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Plan and Equipment of a
Structural Steel Shop

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I. INTRODUCTION.

The purpose of this thesis is to set forth some of the considerations that must be kept in mind to successfully plan and operate a structural-steel shop. The statements made and the figures herein given are based, to a large extent, upon the experience of the writer in various departments of bridge and structural-steel shops.

Before any planning can be done, a general estimate must be made of the amount and nature of the business that is available, of any probable future business, and an idea formed as to the most economical method of operation.

Although the capital to be invested generally governs the size and the equipment of a plant, it may not be for the best if the capital is large and the amount of the particular class of work for which the plant is designed is limited. Furthermore, no plant can hope to successfully manufacture all classes of structures, unless it be divided into what would in reality amount to several smaller plants, each one complete in itself. A company whose shop is designed for the building of light highway bridges would fail if it attempted to build heavy railroad bridges; a shop equipped to manufacture heavy bridges would manufacture light bridges only at a loss; and a shop designed to turn out office and mill buildings may not be at all suitable for the manufacture of bridges.

In some cases a company erects a small shop and begins the manufacture of light structural iron at the rate of two or three hundred tons per month. As the business prospers the capacity of the plant is increased by enlarging the shops and investing in ma-
chinery until the point of a maximum return on the investment is reached. Further investment forces the company into the field of heavier work in order that the larger plant may have a correspondingly increased tonnage. Then the percentage of profit on the invested capital suddenly becomes less. There are several causes for this. First, in the extensive rather than intensive policy of the company, it can not give the old style of product the attention that it formerly did; second, the plant having hitherto handled only light work is not equipped to handle economically the heavy work; and third, the employees are not familiar with the methods of handling the new product. By the continuation of a certain class of work the men become experts in the handling of the same, and this is naturally one of the most important factors to be considered. Again, the nature of the work available depends greatly upon the location of the shop. If in or near a large city, mill and office buildings and heavy railroad bridges will most likely be available, while if in a small town highway bridges and small structures will probably constitute the larger part of the work.

According to the reasons above mentioned, a shop should be carefully planned both for the particular class of work that is to be done and for a certain capacity.
II. SITE.

Art. 1. Receiving and Shipping Facilities.

Choosing the most advantageous site for a plant is another problem of moment to the prospective manufacturer. With the exception of the price of the land, the most important factors to be considered are the receiving and shipping facilities, power, and labor.

The ideal location would be in some large railroad center and near a transfer or switch-yard. Such yards are generally connected with all railroads entering the city by means of a belt line. Steel from the mills could by such an arrangement reach the plant with but little loss of time due to switching. The same arrangement would greatly facilitate the shipment of the finished product. Promptness in receiving and shipping material, does not only often give a contract to the company which commands it, but it is also a decided advantage toward the economical operation of the plant. This will be shown later.

When a location such as described above is unattainable, the next best site would be at the junction of two or more railroads. At such a point the material may be received and shipped over the more direct of the several roads, thus saving time and money in transportation and switching.

Art. 2. Power.

The choice of motive power may not often influence the selection of a site, but there may be occasions when one location will offer advantages over another in this respect.
In the modern shop the machinery is driven by the individual motor system. The old shaft driven machinery is uneconomical in respect to energy and space, dangerous to life and limb of the employees, and requires that the building be designed to withstand the extra load and vibration caused by the shafting.

The real power problem then is to decide how the electricity shall be generated, or if, in case a power company is reasonably near the proposed site, to ascertain whether the power can be bought cheaper than it can be generated on a small scale. Water power to drive the generators for a single plant is seldom available. When it is available, it should, under normal circumstances produce power at a lower rate than power produced in any other way. The other alternative to hydro-electric power is to generate the power by means of a steam plant. Taking the number of structural shops that are operated by means of their own steam plants as evidence that this method is cheaper than to purchase the power from a power company which must resort to steam, the private steam plant ranks next to the cheapest method of obtaining motive power. Furthermore, and this is probably the chief cause of the popularity of the private steam plant, it is independent of the location of the shop. Therefore, unless purchased power is very cheap, the private steam plant is probably the most satisfactory method of obtaining motive power.

From the above it is evident that the power problem seldom has any weight in the question of location.

Art. 3. Labor.

In the operation of a structural shop, all classes of la-
bor from the illiterate foreigner to the skilled mechanic and from the mechanical machine hand to the technical graduate are used. While it is generally conceded that labor will go where work is to be found, yet a manufacturer cannot entirely neglect to consider either the distance that his employees must travel to and from their work or the question of the transportation service that they require. Labor does not inconvenience itself without looking for remuneration, and it is only by out-bidding the more favorably located employer that the more unfavorably located one can secure his labor.

