PROCESS PLANNING AND ASSEMBLY LINE BALANCING USING RPW TECHNIQUE

UNDERGONE IN

SHANTHI MACHINE TOOLS Pvt. Ltd.,
AVINASHI, COIMBATORE.

A PROJECT REPORT

Submitted by

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In partial fulfillment for the award of the degree
Of

Bachelor of Engineering
In
Mechanical Engineering

DEPARTMENT OF MECHANICAL ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY

Coimbatore - 641 006.

ANNA UNIVERSITY :: CHENNAI 600 025

APRIL - 2009

ANNA UNIVERSITY : CHENNAI 600 025

BONAFIDE CERTIFICATE

Certified that this project report entitled **"Process Planning And Assembly Line Balancing Using Ranked Positioned Weight Technique"** is the bonafide work of

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Coimbatore - 641 006

Shanthi Machine Tools Private Limited

SMT

ISO 9001 Certified

CE Marking as per PED 99/25/EC

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Phone : +91 – 422 – 2563360,2218948,211043

REF: SMT/HRD/PRO-04/04/09 12/04/2009

CERTIFICATE

We hereby certify that MR. P.AJAY (71205114003) (Final Year-BE Mech.) KUMARAGURU COLLEGE OF TECHNOLOGY, COIMBATORE-641 006 has successfully completed the project "PROCESS PLANNING AND ASSEMBLY LINE BALANCING USING RANKED POSITIONED WEIGHT TECHNIQUE" in our industry from 02.01.2009 to 31.03.2009

During the above mentioned period, his conduct and character were found to be Good. We appreciate his creativity in handling the key areas of the project.

The management wishes him for his bright future.

For Shanthi Machine Tools Private Limited

SRI MOOKAMBIKA AGENCIES

PARTNER

General Manager

Shanthi Machine Tools Private Limited

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COIMBATORE , TAMILNADU

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ADVANCES IN MECHANICAL SCIENCES

CERTIFICATE

This is to certify that Mr/Ms P. AJAY

as participated and presented a paper entitled Process planning and assembly line balancing using RPW technique

in the 3rd National Conference on "ADVANCES IN MECHANICAL SCIENCES" during 26- 27, March 2009.

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VICE PRINCIPAL

ABSTRACT

Increasing competition in global market scenario, urge companies to go for modern concepts of operational management. To compete in market, the companies strive to achieve optimum results at all levels. Time management has now become a mandatory one for survival in market. In the times of 'The great economic depression' in U.S.A which shook the entire automotive industry, a nascent company called Toyota reinvented many optimization techniques under a common name called 'Toyota Production System'. Though it didn't make a good first impression, it came to the lime-light when for the first time Toyota was ranked no.1 by J.D Powers. Line balancing is one of the most effective optimization tools in TPS.

This project seeks to optimize the 'Pressure Transducer' assembly line at SHANTHI MACHINE TOOLS Pvt. Ltd. using state-of-the-art procedures. The output target of the company had to be increased without compromising on Quality and Delivery Time. The assembly line was optimized taking into account the machining times, number of early jobs, total requirement, tag time etc.. A hybrid approach is followed to optimize the above parameters. A near optimum solution is found out using a newer technique. First a precedence graph was plotted based on which RPWT was carried out.. This undertaking also attempts to incorporate the various subassemblies into the line and balance it as a single unit. It is to be noted that this was never done before and this is a novel attempt. This was done for three different variants assembled on the same line. As a result, the production rate was improved from 350 components per day to 500 components a day, as per the firm's requirement. The line efficiency thus attained were 92.3% .

Keywords:

Line balancing, RPWT (Ranked Positional Weight Technique), Precedence graphs, optimization, time management.

ACKNOWLEDGEMENT

We owe our sincere thanks to all our elders, our parents, teachers and d Almighty who have bestowed upon us their generous blessings in all eavors.

We are ever indebted to our guide **Dr. Palanisamy**, Kumaraguru College Technology, Coimbatore for his excellent, constructively critical guidance, nost motivation, valuable advice, untiring support, timely suggestion, nstant encouragement enthusiasm, relentless patience, continued keen interest d inspiration throughout the study, holding us in all the places we faltered. If t for him, this thesis wouldn't have seen light of the day.

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We wish to express our deep sense of reverential gratitude to **rof.R.Annamalai**, Vice-Principal, Kumaraguru College Of Technology, oimbatore, for the ample facilities made available for completion of project.

We also express our heartfelt thanks to **Mr. T. Srinivasan**, Head of ndustrial Engineering Department of SHANTHI MACHINE TOOLS Pvt. Ltd., Coimbatore who guided and supported us throughout the project.

We sincerely thank all the Staff Members of Department of Mechanical Engineering, Kumaraguru College of Technology, Coimbatore for being upportive and understanding.

Our love and overwhelming thanks are due to our parents and friends who helped us to complete this study.

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LIST OF SYMBOLS, ABBREVATIONS AND NOMENCLATURE

RPWT	Ranked Positional weight technique
SMT	Shanthi Machine Tools Pvt. Ltd.
CAPP	Computer Aided Process Plan
OP.No	Operation Number
T	Total Work time
C_{max}	Maximum allotted time
C	Maximum time required to complete a product cycle
N	No. of workstations
η	Efficiency of the line

ABOUT THE COMPANY

ABOUT THE COMPANY

Shanthi Machine Tools Pvt. limited was established in 1976 at Coimbatore, Tamil Nadu, India, and commenced manufacturing operations in 1978 in the precision engineering field of industrial pumps. SMT is managed by Mr.T. Srinivasan, supported by a team of professionals.

Today, SHANTHI Machine Tools is the market leader enjoying 23% of the local industrial pump market share.

Shanthi Machine Tools has two manufacturing facilities, one at Nangappa Road and another at Avinashi Road. Between both the plants SMT employs 45 people. SMT specializes in the production of different types of Pumps, Pressure regulators and Pressure transducers.

Plant I located at Avinashi road, 16 kms from Coimbatore, manufactures and services Compressors and submersible pumps.

COMPANY PROFILE:

Plant Area : 580 Sq.yd.

Suppliers : Renuka Castings

Dealers : 1.Mookambika Agencies
2. Krithika Agencies

Total no. of staff: 45

Turnover in year 2007-2008 : Rs. 2.46 Crores

PRODUCTS RANGE

- Air Compressors (1.5 hp-14 hp)
- Submersible Pumps (3 hp-25 hp)
- Monoblock Pumps
- Industrial Pumps
- Grinders.
- Pressure Regulators
- Pressure transducers.
- Piping valves.
- Oil Pumps for two-wheelers, disc Brakes for two-wheelers, textile Counters and Controls, Fare Meters etc.

SMT is a

- ISO 9001 – 2000 Certified for Quality systems by RW TUV NORD, Germany.
- CE Marketing Certified as per PED 97/23/EC/ Module H by RW TUV NORD, Germany.
- API 6D Monogram, API spec Q1, API spec 6D by API- USA (license for manufacture of pipe line valves).
- Approved Steel Casting Manufacturer for Marine Application by KR - Korea.

The implementation of the line balancing techniques is focused to the pressure transducer line in plant I. Pressure transducer is a device used to sense the pressure and to send a signal to one or more actuating elements, so that the pressure can be regulated. This pressure transducer has a rheostat type of arrangement with a movable jockey. This unit comes as three variants namely, 'Single output', 'Two output-with warning light', and 'Two output without warning light'.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO PROCESS PLANNING

- Process planning can be defined as an act of preparing a detailed processing documentation for the manufacture of a piece part or assembly.

- It is understood that the product design for each product has been developed in the design department. To convert the product design into a product, a manufacturing plan is required. The activity of developing such plan is called PROCESS PLANNING.

