Implementation Of Lean Manufacturing System Enhances The Productivity Of An Organisation At A Pump Manufacturing Unit In Coimbatore – A Case Study

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Abstract:

In today's competitive world paying attention to the customer and keeping customer in mind is an important beginning, but when all the companies do the same to produce what customer wants, then the competition to the area of production and the one who is better in quality, faster in delivery, cheaper and more agile wins Competitiveness is one of the main strategic goals for all the companies. To be more competitive, one of the ways is to meet the customers demand promptly, to respond to customer' faster. Lean management system can be implemented in industries that are highly assembly oriented or have a high amount of repetitive human process. These are typically industries for which productivity is highly influenced by the efficiency and attention to detail of the people who are working manually with tools or operating equipments. One such industry is the pump industry. This research paper will show the readers implementation of lean system in the company, resulted in increasing benefits in terms of customer satisfaction, product quality and reduction in lead time thereby improving the performance of the company. The scope of this study is focused on implementing lean manufacturing system for a pump industry. For this, a study has been carried at a pump manufacturing unit manufacturing various types of pump sets in Coimbatore. Various tools of lean manufacturing have been implemented in the selected unit and the results are discussed.

Key words: Lean manufacturing, lead time, productivity.

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1.Introduction

In today's competitive world paying attention to customer and making production regarding customer is an important beginning, but when all the companies do the same to produce what customer wants then the competition starts in the area of production and the one who is better in quality, faster in delivery, cheaper and more agile wins the competition. Production time is one of the main factors to achieve competitiveness. Competitiveness is one of the main strategic goals for all the companies. To be more competitive, one of the ways is to meet the customers demand promptly, to respond customer faster.

The pump industry is a very large industry and plays a critical role in almost every facet of our lives like water, oil and gas, power plants, sump pumps at homes, processing industries and many more. The Indian pump industry at one point of time was not very conscious about modernization and up gradation and was quite satisfied with its casual approach. Today the business scenario has become very competitive like never before because of globalization in almost all the fields. So the time has come to implement appropriate manufacturing practices such as lean manufacturing to enhance productivity, quality and service to customer. The industry faces threat from big and multinational companies.

1a. Introduction to the concept

"Lean manufacturing" is a leading manufacturing paradigm being applied in many sectors of the economy, where improving product quality, reducing production costs, and quick to respond to customer needs are critical to competitiveness and success. Lean principles and methods focus on creating a continual improvement culture that engages employees in reducing the intensity of time, materials, and capital necessary for meeting the customer's needs. While lean production's fundamental focus is on the systematic elimination of non-value added activity and waste from the production process, the implementation of lean principles and methods also result in improved performance. Numerous companies of varying across multiple industry sectors are implementing such lean production systems. There are several lean tools available for implementing lean manufacturing systems. In this research paper the lean tools like Layout optimization, 5S, Work station design,

Visualcontrol, and Value Stream Mapping are used.

Layout optimization refers to an optimum arrangement of different facilities including man, machine, equipment material etc. Since a layout once implemented cannot be easily changed and costs of such a change are substantial, the layout design is a strategic decision.

5'S occupies a prominent role as one of the basic tools to enhance the quality of work place. 5'S is a an acronym for five Japanese words and denotes a step by step approach for developing a clean and well organized work place. A well designed and implemented program of 5'S would inst all discipline and change in attitude of employees towards work. It is one of the foundation level techniques for continuous improvement.

The work station design affects the production rates, efficiency and accuracy with which an operation can be performed. A work station not only needs space for the worker and the machine, but abo money other items which also need accommodation. There must be space for worker to stand, sit, & or turn comfortably to operate the machine. Space for bins storing incoming material and processed goods, space for necessary tooling and supplies required by the worker, and space for additional attachments, accessories, jigs and fixtures must be planned.

Visual controls are important tools for lean manufacturing principle. The intent of a visual factory is that the whole workplace is set-up with signs, labels, color-coded markings, etc. such that anyone unfamiliar with the process can, in a matter of minutes, know what is going on, understand the process, and know what is being done correctly and what is out of place.

Value stream mapping is a lean manufacturing technique used to analyze the flow of materials and information currently required to bring a product or service to a consumer. Through Value Stream Mapping, a team of employees can map the current state from customer back to raw material including all steps, both value-added and non-value-added, and develop a future state vision to act as a blueprint for Lean activities. The VSM team will develop an implementation strategy to make the Future State a reality. The most urgent needs will be addressed first, and can typically be accomplished in a very short time frame with the appropriate resources applied.

