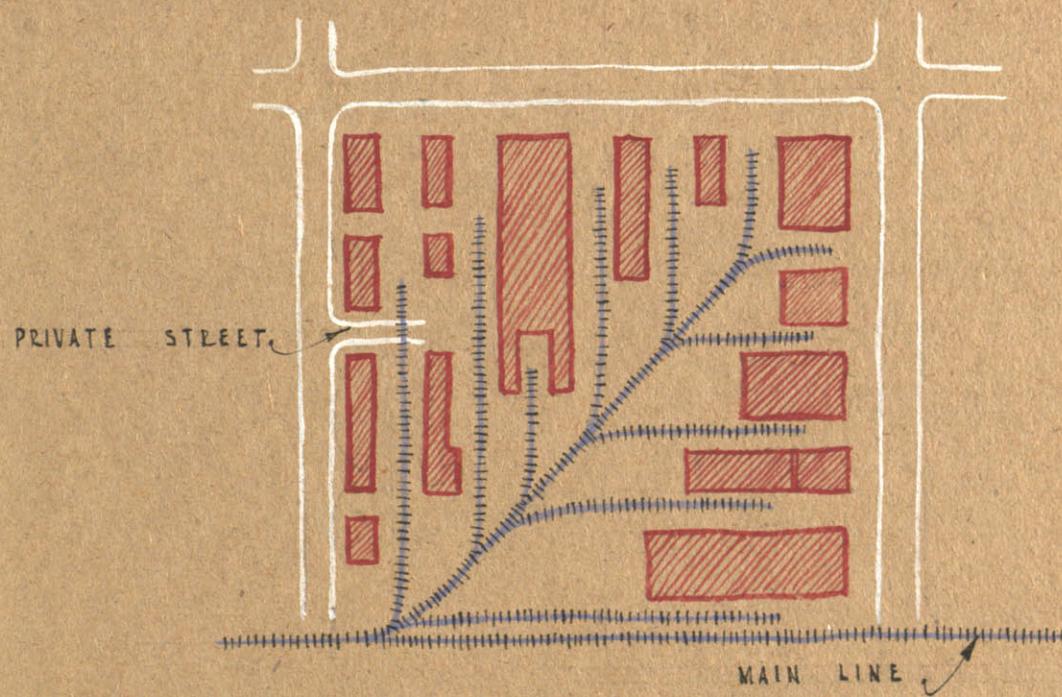
Another very flexible arrangement may be obtained by arranging the buildings on the plot so that the gap between the factories is equal to half the total frontage, and half the depth at the rear. It can therefore be seen (see sketch) that the four factories, A, B, C and D can each expand in a different way and to a different degree. The question of 'land expansion' is important, and the estate should require the tenant to rent such a reserve or purchase an option on adjacent land for a period of two years, because few manufacturers foresee the possibility of expansion, and the great majority ultimately require it.²³

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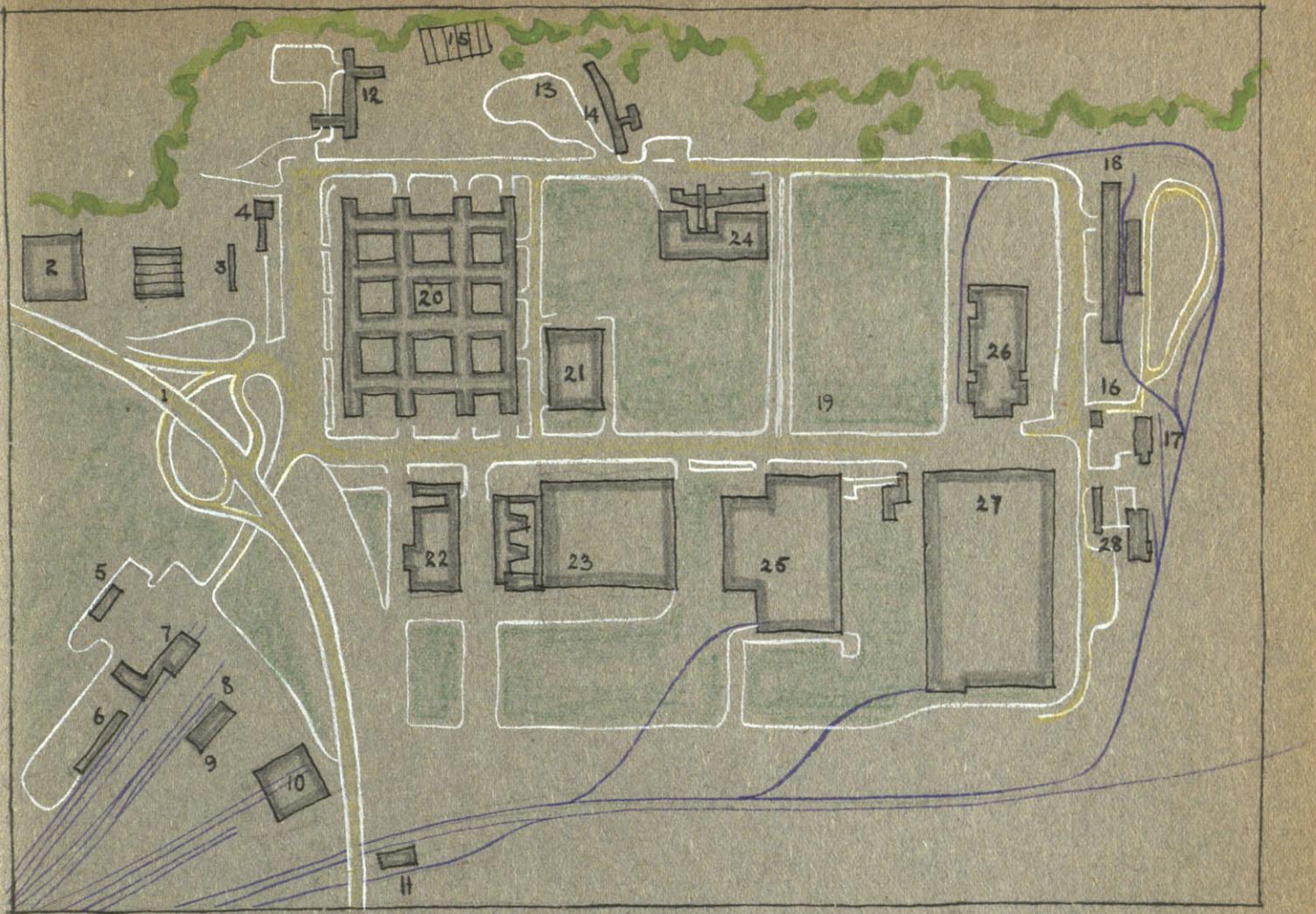
Apart from the large factories with which we have been concerned up to this point, there is another class of plant known in England as the 'bijou' or 'flatted' type of factory. As the names imply, they are special mills of considerably smaller size than the usual type, and are most useful for the many ultra-light industries such as toy-makers, clothing firms etc. and the many 'yard' type trades like the building profession. These industries usually make up the vast homeless kind of employment which tends to clutter up the odd crevices of already chaotic towns, and are continually being pushed around from place to place as for one reason or another the old occupancy becomes uninhabitable.



METHOD OF PROVIDING FLEXIBLE LOTS



IDEAL TRACK LAYOUT FOR INDUSTRIAL ESTATES



LAYOUT of an INDUSTRIAL ESTATE : KNUTSFORD : Arch. Yorke, Rosenberg & Mardall.

- 1. Main Road
- 2. Bus Garage
- 3. Petrol Pumps
- 4. Fire Station
- 5. Builder's Yard
- 6. Loading Bay
- 7. Inwards Shed
- 8. Outwards Shed
- 9. Fish
- 10. Warehouse
- 11. Railway Station
- 12. Administration
- 13. Sun Terrace
- 14. Café and Shops
- 15. Sports Ground
- 16. Transformer Sheds
- 17. Boiler House
- 18. Cement Products
- 19. Area for Future Developments
- 20. Flatted Factory
- 21. Narrow Band Weaving
- 22. Fresh Food Factory
- 23. Electrical Engineering
- 24. Printing
- 25. Light Engineering
- 26. Light Alloys
- 27. Agricultural Implements
- 28. Dry Ice Factory

At Slough in England there are 59 of these flatted structures; their rent is low, and they fulfil a very valuable purpose in helping a young industry to find its feet before expanding to one of the major plants. Therefore they have been very successful whenever tried, and the demand for them has always exceeded the supply. They are restricted in occupancy to industries with no heavy equipment and no special service needs, so that these small firms can work comfortably in a two or even three story block, as the word 'flatted' implies. They are, therefore, innocuous, rapid turnover types of industry, and they derive particular benefit from being sited contiguous to major factories, which, beside lending their prestige to the location, often supply the smaller industry with all its raw materials. At the same time they benefit from the many sociological advantages which have been discussed, and which they could never hope to achieve on their own premises in the city center.

Three examples of Industrial Estate Development

1: Clearing.

To illustrate how the above information is made to work in the various industrial estates, I have studied three famous examples in some detail, the the following notes on Clearing, Boston and Dallas show how three widely differing contrasting organizations are working today.

The most important industrial estate in America is the one at Clearing where in 1910, on a 40 acre plot of land, the first unit of a block now over 3 miles long, was built on the south-west limits of the city of Chicago.

Clearing profits much from an ever increasing fund of knowledge and experience and is now working very smoothly and well. The simple enumeration of the facilities to be enjoyed is sufficient to make the district attractive to a prospective manufacturer. These services include rail connections, warehouse space, banking facilities with the National District Bank, fire and police protection, watchmen, heat, light, gas and water.²³ The district staff plans and constructs all streets, sewers and watermains, which become the property and responsibility of the owner once the land is let. In addition to the above, the district helps to maintain a high standard of employee health by providing a street cleaning service, an ambulance service, two emergency hospitals for treatment under a compulsory insurance plan, and routine pre-employment checks.

Another unique feature is that the Trustees provide financial assistance in properly accredited cases up to as much as 80% of the price of the land and the structures. This system has the further advantage that the transaction is known only to the signatory parties and does not subject the manufacturer to opportunist parties or lead

him to have recourse to outside capital; it is therefore no drain on his capital resources. There is also land for outright purchase, land for high development and land for straight line production with low land costs to enable expansion to take place without surcharge.²⁴

More recent financial arrangements allow for a down payment for plants of 25% and the balance due in 10 years, or alternatively land can be bought on a 15 year lease at 6% of the total value plus 3% for amortization. It is the present policy that when all the land is sold (in a period envisaged to be in 20 or 30 years time), the streets will be turned over to the Clearing Industrial Association which will be composed of plant executives and this group will control the district.

Recently it has been made a rule of the district that although the incoming firm may have its own architect, yet the zone's own architect and engineer (John Cromelin) does all the building work and he becomes the architect on the job. While there is the danger of staleness in the similarity of design in so huge an area, the standardization involved reduces costs and allows the district to stockpile in the manner that has been described elsewhere. This design group under the leadership of Cromelin, has achieved a unique success in that they have been successful in pro-

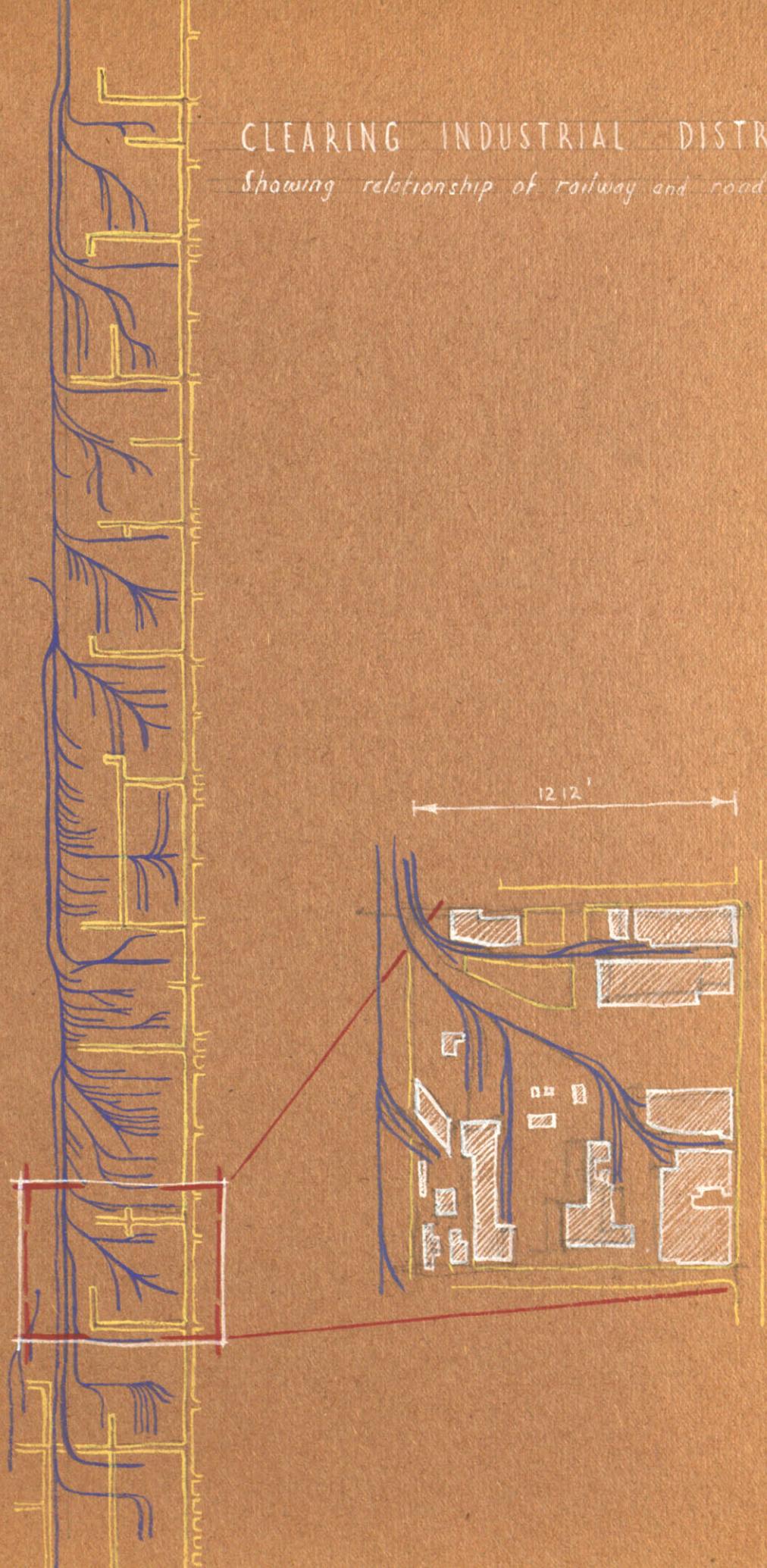
ducing a homogeneous style of architecture, which, while lacking somewhat in design skill and imagination, yet gives a tidy, cared for appearance which is most attractive.

We mentioned previously the value of land for expansion, and at Chicago the District reserves vacant land between factories for sale to the respective owners: a two year option was given on this adjacent land at the time of purchase. The total industrial zone now covers the prodigious area of over 400 acres and borders on the sorting yards which serve the three railways entering Chicago. The district has been developed in approximately 40 acre units, as may be seen in the accompanying diagram, the first units allowed the lead track to enter the plot at 90° . This has now been changed and later development shows the tracks entering at 45° giving the more flexible arrangement of individual sites. It will also be noticed that the later plants are smaller in size, as it was found that they did not require as many railway facilities, owing to the advent of trucking on a large scale.

The original street had a 30 ft pavement with 5 ft sidewalks, 10 feet for planting and utilities and a 10 ft set-back to the building line. Recent experience has led to the use of a 40 ft pavement with 5 ft sidewalks, a 10 ft planting strip and a 20 ft setback. 110 ft has been

CLEARING INDUSTRIAL DISTRICT

Showing relationship of railway and road



set as the distance between buildings.²⁵

2: Boston

The Boston District presents a completely different aspect to the one we have just discussed. It is an example of a peripheral estate and is situated close to Routes 128 and 9, the former being a huge circular highway surrounding the Boston Metropolitan Area, and the latter the main radial highway from Boston to New York. The New England District has rail transportation such as has been described, in that it picks up office commuters on the return journey to Boston. Its position in the road system enables employees to drive to it from any location in Boston travelling across country, - a very important point when most radial roads in large cities are jammed with traffic at peak hours. The sketch shows the disposition of the site and it will be noted that the cloverleaf junction with the main highway helps to keep the roads clear, and there is only one point of intersection between road and rail transport. In layout the pavement is 40 ft wide with a 5 ft wide grass strip, a 3 ft sidewalk and an unusually low land coverage limit of 33%. The setback from the main street is enforced at 50 ft, and a 40 ft limit obtains on all other roads. The most unusual factor is that 2/3rds of the total area is to be landscaped, and

the remaining open area is reserved for car parking. Furthermore no on-street parking is permitted and all open storage is prohibited. Great care is taken over the supervision of plans, and all alterations to the same, and the use to which land and buildings are put. The models of the site show that an extremely high standard has been set, and it would appear that the site offers an admirable opportunity for contemporary architects to show their mettle, for on this occasion they cannot complain of cramped, unsuitable sites, and there would appear to be no excuse for the stereotyped, dull cliffs of masonry that are so characteristic of many recent industrial plants.

3: Dallas.

Our final estate is situated in Dallas, and was started in 1945 and called the Airlawn Industrial District. It is 4 miles from downtown Dallas and is built on 256 acres. A railroad company sponsored the project, laid out the roads and railways and also promoted the finding of interested manufacturers and helped in the financing of plants. This is an example of one railroad giving promotional help where a two-company sponsorship might give better competition but no promotional assistance. In this case, after the streets and utilites had been installed, they were turned over to the



NEW ENGLAND INDUSTRIAL DISTRICT - BOSTON



AIRLAWN INDUSTRIAL DISTRICT - DALLAS

On the left is the existing layout. Note the cross-circulation. On the right is a revision incorporating the principles discussed in the text.

city. The pavement is 40 ft wide, with a 10 ft utility strip on each side and no sidewalk. A 100 ft setback is maintained on main streets but only 25 ft is required on secondary roads. No cars or trucks may be loaded at the sides of the buildings on any street, and this ruling helps to foster the planning of internal loading courts.

The sketches show how the Dallas site appears to be imperfectly planned with frequent road and rail intersections. Maybe there was some valid reason for this congestion-causing system, but it would appear that the amended scheme would provide a much happier solution as far as the internal working of the district is concerned.

Chapter 4

Factory Planning

In this chapter it is my intention to analyse in some detail the layout and structural concepts of plant construction so that we may have before us firm guiding principles upon which the industrial architect may conceive his design.

Contrary to the procedure followed by many architects when approaching a normal design problem, plant construction cannot be "dreamed up" as an aesthetic vision before any preliminary analysis is attempted. Such an approach is doomed to failure and brings nothing but disrepute when applied to mill design. The architect should realise that all mill structures are entirely dominated by the production flow and corresponding machine layout.

Layout problems may be classified in the following manner:-

1. Design change, involving alteration to existing structure.
2. Enlarging a department.
3. Reducing a department.
4. Adding a new product.
5. Moving a department to a new location.
6. Adding a new department to the plant.

7. Planning an entirely new department.²⁶

Embracing these 7 classes are two major divisions into which any one of them might fall; these may be defined as stable and changing products, - a steel mill being an example of the former, and a motor works with its annual changes, an example of the latter.

When considering plant layout the designer should have a clear picture of what he is trying to do and the objectives he wishes to attain, and to clarify this process the points may be enumerated as follows:-

1. To facilitate the manufacturing process.
2. To minimize materials handling by suitable mechanical methods.
3. To maintain flexibility of arrangement and operation.
4. To maintain a high turnover.
5. To minimize undue capital expenditure in equipment.
6. To make economical use of the floor area.
7. To promote effective utilization of labor.
8. To provide employee convenience and comfort, a consideration of which the architect by training should be particularly well qualified to ensure.²⁷

Consideration of these points will determine the most efficient and therefore most economical operation for

any given task, and will eliminate potential congestion or bottlenecks in the flow of work by a proper balancing of man and machine hours. The flow lines should be as short as possible, the less distance materials have to travel the better, and the straighter the production line the easier the task of working out materials flow charts. This problem of a fluent production line should be uppermost in the designer's mind from the outset, and when viewed on paper it should resemble a stream, - free of bottlenecks, backwaters, eddies, overflow and turbulence.

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Many factors influence the planning of such an ideal layout, and they should all receive due consideration. The product to be manufactured and the production quantities of the same, are of primary importance, and these will be the first figures to be obtained from the manufacturers. The type of process and the sequence of operations should be set out in chart form, and the designer should have this pattern constantly in mind. The type of machines and mechanical equipment should be assessed at an early stage for their size and weight will have an important effect upon the structure. The architect who specializes in this type of architecture, will, over a period of years, acquire a

considerable knowledge of such machines for varying types of products, and in particular he can make himself conversant with the ever more efficient types of materials handling equipment which are constantly appearing on the market, and which may be quite beyond the ken of his client who heretofore might have relied on more antiquated methods. The sequence of operations will decide the arrangement of equipment, and for processes which require heavy facilities like cold-rolling mills the layout should obviously receive great attention, because once installed, second thoughts are a very expensive luxury.

Equipment placing will in turn dictate the location of service areas, and, through these, department stores, some of which will be the stocks for special processes. The raw material storage will also be determined by these locations and the overall flow pattern. The type of materials handling should be discussed at an early stage and the method decided upon will probably result in major design assumptions around which will revolve the whole scheme. Other more secondary factors affecting layout may be such points as aisle space requirements, desirable working conditions, production control, supervisory requirements and the degree of flexibility considered necessary by the management.

One final factor is, of course, the building, and it may be that the limitations of building structure will

affect the layout. The aim should naturally be to design an ideal layout and then clothe it with structure, but span limitations, light availability, strength and safety factors may all eventually lead to modifications of the ideal layout.

The Analysis.

The requirements I have just listed may appear a formidable task for any architect to assimilate and become proficient in their use, but familiarity with this process is essential and to assist the acquiring of this facility I include an outline of the procedure which may be followed when presented with the task of analysing the problem of industrial construction.

The prime essential is to set the problem down on paper, even before many facts have been ascertained. A simple line drawing can sweep away the haze that always hides glaring errors in original assumptions when these assumptions are made from a mass of intricate, detailed information.

The first progressively constructive step, however, is to make a parts list of the many elements which go to make up the whole process, analyse each one, and make

a tentative routing for it. Then, in conjunction with the management, construct an assembly chart to show the interrelationship between these parts, and by the time this step is completed the designer who has approached the task in a thorough, painstaking way will have a very good idea of the type, limitations and method of operation of the machines which form the dominant factor in his problem. This acquired knowledge will not only stand him in good stead throughout the problem but will give a psychological 'edge' over the task, since working with unknown, strange components is always a dispiriting and dangerous procedure.

A plan of the flow of materials should then be drawn up in line diagram form, and to do this correctly, accurate and up to date process sheets are essential, together with full production figures on all the processes involved in the production. From this, information process charts can be compiled which are divided into 3 tables. The first shows the distance in feet between the relevant operations, the second shows the number of operations, and the third gives a description of the operation. With this information, in the case of a new plant, a sketch plan can be set up with the production lines shown in line form, and where a redeployment scheme is in progress, the line diagram should be laid over a plan of the existing works to show where existing errors are located, and to determine how far

the structure will permit the proposed changes.

Methods of materials handling should be decided at this point, and when this is done a preliminary Operations Analysis can be made of each operation and a Layout Planning Chart can then be made to tie together the Operation Analysis of each sub-process. The flow diagrams can then be revised and brought into line with any necessary modifications revealed in the detailed Operations Analysis, and from this, a master layout can be prepared for submission to the management for approval. This layout should include proposals for all the ancillary features such as servicing, recreational and toilet facilities.

Changes to an Existing Factory.

In an existing factory where the problem concerns a revision of the present working conditions the architect will be required to make a detailed study of existing methods and his task will be to discover where improvements could be made. The danger in this assignment always lies in a tendency to make alterations simply because they are expected of one, and it should be remembered that an increase in production is the sole aim of the designer rather than a wholesale change simply for its own sake. Increased production is the important factor even at the expense of the monetary

cost of the floor area, which can usually be made to pay if the layout is sufficiently efficient. Many factories have already improved their machines and reassembled their work-places to a very advanced state and the point of diminishing returns may have been reached. In this case, cost of materials handling offers managements the best opportunity to effect savings in operating expense. The following list sets out some of the points which may be considered and checked when trying to evaluate the competence of an existing structure.

1. Consider the receiving department and check whether it is jammed with materials, and whether there are ensuing delays in truck lines.
2. There may be a record of materials damaged by exposure to the elements, and adequate protection of raw materials may in itself reduce wastage.
3. Note how many men are working in the open air, for what periods of time, through what distances they are required to move, and the importance of the goods they are handling.
4. Check the accident record, and if this is high it is an indication of inefficient working, and dangerous conditions due to congested machinery.

5. Note the conditions in the store rooms. If these are overcrowded, inefficiency will result, and there is in all probability a record of damaged goods in these locations.
6. Note the ratio of store room clerks and material handlers to production operatives.
7. Check the records for lost materials and see whether the present inventory system is working efficiently.
8. Note the number of times materials are rehandled and stored before processing.
9. Note the stage in production when skilled operators handle the materials and check whether this stage could not be avoided by the use of materials handling equipment.
10. When considerable piles of material lie around on the floor out of production control, more efficient routing is indicated.
11. When aisles are long and narrow, when they occupy over 15% of the total floor space, when they are congested, and hazardous, production suffers.
12. Check the servicing system for production equipment and if this is tenuous, time will be wasted in maintenance.
13. Note the number of operator complaints, particularly

over matters such as insufficient or over-heating, lighting, ventilation, congestion, hazard or complaints about rest room facilities.

14. If there is a high labor turnover figure it is an indication that conditions within the mill are unsatisfactory, and if a record is kept of reasons for leaving, its study should be beneficial.

15. Foremen and supervisors may be consulted for information, and if they complain of lack of floor space, a check should be made to see whether overhead space is being wasted.

16. In some cases, more space than is strictly required may be allocated to an operator and this makes him as inefficient as does congestion.

17. Lastly, where goods yards are unsightly, maintenance costs are high, and frequent rearrangements and additions are necessary; this is usually an indication of radical flaws in plant layout.²⁸

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In this early stage of plant construction, whether in new or existing work, the architect should work closely with the layout engineer who has specialized knowledge of important items such as standard times for the preparation

of route and assembly sheets, time study and motion analysis, which estimates the time required for any given process.

The engineer also has a detailed knowledge of processes and machines, and what each does at the moment, and what it could be made to do in the new layout. His ability to develop flow and process charts can save the designer much time. Many big companies like the Westinghouse Corporation have several branches and at Headquarters a special section is devoted to plant layout,

Consultation with workers is essential and saves many mistakes made even by layout engineers, for their more intimate knowledge with machines can often prevent them being placed where they would be difficult to maintain, and from these discussions much practical information may be obtained. Furthermore, bringing the workers into discussions at this stage is of great psychological importance, since they are made to feel vitally interested in the proposals from their conception, and can feel some sense of responsibility for final decisions.

The Growth of Specialization and the Influence of Time Motion Study.

This whole discussion is based, of course, solely on the fact, and as a result of, the remarkable degree of specialization to which modern industry has progressed. The

reason why all this analysis is necessary is due to the fact that in only the small light industry does the modern worker produce both the initial part and the final product. It is strange however, that we have only in recent years come to really study the implications of this and build our modern, and still rather experimental system of production analysis, because it can be shown that the concept is anything but new.

The science of Time, Motion Study has now grown to such proportions that large firms specialize entirely in its practice and many have records of savings of many thousands of dollars as a result of their efforts. Its real beginning as an objective study came into being late in the 19th Century, and Ralph Barnes says "It is generally agreed that time study had its beginning in the machine shops of the Midvale Steel Company in 1881, and that Frederick W. Taylor was its originator."²⁹

Taylor's own definition of his work and the value he attaches to the study runs as follows: "Time study is the only element in scientific management beyond all others making possible the transfer of skill from management to men . . . Time study consists of two broad divisions, first, analytical work, and second, constructive work."³⁰

It will be noticed that up to this point time study only has been mentioned and that its implication carries

with it solely an interest in the time taken for a man or a machine to do a given job. Taylor placed emphasis on materials, tools, equipment and the human acting as a machine rather than upon the human side, and no account is taken of psychological and emotional reactions to certain conditions. This was left to a man and wife called Frank B. and Lillian M. Gilbreth who saw the gap left in the science as it was formulated up to that time and they began a new approach to called Motion Study which has now become an accepted and essential corollary to Time Study. The new approach was born of a desire to study human psychology and was combined with real human understanding.³¹

Unfortunately experts in this combined science have in the past tended to become overbearing in their approach to management and workers; often presuming to hold in their power some secret elixir which, with a few deft strokes, will cure all production problems. Richard Neuschel has endeavoured to disuade experts from this attitude by setting forth a series of cautions akin to those I mentioned briefly in an earlier chapter. He warns particularly against "Master minding" and urges the expert to establish a reputation for helpfulness. He also cautions against the tendency to overcriticise existing conditions, for in spite of the possible hopeless inefficiency of the layout, there is usually a very valid excuse for their inception, and this reason should

be sought before any move is made. Neuschel stresses the need to avoid the spectacular change made simply to prove that the expert is on his toes, and urges that he think vicariously, to put himself in the other man's shoes and to study his attitude to the job, rather than to force his own convictions upon an unwilling subject.³²

Design for Straight Line Production.

For the most efficient production, complete sub-assembly should be aimed at. This makes final assembly much more efficient and men like Henry Ford and C. W. Nash, prior to World War I, were quick to see the advantages of continuous assembly. This naturally leads to the principle of straight line assembly which governs the layout of huge plants such as the Willow Run, and this method of production has the following advantages:

1. Ease of scheduling and controlling production.
2. A balance in production is easily maintained.
3. It results in a reduction of handling and moving materials since they can be located immediately adjacent to the production line.
4. A less volume of work is in progress at any given point in the process.
5. There is a lowering of overall manufacturing time.

6. Less counting, inspection and clerical work is involved.
7. It results in a reduction in the amount of supervisory attention needed.
8. There is less damage in handling.³³

Straight line production is essentially a mass production device. It is geared to that type of work, and its jigs and fixtures must be strong, rugged, adaptable and have adequate dimensional control.³⁴ It is important that they be salvageable, economic and have good appearance for the psychological reasons that will be discussed later.

The reliability characteristic is especially to be desired in straight line production, because a breakdown or lack of efficiency can result in delay which has repercussions on the whole line. Therefore if such a method is decided upon in a factory with which the designer is concerned it should be remembered that a high degree of planning is required to operate it successfully, and the operating times must be skilfully balanced to ensure the smooth flow that makes for higher production and lower unit costs. To balance the production line the three basic essentials in information, (i.e., the production required, the list of operations and their sequence, and the standard times and hourly production figures for each operation,) must be obtained, and correlated by the production engineer.

This line will then be set up for a certain production rate and this in turn will determine the breakdown of operations and the number of people to be used on the line. Variations in production requirements can then easily be met by increasing the number of the operators or machines.

The principle difficulty in straight line production is the danger of breakdown along the line, because a delay of any considerable time will result in complete stoppage of production. The implication of this is that stocks of material and reserve equipment will be necessary along the line which will cover not only breakdowns, but also variations of speeds of machines and loads in departments.

Balancing a machine line is much more difficult than the problem of balancing assembly lines, because it is not so easy to divide operations and disturb elements. A detailed analysis is therefore the only way, and speeding up individual parts as the time schedule permits; faster handling and maybe new and faster machinery are other avenues to explore.³⁵

Design for Machine Line Production.

To attain flexibility in a machine line is even more difficult, and this can be helped in some measure by the use of standard machines, and special purpose machines to quicken output and to be adaptable to other uses. Other

valuable aids to flexibility are the insistence upon the use of standard tools, fixtures and moveable machinery. Large, unobstructed floor areas, electrical connections to allow the plugging in of machines at any point in the factory, machine mobility, the choice of portable conveyor units, the extensive use of small tools, portable jigs and fixtures and the provision in the building structure for expansion, all militate toward greater flexibility.

Possibly the most difficult problem facing the designer who is in search of flexibility, confronts him when asked to layout a textile mill, and more particularly a textile plant in England, for in America the tendency is to specialize in one or two types of cloth. British textile firms, however, specialize in many fancy cloths, and in my father's mill in Lancashire, for instance, they are presently weaving 70 different types of cloth on rather less than 1,000 looms. This kind of production obviously rules out any 'straight line' concept since it is virtually impossible to set up anything a 'line'. And the most that can be achieved in these cases by the designer is the provision of large uninterrupted open spaces, and the convenient disposition of warehouses so that the looms may occupy any position. By these means, the work of the future layout man will no longer have to be a compromise between an ideal layout and physical restrictions.

The basic difference between the types of production rests in the method of grouping the machines. Textile mills are an example of the system in which machines of a similar type are grouped together for ease of working, supervision and supply, while an automobile factory shows the opposite approach in which machines are grouped according to process, and the product starts at one end as raw material and comes out of the line as a finished product.

Materials Handling Equipment and Methods.

