GENERAL MANUFACTURING ANALYSIS OF

A BOILER WORKS

For

Professor F. E. Raymond
Professor K. D. Fernstrom

Department of Business and Engineering Administration

By

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Massachusetts Institute of Technology
Cambridge, Massachusetts

May 13, 1936

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Cambridge, Mass.
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Professor George W. Swett
Secretary of Faculty
Massachusetts Institute of Technology
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INTRODUCTION

GENERAL MANUFACTURING ANALYSIS OF A BOILER WORKS

INTRODUCTION

Because this plant has never been covered in thesis work before, it makes an especially interesting research problem. In tackling the numerous problems in connection with this work, a single purpose or ultimate goal was kept in sight always. It often happens that a compromise between a theoretically perfect system and present methods must be effected. This proved to be so in this case and the deciding factors were always; first, what will these changes cost, and second, can the cost of these changes be written off through the savings they effect in a reasonable length of time?

The study logically divided itself into five divisions which were approached individually, and then with respect to each other. They are as follows:

(1) What revision of the present plant layout can be made so that simple and effective control may be had upon storage and work in process?

(2) What type of production control system can be devised to super-impose upon the revised layout such that the greatest efficiency in production may be effected?

(3) Can stores of materials and accessories be more conveniently placed so that they may be routed into production easily and with a minimum of labor?

(4) Are there any changes in the present labor relations that can be made either in the field of supervision or in the direction of a finer wage payment system?

(5) What is the best treatment for the waste materials so as to obtain the least scrap originally when cut and its most efficient disposal?

(6) Is it possible to even out production by manufacturing standard products after the seasonal peak is passed, thereby increasing the annual capacity for business, and reducing unit overhead charges.

The answer to these questions must always keep in mind the fundamental desire to approximate the best ratio among the factors of management, labor, and capital in the plant as contributing to the lowest unit cost of manufacture, remembering that any suggestions we made must be at once inexpensive and practical in their application.

Since about 70% of the business of the A. F. Robinson Company is composed of tank manufacture of some kind, the larger part of the analysis has been confined to attempting to improve these productive conditions.

At the outset of this study, various factors in the form of labor problems, reduction of waste in cutting operations, storage, diversification of manufacture to offset the seasonal slump, etc. seemed to have a definite place in the horizon. However, as the analysis progressed it was seen that the larger percentage of these factors were reduced to much lesser significance. Above all, plant layout methods seemed most important and proved to be so because of the high premium on

manufacturing space. All detailed study of financial and labor problems has been omitted at the request of the management.

Any complete manufacturing analysis must necessarily start with a study of present productive methods used by the concern in question. For this purpose, all operations both direct and functional must be broken down into their elements, analyzed, improved upon if possible, and then re-assembled into a coordinated whole. The present processes may be made more tangible by some visible means and for this purpose a present layout drawing is necessary. This furnishes a basis upon which to study the inter-relations of productive factors as applied to the individual job. After a study of existing methods we attempt to establish an unbiased 100% perfect set of methods. This takes the form of tentative proposed layout drawings. Next, a practical application of theoretical 100% perfect methods shows that certain changes are necessary to conform to these practicalities. The changes are made and there evolves a set of new principles which most perfectly fit the existing situation. Of course, any degree of bias entering into the analysis will deduct a certain percentage of effectiveness from the argument. Super-imposed upon this new set of proposed changes, we must set up a system of production control for effective operation of the new scheme.

Comparative costs form a very elusive part of the analysis. The only savings which have been made are on intangible items such as time, overhead, burden, etc.

CONCLUSIONS

As the outcome of about three months investigation at the Robinson Boiler Works, the following conclusions have been reached as regards the production methods employed by that concern:

(1) That although the products made by this company are of widely varying sizes and shapes, the sequence of processing and the number of processes for any particular tank are very similar.

(2) That since approximately 70% of the company's business annually is done upon tanks, it is about tank manufacture that any plan must be molded and fitted, with plans for special or repair work made subsequent to the major manufacturing interest of the company.

(3) That much of the present confusion and lack of efficiency in the plant today arises from helter-skelter storage of materials and allowing miscellaneous piles of scrap and old machinery to accumulate.

(4) That a coordinated and systematic flow of work in process will bring about an increase in potential production and permit easier and more effective control.

(5) That efficiency and coordination of labor could not be enhanced by altering the present wage payment system except by excessively increasing labor costs. The present slackness is therefore a result of poor supervision of the men and control over the work rather than the fact that there is no incentive system of paying the men.

(6) That the present company office is entirely inadequate for the normal yearly volume of business enjoyed by the company.

(7) That more economical cutting and layout of material cannot be effected, the savings being more likely to be found in prompt and efficient disposal of waste as it is created.

(8) That provision of a suitable control and flow plan for the company will enable the company to undertake more business during the peak season.

(9) That evening out of seasonal peaks in production has already been accomplished to its greatest degree by the manufacture at this time of standard septic and oil burner tanks.

RECOMMENDATIONS

(1) The company business should be divided into the three classes of work: tank manufacture, special jobs, and repair work.

(2) Tank manufacture should be changed to line production as in the proposed layout, and a definite sequence of operations should be established. (see Appendix B)

(3) Inventory of the stored and scrap material and unused machinery should be made with an eye to cleaning up the plant before attempting to establish any system.

(4) A third foreman should be maintained making a foreman in charge of each department.

(5) A new office should be created as shown in the layout chart at a total cost of approximately $800.00.

(6) A new monorail conveyor should be installed at a cost of approximately $100.00.

(7) An improvised wooden shed should be erected upon the existing framework in the factory yard for storage of special plate as shown in the plant layout chart, this to be constructed at a cost of not more than $25.00.

(8) Storage should be decentralized into the three departments and supervised by each department foreman.

(9) The manufacture or purchase of an additional tank roller and a floor type roller conveyor. The tank roller will be motor powered and the conveyor will be hand powered. This is conditioned upon the adoption of the proposed layout. Cost of these machines should not exceed $75.00.

(10) Machines as follows should be moved to conform with the requirements of the proposed layout: (see proposed plant layout, Appendix B)

a) Small circular cutter
b) Small plate cutter
c) Tank roller
d) End bender for beading purposes

(11) Small cost and minor improvements should be made in the washing and toilet facilities for the men and should also include inexpensive heating units to be placed in the men's room.

