Productivity Improvement in Reciprocating Air Compressor Manufacturing

A Project Report

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Final year B.E. Mechanical Engineering of Kumaraguru College of Technology, Coimbatore
have completed their project work entitled

PRODUCTIVITY IMPROVEMENT IN RECIPROCATING AIR COMPRESSOR MANUFACTURING (Model: TRC 1000 MN)

in our concern from jan'06 to apr'06.
Their observations and findings to improve the productivity is acknowledged and taken for full-fledged implementation.

Their conduct and character were found good during the project period.

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ABSTRACT

A product is occasionally a single part, but it is usually an assembly of a number of parts. Traditionally assembly is a process of less importance but with the increasing living standards and disposable income, there has been an escalating necessity to produce goods in larger quantities with improved quality at lower cost. The inflating labour costs have accentuated the demand for efficient assembly.

The project aims to improve the productivity of TRC1000 MN compressor, a product of ELGI EQUIPMENTS LTD. used for braking applications in electric locos of Indian Railways. Presently, this product follows Group assembly methodology for its manufacture. During the course of study the superfluous activities were identified and the methods to eliminate the same were proposed.

The Line assembly methodology was proposed and a trial implementation was successfully performed in the company, which has shown a 100 % improvement in the productivity. The company has acknowledged the proposals and taken them for full fledged implementation.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols/ Abbreviations	Description
Approx.	Approximately
Std.	Standard
P	Pressure
V	Volume
T	Temperature
C	Celsius
kg	Kilogram
min.	minute
m	Meter
cm	Centimeter
mm	Millimeter
ml	Milliliter
hr	hour
rpm	Revolutions per minute
kgf	Kilogram force
FAD	Free Air Delivery
D	Diameter of cylinder
N	Speed
L	Length of cylinder

S	Number of cylinders
n	Polytrophic Index
v_r	Volume of air receiver
Pd	Pressure differential
FEPCOT	Federation of Productivity Council of Tamil Nadu
Al	Allowable motor cycles per hour
RH	Relative Humidity

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO LINE ASSEMBLY

Line assembly is a method by which the activities needed for assembly of a particular product are segregated to what are called work stations as shown in the Fig. 1.1. The activities are divided in such a manner that each work station consumes equal amount of time. The tools and materials required for the assembly activities are kept at the respective work stations. This avoids the time spent for searching the tools and materials.

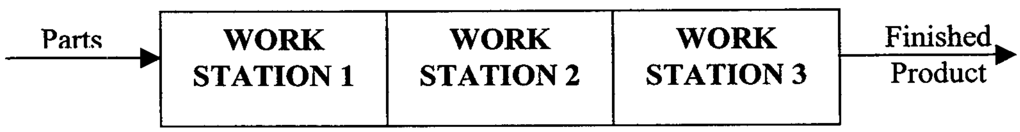

FIGURE 1.1 LINE ASSEMBLY OUTLINE

The product under study is TRC1000 MN compressor of Railways division, ELGI Equipments. In this compressor TRC1000 MN

TRC stands for Two Stage Reciprocating compressor
1000 stands for thousand liters per minute of air delivery
MN stands for Modified Needle bearing

This compressor TRC1000 MN contributes for more than 50% of the revenue of Railway Division at ELGI Equipments. Further the demand was high for this product so it was taken for study. The core idea behind the study was to improve the productivity of the compressor by reducing the cycle time and hence increase the revenue.

1.2 ACTION PLAN

"Anything well planned is half done". Anything that is to be carried out requires proper planning. Since the project of study is Improvement in Productivity it required meticulous planning. So before starting the project the Action Plan was prepared, and it is shown in the Table 1.1. The action plan shows the number of weeks taken for the plan and action for each activity.

ACTION PLAN FOR PRODUCTIVITY IMPROVEMENT IN TRC 1000 MN COMPRESSOR

TABLE 1.1 ACTION PLAN

		Number of Weeks												
		3	4	5	6	7	8	9	10	11	12	13	14	15
Conceptual Study	P	■												
	A	■												
Study on assembly activities	P		■											
	A		■											
Work Study	P			■										
	A			■										
Identification of non value added activities	P				■	■								
	A				■	■								
Defining Solutions	P						■	■	■					
	A						■	■	■					
Implementation	P									■	■			
	A									■	■	■		
Standardization and validation	P											■		
	A												■	
Results	P												■	
	A													■

P - PLAN
A - ACTION

1.3 COMPANY PROFILE

Elgi Equipments Ltd. is the technologically innovative company with four decades of expertise in the manufacture of compressors, based in Coimbatore, India. ELGI is one of the largest manufactures of compressors and also a leader in Automotive Service Equipment and Diesel Engines.

An ISO 9001 company practicing Six sigma and TPM, ELGI employs best in class practices and provides total in-house capabilities to design and manufacture products to meet international standards

ELGI is driven by the principle of "Extra Engineering" It means building extra value into everything they do, right from concept to design, development to manufacturing, marketing, delivery, service and knowledge sharing.

ELGI manufactures a comprehensive range of products for compressed air applications such as Reciprocating Air Compressors .Rotary Screw Compressors both Oil-flooded and Oil-free and Centrifugal Air Compressors. ELGI also manufactures the Airmate range of Air Treatment downstream auxiliary accessories-Refrigeration Air Dryers, combination Air Filters, Air Receivers, Jack Hammers and more.

ELGI has a committed and technically strong team of 1100 with 325 engineers. ELGI operates from two state of art manufacturing plants in Coimbatore, India with 30 acres of land and around 350,000 sq. feet of built up factory area. Elgi operating out of an advanced and sophisticated manufacturing facility with R & D and CAD facilities, a totally integrated machines shop, CNC helical rotor cutting machines, tool management centers, and Metrology Laboratory.

ELGI has collaborations and technical tie-ups with leading foreign companies, institutions and consultants that ensure ELGI remains at the cutting edge of manufacturing technology. Axis Airends are designed and developed by ELGI under joint technology agreement with the Positive Displacement Compressor Technology

Research Centre at City University, London. Also entered joint venture with M/s Hitachi Limited, Japan for. manufacturing Oil Free Screw Compressor & with M/s Samsung Techwin company Limited, Korea for producing centrifugal air compressors.

Elgi has a vast network of sales and service outlets manned by well trained, highly qualified and motivated engineers worldwide. Elgi is leading exporters of top blocks of reciprocating air compressors and air ends of screw compressor for OEM's and complete compressor packages all over the world.

ELGI truly has global presence with over 30 percent of its production reaching end users and OEM's in the USA, Europe, Australia, South East Asia and Middle East.

Based on the firm foundations of reliability, technology, capability and value, Elgi faces the future with confidence. We are today in a strong position to strike new partnerships for growth, and drive through mergers and acquisitions, to keep abreast with the latest technology from around the world. As always, innovation will continue to be our key differentiator. To bring better products and services that put a smile on the face of our customer.

CHAPTER 2

COMPRESSOR FUNDAMENTALS

2.1 INTRODUCTION TO COMPRESSED AIR

We live at the bottom of sea of air called atmosphere. This atmosphere is in reality, a gaseous envelope that surrounds the earth, exerting pressure on everything around us. The pressure of air, which is measured by barometers, will vary depending upon our position (altitude) above or below sea level.

When we place air under pressure, we have compressed it developing a higher level of pressure than the normal state. This air under pressure, if controlled, can be made to do useful work.

2.2 AIR COMPRESSORS

Air compressors are the machines designed to raise air pressure from atmospheric pressure to a higher pressure. What the compressor does is – it changes mechanical energy into gaseous energy in two ways.

i) By Positive Displacement of gas into a smaller volume. In this the flow rate is directly proportional to the speed of the compressor but the pressure ratio is determined by the pressure in the system into which the compressor pumps.

ii) By Dynamic Action imparting velocity to the gas and it is then converted into pressure ratio vary as a function of speed but only within a limited range and only then with a properly designed control system.

Generally, positive displacement is used for small to medium flows and for all pressures and dynamic is for medium to large flows and low to medium pressures.

2.3 HISTORY OF COMPRESSED AIR

The use of compressed air can be traced back to 3000 years BC when it was being employed by Egyptian goldsmiths for the air blast to melt gold. The hand driven bellows evolved as history's first air compressor system.

The development was followed by bellows operated by foot or driven by water wheel. Early use of compressed air was, however confined mostly for combustion blast for metal working.

Compressed air really got going in the 19^{th} century with the first large scale use of this energy source during the construction of Mt. Cenis Railway Tunnel in the Swiss Alps in the year 1857. The 13.6 km tunnel was driven with pneumatic rock drills first used with compressors working at a pressure of 6 bar. From here the compressed air equipment was on the road to success.

It was in the 20^{th} century, especially after the world war, that compressed air found its extensive uses in various other sectors. It has been perhaps one of the largest growth areas in the industrial scene in India and abroad over the past decades. Nowadays in most manufacturing industries compressed air has become essential for production.

2.4 ADVANTAGES OF AIR POWER

Compressed air is most versatile and more readily available power source when compared to Electric power and Hydraulic power.

2.4.1 Compressed Air Power Vs. Electric Power

- Flexibility to use anywhere
- High power to weight ratio
- More safety (No shock hazard)
- Easily controllable over a broad operating range (Storable)

- Runs cooler, less operator fatigue
- Fewer parts, less maintenance

2.4.2 Compressed Air Power Vs. Hydraulic Power

- More suitable for rugged applications
- Stringent maintenance
- Less expensive
- Could be transported for longer distances
- Devices not harmed by adverse operating conditions

2.5 APPLICATIONS

Like electricity and water, compressed air has numerous industrial, agricultural and domestic applications. The major areas of usage of compressed air are:

- Power applications
- Process applications
- Control applications

2.5.1 Power Applications

Compressed air is used to produce a motion, exert a motion or both

Examples:

- Linear actuators
- Pneumatic tools
- Clamping devices
- Air lifts
- Pneumatic conveyors

2.5.2 Process Applications

In process applications the compressed air enters the process itself for doing the work.

Examples:

- Aeration
- Dehydration of food
- Combustion
- Liquefaction

2.5.3 Control Applications

In control applications compressed air triggers, modulates and controls machine processes.

Examples:

- Automated assembly stations
- Automated machinery

2.5.4 Applications In Some Major Industries

Aircraft	:	Riveting & jet starting
Automobile	:	Pneumatic tools Automated assembly lines
Agriculture	:	Water lift pumping & Bore wells
Cement	:	Conveying & Quarrying
Construction	:	Drilling & Back filling
Health Care	:	Breathing air supply, Dental Application, Drug processing and packaging
Foundry/Forging	:	Combustion of coke Preparing moulds and cores Cleaning by blasting
Mining	:	Percussion and Augur drilling Exploration & Transportation
Power Plants	:	Starting turbines & Soot blowing Pneumatic controls
Railways	:	Air tools for production, Air brakes
Textiles	:	Baling presses, Air jet looms

2.6 CLASSIFICATION OF COMPRESSORS

The classification of compressors can be done based on the following:

- **By the Method of Compression**

  Based on the method of compression, compressors are classified as positive displacement and dynamic.