The higher classes of laborers are willing to travel farthest to and from work since they have the shortest working day, but they insist on comfortable and quick transportation service. Therefore a site near a settlement of laboring people, and not too far from a better section of the town or city is the most favorable with regard to labor.
III. PLAN.

Art. 4. Governing Factors.

A definite plan for this plant will now be considered. After arbitrarily choosing the capacity desired and the class of work to be done plans may be made accordingly. For shops of different capacities and different classes of work, the plans would then, in accordance with what has been said above, necessarily be somewhat changed. To assist in the accomplishing of the purpose of this thesis, it is decided to plan a shop of about fifteen-hundred tons monthly output. The work shall consist of mill and office building work. It is also assumed that a satisfactory site has been obtained and that all the ground necessary is available.

In any plant where the product passes through a series of operations closely related, it is an advantage to so arrange buildings, tracks, cranes, and machinery that these operations will follow in close sequence with a minimum amount of handling of the materials. The machinery should also be so arranged that the work may always proceed in one direction. When these objects are gained the economy of both time and machinery is maximum.

A general plan of the plant should now be prepared, showing the relative positions of the different buildings, the receiving yard, and the shipping yard. On this plan assumed positions of the machinery may be indicated and a trial made of the system. The best trial is made by following different items of product through the series of operations necessary for their manufacture. In mill and office building work the chief items are columns, roof-trusses,
channel purlins, floor-beams, and girders. An arrangement which is found to be suitable for one of these items may not be so for another, and it may be necessary to try several arrangements before one is hit upon which will serve the largest number of items best. In the plan, Plate I, this method has been used, and the route of the different items or their component parts, through the plant has been traced in the manner indicated above.
PLATE I

GENERAL PLAN of PLANT.

FORGES 7 SHAPER 13 BULL DOZER 19 REAMERS
2 AIR HAMMER 8 AIR COMPRESSOR 14 PUNCHES 20 PLATE PLANER
3 LATHE 9 GENERATOR 15 NOTCHER 21 MULTIPLE PUNCH
4 DRILLS 10 ENGINE 16 SAW 22 STATIONARY RIVETER
5 NUTTWIPPER 11 BOILERS 17 ANGLE SHEAR 23 FURNACES
6 DOWEL CUTTER 12 MILLING MACHINE 18 PLATE SHEAR 24 EMMERY WHEELS
IV. DEPARTMENTS.

Each department is, in the following articles, taken up in detail, giving a plan of the same, showing its relation to the other departments, describing the work to be done and the method of doing it, and giving in a few words the desirable qualifications of the employees.

Art. 5. The Office.

The office is not always considered as one department. It can be divided into two parts, a general office which may or may not be located at the plant, and another office which serves the men directly connected with the operation of the plant. In this thesis, however, it shall for the sake of completeness be considered that both parts are located at the plant and occupy one building.

The building should preferably be located at the receiving end of the plant and at some distance from the shop, since at this end there is less dirt and smoke, and less noise than at the shipping end. This location is also favorable for the reason that the template shop is naturally located at the receiving end, and the drafting room should be as close as possible to the template shop. There is always considerable consultation between the template shop foreman and the chief draftsman, even when the drawings are carefully prepared and checked. Therefore if the two men can get together easily their departments can be operated more harmoniously and to better advantage than if they are separated by the length of the plant.

A good arrangement is to make the office a two story building, with the general offices on the main floor and the drafting
and blue-printing room on the second floor. The building should be of good construction, well heated and well lighted. The drafting room should be furnished with sky-lights if necessary to secure ample light.

The general offices should consist of rooms for the president, chief engineer, business manager, superintendent, inspector, book-keeper, time-keeper, shipping clerk and stenographers. On the second floor the space may be divided into a blue-print room and a drafting room. When the building is planned the purpose of the rooms should be kept in mind and conveniences installed for the employees who will use them; and above all the rooms should be assigned with reference to placing those men who have most business in common, in adjacent rooms. This has been attempted in the plans given herein. See Plate II.

The duties of the office employees except where they are self evident will now be described. The business manager should keep in touch with the steel market and the rolling mills so as to buy stock advantageously. He should also, upon the order of the superintendent, buy tools, materials for repairs, supplies of all kinds, paints and oils, template lumber, etc. He should preferably but not necessarily, be the treasurer of the company.

The theory embodied in the last statement might well be extended to read that all employees holding executive positions should be financially interested in the company. Even if they should hold only a small amount of stock, this would serve to make them feel that they are working for themselves, and give them a greater interest in the welfare of the organization.

The shop inspector's position may sometimes be hard to de-
termine, especially as nearly all work is inspected by a man in the employ of the party for whom the work is being done. The shop inspector should be a man who commands the respect of every man in the plant, the superintendent not excepted. When the work does not receive any further inspection, he is in a position to save large sums of money for the company by conscientiously performing his duties, and when the work is to be inspected later, he can save time and money by seeing that it goes to the other inspector as nearly perfect as possible. His position calls for a great deal of tact and diplomacy for he must nearly always enforce his wishes against the opposition of department foremen, and sometimes against that of the superintendent. The inspector's office should contain a desk and other conveniences for the visiting inspector.