BODY OF REPORT

GENERAL MANUFACTURING ANALYSIS OF A BOILER WORKS

History: The A. F. Robinson Boiler Works Inc., at 200 Second Street, East Cambridge, was founded prior to 1900. The company engaged primarily in the production of large industrial boilers at that time. With the increase in truck transportation of oils, however, a gradual change to the production of oil tanks occurred. This work now accounts for about 70% of the annual business and is confined to the winter months. The last few years has seen the introduction of stream-lined tank jobs, ordered mostly by the large oil companies for advertising purposes. Production of oil tanks is peculiarly seasonal with a peak occurring about December and January. During the off-season the company manufactures standard septic tanks and oil burner storage tanks for small individual customers. These tanks are stored in the yard to await shipment. The remaining 30% of business is roughly confined to repair work (both internal and external) and to special jobs of all descriptions. The company has earned a reputation for quality work and accepts work of all types at any time. Among truck and oil companies, Robinson has consistently maintained a reputation for the quickest delivery of any similar manufacturers in the vicinity. The shortest time of delivery now is about two weeks while the longest time may extend to two or three months. This is during the rush season.

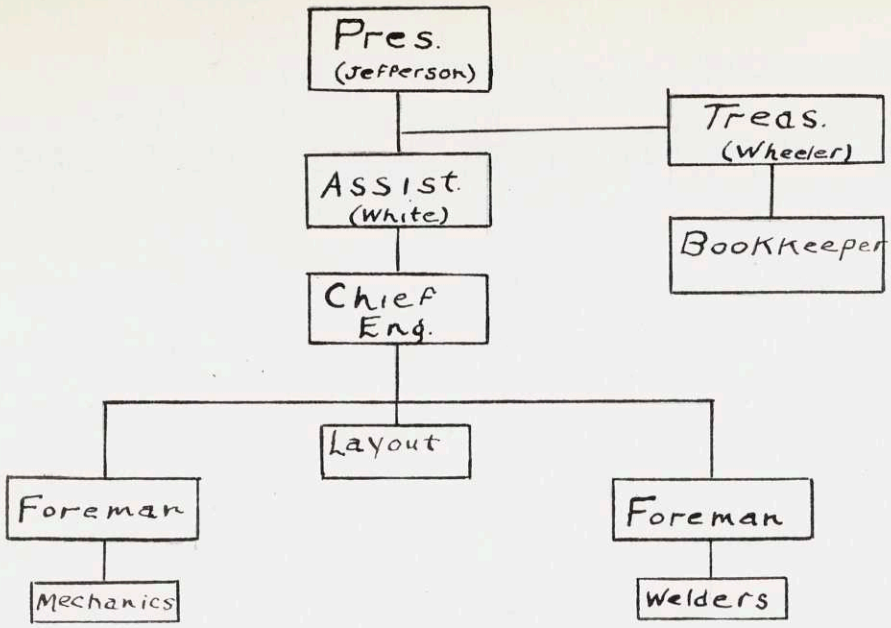
The capitalization of the company consists of 1000 shares of $100.00 par value common stock divided about equally

among Mrs. Robinson (the widow of the founder), Mr. Jefferson (the president), and Mr. Wheeler (the treasurer). Annual meetings are held in February of each year.

The company has found it impractical to maintain cost records since the expense would not warrant the control gained. This feeling comes about through the wide diversification of business. In this shop every order is different from any preceding job done. Standardization is practically non-existent, but it is possible to lay down a set sequence of operations for the manufacture of tanks regardless of their size, shape or materials from which they are made.

Organization and Personnel: The corporation is organized along very simple lines. The executive branch composes Mr. John A. Jefferson as President, Mr. Frederick B. Wheeler as Treasurer and Clerk, Mr. White, with whom most of the contacts at the plant were made, as Assistant to the President and is in charge of production. The executives are aided by a staff of three, consisting of the bookkeeperand two stemographers.

The shop personnel is headed by a chief engineer and a layout man followed by two foremen and their groups, as delineat in the shop organization shown below.



Mr. Jefferson and Mr. White collaborate on the design and general allocation of production orders. Mr. Wheeler has charge of all finances including both in and out payments.

The two distinct phases of fabrication and repair work are under the direct supervision of two foremen. Under the foreman of the repair department are 30 to 40 mechanics with one or two helpers to each mechanic depending upon the volume of business. The foreman of the welders has an average of 14 expert men under him, also with one or two indirect helpers according to production needs.

The layout man is the practical boss of each tank job since he must explain and show what operations are necessary according to his layout. The tank order, emanating from the office usually goes directly to the layout man and from there to individual men or groups. The chief engineer is, in theory, the boss of the entire shop although orders are rarely delegated through him.

Present Plant, Equipment and Machinery: The present plant of the A. F. Robinson Company was built for its present use by the company. The building is of red brick construction and is supported by 6" I-beams which form the bays respectively numbered 1, 2, 3, and 4 (see Appendix B). Originally the building consisted only of bays 1, 2, and 3. However, with an increase in business, it was found necessary to add bay #4 about ten years ago. Consequently, there is a brick wall separating bays 3 and 4 which is broken at intervals of about 30 feet by four doors. The building is plentifully equipped with sliding doors (four on each side) which are about 12 feet wide and 15 feet in height. This allows for ready delivery at many points throughout the plant of raw materials and supplies.

Windows form a large part of the wall area since they extend to almost the full height of the building. This allows for adequate lighting which is very slightly aided by lights set in the ceiling and spaced about every 20 feet in all the bays. The third bay is also lighted by overhead skylights. Windows from an integral part of the wall area between bays 3 and 4.

A second floor is located above bay #1 to a height of 30 feet and runs the entire length of the bay. (This second floor is not shown in the plant layout charts for purposes of clarity.) The second floor is serviced by a stairway located near the office and an elevator of sufficient capacity (see Appendix B).

The machinery used by the Robinson Company may be broken down into two classifications: (1) movable, and (2) fixed. Movable machinery has been taken as that machinery which can be conveniently transported by the existing lifting apparatus. The expense of moving would not be excessive. In this group would be grinders for sharpening of tools, small cutters both circular and longitudinal, steel plate storage bins and other small machinery weighing probably not over one ton.