- **By the Techniques used for Compression**

  Based on the techniques used, compressors are broadly classified as reciprocating and rotary.

- **By the Stages of Compression**

  According to the stages, compressors are classified as single stage and multi-stage.

Given below in Fig 2.1 is the classification of compressors:

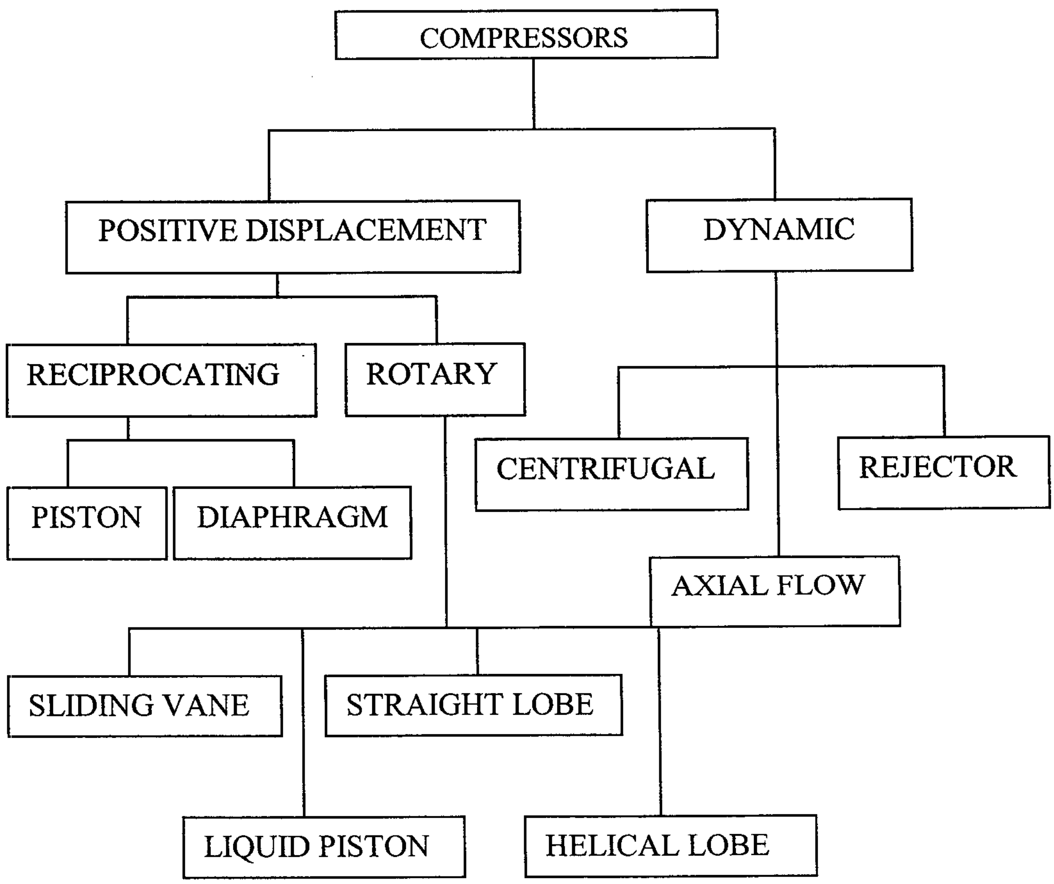

FIGURE 2.1 CLASSIFICATION OF COMPRESSORS

2.7 COMMONLY USED COMPRESSORS

Even though in the classification chart a variety of compressor types are shown some of the compressor types are found in limited applications and some of the compressor types are preceded by the other. Only a few types of compressors cater to the large number of applications. The types of compressors commonly used are:

- **Piston Compressors**
  In which a piston or pistons reciprocates in a cylinder or cylinders and doing the action of compression.
- **Screw Compressors**
  Where the compression is done by helically grooved rotor (or) rotors.
- **Centrifugal Compressors**
  In which compression is achieved by imparting velocity to air by an impeller and converting the velocity to pressure.
- **Sliding Vane Compressor**
  Where the compression is done by an eccentric rotor provided with sliding vanes.
- **Roots Blower**
  In which the compression is done by two rotating lobes inside a casing.

2.8 COMPRESSING IN STAGES

FIGURE 2.2 SINGLE STAGE COMPRESSION

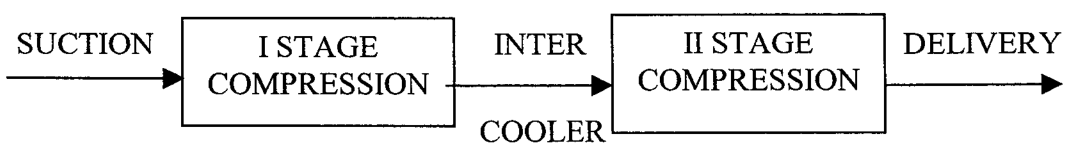

FIGURE 2.3 TWO STAGE COMPRESSION

Air can be compressed in one or more operations called stages. Each stage can handle practical increase in pressure, before the temperature increases. Staging permits high pressures and lower discharge temperatures.

t gas varies directly as its temperature, when the pressure remains constant

i.e. $V_1/T_1 = V_2/T_2 = V_3/T_3$ .... = Constant

2.9 COMPONENTS OF THE COMPRESSOR

During compressor installations, depending on particular requirements, compressors are fitted with ancillary equipment. The following are the various items of ancillary equipment which are generally used with compressors:

2.9.1 After Coolers

After coolers are devices for removing the heat of compression of the air or gas after compression is completed. They are one of the most effective means of removing moisture from compressed air.

2.9.2 Moisture Separators

Moisture Separators are devices for collecting and removing moisture precipitated from the air or gas during the process of cooling.

2.9.3 Air Receivers

Air Receivers are tanks into which the compressed air or gas is discharged from the compressor. Receivers help to eliminate pulsations in the discharge line and also act as storage capacity during intervals when the demand exceeds the capacity of the compressor.

2.9.4 Regulators

Regulators are used to adjust and hold pressure to the best operating levels.

2.10 TERMINOLOGY

- Booster compressors are machines for compressing air or gas from an initial pressure which is above atmospheric pressure, to a still higher pressure.
- Vacuum Pumps are machines for compressing air or gas from an initial pressure which is below atmospheric to a final pressure which is near atmospheric.
- Single-stage Compressors are those in which compression from initial to final pressure is completed in a single step or stage.
- Two-stage Compressors are those in which compression from initial to final pressure is completed in two distinct steps or stages.
- Portable Compressors are those in which the compressor and driver are mounted as a single unit in a skid or trolley so that they can be moved around.

2.11 COMMON DEFINITIONS

Pressure:

Pressure is force per unit area and the units of pressure are kg/cm^2, psi and bar.

Atmospheric Pressure:

Atmospheric pressure is the pressure exerted by the atmospheric gases due to gravity. Atmospheric pressure varies with the altitude above the sea level and the state of weather. Normal atmospheric pressure is 1bar or 1.02 kgf/cm^2 (14.5psi)

Gauge Pressure:

Gauge pressure is the pressure above the atmospheric pressure.

Absolute Pressure:

Absolute pressure is the existing gauge pressure plus atmospheric pressure.

Volume of Gas:

Volume of gas is the volume occupied by the gas at standard atmospheric conditions.

Displacement:

Displacement of a compressor is the volume swept through the compressor within a unit of time. Displacement of a multi-stage compressor is that of the first stage only, since the same gas passes through all the stages in series.

Free Air Delivery (FAD):

Free air delivery of a compressor is the actual volume of air delivered by the compressor within a unit of time. It should be measured at standard atmospheric conditions.

Volumetric Efficiency:

Volumetric efficiency is the ratio of the actual capacity (FAD) of the compressor to displacement and it is expressed in percentage.

Compression Efficiency:

Compression efficiency is the ratio of theoretical horse power to the actual indicated horse power required to compress a definite volume of gas.

Mechanical Efficiency:

Mechanical efficiency is the ratio of the indicated horse power in the compressor to the indicated horse power in the power cylinders. It is expressed in percent.

Overall Efficiency:

Overall efficiency is the product of compression efficiency and mechanical efficiency.

Load Factor:

Load factor is the ratio of the average compressor output during a certain period of time to the maximum rated output of the machine

2.12 RELATED LAWS

2.12.1 Boyle's Law: Boyle's law states that the absolute pressure of a given gas varies inversely as its volume, when temperature remains constant

i.e. $P_1V_1 = P_2V_2 = P_3V_3$ .... = constant

2.12.2 Charles Law: Charles law states that, the volume of a perfect gas varies directly as its temperature, when the pressure remains constant

i.e. $V_1/T_1 = V_2/T_2 = V_3/T_3$ .... = constant

2.12.3 General Gas law: In order to deal with all practical cases the Boyle's law and Charles law combines together which gives general gas equation

i.e. $P_1V_1/T_1 = P_2V_2/T_2 = P_3V_3/T_3$ .... = constant

The general equation combining the actual mass of gas with the Pressure, Temperature, Volume and Gas Constant is

$PV = mRT$

2.13 RELATED FORMULAE

FORMULAE

Swept Volume (V) $= 0.785 \times D^2 \times L \times N \times S$

D = Diameter of cylinder (m) L = Length of cylinder (m)

N = Speed in RPM S = No. of Cylinders

2.13.1 Single-Stage

Indicated Power (Watts)

Indicated Power = $n/(n-1) \times P_1 \times V_1 \times (P_2/P_1)\ (((n-1)/n)-1) \times 10^5 \times 1/60$

n = Polytrophic Index which varies between 1.3 and 1.4

P_1 = Atmospheric Pressure in Kgf/cm^2

P_2 = Discharge Pressure in Kgf/cm^2 (Absolute Pressure)

V_1 = Swept Volume in m^3/min

Brake Power (Watts)

Brake Power = Indicate Power / Mechanical Efficiency

Mechanical efficiency varies as per individual manufacturer and model

2.13.2 Two-Stage

Indicated Power (Watts)

Indicated Power = $(n/(n-1) \times P_1 X V_1 \times P_2/P_1)\ (((n-1)/n)-1) \times 10^5 \times 1/60 +$

$(n/(n-1) \times P_2 \times V_2 \times (P_3/P_2)\ (((n-1)/n)-1) \times 10^5 \times 1/60$

n = Polytrophic Index which varies between 1.3 and 1.4

P_1 = Atmospheric Pressure in Kgf/cm^2

P_2 = SQRT (P_1 x P_3)

P_3 = Discharge Pressure in Kgf/cm^2 (Absolute Pressure)

V_1 = Swept Volume in m^3/min (LP Cylinder)

V_2 = Swept Volume in m^3/min (HP Cylinder)

Brake Power (Watts)

Brake Power = Indicated Power / Mechanical Efficiency

Mechanical efficiency varies as per individual manufacturer and model.

$$\text{Time taken to fill a tank in mins} = \frac{\text{Tank Capacity(CU.FT)pressure difference}}{\text{FAD in CFM x Atm. Pressure}}$$

FAD in CFM = Swept Volume x Volumetric Efficiency x 35.315

2.13.3 Volume of Compressed Air

The air receiver must be of correct size to be able in particular in fulfilling its task of storing compressed air .