- Process planning, also known as operations planning, is the systematic determination of the engineering processes and systems to manufacture a product competitively and economically

- According to American society of tool and manufacturing engineers, process planning is the systematic determination of the methods by which a product is to be manufactured economically and competitively

1.2 DETAILS OF PROCESS PLANNING:

A detailed process plan usually contains the route, processes, process parameters, and machine and tool selections.

1.3 INFORMATIONS REQUIRED FOR PROCESS PLANNING:

In order to prepare a process plan, also called as route sheet, the following are required.

1. Assembly and component drawings and bill of materials. This detail give the information regarding the general description of part to be manufactured, raw material specification, dimensions and tolerances required, the surface finish and the treatment required.

2. Machine and equipment details:

(i) The various operations that can be performed

(ii) The maximum and minimum dimensions that can be machined on the machines.

(iii) The accuracy of the dimensions that can be obtained

(iv) Available feeds and spends on the machine

3. Standard time for each operation and details of setup time for each job.

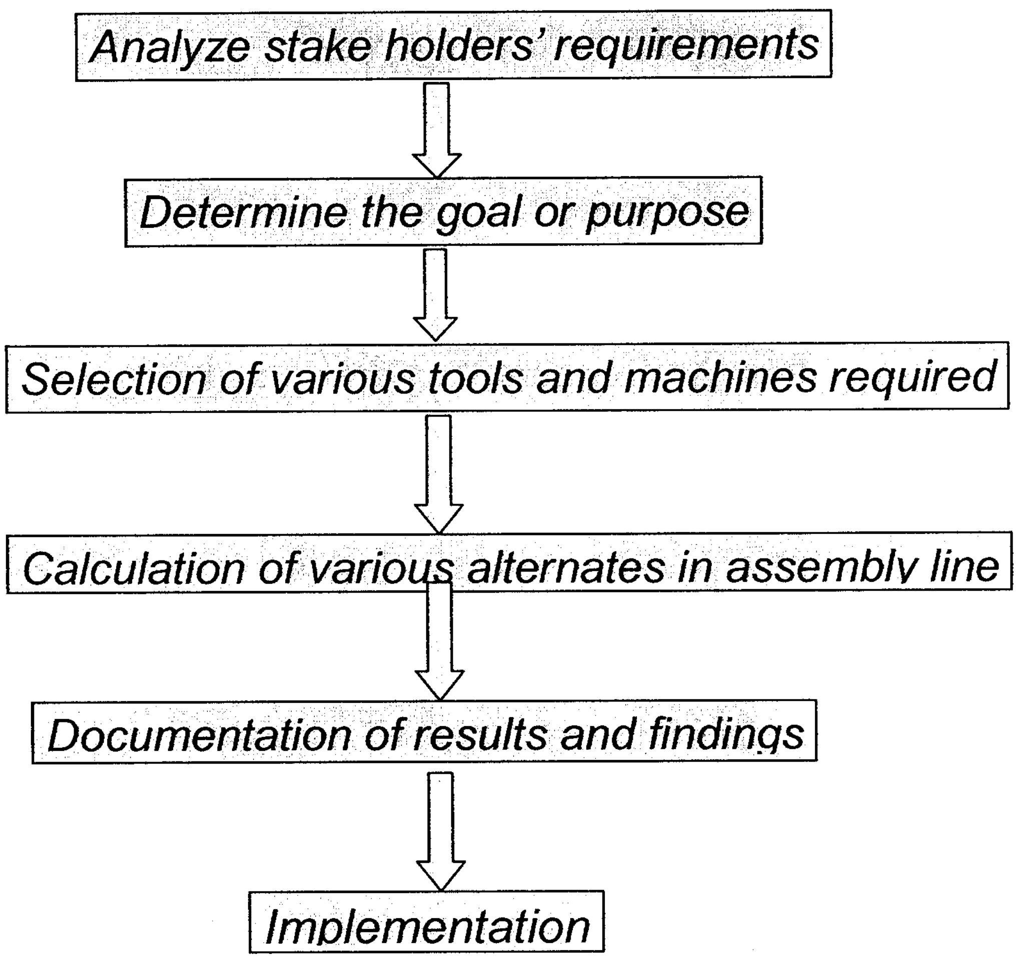
4. Availability of machines, equipment and tools.

1.4 RESPONSIBILITIES OF PROCESS ENGINEER:

The specialists managing the process planning task are called process engineers or process planners. The various responsibilities of a process engineer are given below:

1. Interpreting part print analysis and symbols.
2. Gathering the fundamental details of product design like
    - Type of rough works
    - Dimensional tolerances
    - Type of finish
    - Production time and downtime
    - Scrap losses etc.
3. Selecting the machining processes
4. Selecting proper machining with allied tooling based on the following:
    - (i) Required machine capability
    - (ii) Set up time
    - (iii) Practical lot size
    - (iv) Quality of parts
    - (v) Type of tooling
    - (vi) Quality of tooling
5. Sequence of operations
6. Determining appropriate production tolerances
7. Determining proper cutting tools and cutting conditions
8. calculating overall times using the work measurement techniques

1.5 PROCESS PLANNING ACTIVITIES



1.6 APPROACHES TO PROCESS PLANNING

There are two general approaches to process planning. They include:

1. Manual Process Planning
2. Computer Aided Process Planning[CAPP]

Further the Computer aided process planning can be divided into two types. The two types under the Computer Aided Process Planning include

- Retrival Computer Aided Process Planning system.
- Generative Computer Aided Process Planning system.

We will have a brief glance of these approaches

1.7 MANUAL PROCESS PLANNING:

In traditional process planning systems, the process plan is prepared manually. The task involves examining and interpreting engineering drawings, making decisions on machining process selection, equipment selection, operations sequence and shop practices. Therefore, the manual process plan is very much dependent on the skill, judgement and experience of the process planner. That's why, if different planners were asked to develop a process plan for same part, they would probably come up with different plans.

ADVANTAGES:

(i) This type of approach is very much suitable for small scale companies within few plans to generate

(ii) This method is highly flexible and requires less investment costs

DISADVANTAGES:

(i) This approach is a very complex and time consuming job requiring a large amount of data

(ii) This method requires skilled process planner

(iii) Inconsistant process plans result in reduced productivity. Also increases paper work

1.8 COMPUTER AIDED PROCESS PLANNING [CAPP]:

In order to overcome the drawbacks of the manual process planning, the computer aided process planning (CAPP) is used. With the use of the computers in process planning, once can reduce the routine clerical of manufacturing engineers. Also it provides the opportunity to generate rational, consistent and optimal plans. In addition, CAPP provides the interface between CAN and CAM.

BENEFITS OF CAPP:

- Process rationalization and standardization
- Productivity improvement
- Product cost reduction
- Elimination of human error
- Reduction in time
- Reduced clerical effort and paper work
- Improved legibility
- Faster response to engineering changes
- Incorporation of other application programs

APPROACHES OF CAPP:

1. Retrieval CAPP system
2. Generative CAPP system

RETRIEVAL CAPP SYSTEM:

The retrieval CAPP system, also called as variant CAPP system, has been widely used in machining applications. The basic idea behind retrieval CAPP is that similar parts will have similar process plans. In this system, a process plan for new part is created by recalling, identifying and retrieving an existing plan for similar part, and making the necessary modifications for the new part.

GENERATIVE CAPP SYSTEM:

In this type of approach,the computer is used to synthesize or generate each individual process plan automatically and without reference to any prior plan. A generative CAPP system generates the process plan based on decision logics and pre-coded algorithms. The computer stores the rules of manufacturing and equipment capabilities. When using a system, a specific process plan for a specific part can be generated without any involvement of a process planner.