Fixed machinery for the purpose of this analysis is that machinery either imbedded in concrete or impractical and too expensive to move. In this classification falls such machinery as steel plate rollers to form tank walls, the shearer to cut at one operation about 8 feet of steel plate, the breaks used to bend steel plate into the desired angle, the elevator for servicing the second floor, punch presses which form rivet holes etc., the angle bender and other similar apparatus. This accumulation if fixed machinery will serve as a nucleus about which any proposed changes in layout must be woven.

The company's equipment consists of forges, breaks, rolls, shears, varying types of spot and portable welders (electric), cutting torches, as well as various specialized machinery designed and assembled by the company to suit the convenience of the plant in turning out its production. The plant is built in bays, four in number, and each bay is serviced by three hoists as shown in the plant layout (see Appendix A).

In addition to the main plant and equipment upon the ground floor, the company maintains a rather complete small machine shop, a wood-working shop for sills etc., and a storeroom for odds and ends upon the second floor, situated directly above bay #1.

Present Layout and Methods: At present approximately 70% of the company's yearly business is done on oil tanks for trucks. The remaining 30% of the annual business consists of repair work on the existing company-built tankers and special fabricating work done to order. At present, repair work and the custom order jobs are done wherever room may be found in one of the four bays of the plant.

Storage is not functionalized; fittings, piping and finished tanks are to be found on racks in different corners of the building.. There is, however, a storeroom by name that is used to house the more expensive fittings such as pumps, motors, valves, etc. This room also provides a space for miscellaneous small machinery, a grinder, a drill, and a small lathe, all used for keeping the tools and equipment in working order. These machines are used primarily by the "all-around maintenance man" and are run by overhead shafting. This room also contains a toilet and wash basins for the use of the workmen.

Since tank trucks constitute such a large percentage of the company's annual business, the opportunity has been taken, both by the company in the past and by this analysis, to concentrate attention upon this type of work and make other

orders and work secondary to it. The dollar value of tank manufacture is also greater than that of special and repair jobs. This being so a tabulation of the productive steps in making these tanks is in order so that the reader may be conversant with the details and difficulties presented.

Partly because of the nature of the business, but more because of the present arrangement of the layout, it is impossible to present a simple, concise flow plan of production in the present layout. It is possible only to describe the engineering steps taken to produce a finished product with no attempt made to ascertain where the work in process is located. When shearing is spoken of, for example, it is meant that the piece to be sheared is brought to the machine, sheared, and then toted over the shop to wherever the work happens to be located.

The first step taken when an order arrives is to draw up the specifications and send them to the layout man. It is his work to lay out the sizes on the steel plate prior to cutting it to size. The plate, with the lengths and widths marked upon it, is then carried by the hoists to shears and rolls where it is reduced to the proper shape. Simultaneously with this operation, the heads are cut ready to be fitted to the shells as soon as they are shaped (see Appendix B). The next step is to weld the seams and one head into the tank. Then the proper manholes and the pipe outlets in the bottom are cut out, while at the same time, the can racks (to go on the side of the tank) are fashioned and the proper collars and fittings for the manholes are being assembled or made. Next, the other head

is welded in and the tank is ready for a hydraulic test of the welds. Provided the tank passes this test satisfactorily, it is now ready to be mounted on the truck chassis. Wood sills are made, mounted upon the chassis and on these sills are placed the saddles forged from angle iron. The tank is hoisted on the saddles and welded or bolted down. Then the tank and the frame are hoisted on the chassis and strapped down with large iron straps. The can racks and cat-walks are welded on the saddles and the unit is ready for fitting. The piping, power take-off, and pump are added. The meter, rear bumper, hose reel and hose, plus the necessary wiring are added one by one until the tanker is completely fitted out. Then comes a period of oil pressure tests and adjustments on the pump and meter of the truck. The tank is finally given a general O. K., the outside cleaned up with gasoline and sprayed with a prime coat of paint. Then the company's work is through--the unit is ready for shipment.

The present method of decentralized storage of small parts should, in our opinion, be continued. The only suggestions being that the place of storage be relocated to conform with productive operations as outlined on the proposed plan of operations (see Appendix B), i. e., the piping should be arranged on wall racks in bay 1 so that it will be close at hand when the piping operations are commenced. The pumps, valves, meters, and other more expensive fittings are to be stored in a closed cage-work against the wall in pump-fitting space.

Criticism of Present Layout: At this point a question may arise as to why changes should be made in the present methods of production. It is fully realized that movement of the product in process has very rarely been attempted in this type of industry. Parts and equipment have always been transferred to the scene of assembly of each unit except in the case of large fixed machinery where the work is brought to the machine and then moved back to the working space allocated to it. This, of course, results in many waste motions of labor since men must carry work and tools back and forth throughout the plant. Adequate supervision is, therefore, hard to achieve. Throughout eight hours of the working day we can readily see how the expense of this waste motion will mount. In addition, a longer time is taken to produce an individual unit which directly reflects upon the volume of business transacted within a seasonal peak. Skilled men now use probably 30% of their time in unskilled work such as transportation of work, materials, and equipment.

This type of work is unstandardized, e. i., one unit relative to any succeeding unit. However, it is believed that processes may be standardized. In this way, the management will find it much easier to confine the time of skilled labor to the skilled operations. At present, indirect labor is used to combat the waste of valuable time of skilled men, but it is believed that this system does not function with its contemplated efficiency.

The weight and bulk of the tank in process may, at first glance, appear to prohibit any degree of mobility. With the use of proper equipment in the form of hoists, slings and roller conveyors this may be overcome. Most of this equipment now exists in the plant.

As the plant exists now there has been developed, over a period of years, an accumulation of miscellaneous scrap and machinery. Robinson has in the past sold its steel on a very favorable basis (contract--about $5.00 per ton) to a junk dealer across the street. Weekly collections are made and it is believed that this arrangement is entirely satisfactory. Small fluctuations in the price of scrap steel makes little difference from the point of view of dollars and cents since the volume is small. This being so, there is little excuse for allowing accumulations to build up at various points within the shop, thus impeding production to a marked degree.

Old machinery constitutes what appears to be an impediment to efficient operation. Not only does the existence of such a situation impede production through the use of valuable floor space but it constitutes an unproductive investment. The management has felt that old machinery either obsolete or broken down should be carried in the inventory because of its occasional use. If the loss of interest on the investment and the depreciation warrants such a feeling, the machinery should by all means be maintained. However, some unused corner of the plant should be set aside for this accumulation.