1b. Introduction to the industry

India has been a global producer of pumps. Recent globalization has paved the way to for the Indian pump industry in the global market. The export of pump & grows by ten percent per annum. Pump exports from India have been sent to a number of countries like US, UK, Germany, Italy, Singapore, Australia On the other hand China is becomes major threats to India in the global market.

The Indian pump industry is characterized by the coexistence of a large number of SSI units, some large manufacturers and plenty of foreign manufacturers. The domestic market demand is growing day by day because of urbanization and these result in increase in consumption of number of pump units. The absence of entry barriers and low technology requirements of this sector have also had a major impact on the competitive advantage. The pump industry suffers serious jolt & in sales as the industry is grappling with the twin problems of rising input costs and inability to raise the product prices due to competition and market apathy. Therefore the industry is challenged globally, and it must continuously improve productivity, quality & service to the customer to stay in business. Good business planning should include the engineering expertise that has made such business possible in the past & will, without doubt, continue to do so in the future.

1c. Introduction to the company

Coimbatore in Tamil Nadu forms the major manufacturing hub for the pump industry. The scope of the study is focused on implementing lean manufacturing system for a pump industry. The study was carried at a pump manufacturing unit, manufacturing various types of pumpsets in Coimbatore. The company is an ISO 9001 certified company with 43 years of experience in pump manufacturing. The company is located in the industrial belt of Coimbatore. The company manufactures the entire rage of pumps like Monoblock pumps, Submersible pumps, etc to cater domestic needs, agriculture as well as various industrial requirements. The company has got 46% of the market share the company also has its own foundry division to meet its captive requirements of fine quality castings. The company was the first to introduce the concept of mini monoblock pumps.

2. Objectives of the Research

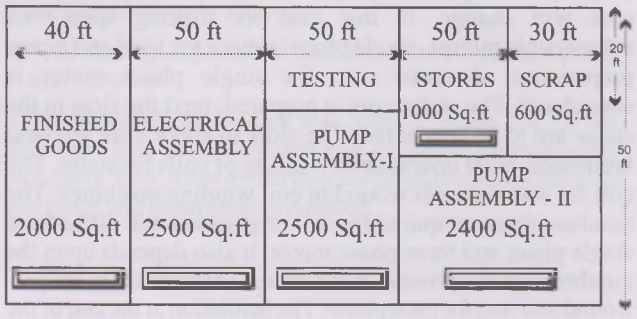
The objective of this research is to convert the traditional manufacturing system of the organization to a lean manufacturing organization.

3. Research methodology

In order to achieve the desired objective, Before and After experimental research design is used. The existing manufacturing process was studied using, Process flow analysis, Method study, Time study techniques and Value Stream Mapping. These methods helped to determine the 3M's (Muda, Mura, and Muri) present in the system. Tools such as Just in time production, kanban technique etc., was are used to implement lean production in all the functional areas of the organization. The research is being carried out in the production departments of the selected organization. There was are various departments in the organization like foundry shop, machine shop, pump assembly dept I, pump assembly dept II, Stores etc. The company manufactures different types of pumps like Open well submersibles, Mini mono block pumps, and multistage centrifugal pumps and mono compressor pumps. For this study the manufacturing of open well submersible pump was is selected. It is used for houseold and agriculture applications.

4. Analysis and implementation

4a. Existing Manufacturing Layout of the Company



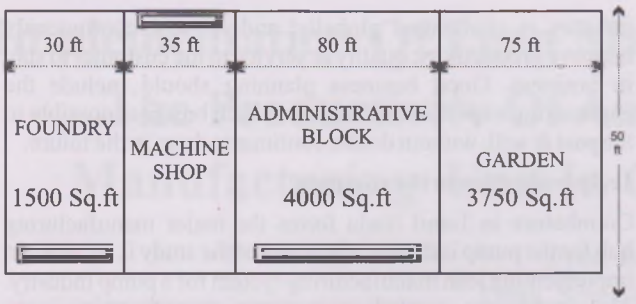


Figure 1: Existing layout of the company

The various departments of the company are foundry shop, Machine shop, Electrical assembly, Pump assembly dept-I, Pump assembly dept-II, testing and stores. The layout of various departments of the company was analysed and the area of each department is shown in figure 1.

4b.Production Process

Foundry shop

Foundry shop is the place that produces metal castings. Metals are turned into castings by melting them into a liquid, pouring the metal in a mold, and removing the mould material or casting after the metal has solidified as it cools. Stainless steel castings, gunmetal castings and aluminum castings are made, the pump casting parts are pump casing, and impellers, Back cover, delivery flange, strainer etc are made in foundry. The raw material requirement for making pump castings is stocked in foundry stores. Next the casting materials are moved to machine shop.