Determining air receiver (Vr) volume is primarily by value gained from experience

Vr = (Q x Cx28.317) / (Al x Pd)

Q = FAD of compressor (CFM)

C = Constant Factor 15 for Piston Compressor

Constant Factor 5 for Screw Compressor

Al = Allowable motor cycles per hour

Pd = Pressure differential (On/Off) (kgf/cm2)

Vr = Volume of Air Receiver (Liters)

2.14 COMPRESSOR SELECTION

The selection of compressor air system for an application must stand the test of overall economics. The compressed air system consists of compressor, down stream accessories and piping design.

The major considerations for selecting a suitable compressor type for an application are

- Effect of ambient conditions
- Exact air requirements of devices
- Air system considerations

2.14.1Ambient Conditions

Compressed air output is not the same at different locations. It is affected by the ambient conditions like pressure, temperature and relative humidity. (RH in %)

Pressure:

Higher the altitude lower will be the inlet pressure. Every 300m (1000 feet approx.) of altitude lower air density a shortfall in capacity is to the tune of 2.8%

Temperature:

Higher inlet temperatures reduce the density. For every 3 Degree C raise in inlet temperature above 20 degree C compressor capacity decreases by 1%

Relative Humidity (RH in %) :

Greater the RH, lesser will be dry air output. For every 20% increase in RH from 0%, the capacity reduction will be around 1 – 1.5%

2.14.2 Air Requirements Of Devices

Air consumption of devices is based on the duty cycle of the device.

Air consumption = Air requirement x Work factory x Load factor

$$\text{Work factor} = \frac{\text{Actual time of device in operation}}{\text{Total time}}$$

$$\text{Load factor} = \frac{\text{Actual air consumption}}{\text{Full load requirement}}$$

2.14.3Air System Considerations:

The following system requirements are to be considered during the selection of compressors:

Single Pressure or Dual Pressure System: Dual pressure system will call for multiple types/pressure ratings.

Average and Peak Air Requirements: The decision to go in for single or multiple compressors will be based on this.

Air Quality Requirement: The decision to go in for oil-free or oil-flooded compressor will be based on this.

Expansion for next five years: Additional capacity requirements can be calculated based on the above.

Centralised or De-centralised system: The decision to go in for a single or multiple compressors will be based on this.

Based on application requirement of quality of air the down steam accessories are selected. The compressed air usually has solid and liquid contaminants. The solid contaminants exist in solid form with particle size ranging from 0.01 to 100 microns. The liquid contaminants exist in three forms i.e. free liquid, Aerosol mist and vapour. It is essential to remove/reduce these contaminants for certain applications. Removal of these contaminants is known as compressed air treatment. The compressed air requirement in a typical industry is shown below in Table 2.1.

TABLE 2.1 COMPRESSED AIR REQUIREMENTS IN AN INDUSTRY

Appliance	Consumption Free air Litres/sec	Gauge Pressure (bar)
Air motors per KW	16 – 22	-
Contractor's tools, breakers, diggers	2 – 35	5.5
Controls, typical	0.005 – 0.01	1.0
Laboratories, bench outlets	5 – 15	1.5 – 5.5
Workshop tools, blast clearers, small	10 – 13	6.5
Blast clearers, large	100 - 110	6.5
Percussive, light	2 - 8	5.5
Percussive, heavy	10 - 15	5.5
Rotary (eg drill etc.)	2 - 15	3.5 – 5.0
Spray guns	0.5 - 10	2 – 5

2.15 METHODS FOR SAVING ENERGY

Proper maintenance and usage of compressed air system save considerable energy.

- The compressor will operate more efficiently with a clean inlet air filter. The filter has to be cleaned every 50 – 150 hours depending on the dust conditions.
- The compressor will operate more efficiently with outside (inlet) air. Hence the air flow to the inlet should not be restrict.
- Leaks cost money and cause pressure drops at the points of application. Check all piping and fittings regularly to avoid leaks in the system.
- Pressure losses happen in hoses also. Hence avoid lengthy hoses.
- Air leak in an 1/6" orifice will account for 1, 80,000 cu. ft. air loss in a period of 30 days. Hence rationalize using free air.

The pressure drop between the compressor and the point of use is irrecoverable. The preferred location for any compressor is near the centre of its load. Piping will be economical if the compressor is located close to consumption points.

The following are the general guide lines for a compressed air distribution system:

- The piping should be large enough that the pressure drop does not exceed 10% between the receiver and the point of application.
- The size of the pipe should be greater than the size of the discharge valve.
- Pipes should be galvanized or anti-corrosive treated.
- All pipes should be sloped away from the compressor so that they drain towards a drop let or moisture trap. Sub-headers should always be taken from the top of the pipe line to prevent carry over of moisture to the tools.

CHAPTER 3

SCOPE OF STUDY

3.1AREA OF STUDY

ELGI EQUIPMENTS manufactures a number of products under the following five major divisions.

- Rotary screw compressors
- Railway compressors
- Reciprocating compressors
- Automotive equipments
- Diesel engines

The project was carried out in the Railway Division of Elgi Equipments and the fastest moving product TRC 1000 MN compressor was taken into study. It is being used for braking purpose in railway locos. The monthly demand for this particular product is 60 numbers involving a large work force.

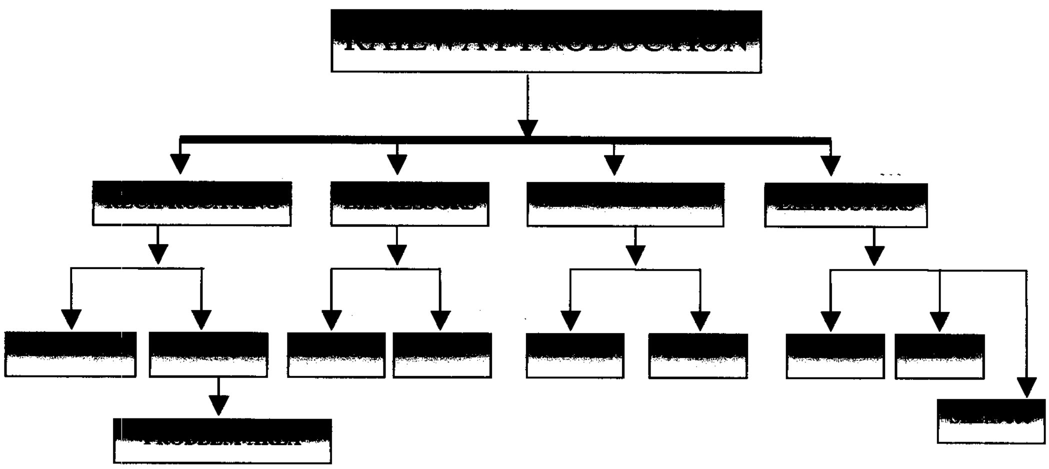

FIGURE 3.1 AREA OF STUDY

The main scope of this project is to improve the productivity of the particular product TRC 1000 MN which is depicted in the Fig. 3.1.

3.2.1 Introduction

The Elgi air compressor model TRC 1000 MN shown in Figure 3.2 is driven by an electric motor by means of resilient flange coupling. It consists of three cylinders arranged in a W form on a crankcase. Oil bath air filters are fitted to the suction side of the LP cylinder heads. The discharge ports of the LP cylinder heads are connected to the intercooler for effective cooling. Intercooler is connected to the suction port of the Hp cylinder head. The discharge port of the HP cylinder head is fitted with a motor and mounted on a rigid, compact base. The air filters and other pipe fittings are all clamped properly to arrest vibration. A fan with a fan guard is provided to direct cool air on to the compressor unit. The fan draws the air over the motor thereby cooling the motor also. An eye bolt used for lifting the motor is provided at the terminal side of the motor.

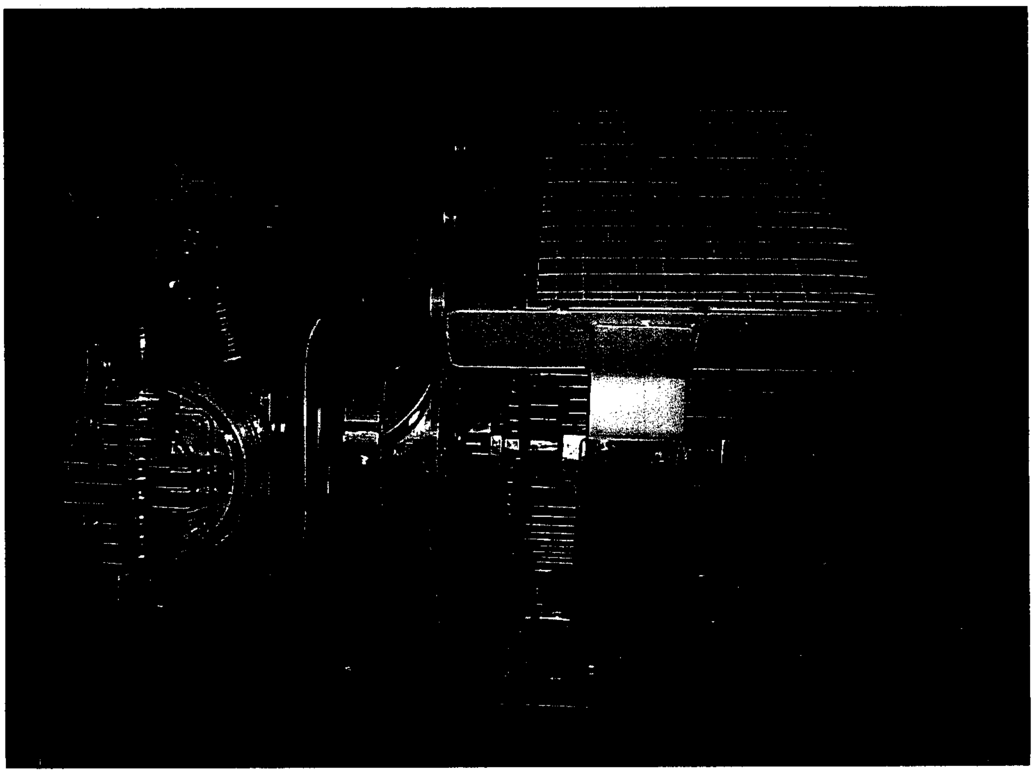

FIGURE 3.2 TRC 1000 MN COMPRESSOR

3.2.2 Crankcase

The crankcase is made of high grade cast iron and houses the crankshaft assembly and cylinders. It acts as the sump for lubricating oil and is provided with a breather, drain plug and a dipstick assembly. The breather maintains a partial vacuum in the crankcase to facilitate better lubrication.

3.2.3 Cylinder and Cylinder Head

The cylinders and cylinder heads are made of high grade cast iron and they have close deep fins for effective cooling. The hardness of the cylinders is closely controlled to ensure high wear resistance.

3.2.4 Oil Bath Air Filter

In this filter, first suction air passes through the oil bath and the wire mesh. While passing through the oil bath all dust particles in the air will be adsorbed by the oil and few of particles may mix with air. During its passage through wire mesh, the oil particles will be separated from the air. So suction air will be free of dust.