This question of old machinery coupled with a laissez-fair attitude as to raw material storage has resulted in a conglomeration of waste materials and steel plate lying around piled in valuable working space and a general hampering of the most productive areas. Storage of the quantities of steel plate needed for production is undoubtedly quite a problem, but it appears as if a better balance between material and working space should be struck in order that some of this space may be released for productive labor.

The second floor machine shop, wood-working shop, and storage space constitutes minor problems of their own. However, since the machine shop is more or less functional in nature as is storage space, little criticism may be made of them. The wood-working shop is large enough and the demands made upon it are so small that no changes are necessary for the best interests of the company. The only point of criticism that may be raised concerning the second floor at all, is that arising from the use of the storage facilities. As in other parts of the plant, these facilities are not being used to great advantage. This comes from a lack of system in the storage of raw materials and a failure to get rid of old packing cases, tin containers, and the like. The present method of storage also leads to considerable pilfering on the part of employees.

Another feature of the present layout which, it is believed, may be improved upon is the position of the drafting room. This function is of utmost importance as a means of conveying to the shop the specifications evolved by the management.

Adequate and complete drawings are essential. Beside this, there is a certain advertising value to be gained through customer recognition of a satisfactory designing and drafting room. In its present location in the boiler shop under the office, it is felt that this function cannot be most efficiently carried out.

Proposed Layout and Methods: The proposed layout has been designed to be eminently practical in all respects. For this purpose the three functions of (1) tank manufacture, (2) special jobs, and (3) repair work have been segregated and allocated to the particular section of the shop in which it is believed that the functions may most efficiently be carried on (see proposed layout, Appendix B).

(1) Tank Manufacture: This function is carried on in the two bays nearest to the office. The proposed process flow of the mobile tank and its constituents has been conditioned mostly by the location of fixed machinery as well as present location of functional apparatus. The layout has been designed to minimize waste of time through walking and waiting for materials. Frequent reference to the proposed plant layout chart should be made by the reader of this discussion.

Storage of steel plate has been roughly divided into two types: (1) regular plate about 36" x 108" and from 14 to 18 guage--this division of plate would be used in the manufacture of the majority of tanks. (2) special plate composed of odd sizes and alloy steel--this plate would enter into production relatively infrequently. Storage of regular plate

should take place near the door on Second Street in bay #2. This location will allow supply trucks to back into the shop so that plate may be hauled off the truck and stored on its long edge in the compartments provided (see proposed layout, Appendix B).

Special plate will be stored in the yard under a suitable shed, covering preferably of wood and shingles since a galvanized iron shelter would corrode prematurely in the sulphuric acid contaminated air of the surroundings. A hand-powered monorail should be equipped with slings for easier and less costly handling of the plate. (For cost of shed and monorail, see Appendix C.)

Layout procedure comes directly after the storage function. Suitable tables and equipment are available in the existing plant. A small cabinet for tools, chalk etc. would be located adjacent to the layout tables, preferably in the center line of the I-beams between bays #2 and #3. This proposal will allow for sufficient room for foot-travel from office to repair department as exists now.

The shearing functions follow layout and are of three distinct types: (1) shearing of plates to the proper circumference for the tank shells--this operation is performed on the shearer which will handle cutting requirements up to eight feet in length. (2) cutting of cylindrical and oval head ends and compartments--these operations are performed on the circular cutter (3) cutting of can box, skirt etc.. This miscellaneous shearing is more adapted to the small cutter, although extra long work

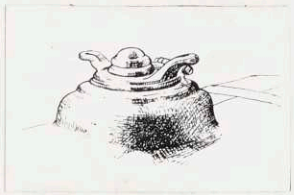
may be done in the shearer. There is no specialized equipment necessary to shearing, so that we have no storage to contend with.

From shearing, the individual parts progress to the breaking and rolling operations. The break is designed to bend steel plate either longitudinally or diagonally into the desired angle. Break #1 will take care of the majority of operations, while Break #2 will supplement for smaller work. The latter will also be convenient for use of special jobs. Rollers #1 and #2 are designed to roll steel plate into the desired circumference for the walls of the tank. The flange roller shown in the diagram serves to fashion a flange around the edge of the head ends. This operation enables easier construction of tanks.

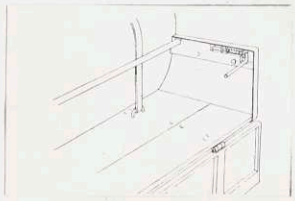
These constituent parts (head ends and walls) now flow together to the next operation of welding the longitudinal shear of the walls and beading in the ends. Meanwhile canboxes and accessories are moved along through the tank rollers and are welded together there.

The semi-completed tank shall then proceed to be mounted upon either of two tank rollers which are power operated. Here the welding operations on the tank itself are completed. The tank rollers serve to revolve the semi-welded tank, and thus provide for easier work on the tank itself. While the tank is on its roller, such operations as cutting manholes and outlets in the bottom may be performed. As the final operation while the tank is on the roller, the other head end is welded in after the inside of the tank has been wiped out.

Next the tank goes to the diverse but similar operations of welding in the domes, outlets, and can-boxes. In this respect, it must be noted that the collars are fashioned on a special machine located in the repair department. This necessitates extra travel of labor and materials to and from the machine. However, these parts are small and can be easily carried by one man. The collars must move from the special machine to their place in the production line as shown in the diagram.



Dome

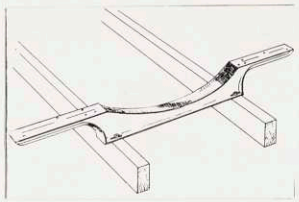


Can-box

Now we come to a cross-over from bay #1 to bay #2. Since this cannot be accomplished by a transfer from crane to crane, it is suggested that the tank be swung over onto floor rollers. The tank should be placed lengthwise on these rollers, and may be pushed by hand across to bay #1 where it can be picked up by another crane. Hydraulic testing is done in the southwest corner of the plant. This will necessitate moving the present apparatus, but it is believed that this procedure will be inexpensive in view of its relation to the whole productive process.

At this point, channel iron saddles which have been fashioned in the forge shop are moved by an existing monorail from bay #3 to bay #1. From the monorail, they may be moved by either hand or crane down bay #1 to the saddles and frame

operation. Wooden sills or frames which have meanwhile been made in the wood-working shop on the second floor are moved down to the first floor by means of the elevator and enter directly into the process at their exit from the elevator.