This field is probably the greatest potential money-time saver which has yet to be fully explored. Great advances have been made in the last few years and some firms report phenomenal savings since the inception of one or other of the various systems.³⁶ The potential economies to be wrought in the speeding-up of internal transport systems has been appreciated for some time, and in 1924 C. F. Talmon wrote, "the incongruous spectacle may still often be witnessed of mavourously ingenious automatic machinery for making things used side by side with crude non-automatic methods of moving them."³⁷

The subject is of added importance to the architect because it must be decided before construction drawings begin, what particular system is going to be used. Planning and

structure will be vitally effected in many cases, depending upon such factors as aisle space requirements and structural reinforcement to withstand the loads imposed by hanging and suspended loads imposed by the conveyors. The correct apportionment of preference given to materials handling may be gauged from the fact that even in normal plants this item accounts for 36% of all production costs, and in some industries they are as high as 62%.³⁸

It is so easy when planning material handling equipment, to let the goods get sidetracked more than is needful, or to allow them to accumulate where they will have to be moved again. In actual operation this can be mitigated by giving the task of materials control to one man, and one man only. In small firms he may be required to combine this duty with other tasks, but he should be the only person in complete control and he should be responsible directly to the executive. Experience shows that when more than one person supervises material movement, delays and confusion are very prone to set in.

A golden rule of materials handling is to use gravity wherever possible. It is free, it never breaks down, and it completely eliminates handling provided the conveyor is correctly designed and the run is not too tortuous. Some processes may even have a continual slope on the floor and

the goods can be simply rolled from one operation to another.

Many processes like flour milling are naturally adapted to gravity feeding and as such have been housed in multistoried structures from the beginning.

It is a good plan to take the plant, department by department, in this respect and determine the most efficient system to meet the requirements in each case. The following 'leads' will help to channel one's research in the most productive direction:

1. Take careful note of the physical facilities. Consider the plan relationships, the space allocated to the process and to handling equipment. If one is considering an existing factory, the conditions of the floors should be studied, for their unsuitable nature may well determine the use of suspended systems.
2. Note the commodities to be handled and ascertain their size, weight, density and quantity.
3. The sequence of operations. This of course can be studied on the flow charts and the number of handlings can be ascertained from this.
4. A separate routing diagram should then be made showing the handling sequence in detail. This will assist in showing up errors in basic thinking and can be preserved for reference

MATERIALS HANDLING SYSTEMS.

'Periodic' or lot-delivery equipment.

		Castor skids & racks.
Manual.	Platform.	
	Lift.	
Trucks.		
Trackless carriers.	Power.	Platform.
		Tiering.
		Lift.
	Tractors.	Storage Battery.
	Combination.	Gas.
	Trailers.	
Rail Carriers,	Standard Gauge.	Steam.
	Narrow Gauge.	Gas.
		Electric.
Overhead carriers.	Cableways.	Overhead travelling.
	Monorail.	Cantilever.
	Cranes.	Gantry.
		Boom(locomotive).
		Girder.
		Pillar.
Lifts.	Platform elev.s	Guy.
	Derricks.	Stiff leg.
	Hoists.	Chain & cable.
		Pneumatic.
		Steam.
		Electric.

'Continuous' flow delivery.(conveyors.)

		Straight.
Gravity Conveyors.	Roller.	Spiral.
	Pipe lines.	
	Chutes.	Straight.
		Spiral.
Pressure- tube Conveyors.	Steam Jet.	
	Pressure pipe lines.	Suction.
	Pneumatic tubes.	Blower.

(continued overleaf)

Mechanical Conveyors.	Endless chain. Power-driven rollers. Screw conveyors. Reciprocating. (grasshopper).	Apron. Belt. Bucket. Hook. Flight.
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and overlays when future modifications come to be made.

5. In an existing factory the obvious course is to study the existing routing system, and from personal observation and discussion with operatives find out if the system needs improvements and at what points.

The accompanying table should be useful to designers in that it classifies most of the various systems of materials handling and can be referred to when making initial assumptions about the type of system most likely to be of use.

Planning the Administrative Block.

Before completing this Part and making some recommendations, I wish to mention one more facet of industrial planning which has not yet been subject to dicussion, but which is an integral part of its organization. The office block, or administrative section is vitally concerned in the production of the plant, and its efficiency is essential to the maximum production in the manufacturing rooms. The architect will naturally be called upon to plan these areas, and since many of the planning concepts are familiar to him, and dimensional data can be easily looked up in technical sheets, I do not intend to dwell overmuch upon the details but simply

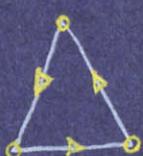
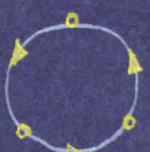
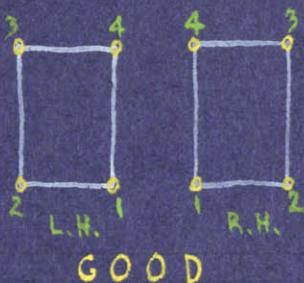
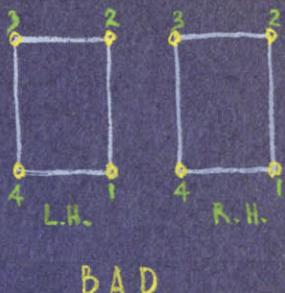
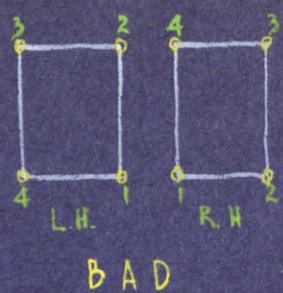
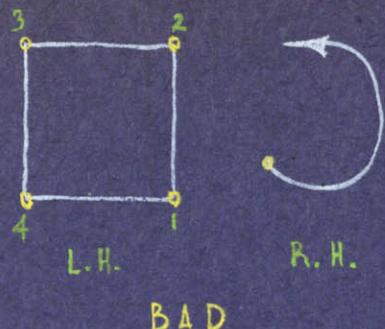
enumerate them to make this section of the thesis complete in itself.

The most important overall planning concept is to place the offices in correct relation to both the public and the factory, between whom the office attention must be equally divided. Visitors to the plant should be met by a clean, spacious, well-designed unit, for it is here that first impressions are gained.

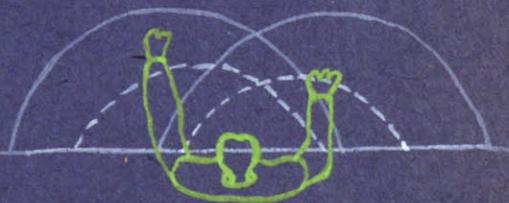
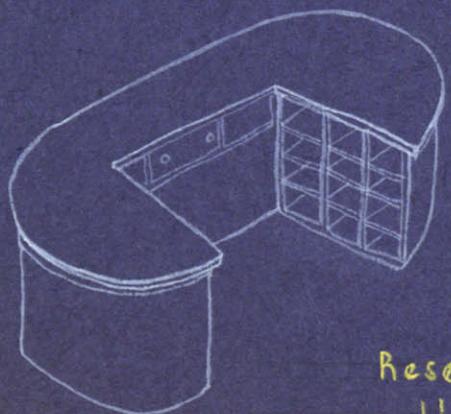
The office layout should be carefully designed to avoid overcrowding; drawings should be made, and the process worked out very much as has been described for machine layout. The breakdown into the job's various components will enable charts to be drawn up so that standard equipment can be specified, - a move which will simplify the planner's work to a great extent. This not only gives a neater appearance to the office, but the standard equipment makes the area more flexible and changes may be made when required.

Recognition of the normal human reach leads to less fatigue and higher efficiency, and a typical example of the application of such analytical thinking may be seen in the accompanying sketch.⁴⁰ It will be noted that in this arrangement chair space does not have to be allowed and the desk takes up less room than ordinary fittings.

POOR & EFFICIENT SIMULTANEOUS HAND MOVEMENTS



A circular motion between points is most efficient. see LEFT.



Research such as the diagram on the right resulted in the desk on the left

Many combinations or permutations of equipment placing should be possible in office layout; a certain official may find it necessary to have two assistants adjacent to him, offices of departmental heads may need to be of equal size to avoid a feeling of preference, offices with considerable intercourse should be fairly adjacent, and the whole should be a flexible unit for easy dismantling and reerection to conform with different working schedules.

There is a considerable difference of opinion in office planning centering round the question of whether the offices should be partitioned into small private areas, or left open in one large space. The advantage of public offices are firstly, that they have a lower cost per person, secondly, much greater flexibility, thirdly, a much better layout is usually possible, fourthly, they are more efficient and reduce time wastage, and finally, they are much easier to supervise. Private offices, on the otherhand, permit secret or confidential work to be carried out with better security precautions, there is much greater freedom from noise and distractions, and the privacy facilitates contacts with outside people for interviewing and conference work. Finally the comfort and prestige which the private office gives the individual is a considerable morale lifting factor, and its importance should not be overlooked since individuals have been found to automatically take on a much greater sense



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P. 89

of responsibility and importance when sat behind their own desk in their own private space.

Space standards should be used as a guide for office layout and the following figures will be useful for reference. For individual offices 100 sq ft per person is sufficient, while for general office workers this figure will include corridors, and if corridors are not required in the plan, the figure may be reduced to 80 sq ft per person. Major executives' offices should be considerably larger and require at least 400 sq ft per person, while subexecutives should be allowed 200 sq ft per person. Conference rooms for 10 or 12 persons should be not less than 600 sq ft with reception room of about the same size. Interviewing rooms should be planned adjacent to executive offices and will be sufficiently large if allowed 200 sq ft. The central filing department should receive careful attention, and the active file room should allow 5 sq ft per file, while the inactive file department may be reduced to $3\frac{1}{2}$ sq ft per file.⁴¹

For detailed office planning the following standards should be considered the minimum acceptable.

1. The aisles to the main exits should never be less than 44 ins and are better than 66 ins. 36 ins, 44 ins and 60 ins are acceptable widths for secondary, intermediate and main aisles between desks, and where these have end opening closets,

the dimensions should be clear span figures when all the equipment is fully extended.

2. The working space between the back of desks and the front of others should be a minimum of 28 ins, though 3 ft is more acceptable. This dimension should always be used if chairs are arranged in rows.⁴²

3. If files face the aisles or desks there should be at least 36 ins in the clear when the file is open.

4. Solid wall partitions should always be avoided as they are too inflexible, and there should always be two exits when there is more than two or three people in the same office.

5. The plan should be so laid out that light comes over the left shoulder, and desks facing the source of light should be avoided.

6. No two desks should face each other unless the two persons' work is closely related and such a position is advantageous for the purpose of their work. Otherwise talking and mutual disturbance inevitably results.

7. Not more than two desks should be placed end to end, so that each person has access to an aisle.

8. Desks should be arranged as the factory production chart is ideally made up, - that is a straight line flow of work

from the beginning of correspondence to its final dispatch to mail, other departments or into the filing system.

9. Files are most conveniently placed against walls, or if this is impossible, they should be made to form an aisle guide to delineate space and channel activity. Safes and other very heavy office equipment should be planned to be set against columns or bearing walls so that advantage may be taken of the minimum bending moments which occur at these points, and permit more economical beam design.

10. Employees should be placed nearest the supervisor with whom they work, those with the 'closest' work should be nearest the light, and those persons with the most contacts, (interdepartmental liaison and general communication activity) must be placed nearest the doors.⁴²

NOTES ON PART ONEChapter 1.

1. Bethel, L.J., Atwater, F.S., Smith, G., and Stackman, H.A., "Industrial Organization and Management", 1945, p.198.
2. Yaseen, L.C., "Plant Location", Business Reports Inc., N.Y., 1952, p.3.
3. Ibid, p.24.
4. This is one advantage of building in an industrial estate. The fact of building within an industrial community brings with it the railroad which is tapped to serve each factory so saving one handling at the origin. See pp.56-7 for a full discussion of this and other aspects.
5. The waterway's record of safe handling was rudely shattered in 1951 when a barge overturned near Cairo on the Mississippi and dumped 353 brand new Plymouths to the bottom of the river!
6. See Horowitz R.M., "A Development Study for North Philadelphia Airport", M.Arch. Thesis, M.I.T. Sept., 1954. Much of the data from this dissertation has been used to show the comparative values of air-land-water freight transportation.
7. This should make its appearance about 1958: see Ibid. p.40.
8. This is corroborated by Lipman in his survey. See below p.40.
9. Ibid. p.53.
10. Knowles, A.S., & Thomson, R.D., "Industrial Management" N.Y. 1946, pp.58,59. I am, of course, aware of the many factors which act unfavorably to New England as a future textile center but these points are still applicable to many other industries.
11. The swift flowing streams of northern New England were essential to operate the machinery where water could turn

the wheels with its impetus, and quite frequently these mills were situated about the fall line of navigable streams so that small ocean going vessels could reach the wharves just below the plant. Such a situation may be seen at Trenton, Philadelphia, Baltimore, Richmond, etc.

12. Yaseen, op.cit. p.91.

Chapter 2.

13. "Industrial Development for a Community", prepared by the Policy-holders Service Bureau, Metropolitan Life Insurance Co., N.Y., 1932.
14. Again, I do not expect the architect to master the art of sociological survey techniques but merely to be aware of their importance and to have an idea of how to interpret the facts they elicit.
15. The new Statler Hotel in Dallas, Texas, proposes a helicopter station on the roof, so heralding this new "age".
16. Knowles, A.S., and Thomson, R.D., op.cit. p.69; this is also a typical form for recording information about available buildings, and can be used to compare several alternatives in an area. The various buildings should be listed as shown and comparison will be facilitated by the orderly presentation.

Chapter 3.

17. From a discussion on "The Planned Industrial District" recorded in the Architectural Forum, April 24th, 1954.
18. The Planned Industrial District. op.cit.
19. In his research in the B.M.A., Lipman op.cit. p.14, estimated that, where the land coverage ratio exceeded 50% only 4 out of 39 plants had adequate parking facilities.
20. An excellent suggestion has recently been made to relieve the situation by E. L. Tennyson, the Traction Commissioner for Youngstown, Ohio, in the Architectural Forum for April, 1954. It would provide for an invest-

ment of 5% in transit lines which would boost the number of people travelling by this means by over 400% and so relieve much of the congestion on the roads. A transit line costs only \$150,000 per mile, compared with \$8,000,000 per mile in some areas for an expressway and the economy and convenience of the scheme can be readily appreciated. People will travel by such means as long as it is fast and comfortable, and in Cleveland's Shaker Heights suburb, even the rich ride by streetcars which go at 50 m.p.h. on their own track. The difficulty in this method of transport is one of inter-connection between the surrounding suburbs, - from which many of the workers come, and it becomes desirable to add "belt" lines to supplement the rapid transit line from the factory to the city center. Careful scheduling of operation can often be arranged to take factory workers out of the city, and bring office workers in on the return journey, owing to the shorter office working hours.

21. Planned Industrial District, op.cit. These figures should be regarded as a guide only: it will be noted that Clearing is over 400 acres and therefore "oversized", but the range gives the client some rule against which to judge the "development maturity" of the zone.
22. Logie, "Industry in Towns", op.cit. p.43.
23. Knowles and Thomson op.cit. p.60, c.f. Planned Industrial District, op.cit. where it says fire protection is provided by Chicago.
24. from "Speaking for Ourselves" by Richard Hackett, Manager of the Chicago Central Manufacturing District in Silver Anniversary edition of the C.M.D. Magazine, Jan. 1941, Vol. 25, No. 1, fig. 9.
25. Most districts have now adopted physical planning standards similar to those at Chicago, e.g. the minimum setback may be anything from 46 ft to 100 ft, and this has been found necessary to prevent trailers loading off the sidewalks. Side clearance is also insisted upon and land coverage is strictly controlled with the majority insisting on not more than 60% coverage and some as low as a 30% maximum.. The importance of landscaping is being increasingly realised and an allowance of up to 20% is often made for this item in the budget cost. These restrictions have been found easier to enforce when the land is under lease as it has proved difficult to police a vanished interest.

Chapter 4.

26. Sansonetti, J.H., & Mallick, R.W., "Adopt the Best in Layout", in Factory Management and Maintenance. Aug., 1945, p.102.
27. These points have been abstracted from a discussion of the subject to be found in Apple, J.M., "Plant Layout and Materials Handling", 1950, pp.6 to 14.
28. Immer, J.R., "Layout Planning Techniques", 1950, p.7.
29. Barnes, R.M., "Motion and Time Study", N.Y., 1940. p.7.
30. Subcommittee on "Administration of the A.S.M.E., "The Present State of the Art of Industrial Management", Transactions A.S.M.E., Vol.34, pp.1199-1200.
31. Filmgoers may remember the recent movie called "Cheaper by the Dozen", starring Clifton Webb and Myrna Loy, in which a lighthearted account of life in the Gilbreth household is shown as retold by one of their twelve children.
32. Neuschel, R.F., "Streamlining Business Procedures" N.Y. 1950, pp.96-98.
33. Immer, op.cit. p.130-40.
34. Bryant, L.A., and Dickenson, T.A., "Jigs and Fixtures for Mass Production", N.Y. 1947, p.4.
35. In addition to Immer op.cit. a good reference book for more detailed information is given by Muther, R., "Production Line Technique", N.Y., 1944, Chapter 7.
36. One plant reports the use of 55 men where 550 were used before, another saves \$300,000 per year, - Reported in "Manual of Industrial Transportation", pub. by the Lakewood Engineering Co.
37. Talmon, C.F., "Outlook", Nov. 11th, 1924, p.385. The installation of materials handling equipment should be shown to be necessary before it is installed and the following guide has been drawn up by Time-Motion experts as a rough check. It is necessary:
 1. Where 3 or 4 men are working on one job for 2 hours at a time, even though the work is not performed more than 3 or 4 times a week.

2. Whenever a man has to lift anything from his feet to above his head.
 3. Whenever a man has to lift more than 50 lbs from his feet to above his shoulders.
 4. Whenever a man has to lift more than 100 lbs from his feet to above his waist.
 5. Whenever a man has to lift more than 150 lbs from his feet to above his knees.
 6. Whenever a man has to move materials sideways more than 6 feet or 2 steps.
 7. Whenever a man has to stand in one place steadily moving materials for over 30 minutes.
 8. Whenever a man, or group of men, although moving around in a small radius, has to move more than 10 tons of material in an hour.
- McLain, R.H., "A Brief Directory of Materials Handling Apparatus", General Electric Review, Vol.24, No.4., p.306.
38. Apple, op.cit., p.47.
 39. Table reproduced in "Railway Mechanical Engineering", July, 1926, p.454.
 40. Immer, op.cit., p.39, the sketch is reproduced in Fig.9.
 41. These figures extracted from an article by Ripon, K.H., "Space Standards in Office Layout", Office Equipment Digest, Nov. 1942.

PART TWO

CONSTRUCTION AND DETAILED DESIGN CONSIDERATIONS

PART TWO

Chapter 1Single versus Multi-Storey Structures.

It has been said that "Probably the most important single development in factory designing in recent years is the continuing tendency towards large areas of one story floor space in outlying areas."¹ This tendency is so marked and so universal all over the country that it obviously requires some thought on the part of the designer before he makes a decision to build on more than one floor. On the face of it, it would seem that there are many advantages to multi-storey plants - at least up to three stories, at which point one may reasonably expect the cost of stairs and elevators to offset any other savings. But in fact, the situation in America is such that land is cheap enough on the outskirts of big cities to make economic the buying of huge plots of land for this more expensive type of construction, with its extra foundation and roof costs, longer service runs and larger heating bills. The overriding advantages of one storey development lie in the ease of setting out production lines, and the ease of providing for future expansion, a contingency which has not been readily foreseen by manufacturers in the past.

General Robert Johnson, the outspoken President of Johnson and Johnson Enterprises, has always insisted on one storey mills cited away from city areas in order to avoid having to work in industrial slum conditions. In the city he maintains

that the existing pattern dominates the atmosphere, and he wishes to be away from this influence where he can dominate the scene and create his own visual standards. This is an excellent point, and when made by a person with the esthetic consciousness of General Johnson it is of some importance, for he has been one of the pioneer figures in pointing the way to a better appreciation of the part that visual qualities can play in terms of added production and sheer hard cash profit.

The present trend may be judged from the experience of John Cromelin at Clearing, who states categorically that multi-storey structures are to be avoided. He says that 80% of the manufacturies in the District come from such structures and none of the managements have any wish to go back to them. This is not to preclude a variation of roof level within the plant; indeed, this has been found to be a very desirable feature, and again at Clearing, a central high bay is incorporated in the design of standard structures, because it has been noted that it provides extra flexibility, and the manufacturers like it. Even if a particular tenant has no use for it, the extra 3% cost is well worth while for the use of future tenants.²

As this thesis goes into its preliminary draft, I note that the trend to one storey structures shows no sign

of losing popularity, for a further report states "As to type of buildings, a continuing heavy demand for one story buildings existed, with prices and volume of sales stable. On the other hand, multi-story plants were beginning to be a drug on the market, with more offered for sale, fewer buyers and the prices weakening.....no generality can cover each owner's specific case: but there does appear to be a clear implication that the low, spreadout plant, which requires a generous site found in suburban or rural areas and not within the city limits has proved economically sound."³

I think the reference to the danger of generalities is very important in this respect, for there are grand exceptions to the rule as we may see in the recent plant for H. J. Heinz in Pittsburgh where the plant is built right in the city center. Moreover there are types of production (such as shoe manufactory) which are suitable to a high structure, and others like flour milling, to which the multi-storey is almost essential.

Lighted versus Windowless Plants.

The next big decision in the matter of structural design is the vexed question of windowless plants. To many industries, the increased technical knowhow in terms of ventilation and lighting developments make this solution very

attractive, and many cotton mills in the South have embraced its advantages with some avidity, for the control over humidity alone is an important factor. The constant threat of war is also given as a reason for the rash of windowless plants which have appeared all over the country. I suppose that by using the word "rash" I have given away my own position in this matter, for I cannot honestly agree with the protagonists of this form of construction.

In the first place I agree wholeheartedly with Clarence Dunham who makes the point that man's eyes are attuned to natural light and are essentially at their best when working under those conditions. He maintains that the excuse of defence in war is not sufficient, and says that "If mankind's thinking and planning are to be concentrated perpetually on warfare, then we must drastically change our ideas about many things, including our way of living".⁴ There is, of course the contention that for three shift working it makes the conditions the same for all concerned, but even here it is significant that in recent years there has been a tendency to reserve the windowless structure for one special department which definitely works better under controlled lighting conditions.

I believe, however, that there are still more important reasons for rejecting the windowless structure, but

they lie unfortunately in the very arguable, intangible field of psychology. Firstly, man's natural element cannot be denied him without there being some significant repercussion on his whole attitude to life when the visual manifestation of those elements are not present. The mere fact of approaching a huge plant with its bleak walls, innocent of windows, or any pretence at fenestration, is sufficient to create in him a resistance to working within its walls, and can generate a grudge against the denial of his natural environment that its mere presence symbolises. The reader will surely recall how often one has felt reluctance to re-enter the confines of the office after the dinner hour break with its relaxation on the grass in the sunshine. The office has windows; consider therefore one's reaction to returning to a complete unawareness of the prevalent weather conditions. One factory has so far acknowledged this fundamental need as to broadcast frequent reports on the state of the weather to the workers in the windowless sections of the plant!

General Johnson states that "the plant definitely will have windows", for he believes in the psychological benefits to be derived from the provision for natural daylight. Louis Kahn tells the story of how during the war, in an opaqued windowed plant (one that had been blacked out) there was no trouble during the winter months, but in the first days of spring the window breakage went up alarmingly.

The maintenance department were for some time at a loss to account for this sudden upsurge in window replacements, until it was one day discovered that the men were deliberately throwing hammers at the blacked-out glass to see what was going on outside! These various aspects of the problem should be put before managements as soon as the time comes to decide the matter for they will naturally have a profound effect upon the eventual appearance of the factory.

Chapter 2

Bay Sizes

The next major decision comes when the building structure must be decided. The question of column spacing is of critical importance, and it must be obviously decided on the basis of the type of machinery to be employed and the production flow which will have been already worked out at an earlier stage.

For many years the accent was on a constant search to provide ever greater spans to ensure more freedom of machine placement: so strong has been this movement that there has tended to be an overemphasis upon its value and some industrialists have failed to realize that for certain industries the point of diminishing returns has definitely been reached. Industries with small unit machinery have generally no need whatever for the colossal spans which can now be obtained - at tremendous cost - and it sometimes falls to the architect to warn his client of this, and advise the savings to be gained from the use of adequate lesser spans.

In general, spans of less than 17 or 18 feet should be avoided as an uneconomical dimension for not only is the number of columns excessive, but there results a certain per-

centage of waste in roof trussing and framing, since the sections are very light if used according to design figures and one must maintain certain minimum safety standards. Furthermore such small bays obviously mean closer column spacing and Albert Kahn once observed that each column accounts for at least 8 or 9 square feet of floor space. Conversely, column spacing of over 25 feet involves the use of excessively heavy steel members, and unless thoroughly justified by machine spacing requirements should be avoided.

A considerable amount of research has been done by engineers on this subject of optimum bay sizes and Apple states that for plants under 100,000 sq. feet, a size of 20' by 35' is a very desirable limit.⁵ Even more recently in the Architectural Record, F. L. Witney in a more analytical survey states that for spans of over 40 feet economy demands the use of trusses and his research indicates that a bay size of 24' by 33' is the optimum, being at once the maximum economic flange section and the maximum sprinkler coverage for any one bay.⁶ In any event, the actual dimension will ultimately be determined for economy by the nearest suitable standard window dimensions, and it is relevant at this point to bring out the necessity of settling this important item before the structural design proceeds beyond this point.

Steel or Reinforced Concrete?

The next major decision concerns the type of construction to be used, and in the main the choice falls into one of two classes; steel or reinforced concrete. I can do little more than draw attention to the advantages and disadvantages of each, for final selection must inevitably be based on the prevalent conditions, and no generalization can hope to be completely true for any given case. The two alternatives are so important and far-reaching in their implications that each will be considered separately begining with reinforced concrete.

The designer should consider the use of concrete as a complete material in its own right. This may sound rather trite, but so often in the past the tendency has been to consider the material as an alternative to steel - in which it would play a similar role. This is a false conception, as concrete has positive properties which make it the obvious choice for certain uses by virtue of these properties, and not simply because it competes favourably with steel. In fact it is safe to say that if the structure is designed with steel forms at the back of one's mind, there are very few occasions when concrete will turn out to be competitive in price if an alternative price is called for at the last minute. Here are some advantages of reinforced concrete work.

1. Concrete structures ordinarily act largely as continuous frames; it is inherent in its nature, and the property should be exploited to the full.
2. Concrete is strongest in compression, and it therefore follows that it will be more successful in use as a column rather than as a beam.
3. Reinforced concrete is flexible and can be moulded into an infinite variety of shapes. The most important of these shapes at the moment is the much publicized shell roof with its extra thin construction. The plastic forms involved use the material well - so well that great spans can be bridged with a roof only $2\frac{1}{2}$ " thick at the center.
4. This use of the thin shell results in a saving of up to 50% steel over the conventional slab. The north light shell roof is a form we have seen in increasing numbers in the last few years, and I feel that there should be some possibilities in the use of precast north light trusses. Mills states⁷ that during the Second World War in Upper Silesia, precast cylindrical shell roofs covering areas 16'6" by 33' were produced, but none have so far appeared in England nor, to the best of my knowledge, in the U.S.A. It would appear quite possible to develop a precast north light roof in sections 22' long and ship them to the site and avoid the time lag for setting and the cost of site formwork.

5. Reinforced concrete requires no maintenance.
6. It is highly resistant to fire and corrosion, which makes it a serious contender against steel when chemical plants are to be built, even if steel would appear to be more suited on structural grounds.
7. It is clean in use and appearance.
8. It is highly reflective to light, and when correctly studied can usually be relied upon to give higher readings than similar conditions for steel. North light construction reflects light very well off the curved surface, and in the new factory at Brynmawr in Wales, another good application is to be seen where large portholes are let into the dome to light the floor, while side light floods the soffit from windows under the stiffening beams.
9. Reinforced concrete requires no pointing.
10. In areas where structural steel is required to be encased in concrete, reinforced concrete obviously becomes a serious challenger to steel regardless of the suitability of the form as set out above, but as noted above, the structure should be conceived in concrete for maximum economy.⁸

There are, however, several inherent limitations to the use of this material, and provided their existence

is admitted, much can be done in the design stage to eliminate any difficulties which may occur later. In fact, the use of reinforced concrete involves some very careful forethought on the part of the designer, for once the operation is finished and the material set, it does not have steel's ability for last minute alterations. Further, the plastic nature of the material makes jointing a problem to be considered well ahead of time.

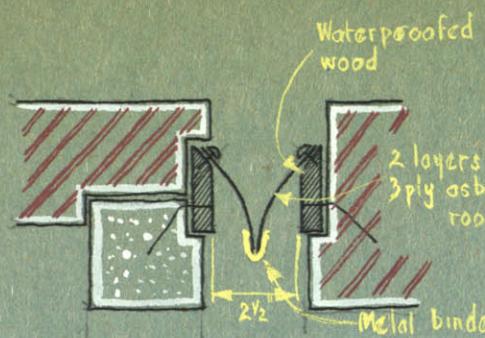
In particular, framed connections are difficult to make in reinforced concrete, and junctions between columns and beams should be made by pouring the members monolithically, otherwise it is difficult to provide for transverse shearing stresses. Construction joints should be so located that each beam has adequate bearing on a supporting member. Simplicity of shape reduces the amount of formwork necessary, and the design should be such that the same forms can be used over and over again. Formwork should be the predominant factor in one's mind when considering architectural details, for they should be so designed that the forms can be ripped off without damage to either the work or the forms. Similarly, good pouring facilities should be considered so that spalling, honeycombing, slumping or air traps will not effect the quality of the work either during construction or in the stripping process.

To achieve these desiderata, the sequence of pours should be worked out in the general planning stage, in order to ascertain the practicability of any detail or structural device. Remember that the extent of the pour is governed by the size of the machine and the area to be covered.⁹

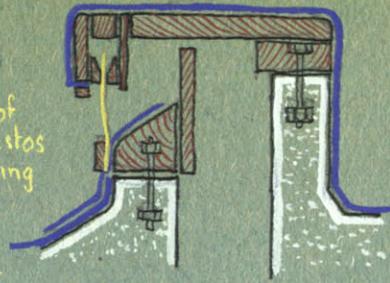
One should not be too niggardly with design live loads. Little can be done to strengthen a concrete structure once it is up, and owners have a perennial habit of making more and more demands on the buildings they occupy. Furthermore, the cost of concrete structures is not directly proportional to the mass of the concrete; formwork alone takes anything up to 40%, and skimpy proportions may therefore result in false economies. In most reinforced concrete work, steel reinforcement is a critical part of the design, so that skimping and overstressing here should also be guarded against.¹⁰ Shrinkage is another problem, for the material shrinks $\frac{3}{8}$ " per 100 feet, and to avoid unsightly cracks in the structure, contraction joints should be allowed: these, of course, will also act as expansion joints later in the normal life of the structure.

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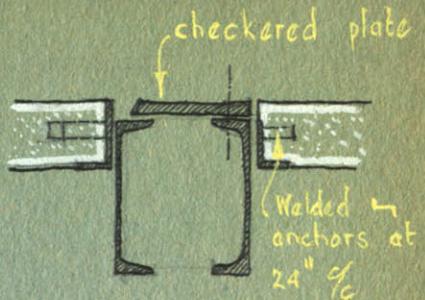
The consideration of steel structures can come under various headings owing to the recent developments in



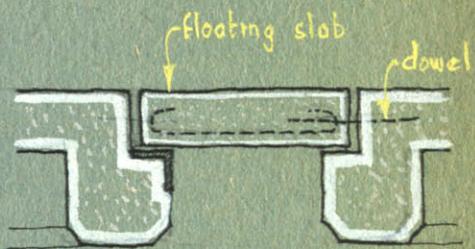
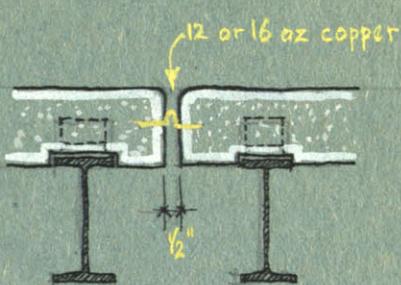
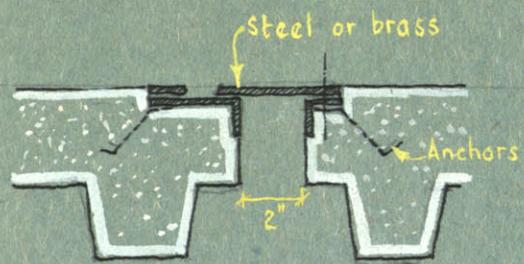
VERTICAL EXP. JOINT IN BRICK FACING



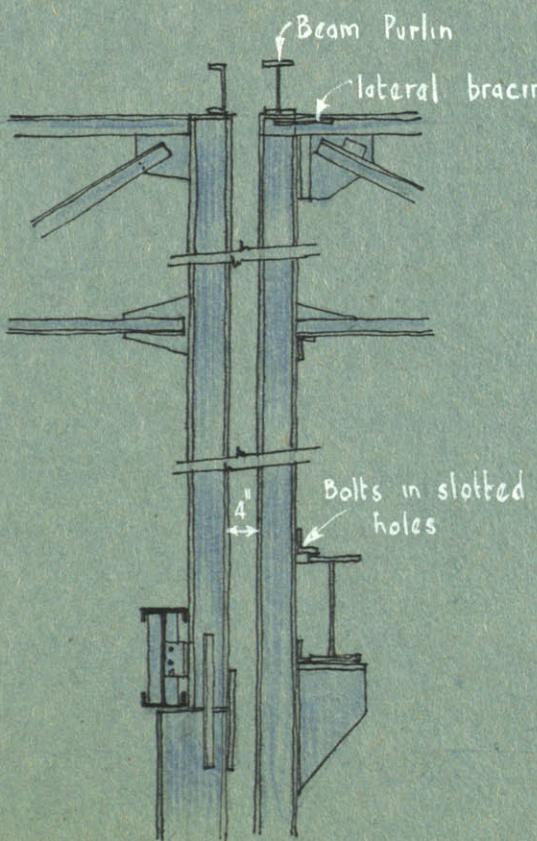
HORIZONTAL EXP. JOINT



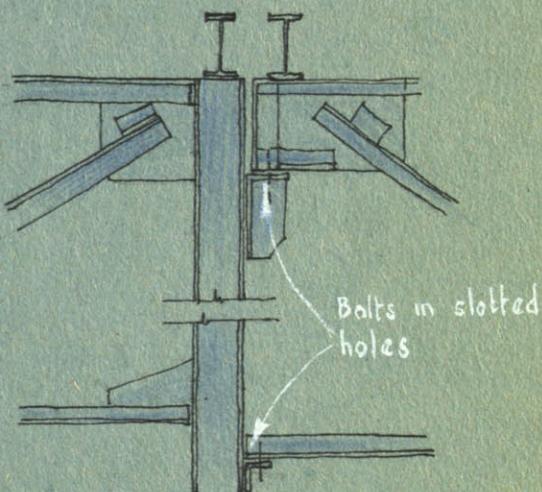
FLOOR EXPANSION.