Machine shop

Machine shop is a workshop where power-driven tools are used for making, or finishing of machine parts. Basically five types of machining operation is carried out in machine shop - Milling, Drilling, Turning, Boring and Grinding. Machine shop has got mother machines like Turning centers for drilling and boring operation. Machining centers perform, drilling, tapping, milling and boring operations. Grinding centers are used for grinding operations. Here the rough castings produced in machine shop are converted to semi finished parts by the above said machining operations.

Electrical assembly

The electrical assembly department prepares stator core, rotor cores for different types of pumps.

Stator core preparation

The stator core is made of several laminated steel sheets having slots to place coil. The laminated sheets are cut into specific shape in punch presses. Depending upon single phase or three phase supply for motor the shape of stator core will change. In this case for making open well submersible pumps, single phase motors are used and hence preparation of stator core for single phase motor is considered. The stator core is prepared; next the slots in the stator are to be laminated. The slots in stator core are next laminated. Next operation is winding of coils for stator. The coil for stator core is wound in coil winding machines. The number of turns required for coil preparation will differ from single phase and three phase motor. It also depends upon the number of poles present in the stator. Then the coils are pre-wound and tied for each phase. The insulation at the end of the stator coils is then removed and kept free and the next step is insertion of TOC inside the stator coil. TOC means thermal overload protector, a device that will switch off motor when the temperature limit is exceeded. The stator coil preparation is now completed. The coil is now placed in side the stator core. Now as a unit the stator core is immersed in varnish completely and kept in heating oven for three hours. Now the entire process involved in the preparation of stator core is over.

Rotor core preparation

The rotor core preparation involves preparation of rotor core stampings and locking of stampings to rotor shaft. The rotor core stampings are prepared by cutting the stampings to defined shape by using punch presses. These stampings are then placed close to each other and then locked to the rotor shaft. There are only few operations involved in the preparation of rotor core. Now the stator core and rotor core is ready. The stator core is placed inside the motor frame. Motor frame is a separate casing. Pump assembly involves assembly of Electric motor and pump.

Pump assembly I

In pump assembly department I, Pumps like open well submersible and mini monoblock pumps are assembled. In assembling pump the materials like motor frame with stator core, rotor, ball bearings, are moved to the work centers. Casting items for the pump are moved from machine shop to work centers. There is a testing department present within pump assembly department I. Here all the pumps are tested for standards and the department consists of 5 work centers for assembling the pump. Any type of pump can be assembled in any work centre and it will vary from time to time depending upon load.

Pump assembly II

In pump assembly department II, pumps like deep bore well submersible, mono compressor, and multi stage centrifugal pumps are being assembled. Here also the department consists of 5 work centers for assembling the pumps. Any type of pump can be assembled in any work centre and it will vary from time to time depending upon load. The material flow to this assembly is like that of first assembly where the casting items will come directly from machine shop. The purchased items will be moved from stores, the stator and rotor for motor will be moved from electrical assembly department. A portion of the department is allotted for scrapping of waste materials. Store is present within the assembly. Stores provide materials for electrical assembly as well as pump assembly.

4c. Operation Analysis

Operation analysis is a detailed study of different operations involved in doing work. Operation analysis becomes necessary in order to investigate the shortcomings of the existing method and to develop an improved procedure. Operation analysis is done by synthesis of data recorded in method study. The various calculations regarding time taken for machining of pump castings, preparation of stator and rotor cores, assembling of pump was arrived by identifying the areas and recording the same.

Work Study conducted at machine shop, electrical assembly and pump assembly

Work Study was conducted in the machine shop, electrical assembly and the pump assembly sections. The flow process chart (chart1) gives the detailed information about the existing process followed in the machine shop. The flow process charts (chart 2,3,& 4) gives the detailed information about the existing process followed in the preparation of the stampings and the preparation of stator core and rotor core in the

electrical assembly section respectively. The flow process chart (chart 5) gives the detailed information about the existing process followed in the Pump assembly section.

Two Handed Process Chart

The Two-Handed process chart is a motion study tool which shows all movements and delays made by the right and left hands. Careful observations were made in the pump assembly section while a worker was doing the operation. The two handed chart (chart 6) gives the detailed information about the existing motions in the pump assembly section.

Calculations Relating to Existing Manufacturing

Time taken for machining of pump casing	65 minutes
Time taken for Preparation of stator core	55 minutes
Time taken for preparation of rotor core	25 minutes
Time taken for assembling pump	50 minutes
Time taking for testing of pump	25 minutes

Takt time = Available effective time / customer demand(present target) = 7.5 hrs X 60 min/hr / 9 = 50 min/pump

Plant cycle time = Takt time * Original equipment effectiveness (O.E.E) = 50 min * 0.85 (assume) = 42.5mins.