The human role in running the system includes:

1. Inputting the GT code of the given part design
2. Monitoring and functioning

CHAPTER 2

OBJECTIVES AND PROBLEM DEFINITION

2.1 OBJECTIVE

Today in the international scenario, one of the most severe problems of any company management is the stiff competition it faces.The 21st century is seeing a paradigm shift for Indian Manufacturing industry. Companies looking at local markets are now aiming to be connected with Global markets. To reach out to newer markets and alliances and business opportunities, company's are faced with the hard fact that unless they improve their return on investments, comply with tough regulatory norms and enhanced safety requirements, they will miss the mark The competition may be from old well-known domestic firms or from the ever-prospering foreign competitors. Companies which earlier were competing with each other with stand-alone equipment, lower production costs, and a market scenario where markets were defined by products are now looking at a new era in manufacturing.

Competition is today in terms of value chains, with a lot more emphasis on time and delivery cost to market. Manufacturing firms have to look at a scenario where they have to sense the customers need and respond immediately. The company finds itself in a continuous struggle of survival, which is of immense proportions and complexity. Many companies are facing great challenges in Quality, Reliability and continually rising costs and increased Government Directives and Regulations. Facing world-wide competition of low-costs industries, Indian manufacturing firms need to develop services as a growing source of differentiation and mean of valorisation of the product. Even though industries are aware of the role of services in their competitiveness, they lack of methods for the definition, organisation and assessment of costs of the service offer. Management and monitoring tools are needed to help to move from an industry of “product manufacturing” towards an industry of “customer’s needs satisfaction Due to globalization, entry of multinationals, newer technologies and ruling of World Trade Organization, the goods and services of our Indian origin have to face stiff competition on cost-front. Operational effectiveness, profit pressures require manufacturing to contribute and the industry has to work together to enable a compliant manufacturing environment that delivers product to plan with minimal cost and risk. The role of automation technologies is thus crucial in facilitating processes that enable measurement and control, ensure optimum efficiency and increase productivity.

2.2 PROBLEM IDENTIFICATION

In such a scenario, to meet ever increasing customer demands it becomes imperative for this organization M/s SHANTHI MACHINE TOOLS Ltd to adopt a systematic and structured approach to improve the technology of manufacturing, with aim of providing a holistic framework to meet customer Quality, Delivery and reduce cost. The customer requirement has increased from 350 components a day, to 500 components a day. So the existing station assignment is to be completely changed and the line has to be balanced.

2.3 PROBLEM DEFINITION

To solve the process planning problem that the company faces, a line balancing methodology should be followed to get optimal schedule model. The identified problem consists of 3 types of products made on the same assembly line. Various machining times are to be calculated and no. of work stations required is also to be calculated. RPW technique is used for optimization of the assembly line.

The implementation of the line balancing techniques is focused to the pressure transducer line in plant I. Pressure transducer is a device used to sense the pressure and to send a signal to one or more actuating elements, so that the pressure can be regulated. This pressure transducer has a rheostat type of arrangement with a movable jockey. This unit comes as three variants namely, 'Single output', 'Two output-with warning light', and 'Two output without warning light'.

2.3 LITERATURE SURVEY

- The practical Line balancing is complex and can be implemented only through computer programming.
- In 1966, ARCUS developed a computer method of sequencing operation for Assembly lines (Product line) called COMSOAL.
- In 1973, Dar-E1 developed another computer program to solve line balancing through RPWT. This is called MALB.
- Buxey, in 1974, developed an extended line-balancing program using multiple lines in parallel.

- ‘State-of-the-art exact and heuristic solution procedures for simple assembly line balancing’- *Armin Scholl, Christian Becker (*2003) speaks about the latest techniques and algorithm involved in line balancing.

CHAPTER 3

INTRODUCTION TO PRESSURE TRANDUCERS

Introduction to Pressure Transducers

What is a pressure transducer? A pressure transducer is a transducer that converts pressure into an analog electrical signal. Although there are various types of pressure transducers, one of the most common is the strain-gage base transducer. The conversion of pressure into an electrical signal is achieved by the physical deformation of strain gages which are bonded into the diaphragm of the pressure transducer and wired into a wheatstone bridge configuration. Pressure applied to the pressure transducer produces a deflection of the diaphragm which introduces strain to the gages. The strain will produce an electrical resistance change proportional to the pressure.

A **pressure sensor** measures pressure, typically of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area. A pressure sensor generates a signal related to the pressure imposed. Typically, such a signal is electrical, but optical, visual, and auditory signals are not uncommon.

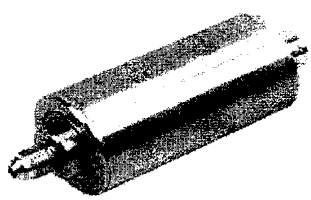
Pressure sensors are used for control and monitoring in thousands of everyday applications. Pressure sensors can also be used to indirectly measure other variables such as fluid/gas flow, speed, water level, and altitude. Pressure sensors can alternatively be called **pressure transducers**, **pressure transmitters**, **pressure senders** and **pressure indicators**, among other names.

Pressure sensors can vary drastically in technology, design, performance, application suitability and cost. A conservative estimate would be that there may be over 50 technologies and at least 300 companies making pressure sensors worldwide.

There is also a category of pressure sensors that are designed to measure in a dynamic mode for capturing very high speed changes in pressure. Example applications for this type of sensor would be in the measuring of combustion pressure in an engine cylinder or in a gas turbine. These sensors are commonly manufactured out of piezoelectric materials such as quartz.

Some pressure sensors, such as those found in speed cameras, function in a binary manner, i.e., when pressure is applied to a pressure sensor, the sensor acts to complete or break an electrical circuit. These types of sensors are also known as a **pressure switches.**

HIGH PERFORMANCE PRESSURE TRANSDUCER:



This transducer has a 10 year MTBF rate and is stable to 0.1% of FSO over an 18 month period, utilizes OMEGA's thin film technology, and the micro-geometry design of the sensing element reduces effects of mechanical vibration and shock.

Electrical Output of Pressure Transducers:

Millivolt Output Pressure Transducers

Transducers with millivolt output are normally the most economical pressure transducers. The output of the millivolt transducer is nominally around 30mV. The actual output is directly proportional to the pressure transducer input power or excitation. If the excitation fluctuates, the output will change also. Because of this dependence on the excitation level, regulated power supplies are suggested for use with millivolt transducers. Because the output signal is so low, the transducer should not be located in an electrically noisy environment. The distances between the transducer and the readout instrument should also be kept relatively short.

Voltage Output Pressure Transducers

Voltage output transducers include integral signal conditioning which provide a much higher output than a millivolt transducer. The output is normally 0-5Vdc or 0-10Vdc. Although model specific, the output of the transducer is not normally a direct function of excitation. This means unregulated power supplies are often sufficient as long as they fall within a specified power range. Because they have a higher level output these transducers are not as susceptible to electrical noise as millivolt transducers and can therefore be used in much more industrial environments.

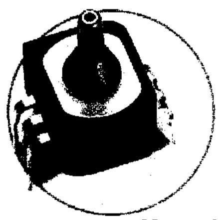
4-20 mA Output Pressure Transducers

These types of transducers are also known as pressure transmitters. Since a 4-20mA signal is least affected by electrical noise and resistance in the signal wires, these transducers are best used when the signal must be transmitted long distances. It is not uncommon to use these transducers in applications where the lead wire must be 1000 feet or more.

Styles of Pressure Transducers

PC Board Mountable Pressure Transducers

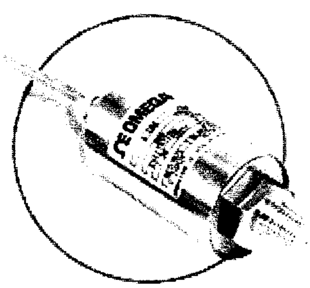
PC board mountable pressure transducers are generally compact economical pressure transducers designed to mount on an electrical PC board and be integrated into other products.