EXPANSION JOINTS IN FLOORS



EXPANSION JOINT IN HEAVY
STEEL FRAME BUILDING



EXPANSION JOINT IN LIGHT
STEEL FRAME BUILDING

tubular and welded steelwork. The main prerequisite for economical steel design is that the plan and section be rectilinear. The moment curved members have to be introduced, the cost goes up and the best is not being got out of the material. The two main advantages of steel however may be listed as follows:

1. Almost any structure within reason can be built of structural steel, making it a tremendous asset because of the great variety of shapes and sizes which can be fabricated to meet the varying requirements of industry.
2. A steel frame building may be remodelled to suit new conditions, making it very flexible.

Subsidiary points in its favour can also be found. The erection of a steel framed building is independant of weather conditions, and frost does not interrupt the progress of work. Further, the trend toward welded structures leads naturally to an increase in prefabrication techniques, where much of the frame can be welded in the shop, and a simple field weld will complete the structure on arrival on the site. This technique minimizes a further disadvantage of ordinary steelwork; the menace of dust dropping from rusted trusses.

For certain industries like the cotton trade, this, in the past, has been a major source of trouble for any

droppings from the roof can be ruinous to the work below. That is why reinforced concrete has been hailed as a boon to such plants. Concrete has the disadvantage in this respect, though, that unless carefully foreseen, nothing can be hung from the roof, and many manufacturers wish to be able to redeploy machines and materials handling equipment, both of which often require ceiling fasteners or overhead suspension. Welded construction, however, does away with the worst features of the ordinary truss (its multiplicity of members and innumerable rivets, each one in time a harbinger of dirt and rust), and yet allows machinery and equipment to be hung from it in the normal way for steel structures.

The rigid frame, inherent in the design of welded construction also results in reduced sizes for members and, especially when the building industry becomes thoroughly familiar with its techniques, we can confidently expect there to be some real financial saving from its use. Indeed it is astonishing how slow the industry is to equip itself to employ new developments. I am told that there are only three firms in the East who are thoroughly equipped to do all-welded construction, and this in spite of the fact that welded steelwork has been practiced for years. It was particularly surprising to find this conservatism in America where one had been led to believe that new methods were

eagerly embraced and outmoded methods ruthlessly juked by the wayside - in contrast to Europe!¹¹

Tubular steel is another new development, largely fostered by the war and now being experimented with on a large scale. Spans of great variety and length have been erected (from 15' to 120'). And not only structural members: included among the many novel uses have been sectional wall frames (which appear to me to have great possibilities in these days when flexible and salvageable walls are becoming a prerequisite), door frames, and special factory fabricated frames for water towers, pylons, gantries and pipe bridges.

The advantages of tubular construction are several:

1. Its use facilitates rapid erection.
2. There is a considerable economy in material; the circle, of course, is the strongest and most efficient section available.
3. The weight/strength ratio is very high, and moreover, the joints which are usually the weakest part of the structure are in this case the strongest.
4. Complete factory welding can be obtained or the work can be done on the site as desired.
5. The circular section and welded joints are more easily

protected against corrosion than other forms.

Roof Construction

The next problem which might be mentioned at this point concerns the roof, for it follows naturally the discussion of the type of construction to be employed. Lightness is the most sought after quality, of course, and much attention has been paid by engineers to this aspect, although it has to be remembered that roofs have to be fastened down as well as held up, and that wind pressures can be so powerful in this respect that lightness had to be sacrificed to rigidity.

Flat roofs should be designed to withstand a superimposed load of 40lb/sq.ft. in snowy climes (50lb /sq.ft. if there is a 3 ft. parapet wall), or 30lb/sq.ft. if the plant is built in a moderate zone. The present tendency to erect one storey mills offers the opportunity to cheapen the sewer construction in this connection. As the accompanying sketch shows,* the rainfall on a factory site falls largely on the roof, if there is a 60% ground coverage and if the runoff can be so controlled as to minimize flooding, then the sewer sizes can be drastically reduced, for they no longer have to be designed to cater for the worst flood conditions. This simple device can be done at no extra structural cost, for no one rain storm

* See opposite page 231.

can equal the load designed for snow, so the roof will be sufficiently strong in any case. The only extra cost is in a certain amount of tanking which is very small compared with the total saving.

On sloping roofs, the wind load is the most critical, and design loads of 20 lb/ft. of vertical height for buildings less than 50 feet high, and 30 lb. where the building is over 50 feet high, should be assumed.¹³

This mention of sloping roofs is an appropriate point to mention briefly some of the salient points in truss design. No fixed rules regarding shape can be formulated, for the roof to an industrial plant is just about the most custom-built thing in the structure, and must be entirely dictated by the industry's special needs. The first things to be ascertained should include the required clearance, the monitor or light desirable and the number, position and weights of all items of any description which are required to be suspended therefrom. These facts will then help to decide the general shape, the slope, the span between columns, and the purlin spacing, which in turn will decide the type of roof covering to be used.

Truss depths should in general be from an 1/8th to 1/12th the span, and in general the deeper it is, the less will be the chord area for a given span and loading. The danger of too deep a truss lies in the extended web member,

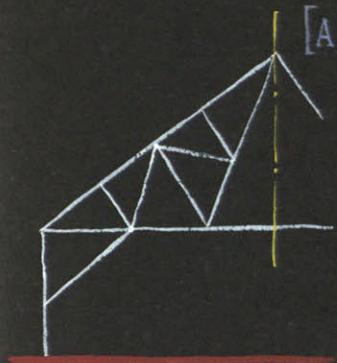
for they tend to become too slender, and the compression members are no longer efficient. It may be useful to record some common industrial trusses and to note the design criteria referring to them. The following information has been abstracted from Durham's book¹⁴ and the data may be taken as a good guide for a total load of 75lb/sq. ft.

(a) For trusses with parallel or nearly parallel chords up to spans of 120 feet:-

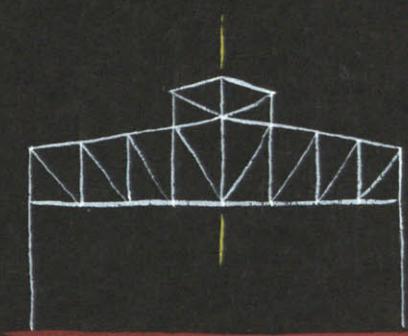
- (1) Simply supported trusses:- $d = 1/10 L$ at center.
- (2) Trusses continuous at one end: $d = 1/12$ at center. This depth may have to be increased to $L/10$ at the continuous end to avoid heavy chords.
- (3) Fully continuous: $d = L/12$ at the center and at least the same at the supports.

(b) For trusses with pitched roofs up to spans of 120 feet:-

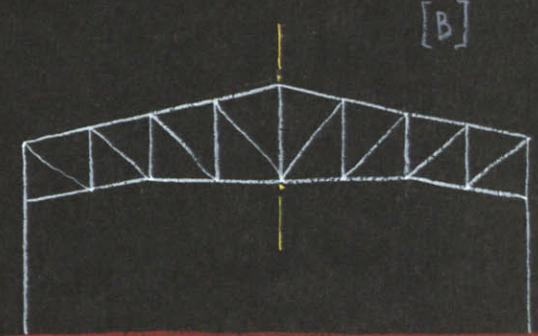
- (1) Trusses such as those in Type A (see sketches overleaf) will usually be deep enough owing to the dictates of the minimum slope of the roof covering but the minimum depth should never exceed 1/8th the span.
- (2) Trusses such as those in type B (see sketches



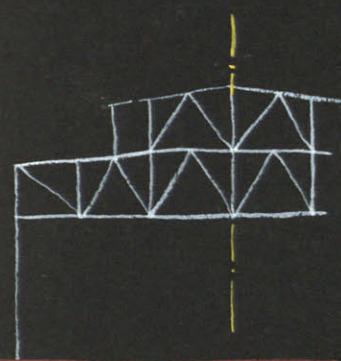
FINK TRUSS



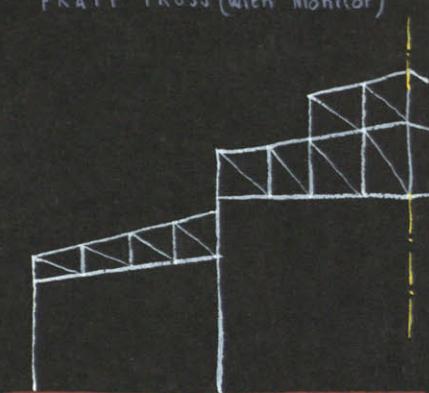
PRATT TRUSS (with Monitor)



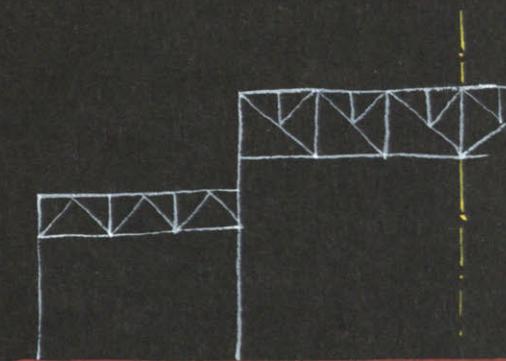
PRATT TRUSS (with bent lower chord)



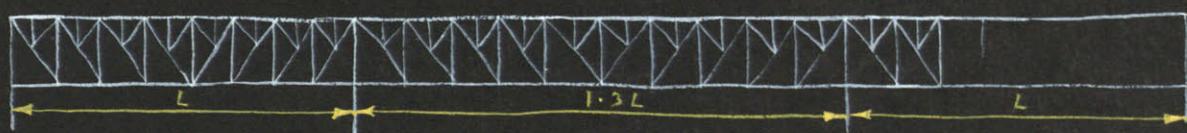
WARREN TRUSS (with Monitor)



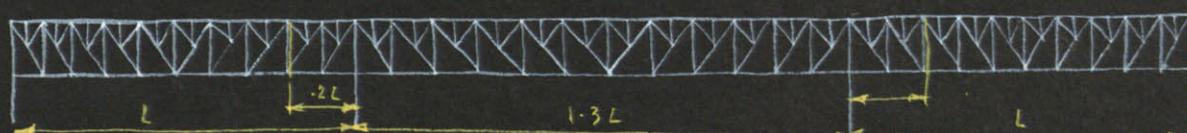
PRATT TRUSS



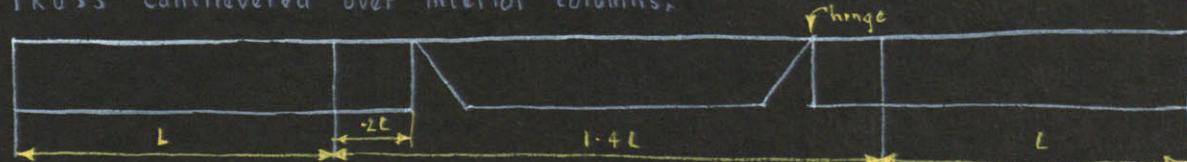
SUBDIVIDED PRATT TRUSS



TRUSS Fully cont. across interior columns.



TRUSS cantilevered over interior columns.



TRUSS cantilevered From outside aisles.



Cantilevered TRUSS when unsymmetrical.

overleaf). Depth should be between L/8 to L/10 at the center.

- (c) For trusses having spans from 120 feet to 200 feet.
 - (1) (1) Use the same depth ratios as in (a) but a practical tip concerns the depth, for if this is over 11 or 12 feet deep, the truss must be delivered in bits to the site; it may well be therefore, that slightly uneconomical steel sections in the chord member will pay off in the long run.
 - (2) When the span is over 120 feet it is worth considering trusses under type (c) (see sketches over), which employ continuity. For simply supported spans in the range of 100 to 200 ft. the long, double gusset construction like that employed in bridges may be best.
 - (3) Types A and B are not suitable for such long spans.

There has been considerable publicity given to continuous beam and truss construction and the economies of hung bays but, particularly with reference to factory construction, there are two very important factors which plead caution when such a course seems superficially attractive.

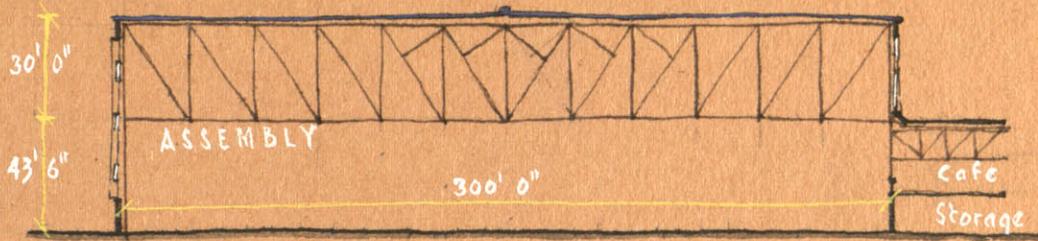
The first reason is common to all such work and

concerns the difficulty of splicing the truss over the columns and the necessity to do this adequately.

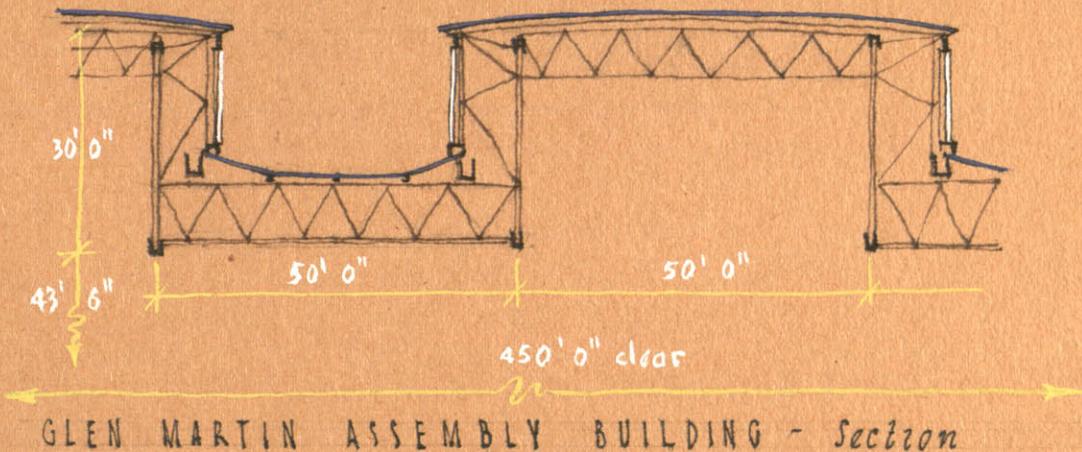
The second reason is critical and of paramount importance. The moment continuous structures are employed, there is a corresponding loss in flexibility. A desire to expand a bay or so is liable to be extremely difficult, if not impossible since it will alter the whole design of the truss and the stresses within the members. The need to expand is an everyday occurrence in a modern industrial plant, and there must be very sound reasons for limiting this tendency in this way.

Again, there is little point in striving to attain absolute minimums in roof design for industry, because manufacturers are notorious for suspending extra loads from the trusses or mutilating them to suit their purposes. This is one reason why a designer of the caliber and convictions of R. Buckminster Fuller would have to be especially on guard, for his geodesic designs could be completely ruined by an unheralded crane being hung from one of the members.¹⁵

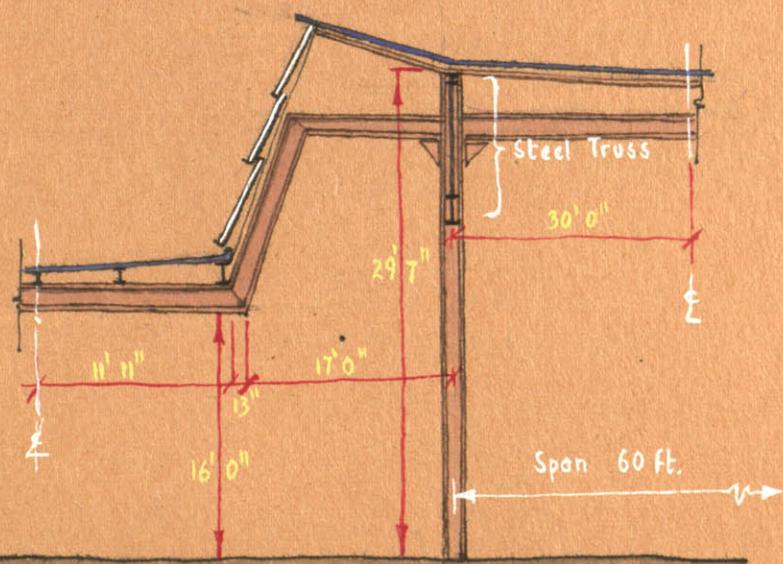
Nevertheless, outstanding economies can be achieved by close collaboration between architect and engineer, and in the accompanying sketches it can be seen how extremely long spaces may be economically designed. The Glenn Martin assembly building was unique even for the ubiquitous Albert



GLEN MARTIN ASSEMBLY BUILDING - Section



GLEN MARTIN ASSEMBLY BUILDING - Section



CHRYSLER PLANT Bays measure 60' x 40'

Kahn, for its span of 300' x 450' was the largest used up to that time.. The efficiency of the design is shown by the fact that only 34 lb. of steel was used/sq. ft. of floor space.

The other sketch illustrates a section through the Chrysler Plant. This design combines economy and esthetic beauty, for the all welded structure is most graceful and uncluttered internally, and gives a fine, powerful line, indicative of its purpose, from the outside. The bays measure 60 feet by 40 feet and due to the cantilever, effected by holding the column back from the glass line, there is no more steel employed in the design than in a bay of normal construction measuring 30' x 40'.

Roofs should have adequate insulation for they make up by far the greatest potential heat loss surface in contemporary factories. This insulation can take many forms, some suitable, others less so, and I will run briefly through the attributes of the better known methods.

(a) Wood planks. If tightly jointed, their rating is high, though for very large areas it is doubtful if their use would be very economic.

(b) Cork, fibre glass, mineral wood, insulation boards etc. These comprise the better known methods and

all give excellent results providing a reputable manufacturer is chosen.

(c) Materials incorporating air spaces in small pockets; these are not so efficient in large, ventilated roof spaces.

(d) Stone concrete. This is useless for factory construction being far too heavy and having too low a coefficient of conductivity.

(e) Special lightweight concretes and porous aggregates are better, but the coefficient of conductivity should be checked before use.

(f) Gypsum and similar fine grained porous materials; these are usually even better insulators than are products of the same thickness of Portland cement.

(g) Steel and other metallic sheets; these are radiators, even when covered with asbestos.

(h) Built up bitumous roofings, roofing paper, asbestos or asphalt shingles and slate are not very satisfactory.

Finally it should be borne in mind that good insulation costs little more than bad and is a very worthwhile investment, particularly as the roof is usually the

most expensive component in the whole structure in any event. The insulator should be put on top of the structural roof and ease of erection will be a prime selection factor. Prefabricated units will obviously have a considerable advantage here, for once laid they form a framework for the work ahead. The selected material should be checked for condensation; dripping is intolerable to most manufactures. It must also be rot proof and must have an equally long life with the structural roof.

Walls.

Our next consideration should be to give some thought to the type of wall in which to clothe the factory. A great deal of loose thinking has taken place in this sphere, and I would like to caution against one or two of the more prevalent pitfalls. The first concerns the almost traditional mistake of building walls too permanently with materials which will far outlast the intended life of the factory.

Today's plants are built on something like a temporary basis; that is, they are conceived as a structure which before long will require alteration, enlargement, or even demolition. At least, this should be the assumption, and I have noted a prevalent trend in America to erect in this way,

in strong contrast to England where there is still a tendency to cling to traditional materials in spite of the evidence to demonstrate the unwisdom of this.

The logical approach to building a factory wall is that it be economically expanded or revised. Masonry is at an obvious disadvantage here, because of a certain lack of flexibility. The trouble is that manufacturers often insist upon brick or stone for the sake of "appearance" - giving a solid traditional effect which will go down well with clients and establish an air of "good, safe business". To this type of manufacturer, panel methods strike him as "substitutes" and they still think of a mill as an ancestral home of a corporation, rather than a shell over a mechanical process.

The second mistake is the antithesis of the first and is largely responsible for the continuance of the former's faults. It concerns the type of plant which has decided to embrace the theory of flexible walls, and instead of getting sure and safe methods, has fallen into the mistake of building in cheap and temporary materials. This happened in England to some extent after the second World War, when "temporary processes" were required to be housed. Needless to say they are still all there, and they were built of Nissen hut¹⁶ construction with its cheap first cost and attractive

quick erection. In spite of the claims made for them, however, they were not cheap to erect, and the cost of heating, servicing and maintaining them has been hopelessly uneconomic. In general they have been accepted as permanent and are very poor substitutes costing more year by year because of the low standard of the amenities provided.

The effect of this class of construction on the old diehards still "rooting" for brick is not hard to imagine. A much more scholarly and scientific approach to the design of factory walls has to be taken if any progress on a large scale is going to be made. The most important point about walls to remember is that compared to the total cost of the mill, they are a relatively small item. This means that a good deal of thought can, and should, go into their design, for in contrast to their effect upon the budget, their influence upon the morale and psychological wellbeing of workers, management and the community as a whole is so great as to be inestimable, for they are in effect the only thing about the factory which can be readily appreciated by the man in the street. This is a point which I have never seen stressed, and I doubt if architects or engineers ever seek to bring it to the manufacturers notice when considering wall finishes. It can be readily demonstrated that any small extra initial cost will soon be lost in the vast sums of money required to carry out an industrial undertaking.

It is infinitesimal when compared with the length of time people will have to look at the structure, and can be more than amortized in the first six months in terms of Goodwill, business and general contentment it will bring to the factory and its workers.

What then are some of the ways in which temporary walls are being studied by responsible research workers? Dunham says, "A large amount of development and experimental work is being carried on with the object of securing lighter, cheaper and better walls than those that have hitherto been in common use in the case of industrial structures, the use of the prefabricated panel may bring about considerable changes in one's ideas of suitable construction." The prefabricated panel has great possibilities for industrial structures if only for its attribute of only lasting as long as the intended life of the plant, for it will be noted that when a traditionally built mill is scrapped, it always involves a laborious and wasteful demolition of perfectly good masonry walls.

The present common types of prefabricated panel comprise precast, prestressed concrete units, asbestos cement sheets in a wide variety of shapes, sizes and textures, light alloy sheets, steel sheets, resin bonded plywood, and glass in its many forms either clear or opaque.

The trouble with all these materials is that they have a high thermal conductivity value, and they must therefore be combined with some form of insulation to make them usable. This extra layer usually comprises such materials as cork, fiberboard, woodwool products, expanded rubber plastics, lightweight cellular concrete, glass fiber, etc. Before any of these materials are used there should be some research done to assure that they will not be attacked by any particularly voracious animal or insect - especially in America. More research is required on all types of sandwich panel, for this lack of knowledge results in a reluctance to market the products, and there is at present a dearth of readily available types.

No account of panel construction is complete without mention of the new lightweight aluminum alloy sheeting which is being given much publicity at the moment. This method again has the potential disadvantage of high thermal conductivity, but the standard sandwich panel of which it is a part makes it a very acceptable wall cladding, being at once strong, light, easily erected, durable, non-corrosive, 100% salvageable, and, in some forms, very attractive.

This last attribute (once the others are established) is of special interest to the architect whose job it is to get the utmost esthetic value out of the building. The Alcoa firm

is one of the foremost champions of the aluminum panel, and they have demonstrated their faith in its possibilities by repeatedly using it in their own buildings.

The dangerous limitation of an aluminum sheet is its undue flexibility, but this can be overcome by pressing it into shapes which strengthen the section, and make pleasing decorative effects. The surface of the panel can be textured into many different forms (striations are particularly effective) and color can be applied by the baked enamel process. Of the remainder of the panel systems, asbestos appears to have many advantages. Unfortunately it is brittle and unsafe under stress,¹⁷ and it does not weather well. A wide range of sections are now available in this material, and it would seem that there is an interesting field for research to developpe the potentialities of asbestos. To date, in England, commercial firms have been preoccupied with trying to produce coloured asbestos which will provide a variant to the natural dead white of the material. At the time of writing, all they have produced is a series of ghastly hues, and the imagination searches in vain for a situation in which they would be tolerable, let alone effective.

Finally, mention might be made of a new plastic panel which is composed of a corrugated sheet of fiberglass,

mat impregnated with resin. This is still in the experimental stage, and has yet to be made fireproof, but indications are that it will have a great future, especially in circumstances where there is chemical action, such as in a chlorine atmosphere, to be resisted. It will withstand these conditions without maintenance. It is claimed that it will affect design and command new thoughts on industrial lighting due to its translucent nature.¹⁸

The advent of the wall panel brings with it the need to study the structural bracing to which it is attached. Overbracing should be guarded against since it must be capable of giving way correctly under temperature changes, and the design must be such that it is readily changeable; otherwise the inherent advantage of flexibility in the wall panel will be nullified. Each design should be carefully based on the merits of the job and the type of panel to be used, so that wind pressures and super-loads can be evenly distributed in spite of the intervention of doors and windows. The problem of bracing is essentially three-dimensional, and in order to assure that all loads are carried, a perspective of the frame should be set up.

Floors

Floors are the most abused part of the factory. They have to stand up to all sorts of impact loads, abrasive

actions and the ravages of constant liquid drippings in the form of water or more potent chemicals. It is obvious that the floor construction will be determined by the use, and the types of floors can be classed as heavy, medium and light .

1. The heavy duty floor is best constructed of creosoted end grain wood laid in mastic. For heavy truck traffic, a 5" reinforced concrete slab covered with an embossed steel surface or an armored grid is good.¹⁹

2. For medium duty, a concrete surface treated with iron or silica compounds, or patented liquid hardeners gives satisfactory results, but the joint edges will need protection if trucks are to be used.

3. Light duty; most normal floors will be suitable, and of these $1\frac{1}{4}$ " hard maple strips laid on sleepers or other suitable grounds will be found to give good results.

Chapter 3Lighting

I mentioned in the Preface to this thesis that the subject of lighting and color is one which is becoming well documented - unfortunately sometimes by charlatans who have no real qualification for the job. This is particularly regretable, for the field deals, in the last analysis with human health, so that it behoves architects to thoroughly check any suspect data on the subject.

Lighting in its broadest context has recently been the subject of a special study by Derek Phillips²⁰ who dealt with the subject wholistically as it affects the physical and mental outlook of man. I have no wish to enter deeply into such a discussion for I myself cannot be considered an expert. There is, however, a growing weight of opinion which reinforces certain concepts, and some data can now be quoted which should be of real guidance to the architect looking for factual information.

The over-riding consideration in any study of lighting, is to make sure that the subject will be slightly lighter in tone than the background. The converse situation will result in strain, whilst too great a contrast will produce equal strain with after images.

With the low, one storey factories which are now in vogue, one cannot hope to illuminate the inner space adequately with wall light alone, but where multi-storey construction is possible, the following guides will be of assistance.

Mitchell says that a distance 4 times the height of the window should be the maximum width of the factory, for after this, the level of illumination is lower than 10 foot candles; he further advises lowering this limit by 25% to allow for dirt, grease, overhead gear and other obstacles.²¹ Barnes,²² is more pessimistic, for he says 3 times the height is the maximum without artificial illumination, and he further adds that if the windows are not washed oftener than once every six months, the limit should be reduced to twice the distance. This figure is agreed with by Dunham²³ who also adds the following information:

1. The maximum intensity of illumination on any work plane should not exceed 3 times the minimum level in the room - the object being to attain a uniformity which was mentioned earlier.
2. The areas of the windows should be at least 30% of the floor area in order to assure at least a 10 foot candle minimum, assuming 6 months dirt on the windows.
3. The upper part of the window is the most effective in lighting the central portion of the room.

4. Increasing the size of side windows affects the minimum intensity more than in direct proportion to the change in size, whereas on the other hand, it has less effect on the maximum intensity.

5. Sloping windows let in more sunlight than vertical, but they collect more dirt and are more difficult to clean, they should therefore only be employed when the management is fully cooperative in the matter of good housekeeping.

6. Vertical windows with a 6 month accumulation of dirt lose 50% of their efficiency, windows with a 30° slope in the same condition lose 75%, and windows with a 60° slope with 6 months dirt lose 83%. In addition to the above it has been calculated that for a given length of time, the accumulation of dirt on a vertical window is 75% on the inside and only 25% on the outside.²⁴

To attain these conditions, the height of adjoining buildings should not be greater than the distance between buildings, and the width of the window should be at least 80% of the bay spacing, and they should at all times be made as large as possible. It is axiomatic that the nearer to the ceiling the windows are placed, the more efficient the lighting, and this has its repercussions for the architect and engineer who may think in terms of flat slab construction rather than wall beams to get the frame as high as possible.

Glass bricks deserve a mention, for they are easy to build, eliminate framing, they diffuse the light well, and have good thermal insulation. Unfortunately they have acquired a bad reputation with certain manufacturers who used the ordinary type of glass block which reflects the light directly into the room and so produces a most offensive glare.²⁵ Happily there is a special type now on the market which refracts the light up onto the ceiling, thus giving excellent light with no glare whatsoever at the window plane. The difficulty, of course, is that the wall becomes inflexible, the blocks must have no load upon them, and frequent expansion joints must be provided.

Opening lights must be carefully considered both to give clearance to travelling cranes and structural features, and also to give access for cleaning the windows. Windows that are difficult to clean and maintain are a costly item, for managements will not struggle to keep them clean, and they eventually go into disuse and become mere inefficient units which have no structural value and little or no light giving properties.

The insides are always the most difficult to clean, and the question of cat walks should be thoroughly studied. Permanent cat walks are a mixed blessing, for in order to be

accessible to the windows they inevitably keep light out and an ingenious temporary system is therefore indicated.

For roof lights, the traditional north light truss can be said to be in disfavor at the moment: "The north light, despite its long popularity, can be said now to be inappropriate for most kinds of work."²⁶ It lights only one side of the work, casts a hard shadow and makes the factory look dirty. This, I feel, is a particular attribute of the old steel frame truss, and I believe much better results could be achieved by using a shell concrete north light section with the curve painted white on the underside, and carefully calculated to make the very most of the reflection of light from the 60° side. I feel this would considerably lighten the shadows which are at present cast on the dark side of the machines.

Research is being carried on to obtain the best results, and present studies indicate that there are considerable possibilities in a modified version of the American monitor roof light, which has been used on the Sigmund Pump Factory at Gateshead, England. The problem is essentially one of uniformity and shadowless light, and at the above factory the section gives an even distribution of light at a relatively high intensity for natural daylight.

Artificial light is required in every plant, and

it is here that charlatanry enters the scene. It is good practice to place the lighting in rows parallel to the windows, so that as the natural illumination fades the artificial light may be switched on from the rear outwards, and so save power. It is also a good rule to avoid the source of light being too easily seen, for very often in present factories the brightness is far too high. Fittings could be made of translucent material sufficiently dense to prevent light from being unduly bright when seen at angles of less than 60°.

Dark ceilings are another big fault, for they reduce the illumination, heighten the contrast and do nothing to eliminate shadows. Albert Kahn, whose opinions on any facet of industrial architecture are worth considering, maintains that 25% of the total light output should be reflected up to the ceiling.

Incoming current should be carried by two or more high voltage lines, any one of which should be capable of taking the load if there is a breakdown in one of the lines. Double-row switches or breakers at the master station make any such transfer a matter of seconds. Sub-stations are best underground, for the mezzanine type which were popular in the interwar years have been found to be light obstructors, difficult to frame round, and they foul up crane lines and

cables; their accessibility makes them too prone to sabotage and they are not easily guarded. The only disadvantage of underground stations is that they require ventilation for the transformers which generate considerable heat.

For calculating the load, use the lighting load as this is fairly stable. Take 5 or 6 watts per square foot of floor area if the incandescent type is to be used, and 2 watts per square foot if flurescent are involved. This figure permits intensities of 50 foot candles or better,²⁷ a standard which is often given as a desiderata in America, and it is noticeably higher than in England where 30 foot candles is usually considered sufficient.