The duties of the other occupants of the general offices are the same in the office of a structural steel plant as in the office of any other manufacturing concern.

On the second floor the chief draftsman is in charge of the draftsmen, checkers, tracers, and boys who figure weights and make blue-prints. The chief draftsman must have a good knowledge of the methods pursued in the shop, and of the capacities of the different machines in order that he might intelligently direct the making of the detail drawings.

The making of the detail drawings constitutes the chief part of the drafting room work. Shop drawings, as they are often called, are detailed from the design furnished by the chief engineer or some other engineer. The details are generally first drawn on heavy paper and then traced on tracing cloth. Sometimes a skilled draftsman can save time by making the drawing in pencil directly on the
tracing cloth or on thin bond paper and then inking it in. The tracing is then turned over to the checker. It is the checker's business to make sure that the engineer's design and the specifications have been followed, and that the parts as detailed will match the parts to which they are to connect. He must also watch for details which might cause difficulties in the shop or in the field. When the tracing has been checked it is sent to the blue-print room where a boy makes prints of it. The sunlight or an electrically lighted machine may be used in this operation. The former is of course the cheaper method, having only the disadvantage that prints can only be made during bright though not necessarily clear days. Figuring weights is also generally part of the drafting room work. The detailed drawings are used in this work, the shipping weights of each piece being determined by adding the weights of its composite parts. The results are used as a check upon the scale weights which are generally determined by the foreman of the shipping yard or by the shipping clerk.

The drafting room as designed, Plate II, will easily accommodate seventeen or eighteen tables, and these will probably be enough for the tonnage and the class of work previously decided upon.

Art. 6. The Template Shop.

The natural location for the template shop, is, as has been mentioned before, between the office and the steel-shop. It should be as close as possible to the steel-shop, so as to prevent the carrying of the templates any great distance. It should, however, not be directly connected as the dirt and noise from the steel
shops is very disagreeable and disturbing to the template-makers. A distance of only a few feet between the buildings will aid greatly toward making the template-shop pleasant.

The plan of the building, see Plate III, shows that it is comprised almost entirely of one large working room. In addition a lumber storage, a template storage and a toilet-room are provided. The working room should be long enough to allow chord and girder templates to be laid out full length for checking purposes. It must be wide enough, so that besides furnishing room for the benches and machinery, floor-space will be available for checking trusses by pinning the templates together on the floor. To leave as large a floor-space as possible open for this purpose, the benches are arranged along the walls of the room and the machinery placed well toward one end. The benches are placed so that the workmen will face the windows when laying out work. Each bench should be furnished with a drawer for blue-prints, and a screw-vise or clamp for holding small pieces on which the template maker may wish to work. It is also a good plan to furnish the workman with a low bench or at least some low "horses" on which he may pile the long strips that he is to use as also the finished templates. A shelf under the bench will serve the same purpose for detail templates. The idea is to keep both the dressed lumber and the finished templates off the floor if possible. On the floor they get gritty and dirty, and are too apt to be broken.

The machinery necessary in the template-shop will vary slightly with the material used for templates. For long strips and large frames, wood is used, but the detail templates may be made of either wood or heavy paper. If paper is used a large paper-cutter
FLOOR PLAN OF TEMPLATE SHOP

OLD TEMPLATE STORAGE

TOILET

LUMBER STORAGE

DETAILED TEMPLATE BINS

BLUEPRINT CABINET

TEMPLATE RACK

BAND SAW

JOINTER

BAND SAWING MACHINE

BENCH

BENCH

Bench

Bench

Bench

Bench

Bench

Bench

Bench

Bench

Bench

Bench

Bench

Bench
is necessary. In either case a circular saw, a jointer, a trimmer, and a boring machine is needed. The saw, jointer and boring machine should be driven by individual motors, but the paper-cutter and the trimmer can be operated better by hand.