3.2.5 Connecting Rod Crankshaft Assembly

The connecting rod and crankshaft assembly is precision machined and dynamically balanced. The combined crankshaft is forged out of carbon steel, hardened and precision ground. The crankshaft is provided with single row heavy duty ball bearing at both ends. The main connecting rod big end is provided with steel bearing rollers and small ends are provided with needle roller bearings.

3.2.6 Piston and Piston Rings

The pistons are of automotive type and made out of low expansion aluminium alloy. They are provided with plain compression rings, steeped compression rings and slotted oil control rings. The rings are made of special quality close grained cast iron and designed for controlling wear and oil consumption to a minimum. The gudgeon pins are of chrome steel case hardened and precision ground.

3.2.7 Disc Valves

Special type concentric disc valves have been used for suction and discharge operations. The springs used are of high quality spring steel.

3.2.8 Intercooler, Safety Valve and Aftercooler

The intercooler consists of a series of copper tubes, on which fins are wound for effective cooling. It is mounted above the motor. It is provided with a safety valve and a drain valve. The aftercooler is also made of copper tubes with fins wound on them and arranged together for better cooling. A drain valve is provided on the aftercooler.

3.2.9 Coupling

The flexible resilient coupling connecting the motor and the compressor consists of two hubs. Each hub is provided with a number of grooves to hold a spring which transmits the rotation from the motor to compressor. Care is necessary in assembling the couplings, particularly in checking for parallel and angular alignment and in setting the correct gap (0.8 mm) between the two hubs of the coupling.

3.2.10 Fan and Fan Guard

A good quality aluminium fan is fixed on the motor shaft to supply air for efficient cooling. A fan guard made of steel sheet with enough strength is mounted as a safety measure

3.3 PRODUCT SPECIFICATION

The following list shows engineering data of the TRC1000 MN compressor.

1. Model		: TRC 1000 MN
2. Type		: Reciprocating air cooled, "W" type and oil splash lubricated
3. Working pressure	Kg/cm^2	: 10.5
4. Displacement	m^3/hr	: 78.48
5. Free air delivery	m^3/hr	: 60.00
6. Cylinder size and stroke	mm	: 100 x 60 x 100: 85 mm
7. Number of stages		: 2
8. Compressor speed	rpm	: 980
9. Types of valves		: Disc valves
10. Direction of rotation		: Anticlockwise as viewed from Non-driving end
11. Type of drive		: Directly coupled with motor By a resilient flange coupling
12. Crankcase oil capacity	ml	: min. 600 : max. 1350
13. Recommended oil		: Elgi air lube
14. Net weight	kg	: 405
15. Overall dimensions L x W x H	mm	: 1050 x 770 x 965
16. Safety valve pressure	kg/cm^2	: 6

3.4 MOTOR MAINTENANCE

3.4.1 General

The motor used will be of reputed make and thoroughly inspected to ensure long and trouble free service.

3.4.2 Aligning of Motor and Compressor

While assembling fan flange and coupling over the motor shaft appropriate tools should be used. While changing the fan, complete fan with flange assembly should be changed to avoid unbalance or after changing the fan; the fan with flange assembly should be balanced. The shafts of the compressor and motor should perfectly be leveled and aligned.

3.4.3 Electrical Connections

The connection on the terminal board of the motor should be in accordance with the wiring diagram which is pasted in the inside portion of the terminal cover. Connect earthing wire to the terminal marked with earthing symbol on the terminal board. Separate earthing links are provided on the main body of the motor and this should be connected with a cable of suitable cross section as per IS 900. All fixed electrical connections should be checked for tightness. To change the direction of rotation of the motor any two of the supply leads (phases) should be interchanged. Motor starters of air brake contactors with overload relays shall be used. In addition back up fuses of the HRC cartridge type are essential to protect the motor insulation as well as thermal overload relays of the starter against short circuit.

3.4.4 Maintenance

Motors should be cleaned by blowing dry air at regular intervals to keep the ventilating passages clean. The bearings are pre-lubricated with lithium based grease having a dripping point above 160 C. only recommended grade of grease should be used for the bearings. In case of motors that have re-greasing attachment frame size up to and including AM 200 and AJ 180, the grease in the bearings shall be changed at an interval of 2 years. While re-greasing, the bearings and bearing covers should be cleaned well and then the grease shall filled.

In case the motor is stored idle for long period or if it is transported under very damp condition, the insulation resistance should be checked before connecting it to the supply. The insulation resistance of the motor shall be measured between the windings of the motor is less than IMDHM/ KV when the motor is cold, it should be dried out before full voltage is applied to the terminals of the motor.

The motor can be dried by placing heaters or lamps around it and inside also or by blocking the motor so that it cannot rotate and then apply such a low voltage to the starter terminal that full load current flow in the starter. Care must be taken during the drying out the windings that the temperature of the induction coil does not exceed 155 C which is the max, allowable temperature for class F insulation

3.5 REPAIRS

3.5.1 General

Only a skilled mechanic who knows about the compressor should dismantle and reassemble the compressor. Before dismantling the compressor, make sure that it is free of compressed air. Pull the safety valve and ensure this. Also make sure that the electric power is disconnected from the unit.

3.5.2 Accessories

Remove the intercooler after removing the respective ermito pipe fittings and bolts. Remove the aftercooler and suction filters. Open the drain plug and drain the oil from the crank case.

3.5.3 Cylinder Head, Disc valves, Cylinder

Remove the cylinder head and take out the disc valve. Take care not to damage the disc valves. While dismantling the disc valve, the position of the springs should be carefully noted this will help during reassembling. If damaged the springs should be replaced with new ones. Also check the packing and if necessary replace by new ones. Unscrew the cylinder and remove the cylinder. If the cylinders are tightly fixed to the crankcase rotate the fly end hub. The cylinders will automatically come up.

3.5.4 Piston Assembly

Remove the circlip by using a circlip plier and gently knock out the gudgeon pin. Inspect for scratches or slackness in the piston boss. If the pin is worn out use a new pin. Remove the piston rings using a piston ring expander.

Clean the piston rings and the ring grooves in the piston. Measure the piston size, gudgeon pin bore size, piston ring gaps at butts and side clearances. Replace the rings as a set when limiting clearances have been reached.

3.5.5 Crankshaft Assembly

Remove the coupling cover. Take out the springs from the coupling hub grooves and remove the coupling hub. Then remove the free and cover. Using puller remove the fly end cover from the crankshaft assembly. Clean the crankshaft and connecting rod assembly thoroughly in kerosene and dry with compressed air. Inspect the bearings, if found damaged replace them with new ones.

3.5.6 Bearing

- **Removing Ball Bearings from the Crankshaft**

  Take a small steel wedge and gently hammer it keeping in between the crank web and the bearing. Then use a suitable puller and take out the bearings.

- **Assembling the Bearings on the Crankshaft**

  Heat them to a temperature from 100 C to 120 C in an oil bath or on a hot plate which is heated by a flame or electricity insert the bearings on the shaft so that they will slide in and fit tight when cooled.

3.5.7 Assembling Connecting Rod and Crankshaft Assembly in the Crankcase

Take the connecting rod and crankshaft assembly, clean it and oil the bearings. Rotate the bearings by hand and check for any tightness. They should have free rotation. Check whether the splasher pin is secured in position. The flat sides of the splasher pin should be perpendicular to the axis of the shaft.

Fix the fly end cover on the crankshaft assembly. Insert the crankshaft assembly through the fly end cover bore on the crankcase. Fix the free end cover on the other side. Then fasten the end covers bolts uniformly.

3.6 SAFETY FEATURES

3.6.1 Pressure Release

- Manually pop the safety valve when the compressor is operating, at least weekly, to make sure the safety valve is not blocked, closed obstructed or otherwise inoperative.
- Select appropriate during maintenance of air hoses, pipes, valves, filters and other fittings. Do not exceed manufacturer's rated safe operating pressure for these items.
- Secure all hose connections by wire, chain or other suitably retaining devices to prevent tools or hose ends from being accidentally disconnected.
- Vent all internal pressure prior to opening any line, fitting, hose, valve, rain plug, connection or other components such as filters.
- Keep personnel out of line with and away from discharge opening of hoses or tools or other points of compressed air discharge.
- Do not use air at pressure higher than 2.5 kgf/cm^2 for cleaning purposes.
- Do not engage in horseplay with air hoses as death or serious injury may result.

3.6.2 Fire and Explosion

- Clean up spills of lubricant or other combustible substances immediately, if such spills occur.
- Shut off the air compressor and allow it to cool. Then keep sparks, flames and other sources of ignition away and do not permit smoking in the vicinity when checking or adding oil.
- Do not use flammable solvent for cleaning purposes.
- Keep electrical wiring and other terminals in good condition. Replace any wiring that has cracked, cut abraded or otherwise degraded insulation; keep all terminals clean and tight.
- Keep grounded conductive objects such as tools away from exposed live electrical parts such as terminals to avoid arcing which might serve as a source of ignition.
- Keep oil rags, trash, leaves, litter or other combustibles out of and away from the compressor.
- Do not operate the compressor without proper flow of cooling air/cooling water or with inadequate flow of lubricant or with degraded lubricant.
- Do not attempt to operate the compressor in any classification of hazardous environment unless the compressor has been specially designed and manufactured for explosive application.

3.6.3 Moving Parts

- Keep hands, arms and other parts of the body and also clothing away from belts, fan and other moving parts.
- Do not attempt to operate the compressor with the fan guard removed.
- Wear snug fitting clothing and confine long hair when working around the compressor, especially when exposed to hot or moving parts.
- Make sure all personnel are out of and / clear of the compressor prior to attempting to start or operate it.
- Disconnect and lock out all power at source and verify at the compressor that all circuits are de-energized to minimize the possibility of accidental

start up or operation, prior to attempting repairs of adjustments. This is especially important when compressors are remotely controlled.

- Keep hands, feet, floors, controls and walking surfaces clean and free of fluid, water or other liquids to minimize the possibility of slips and falls.

3.6.4 Hot Surfaces

- Avoid bodily contact with hot oil, hot surfaces and sharp edges and corners.
- Keep all parts of the body away from all points of air discharge.
- Wear personal protective equipment including gloves and head covering when working in, on or around the compressor.
- Keep a first aid kit handy. Seek medical assistance promptly in case of injury. Don't ignore small cuts and burns as they may lead to infection.

3.6.5 Toxic and Irritating Substances

- Do not use air from the compressor for respiration.
- Operate the compressor only in open or well ventilated areas.
- Lubricants used in the compressor are typically of the industry. Care should be taken to avoid accidental ingestion and / or skin contact. In the event of ingestion, seek medical treatment promptly. Wash with soap and water in the event of skin contact.

3.6.6 Electrical Shock

- Keep all parts of the body and any hand held tools or other conductive objects away from exposed live parts of the electrical system. Maintain dry footing, stand on insulation surfaces and do not contact any other portion of the compressor when making adjustments or repair to exposed live parts of the electrical system. Make all such adjustments or repairs with one hand only so as to minimize the possibility of creating a current path through heart.
- Attempt repairs only in clean, dry and well lighted and ventilated areas.