The most important point is that an even distribution of light is maintained, for the National Safety Council Incorporated says that 15% to 25% of all accidents in factories are caused by poor lighting. Furthermore, even, overall lighting permits full use of the available floor space, and for special work extra, directional brightness can be obtained.

The speed of seeing is another factor. An increase in illumination from 1 foot candle to 20 foot candles increases the speed of seeing three times.²⁸ This naturally affects everything the worker does; furthermore, a long arduous task requires a higher level of illumination to keep concentration at a high standard.

Color

The question of color is the most ill-considered of all interior industrial design work. In my previous study in England, I visited over 70 mills, and in not one did I find evidence of the slightest interest or knowhow in the subject. I remember two mills which had a refreshing off-white and grey combination which resulted in a clean, airy appearance, but for the rest, there was the usual distressing cream and emerald green (to dado), or the somber, hopeless, buff and dark brown. The sheer obtrusiveness of these colors is evidence that the manufacturers are not afraid of color for its own sake; it simply tells the story of crass ignorance of the true function of color and its profound mental and physical effect upon employees.

What then are the main points to watch for when thinking in terms of color relationships for industrial use? Perhaps the first thing for the architect to remember is a practical hint; make sure the chosen colors are easy to duplicate and maintain (if possible as easy as the traditional green and cream) for this will at once help to win the manufacturers confidence and sympathy.

The first functional point to grasp is that color in factories should never be pure or saturated. Such use of color can be very distracting, and there is a temptation for

the young architect, fired perhaps with the missionary spirit, to go slapping bright reds or vivid blues on walls and ceilings under the mistaken impression that by such decoration he is helping to create "focal points" or "visual stops". The colorist's job is not to "decorate" the factory, but to prove his worth by speeding production through bettering the employees' moral and physical wellbeing.

This is not to say that color is out! Far from it; but pastel shades in their infinite variety should be the aim, and it is a good rule to restrict oneself to the paler hues. Since the work should always be lighter than the background, the walls are better in restrained color and subdued in tone. Floors are usually too dark and make too much contrast with the work. Furthermore they lose their value as light reflectors, and floors laid in whitened concrete have been found to raise the level of illumination considerably.²⁹

The eye sees no color within its vision as a fixed quantity, but is always modified by adjacent colors either in intensity or hue. For instance, a tan background with a low reflection factor will enhance and strengthen the blueish hue of steel, and therefore accentuate the form. Similiarly, copper and brass with their orange hues are best seen against a background of grey or blue-green. Green machines look best, and are most easy to distinguish against a light, pinkish-grey. Painting walls in light grey may not be nearly so

dull as it sounds, for they may be 'lent' color (to the eye) by the close proximity of strongly colored machines, columns or bands of color on the wall itself. This brings up the question of the after-image which is a well known phenomena to those who have tried the color quizzes to be found in diagrams in books on the theory of color. It indicates that soft, complementary colors should be chosen to the one the worker sees predominantly in his task.

The following tricks of color combination are well known to colorists, but it appears that they are virtually unknown to industry and the decorating trade which advises industrialists. I make no apology, therefore, for restressing these relationships in this context. If a cool effect is required in a room, the vestibule or entry can be used to create this impression by decorating it out with a predominance of orange. A warm grey-green is the complement of dark red (such as that to be found in coagulated blood, so making the cooler color particularly applicable for use in operating theaters), burnt orange and maroon are advancing colors and are therefore used when trying to shorten the appearance of the room.

Colors also have strong psychological associations and their use may have application in various sections of the plant where totally different moods are required - such as the canteen, the production center, the board room, the rest

room, etc. Among the better known of these associations are yellow with its good cheer, blue for tranquility, purple is depressing, red excites, while orange is the most powerful stimulant in the spectrum. It is interesting to note that green has no discernable effect upon human emotions.

There is no excuse for the architect to complain of lack of colors or range. Theoretically, there are 150 hues discernable to the human eye in the spectrum of sunlight; times 10 for the variations in the value of the hue, and multiplied by 10 again for the variation in intensity at each value level, making a grand total of 15,000 colors, of which 1000 is the maximum ever likely to be required by the architect.³⁰

Dados are of great value in industrial plants, for they can be painted appropriate colors to get the necessary rest for the eye and act as backgrounds to the work plane. Above this level there may be lighter colors to get reflection and raise the level of illumination. No particular color can be designated "best"; relative values and intensities should be studied in individual cases and become the governing factors. Esthetic values in color selection are of great importance and contribute to the well being of workers. Many directors attribute headaches and bad temper to "acidity" but the old officious mahogany desk is often to blame - there being too much contrast between the dark wood and the

white paper.³¹

Again, this question of undue contrasts comes up, and the architect should be sure that throughout his scheme contrast is permitted only for definite effect. In the factory, contrast should be avoided where trusses and structure is seen against the light and they should be painted white. On the other hand, strong contrast can be used throughout the plant as a means of indicating danger or defining the duties of certain items of machinery. I refer to the painting of pipes containing water, gas and electric cable etc. in accordance with a color code which makes them readily found wherever they may be in the plant. America's Faber Birren evolved such a code for use by the U.S. Navy during World War II and in England recommendations for similar differentiated pipes and machines are set out in British Standard Specification No 1710, 1951 and 349, 1932.

The place where the designer can really set out to display his ingenuity is in the main entrance hall. Here the decoration can be as gay, as decorative, as attractive as the management will allow - for they will usually call a halt to such escapades! The entrance hall is the place the visitor gets his first impression of the mill and it is here (if my recommendations were followed!) that the worker would get his psychological uplift as he enters the workroom.

The best use of such opportunities to date is to be seen in some of the Swiss factories. Their use of different color combinations is masterly and worthy of Klee or Nicholson, and is quite probably in some cases inspired by the former, a native of the land.

There is a danger in America and Britain of thinking of color as something applied to a surface by man. Here again I feel we have much to learn from the Scandinavian countries who use wood in the most delightful manner to make the most of its color; and when set off against the infinite variety of green to be found in nature, their plant studded entrance halls are a joy to behold - and smell. The question of using nature in the form of plants is a difficult point on which to convince managements. There is no doubt that their use involves constant and careful maintenance, and many hardheaded manufacturers will not hear of it, and at best one is permitted to use artificial plants - perish the thought!³² It is the opinion of the writer that one of the greatest charms in the architecture of Switzerland and Scandinavia lies in the exuberant use of foliage and plants of all descriptions. I have even seen a tree growing with supreme beauty and eloquence within one of the most recent of the many excellent contemporary churches in Zurich. This took real artistic skill, taste and conviction by all concerned. Why not in a factory lobby?

This pet contention relies for its execution upon a painfully slow process of education, first of management - and then the workers will gladly follow suit. There is much talk of the destructiveness of employees and this has been quoted to me as an argument against natural foliage in too close proximity to workers. Again I point to Sweden and Denmark where, by constant use and familiarity, plants and trees are accepted as part of the decor of any scheme and respected as such. The possibility of vandalism is as remote as an act of sabotage, and if the move fails when first introduced - so much the more reason to try again.³³

Finally, and for the record, it is interesting to note the practical gains in cases where color has been tried. Faber Birren³⁴ reports that in 1947 the National Industrial Conference Board asked over 350 companies which had used color on large or small scale to comment on progress. 64.7% said that color had improved lighting, 27.9% reported production increases, 30.9% noted an improved quality of work, 19.1% commented favourably on reduced eye strain, and 14.7% contended that it reduced absenteeism. In all, 75% reported that they were satisfied with the changes, 5.9% said they were not, and 19.1% had no comment. When one reflects that of the few unsatisfied and unconvinced, the vast majority probably had a poor color scheme done by a "quack", one can safely contend an overwhelming victory for the advantages of color in factories. More recently the New York City Transit System

has reported that its new safety color code has reduced the accident frequency rate by 42.3% over a period of 18 months, and this over a total working force of 38,000 employees. This reduction results in an insurance saving alone of £500,000 per annum! Q.E.D.

Chapter 4Ventilation.

Finally, a few notes on more mundane matters which again are often the business of experts but which are an important part of the architect's equipment. Ventilation should be studied with respect to flow diagrams to chart the flow of air and make sure no areas are short circuited. The natural ventilation should first be studied in conditions of still air, then under the influence of outside wind and finally under the influence of artificially circulated air. This is where some knowledge of the behavior of air currents of different temperatures is important and the following points are worth remembering:

1. When warm air is discharged near the ceiling it will fall as it cools and as displaced by more warm air, so giving downward circulation.
2. When warm air is introduced near the floor, it tends to rise at once and displace cooler air; the warm air thus tending to collect near the ceiling.
3. When warm air outlets are near the ceiling and under intakes, circulation will short circuit the far side of the room. When the intake is on the far side of the room the

circulation is better.

4. When vice-versa, the position is the same except that when the intake is on the far side of the ceiling the circulation tends to go up one wall and across the ceiling to it, so short circuiting the room.
5. In view of the above, consider using multiple inlets and outlets.
6. Strong downdrafts or lateral movements of cool air may be injurious to occupants.
7. In view of the opposite conditions in Summer as against those prevalent in winter, it may be worth while installing dampeners and cross connections to reverse the process.
8. All inlets and outlets should be controllable by dampeners so that in summer, with the windows open, the system may be partially used.
9. Cyclones, fans, motors and ducts are remarkably large pieces of machinery, each requiring ample space, convenient situations and easy accessibility, and they must therefore be taken into account at a fairly early stage in the planning.³⁵

Heating

The days of the old centrally placed boiler house which supplied heat for the whole plant are now largely at

an end. One major factor in this change was the switch from central to individual drive for the machines. The elimination of the plant to drive the old rope race and belts meant that the only remaining use for the boiler house was to heat the factory. This, in turn was found to be too inflexible and it was difficult to control the particular requirements of special rooms.

Therefore the use of individual heating units is growing, and its several advantages may be set out as follows.

1. They can be readily located in existing buildings with no necessity for duct work.
2. They can be relocated to meet the changing demands of production.
3. Their range of capacities in either individual units or combinations meets the demands of large or small spaces.
4. They give positive circulation of warmed air, particularly where there are high ceilings, for it is in these conditions that a central system tends to short circuit some of the space, and the warm air gets stuck just under the ceiling, the thermostat closes and the areas below are still cold.
5. When they are suspended they save valuable floor and

ceiling space which is required for other purposes.

6. The efficiency of the heating units enables there to be fewer heating elements; there is also less piping involved, together with the appropriate connections and fittings. This reduces first cost.

7. Units make it possible to have temperature variations within the room, and even in various parts of the room.

In considering a heating system, adequacy is the first essential, and then accessibility - a point which was often overlooked by the early engineers. The main types of heating element employed are steam, hot water, electricity and gas. In nearly all these methods the air is drawn over the heated surface by a propellor or centrifugal fan. The convector surfaces have built up fins which extend the surface area, and they should be of non-ferrous metal - particularly where humidifiers are used in conjunction with the system, or where there is liable to be any dampness.

Services

The only remaining major item to discuss is that of the services, and the average architect will have ample experience in this field to obviate the need for elaboration here. The only points to watch with especial care are the following: The size and scope of big industrial undertakings are such that there are often four types of drainage:

(a) Land drainage, (b) Surface or rainwater drains, (c) soil drains, (d) Trade effluent drains. It may be most important to keep these various types of trade effluent separate, and ample provision should be made to meet the requirements. Many industries use phenomenal amounts of water, and their needs should be checked against the availability of water from the local Water Supply Undertaking, and plenty of storage capacity allowed. Constant revision and maintenance of pipes in a factory is inevitable, and it is therefore imperative that all the main pipes be housed in service ducts where they are accessible at any time. This is a matter for some careful planning for the ducts should be routed so that when alterations are required, no road, or main section of the factory floor has to be taken up. The difficulty is not only at the time but later, for the infilling always settles and forms a trough which leads liquids in the wrong direction, and harbors dirt and is dangerous to pedestrians. The ideal method of course, is a system of removable duct covers, or, if the duct is very large and important, it is worthwhile making it large enough to be crawled, or even walked into, by maintenance men.

The architect's responsibility for the adequate provision of maintenance facilities was mentioned in Part I, and I would amplify it here only by saying that the central store should be handily located. For the main workroom, a

popular place is somewhere in the center of the plant underneath a mezzanine toilet block, although Kahn is convinced that the place for the toilets is underground, connected by passage to the open air, so that the workers may pass directly from the car park, through the time checks and cloakrooms to their workplaces just above.³⁶

When deciding materials from the standpoint of maintenance it is sometimes worth considering less enduring materials because of their ease of replacement. This goes particularly for the roof, where many of the proprietary roofing sheets are cheap, light and easy to replace. Roof maintenance does not require any stoppage of work and the saving in initial cost and the lighter construction used in the steelwork over traditional materials is enormous. As was pointed out earlier, the floor takes the heaviest pounding and no economies may be employed with impunity.

Industrial Accidents.

Finally in this part I would like to draw attention to the question of accidents and quote a few figures, for I believe it is by doing this that I can point most effectively to the importance of some of the design considerations I have tried to stress.

The Royal Society for the Prevention of Accidents states that 25% of all accidents in factories are due to handling mishaps, that is more than any of the 28 other hazards listed.³⁷ This argues the better and more efficient use of materials handling systems and the fully automatic plant; it also illustrates the importance of good lighting and good design. A further 12% of accidents are caused by simply falling down, and half of these when walking on the level! This is not so strange if one has seen the condition and unevenness of some of the "flat" floors in some of the old British and New England factories. Indeed, this is the prime reason for this high class of percentages, for the unevenness causes pools of water and oil to form and so heighten the dangers. The other reasons for these falls are bad lighting and bad ventilation which sometimes results in clouds of steam or dust temporarily or even permanently obscuring the view.

A further 12% of all accidents is caused by falling objects and the majority of these could be avoided if all balconies were provided with small upstands at the edge so that objects could not be pushed over the edge onto the heads of operatives below. 17% of all accidents are due to machinery and although the architect can do little to dictate the design of machines, his contribution can be effective by providing

1) non-slip floors which prevent operatives from falling onto machinery; 2) adequate personal storage space to eliminate untidiness due to personal articles lying on the machines; and 3) good lighting conditions to avoid glare and unsafe working.

In England alone, \$30,000,000 worth of property is lost each year through the ravages of fire. The major causes in order of importance are as follows:

1. Electrical installations: defective or inadequate systems.
2. Inflammable liquids or gases: inadequate protection against accidental ignition.
3. Spontaneous combustion: inflammable materials left or stored near undue heat.
4. Dust explosions and poor ventilation, lack of cleanliness and the accumulation of dust, much of which can be alleviated by good planning.
5. Miscellaneous hazards: smoking in unauthorized places, water contact via leaky roofs etc. with sodium or potassium etc.

These impressive figures should convince the architect

that beyond the provision for utility and beauty which he strives after, the principle of "safety first" should be also a prime consideration. Industrial plants are fraught with opportunities for the worker to harm and mutilate himself, and the removal of every conceivable risk should therefore be the aim of every designer.

NOTES ON PART TWOChapter 1.

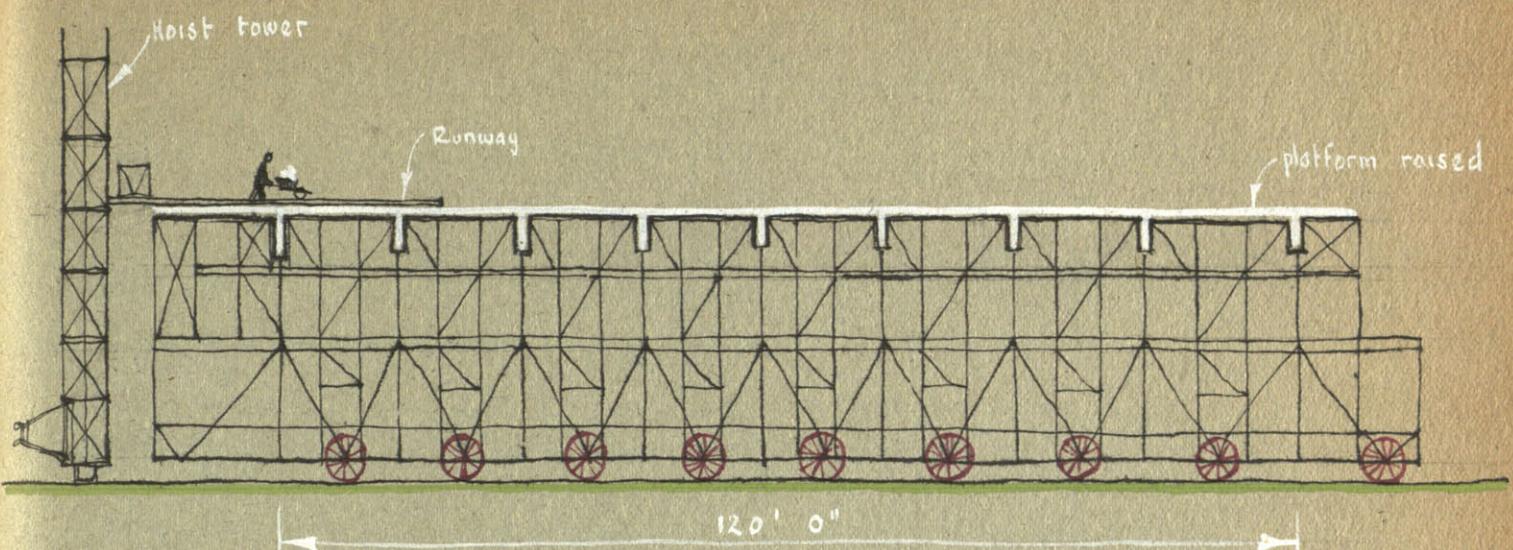
1. H.F.Ferguson, President of the H.F.Ferguson Co., from an article in the Architectural Record, Jan. 1941.
2. Experience has shown that 30% of the production area should be covered by a high bay, and that all factories larger than 30,000 sq ft should have it.
3. Architectural Record, "Factors Affecting Industrial Building Design" July, 1954. p.151.
4. Durham, Clarence W., "Planning Industrial Structures", 1st Ed. McGraw-Hill Book Co. Inc., N.Y. 1948, p.33.

Chapter 2.

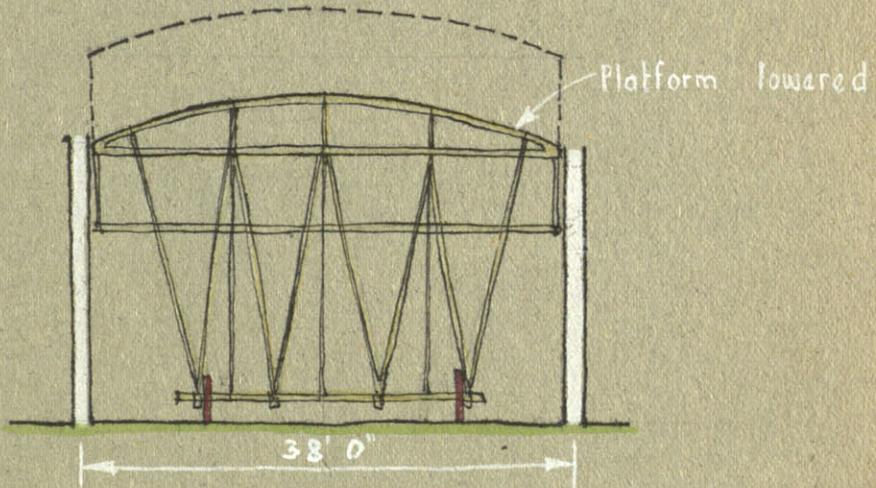
5. Apple, J.M., Plant layout and Materials Handling, N.Y. 1950, p.270.
6. Architectural Review, Building Study Types No 201, Industrial Buildings Aug. 1953, article by Whitney F.L., "Newer Trends in Industrial Buildings" p.152; c.f. Eberhardt W.R., "How much does a column cost?" in Cross Section Vol. 3, No.12, p.10, the H.K.Ferguson Co. Dec. 1929, in which he contends that a single storey building with a single row of columns would be 10% cheaper than with a clear span, while a 120' span would be 16% cheaper with a central row.
7. Mills, E.D., "The Modern Factory", op.cit. p.59.
8. European engineers, who are more given to reinforced concrete work, continuously make jokes at the English and American practice of erecting a steel frame building, and then cover it with 2" or 3" of concrete for fire precautions. With reason they ask "Why not use reinforced concrete in the first place and enjoy the terrific steel economies which will result?".
9. An example of the extreme care and efficiency which Kahn puts into this aspect of industrial design may be seen over the page where, for the Chicago Dodge Plant,

DODGE CHICAGO PLANT:

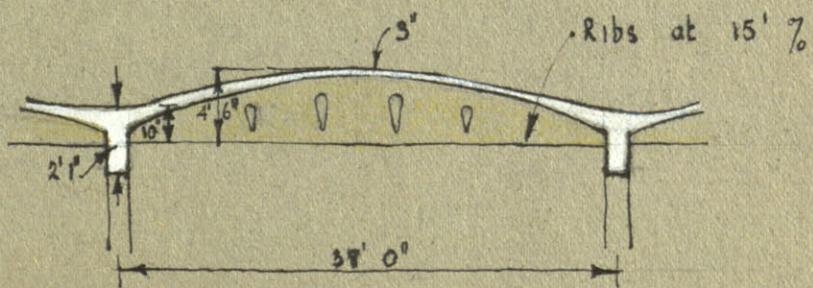
Showing Kohn's moveable 'Trojan Horse' Formwork



Side elevation : showing method of pouring



Section : form lowered for moving



Completed Section.

he invented a special "Trajan Horse" formwork which, with carefully worked out pours, would expedite the construction to an almost unbelievable degree.

10. e.g. increasing the permissible tensile stress from 20,000 to 25,000 may seem to reduce steel use by 20%. This is true at critical points, but such a lot of reinforcement has to be used for various purposes throughout the length of the beam, that in this instance the total saving is barely 5-8%.
 11. I was also startled to note that in America galvanized windows are an extra, whereas in England it is standard finish, and although this particular case may be attributed to rigorous weather conditions, there are other such interesting anomalies.
 12. "Planning Industrial Structures." op.cit.
 13. To illustrate the serious character of some of these "alterations", I quote two cases: a) In a factory truss shaped:
- 
- a vent duct was required right on the line of the bottom chord. It was promptly burned out and the duct put in. It stood up by acting as a 3 hinged arch! b) Strong longitudinal bracing was provided in a 40 ton crane runway. The operation wanted a machine there, so the bracing was naively cut away - with no replacement elsewhere. Engineers later hurriedly added reinforcing braces to adjoining bays.
- 14.
 - 15.
 16. These are the equivalent of the American 'Quonset hut', and I understand that much the same conditions prevail with regard to them. This word 'temporary' is the bane of all architectural work. We can see the dangers of it on our own campus here at M.I.T., where at the rear of the school is a gaggle of unlovely structures which will no doubt be there for years to come: I live in Westgate West with its temporary dwellings; they will be up yet probably for decades and in the meantime generations of families will have to put up with the faults of this type of construction.
 17. When I was in hospital recently in Britain, a patient in the next bed was a building laborer suffering with a broken back which had been caused by a fall due to the

sudden failure of a corrugated asbestos roof slab on which he had been standing.

18. Reported in the Architectural Record: Building Study Types No. 201, Industrial Buildings. Aug. 1953, Whitney, F.L., "Newer Trends in Industrial Buildings" p.151.
19. Reid, Kenneth, "Industrial Buildings - The Architectural Record of a Decade", Pub. by F.W.Dodge Corp., N.Y. 1951, p.22. The main danger to avoid is that of "dusty" concrete floors. Binders should be added as a matter of course to all concrete finished floors. The famous Christian Science Printing works in Boston, Mass. uses Oregon Pine on the end grain wherever there is particularly hard wear. This was chosen as the hardest floor obtainable.

Chapter 3.

20. Phillips, D., M.I.T. M.Arch. Thesis, Jan. 1954.
21. Mitchell, W.N. "Organization & Management Production" N.Y. 1939, p.147.
22. Barnes, R.M., "Industrial Engineering and Management", N.Y. 1948, p.239.
23. Dunham, C.W., "Planning Industrial Structures", N.Y. 1948, p.39.
24. From information by Detroit Steel Products Co., also Randall W.C. and Martin A.J., "Making your Windows Deliver Daylight" Trans. I.E.S. Vol. 22, p.239, March, 1927.
25. In a factory I visited in North Adams they had just installed glass brick wall to the weaving shed and the workers were complaining of strain and undue heat from the wall. This was undoubtedly due solely to the glare from the wall giving an illusion of great heat, for the thermal insulation of the glass block was far greater than that of the glass they had just dispensed with.
26. "Factory Lighting in Great Britain", by W.A.Allen and J.B. Collins, a paper presented to the Building Research Congress 1951.
27. Reid, Kenneth, "Industrial Buildings" op.cit. p.58.

28. Ibid. p.63.
29. As an example of this, in a recently built airplane factory, 61% more light was reflected from the white floors than from the ordinary grey concrete in the warehouse. It was further found that the white floor saved 20% of the fluorescent fixtures, copper in the distribution system, smaller transformers and switch-gear equipment, and less steel and aluminum for the reflectors, less magnesium for cutouts, lead for cables, less zinc, rubber resin and current. When added up at 5¢ extra / sq ft, it was found that the floor amortized itself in 7 months, and it now yeilds 90% annual- ly on the investment.
30. Just before I left England (1953) Jenson and Nicholson of London brought out a magnificent range of 999 colors which can be mixed easily by the amateur and are all available commercially.
31. Julian Ellsworth Garnsey: a colorist quoted in Reid, K. op.cit. p.209.
32. This attitude prevails throughout American business. Recently when designing a large hotel for one of the 3 foremost American hotel chains, I tried to sell the idea of live plants in the entrance hall. "Not a chance!" I was told, "Nobody will look after them. If we use anything, it will be artificial flowers: there's a simply marvellous firm in New York . . ." And this in the lobby of a hotel for 1,500 people!
33. I have even seen this work in Lancashire, England. An enlightened Borough Surveyor for whom I was working in an advisory capacity had planted several trees on a play lot. The first group were mutilated by the children. He told me "I just kept of putting new ones in until they got fed up of destroying them". His ninth group succeeded and the healthy group of young trees are now the joy of the neighborhood and a delight to young and old.
34. Birren, F., "The Functional Use of Color" paper presented at the Building Research Congress.

Chapter 4.

35. It will probably have been noted that I have repeatedly been drawn into saying a given service shall be considered

"at the start". The architect is used to this constant cry from all the various specialists and nowhere is it more justified than in industrial work where everything is liable to be on such a colossal scale. In his capacity as an organizer and liaison officer as well as designer, I maintain again that the architect is basically well equipped for the job of industrial designer.

36. I am inclined to agree with this theory - except that I would lead the workers through a nicely furnished entrance hall complete with well designed exhibition cases of the firm's work. The position of the toilets above the maintenance supply could well be replaced by the formens' or shed manager's office. From this vantage point the whole shed would be visible, and by a system of colored code signs, the worker could relay to the office calls for maintenance assistance or supply. The message could then be simply relayed down below and the breakdown rectified. This would remedy the present system in which maintenance men often walk miles in a week, simply looking for work in the shed.
37. Mills, E., "The Modern Factory" op.cit. p.47.

PART THREE

THE VISUAL ASPECT OF THE FACTORY

PART THREE

Chapter 1.Recommendations and Conclusions.

The final part of this thesis is concerned with some thoughts on the purely esthetic side of industrial architecture. It is to this end that the work has been conceived, for until the outbreak of the Second World War there had been virtually no thought given to the problem of expressing this manifestation of our age in a manner which showed any promise whatsoever of heralding a style befitting the importance - not to say the urgency - of the case.

Until that time, it was quite evident in the writing (and still more evident in the absence of the writing!) on industrial architecture, that nobody had come to realise that sooner or later the problem would have to be tackled if utter chaos was not to reign supreme in the urban scene. As late as 1931, Barnes, in his book "Industrial Engineering and Management" devotes a 122 page section to industrial plant design and equipment, and of this he gives 20 very hesitant and reserved lines to architectural composition. He concedes that good design has some effect on morale and even advertising, and his attitude is best summed up in his own words; "a pleasing appearance is worth having ... this is to be recommended when no great additional cost is involved."¹ The extent to which he discusses or even hints at industrial psychology is seen when he notes that some managements insist

on cloakrooms and locker rooms being placed so that the worker must pass and visit them before ringing his time card!

This is the sort of attitude which has put us in our present position. We see in history how Dickens tried desperately to expose its evils, and it is well known that much legislature was enacted to relieve the physical trials of the time. Although these things are now long passed, the esthetic conscience of many industrialists is only just beginning to be stirred, and the attitude of some is still only a hair removed from that of their forebears in the mid-80s. In fact I would say that in Lancashire, England, the attitude of the majority of managers is still indistinguishable from that of Dickensian Britain in this matter.

Some writers, however, strove to point the way to something better, and in 1935 L.H. Bucknell embarked upon a lengthy defense of the functional approach to industrial architecture, and stressed the oft-repeated slogan of the moderns that, since we are living in an age with new requirements, there is no justification for trying to solve novel problems with esthetic formula derived for use in another era.²

Some time prior to this date, of course, a select

group of well-known architects were alive to their responsibilities, and had come to some re-evaluations of the whole philosophical approach to the age in which they were living. Few of these got as far as making any statement in their work concerning their outlook on industrial architecture, but one in particular, Peter Behrens, will go down in history for his remarkable Turbine factory for A.E.G. in Berlin as long ago as 1909. This is the first example of the use of glass, steel and concrete in the modern idiom on such a large scale, and the power and excellence of the design still makes it widely quoted in architectural treatises. It is years ahead of its time - not that it was before its time, for it was long overdue - but not for many more years was an architect of vision given the opportunity to make such a bold, vigorous statement of the new principles as they could be applied to industry.

Behrens realized that the turbine was yet another symbol of the new age and strove to express this, not simply because it was new (or we would be in danger of arguing that everything novel automatically requires a new type of building) but because nothing in the vocabulary of styles up to that point went anywhere near being an acceptable solution to the huge nature of the problem. It was not long afterwards that the problems became even larger in scale. The aeroplane, for example, had no prototype, and the problems of scale and

proportion unprecedented. Caught unawares, the builders were forced to erect something quickly and without any attempt at an esthetic analysis and synthesis, so that the result was probably only what one could expect - great barnlike structures devoid of scale, feeling, fitness or beauty.

This led to a new danger. The man who could evolve a means for erecting these titanic structures with the least possible expenditure, with the fewest materials, in the least possible time became confused with the man who really had the true answer to the problem.³ Thus it came about that Albert Kahn's genius was so widely hailed in the architectural press. His truly phenomenal powers and gift for organization found a fertile soil in the American industrial scene. His inventiveness and versatility enabled his expanding firm to play an ever widening role in American industry. This is evidenced by the fact that in 1938 Kahn's work totalled 19% of all architect designed buildings in the U.S.A.⁴ This expansion was apparently slavishly applauded by most sections of the American architectural press, and I personally have never been able to find any esthetic assessment or criticism of his work which would in any way draw attention to its shortcomings. The technical press was full of industrial work in the years following the outbreak of war and in the opinion of the writer, only a very small fraction

of that work had any right to claim a place in a magazine seriously purporting to illustrate and sponsor the work of men who were making any contribution to the search for a new esthetic.

These plants were mostly on the grandiose scale and their sheer impressiveness led to the error of believing them to be significant works of architecture. Much of this grandness was imparted by the endless repetition of small units, and it is well known that under such conditions even badly designed units can appear tolerable. The barrenness of esthetic insight is seen to the full when there is an intersection in the mass, or where it is broken at entrances or at junctions with other buildings of different use, such as offices or administrative blocks. At such points the transition in feeling and scale is usually effected with little understanding of the basic facts of composition and design, and hence the total result is confused and disappointing.

The office of Giffels and Vallet Inc. and Rossetti, is another whose work has received great publicity. The standard of work, architecturally speaking is much higher here, and this is doubtless due to the powerful influence of Rossetti, the unincorporated architectural partner. Here again, however, is an office of 1000 men working at top pressure⁵ turning out buildings in the most machinelike way,

and quite understandably with the most machinelike results. This rather forthright statement is not intended in any way to decry the magnificent and unique contribution made by Kahn and others, but it is an attempt to counterbalance a lot of the adulatory nonsense which has been talked and written about them, by people speaking from an architectural 'platform'.

It is, however, largely due to the tremendous volume of revolutionary structures erected by Kahn that the architectural concept of the industrial plant has radically altered in the past decade. It is through his work that industry has come to accept contemporary architecture because of the substantial economies which could be shown over traditional styles. I believe that the time is ripe for men of deep sensitivity and thoughtfulness to infuse into contemporary plants the feeling for scale, texture and line that seems so often to be a fortuitous by-product of current work.

Oddly enough, one of the most enterprising and promising sources of this new feeling comes from another 1000-man firm. Skidmore, Owings and Merrill (all architects) are divided into three offices in different centers in the U.S.A. and this greatly helps the intimacy in each office. Further, in such a vast firm, much depends on the authority and quality of the job captains or group leaders. Gordon Bunshaft

is ideal for this role. His brilliance brought forth the Lever building in New York, and in direct line with this example came the recent factory for H. J. Heinz in the center of Pittsburgh, which is discussed later.