PX40 PC Board-Mountable Pressure Transducers

General Purpose Transducers

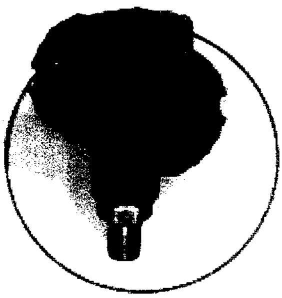
General purpose pressure transducers are the most common since they are designed to fit the broadest set of applications.



PX305 General Purpose Transducers

Heavy Duty/Industrial Pressure Transducers

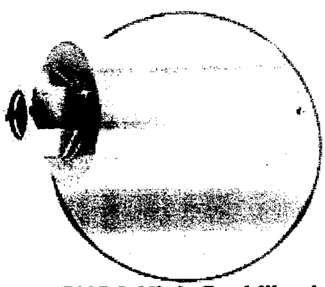
Heavy Duty/Industrial Pressure transducers feature a much more rugged enclosure than other transducers. They are designed to accommodate heavy industrial environments. They also often feature a scalable 4-20mA output that provides much greater immunity to electrical noise which is not uncommon in industrial environments.



PX725A Heavy Duty/Industrial Pressure Transducers

High Stability/High Accuracy Pressure Transducers

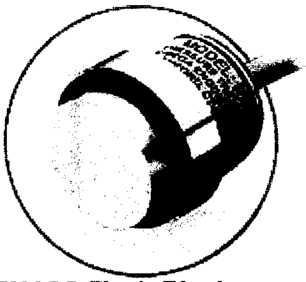
Most pressure transducers feature an accuracy of 0.25% of full scale or higher. High stability and high accuracy pressure transducers can offer errors as low as 0.05% of full scale, depending on model. Although more expensive than general purpose transducers, they may be the only option if high precision is required.



PX01 High Stability/ High Accuracy Transducer

Flush Diaphragm Pressure Transducers

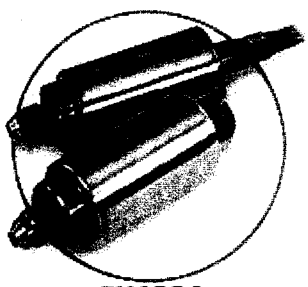
With flush diaphragm pressure transducers, the diaphragm is flush to the fluid matter from the process. In certain applications, this may be very undesirable. Those applications include monitoring the pressure of foods or liquids that have very high viscosity.



PX102 Flush Diaphragm Pressure Transducer

Special Purpose Transducers

OMEGA offers a variety of pressure transducers with special features. These include pressure transducers designed for pressure measurement in very high or low temperatures, submersible pressure transducers, barometric pressure transducers and pressure transducers with digital communications output or wireless outputs.



PX1004 Special Purpose Transducers

Applications

There are many applications for pressure sensors but we can narrow them down to three major categories:

- **Pressure sensing**

This is the direct use of pressure sensors to measure pressure. This is useful in weather instrumentation, aircraft, cars, and any other machinery that has pressure functionality implemented.

- **Altitude sensing**

This is useful in aircraft, rockets, satellites, weather balloons, and many other applications. All these applications make use of the relationship between changes in pressure relative to the altitude. This relationship is governed by the following equation:

$$h = \frac{(1 - (P/P_{ref})^{0.19026}) \times 288.15}{0.00198122}$$

This equation is calibrated for an altimeter, up to 36,090 feet (11,000 m). Outside that range, an error will be introduced which can be calculated differently for each different pressure sensor. These error calculations will factor in the error introduced by the change in temperature as we go up.

Barometric pressure sensors can have an altitude resolution of less than 1 meter, which is significantly better than GPS systems (about 20 meters altitude resolution). In navigation applications altimeters are used to distinguish between stacked road levels for car navigation and floor levels in buildings for pedestrian navigation

- **Flow sensing**

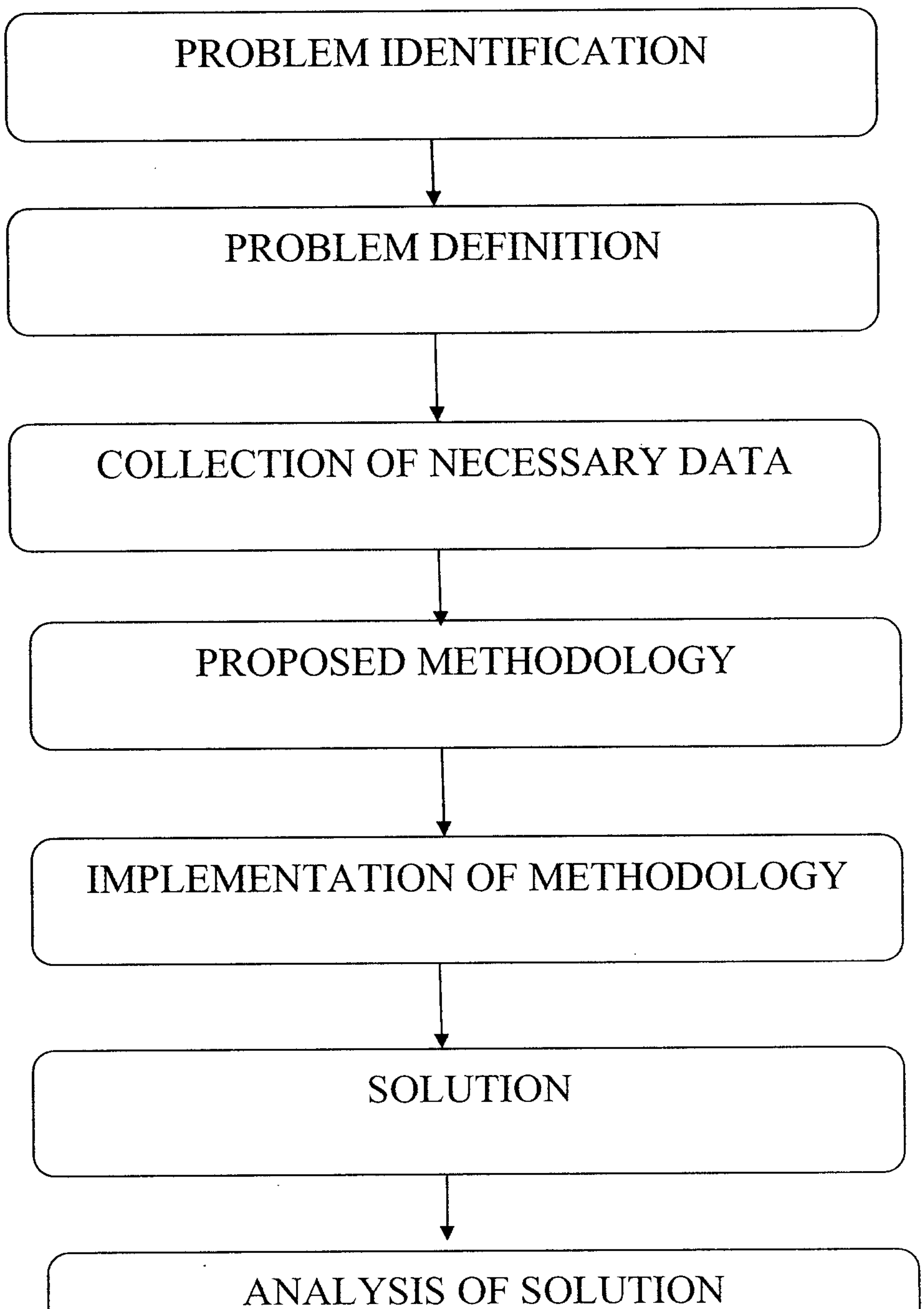
This is the use of pressure sensors in conjunction with the venturi effect to measure flow. Differential pressure is measured between two segments of a venturi tube that have a different aperture. The pressure difference between the two segments is directly proportional to the flow rate through the venturi tube. A low pressure sensor is almost always required as the pressure difference is relatively small.