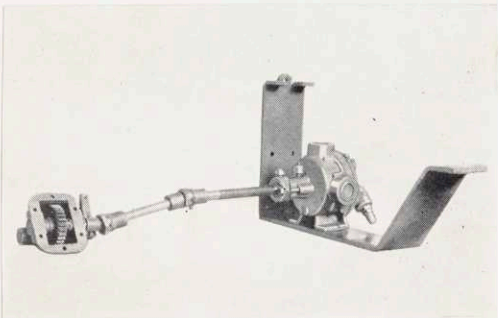
Sills and Saddle

The can-box which has been cut and fastened together in previous processes is attached to the chassis or tank as the case may be.

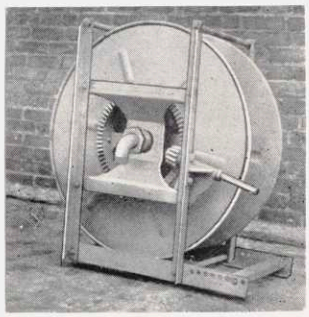
Along the wall nearest Binney Street, waiting chassis should be stored. There seems to be some question whether there is sufficient room in bay #1 to store chassis and at the same time allow for tank manufacture. The width of the bay is about 30 feet. Taking the chassis width as 10 feet, that will leave a space width of 20 feet for tank manufacture. This should be sufficient for working processes if the tank is placed and moved longitudinally. At the same time, it allows for centralized chassis storage and eliminates useless movement of skilled workmen to and from the different jobs.

The tank is mounted on the chassis after saddles, frames, and can-boxes have been attached. After mounting, the tank is fastened by means of straps, and such miscellaneous items as felt padding and bolts and nuts are stored in adjacent small bins.

Next the pipe lines and the side racks are put up, from which operations the tank and chassis move to the power take-off, pump, meter, hose-reel, etc. All these accessories are stored adjacent to their point of entrance into the process. An oil pressure test completes the primary operations. From here, the chassis (with tank mounted) moves to the northwest corner of the plant for final operations in the form of adjustments, final tests, clean-up, and spraying.



Pump



Hose-reel

(2) Special Jobs

Since only about 15% of the company's business is made up of special jobs of all descriptions, from riveting of steam shovel buckets to forging of 20-foot hinges, we must provide a space for this work in proportion to its volume. It is felt that in view of the existing equipment which may not be altered by the proposed layout changes, that this work may most economically and easily be carried out in bay #3. Such equipment as the small break, the forge, and welding equipment are conveniently located in this bay. No special order of production is to be desired here from the mere diversity of jobs and operations. It is suggested, however, that the location of the individual jobs be made with due regard to the time of completion. This will allow easier movement of the jobs in

and out of the shop. Thus, jobs intricate in nature, and taking a long time, should be placed farther down the bay and nearer to the forge shop, while short jobs may be performed near the door on Second Street.

Special job--Tractor Snow-plow

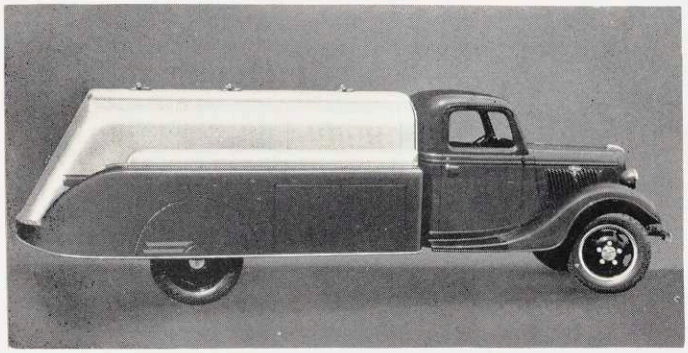
During off-season periods when tank manufacture is at a comparatively low ebb, it would be possible to mushroom other operations out into bays #1 and #2. Our proposed layout, although based primarily upon tank manufacture, was also completed with this possibility in mind. This will make it possible to utilize a maximum of working space in the plant at all times without losing the individual identity of the three departments of manufacture.

(3) Repair Department

Work done in the repair department comprises only about 15% of the total company's business. For this reason, its revision forms a very small part of this analysis. These repair jobs are also of a very specialized nature, including stream-lined body work. The present method of placing the truck chassis at a 45 degree angle with the wall has been scientifically proven to be the best method for ease of movement in and out of the shop. It also conserves valuable floor space.

It is suggested that all tools and equipment used on repair jobs be stored in convenient places throughout the repair shop. This storage will be under the direct supervision of the repair department foreman.

Future of Stream-lined Tanks: During the past few years, Robinson has had an increasing number of stream-lined tanks to manufacture. In the main, these orders come from large oil companies. Just recently, Colonial Beacon has put several new jobs of this type on the road. There seems to be no particular advantage in this type of construction either economically or mechanically, but the advertising thus gained is great. Robinson, with this new trend, has kept up by designing several standard chassis. These are advertised in a small booklet put out by the company.



Typical Stream-lined Tank Job

A series of interviews with various men connected with this industry proved that the future of stream-lined oil trucks is decidedly limited. This is because of two reasons--the extra cost of manufacture does not warrant the advertising advantages gained, and the stream-lined shell prevents accessibility to

some of the most important parts of the apparatus for repair purposes. Even the past season's production has seen the beginning of the decline of this type of design.

Production Control: Control of production under this new proposed layout will be at once much simpler and more effective. Upon receipt of an order by Mr. White or Mr. Jefferson of a tank, it will be made out in triplicate, two copies of which will be retained in the office and one sent to one of the three foremen in charge of the different departments according to the type of job.

These triplicate forms, it is believed, can be used to greatly simplify control of the work in process. They could be made with perforated divisions so that the tag was made up of six or seven sub-tags which can be detached if desired. These tags would be of such a nature that it would be possible to use them in any one of the three types of work performed by the company. A representative tag is drawn below:

Order:	Date:	Dept:	Operations		Del. Date:
No.:	Description:				
1.) Layout	2.) Shearing	3.) Forging	4) Welding	5.) Fitting	6.) Special
No. Pieces:	No. Pieces:	No. Pieces:	No. Pieces		
Size: Etc.	Size:	Size:	Size:		
Remarks:	Remarks:	Remarks:	Remarks:	Remarks:	Remarks:

As has been stated above, when an order is received it would be made out on the triplicate form shown. The original would be posted on a board in the office, the first copy would be kept as a reference, and the second copy would be sent direct to the foreman in charge of the department in which the work is to be done. The third copy will be kept in the office where the tags will be torn off and sent to the department for which the work is assigned.