The way is open for others who are willing to prepare themselves in the way I have tried to outline. Industrial work disciplines the architect: function is the predominant characteristic and this is closely followed by cost. This is one field in which no esthetic argument has the slightest chance of prevailing unless backed up by solid fact and logic, and is consonant with the overriding functional prerequisite. The matter is not even arguable with industrialists. Such a concept is very wholesome; it would be of considerable help to architecture if this were the dominant criterion in all works executed, for it would at least sweep clear a great deal of the eclectic banalities which are still being erected.⁶

As Reid says⁷, any competent architect can venture into the industrial field, but he would be extremely ill-advised to do so alone. The aid and intimate cooperation of engineers, both structural and mechanical is essential, and I feel greater intellectual preparation than is hinted at by Reid, is desirable.

Cost is of pre-eminent importance once the function is satisfactoraly completed. Manufacturers cannot be put off with vague prices and wide "margins of error". Industrial undertakings involve vast sums of money and the architect should be able and capable of producing accurate costings of any scheme he comes up with. It is through economics that the way to the esthetic heart of the client is to be won.⁸ The architect will often find the client willing to spend an extra for some special architectural feature in either finish or decoration, if he has just previously taken £100,000 out of the mechanicals or the structural system. Careful study may result in savings which will in turn win the manufacturers confidence in the archtect's overall ability, and it is then that he is most likely to listen to reasoned arguments on the psychological and even material benefits to be derived from certain esthetic effects. Although time is usually of the essence in this class of work, and alacrity will be regarded with especial favor, design is possible as evidenced by the work of the few who have achieved a satisfactory result.

The greatest challenge in industrial architecture is that of size. The sheer immensity of the scale presents a colossal problem to the architect who is sensitive to the need to establish in any work some frame of reference against which man may establish his position in relation to the

structure before him.

This is one of the main problems concerning the larger works of industrial architecture, an extreme example of which is a massive structure like Willow Run which covers a vast acreage; rearing up huge bleak walls on all sides which are innocent of the slightest hint of depth, decoration or relief, which would give any clue as to scale. I feel there is something inherently wrong with any solution to an architectural problem in which the only chance one has to orientate or find oneself within the scheme, depends upon catching sight of a small, insignificant doorway every few hundred yards in an otherwise completely unbroken cliff of corrugated asbestos.

Glancing through the illustrations to Reid's recent book on Industrial Buildings which has been mentioned before in this work, one is struck by a further factor: so very often, these huge plants are not built of temporary materials like asbestos, but of solid masonry, which most certainly renders them quite inflexible, and this in an age when impermanence is imperative to industrial structures if they are going to be able to accommodate the ever changing demands of new techniques. The present imperfections, both practical and esthetic, of asbestos have been mentioned, but, as Buckminster Fuller is never tired of stressing, hardly a

day passes but what a new plastic is invented... As architects and engineers, we know scarcely anything of the exciting possibilities which are opening daily to the building industry in this field.

Amendations to local building codes have made it possible in many communities to use the curtain wall or sandwich panel, and in spite of the research which is going on apace to find new and exciting wall coverings, when it comes to actual costing and trying out a given innovation it is surprising and disappointing to note how often the architect is driven back again to using brick if permanence is required, or asbestos if a more temporary structure is desired.⁹ In short, we are still waiting for the industry to come up with a really competitive selection of varying panel types which can be taken to the industrialist and 'sold' to him on the basis that they are at least as economical as traditional materials. In theory this should be eminently possible when one considers that a brick wall is laboriously constructed, takes time to dry out, and its erectors are paid the phenomenal salary of \$3.08¹/₂ per hour! The fact that it seems impossible at the moment is an indictment of the building industry for its hesitancy and the chemical industry for not having demonstrated enough unmistakably high quality successes in this field.

Prefabrication must produce a greater supply of interesting, durable materials, which are capable of 100% salvageability when the structure is demolished. The opponents of prefabrication have had their say too long. Where economy is vital, prefabrication can prove to be infinitely more variable than in-situ work or traditional construction. This seeming anomaly has been conclusively demonstrated in post-war England. It was argued that prefabrication resulted in sameness, and lack of interest, and most of the buildings were therefore built of brick and tile as of old. The trouble was that the small, infinitely variable unit, the brick, was so small, that to produce a variation cost a great deal of time in the drafting stage, and still more time in the construction stage, for only a skilled man could read the alteration and affect the change. As a result it became too uneconomical to vary a layout of house types, and literally hundreds of thousands have been erected - all identically the same! all potentially infinitely variable.

On the other hand, Aslin of Hertfordshire approached the problem of school construction in the way I feel industrial work should be tackled. He assembled a team of design research workers, and they set out to produce a system of prefabrication which would be variable, economic, and when handled sensitively, visually satisfactory. The research was done intelligently with the close cooperation of builders, scientists and engineers,

and the result, as the world knows, is a system of school building which has made that class of work England's special contribution to post-war architecture. The variety of the school types and elevational treatments is answer enough to the charge of "dullness". Variations are easily detailed and each comply with the fixed modular pattern. The change can be affected by unskilled labor since no intricate shop drawings are required and no intricate site work necessary.

I have undertaken this deviation into another class of work merely to show how the problem has been tackled in other spheres. It is surely irrational to clothe buildings which enclose vital, revolutionary products of our age in materials which were logical for use 5 centuries ago - especially when the inner structure of the building itself so often contains some unique structural innovation.

Let us now briefly look at some of the statements made by General Robert Johnson of the famous Johnson and Johnson Enterprises. He is probably the most enlightened patron of esthetics in industrial architecture in America, as evidenced by his public proclamations and his factories which back up his works. In his six basic essentials to good industrial management¹⁰ he lists: 1) Good housekeeping, 2) Simplicity and beauty of plant and facilities, 3) Human engineering, 4) Decentralization, 5) Emphasis on growth, and

6) Cost consciousness. This list is remarkable enough in itself when one considers the change in attitude between Johnson and the Mr Bounderbys of the 19th Century. But when one studies the order in which the items are listed it is nothing short of miraculous.

The first item, (good housekeeping) is one towards which the architect can contribute immensely and indeed a large part of this thesis has been devoted to showing how these conditions may best be attained. Johnson stresses the desirability for openness in the plan, for not only does it give more flexibility, but it compels staff and management to clean up dirty spots for the isolation of such areas becomes impossible under such conditions. This housekeeping fixation is evident in every detail of Johnson and Johnson factories: no materials are used but what are easily cleaned, safe to use or walk upon, and economical to maintain. As any housewife knows, it is easy, and even a pleasure to keep clean a thing which lends itself to cleanliness and utility - and a very high proportion of workers are housewives.....

The second point, (simplicity and beauty of plant and facilities,) is, of course, very satisfactory to one striving for beauty in architecture, and its elevated position in this list is most gratifying to architects after a

century of wandering about in an economic wilderness. Johnson enlarges on this by stating his belief that workers should come in through the "main" entrance and be greeted by a well designed hall lined with exhibition cases so that they may "feel the same admiration and pride in their work that the management and visitors feel." This coincides so nearly with the views I expressed and elaborated upon earlier, that no further need for comment is called for.

Finally I would like to make mention of a design factor I have never seen stressed in any treatise on industrial architecture. It concerns the unique contribution which I consider landscape architecture can make to the question of expression in factory buildings.

My earlier remarks may have been received cynically or unsympathetically by some who read into my complaints of bare, unrelieved walls, a plea for breaks and an articulation not necessarily called for by the function of the plan. I realize full well that great expanses of wall are inevitable in structures of this class - therein lies the design challenge I mentioned, and until the building industry can offer designers a reliable range of interesting and varied wall cladding materials, I feel that intelligently conceived landscaping can go a long way to fill the gap.¹¹

In the first place, few designers have thought of the wonderful effects to be achieved by putting a sparsely leafed tree close against a bare wall. The calligraphic effect of the limbs drawn against the wall surface presents a beautiful texture such as would be hard to equal by other means. Furthermore, the added effect of sunlight throws shadows on the wall which adds not only complexity to the design, but also gives the dimension of time, for the design changes throughout the day, giving mobility to the composition.

Another concept has been completely overlooked in the past. The size of today's factories is often overwhelming, and a lack of any sense of intimacy or of the importance of the individual is most apparent when one sees photographs taken along an exterior wall with the roof and ground line almost appearing to meet at infinity hundreds of yards away. This can be avoided by use of trees and shrubs, so grouped that no more than certain sections at a time are revealed to the approaching eye - sections which can be carefully selected for especial compositional interest, utilitarian importance or orientational value. Tree massing and grouping appears to be a lost art in America and it would appear that in this context in particular, architects would find great inspiration from studying the techniques of some of the great English romantic landscape architects like Lancelot Brown and Batty Langley.

These men understood trees and were able to use their varied form in conjunction with the land form and building massing to produce the most powerful and intriguing visual effects. There is little to be gained, for instance, by lining a driveway to a large plant with trees spaced regularly, at intervals; for the only effect gained is that of shade for the approach road and some sense of direction of the main entrance. For the rest, the eye looks beyond the tree trunks and sees the bare factory walls in the normal way. Yet this is frequently done. The best romantic landscape designers understood that tree forms can give dynamism or movement to the whole composition. If thought be given to this statement it will be seen that, if true, it has profound significance for industrial designers striving for sensitivity. One of the main problems in the treatment of large factories is how to convey to their expression some sense of the terrific power they enclose, the scale they represent, and the feeling of "movement" or "direction" which is essential to all true works of architecture; the static form of a rectangular unadorned shape of vast dimension is difficult to deal with. When trees are brought into the picture, however, a sense of movement is immediately possible, for they can be planted either singly or in groups in varying planes as they recede from the eye. Therefore, as the observer moves along the drive, the composition of tree to tree, group to group and

all to the factory, is a constantly changing, kaleidescopic sequence of arrangements which can impart to the factory a sense of movement and vitality which, of itself, it is entirely without. All this is entirely apart from the calligraphic effects of the trees against the factory walls as a matter of texture and surface pattern which can be employed at close range.

Trees may also be used for acoustical or other masking problems where noise or certain visual aspects of the plant are undesirable. The problem of looking down upon a factory is one for which the architect should be constantly on his guard, for in these days of single storey plants it is very easy in undulating country to get above the roof level and look down upon a bleak, forbidding flat roof stretching away into the horizon. This is a problem which the architect can often solve by choosing for his roof construction plastic, interesting shapes which makes its appearance from above not unacceptable in the first place. When this is impossible, views of the factory roof from eminences can be blocked by planting or masked into insignificance.¹²

Color composition is also possible to a very high degree in the landscaping. Trees are not just green, they are countless shades of green, red or yellow, and they need blending with care and understanding. Flowers and flowering

shrubs have great potentialities for enlivening a facade, drawing attention to a utility or some special feature of the plan. This thesis is no place to embark upon a description of tree forms or indulge in botanical detail; this is well documented, but my purpose is to draw attention once more to the many exciting possibilities which await discovery by the designer conscious of the effects which may be achieved. Some of the effects I have discussed in this chapter are to be seen in the best work in America, and I would like to close this dissertation by drawing attention to several of them and discussing their contribution to a significant architecture for industry.

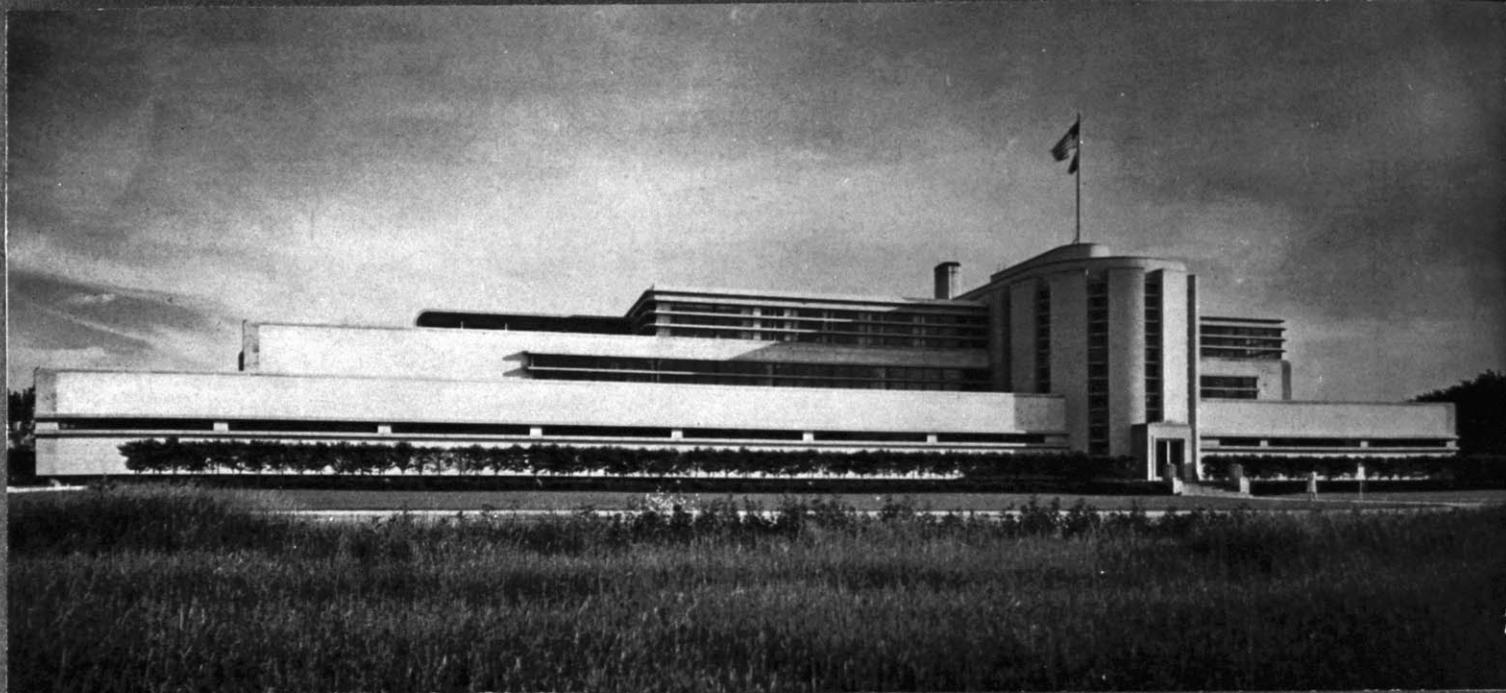
G. D. Searle & Co. : Skokie, Ill. H. G. Banse, Architect.

It may be of interest to start this brief survey with one of the last 'pre-priority' plants to be erected before the U.S.A. entered the Second World War. The manufacturing plant for G. D. Searle & Co. illustrates perhaps the best in prewar industrial architecture. It displays a bald statement of its purpose, - the large masses are vigorously handled and fenestration applied logically so that the asymmetry is frankly asserted and any faking of the mass or plan has been rigidly avoided.

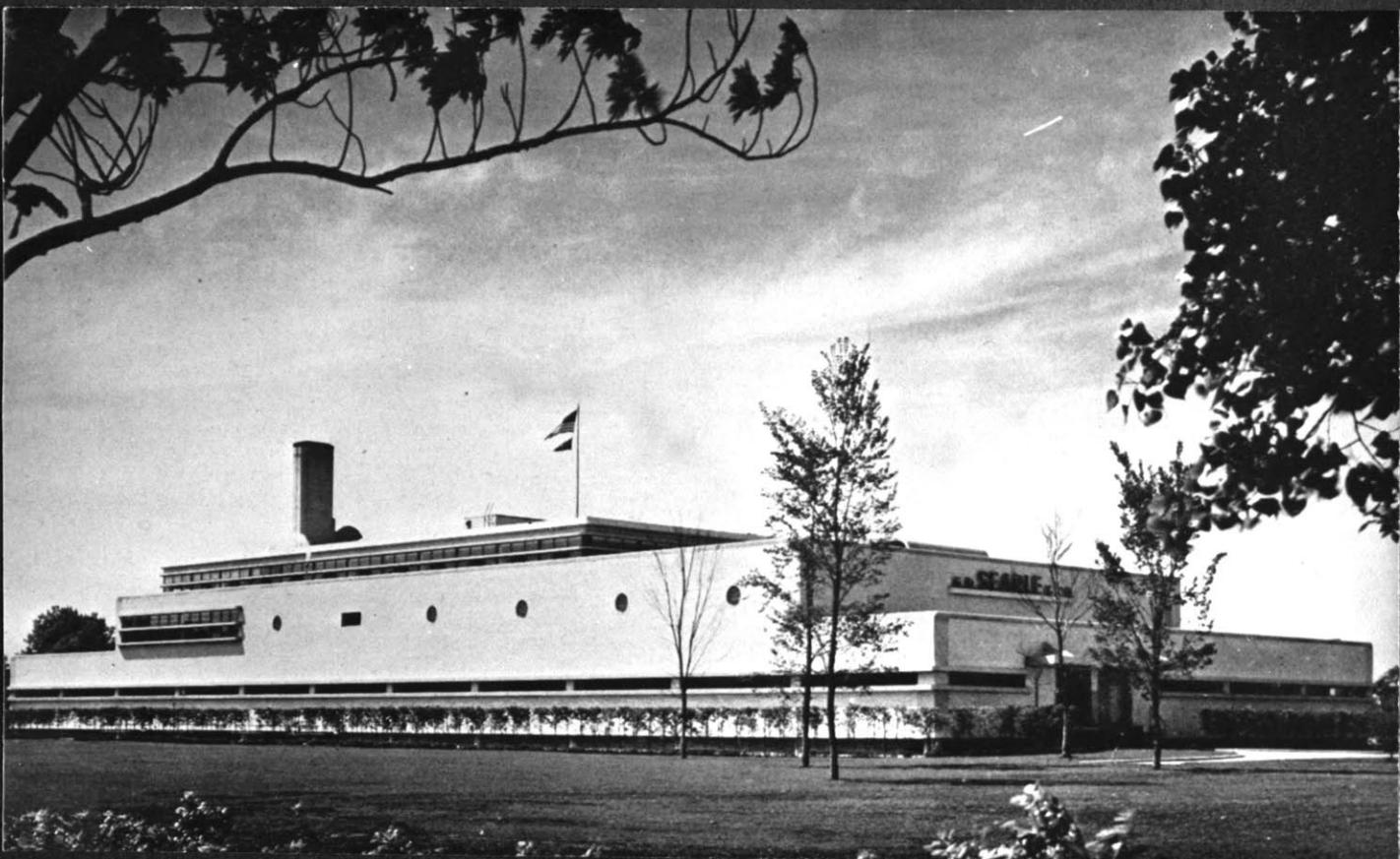
The first story contains the principle manufacturing area and with reference to what has been said earlier on the demerits of windowless plants it is very interesting to note the following statement issued in the publicity on the plant. "This part of the building is, in effect, a windowless plant with windows, hence the narrow horizontal band. The windows are only to permit the employees to see out, not for lighting or ventilation".

As shown in the photograph, there is a definite, if weak attempt at an organized landscaping scheme. The low, regimented and pleached trees at the foot of the facade enhance the horizontality of the design, but as one follows them round to the rear, there is a certain lack of imagination and need for relief which could have been supplied by an in-

formal grouping of trees to afford a visual stop, to turn the eye out into the open landscape for change and rest before embarking upon a further appraisal. The word 'informal' is purposely used for in an asymmetric scheme such as this, a rigid, patterned design would probably be out of keeping.



G. D. Searle & Co., Skokie, Illinois. Arch: H. G. Banse.



G. D. Searle & Co., Skokie, Illinois. Arch: H. G. Banse.

Curtis Wright Aircraft Plant, Columbus, Ohio. A. Kahn,
Associated Architect and Engineers, Inc.

This factory is included as an example of the misplaced adulation given to one of the greatest men in his field which America has produced. Built almost 1 year prior to Pearl Harbor, the main facade of this structure can at best be described as mediocre. It reveals lack of taste, lack of rhythm and is quite devoid of any sense of scale. (Were the figure and the main doorway covered, one would be at a loss to determine the size of the structure.)

The interior is no better. The main lobby as illustrated, presents a woeful appearance and is sufficient to leave the sensitive client aghast. The executives dining room is equally ill-conceived, and the sham-Chippendale chairs add the final touch of bad taste. The important point about this discussion, is that the plant was amply illustrated in glowing terms by one of the most widely circulated American architectural magazines. The comment on the interiors is that they are "done with characteristic Kahn simplicity". There is nothing casual, however, about the atmosphere of capable efficiency that the rooms manage to convey".

Esthetics apart, the plant is an admirable example of Kahn's method of putting all employees facilities under-

ground. For straight-line production this works excellently and a 25' wide tunnel extends the length of the building. Off this subway are the locker and toilet rooms, cafeteria and lunch rooms and stairs rise at appropriate intervals so that congestion on the production floor at the shift change is eliminated.



Curtis Wright Aircraft Plant. Arch: A. Kahn.



A. G. Spalding & Bros. Inc. : Willimansett, Mass. Lathrop
Douglas, Architect.

This plant for the famous sports firm specializes in the wood processing part of the manufacture of tennis and badminton racquets etc. Although the exterior is undistinguished, the entrance lobby has some feeling for the welcoming atmosphere which has been stressed as a desiderata for this section of a plant. There is a refreshing airiness, and a clean, uncluttered sense of design which helps toward a feeling of quiet, businesslike propriety, and makes this solution stand head and shoulders above many of the factory lobbies which are currently illustrated.



A. G. Spalding & Bros. Inc., Willimansett, Mass. Arch: Lanthrop Douglas.

Bluebonnet Plant, Corn Products Refining Co. Corpus Christi, Texas. H. K. Ferguson Co., Industrial Engineers and Builders; F. L. Whitney, Architect.

The sense of pleasure which is felt when one approves a plant of this quality is difficult to describe when several weeks have been spent looking for examples which display the visual qualities we have been discussing. This plant is the epitome of several ideals.

Firstly the client is to be commended in that he specifically stated that the buildings should be visually stimulating. Secondly, the plant is an excellent example of intimate and understanding cooperation between the architect and engineer acting as co-equals throughout the entire job. Thirdly, it illustrates the results which can come from painstaking, analytical, intellectual research.

The problem was first attacked in the Steep House, where acid fumes used to eat out the window sashes and the settings to glass bricks, - to say nothing of the workers' health. The suggestion to leave out windows was revolutionary, but once accepted, the contention to leave out all walls except where strictly necessary was easier to carry out. The result is an open, cagelike and perfectly integrated structures in which architecture, engineering and the mech-

anics of the process are welded together in a harmonious whole.

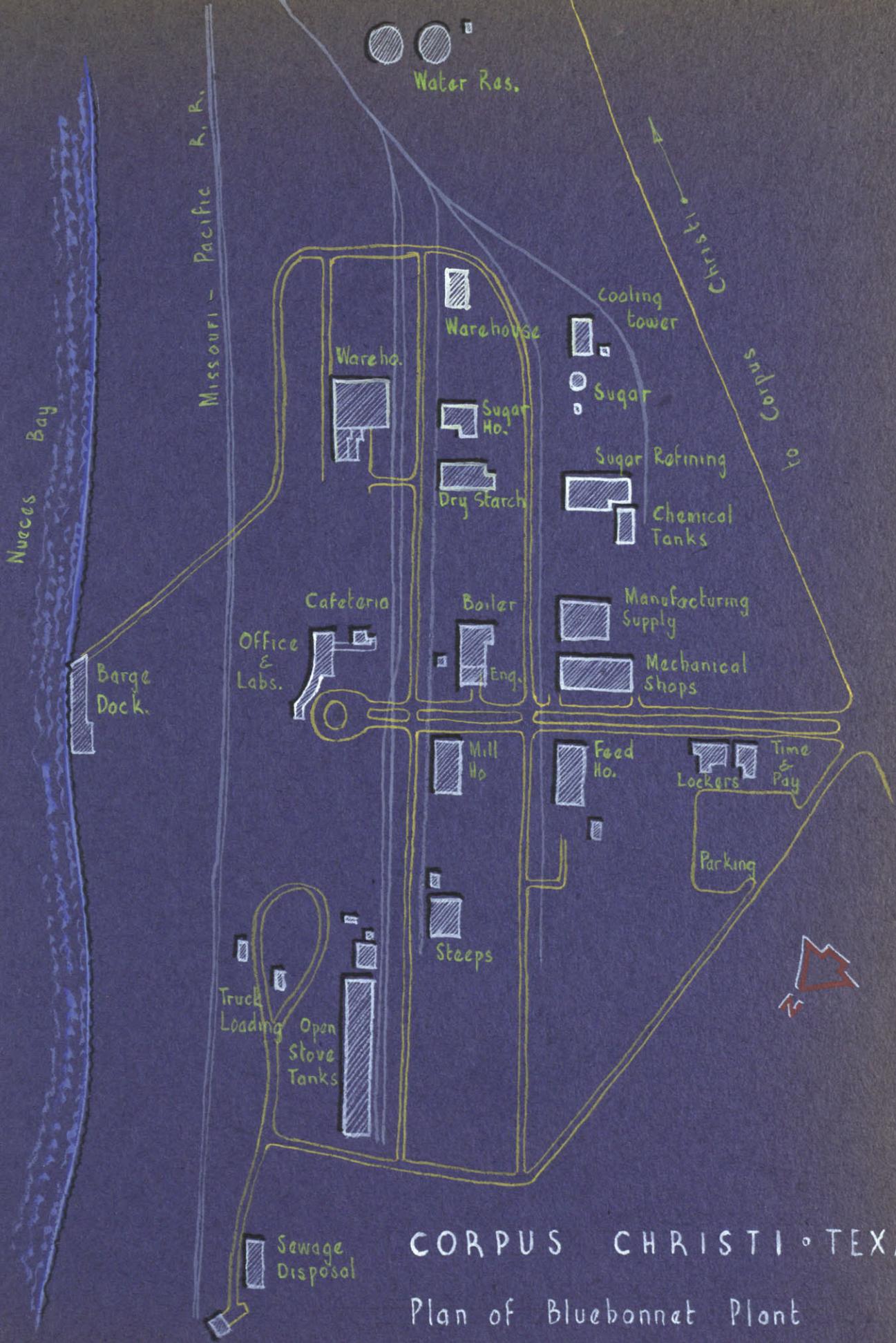
The practical advantages justifying this expression are formidable. The warm air of Texas requires no walls; the torrential rains demand a roof; the sun, the expressive horizontality of the reinforced concrete louvres; the breeze from the bay blows away all fumes from the steep house and dust from the grain conveyors, - automatically doing the housekeeping and removing an explosion hazard.

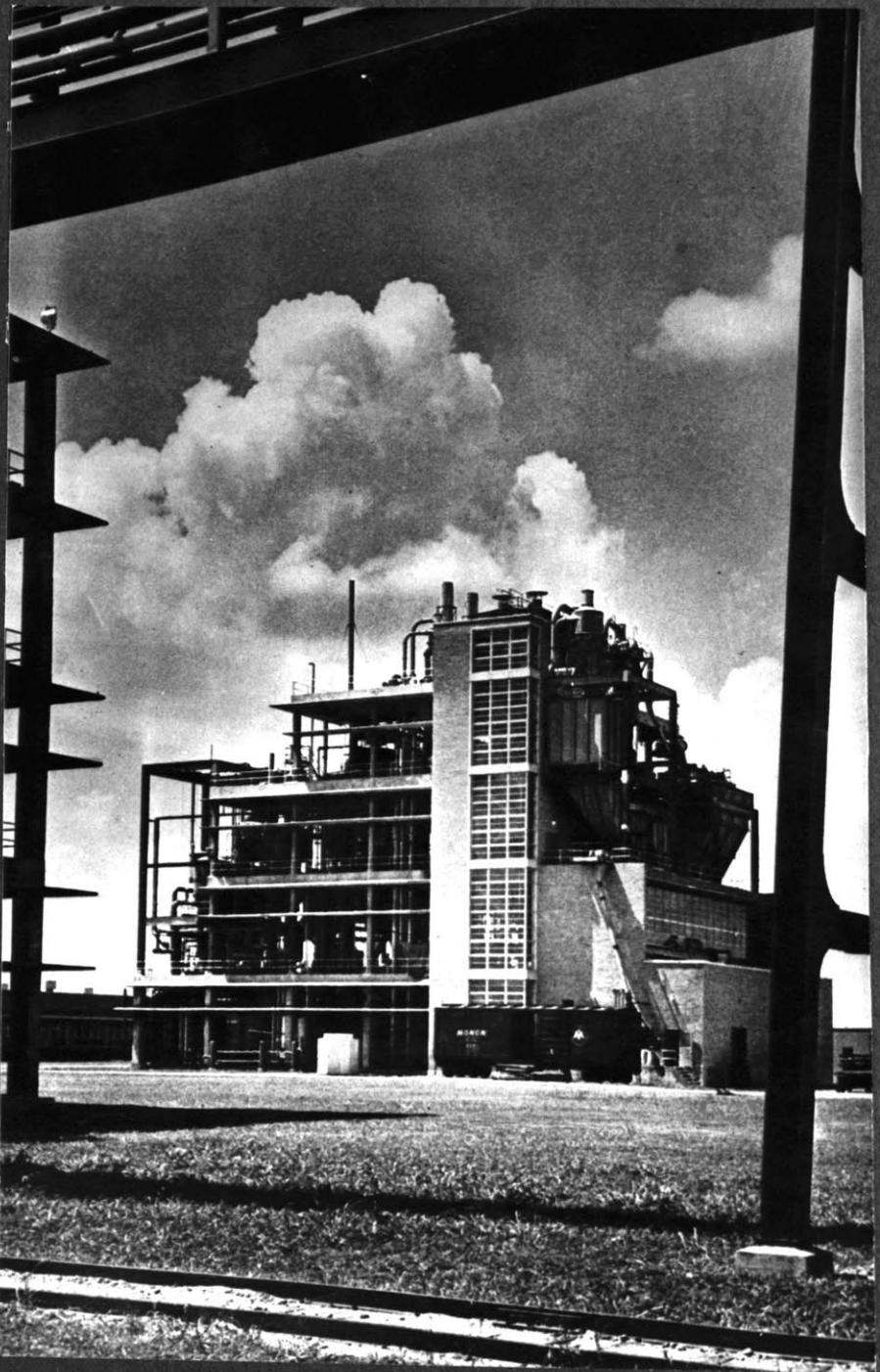
This type of open construction is not new, for oil refineries have used it for years, but it is new in such an ancestral industry as flour milling. It proves conclusively that with all-round cooperation, the 'bowels' of certain sections of industrial plants can be exposed with dynamic results.

The average architect however, would require a "brainwash" before being naturally inclined to getting the best out of this novel form of expression, and the engineer would have to realise that his structure in most cases was the architecture and esthetic considerations effecting even the smallest joint, are of vital importance. Equipment manufacturers would also have to learn the same lesson and in this instance, they were on several occasions required to

restudy their machines in order to design them into the overall concept.

One could write at length on this refreshing example of 20th Century architecture, but I show instead one or two examples from the many photographs in the Nov. 1949 issue of the Architectural Record. It will be noticed that the night views offer a whole new field of visual delight and intricacy and my only criticism of the whole vast scheme is a certain barrenness when seen at a distance, due to the total lack of landscaping, and the cross-circulation between rail, road and pedestrian traffic. There may be some perfectly valid reason for this latter situation, but the sketch illustrates what appears to be some unfortunate intersections both from a visual and practical point of view.





Bluebonnet Plant, Corpus Christi, Texas.

Ind. Eng: H. K. Furguson Co.

Arch: F. L. Whitney.



Bluebonnet Plant, Corpus Christi, Texas.
Ind. Eng: H. K. Furguson Co. Arch: F. L. Whitney.

Electronic Engineering Association Ltd. : San Carlos, Calif.
F. J. McCarthy, Architect.

This plant was placed second in the Industrial Class in the 1951 Honors Award Program of the A.I.A., but I have chosen to illustrate it as an excellent example of a small factory sensitively handled, and using the domestic, informal scale where the program allows such a treatment. The workers' feelings are taken into consideration in that, as one can see in the photograph, the domestic scale gives a 'homelike' feeling which is bound to give a sense of satisfaction in that it imports a sense of "being personally catered for".