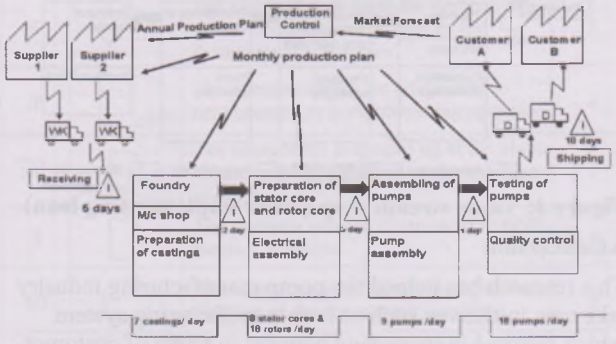


Figure 2: Value stream map

Based on the data collected during workstudy, the current status of the manufacturing process is mapped and the same is given in fig.2. By examining the recorded events critically and in sequence, it is found that the time taken to complete the activities are more. This was mainly due to improper layout of plant, push system, & absence of line balancing. Apart from these problems, there were problems associated within the functional departments like machine shop, electrical assembly and pump assembly. **Drawbacks in Machine Shop, Electrical& Pump Assembly**

In **machine shop** the layout of the machines are scattered. Since the method is push system the components after processing in machine are being pushed to the next machine for next operation, which created unwanted inventory to pileup at work centers, there was also no operation and route sheet for machining of components, which resulted in over processing of the components, unnecessary setup at machines, thereby increasing time and cost, the arrangement of tools and other accessories for the worker were not convenient for the worker, there was also unnecessary movement of men and materials, which resulted in fatigue of the workers. Piling up of inventory at work centers resulted in damage to components, and unnecessary delay between work centers.

In **electrical assembly**, position of coil winding machines etc were far away from the stator core preparation area, Push system of assembly and no proper material movement. The layout is congested for workers and for material time post. The movement of trolleys was difficult Both the W.I.P inventory and finished goods inventory were getting piled up and causing bottlenecks. There were no visual charts and instruction sheets.

In pump **assembly** the work centres have no proper layout and it was uneasy for the worker to assemble the pump. The activities involved unnecessary movement of men and materials, push system of production created inventory to pileup at work centres, more fatigue to workers, between each operation there were unnecessary delays, there were some unnecessary steps involved in preparation of stator and core. There was no proper visual control, the arrangement of work centres were not easy for the operator to carry out the job, there was no work instructions. Since the production system is of push system, there was over production with inappropriate processing, there were unnecessary movements made by the worker.

4d. Implementing Lean Tools

Layout Optimization

A poor layout will result in continuous losses in terms of higher efforts for material handling, poor space utilization and more scrap & rework. The present plant layout posed material handling problems and complicated the existing process. Hence the plant layout is slightly modified to overcome the drawbacks of the existing method and the new layout is given in fig3.

Improvements Made in Plant Layout

a) The machine shop has been shifted to finished goods area.

b) The stores have been shifted to beginning of the assembly line.

c) The layout of the Electrical assembly has been changed to two portions comprising Stator assembly and rotor assembly.

d) The pump assembly area was reorganized to separate individual assembly lines.

e) The testing department was integrated with the pump assembly line.

f) The finished goods area was shifted to the end of the assembly line, scrap yard was also located at the end of the assembly line. After modifying the plant layout the through put times was considerably reduced.