The office will have to figure out whether the sills, saddles, meter, or what-not will take the longest time to obtain ready for assembly on the spot. Let us suppose, for example, that it is the meter on a tank job. Then a tag (the special tag for the operation) will be immediately detached, filled out, and put on file ready for an immediate ordering of the meter. If it is estimated that the forging of saddles will take a longer period of time than the construction of the tank proper, ready to be mounted, then tag (corresponding to the operation) will be detached and sent to the proper man in the forging division of the shop, ordering him to turn out so many saddles of such and such a dimension. Thus, by a glance at the control board in the office, the progress of any particular order through the shop may be ascertained at any particular time.

Tank manufacture is of such a nature that some of its constituent parts, such as meters, pumps, etc., must be ordered especially from other manufacturers. Production control, therefore, must be designed to secure these parts on time and ready to enter into production when the tank shell approaches the particular process. For instance, if a pump will take ten days

to be delivered, the management must immediately order the pump and delay starting to manufacture the tank until the seventh day (assuming it will take three days to complete all processes up to the pump installation). Planning the production in this way for each part will prevent unnecessary delay in the production of any particular job. This planning also presumes the necessity of chasing up orders which have been issued to see that they are completed in the allotted time.

The proposed scheme of control, if properly carried out, will eliminate idle jobs in process. Each tank in the process line will always have some job being performed on it. In this way, valuable manufacturing space is conserved.

Some practical considerations should be discussed here. Customers have a habit of calling in person every few days to note the progress of their order. Under the proposed plan, they may find that their job has not even been started. However, if it is pointed out that the pump is holding up production, the customer may feel more inclined to apply pressure to the pump manufacturer. It can also be shown how the other accessories are being made and the production plans. It is a question whether, with the present office staff, the control system may be carried out. However, with practice it is felt that a coordinated and systematic plan for each job may be accomplished.

The plant is too small to establish a more elaborate system with control and allotment of the work to the various machines.

Summary of the Wage Conditions: The Robinson Boiler Works has always pursued a policy of high wage payment. By this means, they have been able to enlist the services of excellent men. The policy also offsets to some degree the laxity in maintaining the best of working conditions. Throughout the depression when other manufacturers were cutting wages, this company maintained their's to the last moment, but were eventually forced to accept a 20% wage reduction.

Wage differentials among the men are determined mostly upon a basis of skill as judged by the foremen. Because welding calls for more experience and dexterity than is called for in mechanics, the welders, as a class, receive proportionately more than the mechanics. A certain amount of differentiation arises only as altering the order of layoff in slack periods.

Wages are based upon an hourly rate ranging from 70 to 80 cents an hour for the skilled men such as welders and mechanics down to 35 to 45 cents an hour for the less skilled men such as helpers and assistands. Payment is made to the individual employees directly and in cash upon Saturday of each week. Normally an eight hour day is in force, the men starting work at 8 o'clock and stopping at 5 o'clock. Very rarely is there any overtime even at the height of the peak season. There is only one shift and all the men work the full eight hours except in depression periods when a policy of spreading the work is adheared to.

The company almost always deals directly and individually with its employees. Under the N. R. A. codes, of course, provisions

were made for collective bargaining, but these were dropped when the codes were invalidated. There is, at present, a loose form of employee alliance or company union that collects monthly dues and provides an outing for all the men, together during the summer, but aside from this it appears to have no particular function. There is no form of employee estimation beyond that in the foreman's mind, i.e., there are no efficiency charts or other scientific means of determining an individual's ability. The company has never used them and believes itself to be of such a managerial size that it will function sufficiently well under the present system.

Criticism of Present Labor Conditions: (1) The discussion of labor conditions will be limited to merely making suggestions where, it is believed, a small capital investment will warrant a large return in labor morale. Such items as the adequacy of the wage system and safety apparatus are eliminated here since they seem entirely satisfactory. The main problem confronting the management in regard to labor problems seems to rest in the fact that morale is at a low ebb. There should be no pecuniary reason for this situation since the wage level is as high or higher than that existing in other businesses of the same type in the locality. Then, it seems that the solution lies in an improvement of working conditions coupled with a better cooperative spirit between the men and the management. Better spirit may be partially gained through an improvement in the productive processes, since each man knows his job and the possibility of mistakes and "passing the buck" is lessened.

From the employee's point of view, the chief criticism of the company's policy toward its workers lies in the working conditions. It is realized that a boiler shop is no country club, but the company is deficient in looking after the health of its employees and their safety. Although examination is made by a doctor as a pre-requisite to obtaining work initially, there is no set system of checking up on the workers' health after they have been employed by the company for any length of time. The toilet and washing facilities could be improved upon immensely, and if they were improved upon there would be a higher morale created among the workers. Heating is entirely inadequate, being accomplished by improvised shut iron furnaces set up for the winter period only. The lack of heat hampers the men and slows the work since the men snatch at every opportunity to run errands to heated portions of the plant for warmth.

From the company's viewpoint, this last is decidedly disadvantageous, resulting in increased cost from the longer production times and the inefficient work. Beside this, there is the storeroom on the second floor in which the less skilled men find occasion to loaf or to seek some other unsupervised work. This is a direct result of lack of morale and proper supervision.

(2) It is realized that to attempt to heat the entire shop would be highly impractical and costly because of the large window and door area. Any return in the form of increased output would not be balanced by the additional investment. However, it is suggested that a few small kerosene stoves be

set in the men's quarters would aid greatly in building up employee morale. It may be possible, if the proposed office plan is installed, to pipe steam heat directly to the men's quarters. The present boiler capacity is sufficient.

While on the subject, it seems advisable to point out the fact that, if changes are made in the productive processes with a decreasing time for labor to loaf, there will be aroused a feeling of antagonism against the management. A new office will also probably convince the men that they are not sharing equally in the profits of the business with the management. To offset this feeling and at the same time improve the men's working conditions, it is suggested that such small cost improvements in the form of new toilets, wash stands, and card tables be set up in the designated men's quarters.