Formerly lumber from one half to one inch thick was used in making all templates, but the increasing price of good lumber has caused the substitution, in many shops, of a heavy paper about one eighth inch thick for making detail templates. Under the old method, lumber wide enough for large plates was very difficult to get and much time was lost in gluing boards together for this purpose. The paper now used can be procured in sheets large enough for most connection plates. When unusually large templates are to be made a wood frame makes a better template. Thus it is seen that only narrow strips are needed in the work, and these can easily be made from six and eight inch boards. The best thickness is one inch lumber dressed on both sides which in reality makes it about seven eighths inch thick. This thickness is recommended because it is stiff enough to stand the handling it will receive, and also because the holes will not wear out as fast as they will in thinner lumber. Still another reason for using this thickness is that when the templates have been used the holes can be plugged by gluing a wooden plug into each, and the whole template planed until it is a clean piece of lumber which can be re-used. Some template makers prefer this old lumber to new lumber, because it is nearly always seasoned to about the proper dryness. New kiln dried lumber is often too dry, so that when the template is used in the steel-shop for a day or two it swells until no longer of the proper dimensions. This lengthening may amount to an eighth inch in fifteen feet parallel
with the grain, and the same amount in one foot perpendicular to the grain. On the other hand if the lumber used is very wet, the opposite may be true, especially if the finished template should lie in the warm and dry template shop for several days before being used. The template shop foreman has here an opportunity to use his judgment in the using of the lumber, storing of the same, and the storing of the finished templates. For important strips, such as chord templates and milling templates it is a good rule to re-check them just before they are to be used.

When lumber is stored it should be piled with blocks or strips between the boards, so that they will be exposed to the air. The storage room may be located outside of the template shop proper, but a door connecting the two will be found very convenient. The storage room should be dry and airy, but should not be heated. A practical arrangement for storing finished templates, is to make stalls for the detail template, each stall marked with the proper contract number; and to make a frame divided into several compartments to accommodate the long templates. This system keeps the different contracts separated and reduces the labor of finding any desired piece. To some extent the same system may be followed in storing the old templates. They should be kept for some time after the contract has been shipped and preferably until it is erected, for some piece may be lost or broken and if the template is intact it will not take so long or cost so much to make a new piece. Again, the marker may make a mistake or a miscount may be made so that the template may be needed very soon after it has been returned from the shop.

The force in the template shop for this plant would con-
sist of about seven template makers, one man to dress lumber and bore holes, a boy to do odd jobs, and the foreman. The foreman in a plant of this capacity would work as a checker, when necessary calling on one or two of the template makers to assist him in this work. It is his duty to care for all the blue-prints as they come from the office; to see that the work is taken up in such a way that the templates will be made first for those members that are to be erected first, and that the rest of each contract will follow in proper sequence. He is wholly responsible for the manner in which the work of the department is carried on, and must therefore have authority to hire and to discharge the men under him at will. He must be well versed in the manner of carrying on the work in the laying-out department, and should work hand in hand with the foreman of that department. He should, with the latter, always be on the look-out to improve the system of template symbols so as to make the marking of the steel as simple as possible and reduce the danger of errors. The template makers should also have a good understanding of the use of the template in the laying-out shops, as otherwise it is almost impossible for them to make the template properly. The best template makers are men who have advanced from the position of markers. The template maker generally only lays out the template putting all necessary instructions and symbols upon it, and indicating where the holes are to be bored. Then the man who dresses the lumber in the first place bores the holes and makes the cuts that are required to finish the template. This man only receives one half the wages that the template maker does, and can do this work equally well. A boy or another cheap man can well be employed to do odd jobs, such as oiling the machinery, sweeping the floor each
night, plugging old templates, and taking care of the templates when they are returned. He can also often assist the other man by boring holes or dressing lumber.

Art. 7. The Steel Yard.

The steel-yard or receiving-yard, as it is also called, is what the name implies — a place where the steel is stored until it is wanted in the shop. The room required for the steel depends upon whether the company desires to keep a stock on hand, or intends to order the material as it is needed. The rolling-mills can furnish any of the standard shapes on very short notice, but often even a short delay means the loss of a contract, or loss of time in getting started on a piece of work already contracted for. It is therefore an advantage to keep on hand a stock of standard shapes which can be used when immediate shipment is required. On the other hand it is a disadvantage to have money invested in stock which may not be used for a long time. How much and what kind of stock to carry are therefore very important questions on which the business manager and the chief-engineer must use their judgment in deciding. For the plant in question it would very likely be of great advantage to carry a large stock of standard angles such as could be used for columns and roof-trusses, and also light plates and lacing bars for details.

But whether a large or small stock is to be carried, the steel-yard should be covered with a roof so that the rain and snow will be kept off the stock; for with but short exposure to the weather it becomes covered with rust. Rust not only eats into the steel and injures it, but increases the labor necessary to use it. The
men throughout the plant dislike to use rusty material, and when the painting is to be done much labor is required to brush it and scrape it before the paint can be applied.

An area of 16,000 square feet as shown in Plate I would be large enough for storage of the stock for this plant, and would allow the steel to be stacked in convenient piles. A 20-ton crane of about 75 feet span, traveling the entire length of the yard would be able to do all of the unloading and shifting of stock.