- Do not leave the compressor unattended with open electrical enclosures. If necessary to do so, then disconnect. Lock out and take all power at sources so other will not inadvertently restore power.
- Disconnect, lock out and tag all power at source prior to attempting to repairs or adjustments to rotate the machinery and prior to handling any ungrounded conductors.

3.6.7 Lifting

- If the compressor is provided with a lifting bail then lift by bail provided. If no bail is provided then lift by sling. Compressors are to be air lifted by helicopter must not be supported by the lifting bail, but by slings instead.
- Prior to lifting, inspect lifting bail and points of attachment for cracked welds and for cracked, bent, corroded, or otherwise degraded members and for loose bolts and nuts.
- Make sure entire lifting, rigging and supporting structure has been inspected, is in good condition and has a rated capacity of at least the net weight of the compressor plus an additional 10 % allowance for the weight of mud or stored tools and equipment. If you are unsure of the weight, then weigh compressor before lifting.
- Make sure lifting hook has a functional safety latch, or equivalent, and is fully engaged and latched on the bail.
- Use guide ropes or equivalent to prevent twisting or swinging of the machine once it has been lifted clear off the ground.
- Do not attempt to lift in high winds.
- Keep all personnel out from under and away from compressor when it is suspended.
- Lift compressor no higher than necessary.
- Keep lift operator in constant attendance whenever compressor is suspended.
- Set compressor down only on level surfaces capable of supporting at least its net weight plus an additional 10 % allowance for the weight of mud or stored tools and equipment.

CHAPTER 4

LITERATURE SURVEY

In ELGI EQUIPMENTS the management has 'quality circle' groups in which the workers are divided into a number of groups. Each quality circle group is expected to carry out a project once in six months. As per the past records many projects have been carried out in various departments. A project was carried out in TRC1000 MN compressor.

In that project the workers concentrated on design of the coupling because the alignment of the top block with motor consumed a lot of the assembly time. So they worked on the design and successfully came out with an alternate design. In this design the alignment need not be checked instead it can directly be coupled together. This design has been approved in the company and presently it is in the testing phase.

A similar project was undertaken to improve the productivity at Boeing Corporation Chicago in which U shaped assembly was used to reduce the cycle time. The case study is explained below.

4.2 A Case Study at Boeing Corporation (Chicago)

When the Boeing Co.'s (Chicago) Mesa, AZ, manufacturing facility began its transition to assembling the next-generation AH-64D Apache Longbow helicopter in 1998, the assembly operation's overall performance declined and cycle times increased.

Deploying lean concepts including high-performance work teams turned things around dramatically for the Boeing facility, which to date has delivered nearly 1500 Apache Longbow helicopters for the US Army and 10 international customers. Implementing lean techniques adopted by Boeing in the late 1990s allowed the Arizona helicopter manufacturer to reduce final assembly, integration, and test hours per aircraft by 85% over the past five years, Last March, the Mesa facility's performance helped win the prestigious Shingo Prize for Manufacturing awarded annually by the College of Business at Utah State University (Logan, UT).

In 1998, Jim Luby, manager, Quality and Lean Enterprise, at the Boeing facility in Mesa realized that performance was going down, while recalling the Mesa operation's transition to the next-generation Apache. All the numbers, like cycle time, cost, were headed the wrong way. Every aircraft literally took longer than the last one, and one would think when applying normal learning, that shouldn't be.

Reducing costs and eliminating waste, the Boeing plant initially installed a single lean pulsed production line to manufacture the Longbow helicopter. With its lean framework, the facility uses an enterprise value stream process that identifies the key processes associated with Apache production, managing how work is done. The system allows the flexibility to meet customer demand by providing necessary resources to mechanics at point of use, and working to standard repeatable processes that enable a single-piece flow.

At the 2-million square ft (186,000 m^2) manufacturing facility in Mesa, Boeing employs about 4500 people using the lean manufacturing techniques of the Boeing Production System, which integrates processes, people and tools into the manufacturing support systems. The Mesa facility is a component of Boeing's Integrated Defense Systems (IDS), a $30.5 billion business with more than 78,000 employees.

With approximately 64,000 ft2 (5952 m^2) of manufacturing space devoted to Apache assembly, the Boeing helicopter team has shown dramatic improvements in manufacturing metrics since implementing lean in 1999, including on-time delivery of 100% and overall production hours per aircraft reduced more than 48%. The facility also reduced manufacturing cycle time more than 40% over the past six years since 1998. With deployment of a new U-shaped assembly line, Boeing has achieved even lower cycle times since winning the Shingo award in early 2005.

Implementing lean also helped the Mesa site reduce the number of internal defects more than 58% since 2000 while the cost of internal defects (rework, repair and scrap) declined more than 61% in that timeframe. Lost workday case rate declined more than 58% since 2000 along with a 76% reduction in the lost workday rate over the past four years since 2000.

Since winning the Shingo Prize, the plant has added to its lean toolbox by revamping the pulsed line into a U-shaped lean assembly line that has further strengthened Boeing Mesa's production capabilities. They have added to the lean process by putting the structural line in the same building with their assembly line, says Ed Koopman, General Manager of the Mesa manufacturing site. Rather than a straight pulsed moving line, it is now a U-shaped line where they do structural modification and assembly in the same building, and they have realized an additional 5 to 8% reduction in cycle time by doing that.

They started looking at the next year, looking at making the next run at the prize as the General Manager Koopman adds that trying to get a little bit more emphasis on the lean process in their structural area, which is bare-bones airplane, green-airplane structure, as opposed to where it comes off the assembly line with all the rotor heads, tails, and guns. They have taken another step in trying to continue the process.

At the time Mesa introduced lean on the shop floor, several lean initiatives were being introduced throughout Boeing, including the early lean work at the Boeing IDS facility in Seattle where the company currently assembles key wing and fuselage assemblies for the next-generation F/A-22 Raptor jet fighter aircraft A number of Mesa managers, including Luby and Janet Riley, Shingo Prize project leader, received training from the Boeing Lean Office, becoming Accelerated Improvement Workshop facilitators, and the facility also started used the Shingijutsu consultants from Japan that had been used previously by Boeing Commercial Aircraft (BCA).

They obviously piggy-backed on that and they had three events over there in a year's time period recalls Luby of working with Shingijutsu's lean consultants.

One of the key things with the Shingijutsu, and it's probably a cultural thing in that one didn't plan on executing weeks to months later, was their idea that this is what one ought to do, get going.

At that time, the Mesa facility needed major changes to the line. They were changing the line, because there on what they'll call a stagnant, stationary 45° line, with all the aircraft down the line, and it wasn't moving Luby adds that basically, if one thinks of a parking lot at the mall, where ever one finds a parking spot, they parked aircraft--obviously, no visible flow. One couldn't get the status of any aircraft. There was a lot of undoing of work.

Once they started to learn some of the tools, some of them had the opportunity to go to Japan-Ed Koopman was one of them, and he got to work in the same factory as Luby worked there, the Hitachi Air Conditioning. Ed looked at the factory and questioned Luby that Hitachi Air Conditioning builds big air conditioners with wires, plumbing, and parts, and they build helicopters with wires, plumbing and parts--why can't they do the same? So they set out to do that on a line, measure their Takt, and measure every aspect of the production, with the help of Shingijutsu, with help from Boeing Commercial Aircraft, on some of the training to implement lean.

A significant emotional event came later that helped push along the Mesa site's implementation of lean, which often can encounter initial resistance from workers unaccustomed to new ways of working. They found it difficult to lean changes. They're talking about the Japanese culture, and individuals have a tendency to not want to do some things because it wasn't invented in their place.

The real significant event out there was when Ed, the site GM, came out to the floor and saw the simulated shop floor, he had to leave for a business trip for about two weeks, and when he gets back, he wanted to see it implemented.

High-performance work teams also helped along Mesa's lean manufacturing adoption. If one doesn't solidify the process on high-performance work teams and the workers will have to work in cells, they were doing nothing more than following the routine planning. By having them work in high-performance work teams, they take the initiative to improve process, and improve the quality.

Prior to doing this, they were building the engine up in a back shop they were having the engine delivered to the workstation, and the engine never fitted properly, because the couplings were bad, or the B nuts didn't work, or the tubes weren't bent right. So they decided to move the engine build-up right next to the aircraft, and the guy who built the engine up had to install it. And after that the engine fitted properly every time. Otherwise, they had to pull it out and start over again.

With lean, one gets tested because people believe it's a flavor-of-the-month type of thing, and if one was not willing to get into the foxhole and test it, and then it would become just another event. It had never happened it wouldn't have unless they had just absolutely pushed this thing.

On the Apache assembly line, Boeing team members work with kitted parts alongside airframes in the lean work cell.

Lean also has helped the Apache line plan different iterations of the helicopter running at the same time on the same line, Luby notes, allowing the factory to build versions for the US Army right next to copies for allied countries.

Those multiple types go down the same line-it's a mixed-model line-so it's sort of like a Toyota line, where they could have Camry's and Corollas going down the line. These are all Apaches, but the work content could be significantly different in some positions, Luby says looking at any aircraft it could be Egyptian, the next one US Army, and the next one Singapore. They all move at the same rate.

It's extremely difficult, if one talks about the fact that if one were to build re-manned aircraft, aircraft that's come back from theater, which has been completely stripped, and new hardware put on them, and they were building new aircraft for their international customers, all of which have different radios, different avionics suites or electronics, and they've built it on the same line, at the same time, in sequence, by just changing the planning and the flow of parts. The people are just the same. They don't care if it's a pink Volkswagen or a black Volkswagen; they've got planning that does that. A lot of airframers won't do that. They will take specialty aircraft that are meant for international customers and take them to a mod center and do them. That's very expensive.

In most instances, the Mesa assembly delivers kitted parts directly to a workstation functioning as a Just-in-Time system except with some major equipment items, like avionics and other major assemblies. The facility also is applying the process to the Apache's electrical products center, where Boeing builds about 3000 electrical assemblies a month here for all Boeing fixed-wing military aircraft including the C-17, F-18, F-15, T-45 aircraft, as well as ground-based missile defenses.

They also build it with a lean process type of thought process. It doesn't go on a moving line, but it's really process-driven, wherein one has all of the processes consolidated on electrical assemblies in the one area that then goes into unique customer requirements.

Boeing Mesa's lean advances have earned it top honors in the Boeing-wide company lean assessments over the past four years, with the next ranking due out in December. And in addition to the site winning the Shingo Prize for manufacturing this year, the Boeing Mesa team also was the sole recipient of the Shingo HR Medallion award given to the one manufacturing facility recognized for the best human resources practices in support of lean manufacturing processes.

It's important because this is about leadership, about leaders leading, creating the vision, and about people executing. As seen in the above case study changing the age-old group assembly process to line or U shaped assemblies would definitely bring down the cycle times and hence increase the productivity.