Office: Discussion of the present office and any plans for its rearrangement has been reserved until the last because, although it has been a moot question with the management for several years, there are a number of various solutions, varying both as to initial cost and ultimate use to the company which might be effected. Also any change would necessarily have to be a non-productive change, the value of which is to measure in terms of dollars and cents.

There are several positions where a new office could be placed:

(1) Against the factory wall in the northeast corner of the factory yard.

(2) Upon the second floor and approximately above the present position of the office.

(3) In part of the space now occupied by the present functionalized storeroom.

Theoretically, the ideal office should be quieter than the present one, centrally located so as the present close touch with the plant operations may be continued, and inexpensive to build.

All three of the above possible solutions would have the advantage that the office would be quieter because it would be at a greater distance from noisy operations. The first suggestion has the disadvantage that it would be the most expensive to build originally because it would entail the construction of three new walls and a roof in addition to extensive piping in order to heat it.

The second alternative would not provide easy access either for the foreman who desired further instructions, or the customer who desired a conference concerning work to be done at the plant. Also this plan would require a rearrangement of heavy semi-fixed machines which would cost money.

The third alternative, although not perfect, is the most suitable for the case in hand. It costs less than either of the other two plans to build, it is adjacent to and could be used in conjunction with the present office, and it does not take up working space. This latter statement is open to question in that the proposed office would replace part of the present functionalized storeroom. However, under the revised layout the stores have been decentralized and the few small machines which were kept there to enable the storekeeper to stay busy in the off hours can be easily moved up into the regular machine shop upstairs. The management has in mind constructing an office floor in the storeroom to be at a slightly greater height from the floor

than the present office floor. This will allow for a storeroom under the new office and both rooms would have sufficient head room. The estimated costs of construction (see Appendix C) have been gathered with this thought in view. The cost of such an office would be approximately $800.00.

Reference to the present and proposed layout charts will show a plan view of the changes made in the office.

Cost of Proposed Changes: The following is an itemized list of the total cost of each of the several proposals:

(1) Cost of installing proposed layout------$250.00

(2) Cost of monorail (complete)----------$100.00

(3) Floor type roller conveyor (to be made and assembled by company)--- $25.00

(4) Additional tank roller (to be made and assembled by company)--- $50.00

(5) Wooden shed for storage of special steel plate---------- $25.00

(6) New office----------$823.00

Total----------$1273.00

Savings: It is possible to determine within a small margin of error the cost of our proposed changes. It is a very difficult job, on the other hand, to estimate accurately the dollars and cents savings that can be realized from the introduction of our proposition. This inability to estimate accurately arises not through any lack of initiative on our part, but rather through the uncertainties connected with any attempt at estimation of the savings.

It is a fact that the company loses from 12 to 18 thousand dollars of business during the peak season through sheer lack of manufacturing space and time. It is a fact that any additional business that could be undertaken during this period would result in reducing the unit burden charges for a given tank, and that any increment to the yearly profit would be welcome.

However, it is practically impossible to do more than say that we estimate the production time on an average tank could be shortened four days from the ordinary fifteen, required during rush periods to manufacture ready for delivery this average tank. The reduction in burden and the increased profit would be present, and other factors such as customer's good-will through shorter delivery dates which are not as tangible. There also would be a certain saving in direct labor which at present is necessary for carting materials and juggling tanks around that are in the way of one another.

Installation of Proposed Changes: Since this analysis has proposed numerous diversified changes in the methods now employed by the Robinson Boiler Works, Inc., it is only proper to establish what is believed to be a proper sequence of these changes. In the first place, any major alterations must be made during a slack season.

It is proposed that primarily the shop be cleaned upp This will involve a physical inventory of all materials and equipment now lying about the plant. Such items as steel plate, welding apparatus, and tools should be all moved to a designated

and temporary storage space. Scrap material and old machinery should have its value determined, i.e., whether or not it shall be sold.

The next step would involve the movement of small machinery as designated in the proposed layout (see Appendices A and B). Now we are ready to store materials and equipment near its point of introduction into the processing line. Meanwhile, the same thing is being done in the special and repair shops.

At this time the new monorail to serve the plate storage shed and the shed itself should be in the process of construction. The new steel plate storage bin with its compartments should also be on its way to completion. The additional tank roller should be in the process of manufacture. The company is now ready for its usual seasonal peak.

It is believed to be advisable to deter the construction of the new office until the following slump sets in.

CONCLUSIONS

As the outcome of about three months investigation at the Robinson Boiler Works, the following conclusions have been reached as regards the production methods employed by that concern.

(1) That although the products made by this company are of widely varying sizes and shapes, the sequence of processing and the number of processes for any particular tank are very similar.

(2) That since approximately 70% of the company's business annually is done upon tanks, it is about tank manufacture that any plan must be molded and fitted, with plans for special or repair work made subsequent to the major manufacturing interest of the company.

(3) That much of the present confusion and lack of efficiency in the plant today arises from helter-skelter storage of materials and allowing miscellaneous piles of scrap and old machinery to accumulate.

(4) That a coordinated and systematic flow of work in process will bring about an increase in potential production and permit easier and more effective control.

(5) That efficiency and coordination of labor could not be enhanced by altering the present wage payment system except by excessively increasing labor costs. The present slackness is therefore a result of poor supervision of the men and control over the work rather than the fact that there is no incentive system of paying the men.

(6) That the present company office is entirely inadequate for the normal yearly volume of business enjoyed by the company.

(7) That more economical cutting and layout of material cannot be effected, the savings being more likely to be found in prompt and efficient disposal of waste as it is created.

(8) That provision of a suitable control and flow plan for the company will enable the company to undertake more business during the peak season.

(9) That evening out of seasonal peaks in production has already been accomplished to its greatest degree by the manufacture at this time of standard septic and oil burner tanks.

RECOMMENDATIONS

(1) The company business should be divided into the three classes of work: tank manufacture, special jobs, and repair work.

(2) Tank manufacture should be changed to line production as in the proposed layout, and a definite sequence of operations should be established. (see Appendix B)

(3) Inventory of the stored and scrap material and unused machinery should be made with an eye to cleaning up the plant before attempting to establish any system.

(4) A third foreman should be maintained making a foreman in charge of each department.

(5) A new office should be created as shown in the layout chart at a total cost of approximately $800.00.

(6) A new monorail conveyor should be installed at a cost of approximately $100.00.