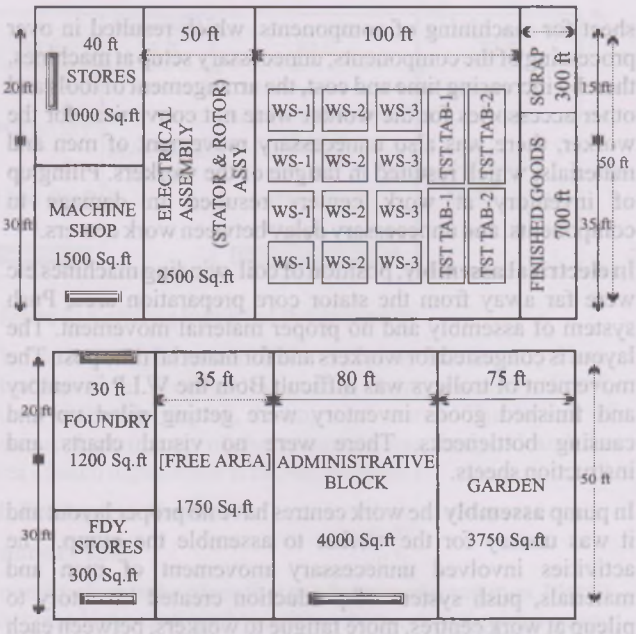


Fig.3.Modified layout of the company

Lean implementation in the machine shop, electrical assembly and pump assembly

From the workstudy data, it was found that the machining of pump casing takes 40 minutes which was too large. Since there was no proper process planning, there was unnecessary movements made for the raw material and setup time was more at machines. There was no proper information to the operator regarding the machine to be used for the particular operation, selecting jigs, fixtures, and other attachments, and other tooling requirements. There were no operation or route sheets. The operation sheet is prepared for each part which indicates the routing of the parts and the sequence of operation to be performed across machines, the tooling requirement, speeds, feeds etc. The specimen of the Operation and route sheet is given in the appendix (Chart 7). As the layout of machine shop was optimized and the operation and routing sheets are made for machining the component. The time now required to machine the pump casing was reduced to 30 mins from 40 mins. The layout of machine shop was changed and 5S practices were implemented and followed in machine shop .Some activities were reduced in the present method, the movement of operator is greatly reduced which is shown in the modified flow process chart (Chart 8).

In electrical assembly and pump assembly sections, the present method involved large number of operator movements; the operations involved were also not in sequence, consuming overall time. 5s practices, Work instructions were clearly specified for each activity in both the sections. The modified flow process chart (chart 9, 10 and 11) shows the improvements in the electrical assembly section and the modified flow process chart (chart 12) shows the improvement in pump assembly. Visual controls were implemented in the pump assembly section and the work place was redesigned for optimum productivity. The two handed process chart for the operator was also analyzed and a revised method is proposed as shown in the chart (Chart 13).

5. Results

5a. Calculations after Implementing Lean Manufacturing

Time taken for machining of pump casing : 45 minutes

Time taken for Preparation of stator core : 40 minutes

Time taken for preparation of rotor core : 20 minutes

Time taken for assembling pump : 32 minutes

Time taking for testing of pump : 20 minutes

Takt time : = Available effective time / customer demand (present target)

= 7.5 hrs X 60 min/hr / 14 = 32 min/pump.

Plant cycle time : = Takt time * Original equipment effectivemess (O.E.E)

= 32 min * 0.85 (assume) = 27.2 mins.

5b. Value Stream Mapping

From the calculation after implementing the lean methods it was seen than the time was reduced in machine shop, electrical assembly and pump assembly. This was achieved by implementing lean tools and following the same. Now the value stream of the modified method has been mapped and given in fig.4 below. The new value stream map shows the changes of the new system at different stages of manufacturing.

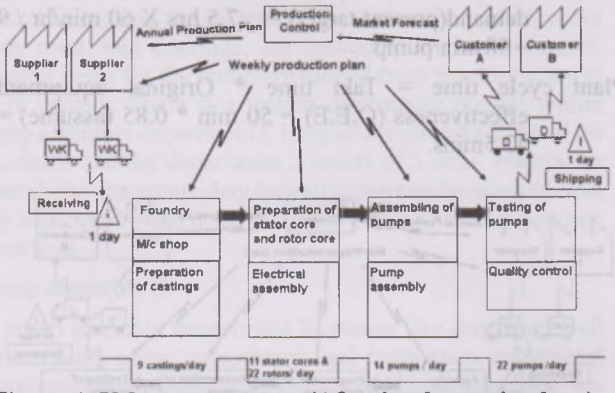


Figure 4: Value stream map (After implementing lean)

6.Conclusion

This research has helped the pump manufacturing industry take new initiatives such as lean manufacturing system which resulted in increasing benefits in terms of customer satisfaction, product quality and reduction in lead time and inventory. The potential benefits after implementing the lean could also be realized to become more cost competitive in today's global market. Many manufacturing companies are just starting to see the benefits of Lean and even those that are considered leaders today realize that they have just scratched the surface of opportunities. Furthermore, lean is getting a foothold in non-manufacturing fields. The potential for applying the same principles in the service sector, health care, military, education, and government is becoming evident.