CHAPTER 4

PROBLEM SOLVING

3.1 GENERAL ALGORITHM FOR PROBLEM SOLVING

The aim here is to develop a process chart for assembly line balancing using RPW technique. The general problem solving algorithm is given below.



This series is followed in order to get optimal results. The precedence as shown in the diagram is carried out in the industry and the results are marked as follows.

CHAPTER 5

DATA COLLECTION

DATA COLLECTION

Qty req. per day = 500
Number of hours a day = 8
Qty to be produced / hour = 500 / 8 =62.5

4.1 SINGLE OUTPUT

Table 1: List of operations

OP. NO	OPERATION	TIME
01	Brush Crimping with assy. housing	6.26
02	Assembly & Crimping	39.83
03	Grub Screw assembly	16.03
04	Leak Testing	21.63
05	Actuator assembly	
06	Spring torsion assembly	
07	Assy. Axle assembly	
08	Plate sector riveting	11.8
09	Spring contact riveting	20.85
10	Spring assembly	14.2
11	Adhesive applying & pressing	15.03
12	Assembly	3.76
13	Assembly	10.30
14	Assy. Bearing swivel assembly	
15	Bobbin winding & adhesive applying	34.27(manual) 8.78 (machine) 17.65(adhesive)
16	Enamel removing	26.5
17	Riveting contact strip with bobbin	35.2
18	Bobbin assembly	
19	Range setting	211.3
20	Assy. Adaptor stamping	9.63+4.5
21	Adhesive applying	33.65
22	Cap stamping	5.5
24	Adhesive applying in cap assembly	17.93
25	Adhesive applying & assy.	
26	Crimping & Lacquer applying	8.97
27	Peripherals mounting	
28	Range setting & inspection	7 (manual) 20 (machine) 15 (parallel) 20.93 (adhesive)
29	Visual Inspection	15.84
30	Packing	14.98

PROCESS OUTLINE CHART:

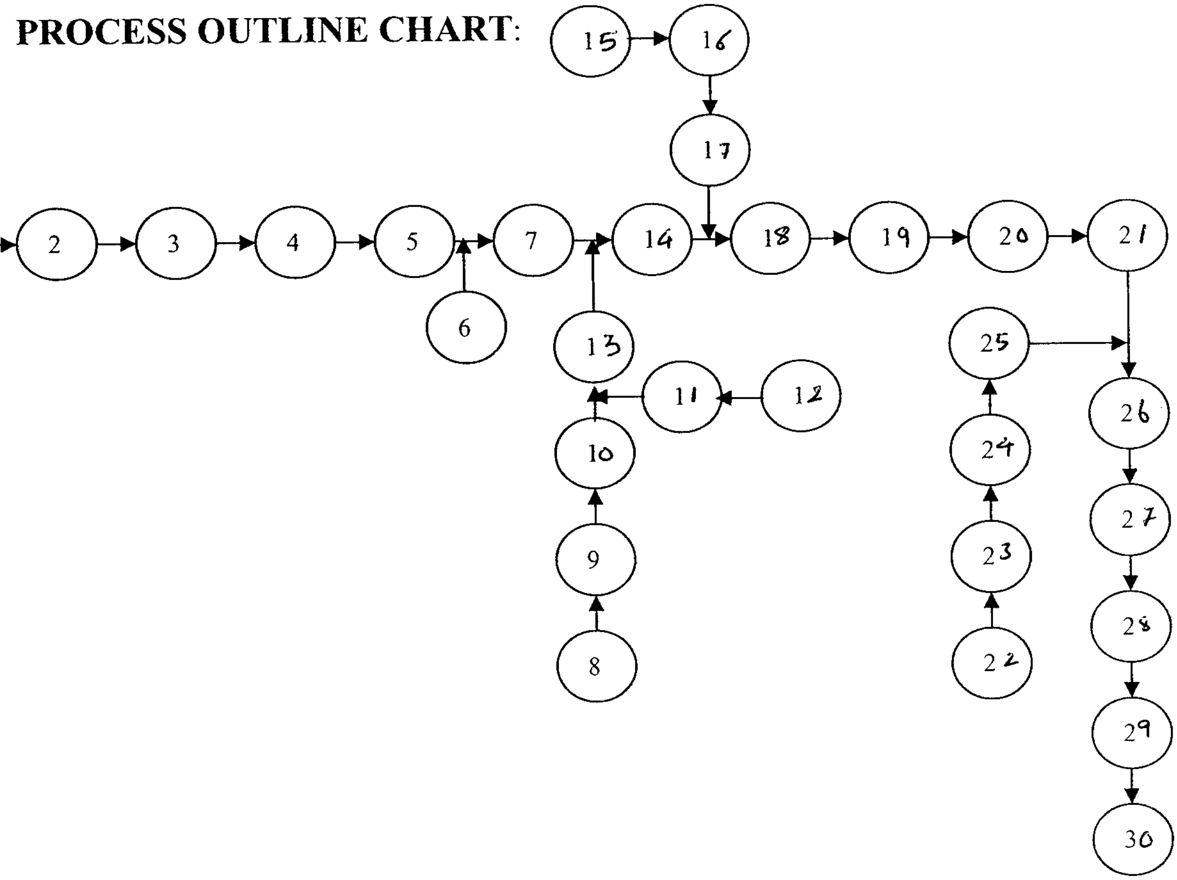


Figure 4: Process outline chart

Due to constraints,

- Operation number 27 is excluded,
- Operations numbered as 4 & 5 and 24 & 25 are combined,
- Operations 6,7,14 & 18 are combined.
- Operations, 15, 16, 20 and 30 are subassemblies.
- Line balancing is done for both including & excluding the subassemblies.

PRECEDENCE GRAPH:

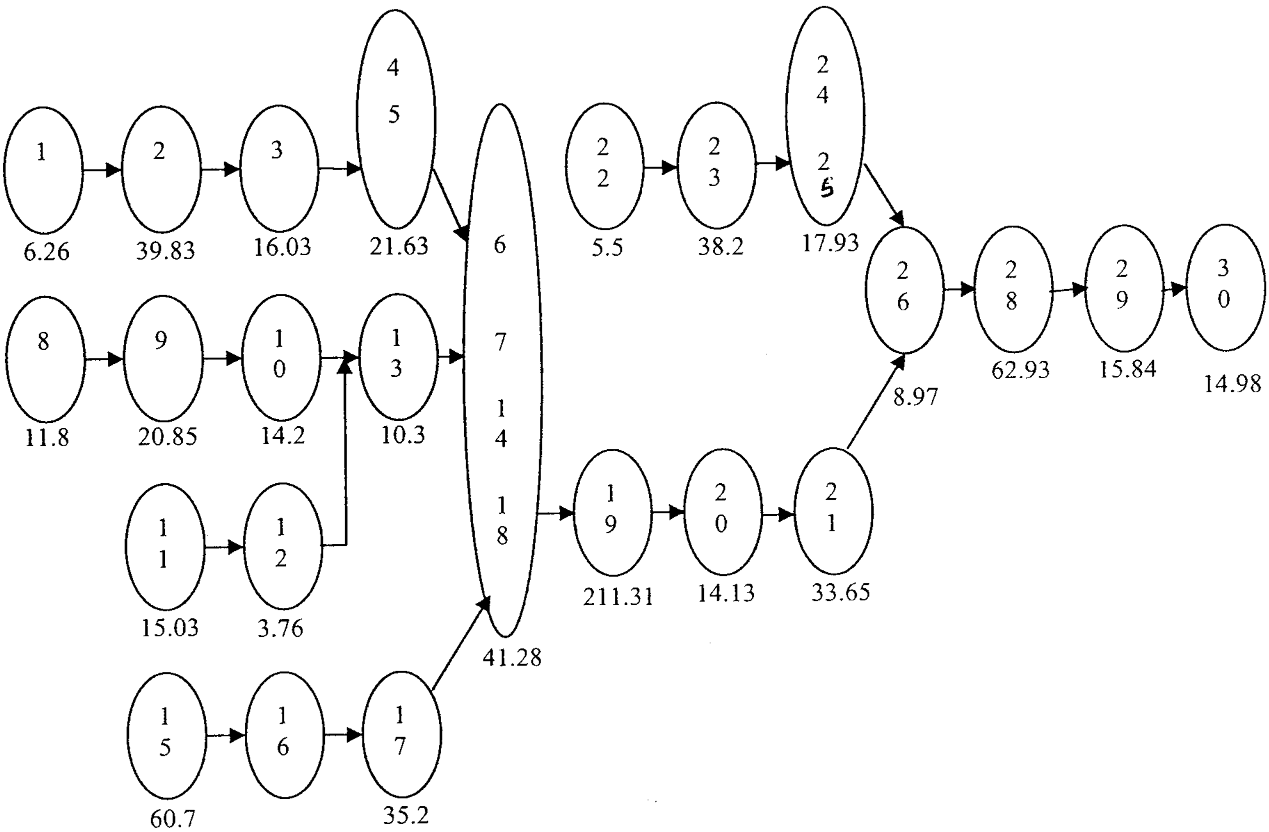


Figure 5: Precedence graph

4.2 DOUBLE OUTPUT-WITHOUT WARNING

Table 2: List of operations

OP. NO	OPERATION PERFORMED	TIME
01	Brush Crimping with assy. housing	6.26
02	Assembly & Crimping	30.13
03	Grub Screw assembly	16.03
04 & 05	Leak testing & actuator assembly Picking up housing, actuator door check, leak & unload	21.63
06	Bobbin winding, pull wire knot on m/c adhesive applying.	60.7
07	Enamel removing, pick up bobbin	26.5
08	Riveting contact strip with bobbin	44.14
09	Riveting - PCB	12.39
10	Wire soldering with PCB	20.57
11	Soldering PCB with bobbin	19.55
12	Assembly	10.52
13 & 14	Spring tension assembly and axle assembly Picking up spring tension, assy. on it	7.61
15	Plate sector riveting	11.80
16	Spring contact riveting	37.38
17	Soldering spring with hearing swivel	28
18	Spring & hearing swivel assembly	14.2
19 & 20	Adhesive apply & pressing & assembly Picking up setting screw, hall fix hexagonal nut & fix	15.03
21	Assembly	10.30
22	Assembly hearing swivel	10
23	Bobbin assembly	11.8
24	Soldering - spring	13.65
25	Continuity checking	18.95
26	Range setting	226.31
27	Stamping adaptor, pick, load, press	4.5
28	Adhesive applying	33.65
29	Stamping – cap, pick, load , press	5.50
30	Cap assembly	43.26
31	Adhesive applying & assembly	17.93
32	Crimping	8.97
33	Range setting inspection & parallel activities	42
34	Visual inspection	15.84
35	Packing	14.98

PROCESS OUTLINE CHART

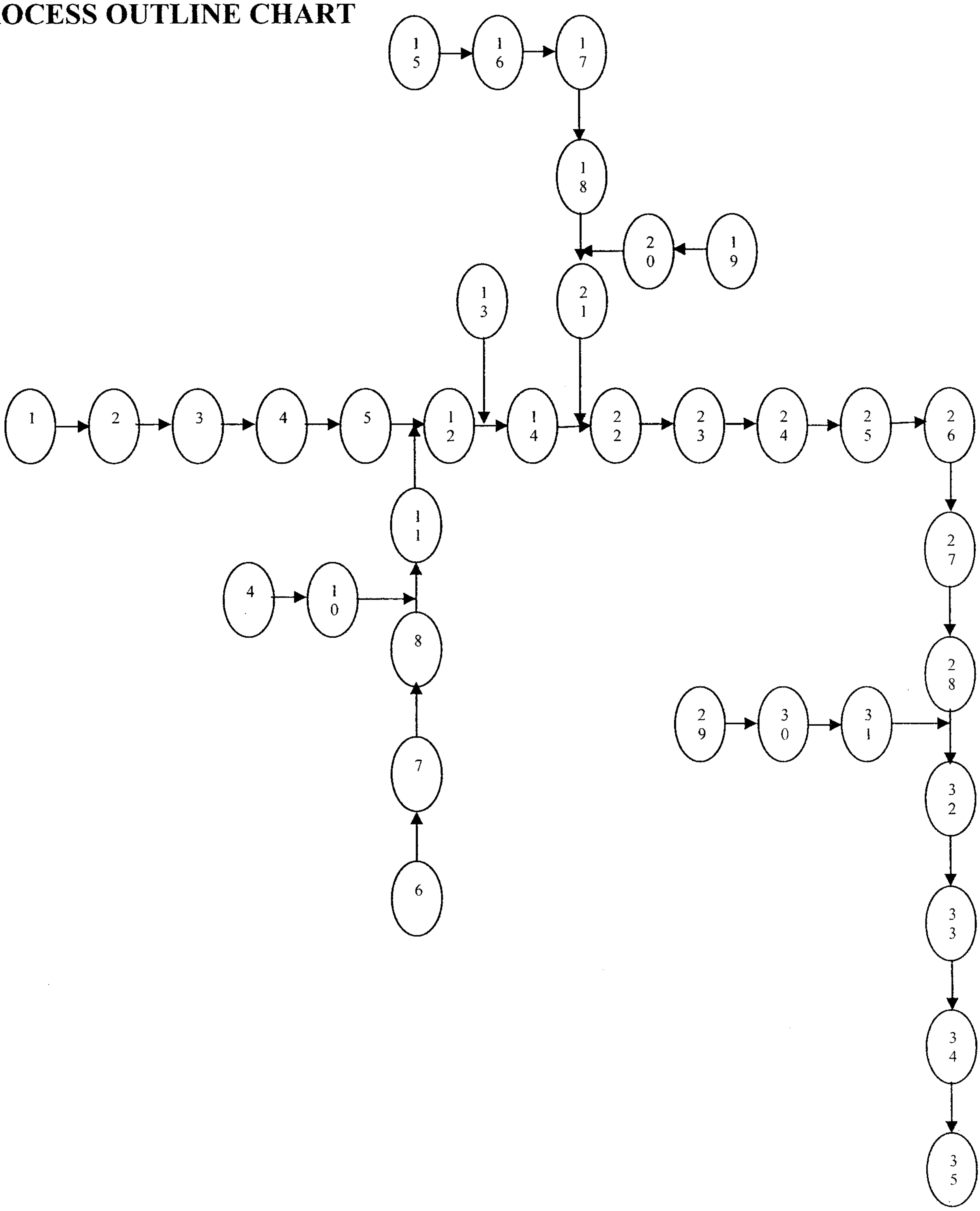


Figure 6: Process Outline Chart

PRECEDENCE GRAPH:

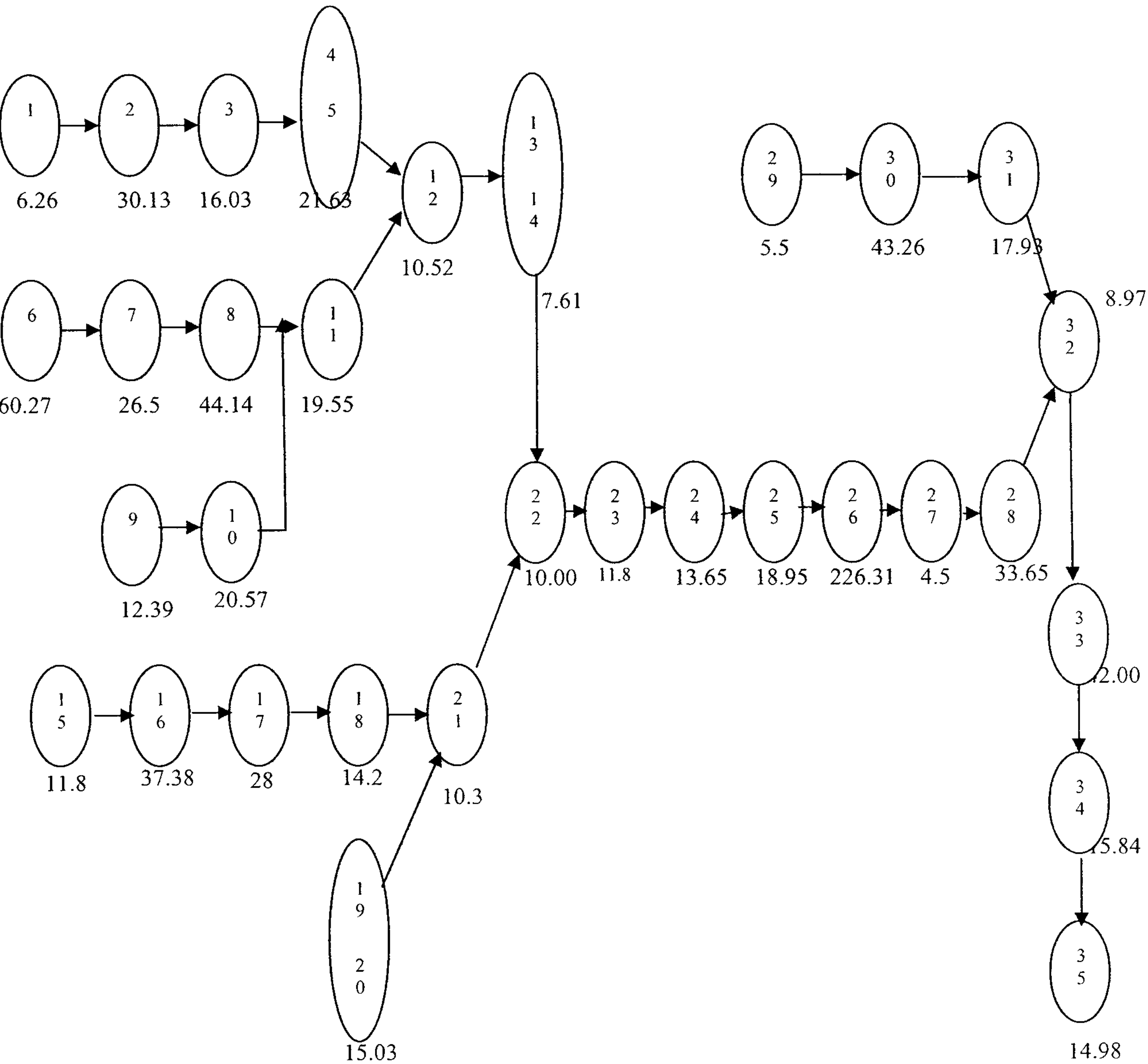


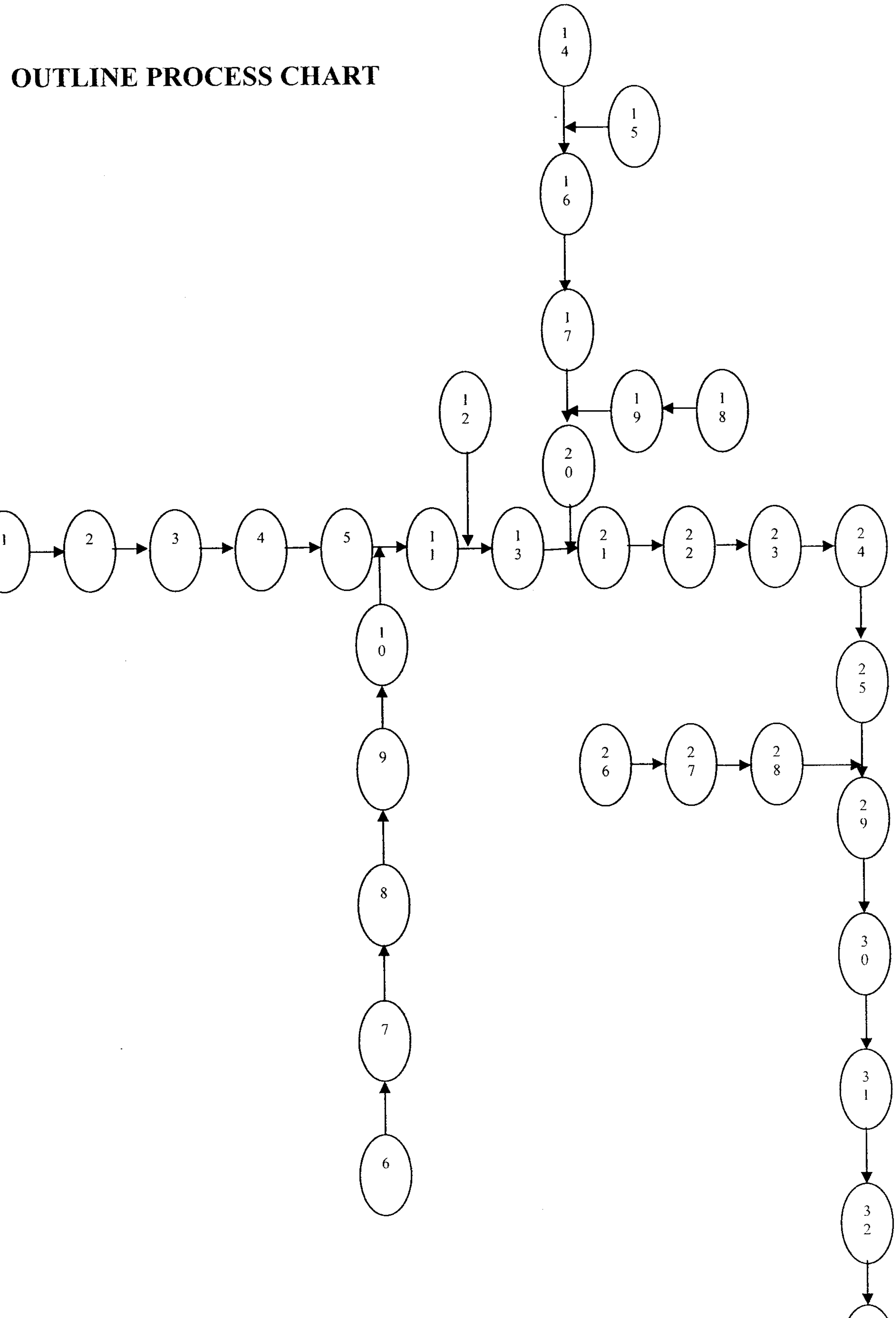
Figure 7: Precedence graph

4.3 DOUBLE OUTPUT – WITH WARNING

Table 3: List of operations

OP. NO	OPERATION PERFORMED	TIME
01	Brush Crimping with assy. housing	6.26
02	Assembly & Crimping	30.13
03	Grub Screw assembly	16.03
04 & 05	Leak testing & actuator assembly Picking up housing, actuator door check, leak & unload	21.63
06	Bobbin winding, pull wire knot on m/c adhesive applying. Pick Araldite & hardener. Mix in 1:1 ratio.	60.7
07	Enamel removing, pick up bobbin, rewind 2 ends, load	26.5
08	Riveting contact strip with bobbin Riveting – P.C.B.	44.14
09	Wire soldering with PCB	20.57
10	Soldering PCB with bobbin	19.55
11	Assembly	10.52
12 & 13	Spring tension axle and spring tension assembly	7.61
14	Plate sector riveting	11.80
15	Contact riveting, pick, place, press	14.13
16	Spring contact riveting	37.38
17	Spring & hearing swivel assembly	14.2
18 & 19	Adhesive apply, pressing, picking up setting screw, hall fix, hexagonal nut.	15.03
20	Assembly	10.30
21	Assembly hearing swivel	10.0
22	Bobbin assembly	11.8
23	Range setting	251.31
24	Stamping adaptor, pick, load, press	4.5
25	Adhesive applying	33.65
26	Stamping – cap.	5.50
27	Cap assembly	43.26
28	Adhesive applying & assembly	17.93
29	Crimping	8.97
30	Range setting inspection	42
32	Visual inspection	15.84
33	Packing	14.98