To make the yard as dry as possible cinders or gravel should be spread on the ground. Large timbers with light steel rails spiked to them give good service as skids. They should be well bedded and should never be moved except when absolutely necessary. The narrow gauge tracks, for the trucks on which the steel is brought into the shop, should be laid on a slight grade sloping toward the shop. It will, with this arrangement, be possible to get the trucks into the shop with fewer men than would be required if the tracks were level.

When the stock is unloaded it should be placed so that it can be brought into the shop with the least amount of handling. Beams and channels should be piled near the truck-track leading to the machines that are used in finishing those shapes, and plates and angles should be segregated in the same way.

About eight laborers, a foreman and a crane man would, under the conditions described, be able to handle all of the steel. The laborers could be divided into two gangs of four men each, one gang doing the unloading and the other trucking the steel into the shop. Of the four men doing the unloading, two would be needed to handle the heavy chains, and one at each end of the car to guide the load.
The four men doing the trucking would be placed in a similar manner, but would unite in pushing the trucks into the shop and in unloading them there. The foreman should be subordinate to the foreman of the marking, punching and shearing department as it is the latter who directs the placing of the material in the shop, gives orders as to what material should be brought in, and when. The craneman needs to be experienced in operating the crane, and should at all times be sober, cautious and quick of action.

Art. 8. The Marking, Punching and Shearing Shop.

As will be noticed by a study of Plate I four departments, the marking, punching and shearing shop, the assembly shop, the riveting shop, and the finishing shop, are all housed under one roof. The several operations through which the steel passes are, however, so logically divided into groups which fall under these heads, and the operation of the plant is so facilitated by the division of this main portion of the plant into the four departments, that it is well to follow this plan.

When the steel is brought into the shop the first operation consists of marking it for punching and shearing. In this operation the templates are clamped to the steel by means of a screw clamp or some other simple device, and then a punch which just fits the hole in the template is inserted and struck with a hammer. This leaves small indentations in the steel which show the machine men where holes are wanted. On long pieces or large plates several markers may work at the same time, each one striking his punch a fraction of a second after one of the others, so that at no time two strike simultaneously. If they should, the vibration of the steel would prob-
ably cause the punch to jump and miss the center of the hole. When the holes and cuts have been located the steel is passed to the shears and from there to the punches. For small plates and angles, these operations are generally partially reversed. Details are first sheared, that they may be more easily handled, then marked and lastly punched. Beams and channels are more often ordered to the correct length, than are angles and plates. This is because beams more than eight inches deep and channels more than ten inches deep must in this shop be sawed instead of being sheared as the smaller sizes are. Sawing is a slow and expensive operation, and none of it should be done except in special cases. Angles and plates are easily sheared and can be ordered in stock lengths unless they are of special section, or a large number of pieces of the same length and section is wanted. Material is more easily ordered and is a little cheaper in stock lengths than when ordered to length. This advantage may, however, be overbalanced by the cost of shearing and the difficulty met with in attempting to use short ends unless the material is of a section commonly used for details.

Short skids, similar to those in the steel yard should be ranged along the truck-tracks for convenience in unloading the material and in picking it up again. Heavy benches or horses must be built on which to lay the metal while it is being marked.

The machinery in this department consists of a rotary saw, a notching machine, a bulldozer, an angle shear, a plate shear, four punches, a drill press, and a multiple-punch. The saw, the notcher and one punch are ranged along one wall, and are intended to take care of the beam and channel work. The bulldozer is also placed in this line although it will be used for bending or straightening all
shapes. On one side of the center of the shop the angle shear and two punches take care of the angle work; and on the other side of the center the plate shear and one punch will handle the plates excepting those that are punched on the multiple-punch. A drill press in this group will be found very convenient for countersinking, and for drilling holes that can not be punched. The multiple punch is placed along the other wall, and occupies a long narrow floor space, as a rack projects in both directions long enough to support the plates that may be punched upon it. Air hoists suspended from the bottom chords of the roof trusses, run at right angles to the tracks; and are used in unloading the trucks and in bringing the material to the machines. At the punches, overhead runways are needed, running parallel to the tracks. Chain hoists supported from these runways are used to hold the steel in position for punching.

About five markers would be required, each one assisted by a helper. One would mark the beams and channels, one would take care of the long angles and another of the detail angles, one would mark the large plates and another the small plates. These men can be shifted so as to help each other when the different kinds of work progress unequally. Ten machine men will be needed, and each should have a helper. The saw and the bulldozer would probably not be busy all of the time, so one man might be able to take care of both machines, but the other machines should each be assigned an operator and a helper. The foreman of this department has probably more to do and more things to watch than any of the other foremen. It depends largely upon him whether the work is to run smoothly through the plant or not. He must watch the stock as it is unloaded and di-
rect its placing with forethought as to when it shall be used, he must see that the proper templates are used on the steel for which they are intended, and he must so time the beginning of the work on the component parts of any item, that they will all be available when the men in the next department begin the work of assembling them.