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Appendix

Chart 1 Flow Process chart

Operation : Machining of components

Component : Pump casing

S.No	Activity	Description	Time (min)
1		Pump castings is present in casting stores	-
2		The operator moves to casting stores to collect pump castings using bins.	3
3		Wait to receive pump casing castings from casting stores.	2
4		The operator receives the pump casing from stores and moves to machine shop	3
5		The operator sets the component in CNC milling machine and starts the operation. Milling operation on the component is made.	3
6		The operator now takes the component out of the machine and checks for dimensional accuracies.	1
7		The operator moves the component to next operator to perform turning operation.	2
8		The component is queued up at the place till the present operation on the machine is over.	1
9		The operator sets the component in CNC turning machine	2
10		The operator starts the turning operation. Turning of the component is made.	3
11		The operator now takes the component out of the machine and checks for dimensional accuracies.	2
12		The operator moves the component to next operator to perform grinding operation.	3
13		The component is queued up at the place till the present operation on the machine is over.	1
14		The operator sets the component in grinding machine	3
15		The operator starts the machine and grinds the comp	4
16		The operator now takes the component out of the machine and checks for dimensional accuracies.	1
17		The operator moves the component to next operator to perform drilling and reaming operation.	3
18		The component is queued up at the place till the present operation on the machine is over.	1
19		The operator sets the component in CNC machining centre	4
20		The operator performs drilling and reaming operation.	5
21		The operator now takes the component out of the machine and checks for dimensional accuracies.	3
22		The operator moves the component to next operator to perform turning operation. on CNC lathe	2
23		The component is queued up at the place till the present operation on the machine is over.	3
24		The operator sets the component in turning centre.	2
25		The operator starts the operation on CNC lathe and turns the component.	3
26		The operator now takes the component out of the machine and checks for dimensional accuracies.	1
27		Store the machined component in stores.	4

Chart 2 Flow Process chart

Operation : Preparation of stator and rotor core stampings

S.No	Activity	Description	Time (min)
1		Lamination stamping sheets for preparation of stator and rotor core is available in stores.	-
2		The operator moves to stores to collect stamping sheets.	3
3		Wait to receive stamping sheets.	1
4		The operator receives the stamping sheets and moves to punch press machine.	3
5		The operator sets the sheets in the punch press machine.	5
6		The machine now starts to make stampings of both stator and rotor.	15
7		The operator inspects the stampings for required dimensions.	3
8		The operator pushes the stampings of stator core and rotor core to stator and rotor core preparation areas.	10
9		The operator places the stampings in respective bins.	5

Chart 3 Flow Process chart

Operation : Preparation of stator core

S.No	Activity	Description	Time (min)
1		Items for preparation of stator core are present in stores.	-
2		The operator moves to stores to get items required for preparation of stator core like rivets, plastic lamination sheets, coils etc.	3
3		The operator waits at stores for receiving the materials.	1
4		The operator collects the materials and moves to his work place.	4
5		The operator goes to the bin which contains stator and rotor stampings and collects the stator required stator stampings.	4
6		The stator stampings are now riveted for preparing the core. The lamination sheets for start core stampings are cut into required dimensions and placed in stator core slots.	7
7		The operator takes the coil and moves to coil winding section.	3
8		The operator winds the coil in coil winding machine, after preparing the coils, The coils are tied .The coil is then placed inside the stator core, TOC is then places inside the coil	6

9	○	The lamination at the end of the coil is removed and shorted to respective phases.	5
10	⇦	The stator is then moved to varnishing section	5
11	○	The stator is impregnated in varnish, then placed in baking oven for setting process	12
12	⇦	The stator is then moved to oven for heating the stator for setting process.	3
13	△	The stator core is then placed in bin	1

Chart 4 Process flow chart

Operation : Preparation of rotor core

1	△	Rotor core stampings are available in bin.	-
2	⇦	The operator goes to the bin which contains stator and rotor stampings and collects the required no of rotor stampings.	4
3	○	The operator first stacks the stampings and places 4 rivets for rotor core	11
4	○	The operator places the assembled rotor core stampings in rotor shaft and locks it with the shaft using key.	7
5	△	The operator then stores the rotor in bin.	3

Chart 5 Process flow chart

Operation : Pump assembly.

1	△	Except the casting items all other items required for assembling the pump is available as one common place.	-
2	⇦	The operator moves to common place to collect those items. Except casting items	2
3	○	Collects all the materials.	10
4	⇦	Moves to work place.	2
5	○	The operator now starts assembling the pump.	50
6	△	After assembling the pump is handed to testing.	-