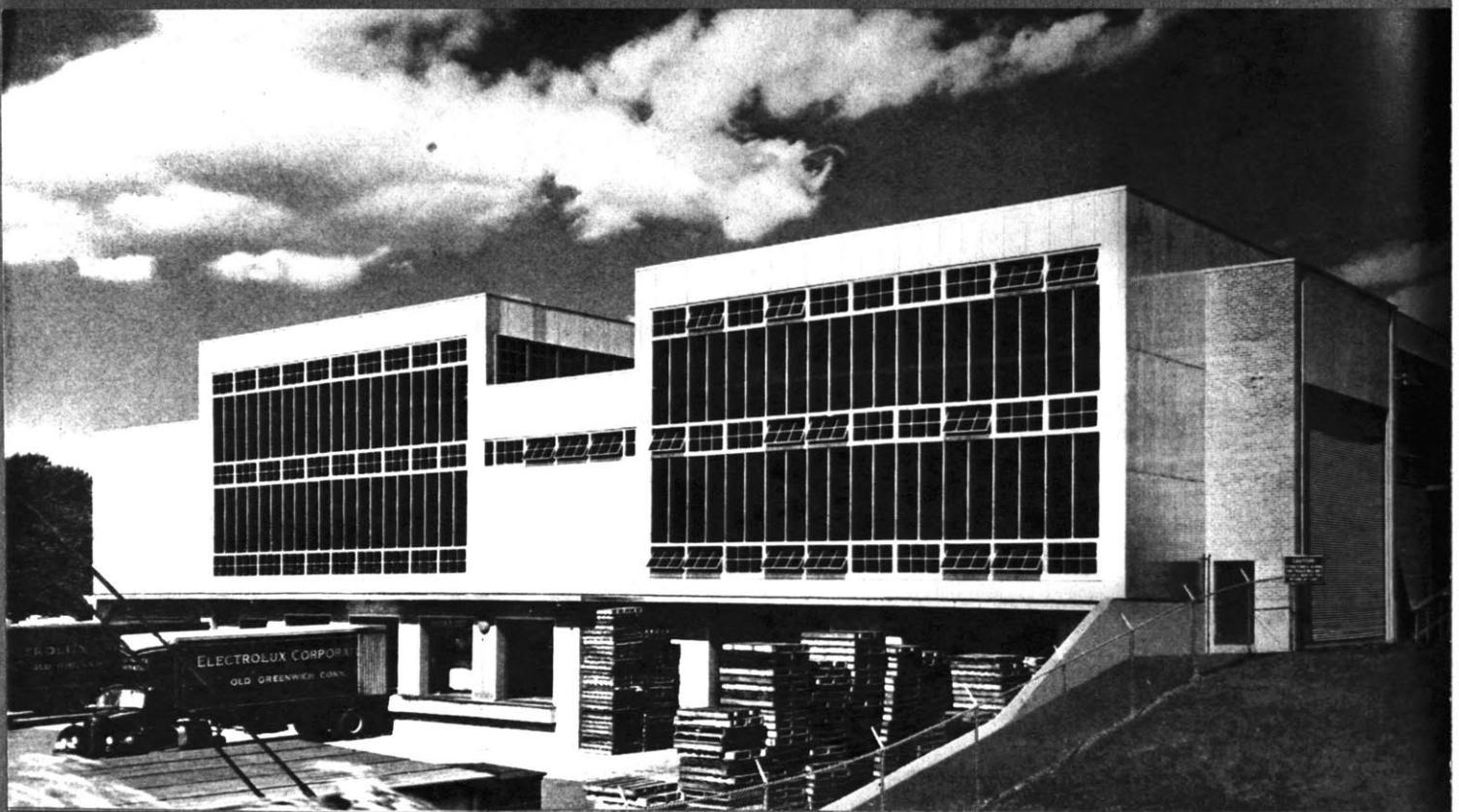


Electronic Engineering Association Ltd. : San Carlos, California.
Arch: F. J. McCarthy.

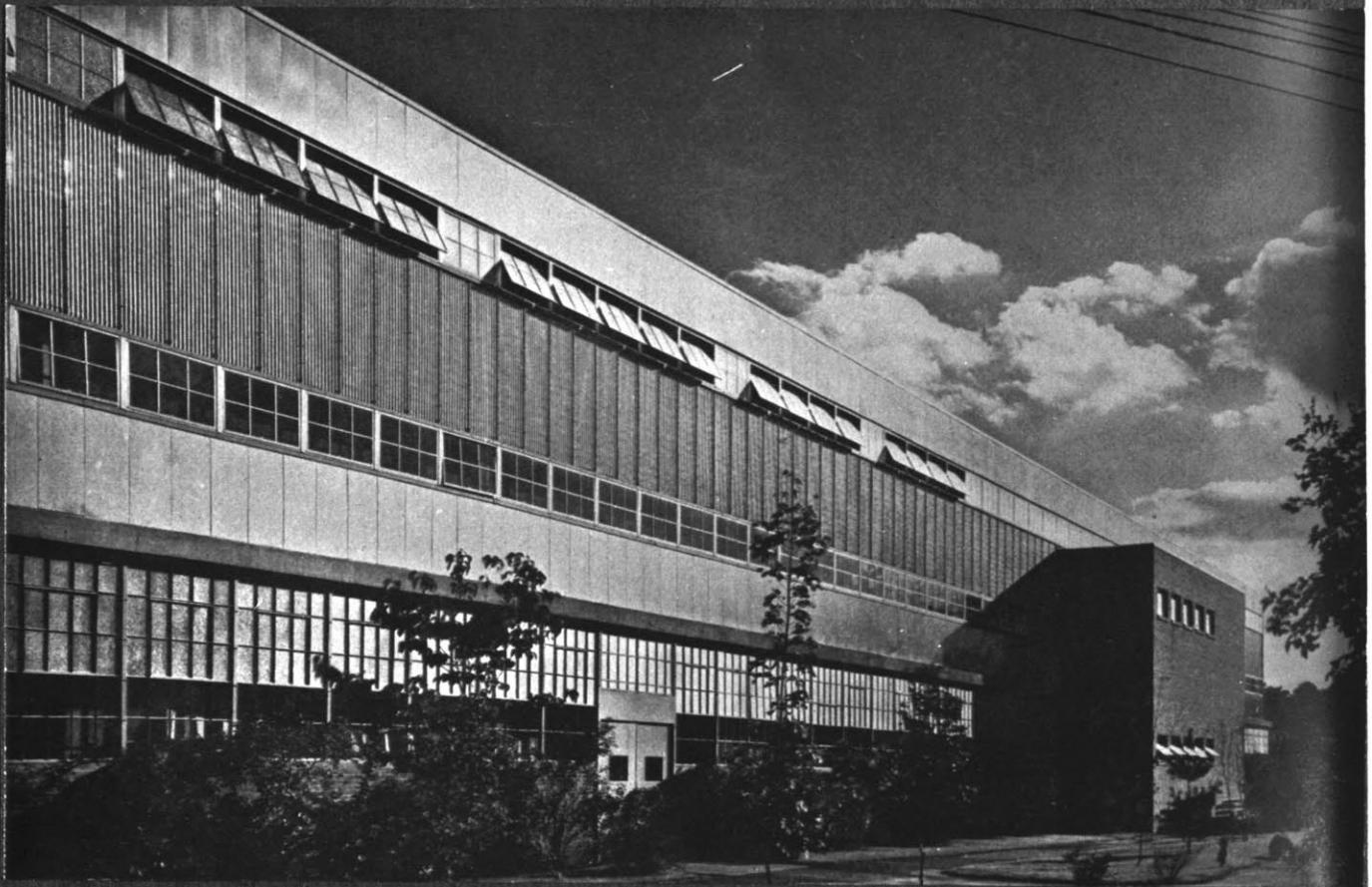
The Electrolux Corp. : Old Greenwich, Conn. Raymond and Rado, Architect-Engineer.

Here is another plant whose exterior expression displays some of the forward thinking, some of the imagination which is so desperately needed in industrial architecture. The only place where solid walls are used is where they are required to withstand impact loads, and for the rest, the extremely expressive combination of clear glass, corrugated glass and aluminum panel presents a careful composition of brilliant metal and blue glass, with a high level of illumination within.

Internally I was impressed by the unusual simplicity, clarity and architectonic form of the structure. This was explained when it was found that the structural engineer was P. Weidlinger, a designer with a deep and sympathetic understanding of what an architect is trying to do when he creates a building. This freedom from the bewildering maze of structure to be found in most plants illustrates the advantages of a) full architect-engineer collaboration, and b) the use of all welded construction, which was stressed at some length in Part II.



The Electrolux Corp., Old Greenwich, Conn. Arch.Eng: Raymond & Rado.



Electrolux Corp. Old Greenwich, Conn. Arch.Eng: Raymond & Rado.



The Electrolux Corp., Old Greenwich, Conn. Arch.Eng: Raymond & Rado.

Atlanta Envelope Co., Atlanta, Georgia. Moscawitz, Willner
and Millkey, Architects.

Mention is made of this plant only to show once more what can be done with simple, carefully disposed massing, making full use of an open, sloping site to landscape intelligently. This attractive little plant has realized the advantages to be gained by 24 hour a day advertizing to the many passers-by who rush daily along the nearby expressway.



Atlanta Envelope Co., Atlanta, Ga. Arch: Moscawitz, Willner & Millkey.

L. M. Ericsson Building, Stockholm, Sweden. T. Wennerholm,
Architect.

This is the largest factory to be erected in Sweden in the last 20 years and it startled the architectural world by the brilliance of the design. I can vouch for the fact that it looks even better than its photographs. The huge masses are sensitively handled and the facades intricately but functionally articulated. The point I wish to bring out, however, is the delightful spaciousness and freshness in the interiors. This is more than a little due to the foliage. Where in America or England is there a factory with a pool and a fountain (which plays!) in it? Where is there a dining room for ordinary employees which delineates spaces with flowers? This is not a super dining room for top executives: 4,000 employees dine daily here. Foliage is quite obviously as much respected as the draperies, the carpets or the chairs. It is a way of life, and we have much to learn from it.



L.M.Ericsson Building, Stockholm Sweden. Arch: T. Wennerholm.



L.M.Ericsson Building, Stockholm, Sweden. Arch: T. Wennerholm.

Machine Shop: Birmingham, England

R. Frankel, Architect.

Nylon Factory: Congleton, England

Here, for comparison with contemporary American work, are two small factories in Britain. These photos illustrate several principles which have been mentioned in the foregoing pages. Firstly, the factory at Birmingham with its Miesian detail and expression shows how careful design for the smallest factory can result in a very worthy addition to the city or landscape. The steelwork has been scrupulously designed so that no frame bolts are visible; fascia plates and corners are spot welded to the structure and the window's metal sash is simply clipped to the columns. The light airy aspect is considerably helped by the attractive color scheme of light blue-grey for the steelwork and white facing brick for the infilling and dark blue industrial brick for the base.

The equally small nylon factory was chosen to show an admirable application of the shell concrete, north-light roof. This plant will be expanded to 5 times its present size but the photographs are sufficient to show the high and even level of illumination which can be obtained with the curved, white painted shell roof. Artificial illumination is equally uniform from the trough lights which are evenly reflected from the curved ceiling.

Factory at Brynmawr, S. Wales ; Architects Cooperative Partnership, Architects.

This factory is, to my personal knowledge, the only one in England to display on a large scale the great material and psychological benefits to be derived from the uninhibited use of the contemporary idiom in architecture. Sociologically, it is situated at the heart of one of the most depressed areas in Britain: over 80% of the male population has a record of idleness. Climatically, the situation is bad, with much rain and very long, cold winters. The scheme was therefore a deliberate attempt by the Government and Brynmawr Rubber Company to raise the general standard of living and morale among the population.

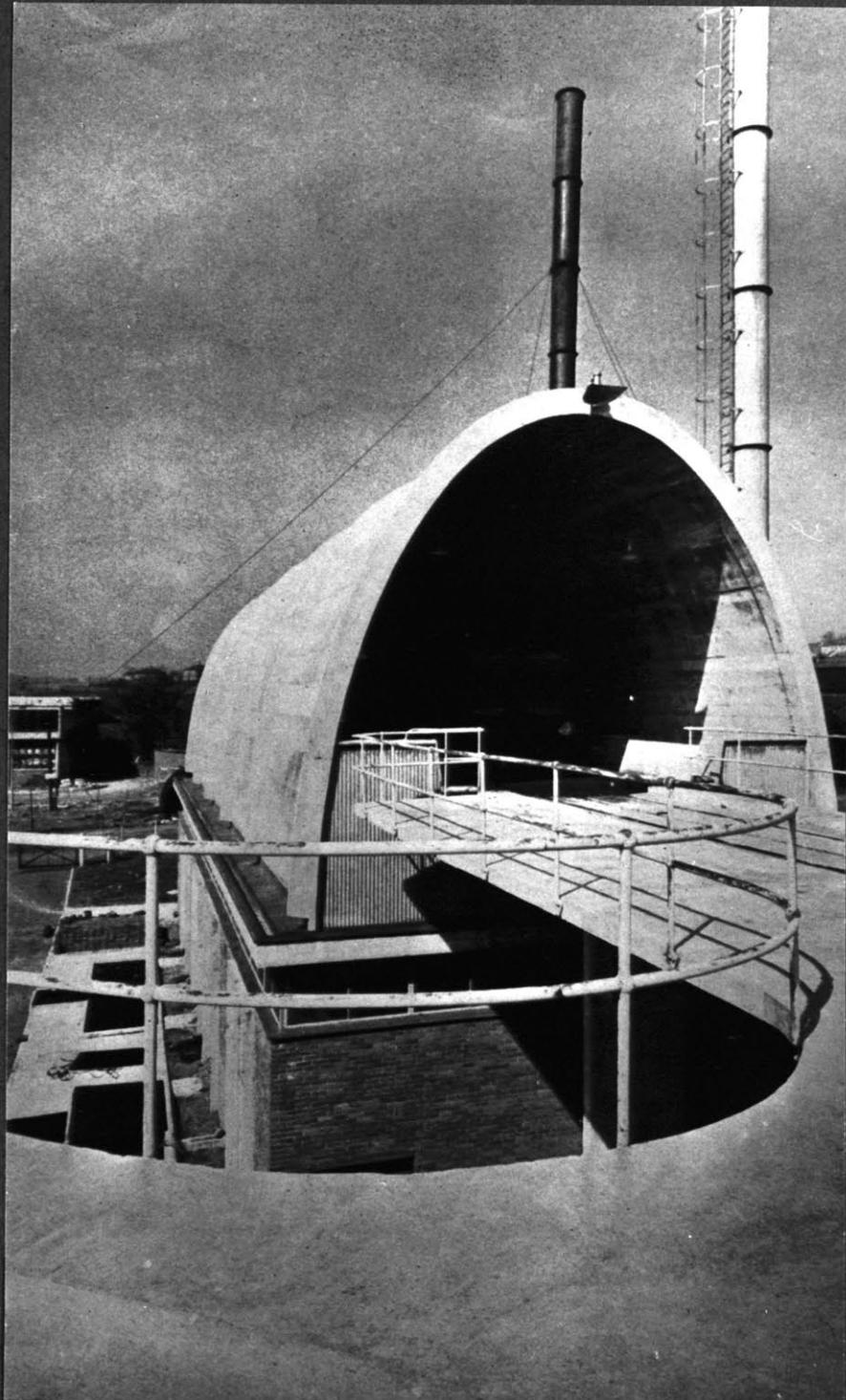
The extent to which this has been achieved can perhaps only be fully appreciated by one who knows the area, but it is hoped that the photographs give some impression of the tremendous 'uplift' that this structure must give to the residents for miles around, living, as most of them do, in condemned structures, devoid of baths, damp courses, even W.C.s. It is literally a pleasure for many of the local people to go to work! The sense of importance as they climb the long imposing ramp to the lofty entrance hall, the well designed, clean restrooms and employee facilities, the large, well lit workspace, and most important perhaps, the feeling

of delight in the new, carefully planned structure imparting the clear impression that it was not erected simply as a shed in which to manufacture an article, but that it is a structure in which people manufacture articles.

This is evident in many ways. The mural on the vault of the entrance hall is specially wrought by the students at the Bath Academy. Notice boards, time checks and many other important, but mundane features are consciously designed to conform to an overall concept. Practical details such as the small spiral staircase and the roof over the boiler house are consciously designed. (Self-consciously designed if you will, and I for one am prepared to stand by and hail the man who has the courage to be self-conscious after a century of anonymous mediocrity in the field of industrial architecture.)



Factory at Brynmawr, S. Wales. Arch: Architects Cooperative Partnership.



Factory at Brynmawr, S. Wales. Arch: Architects Cooperative Partnership.

Design for the Tennessee Valley Authority.

Some of the most dynamic and inspiring industrial architecture in the world is to be found in the various power projects which are scattered about the U.S.A. T.V.A. immediately comes to mind, of course, but there are others, as yet less well illustrated, where by great, bold sweeps of concrete, the earth's surface for hundreds of thousands of acres around is changed beyond recognition, - both in form and nature. Here, surely are science and esthetics perfectly welded into a harmonious concept.

The main problem, - as always in industrial architecture of great size, - is an engineering one. Architecture may only enter the scene when man acknowledges that the immense repercussions of these vast projects demands not only the maximum in technical skill, but the ultimate in its visual impact. There is most hope of attaining that ultimate when people who have spent a lifetime of training in esthetic values are called in to advise upon that aspect of the project.

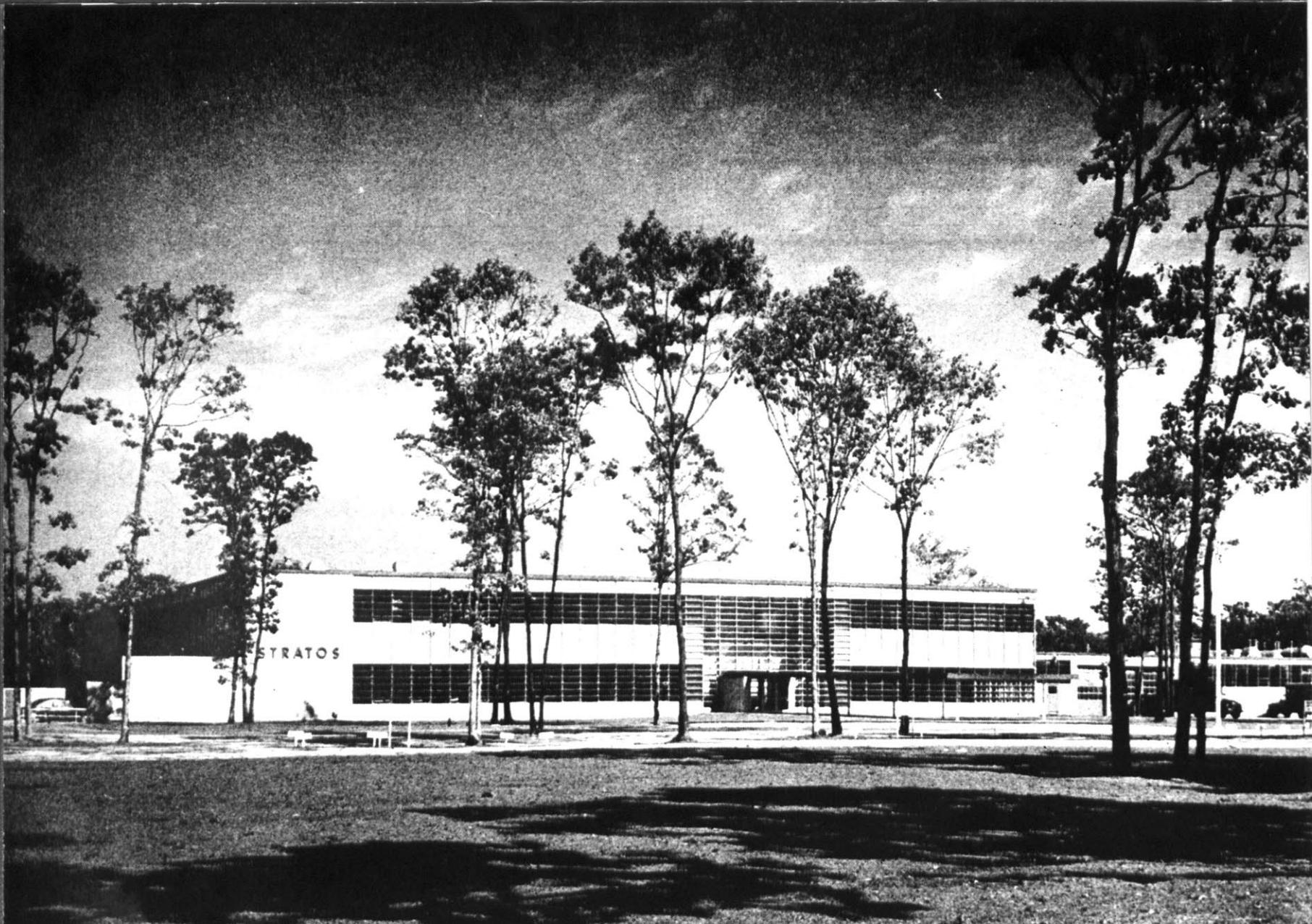
The problem is not how to handle the size, for as in Kahn's great plants, the sheer mass of the main engineering task tends, visually speaking, to solve itself. It is the detail; the intersections, the entrances, lettering, landscaping,

the design and scale of the ancillary buildings which show the degree to which science and art are wedded, - and throughout this thesis I have maintained that until this union is achieved, no lasting expression of our age will be produced.

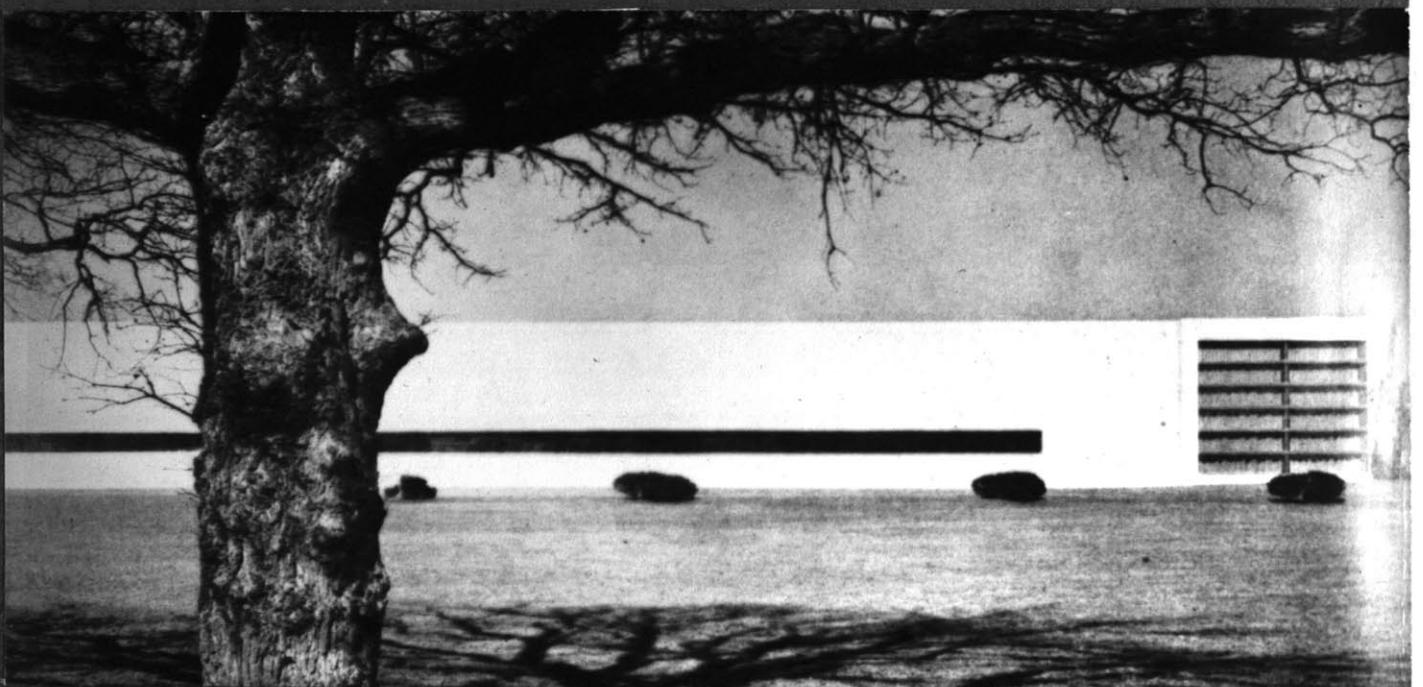
The Fairchild Stratos Plant, - its comparison with A.N.Other.

The two factories illustrated on the following page help to demonstrate quite forcibly the point I have been trying to make with reference to the value of landscape design, in conjunction with textured wall surfaces. Fairchild's Stratos Plant makes full use of flexible, salvageable wall coverings of the panel type and one can imagine the effects that intelligent coloring would lend to the whole composition. The stately, thinly leaved trees accentuate the vertical articulation of the facade, and they are profuse enough to elaborately pattern the green grass in the foreground and provide added intricacy to the elevation with their projected shadows. It appears to the author that this plant would present a subtly different appearance each morning. Dull skies, cloudy skies, clear skies, spring, summer, autumn and winter would each be reflected by some change in the composition; the shade (even hue) of the colored panels, the color harmonies in the brickwork, the bare trees, or trees with bright, mature or autumnal shades, all these things would mirror the changing elements and seasons, and there is an increasing weight of evidence to show that these things are important and that notice will ultimately have to be taken of them throughout the realm of architecture if our culture is to be adequately expressed.

For contrast note the mill in New Jersey. The bleak, unrelieved white marble facing is broken only by the almost 'prison-like' "vision strip" to let the employees see out of their confines. There is neither interest, sensitivity or warmth in this expression. The ludicrous "landscaping" is hopelessly inadequate to provide the poverty stricken elevation with relief and the photographer had to retreat some 200 yards to incorporate a tree which, doubtless he hoped would make the print acceptable to the important magazine which reproduced it and confided to its readers that the "exterior treatment of factories rarely reaches the beautiful simplicity portrayed (here)".



Landscaping and careful exterior design make Fairchild's Stratos plant on Long Island pleasant to enter. Fordyce & Hamby, architects



A. N. Other.

NOTES ON PART THREEChapter 1.

1. Barnes, R.M., op.cit. p.17.
2. Introduction by L.H.Bucknell to a book by Holme C.G., "Industrial Architecture", London, 1935.
3. This situation has a remarkable parallel in England, where due to housing shortage after the late war, the definition of a good architect was the man who could design a house of 1,000 sq ft for \$3,000. The same fallacy is inherent in both cases.
4. Architectural Forum, "Industrial Buildings by Albert Kahn", 1938, Vol. 69, No. 2, p.87.
5. In the May 1951 edition of the Architectural Forum, there is an article on Giffels and Vallet Inc. and Rossetti, which contains an almost ludicrous paragraph lauding the method in which work is turned out, pointing to 14 and 16 hour days with men falling asleep at the board and food snatched in hurried gulps. I maintain that great architecture was never, and can never be turned out in this "plan factory" type of atmosphere.
6. Speaking as an Englishman, it is also a relief to have function put above cost, for since the war, economic stress has had a very unwholesome effect upon housing in particular, and I could cite numerous instances out of personal experience where function has bowed to cost.
7. Reid, K., op.cit. p.28.
8. Another strong influence on design in America is the Federal Tax Structure which makes it desirable for manufacturers to expand the least possible capital on first cost. This often makes the client willing to go in for cheaper, more temporary materials, for with high annual corporate taxes on profits there is more desire to have a high yearly maintenance bill which is an allowable item of cost.
9. In a recent work with which I had direct connection, we searched for some type of wall panel which would look good and be competitively priced. In spite of the theoretical advantages of wall panels e.g. ease of erection, lighter construction etc. we ended by speci-

fying brick, because no other method could compete economically. Skidmore, Owings and Merrill came to the same conclusions when they built the Terrace Plaza in Cincinnati.

10. Reproduced in Reid, K., op.cit. p.197.
11. And from then on it can fulfil its rightful role of foil and enhancer.
12. This problem of views from above, arose recently in the housing scheme for veterans just off Route 9 at Route 128 at Framingham. The danger was completely overlooked, flat roofs were used and although a charming atmosphere prevails within the scheme, the view afforded to thousands of passers by on the raised roadway resembles a chicken farm, more than a housing scheme designed by one of the best contemporary architects.

Appendix 1.

A HISTORICAL OUTLINE OF MILL ARCHITECTURE
IN THE U.S.A.

As I tried to point out in the preface to this work, the main burden of the study is concerned with preparing the ground for a search for a new expression in industrial architecture and not with a historical analysis. Although brevity is therefore a prime consideration in this section, a historical background is vital to a comprehensive grasp of the problems involved, and furthermore it may be of some interest to have the occasional comparison with English developments at certain points in the story. Indeed, the English evolution process is inextricably bound up with the American scene, firstly because industry began in New England under the guidance and knowledge of English settlers, and secondly, as a corollary to this fact, the industry which found very fertile soil for its development in America was the cotton trade, and since nearly all the main technological inventions took place in England and were exported to America, there is in many cases a very interesting parallel to be drawn involving the impact certain inventions had upon mill architecture in the two countries,

Perhaps the most startling difference between the two developments is the method of growth. The textile industry in New England (for it is with textiles that the real story of industrial architecture in America begins) was not a slow motion mature growth as it was in the British Isles, but a hot-house plant; the product of the Revolution and the war of 1812, - just at the time the new machinery was being invented to speed up the spinning, and later, the weaving process. There is not in American a long architectural history of the textile trade to be traced much before this date, although, as we shall see, a start was made in the latter part of the 18th Century. Nevertheless, the intriguing story of the rise and fall of the hand weaver and spinner settlements in Northwestern England is not to be found in New England on anything like the same scale.

The fact that American industry had no roots in an ancient tradition enabled it to make some startling innovations of its own, and the most important of these was the unique type of manufacturing settlements set up by the more forward thinking industrialists. These model housing estates wrote a revolutionary page in the history of town planning, and antedate by many years the much vaunted experiments in this field at Bournville and Port Sunlight in England.

American industrialists were unable to take full advantage of the new machinery until the latter half of the 19th Century, so that in the main, New England villages in particular are free of the worst sociological evils which are so evident in Lancashire, England. Therefore, many of these early settlements grew in an atmosphere dominated by the needs of the waterpowered machinery so that whereas the sooty, smoke-blackened towns of southern and central Lancashire represent the industrialized society of the High Victorian period, New England mill settlements reflect the more spacious, tasteful late Georgian concepts of urban planning.¹

In the larger towns however, which were a product of a later, more concentrated industrial system, crowded conditions often prevailed and ugly masonry row housing was erected to house the workers. These large communities relied entirely upon the textile trade and their economy was completely wrecked when the industrial shift to the southern States came into effect late in the 19th Century.

Such New England towns as New Bedford now present a sorry sight to the visitor, the whole atmosphere giving the feeling so aptly portrayed by Goldsmith in his *Deserted Village*, - the heart which made the settlement 'tick' is no longer alive. Lowell is another splendid example of such a Victorian industrial town. It was large, wealthy, and

produced the most splendid architecture; it is perhaps one of the best examples toward which the student of early industrial architecture in the U.S.A. can direct his research.

A comparison with the haphazard, money-grabbing development in England is well worth drawing at this point, because in the impoverished, socially irresponsible outlook of the average manufacturer in England we can see the reason for the frightful chaos to be seen on all sides in any Lancashire town. I have yet to see a better description of this greedy exploitation than the following extract from "Towns and Town Planning", which I quote in full:-

"The procedure was always the same; as each coal-field was developed speculators bought up the road frontages in the vicinity; factories were dumped down on the roadside, and jerry-built cottages were run up near them, stretching in endless monotony along both sides of the road. As more were needed they were built back to back behind the first row, facing up a narrow parallel street. There was no adequate plan, - the builder was his own architect, for the houses had no more design than rabbit-hutches and the only consideration kept in view was how to crowd the largest possible dwellings upon the given site. If anyone had suggested that trees and grass should be spared and included in the scheme, that gardens should be provided, that the aspect of the house should not be determined solely by the direction of the road frontage, that a site to leeward of a factory chimney or a skin yard was likely to be neither pleasant nor healthful to dwell on, that the monotony of long straight streets might be relieved by breaking the level of house frontages and varying the roof lines, that, since families vary in size, houses should do so too, that finally, the segregation of rich and poor aggravated the perils of both, he would have been met with the immortal retort of Mr Bounderby: 'I know the bricks of this town, and I know the smoke of this town, and I know the hands of this town. I know 'em all pretty well. They're real. When a man tells me anything

about imaginative qualities, I always tell that man, whoever he is, that I know what he means. He means turtle soup and venison, with a gold spoon, and that he wants to be set up with a gold coach and six!".

This last quotation is from one of Dickens' most pungent books, "Hard Times". With Gustave Dore, Dickens was an intrepid campaigner against what he conceived to be the evils of the new factory system, and in his viciously derogative description of his imaginative city of 'Coketown' we see one of his most famous declamations against the new industrialist. The American will see in its word picture (allowing for differences in materials and setting), some similar vices to be found in the shanty suburbs of Paterson, New Jersey, and the slums of North Adams, Mass., and the following sardonic paragraph from Dickens' book is well worth quoting in connection with our subject:-

"It was a town of brick red, or of brick that would have been red if the smoke and ashes had allowed it; but as matters stood it was a town of unnatural red and black like the painted face of a savage. It was a town of machinery and tall chimneys, out of which interminable serpents of smoke trailed themselves forever and never got uncoiled. It had a black canal in it and a river that ran purple with ill-smelling dye, and vast piles of buildings full of windows where there was a rattling and a trembling all day long, and where the piston of the steam engine worked monotonously up and down like the head of an elephant in a state of melancholy madness. It contained several large streets all very like one another, and many small streets still more like one another, inhabited by people equally like one another.....You saw nothing in Coketown but was severely workful.....All the public inscriptions in the town were painted alike, in severe characters of black and white. the Jail might have been the infirmary, the infirmary might

have been the jail, the town hall might have been either, or both, or anything else, for anything that appeared to the contrary in the graces of their construction. Fact, fact, fact, everywhere in the material aspect of the town,"¹.

Most early New England cotton towns have been spared the worst evils described above, and today one can visit one after another of these settlements and admire the sedate, solemn exteriors of the mills as they brood over the streams or ponds which originally formed their life blood. The local materials of warm red brick or cool grey granite contrasting against the white painted window jambs and heads give a lesson in simple, composed massing that many flashy architects of the modern school would do well to study as examples of form perfectly integrated with function. But we have now reached a point where we must study the sequence of development in chronological order so that we may have the evolutionary pattern in mind before proceeding too far.

Although fulling mills were set up in the U.S.A. as early as the 17th Century, they will not be considered in this study as they differed little in style or construction from the houses or barns of the time, and so were considered irrelevant to the main theme.