(7) An improvised wooden shed should be erected upon the existing framework in the factory yard for storage of special plate as shown in the plant layout chart, this to be constructed at a cost of not more than $25.00.

(8) Storage should be decentralized into the three departments and supervised by each department foreman.

(9) The manufacture or purchase of an additional tank roller and a floor type roller conveyor. The tank roller will be motor powered and the conveyor will be hand powered. This is conditioned upon the adoption of the proposed layout. Cost of these machines should not exceed $75.00.

(10) Machines as follows should be moved to conform with the requirements of the proposed layout: (see proposed plant layout, Appendix B)

a) Small circular cutter
b) Small plate cutter
c) Tank roller
d) End bender for beading purposes

(11) Small cost and minor improvements should be made in the washing and toilet facilities for the men and should also include inexpensive heating units to be placed in the men's room.

Respectfully submitted,
Winthrop A. Stiles Jr.
Winthrop A. Stiles, Jr.
J. Lawrence Tobey
J. Lawrence Tobey

A P P E N D I C E S

APPENDIX A

Present Plant Layout

BINNEY STREET

2ND STREET

197'

12' 31' 12' 31' 12' Sliding Doors 31' 12' 46'

Chimney

9'

14'

20'

14'

16'

18'

9'

135'

29'

Monorail

Steel Plate Storage

Electric Hoist 1½ Ton

Electric Hoist 2 Ton

Diff. Hoist

Small Cutter Move

Elevator Fixed

Roller Fixed

Roller Fixed

Shafting

Elect. Weld. Move

Punch Press Fixed

Diff. Hoist

Diff. Hoist

35'

Diff. Hoist

Lockers

Wash Basins

Shafting

Grinder Movie

24'

14'

14'

Closet

Storage of Small Parts

15'

Office

Stairs

30'

Roller

Circ. Cutter Move

Bender Fixed

Shearer Fixed

End Bender Air

Shafting

Tank Roller

Unused Bender

Electric Weld. Equip

Band Saw

Belt Driven Hammer

Forge Fixed

Diff. Hoist

Diff. Hoist

Diff. Hoist

29'

Forge Fixed

Piping

Tank Storage

End Cutter Semi-fix

Diff. Hoist

Diff. Hoist

40'

Storage of Bolts and Rivets

Yard

Present Plant Layout
Robinson Boiler Works
Cambridge Mass.
Drawn by: J. L. Tobey
Traced by: W. A. Stiles
Scale 1/8" = 1' March 25, 1936

APPENDIX B

Proposed Plant Layout

Binney Street

To Final Operations

197'

12' 31' 12' 31' 12' Sliding Doors 31' 12' 46'

Waiting

Truck Chassis

Pump And Meter Storage

Toilet

Wash Stands

Office

Oil Pressure Test

Hydraulic Testing

Install Can Box etc.

Electric Hoist 1½ T

Mount on Chassis

Fasten Tank

Power Takeoff, Pump

Attach Side Racks

Diff. Hoist

Saddles and Sills

Channel Iron

Put up Pipe Lines

Meter, Bumper, Hose Reel, Piping

1

Electric Hoist 2 T

Spot Welder

Floor Type Roller Conveyor

Miscellaneous

Accessories

Elevator

Roller 2

Pipe Racks

Small Cutter

Punch Press

Drafting Room

Tank Roller

Rolling of Shells

Can Box, Skirt etc.

Shearing of Parts

Cut Manholes And Outlets

Welding of Tank

Welding of Long. Shear, Bead Ends

Bending of Parts

Flow Line

Weld Domes, Outlets And Can Boxes etc.

Diff. Hoist

Tank Roller

2

Diff. Hoist

Shells

Heads & Compartments

Diff. Hoist

Layout of Heads, Shells, Compartments, Can Box etc.

Storage of Regular Steel Plate

End Bender Air

Flange Roller

Bender 1 Break

Shearer

Circ. Cutter

Storage of Welding Equipment

B. Break 2

Elect. Weld Equip

Layout Equip.

Band Saw

Punch Press Dies

Hammer

Grinder

Forge

Bender Angle Iron

2nd Street

S P E C I A L J O B S

Forged Iron Parts

Monorail

Diff. Hoist

Diff. Hoist

Monorail

Diff. Hoist

3

Forge

Temporary Storage of Truck Chassis

Grinder

Collar Shaper

Diff. Hoist

Diff. Hoist

Adjustments

Final Test

Tank Storage

R E P A I R D E P A R T M E N T

Clean up

Diff. Hoist

4

Spraying

Completed Jobs Await Shipment

Special Steel Plate Storage

Yard

W S N E

PROPOSED PLANT LAYOUT
Robinson Boiler Works
Cambridge, Mass.
Drawn by: W. A. Stiles
Traced by: J. L. Tobey.
Scale 1/8" = 1' April 9, 1936

APPENDIX C

Detailed Costs

(1)	Cost of installing proposed layout:		
	Movement of:		
	a) Small circular cutter----	$25.00	
	b) Small plate cutter-------	$10.00	
	c) Additional tank roller---	$25.00	
	d) End bender for beading---	$10.00	$70.00
	New Monorail: (100 feet)		
	@ 50¢ per foot for materials & and fittings----------	$50.00	
	@ 50¢ per foot for installation----------	$50.00	$100.00
	Labor:		$180.00
(2)	Proposed office:		
	Brick panel @ $35.00 a thousand in place----------	$235.00	
	Bricking up door on 2nd Street-	$139.00	
	Office street door in place----	$ 20.00	
	Stairs at office door----------	$ 15.00	
	Stairs to drafting room--------	$ 8.00	
	Break wall to drafting room with door in place---------	$ 20.00	
	Hard wood maple office floor @ 25¢ per square foot including joists, postings, and cutting into wall----------	$180.00	
	Heavy wall-board ceiling @ 15¢ per square foot----------	$108.00	
	Paint bricks on inside @ 5¢ per square foot----------	$ 48.00	
	Lights with five outlets @ $5. apiece in place----------	$ 25.00	
	Heating including piping etc.--	$ 25.00	$823.00
(3)	Floor type roller conveyor to be made and assembled by company		$25.00
(4)	Additional tank roller to be made and assembled by company		$50.00
(5)	Wooden shed for storage of special steel plate		$25.00
Total cost of all proposed changes			$1273.00

APPENDIX D

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