Art. 9. The Assembly Shop.

When all the component parts of a shipping piece or item have been sheared, punched and shaped they are brought to the assembly shops where they are fitted together. Fitting-up or assembling consists of temporarily bolting the pieces together with only enough bolts to hold them rigidly in place until they can be riveted. The bolts used should preferably have square or hexagonal heads as round head bolts are hard to work with, especially after having been used once or twice. These bolts are taken out when the piece is riveted and can therefore be returned and used again; but such usage soon batters the threads and it is for this reason that the round head bolts are not serviceable — they can not be held with a wrench while the nut is forced on. Before any adjacent pieces are bolted together the surfaces in contact must be painted to exclude if possible any moisture that might otherwise get between them. All surfaces that are difficult or impossible to reach after assembly should be given two coats of paint before being bolted together.

Sometimes it is specified that all holes must be reamed. This work then falls to the lot of this department. The holes as punched are then about one sixteenth inch less in diameter than the rivets to be used. In such cases the fitter assembles the piece
with small bolts and then proceeds to ream through the parts that are bolted together, increasing the size of the hole to its proper diameter, and replacing the small bolts with some of the same diameter as the rivets. Drift pins, tapered steel pins about six inches long pointed at one end and about one-quarter inch larger in diameter than the rivet hole at the other, are used to bring the holes in the several pieces exactly opposite each other.

Nearly all of the floor space between the tracks in this part of the shop is occupied by skids about two feet high. The part not so occupied is arranged for piling the material for which the fitters are not yet ready. There should be room enough reserved for this purpose, so that the punches can keep a considerable amount of work ahead of the fitters, and yet not be compelled to pile material belonging to different contracts in the same pile. Timbers should be placed on the ground, four or five feet apart, to act as skids for piles of long material. For the storage of details a plank floor is advisable, as the small plates and angles are very easily lost if placed on the ground where dust may cover them. Air-hoists suspended from the roof-trusses in the same manner as described in Art. 8 will provide for the handling of the steel before and after assembly.

The only machinery that is required in this department are reamers and emery-wheels. The purpose of the former has already been described. They should be located between the assembly department and the riveting department so that the steel can be moved continually in one direction. Several emery-wheels will be found useful for fitting stiffeners, removing burrs, etc.

The foreman of this department should have a working force
of four gangs of about four men each. One man in each gang should be able to read the shop drawings correctly, and should act as boss of his gang. The other men can be of the cheapest laborers obtainable. One of these gangs could probably take care of all the beam and channel work, on which there generally is not much fitting to be done. The other three would then take care of the girders, roof-trusses, columns and struts. A good plan to follow, if the class of work in the shop at the time makes it possible, is to give one gang the girder work, another the column work, etc. By following this system as closely as possible, the men become accustomed to their respective duties and consequently become more efficient. The foreman should always make sure that all the material necessary for a certain item is punched and ready for him, before he gives orders for assembling that piece. It is also his duty to endeavor to furnish the riveting department with the particular style of work that it required to keep certain machines in operation. In short, he should always keep in touch with both the foreman of the punching shop, and the foreman of the riveting shop, it being his duty to make his department an effective link between the two other departments.

Art. 10. The Riveting Shop.

The last operation through which most of the steel passes is the riveting. Some pieces must be milled after being riveted, but the larger part of the output is completed, except for painting when it has passed through this department. The rivets are heated to a light red in oil furnaces and then driven by means of compressed air. The pressure of the air is so great that it not only forms a head on the rivet but also compresses the different pieces so that
they are drawn tightly together. Considerable skill is required in driving rivets through several thicknesses, for if an opening is left between the pieces the rivet will flow and will be of no value. The holes that are left open by the fitters are first filled with rivets, and then the temporary bolts are removed and rivets driven in their place. Pieces which when finished must be of an exact dimension should be blocked or clamped rigidly so that the parts can not shift during the riveting. The bolts put in by the fitter can not be relied upon in such cases.

The skids should be of the same height as those in the assembly department as at times the work may consist of long pieces extending from one part of the shop into the other. The hoists will be the same as throughout the other shop. In addition to these, the roof-trusses must support runways for the cars from which the riveting machines are hung. These runways are movable along the chords of the trusses, thus allowing the machines to be moved in both directions, lengthwise and crosswise of the shop.

The machinery consists of five riveters, one stationary and four suspended. The stationary riveter is particularly adaptable to small work which can be held by hand or supported by means of a wall jib crane. In using this machine, therefore, the work is brought to the machine. In using the suspended riveters the machine is brought to the work, that is, the machine is moved along the piece in driving the rivets. Five oil-furnaces will be required to heat rivets, one for each machine.