Chart 6 Two handed chart

Operation : Assembly of open well submersible pump

S.No	Left Hand Description	Symbols		Right Hand Description	Time (min)
1	Idle	D	⇦	Takes the stator from the bin	1
2	Holds the motor frame	△	○	Places the stator inside the motor frame	3
3	Idle	D	⇦	Picks up 6 bolts from the bin	0.5
4	Idle	D	○	Inserts the bolts in the stator individually and locks with motor frame	2
5	Idle	D	⇦	Picks up 6 nuts from the bin	0.5
6	Idle	○	D	Tightens up the nut individually	0.3
7	Idle	D	⇦	Takes the back cover of the pump and places it on the table	0.3
8	Idle	D	⇦	Takes the collar bush for back cover and fixes it into the cover	0.5
9	Idle	D	⇦	Takes the grommet and fixes it in the back cover and takes the lead cable out of the grommet.	2
10	Idle	D	⇦	Takes the drain plug and fixes it in the back cover	5
11	Takes 4 bolt from the bin	⇦	⇦	Collects the bolt from left hand and fixes the back cover of the pump	2
12	Idle	D	⇦	Takes the rotor from the bin	2
13	Takes the thrust brg counter M/s	⇦	⇦	Transfers to right hand and places on the shaft.	0.5
14	Takes the thrust brg pad from the bin	⇦	⇦	Transfers it to right hand and places it on the rotor	1
15	Idle	D	⇦	Takes key for pad and places.	0.5
16	Idle	D	⇦	Takes bush for mono block cover and places it around rotor	0.5
17	Takes the monoblock cover from the bin	⇦	⇦	Transfers it to right hand and places it on the rotor shaft	2
18	Idle	D	⇦	Takes the oil seal and places it at the end of the monoblock cover.	0.5
19	Idle	D	⇦	Takes the impeller from the bin and places it on the rotor shaft	8
20	Takes the key for impeller from the bin	⇦	D	Idle	2
21	Idle	D	○	Locks the impeller to the rotor shaft using the key	0.5
22	Idle	D	⇦	Takes the nut and locks the impeller to the rotor shaft	2
23	Idle	D	⇦	Takes the pump casing and places it on the pump frame	1
24	Takes the bolt for tighting the casing	⇦	⇦	Transfers it to right hand and assembles the casing	0.5
25	Idle	D	⇦	Takes the gasket and suction flange from the bin and places it on the pump suction entry.	4
26	Picks up two bolts and transfers it to right hand	⇦	D	Idle	0.5
27	Idle	D	⇦	Takes and fixes the suction flange to the pump casing using the fixing bolts	2.5
28	Idle	D	⇦	Takes up the gasket for delivery flange & places it on the pump casing at the delivery port.	2
29	Takes up the bolt for delivery flange and transfers it to right hand	⇦	D	Fixes the delivery flange on the pump casing	3
30	Idle	D	⇦	Takes the strainer body from the bin and places it at the suction flange, Takes the strainer and places it over the strainer body	5

Chart 7 Operation and route sheet

OPERATION AND ROUTE SHEET

Part : Pump Flange — Drawing No : T40/815

Operation : Bore,ream, Face And Chamfer — Operation No :

Material : B.s.s. 32/4, 10 Cm Dia — No Of Operations : 13

Machine : — Machine No :

Op No	Operation description	Machine tool	Cutting tool	Cutting speed	Feed	Depth of cut	Setup time	Machining time/ piece	Remarks
1	Load in jaws	Romi	Drill bit	300	5	2	10	5	
2	Drill 27mm diameter		27mm T.S drill						
3	Rough turn face and chamfer		Turn, face and chamfer tool						
4	Grinding	Zayer	Sander						
5									
6									
7									
Operation time:									
Prepared by :		Checked by :						Total time :	

Chart 8 Modified Process flow chart (Machine shop)

Operation : Machining of components

Component : Pump casing

S.No	Activity	Description	Time (min)
1	△	The pump castings (pump casing) is moved to operator by trolleys to corresponding machines.	5
2	○	The operator sets the component in CNC milling machine and starts the operation. Milling of the component is made.	8
3	⇦	The operator now takes the component out of the machine and checks for dimensional accuracies and places in the trolley.	2
4	D	The operator sets the component in CNC turning machine and starts the operation. Turning of the component is made.	5
5	⇦	The operator now takes the component out of the machine and checks for dimensional accuracies and places it in the trolley for next operation..	2
6	D	The operator sets the component in grinding machine and starts the operation. Grinding of the component is made.	7
7	⇦	The operator now takes the component out of the machine and checks for dimensional accuracies and places it in the trolley for next operation.	3
8	D	The operator sets the component in CNC machining centre and performs drilling and eaming operations.	6
9	⇦	The operator now takes the component out of the machine and checks for dimensional accuracies, and places it in the trolley for next operation.	2
10	D	The operator sets the component in the machine, drills and taps the component	4
11	⇦	The operator now takes the component out of the machine and checks for final inspection of the component	1
12	△	The final casting is stored in trolley.	-

Chart 9 Process flow chart (Stator and rotor core stampings preparation)