Our story can begin in the last quarter of the 18th Century, when, according to Meserve³, the first American mill built for cotton spinning was erected in Beverly, Mass., in 1787. It was built of brick, three storeys high and had overall dimensions of 60 feet by 25 feet. There was a pitched roof and a deep basement, "in one end of which moved a heavy pair of horses to furnish rotary power". It is impossible to tell whether the mill was built for the specific purpose of cotton spinning, but the fact that it was built of brick is so singular at that time, that we feel justified in making it a starting point to our survey.

In 1793, however, Samuel Slater erected a water driven mill in Pawtucket, Rhode Island, definitely for spinning cotton, and construction retained the wooden expression of the old barns and farmhouses of the time. It was two and a half storeys high and measured 40 feet by 26 feet, and differed from the typical barn or farm mainly in the addition, over one gable, of a cupola, and in the middle of the roof an extended dormer or primitive monitor light. Later, an extension was made in the form of a wing so that the plan read as a short stemmed T. The monitor was continued over this wing, and the small cupola removed and replaced by a large, elaborate structure on the new wing.⁴

The success of Almy, Brown and Slater led others

to follow their example. Mechanics who had been employed by the firm raised small amounts of capital from local sources and built factories of their own. These appeared slowly in central Rhode Island, eastern Connecticut and southern Massachusetts, and in 1809 the Secretary of the Treasury listed 27 mills operating in that area. All these mills were smaller than the original Slater Mill, but identical to it in form and function.

Owing to the passing of the Embargo Act in 1812, the second decade of the 19th Century saw a boom in the south of New England, and mills were built rapidly. It was during this period that mills lost forever their domestic character, by increasing in size and changing from the hazardous all wood construction to masonry; - either brick or stone depending upon the area. Although they remained for the most part simple rectangles, they were often five storeys in height. The trap door monitor was replaced about 1810 by the clere-storey type which carried through from one gable to the other, often terminating in the cupola which was retained with varying degrees of elaborateness over the gable end.⁶

Typical of the mills of this early part of the 19th Century, were those built at Waltham by the Boston Manufacturing Company, which set the pattern for the Lowell experiment. They consisted of two mills built in 1813 and

1816 to 1818, and were placed parallel to the stream so that they required two belts to drive them. This was an advance on the earlier types in which the factory was built end on to the river: here, the wheel on the gable wall drove the shafting by a belt which ran the full length of the mill. This meant that the belt was often 400 feet long, the risk of breakage was great, and should this occur, the whole mill was thrown out of production.

Although many of these old mills have disappeared, the task of reconstruction is not very difficult, for from examples such as those at Waltham we have precise information as to the structural and esthetic form of the factory. Both Waltham mills were built of brick, and the earlier one had a large, central, octagonal cupola, a feature which the larger, more recent mill lacked. Floor to floor heights were about 10 feet, and the mills are notable for the introduction of external staircases contained in towers on either side of the building. This feature was to become a dominant characteristic of the later 19th Century mills and its use had the advantage of freeing the internal floorspace and providing a break against the spread of fire from floor to floor. A further innovation was made at Lowell when the gap between the two mills was closed and although this had a precedent in New Lanark, Scotland, it is the first example in the

United States of these early mills staking on the form of the modern industrial plant.⁷

The open joist type of simple mill construction was the pattern used in the first of the mill agglomerations in Lowell in 1822. Apart from this, we know little about them, as they were replaced by huge, 6 storey buildings about 1850 which were "driven partly by water and partly by steam."⁸ The mills at Amesbury, Massachusetts, and New Market in New Hampshire, are the nearest examples to these old mills at Lowell and their simple severe style has a serenity and sedate composure which would be difficult to excel.

It will be noted that at first, spinning machinery was the only mechanical device installed in the new mills. When the yarn had been spun it was 'put out' to neighboring homesteaders, and in this may there grew up round these early mills small settlements almost entirely dependent upon the mill for their livelihood. The reason for the installation of the improved spinning machinery was that for many years the simple hand loom was much more efficient than the spinners' wheel; so much so that it took eight persons working hard to keep one hand loom in full production. To add to the weavers' troubles, the first improvement was to the loom, when in 1733, John Kay of Walmersley in England invented the "flying shuttle" making it no longer necessary to throw the

shuttle across the warp by hand. To the spinners' rescue in 1762 and 1764 came Sir Richard Arkwright and James Hargreaves, both of Lancashire, who put hand spinning out of business with their mechanically spun thread.⁹

These improvements were doubtless brought over to America by the continual flow of immigrants and they proved an instant success. Between 1790 and 1810, 250 of these small spinning mills had been erected in the U.S.A., all in the New England area.¹⁰ The mills were usually situated by the side of a stream which they used for water power to turn the shafting by means of the water wheel. The first hamlets which grew up round these factories were of ample proportions, and had well shaped, broad streets. The cottages themselves were the detached type, each with its own garden often marked off with a white picket fence. This spacious quality is very possibly a deliberate attempt to avoid the cramped, squalid sites upon which most of the contemporary towns in England were being erected. The workers of the time were either directly from the British Isles themselves, or were in contact with those who were, and they were obviously determined not to perpetuate the same mistakes - indeed there would have been little excuse if they had.

By this time, many mills in England were employing steam power, and required water only for their boilers. In

America, however, no reliable steam engine could be obtained, and the price was prohibitive compared to the wonderful natural resources flowing freely in the many New England rivers. Indeed it was not until 1850 that the steam engine was introduced into America on a scale and at an efficiency which made it a desirable and economic proposition.

The influence of geography upon the industrial pattern of the time is therefore most marked, and one has only to take a map out and plot the manufactures of the New England cotton industry to have a very good idea of where the main streams are. Of these streams, certainly the most influential was the famous Merrimac River. Its fame is the more widespread because the business-wise, yet philanthropic Lowell decided to implement his dream town upon its banks.

Lowell had a very clear ideal in mind when he laid out the town which now commemorates his memory. Roughly, he envisaged a river supplying his factories which would be sited upon its banks in a 100 yard deep lot. This distance would be delineated by a canal dug parallel to the river so separating the industry from the development located immediately on the far bank of the canal. Here were to be all the workers' homes laid out relatively close together so that the main body of the employees were within easy walking distance of the mills. Behind this development Lowell envisaged

the main road through the town, again running parallel to the river. Beyond this the countryside was to be divided off into streets and lots as desired and auctioned off to the bourgeoisie. It was a simple, direct approach to the problem, and the ideal was often aimed at in the layout of New England towns.

Invariably, the plan was modified or radically altered to suit the particular requirements of the site, and in the case of Lowell itself, the Merrimac was not at all suitable to a layout such as has been described, and sacrifices had to be made. The factory interests were controlled by Lowell and he owned the choicest sites; it is not surprising therefore, that the houses were the elements to suffer in order that the factories might make full use of the river.¹¹ Nevertheless, Lowell still stands before us as an object lesson in the successful integration of its housing and industry. The main contributory reason for this rests on the 'oneness' or comprehensive nature of its conception. The result was an efficient industrial unit, conforming at the same time to a folk custom. Coolidge makes the following observation: "Because the factory dwellings of Lowell realized (the above principles), perhaps they can suggest clues to the solution of our immediate problem."¹²

Mill structures in the late 1830's in New England began to loose the extremely severe lines and attempts were made to break up, or texture the facade with mouldings and ornament, such as the inclusion of decorative cornices or classical detailing round doors and windows. This decorative phase still maintained the primary conception of the mill as a single, separate entity within the mill yard, - an isolated unit. In 1846, however, the mills of the Hamilton Group show the genesis of a new approach. It came about through the desire to expand and this particular group of mills in Lowell saw that the easiest, most economical way to expand their premises, was to join two existing units which happened to be in close proximity. The method employed (seen in embryo at Waltham) was to build a link with a double pitched roof with the ridge running at right-angles to the line of the former roofs. This formed a gabled pavilion in the center of the facade and the unit could be of any given size since, at the rear, the building could be extended indefinitely to make a T shape of the complete block. Many firms in the 1840's took advantage of this innovation. Its impact on the visual form of the industrial scene was most marked. Instead of single objects forming an accent or punctuation in space, the long facade raises an obstacle to space, a dramatic full stop, a delineator of topographical form, a three dimensional screen of great lateral

expansion. This idea could not always be fully worked out owing to the nature and restrictions of the site, but at Lawrence a project for the Bay State Mills dated 1846 shows the principle when taken to its fullest extent. Another very fine extant example of the long screen-like expression is to be seen at Manchester, New Hampshire, where the Amoskeag and Manchester Mills present a curved facade nearly half a mile long. Here, the simple, unadorned brickwork is a rich, warm, red-brown; beautifully weathered, and the walls rise sheer out the Merrimac, - a fine essay in restrained, yet powerful dynamism.

Towards the middle of the century the initial boom days of the inland cotton towns were nearing their end, and except for the subsidiary boom years of the civil war which promoted all trade, their long period of decline began to settle in. The chief cause was the drift of the mills to the seaports, such as Newburyport, Fall River and New Bedford. The advent of the steam engine which could now be worked on an economical basis and the increasing cheapness of coal to feed its boilers encouraged owners to build nearer the ports for ease of transport and cheaper labor. Some idea of the growth of the seaport industrial towns may be got from a study of Fall River, Massachusetts. The first mills there were not built until 1813 when Wheeler and Anthony joined

with property owners along the Quequechan in organizing the Fall River Manufacturing Co. and built a series of factories driven by waterwheel.¹³ By 1845 the town had still a population of only 9,000 persons, 2,000 of them employed in the 6 mills, the remainder of the industrial force being absorbed in 2 calico printing establishments and an iron works. Between 1855 and 1865 however, the number of spindles doubled, and it quadrupled in the following decade. During this period, Lowell and the other inland towns were declining rapidly into second class industrial settlements.

A notable exception to this migration were the famous Arlington Mills at Lawrence and Methuen where worsted and cotton goods were manufactured respectively. The first of these mills was not built until 1865, and was described as a wooden structure of "great charm and simplicity".¹⁴ Unfortunately, but almost inevitably, the mill was razed to the ground by fire in 1866, and its successor, again of wood, miraculously survived until 1888. Although no pictures appear to have been preserved, it was described as having "an Italianate expression, with a large broach spire on the main tower giving a rather incongruous appearance." The new mill, which still stands today, was of brick, slow burning construction, articulated with staircases set in separate towers at intervals along the facade.

By this time, the principle difference in the method of production between English and American mills was apparent. In America, the entire manufacturing process was carried out under one roof, whereas a great deal of specialization was the rule in England. This American trend to have the mill self-supporting in all processes of cloth manufacturing has been maintained to the present day, and it is to be seen in the new mills being built in the South. Externally, however, there is not a great deal of difference between the English and American mills of the mid-19th. Century. In both countries local brick or stone was used for the exterior walls, and four or more stories was the accepted height, with a bay size of about 12 to 14 feet. Windows were the Georgian proportioned, small paned type with soldier arches over the head.

There were differences in detail. Chief of these was the introduction by Robert Dale Owen to America of the Lombard Romanesque style. This romantic style was used as early as 1844 and was found to be highly satisfactory, since it at once met the owners' need for economy and decorative expression. It had the official blessing of the Congregational Church for its "combination of beauty and simplicity" and industrial architecture adopted it enthusiastically, and it remained a firm favorite until well into the 20th. Century. The style is well illustrated in the accompanying photographs,

and it can be seen how the low, squat campaniles admirably fit their new function as water towers, and how the simple, bracketed cornice lends itself to easy brick bonding, providing decoration without a heavy overlay of superficial ornament.

There were also differences in structure. Fall River does not possess a single iron fire-proof mill, and that is the situation over most of New England. American insurance companies would not insure metal framing, so the slow burning system of construction was evolved. This relied on massive wood construction to provide the necessary fire stop. For the main part, the principle floor beams were covered with 3" thick planks, overlaid in turn by 1" boards laid diagonally, and finally surfaced with boards of tough maple or birch, the whole supported on wooden pillars about 12" in diameter. The stairs were also built solidly of wood scantlings, and, following the Waltham pattern, were built externally so helping the fire-fighting problem.¹⁵

The system lent itself to rapid construction, and in some of the feats performed one can see the germ of American industrial drive and organization at work. At Fall River in 1893, a new mill, four stories high, to contain 65,000 ring spindles and 1710 looms was built and roofed in one month, and 8 months later the whole machinery was in full production.¹⁶

The basic form of construction did not change in the New England mills, and in 1903 in New Bedford we read of the mills being still four stories high, of wood construction, with floor to floor heights in the region of 17 feet 6 inches. Windows were the open casement type, but a concession had been made to metal in the outside fire stairs which were now always of iron.¹⁷

• • •

1880 marks the beginning of the challenge of the South. In 1878 there had been a boom in trade which had been very beneficial to the New England mills. However, it also had the effect of stimulating the revival of the southern industry - materially assisted by the Republican victory in the 1880 poll. This shock victory over the hitherto Solid South convinced southern Democratic leaders of the futility of trying to regenerate the South through politics, and that something concrete must be done to raise the standard of living. The creation of a healthy industrial economy appeared to be the obvious solution. Cotton was a natural selection; the raw materials were on the site, and the increasing labor troubles of the northern textile industry made it a susceptible prey to determined competition.

At first, and even today to some extent, only very

coarse cloths were woven, nearly all the counts being under 21s. so that unskilled labor could be used. The speed with which the southern industry wrested the initiative from the northerners is not usually fully appreciated, and to illustrate the point more clearly, the table overleaf has been included. From a comparison of the figures for Massachusetts and South Carolina, one can see how the southern industry has expanded since 1880 to such an extent that it claims more than half the total manufacturing plants even at this early date.

Quite apart from the commonly expressed reasons for the South's expansion, which refer to the cheapness of labor and the nearness of the cotton fields, there is the undoubted greater efficiency of the new mills. The North had to meet the challenge with outmoded structures, and it was faced, to a lesser degree, with the problem that confronts the Lancashire cotton industry today in its efforts to catch up to the American high pressure production methods. The following description in 1903 of a new mill in South Carolina gives some idea of the advantage held by the South in terms of building structure alone: "one of these (mills) at Columbia is a four story brick building, flanked by two handsome brick towers, and measures 552 feet long by 151 feet wide The walls are double, with space between them for ventilation and heating; the elevator shafts are

STATE	NUMBER OF MILLS	NO. OF ACTIVE SPINDLES	SPINDLES USING COTTON WITH OTHER FIBRES	COTTON TAKEN FOR CONSUMPTION	COTTON CONSUMED	MILL STOCKS AUG. 31 ST	AV. CROSS WT. OF BALES
ALABAMA	74	876,944	-	247,467	239,149	29,946	500.7
ARKANSAS	7	12,972	-	4,762	4,411	825	498.9
CALIFORNIA	15	12,284	-	18,219	15,997	3,590	512.9
CONNECTICUT	86	1,215,435	52,630	158,403	147,450	49,060	513.9
GEORGIA	149	1,610,004	14,060	545,385	521,777	62,400	484.5
ILLINOIS	37	31,488	4,646	14,264	13,412	1,575	511.1
INDIANA	21	122,568	11,904	29,675	27,754	4,445	512.2
KENTUCKY	16	82,764	14,164	27,001	25,785	5,220	516.2
LOUISIANA	14	68,724	-	17,404	17,050	799	501.1
MAINE	35	966,864	40,853	166,456	157,152	37,616	519.9
MARYLAND	16	142,384	9,000	65,960	64,998	4,445	493.9
MASSACHUSETTS	204	9,097,236	70,462	1,365,628	1,253,856	367,098	513.4
MISSISSIPPI	26	162,696	8,404	38,854	37,929	3,491	494.0
MISSOURI	39	14,416	312	10,125	9,491	1,168	512.1
NEW HAMPSHIRE	44	1,307,357	50,520	306,783	277,941	82,696	515.3
NEW JERSEY	28	425,791	14,463	46,845	48,294	9,217	513.5
NEW YORK	128	900,506	110,862	206,843	191,884	37,797	508.5
N. CAROLINA	276	2,604,444	6,556	750,400	710,275	84,542	482.1
OHIO	31	-	19,427	23,744	24,533	8,564	517.1
PENNSYLVANIA	132	263,205	137,190	89,476	86,825	12,933	511.2
RHODE ISLAND	74	2,218,905	12,556	245,266	223,035	76,250	521.5
S. CAROLINA	145	3,502,036	-	709,728	668,883	96,487	485.2
TENNESSEE	35	230,358	23,482	65,185	62,522	10,508	480.6
TEXAS	52	103,992	-	41,923	38,602	5,443	509.8
VERMONT	15	106,720	24,032	17,049	13,921	4,470	509.4
VIRGINIA	29	250,758	4,738	72,470	68,668	9,085	493.6
ALL OTHER	92	44,340	20,890	35,879	33,342	6,798	504.9
U. S. A.	1,830	26,375,191	651,251	5,321,203	4,984,936	1,016,738	500.3

fireproof, and the lavatories provided for the use of the workpeople are furnished with polished marble, oak, and nickel plate fittings, exactly like those of the best hotels in New York and Boston." At this early stage in the history of industrial architecture, it is interesting to note the awareness of the need for pleasant working conditions and the vital effect it can have on the reduction of labor turnover figures. When one compares this to the attitude prevalent in England at the time it is small wonder that the British industry lost the initiative.

Before closing this short essay on the architectural history of the industrial architecture in the United States, as it is seen in its principal trade, the cotton industry, I cannot resist comment upon a point raised by Coolidge in the book quoted above. He discusses the role of architecture in the 19th Century with relation to industrial structures, and since this period is critical in any analysis of contemporary work I make no apology for taking sides in this vital issues raised.

Coolidge says: "One of the great contemporary illusions about the 19th Century is the belief that orthodox building was fundamentally static throughout that period"¹⁹

On the other hand his contemporary Giedion states: "Decade after decade of Victorians devoted themselves to the same sterile copying (of the past) For 100 years architecture lay smothered in a dead eclectic atmosphere."²⁰ It is obvious that Coolidge differs radically from Giedion's analysis for he goes on: "So far from being obliged to follow his chosen model in accordance with an immutable method of imitation, the attitude of the designer toward the works of the past was always evolving. So far from being at heart esthetically stagnant, revivalism, the orthodox architecture of the 19th Century, developed continuously in a logical fashion."

This development, Coolidge asserts, has been ignored or denied because it is too complex to permit simple exposition. He considers this complexity reducable to three interacting, coexisting factors. The first of these is a changing repertory of revivals, the second a changing conception of the role that historical styles should play in contemporary architecture, and thirdly, a changing feeling for mass, space, color and texture.

If the main contention of this thesis is conceded, namely that the vast majority of our industrial architecture is esthetically sterile, and devoid of the essential ingredients conducive to a living, lasting style, it must also be conceded

that somewhere in the process of its evolution, architecture has 'missed the way'. Coolidge, in his analysis plainly does not consider the late 19th Century to blame for this, and as he does not pursue the argument and state where he does consider the blame to lie, - or even if there is blame to be laid, I must attack his argument if the rest of my thesis is to carry real conviction.²¹

In the first place, I venture to suggest that there is a confusion of the roles played by architecture and engineering respectively during the 19th Century following the advent of the steam engine. I would concur with Giedion's charge of sterile eclecticism in the thinking of architects, and suggest that the logical development seen by Coolidge is apparent only in the work of the engineers as they struggled to express themselves in the staggering possibilities of the new materials that science had laid before them. It should be remembered that (in England) Telford, Macadam and Paine were engineers, and that it was they who are responsible for the great 'logical development' of the new materials; that Paxton was a gardener, an expert on greenhouse construction, and that it was he who was responsible as far back as 1851, for the greatest, most farsighted use of the new possibilities of glass and steel; that Dickens was a writer, and that he led the literary crusade against the appalling conditions being perpetrated due to the inadequate handling of

new forces unleashed upon an unwary age; that Gustave Doré was an artist and that to him fell the task of exposing the visual chaos brought about through a lack of understanding of the humanitarian and esthetic problems raised by a new concept of living. Shaftesbury was a politician forced by his conscience to protest against the unspeakable conditions in the mills, conditions that to a large extent are reducible to the inability of architects to take a firm lead in providing such logical use of the new structures that light, air, health and amenity were automatic byproducts of their exploitation. In my reading of history, I find it difficult to recall a single architect between the years 1830 and 1870 - when the great harm was done - who raised his voice and ventured to suggest that the enclosing of a steel column in a Grecian pillar was unfunctional, that the hotel to St. Pancras Railway Station in London was a ludicrous Gothic ^{re}gargoyle hiding the bold, expressive, wrot-iron trusses of the engineer designed engine sheds behind, or that the Crystal Palace was the most sublime essay in the new materials yet built. If there was such a one, his lonely voice was carried away on the rising tide of the confusion wrecked by the fruitless, unresolved and dilettante Battle of the Styles. Scott, Soane, Pugin, Ruskin and the rest obviously drowned his plea! In short, I believe that it was in the 19th Century that the architect betrayed his trust to guide man

correctly through the esthetic problems raised by new conditions, and if any progress was made, it can be attributed to the engineer who did his utmost within the limits of his esthetic training. Such changing conceptions of the role of historical styles as did occur, I feel were forced upon the architects by the increasing incongruity which became apparent as the various revivals were tried. All great architecture has come about as a direct result of the careful, clear-sighted analysis of the problems of the day expressed in terms of the materials and building technology most suited to its needs. This analysis was patently omitted or inadequately considered by the exponents of the 19th Century revivalism. The immediate product of the new technology was the factory to house it, and the environment to form its setting. What a wonderful opportunity for original, creative thought! Architects were, however, shown to be completely barren of ideas, the summit of their invention seems to have been the inconsequential addition of superfluous ornament which for the most part made complete nonsense of the structure it covered.

These notes I feel are common ground, and the conclusions they express serve to underline the basic necessity for a thorough investigation of the available facts to show how we may approach the task of designing for industry. We need the desire and conviction to get to know what industry

wants from its structures, and what it, the industry, thinks are some of the possible avenues of exploration. In short, it is a plea for commonsense: what architect worth the name would attempt to design a house without thorough investigation of every material and psychological requirement of the client? Yet this is what practitioners in the past have often tried to do with industrial problems. This thesis therefore, sets out exactly the type of procedure which would be the recognized 'modus operandi' for any job. The difference being simply that the basic information is hopelessly scattered, or not in existence, making a pioneer report of this nature difficult to compile and often very reliant upon personal experience of industry and its problems at first hand.



NEW LONDON · GRIST MILL



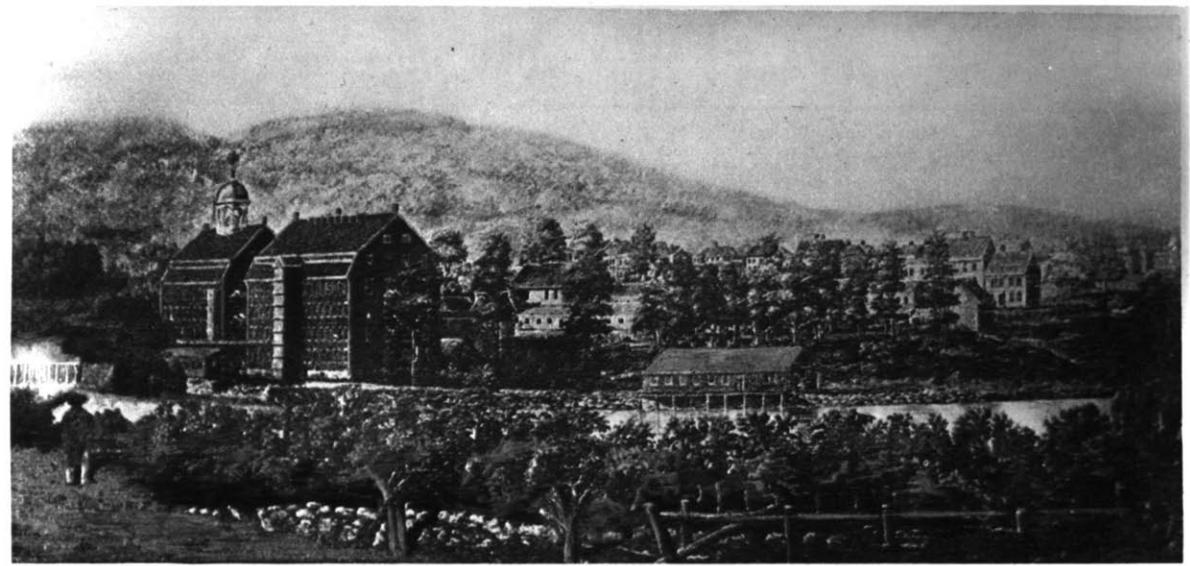
SLATER MILL • PAWTUCKET • R. I.



SLATER MILL • PAWTUCKET • R. I.



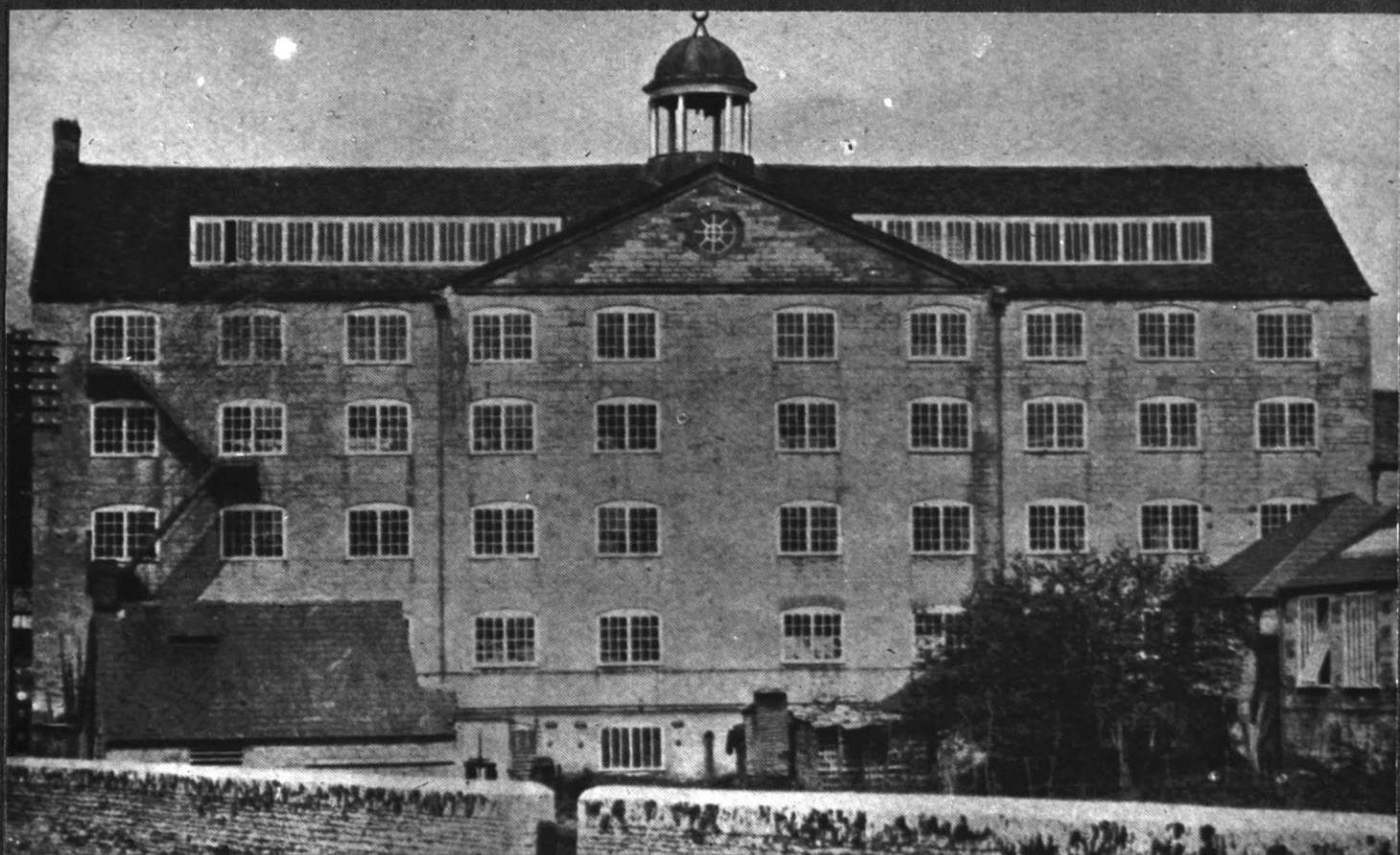
ATTIC · SLATER · MILL · R.I.



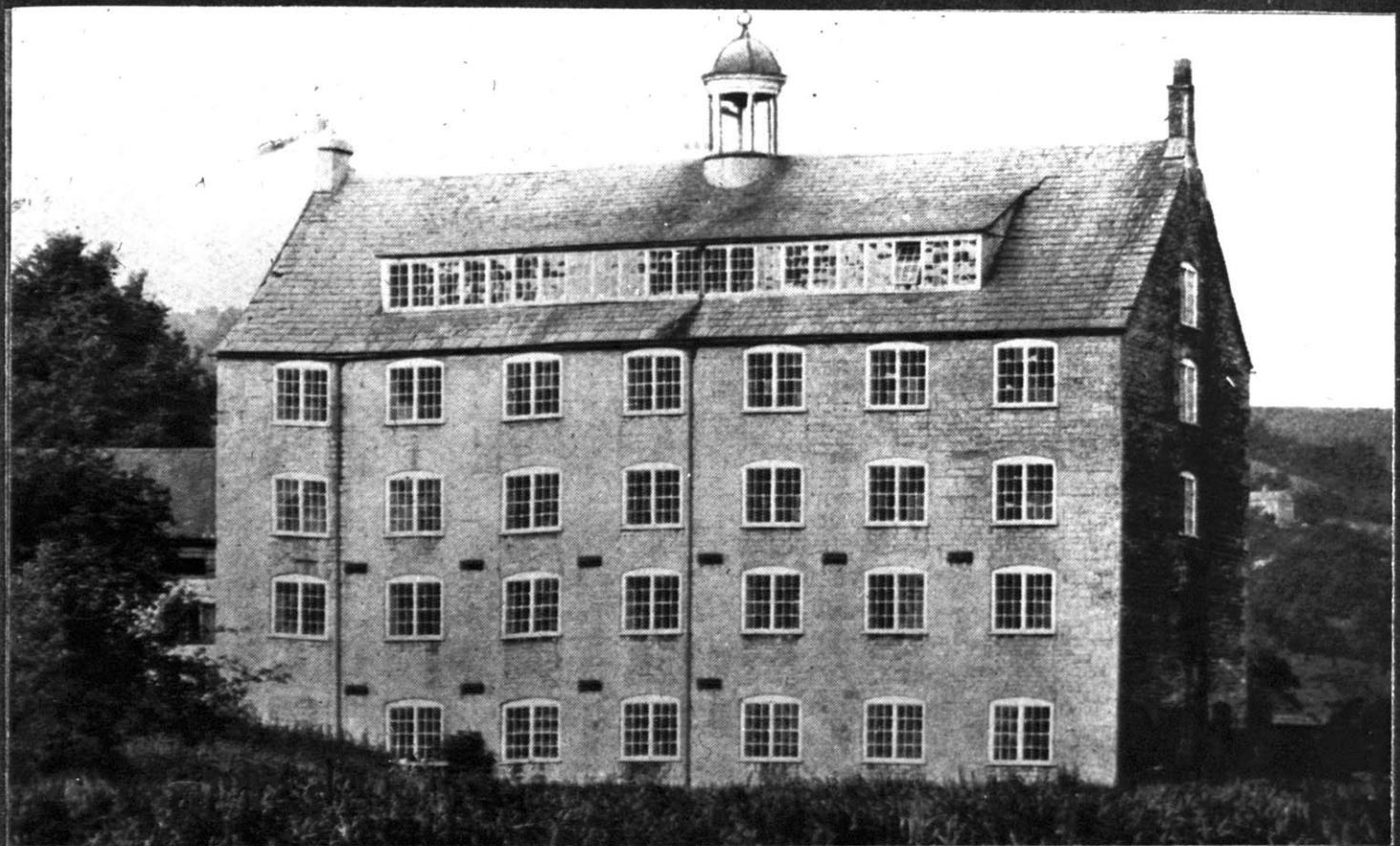
EARLY MILLS AT WALTHAM (1816)



WALTHAM MILLS AFTER EXTENSION



WOODCHESTER • England • BENTLEY'S PIANO FACTORY.



HOPES' MILL. BRUNSCOMBE. ENGLAND.



OLD STONE MILL • 1831 • NORTH ADAMS •



NIGHTINGALE FACTORY , GEORGIAVILLE. R. I.