CHAPTER 5

EXISTING ASSEMBLY

5.1 STEPS IN EXISTING ASSEMBLY

Group assembly is one of the traditional methods by which assembling of components is been carried out. In ELGI they follow this group assembly process for most their products.

They follow group assembly process for the manufacture of TRC1000 MN compressor. In this process, based on the marketing forecast and priority Planning (MRP) production orders are released to the shop floor.. After knowing the requirement the stores releases the materials against the released production orders. All the materials are first collected from the stores and brought to the assembly area. After the required materials arrival the assembly process is started. In this process the whole assembly is carried out in a single place.

The following steps describe the step by step assembly process of TRC1000 MN compressor.

- Ensure cleanliness of machined faces in the basess
- Assemble the alignment adjustor bolts M10x45
- Disassemble the coupling entirely
- Ensure motor seating face is burr free and place it on the base
- Apply servo 150 oil on the shaft and fan bore. Place the key on the shaft and press until it seats on the surface
- Guide and push the fan gently on the shaft with nylon hammer
- Tighten the screw rod with motor shaft
- Place the pusher guide between the fan and the pusher
- Open the air and oil lines in the pusher
- Assemble the grease seal on the OD of the motor side coupling hub and guide it
- Use hydraulic pusher to push the motor side hub along with the fan
- Lock the fan and coupling on the motor shaft
- Turn the motor with shaft projecting inside

- Assemble the motor with the base
- Ensure that seating face of top block is clean and place it over the base
- Place the key on the shaft and press it until it seats on the groove of the shaft
- Lock the top block in the base
- Guide the compressor side coupling on the shaft and key
- Assemble screw rod of the pusher to shaft
- Place the guide between screw rod and nut
- Tighten the nut until coupling seats on the step in the shaft
- Assemble the end disc and lock with hex bolt
- Turn the top block to face the motor shaft
- Maintain a gap of 0.08 mm between coupling faces along the rank
- Assemble a piece spring connecting the coupling halves to facilitate rotation during alignment checking
- Fix the dial mounting on one of the coupling bolt and make the dial tip to touch the OD of the other half of the coupling
- bring the dial to LHS/RHS side of the motor and make zero
- Rotate the shafts and observe the reading at the opposite
- Adjust the motor and top block cross wise perpendicular to crank axis to bring dial reading within 0.08mm
- Bring the dial to the top side and make zero
- Rotate the shafts and observe the reading at the bottom
- Adjust motor and top block by adding suitable shims to bring dial reading within 0.08mm
- Bring the dial to the top and make zero
- Observe the readings at the 90 degrees interval in full rotation within 0.08mm and remove dial
- Torque the motor and top block mounting bolts
- Install stopper bolts on the motor and top block
- Apply Servo RR3 grease on the coupling
- Install the coupling cover and fasten it bolts

- Install 3 intercooler posts on the base using hex bolts
- Install the after cooler in the base
- Install the 1 " ermetos on the intercooler and after cooler
- Install the interconnecting pipes LP1,LP2,ac inlet and delivery pipes

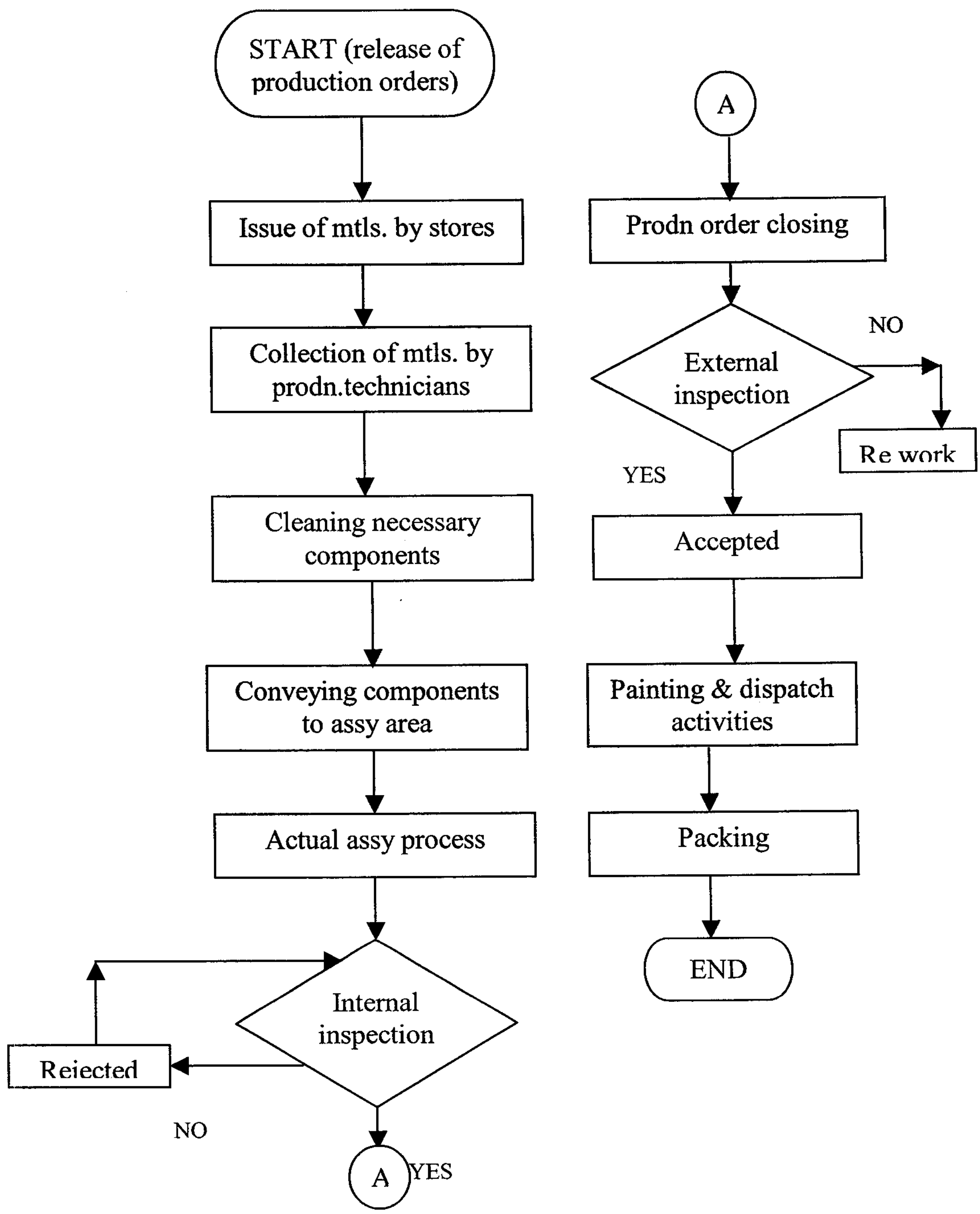

FIGURE 5.1 EXISTING ASSEMBLY PROCESS FLOW CHART

The above flow chart Fig. 5.1 clearly shows sequence of the existing assembly process. It starts of with the release of production order. Based on the order the stores issue the required material to the assembly shop. Then the materials are collected by the production technicians. After the arrival of materials it is cleaned to ensure a smooth flow of the assembly. Conveying equipments like crane, hydraulic lift, etc. are used for bringing the materials to the assembly area. From this point the assembly follows the sequence mentioned in the above list. On the completion of the assembly the compressor is moved to the testing area for internal testing. Internal testing is done by the ELGI itself. Defective components are rejected and sent back for rectifying the defect. After completing the assembly of the required numbers the production order is closed and sent it is sent for external inspection. External inspection is done after the completion of the production order by authorities from the Railways. The approved compressors are sent to the pre- final phase of painting and dispatch. Then finally the compressors are packed and kept ready for transportation.

5.2 Work study

The time taken by the existing assembly process is recorded officially by the FEPCOT, a state government enterprise. The following series of tables (5.1 to 5.14) shows elaborately the time taken for each activity to the minute details.

TABLE 5.1 SUMMARY OF STANDARD TIME

SUMMARY OF STANDARD TIME: TRC1000MN						
S.no	**Operation description**	**Std.Time (mins)**	**Man occu.**	**Total time (man min)**	**Over lap%**	**Thru' put time**
1	Pre-painting	27.47	1.00	27.47	0.00	27.47
2	Material collection	24.36	2.00	48.72	0.00	24.36
3	Base and motor assembly	26.26	2.00	52.52	0.00	26.26
4	Top block assembly and aligning	109.68	1.76	193.30	0.00	109.6
5	Cooler assembly	26.43	1.44	38.00	0.00	26.43
6	Pipes assembly	34.77	1.00	34.77	0.00	34.77
7	Unit testing	27.41	1.10	30.15	0.00	27.41
8	No load run	30.00	1.00	30.00	0.00	30.00
9	Full load run	60.00	1.00	60.00	0.00	60.00
10	Q C inspection	8.53	1.86	15.83	0.00	8.53
11	Name plate assembly	10.65	1.00	10.65	100.00	0.00
	External inspection					
12	Finishing work	40.42	1.00	40.42	0.00	40.42
14	Finish painting	30.13	1.00	30.13	0.00	30.13
15	Final inspection	5.79	1.00	5.79	0.00	5.79
16	Packing	48.01	2.00	96.02	0.00	48.01
	TOTAL	**509.91**		**713.77**		**433.26**

TABLE 5.2 STANDARD TIME FOR PRE – PAINTING

S.no	Activity description	Normal time (mins)	Relaxn alwans (%)	Std. Time	Crew	Cycle Time (man mins)
1	Clean by thinner, waste, emery, air, mix the paint, fill the gun and paint the following items.					
	i. Base frame	7.17	18.0	8.46	1	8.46
	ii. Fan pulley	5.75	18.0	6.79	1	6.79
	iii. Top block	6.75	18.0	7.97	1	7.79
	iv. Cooler posts (3.nos)	2.50	18.0	2.95	1	2.95
Total time (minutes)				**26.16**		**26.16**
Contigency& interference allowance@5%				**1.31**		**1.31**
Grand total time (mins)				**27.47**	**1.00**	**27.47**

TABLE 5.3 STANDARD TIME FOR MATERIAL COLLECTION

S.no	Activity description	Normal time (mins)	Relaxn alwans(%)	Std. Time	Crew	Cycle Time (man mins)
1	Bring the base,top block,motor and all the other required/available material to the workspot from its location and keep them ready for assembly	20.00	16.0	23.20	2	46.40
Total time (minutes)				**23.20**		**46.40**
Contingency & interference allowance @ 5%				**1.16**		**2.32**
Grand total time (mins)				**24.36**	**2.00**	**48.72**

TABLE 5.4 STANDARD TIME FOR BASE WITH MOTOR ASSEMBLY

S.no	Activity description	Normal time (mins)	Relaxn alwans (%)	Std. Time	Crew	Cycle Time (man mins)
1	Retape the base, assemble the bolts, clean the motor base, position the motor on the base. Dismantle the bibly coupling ,clean the motor shaft, assemble fan pulley with motor shaft and assemble coupling with the motor shaft	21.58	16.0	25.01	2	50.02
Total time (minutes)				**25.01**		**50.02**
Contingency & interference allowance @ 5%				**1.25**		**2.50**
Grand total time (mins)				**26.26**	**2.00**	**52.52**