The working force of this department would consist of five riveting gangs of four men each. The man that runs the machine is the boss, and has two helpers and a rivet heater. One of the help-
ers guides the machine and holds it on the rivet to be driven, the other sticks the rivets in the holes and removes all the bolts and drift pins left in the piece by the fitters. The foreman should be quick to see and to adopt any method of performing the work which might save time and labor. Every different item that is to be riveted can be attacked in several ways, so the foreman has many opportunities to exercise his ingenuity.

Art. 11. The Finishing Shop.

In the finishing department the final touches are given to the steel, preparing it for shipment. The milling, chipping, hand-riveting, painting, and inspecting is done in this part of the shop. The milling is confined almost entirely to squaring the ends of columns and finishing them to the proper length. Girders and beams sometimes require milling, but not as a rule. Rough edges and burrs should either be chipped or filed off, the refinement with which this is done depending upon the position of the piece in the finished structure. Countersunk rivets should be chipped flush with the surface where such surface is to be in bearing. Details not conveniently riveted by machines, and rivets that are impossible to reach with the machines are often omitted until the piece reaches the finishing department. Here they are driven by means of pneumatic hammers or by hand. The inspecting and painting of the steel may well be done in the shipping yard during favorable weather, but it is a good plan to have space reserved in the finishing shop for these purposes during cold and wet weather.

Skids about two feet high should cover all of the floor space between the tracks except that portion occupied by the mill-
ing machines. The air-hoist arrangement is the same as for the rest of the shop. It may at times, particularly in bad weather, be desirable to do some of the loading for shipment under roof. For this reason hoists of greater capacity than those used in the rest of the shop might be used here to good advantage.

The only machine in this department is the milling machine. A dubbel-headed machine would be best for this shop as it could be set to cut both ends of a column at the same time, and would do so in the same length of time that a single-header would cut one end. Several pneumatic hammers should be provided for the riveters, also a good assortment of bucking-up bars of different shapes. For heating the rivets, hand forges are best as they can be moved from point to point, and will heat rivets fast enough for hand riveting. A pneumatic cold chisel and an electric reamer would be very valuable tools.

Two, three-men gangs would probably be kept busy riveting. The man that runs the hammer picks up the rivet and holds it in place until his helper gets the bucking-up bar on it. The other man heats the rivets. About two men furnished with cold chisels, hammers and files could take care of the chipping. One man would be sufficient at the milling machine, as he could call on one of the laborers to assist him when setting a piece. About seven or eight men could well be employed in painting and moving the steel. No foreman would be required as the foreman of the riveting shop could supervise the riveting, chipping and milling, and the foreman of the shipping yard could direct the painting and the loading that might be done inside the shop.
Art. 12. The Shipping Yard.

Having arranged to do the painting inside the shop during unfavorable weather, the shipping yard becomes a place where this may be done in good weather, but primarily it is a storage yard where material may be stacked until it is to be shipped. If no room for painting had been provided inside the shop, the yard could profitably be roofed, but for the arrangement made at this shop the yard will be open. A crane runway similar to the one in the receiving yard should be erected so as to serve the storage yard, and to be used in loading material. The runway need not be as long as the one at the other end of the shop, as material is seldom finished a great length of time before it is to be shipped, at least not in large quantities.

The skids should be like those in the receiving yard. About four men in addition to the seven or eight painters referred to in Art. 11 would be enough to do all of the loading and painting. One of the men should be able to act as assistant to the foreman in handling the men that are loading. Both need to exercise much judgment and skill in placing the material on the cars, to insure safe transit and to comply with shipping regulations. The foreman should be familiar with shop drawings, and be quick to notify the superintendent when any piece that is listed for a certain shipment is missing. Often the shortage of one member or the delay of one day in shipment means a large loss in the field, where men are kept waiting. It is therefore very important that the shipping yard foreman be alert and conscientious in the performance of his duties.

The forge and machine shops are best located in a separate building near the main shop. Neither shop need be very large, but should be comfortable and well lighted. The forge shop should have only an earth floor, but the machine shop should have a plank floor. In the forge shop, two forges would be sufficient. A small compressed-air hammer could be used to good advantage. The larger part of the work would consist of tool tempering and repairing, but sometimes structural steel which can not be bent in the bulldozer must be brought to the blacksmiths. Sway and tie rods would always be upset in the forge shop. Two smiths, each having a helper, could take care of all of the forging. One of the smiths should be foreman and be responsible to the master-mechanic.

The machinery in the machine shop would consist of two lathes, a drill-press, a shaper, a bolt-cutter, and a nut-tapper. The latter two would be used to thread rods and special bolts and tap the nuts for them. The standard bolts used in the shop and in the field can probably be bought cheaper than they can be made in the shop. The other machines would be used for the greater part in repair work, but pins and cotters used in structural work are turned in the lathes. Two machinists and two apprentices would well take care of the work that would go to the machine shop. The master-mechanic should be foreman of both the forge and the machine shop. He should also be well versed in electrical work, so that he might supervise the installation and repairs of motors and their connections. He should have complete supervision of all machinery, hoists and cranes, and be responsible to the superintendent of the plant.