LIPPET MILL



INDUSTRIAL HOUSING UNITS. L.L.BROWN PAPER CO. 1825 ADAMS,



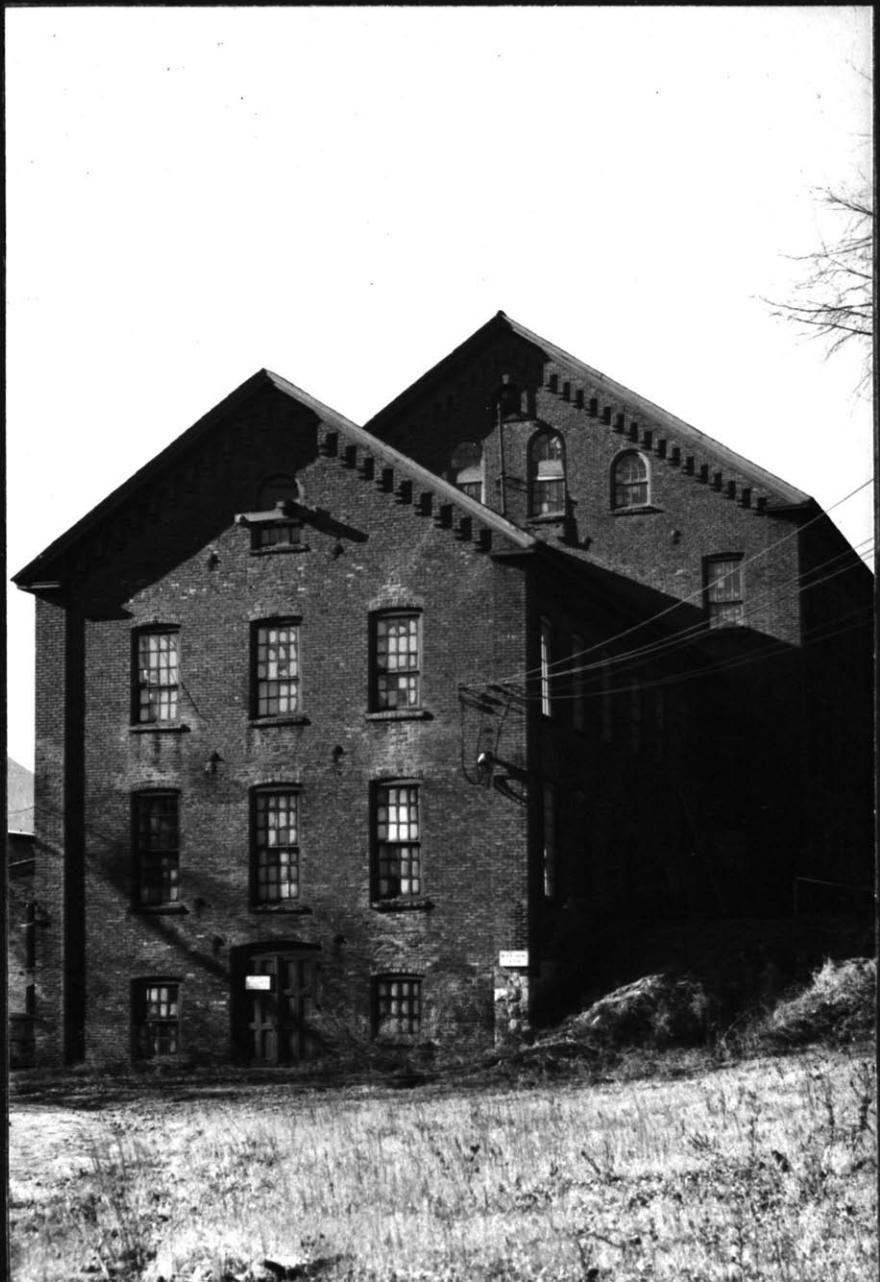
RENFREW HOUSING, ADAMS



INDUSTRIAL HOUSING IN WILLIAMSTOWN, MASS.



Russell Mill • Pittsfield • 1863



NORAD MILL , NORTH ADAMS



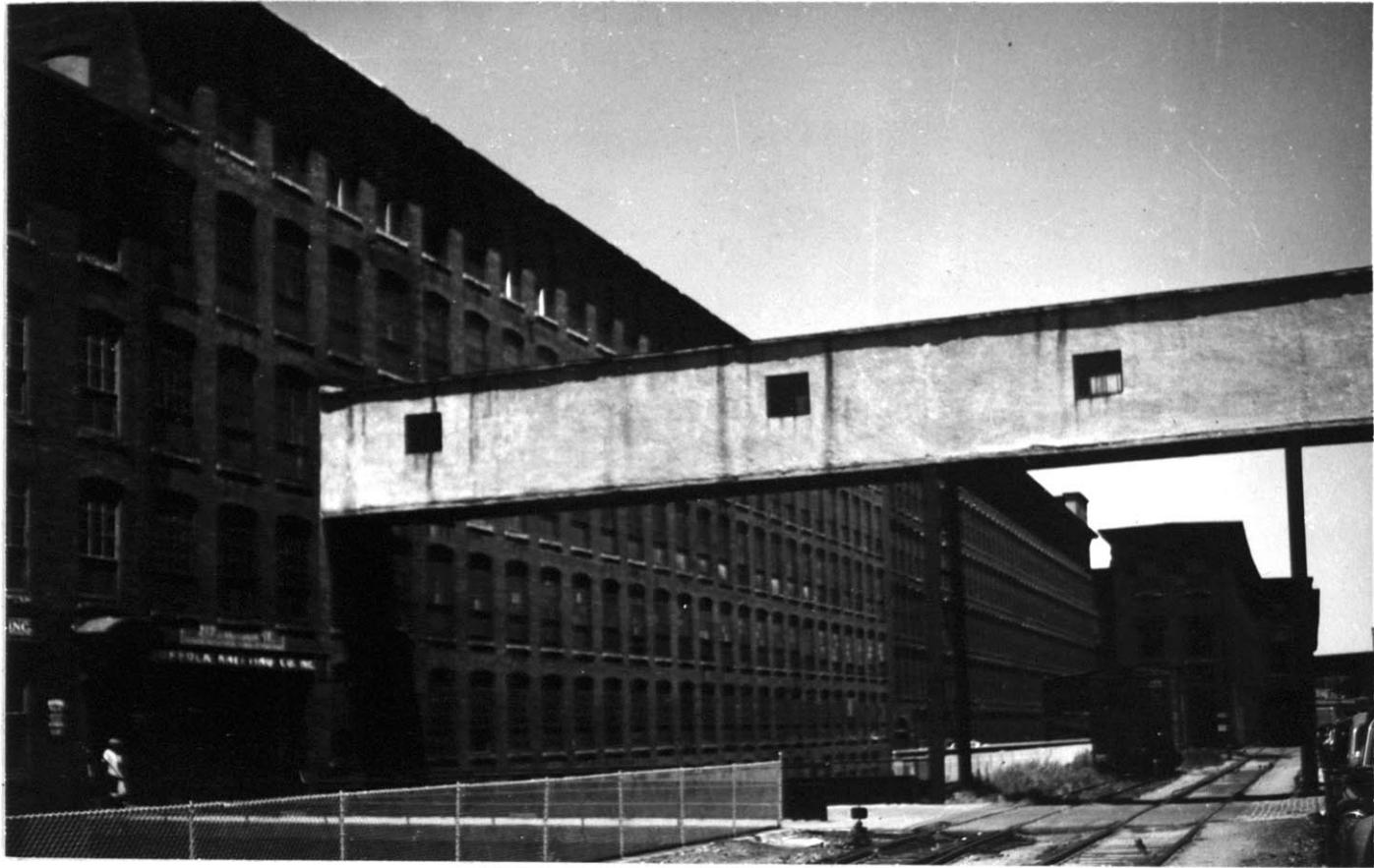
APPLETON MILL, LOWELL, MASS.



MILLS AT LOWELL, MASS., (RENOVATED)



MILL AT WALTHAM, MASS.



MILLS AT LOWELL . MASS. (SUFFOLK MILL)



MILLS AT LOWELL, MASS.



MILL AT LOWELL - MASS.



1898 TOWER · ADAMS · MASS.

NOTES ON APPENDIX 1.

1. See Harrisville, N.H., or Winchendon, Mass.
2. Dickens, Chas., "Hard Times."
3. H.C. Meserve, "Lowell, an Industrial Dream Come True" p.30.
4. Coolidge, op.cit. p.30. c.f. Bagnall, W.R., "S. Slater and the Early Development of the Cotton Manufacture in the United States." p.44, Bagnall says the mill was set up for Almy and Brown, and differs slightly in the date of construction, quoting 1790. See also Hitchcock, H.R., "Rhode Island Architecture."
5. Pierson, Wm. H., "Industrial Architecture in the Berkshires" M.S.S. Yale Univ. 1949, p.50.
6. The earliest industrial use of the clerestory monitor is in the Lippit Mill in West Norwich, Rhode Island. It was built in 1809 and is a wooden structure 104 by 34 feet, and 3 storeys high with an attic and cock loft. Its scale is greater than the Slater Mill and the decorative features are richer. The cupola is delicately detailed and raised on a square base: Ibid. p.61.
7. The construction differs markedly from that of contemporary work in England, where, by 1820, iron frame structures were becoming common. In America the old open joist construction persisted until 1835 when the slow burning "mill construction" was introduced in lieu of the metal frame on which U.S. insurance companies refused to issue policies.
8. Young, T.M., "The American Cotton Industry" a study of work and workers contributed to the Manchester Guardian. Scribner's Sons, New York, 1903. p.28.
9. For a full, chronological description of technological development in the cotton industry, see the author's work "Architectural History of Cotton Mills in the Preston Area", 1951. pp.36-40. (Currently on loan to M.I.T. Rotch Library; after July 1954, University of Liverpool Library, England.) Sufficient only is quoted here to clarify the story of industrial development.
10. John Coolidge, "Mill and Mansion", Columbia University Press, N.Y., 1942, p.11.
11. Ibid. p.26.

12. Ibid. p.116. For additional information see Lowell Historical Society and the Locks and Canal Co., at Lowell.
13. Smith, T.R., "The Cotton Textile Industry of Fall River, Mass. - a Study of Industrial Localization". King's Crown Press, N.Y., p.21. See also Lintner, S.C., "Mill Architecture in Fall River", the New England Quarterly, Vol.XXI, No.2.
14. "The Arlington Mills" a Historical and Descriptive Sketch with some account of the Worsted and Dress-Goods Manufacture in the U.S. Boston, 1891, pp.26-30: also Arlington Mills 1865-1925, the Plimpton Press, Norwood, Mass. 1925.
15. The study of American construction and its comparison with British techniques is the subject of a chapter in The author's thesis "The Architectural Development of Cotton Mills in Preston and District".
16. Young, T.M., op.cit. p.8.
17. Ibid., p.15.
18. Ibid., p.67.
19. Coolidge, J., op.cit. pp.58-60.
20. Giedion, S., "Space, Time and Architecture", p.24.
21. Since preparing the original MS of this dissertation I have spoken to Dr. W. H. Pierson of Williams College, Mass. and a friend of Coolidge. He feels that Coolidge's main point here is that the Revivalists took the various styles and, sometimes through necessity, sometimes with the naivety of ignorance, moulded them into forms which were frequently highly original and marked a definite evolutionary progression. This puts the matter in a slightly different light and on this approach I would agree with Coolidge. Nevertheless, I felt that in his book he is attacking Giedion on the highest critical plane of the true purpose of architecture and I maintain that, judged on these criteria, Giedion's assessment is the more correct. In short, to quote Coolidge, I agree that Victorian architecture "developed continuously" but I cannot agree that it did so "in a logical fashion".

Appendix 2Principle Types of Factory Construction in Trading Estates.

One of the chief differences between industrial estate plants and privately owned concerns is the convertability which is aimed at in the construction of the former type. There are three main types of factory in an Industrial District, and they may be identified by the difference in their ceiling heights. The first type is the standard manufacturing plant with a roof height of between 12 and 14 feet, and this was the most popular and most widely used until recent years.

The second class is increasing rapidly in favor, and has a ceiling height of 18 to 22 feet. This is the warehousing type, and the tremendous increase in trucking has led to a high percentage of this class of construction. Indeed in a report from Clearing, it is recorded that warehouse occupancy is on the increase to such an extent that over 50% of new projects within the district are now being built of this class. The reason for the higher ceiling is determined by the current size of pallets, and the heights quoted above permit stacking to be carried out in lots 3 or 4 pallets high respectively.

The third class of factory has a fairly constant ceiling height of 18 feet, and is constructed to favor the use of overhead conveyors, since it has been found that there is an increasing demand for this type of automation, and its economy and speed has been demonstrably advantageous in many tests with other kinds of conveyor systems.

Bay sizes are also chosen with a view to adaptability, and a 24' or 25' wide grid is the most usually favored with a span of between 40 and 60 feet. Clearing reduces its construction costs appreciably by laying in a stock pile of trusses 61 feet long, and with the use of wood roofing and sprinkler systems, they design to a working load of 3.7 lb. of steel per sq. ft. of building.

Appendix 3Some Design Criteria for Railroad Layout in Industrial Districts

I feel it is appropriate to discuss in an Appendix the problems involved in the design of railroads such as would be found in Industrial Districts. They are particularly a property of the zoned layout, and function to maximum advantage when in such a scheme, for small individual plants cannot afford to tap the main railroads and run a private line to the factory.¹

Industrial railways came into use much earlier than did the tractor (which used the internal combustion engine), and there has been a tendency to let many of the first tracks go into disuse and uproot them. Outside the Districts only large, heavy goods plants, like saw mills and steel plants find them economical for their long, heavy inflexible hauls.

When used within their own system, gauges of 24", 30" and 36" are most common, but anything from 18" to the standard guage of 56 $\frac{1}{2}$ " may be encountered. The weight of the track again depends on the class of work, and 12lb. to 90lb. (normal railway) per yard run may be used.²

The motive power may vary from steam, gas, storage battery, to electric trolley, and the weight or class of work

determines the type to be used. Briefly, steam has been found the most suitable for heavy work, and is capable of dealing with big loads over long hauls for extensive periods. Electric power has the advantage that it has an even turning torque and eliminates the wheel slip which is found in both steam and gas; this is a very important consideration if the work includes much starting and stopping over relatively short hauls with heavy loads. Storage battery locomotives are suitable only for short hauls which do not exceed 2000 feet for the round trip, and 3-rail and trolley transmission has been found to be defective in both safety and overhead obstruction.

The main advantage of rail transport, of course, is that it allows goods to be loaded straight into the waggons at the factory and eliminates possible double handling. Furthermore, rail transport costs no more than roadways; the rails are excellent for heavy duty work, and the locos are little more expensive than tractors and considerably cheaper to maintain, while cars are less costly than the equivalent cubage of good class trailers.³

As the accompanying sketches show, the track layout in an industrial estate can either dominate the plan or play a secondary role, but the main intent is always to avoid any cross circulation with men and materials either pedes-

trian or vehicular. It is important to avoid curves as much as possible, and, where they become necessary, it should be remembered that sharp curves lead to derailments, while the large radii require too much room. Loading points should never be located on curves, for cars cannot be handled even singly on less than 40 or 50 foot radii. Where more than one car is involved, 140 ft. radius is the minimum, while for fast switching, 400 ft. is the minimum.⁴

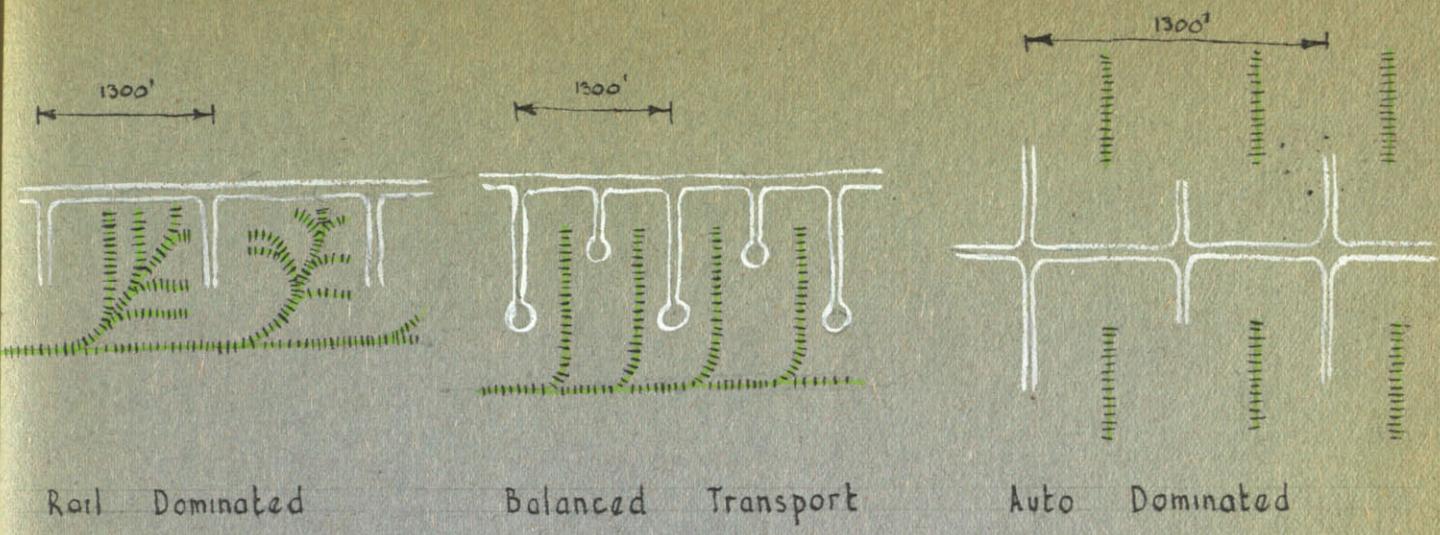
The diagram over leaf shows an ideal track layout for an industrial zone or estate, and it is the method used at Clearing. Its advantages may be ennumerated as follows.

1. The layout results in sites of varying size to suit any industry.
2. The diagonal 'lead' track saves land and gives cheaper and more efficient switch tracks which can be placed at any point upon its length.
3. All factories face a street which gives direct access to road services and there is no cross circulation.
4. The street frontage and cost of paving is reduced to a minimum for each factory.
5. The rail track gives the most convenient and rapid type of switching operation.

When arranging the lead tracks to a plant, the designer should err on the generous side and provide adequate tracks to avoid outgoing and ingoing congestion. In particular, it should never be assumed that one track will serve two departments, because delay always results from this kind of economy.

The loading platforms should be 44" above the track, and in this connection it is interesting to note that more recently, some forethought and research has gone into this question, and the tracks have been depressed to the requisite depth rather than raising the platform. The advantages of this method in terms of economy are obvious when it is realised how much cheaper it is to excavate for tracks rather than build whole sections of the plant 44" off the ground. Indeed some estates have recommended sinking the entire road and rail system in the zone so that the factory level need never be disturbed. This suggestion has interesting possibilities architecturally, and the layout and design of such a district would give the imaginative architect the opportunity to work out exciting new landscape relationships.

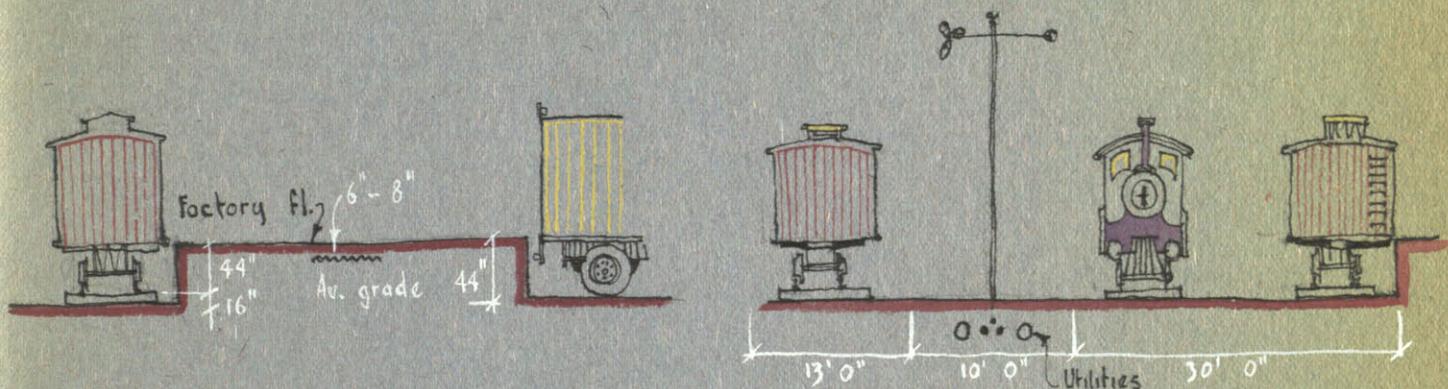
It should be assumed that any large plant will require scales set in the track to check all traffic; these should be sited at the most convenient point in the warehouse, and, to make sure they are both strong and sufficiently large,



Rail Dominated

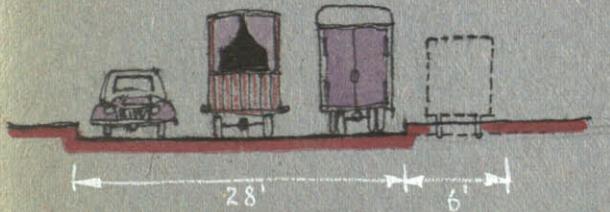
Balanced Transport

Auto Dominated

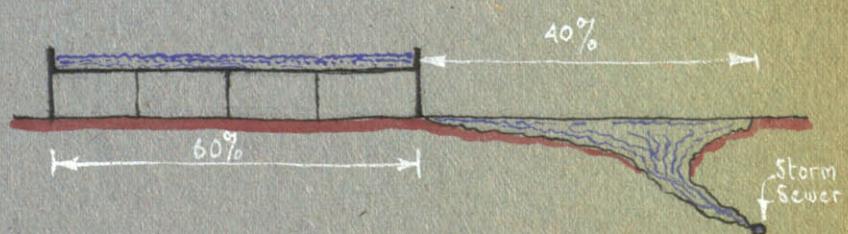


Showing how some districts depress the whole track system and the roads

Utilities are better in railway leads and side tracks than in parking area on either side of street. Setbacks are now 75'-100' and services are therefore more economical in the rear.



Ideal width: 30 ft has been used but is too wide for 3 cars, not enough for 4. Major roads now 40' to keep 4 lanes moving with 1 parked.



Delayed runoff minimizes flooding and permits a smaller sewer. Roofs now often cover 60% of the site so that delayed runoff is an important feature.

it should be remembered that the average length of box cars is 42 feet, and that its maximum load is 210,000 lbs. With the normal gauge of 4'8 $\frac{1}{2}$ ", cross ties are 8 feet long and 8" wide by 6" deep, spaced 20" to 24" on center and the distance between the tracks is 13 feet.

The grade of the tracks should never exceed 5%, and anything over 2% involves the use of a vertical curve which is more expensive to construct.⁵ The platform floor must always be dead level with the car floor, and, if the track is inside, and not depressed as has been recommended, then the rail should come flush with the finished floor level. Externally such crossings should be effected with planks laid to come within $\frac{1}{2}$ " of the railtop, and lastly, at the point at which the track enters the plant, the doors should never be less than 15 feet high. The accompanying sketches illustrate these points in more detail.

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Notes

1. I do not wish to overemphasize the importance of rail facilities for as Lipman shows in his study, (op cit p.18) out of 36 plants, only 8 relied exclusively on rail, 25 on trucks, and 5 on both, for their inbound goods. The outbound figures show a similar bias. This however, does not prove that rail transport should not play a greater part and I feel sure that with properly designed facilities it could do so, e.g. Clearing.

2. Mitchell, W. N., "Organization and Management of Production", New York, 1939, p.159.

3. Ibid.
4. Droege, J.A., "Freight Terminals and Trains", pp.42-43.
5. These figures were compiled from information in Barnes, R.M., "Industrial Engineering and Management", pp.89-91, c.f. Mitchell, "Organization and Management of Production" op.cit. p. 160.

Appendix 4Basic Time-Motion Principles

The architect cannot be expected to become an expert in this highly specialized science, but at least he should appreciate some fundamental principles which govern time-motion analysis, and the following points if thoroughly assimilated will prevent the designer from making basic errors in preliminary layouts.

1. Work should be performed with both hands, and each hand should begin and end each element of motion simultaneously. The accompanying diagrams illustrate some good and bad hand-motions for simultaneous work and it will be noted that for the most efficient production, simultaneous motions should be made in opposite and symmetrical directions wherever possible.
2. The activities at the work place should be arranged to provide a smooth flow in the shortest line of motion with the simplest and fewest elements, and the last element of motion in the cycle should be adjacent to the first element.
3. Free, rhythmic, curved motions are preferable to controlled motions which require sharp changes in direction. Illustrations of this can be seen in the sketch where the movement

between three triangularly spaced points is better made in a rotary motion rather than in straight line movement even though the distance travelled is shorted. It can easily be demonstrated that such a course takes less time and results in less fatigue. A knowledge of simple anatomy is necessary, and from this, elementary principles can be evolved, such as the notion that workers' muscles should never go contrary to the line of motion.¹

4. The required muscular effort should be reduced to a minimum by keeping tools as light as possible, sliding small objects, and using gravity-activated devices to deliver and dispose of materials wherever possible.

5. Account should be taken of the inherent abilities and disabilities of all parts of the human body.² Movement should always be restricted as much as possible, and fingers, wrists, forearm, upper arm and shoulder should be used in that order.

6. The feet and other members of the body should be assigned all possible activities to relieve the hands for other work.

7. The materials, tools and equipment control should be located at definite and fixed positions, preferably in the area in which they will be used and within the smallest practicable work space.³

The time motion expert works on the principle that while congestion results from overcrowded conditions, space constitutes a communication obstacle and it costs money to bridge it by means of machinery, forms, letters, phone calls and the like, apart from money spent in rents and building, and the above suggestions if carefully applied can do much to reduce this wastage.

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Notes

1. For instance, the swing of a golf club is stopped by the impact with the ball and dissipation as it moves up against gravity, and not by any restrictive or contrary muscular action by the golfer. This swing therefore gives tireless movement.
2. I noted in the atomic museum at Oak Ridge, Tennessee, auto-hands of marvellous complexity, which in many respects are much superior to their human counterpart. One instance of this superiority is that the wrists can rotate indefinitely making them more efficient than human wrists for such tasks as turning a screw driver and winding on all manner of screw tops.
3. Barish, N.N., "Systems Analysis of Effective Administration", New York 1951, pp.137-143.

Appendix 5Presenting the Scheme

We have surveyed fairly thoroughly the process through which the designer must go when confronted with the task of planning for industry. When this is done there remains one vitally important step and everything will depend upon the architect's ability to take this hurdle in his stride. It concerns the question of selling the scheme.

New layouts must often be approved by non-technical men, who are usually incapable of appreciating the full implications of a two dimensional plan. It is here that the architect with his special artistic training can be of unique value. Even free-hand sketches can accomplish much more than masses of written material, but these have been known to be inaccurate and the "artistic license" which some architects use when making perspectives has led to grave misunderstandings and misrepresentation, so that models are generally accepted to be a more reliable visual aid. A further value of models is that when they have been passed in principle by managements, they can be displayed in prominent positions in the workrooms for exhibition to the employees whom the changes will naturally effect. This is a valuable psycho-

logical move because it makes apparent the owners' wish to consider them in any changes which are made. The cooperation of the workers can be more fully obtained if suggestions boxes are displayed nearby, and many useful ideas have been forthcoming in this manner, particularly from the type of person who is not readily vocal in group discussions. A further value of the model's display is that it prepares the workers psychologically for the alterations, and they can adjust themselves before the physical change is made.

Easily read models for this purpose should be sufficiently large in scale and $\frac{1}{4}$ " to 1' is probably the best representation. Sufficient detail should be included in the model to make the plan recognisable, and all moving parts should be shown in a neutral position. Colors should be recognisable and true. Over diagrammatic color relationships for the sake of a charming abstract pattern will do little to enhance the model's practicability, although major items such as control points and panels can justifiably be picked out in brighter colors to clarify the layout. Each model should be accompanied by a two dimensional template with additional information which cannot be readily given on the models. Under this heading would be such items as the name of the model and its number; the type of machines indicated on the model with their sizes, weights, center lines, direction of production flow, and maximum vertical

clearances. If the model is too small to be provided with such templates, then the piece of card or plywood should give the machine's name, and a separate report should accompany the model with the missing data properly tabulated. The accent should be on robust construction. The model will probably be given fairly rough handling both by the various plant authorities, and most certainly by the railroad companies if it has to travel to other cities either on exhibition or for approval by top executives or financing companies.

A further refinement would be to show underground and overhead data, and this can be done by constructing a separate model of the different elevation, or, more appropriately, by its combination with the main floor, but with the use of transparent materials for floors and walls. This is perhaps the most successful way of showing the proposals, for the whole layout can then be seen in its proper relationship, and materials and production flow lines can be illustrated by the use of colored, plastic coated wire which can be made to pass from floor to floor through the various processes. The value of this type of work has been stressed by Immer who says; "As services of this nature must involve a great deal of digging for information, analysis and study, which is not always apparent to the client, the ability to present a solution in a manner understandable to non-technical personnel cannot be overemphasized."¹

Together with the model, there should be a report which must be brief, as non-technical as possible, and to the point. It must contain all the information that may be of use to the client, and should certainly list such items as the cost of fabrication, handling under both the present and proposed methods, an analysis of the expected savings, the total cost of the installation and the estimated time for amortization. As with all large projects, the money involved is so large that a sectional development may be decided upon. This a chance for the architect, for with a little experience it is possible to foretell the type of partitioning that will be required, and he can be prepared for questions involving breakdowns to show how much the venture would cost if only part of the plant were to be built at a given time. Several permutations can be calculated, and the author has had experience of the impression that this type of simple foresight creates with clients.

Failing the use of models (which are best used when the layout is reasonably final) there are several graphic methods which may be particularly useful in the planning stage. A successful method is the isometric section, but this again is not very flexible, and I personally prefer methods employing movable templates. One of these consists of moving templates around on transparent sheets, and, by arranging templates on other sheets and overlaying the two,

comparisons of the systems can be made. Another technique employs a transparent backing sheet marked off in squares of 1 sq. in. To a scale of $\frac{1}{4}$ " to 1 ft. the unit would therefore equal 4 feet. Templates of the various machines may then be cut out of transparent material, and each one named and dimensioned. When the templates are in position, a piece of sensitized paper is drawn under the lower base sheet without disturbing the layout. After exposure to strong light the sheet can be developed in the usual way: no elaborate tracings are required and any number of different layouts may be compared.

• • •

Notes

1. Immer op. cit. p.247

Appendix 6

A Check List of Design Considerations

I feel it will be of value to set out a summary of the points discussed in Part I in the form of an Architect's Check List to which he could refer on each job to ensure that all contingencies had been covered.

1. Manufacturing Space.

- a) Description of operations and processes involved.
- b) The approximate floor area - whether plant is to be in separate or combined buildings.
- c) Details of the types of machinery to be housed - the type of services, drainage and other special requirements.
- d) Details of any special departments.
- e) The area and type of accommodation required for supervisors.
- f) The approximate number of operatives.

2. Warehouse Space

- a) The approximate floor area required for raw material, the type of delivery, and any special provisions required for the same.
- b) Details of materials and the type of storage required.
- c) The type of materials handling equipment considered most appropriate for the above task.
- d) The approximate floor area for finished goods, and the

method of their dispatch. Also details of special facilities or conditions required in the dispatch department.

- e) The possibility of fire hazard.
- f) The office accommodation required in the warehouse.
- g) The approximate number of staff normally employed in the warehouse.

3. Laboratories

- a) The class of laboratories required - research, works control, analytical control, etc.
- b) The type of work to be carried out in the various laboratories - biological, chemical, metallurgical, or bacteriological.
- c) The approximate floor areas.
- d) Details and specifications of special work.
- e) The approximate number of staff employed.

4. Offices

- a) The approximate floor area required.
- b) The allocation of space per unit.
- c) Special requirements.
- d) The approximate number of staff employed.

5. Maintenance and General Building Requirements.

- a) Details of the maintenance to be carried out - plant erection, painting and other services.

- b) The number of workshops required
- c) Details of garage space required for works vehicles.
- d) The storage space necessary for maintenance materials.
- e) Special storage requirements for such bulk storage as petroleum, acids, solvents, coal etc.
- f) The approximate number of staff employed.

6. Service Requirements

- a) Details of the services required - gas, electricity, etc.
- b) The drainage required and details of special requirements for acids etc.
- c) Local service requirements for compressed air, vacuum, distilled water, chemicals on tap, etc.
- d) The approximate daily consumption of essential services.
- e) The approximate volume of daily trade effluent.
- f) Fire precautions.

7. Welfare Facilities.

- a) The approximate total population of the factory.
- b) Special washing facilities.
- c) Special clothes to be worn by the operatives and details of the accommodation required for the same.
- d) The number of workers requiring locker and lavatory accommodation.
- e) The area of office accommodation required for welfare personnel.

- f) The type of canteen.
- g) Details of the type of canteen service, including the kind of meals to be served and the approximate number per day.
- h) The recreational facilities in terms of rooms and open space for outdoor sports.
- i) Medical service, including the number and disposition of space for outdoor sports.
- j) The type of day nursery required, and the number of children.

8. Structure.

- a) The type of wall construction to be employed; its average thickness and the desirable degree of flexibility in various sections of the plant.
- b) The type of mechanical equipment etc. to be fastened to the wall, the degree to which it relies upon the wall for support, and the type of fastening to be used.
- c) Windows; their type, size and location, with a note on the ideal source of light.
- d) Doors; size requirements for clearance, and the type, - whether sliding, overhead, folding or swinging, and the location of each.
- e) Columns; construction, size and location.

- f) Sewers; construction, size and location.
- g) Roof trusses: " " "
- h) Floors; " " " "
- i) Ceiling; " " " "
- j) Cranes; " " " "
- k) Railroad sidings, with details of sunken track requirements etc.
- l) Truck docks; with details of special requirements such as enclosed delivery spaces for special materials.
- m) Sprinkler systems; the type of reservoir, sprinkler head and distribution.

9. General.

- a) Special regulations appertaining to work in the factory.
- b) Details of possible future extension.
- c) Special features of particular importance to the building or the site.¹

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Note.

1. This check list is based on a similar list reproduced in Mills op.cit., but I have enlarged it to include several items which I consider important, and which are omitted in the above work as reproduced on pages 26-28.

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