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TABLE 5.5 STANDARD TIME FOR TOP BLOCK ASSEMBLY WITH BASE AND ALIGNING

S.no	Activity description	Normal time (mins)	Relaxn alwans(%)	Std.Time	Crew	Cycle Time (man mins)
1	Clean top block shaft and assemble coupling	6.75	16.0	7.83	2	15.66
2	Position the top block on base and assemble the bolts	2.80	16.0	3.25	2	6.50
3	Align the bibly coupling by using feeler gauge and straight piece	59.10	16.0	68.56	2	137.11
4	Apply grease on coupling spring and assemble the cover	15.00	16.0	17.40	1	17.40
5	Retap the stopper bolt holes and assemble the bolts	6.40	16.0	7.42	1	7.42
Total time (minutes).				**1.04.46**		**184.09**
Contingency & interference allowance @ 5%				**5.22**		**9.20**
Grand total time (mins)				**109.68**	**1.76**	**193.30**

TABLE 5.6 STANDARD TIME FOR BASE WITH COOLER ASSEMBLY

S.no	Activity description	Normal time (mins)	Relaxn alwans(%)	Std.Time	Crew	Cycle Time (man mins)
1	Retap the cooler post assembly holes and assemble the posts	11.20	16.0	12.99	1	12.99
2	Lift the cooler, position it on the posts, assemble bolts. position the fixture, tighten the bolts and remove the fixture	6.00	16.0	6.96	2	13.92
3	Position the after cooler and assemble it with the base	3.50	16.0	4.06	2	8.12
4	Assemble lifting hook rod	1.00	16.0	1.16	1	1.16
Total time (minutes)				**25.17**		**36.19**
Contingency & interference allowance @ 5%				**1.26**		**1.81**
Grand total time (mins)				**26.43**	**1.44**	**38.00**

TABLE 5.7 STANDARD TIME FOR PIPES ASSEMBLY

S.no	Activity description	Normal time (mins)	Relaxn alwans(%)	Std.Time	Crew	Cycle Time (man mins)
1	Remove the plastic end caps and unpack the pipes	3.00	16.0	3.48	1	3.48
2	Clean the holes and assemble ermeto nipples	3.90	16.0	4.52	1	4.52
3	Assemble the side pipes (4. nos)	8.5	16.0	9.92	1	9.92
4	Position the centre pipes,mark,cut,fix cone/ nut and assemble	6.60	16.0	7.66	1	7.66
5	Assemble safety values (3.nos)	3.00	16.0	3.48	1	3.48
6	Assemble oil based air filters and fill the oil	3.50	16.0	4.06	1	4.06
Total time (minutes)				**33.12**		**33.12**
Contingency & interference allowance @ 5%				**1.66**		**1.66**
Grand total time (mins)				**34.77**	**1.00**	**34.77**

TABLE 5.8 STANDARD TIME FOR UNIT TESTING

S.no	Activity description	Normal time (mins)	Relaxn alwans(%)	Std.Time	Crew	Cycle Time (man mins)
1	Carry out wiring and connect power	9.80	16.0	11.37	1	11.37
2	Switch- on the unit, run and check the suction (no load run for 30 mins)	3.20	16.0	3.71	1	3.71
3	Assemble the tank with the unit	2.25	16.0	2.61	2	5.22
4	Check the current, filling time .RPM , leak and write down all the details in built up record card	7.25	16.0	8.41	1	8.41
Total time (minutes)				**26.10**		**28.71**
Contingency & interference allowance @ 5%				**1.31**		**1.44**
Grand total time (mins)				**27.41**	**1.10**	**30.15**

TABLE 5.9 STANDARD TIME FOR Q C INSPECTION

S.no	Activity description	Normal time (mins)	Relaxn alwans(%)	Std.Time	Crew	Cycle Time (man mins)
1	Check the current . filling time ,RPM , and write down all the details in built up record card	6.00	16.0	6.96	2	13.92
2	Dismantle the power connections , tank and keep it aside	1.0	16.0	1.16	1	1.16
Total time (minutes)				**8.12**		**15.08**
Contingency & interference allowance @ 5%				**0.41**		**0.75**
Grand total time (mins)				**8.53**	**1.86**	**15.83**

TABLE 5.10 STANDARD TIME FOR NAME PLATE ASSEMBLY

S.no	Activity description	Unit	Frequency	Normal time (mins)	Relaxn alwans (%)	Std. Time	Crew	Cycle Time (man mins)
1	Punch the specification on the name plates , position it ,mark , punch ,drill and rivet (2 nos-specs-1 No & Ratation Direction -1 No)			8.74	16.0	10.14	1	10.14
	Total time (minutes)					**10.14**		**10.14**
	Contingency & interference allowance @ 5%					**0.51**		**0.51**
	Grand total time (mins)					**10.65**	**1.00**	**10.65**

TABLE 5.11 STANDARD TIME FOR FINISH PAINTING

S. no	Activity description	Normal time (mins)	Relaxn alwans (%)	Std. Time	Crew	Cycle Time (man mins)
1	Mask the safety valve by paper tape and clean the unit by emery	7.05	16.0	8.18	1	8.18
2	Clean the unit by air	0.75	16.0	0.87	1	0.87
3	Apply grease on the name plates	1.00	16.0	1.16	1	1.16
4	Mix the paint ,fill the gun and spray	6.00	16.0	7.08	1	7.08
5	Cover the motor ,spray black paint for cooler	1.80	16.0	2.12	1	2.12
6	Apply black paint for pipes and breather by brush	5.50	16.0	6.38	1	6.38
7	Apply red paint to dipstick top and oil drain plug	0.75	16.0	0.87	1	0.87
8	Paste the logo sticker	1.00	16.0	1.16	1	1.16
9	Remove the mask and clean the name plates	0.75	16.0	0.87	1	0.87
Total time (minutes)				**28.69**		**28.69**
Contingency & interference allowance @ 5%				**1.43**		**1.43**
Grand total time (mins)				**30.13**	**1.00**	**30.13**

TABLE 5.12 STANDARD TIME FOR FINISHING WORK

S.no	Activity description	Normal time (mins)	Relaxn alwans (%)	Std. Time	Crew	Cycle Time (man mins)
1	Assemble filter pipe clamp (2nos) and discharge pipe clamp(1 no)	3.60	16.0	4.18	1	4.18
2	Cut the wire mesh ,position it inside the oil inlet ,insert circlip and close it	2.48	16.0	2.88	1	2.88
3	Remove the screws of the oil inlet cover ,position the chain with clamp ,fix the screws ,dismantle bolt in the top block ,position the washer at the other side of the chain , and assemble the bolt	2.70	16.0	3.19	1	3.19
4	Seal the safety valve	0.75	16.0	0.87	1	0.87
5	Clean air filter rubber bush ,insert it ,assemble end caps and affix tape	0.75	16.0	0.87	1	0.87
6	Position the pulley guard, place the square lock washer, assemble and fold the square washers	4.00	16.0	4.64	1	4.64
7	Assemble discharge flange with elbow and assemble them with discharge pipe	3.38	16.0	3.99	1	3.99
8	Drain the oil from air filter ,clean them ,write the sticker ,paste the sticker and keep them aside	4.00	16.0	4.64	1	4.64
9	Dismantle the oil inlet pipe ,assemble dummy plug and keep the pipe at the top	0.75	16.0	0.89	1	0.89

10	Position the name plates on the pulley guard , mark, punch, drill the rivet the name plates	10.66	16.0	12.37	1	12.37
Total time (minutes)				**38.50**		**38.50**
Contingency & interference allowance @ 5%				**1.92**		**1.92**
Grand total time (mins)				**40.42**	**1.00**	**40.42**

TABLE 5.13 STANDARD TIME FOR FINAL INSPECTION

S.no	Activity description	Normal time (mins)	Relaxn alwans (%)	Std.Time	Crew	Cycle Time (man mins)
1	Check painting quality, markings, stickers etc.and prepare the packing note	4.75	16.0	5.51	1	5.51
Total time (minutes)				**5.51**		**5.51**
Contingency & interference allowance @ 5%				**0.28**		**0.28**
Grand total time (mins)				**5.79**	**1.00**	**5.79**

TABLE 5.14 STANDARD TIME FOR PACKING

S.no	Activity description	Normal time (mins)	Relaxn alwans (%)	Std. Time	Crew	Cycle Time (man mins)
1	Mark the wooden plank, nail bottom reapers ,drill, position the base bolts ,position the unit on the plank ,keep the oil can inside ,strap it, assemble base bolt nuts, tighten them, cover the unit by polythene sheet ,keep the packing note and other required items inside, position the side/top planks, nail them and write down the unit no. on the sides of the wooden box	38.75	18.0	45.73	2	91.45
Total time (minutes)				**45.73**		**91.45**
Contingency & interference allowance @ 5%				**2.29**		**4.57**
Grand total time (mins)				**48.01**	**2.00**	**96.02**

5.3 LIMITATIONS IN THE EXISTING PROCESS

The existing process has certain limitations and among them the following three problems were taken for the study.

- **More Amount Of Crane Work**

Some of the parts used for the assembly are heavy so it is difficult to handle them manually. Only one crane is available for this particular assembly process. At a particular time more than one assembly will be taking place, so when the crane is operated by one person others have to wait for the crane. This results in unnecessary idle time.

- **Improper Handling Of Tools And Materials**

The materials that are required for assembling are not kept in the appropriate places. The workers spend lot of time in gathering the materials. Even the tools are kept in a single rack without any proper arrangement. This results in the workers spending time for searching the tools.

- **Non Value Added Activities**

Any activity that does not add value for the end product is a non value added activity. The paint in base of the top block and the motor has to be removed before assembling. The intercooler and aftercooler are cleaned by running the compressor in no load condition. These activities add no value to the product and by avoiding such activities the time spent will be considerably reduced leading to better productivity.

CHAPTER 6

PROPOSED ALTERATIONS

6.1 RECOMMENDED CHANGES

To eliminate the existing problems and to improve the rate of production , the following changes are recommended .

- Changing the group assembly process to line assembly process
- Developing a 3 work station line assembly
- Proper tool and material handling
- Use of a trolley to facilitate movement of the compressor unit along the line

6.2 LINE ASSEMBLY

To convert the group assembly to line assembly process the time required for the individual processes has to be recorded so that the activities can be segregated.

The work study was performed and the takt time was fixed as 45 minutes. With this time the activities were segregated and a 3 station line assembly was formed. The materials and tools required for the corresponding workstation were arranged and kept to the convenience of the workers. By this way the time spent for searching the tools and the time spent on collecting the materials is completely eliminated. The following page shows the Table 6.1 for work study. Based on the work study the processes, tools and materials for each work station are shown in Table 6.2 , Table 6.3, Table 6.4 in the subsequent pages.