Operation : Preparation of stator and rotor core stampings

S.No	Activity	Description	Time (min)
1	⇦	The lamination sheets for preparation of stator and rotor cores are sent to operator for punching in punch press machine.	5
2	D	The operator sets the sheets in the punch press machine.	8
3	○	The machine now starts to make stampings both stator and rotor.	12
4	⇦△	The operator inspects the stampings for required dimensions and places in the trolley and sent it to stores.	5

Chart 10 Process flow chart (Stator core preparation)

Operation : Preparation of stator core

S.No	Activity	Description	Time (min)
1	⇦	The items required for preparation of stator core like rivets, plastic lamination sheets, coils etc are moved from stores to operator by trolleys	5
2	○	The stator stampings are now riveted for preparing the core. The lamination sheets for stator core stamp -ings are cut into required dimensions and placed in stator core slots and moved to coil winding section.	12
3	○	The operator winds the coil in coil winding machine, after preparing the coils, The coils are tied, TOC is then places inside the coil, The lamination at the end of the coil is removed and shorted to respective phases. The coil is then placed inside the stator core and moved for varnishing.	8
4	○	The stator is impregnated in varnish , then placed in baking oven for setting process	12
5	△	The stator is placed in trolley for next operation.	3

Chart 11 Process flow chart (Rotor core preparation)

Operation : Preparation of rotor core

S.No	Activity	Description	Time (min)
1	⇦	The items required for preparation of rotor core like rotor stampings, rotor core , rivets etc are moved from stores to operator by trolleys.	3
2	○	The operator picks up stampings, stacks the stampings and locks it the rotor shaft.	7
3	○	The operator places the rotor core stampings in rotor shaft and locks it with the shaft.	8
4	△	The operator places the rotor in trolley for next operation.	2

Chart 12 Modified Overall Process flow chart

S. No	Activity	D	○	△	⇦	□	Distance Moved (ft)	Time Taken (seconds)	Remarks
1	Movement of castings from foundry to casting stores						30	6	
2	Movement of castings from casting stores to machine shop						20	6	
3	Machining of pump casting as machine shop.							45	
4	Movement of machined components from machine shop to pump assembly						50	6	
5	Movement of materials from stores to pump assembly.						20	4	
6	Movement of materials from stores to electrical assembly						15	3	
7	Preparation of stator core.							40	
8	Preparation of rotor core.							20	
9	Movement of materials from electrical assembly to pump assembly.						10	3	
10	Assembling of pump.							23	
11	Moving assembled pump to testing department.						10	3	
12	Testing of pumps							20	
13	Moving tested pumps to finished goods area						10	5	
14	Storing of pumps							10	

Chart 13 Two handed process chart (Pump assembly)

Operation : Pump assembly

S.No	Left Hand Description	Symbols		Right Hand Description	Time (min)
1		⇦	⇦	Takes the motor frame from the trolley using both the hands	1
2	Holds the motor frame	○	○	Places the stator inside the motor frame	3

3	Picks up six nuts from the trolley and places near the motor frame.			Picks up 6 bolts from the trolley and places near the motor frame.	3
4	Places nut on the screw and tights it one by one			Inserts the bolts in the stator individually locks it one by one	2
5	Takes the back cover of the pump and places it on the table			Takes the collar bush for back cover and fixes it into the cover	3.5
6	Takes the drain plug and fixes it in the back cover			Takes the grommet and fixes it in the back cover and takes the lead cable out of the grommet	2
7	Takes the rotor from the trolley and places on the table			Takes 4 bolt from the bin and fixes the back cover of the pump.	3
8	Takes the thrust brg pad and key for pad from the trolley and places on the table			Takes the thrust brg counter M/s and places it on the table, Then f ixes it on rotor and places the thrust brg pad on rotor shaft.	2
9	Takes the monoblock cover from the trolley and places it on the table			Takes bush and oil seal for mono block cover and places it around rotor	2
10	Takes the impeller and places it on the table.			Takes key for impeller and nuts and locks the impeller to the rotor shaft.	3
11	Takes the pump casing from the trolley and places it on the table.			Takes the bolt from the trolley and tights the casing.	2
12	Picks up two bolts and gasket from the trolley and places it on the table.			Takes the suction flange from the trolley and fixes it on the pump casing using the fixing bolts	2
13	Picks up two bolts and gasket from the trolley and places it on the table.			Takes the delivery flange from the trolley and fixes it on the pump casing using the fixing bolts	2.5
14	Takes the strainer from the trolley and places it on the table.			Takes the strainer body from the trolley and places it on the table, then assembles strainer body and strainer.	1