The power plant is best located in a separate building at some distance from the main shop. It should be divided into two rooms, a boiler-room and an engine-room. The dividing wall should be so constructed as to keep the heat and coal-dust of the boiler-room from getting into the engine-room. The boiler-room floor should be a few feet below the grade of the railroad tracks on which the coal is brought to the shop, for by this arrangement the coal can be unloaded by gravity. A battery of two horizontal water-tube boilers of 500 horse-power each, furnished with hand fired furnaces would supply the steam necessary to operate the engine and air-compressor. The exhaust steam should be piped to all parts of the shop for heating purposes. In the engine-room a 900 horse power, cross-compound, non condensing engine would furnish motive power to a 600-kilowatt generator. Besides these units, a cross compound, two stage, direct connected air compressor with a capacity of about 600 cubic feet of free air per minute would be required. To drive 7/8-inch rivets effectually, an air pressure of about 95 pounds would necessarily be carried. The same pressure is required for a 6-inch hoist to lift 1 ton, an 8-inch hoist to lift 2 tons, and a 10-inch hoist to lift 3 tons. For the greater weights handled in the fitting and riveting departments, a few 16 or 18-inch hoists would, therefore, need to be installed. Air pressure is also applied to the oil which is used in the rivet heating furnaces. One engineer and two firemen could easily take care of a plant of this size.
V. GENERAL ORGANIZATION.

Art. 15. Officers.

The organization in a structural shop should always be well defined. In the plan for this shop particular effort has been made to divide the shop into departments which can conveniently be handled by one man. The superintendent naturally has charge of the entire shop, and should possess engineering as well as managerial ability. As was mentioned in the beginning of this thesis, he should preferably be a member of the company. His duties are those of a general overseer, for he must leave details to the foremen of the different departments. He should sign all orders for repairing materials, for supplies of all kinds, and in fact, for everything required in the operation of the shop except the steel, which is ordered by the chief engineer. One of the superintendent's most difficult tasks is to secure department foremen that will work harmoniously together. Tact and diplomacy in no small degree are required for this purpose. Next to the superintendent in authority is the inspector. His duties were described in Art. 5 and will not be touched upon here. The department foremen should have complete charge of their respective departments, and should endeavor to so regulate the work in their own departments that the workmen in the next may not be delayed. Above all things the foremen should understand every detail of the work that is to be done in their departments, and should preferably have had personal experience in that work. They should be empowered to hire or discharge laborers as they see fit. They should give a report to the superintendent, ev-
every day, stating the progress made on each contract that is in the shop, and should consult with him as to the work that should be taken up the following day.

Art. 16. Laborers.

Under the department foremen the laborers are divided into convenient groups of two, three, or four men as the case may require. In each group one particular man should be responsible for the amount and quality of work that is done. In the laying-out department the markers would have charge of such groups; in a machine gang the man who runs the machine would have charge; and in the assembling department, where the groups may contain as many as six men, the men in charge would necessarily have to be able to read the shop drawings.
VI. WORKING FORCES.

Art. 17. Shifts.

Throughout this thesis no mention has been made of the working hours or shifts of labor. The number of men noted as required in each department is that number which could conveniently and economically work there at one time. Economy in both machinery and space require, however, that the machinery be in operation almost continually and that the space be occupied at nearly all times. To do this a night shift should be organized much the same as the day shift. It would, however, not be so complete, for some departments are difficult of operation except by daylight.

Art. 18. Day Shift.

The force which has been described and discussed to this time is the day shift. In the day time a full complement of men is employed in all departments. Extra men may be needed in the marking and assembling departments if a night shift is in force. An eight hour day is customary, and has proven satisfactory for the office force. In the other departments there is a question as to whether a nine or a ten hour day is best. With a nine hour day, five hours in the morning when the men are fresh, and four hours in the afternoon, nearly as much work can be turned out as during a ten hour day. The men are also generally appreciative of the longer evening that this system gives them.


As mentioned above, some departments can not advantageously
be operated at night. Template making, marking and painting are best done by daylight, and as not much machinery is used in these operations, the economics of machinery does not enter into the problem. The punches, shears, and riveters should always be kept busy so that the greatest returns upon their cost may be realized. Assembling should only be done as it is necessary to keep the riveters in operation. The working hours of the night shift can well be longer than those of the day shift. Five nights of twelve hours each would thus give the night men a little more wages per week than the day men, assuming the rate per hour the same. No laws can, however, be laid down as to the hours and number of men of each shift, as the operation of each shop would in some degree differ from that of any other, and the superintendent must solve these problems for each case.