TABLE 6.1 WORK STUDY

S. no	Operations	Time in min	No. of persons
	Work station-1		
1	Cleaning of base	5.48	1
2	M10 x 45 bolts 4 nos	5.00	1
3	Removing the spring and disassembling the coupling	5.00	1
4	Cleaning the motor base	2.40	1
5	Cleaning of top block base	2.20	1
6	Assembly of coupling with top block	5.15	1
7	Assembly of fan and coupling with motor	11.05	1
8	Allowance (10%)	4.00	
	Total time	**40.28**	
	Work station-2		
1	Aligning of coupling and tightening of bolts	36.51	2
2	Putting spring , applying grease and putting cover	15.17	1
3	Allowance time (10%)	5.20	
	Total time	**56.88**	
	Work station-3		
1	Assembly of post, intercooler and after cooler	30.00	1
2	Allowance time (10%)	3.00	
	Total time	**33**	

PROCESSES IN THREE WORK STATIONS

TABLE 6.2 PROCESSES IN THREE WORK STATIONS

WORK STATION – 1	WORK STATION – 2	WORKSTATION - 3
Cleaning of base M10 *45 bolts- 4 nos. Disassembling the coupling hub and removing the spring Assembly of coupling hub with top block Cleaning of motor base Cleaning of top block Assembly of fan and coupling with motor	Aligning of coupling Assemble a piece spring connecting the coupling halves to facilitate rotation during alignment checking Checking with dial gauge Tightening of bolts Insertion of spring Applying grease Place the cover	Install 3 intercooler posts on the base Install the inter cooler and after cooler in base Install the interconnecting pipes lp_1,lp_2,ac inlet and delivery pipes
Total Time : 45 min	Total Time : 45 min	Total Time : 45 min

TOOLS IN THREE WORK STATIONS

TABLE 6.3 TOOLS IN THREE WORK STATIONS

WORK STATION – 1	WORK STATION – 2	WORKSTATION - 3
12 -13 double end	Dial gauge	12-13 double end
18 -19 double end	Mirror	16 box bit
Nylon hammer	18-19 double end	Loctite 246
46 spanner, 1” spanner	50 lb ft torque wrench	1 “ spanner
16 -17 double end	Piece spring	Pneumatic tools
M8 12 -13 double end		
M10 16-17 double end		
Hydraulic pusher crane		
Total Time : 45 min	Total Time : 45 min	Total Time : 45 min

TABLE 6.4 MATERIALS IN THREE WORK STATIONS

WORK STATION – 1	WORK STATION – 2	WORKSTATION - 3
Base	Spring	Inter cooler
Motor	Shims	After cooler
Top block	Grease	3 posts of inter cooler
Servo 150 oil	Coupling cover	Connecting pipes
Coupling of motor	Spring	Safety values
Fan on motor side		
Coupling of top block		
Total Time : 45 min	Total Time : 45 min	Total Time : 45 min

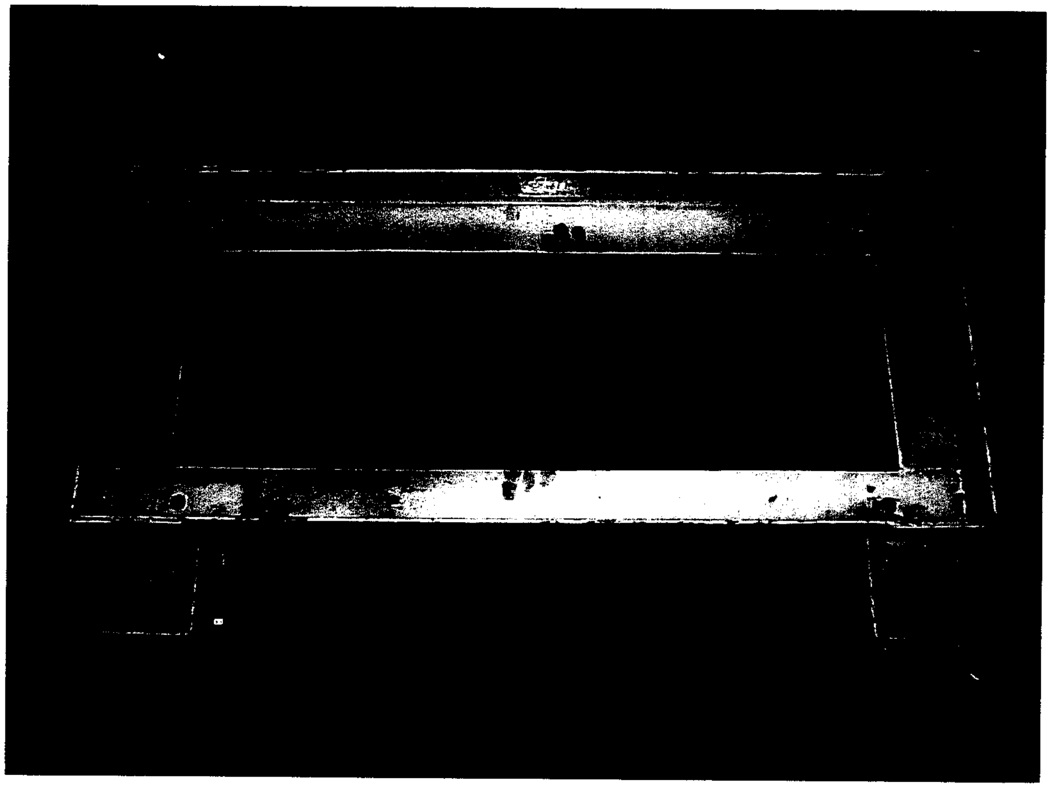

FIGURE 6.1 FABRICATED TROLLEY

6.4 NON VALUE ADDED ACTIVITY

In the assembly process two non value added activities were identifieds.

- Removal of paint from the base of top block and motor.
- Cleaning the intercooler and aftercooler by running the compressor in no load condition for 30 minutes.

In order to avoid removing the paint a suggestion was given to use a **sticker** at the base during the painting process, so that it can easily pealed off during the assembly. It saves the time consumed for cleaning activity.

In order to remove the dust in the intercooler and overcooled the compressor is made to run in the no load condition for 30 minutes. It has been suggested to the clean it before the starting of the assembly i.e. the no of intercooler and aftercooler as per the month's requirement is cleaned and openings are sealed and kept at the beginning of the month itself. This way of cleaning requires only 2 minutes and it also saves a considerable amount of electricity.

CHAPTER 7

CONCLUSION

7.1 RATIOCINATION

The problems in the existing assembly of the compressor were studied and suggestions were given to improve the productivity. After the success of the trial implementation the company had agreed for a full fledged implementation. The activities were segregated to three work stations and the takt time was fixed to approximately 45 minutes. The trial implementation of this line assembly has shown a drastic improvement in the productivity.

With the reduction in the usage of crane the idle time of the workers is avoided. The usage of trolley along the line has facilitated the movement of the heavy compressor unit. The guide pins provided in the trolley facilitates the location of the base, further the wheels being extended outside the frame helps in stacking of the trolleys when they are not in use.

By the proper arrangement of the tools and materials the time consumed for searching them has been eliminated. By cleaning the intercooler and the aftercooler before the start of the assembly the power consumption is considerably reduced. In a nut shell the implementation of line assembly has resulted in 100 % improvement in production as shown below and it is also depicted graphically in Figure 7.1

- Present production rate per day - 4 units with 4 persons
- Production per day after implementation - 8 units with 4 persons
- Improvement in production - 100%

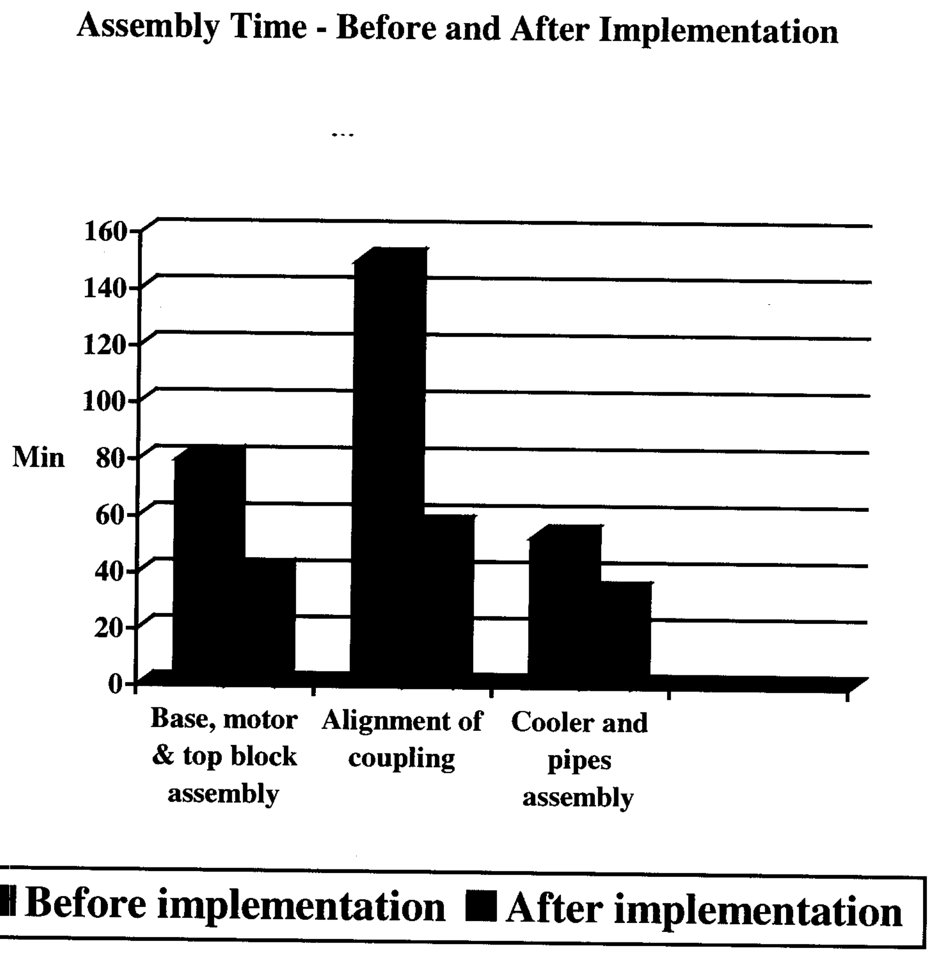

FIGURE 7.1 ASSEMBLY TIME – BEFORE AND AFTER IMPLEMENTATION

7.2 FUTURE WORK

Anything in its early stage has wide openings and flexibility to incorporate further refinements so that it can emerge as a better one. It is very similar to a child at early ages of its life very eager to learn new things and molding itself to become a better human being. In this project the existing group assembly process has been converted into line assembly process. Since it is being implemented for the first time, it is flexible to accept changes.

At present in ELGI they have designed a new coupling for this compressor which is under the testing phase. If comes out successfully the cycle time will further get reduced. The line can easily accept lot of changes until it is automated. The line can further be streamlined by advanced way of tool and material handling. Once the streamlining process becomes saturated we can go for automating it. It is the upper extreme of future work and it will take productivity to great heights.

Without improvement man could not have climbed up the ladder of civilization right from the Stone Age to the world of Nanotechnology. There are no boundaries, everything in this world keeps on changing and the world will become more and more sophisticated.

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