OUTLINE PROCESS CHART



PRECEDENCE GRAPH:

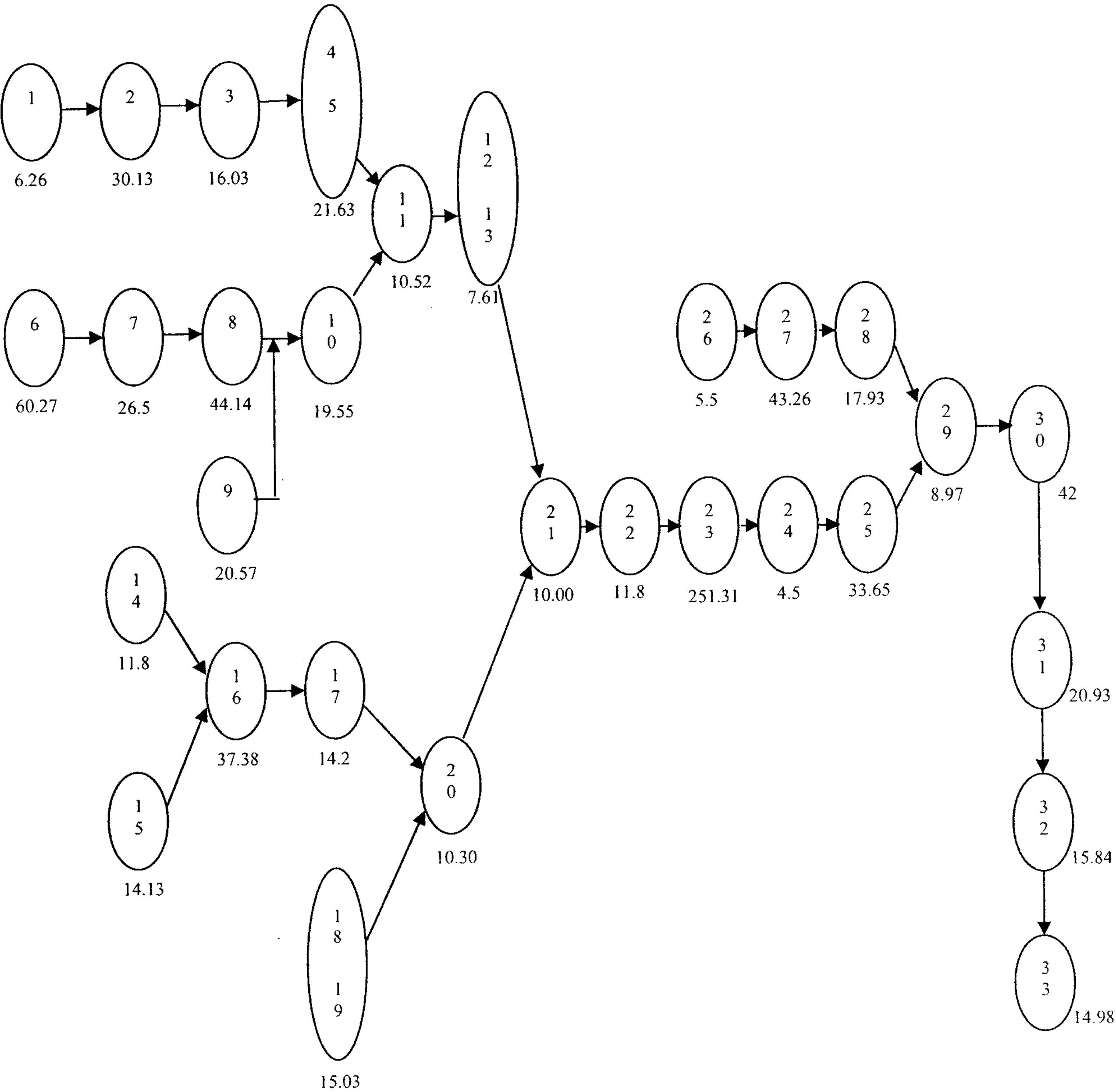


Figure 9: Precedence graph

CHAPTER 6

RANKED POSITIONAL WEIGHT TECHNIQUE

5. RANKED POSITIONAL WEIGHT TECHNIQUE (RPWT)

5.1 INTRODUCTION

In designing a repetitive flow process (a production line), we start by decomposing the process into elemental tasks, each of which represents a separate unit of work. That is, a task does not have to be performed with another task at any work station (although efficiencies are certainly possible by combining similar tasks).

For each task, it is necessary to estimate how long it would take to perform it. This estimate may be on experimentation or established work standards. Clearly these times depend on several factors: the number of people working at the workstation, their skill and motivation, and their supporting equipment and resources. The task times used in the subsequent analysis assume the use of average workers using reasonable support equipment.

Along with time estimates, the designer must determine the precedence requirements for each task. Although all the products require essentially the same processing sequence, at the design stage there is often some flexibility in the exact sequencing of tasks. For example, when assembling an automobile, it may be possible to attach the front's doors before the back doors or vice-versa. The precedence requirements specify which task must be completed before another task can be started. As a group, precedence requirements describe which tasks must be done sequentially and which could be done concurrently.

5.2 CRITERIA FOR EVALUATING WORK STATION DESIGN

Once the task information is available, we can determine how many work stations to have and which tasks to perform at each one. The procedure for creating work stations and assigning tasks to them is called line balancing. It is so called because a repetitive process is viewed as a line of work stations, and efficiency is maximized by balancing the workload among them. The line-balancing problem is often expressed in one of two possible forms:

1. Determine the minimum number of work stations needed and allocate tasks to them to produce at least some target rate of output.
2. For a given number of work stations, allocate the tasks to maximize the output rate.

In practice, the line design process usually involves solving these two problems sequentially. First, we try to find the minimum number of work stations, and the associated assignment of tasks, that produce at least the minimum target production rate. Then the design is refined to maximize output for that number of work stations. On the surface, it might appear that these should be simple optimization problems, but for actual problems they are often computationally intractable because of the lumpiness of the task times (the tasks cannot be divided into arbitrarily small units), and the set of constraints needed to represent the precedence relationships is large and not well structured.

5.3 TERMINOLOGY

The time between production of successive units of the product (ignoring starting effects) is called the production cycle time and will be designated c. When there is no variation in task times, the production cycle time is equal to the longest time the product must spend at any work station. This implies that the

Production rate P = 1/c.

The efficiency or % balance of a line is the percentage of available work station time that is used productively. In general, this can be computed by,

Efficiency (% balance) of the line = [T/(Nxc)] x 100 %

where T is the total amount of work time required to make a unit of product (at all work stations) and N is the number of work stations on the production line.

A useful exercise is to determine the theoretical minimum number of work stations needed to achieve this output rate.

Theoretical minimum number of work stations = $[T/c_{max}]$

where [ ] means round up any fractional value because fractional work stations are not possible. This theoretical minimum number of work stations is derived assuming 100% balance. The minimum number of work stations actually possible may be more than this, depending on the precedence relationships and the lumpiness of the task times.

The basic idea in constructing the production line is to assign as much work to each work station as possible without exceeding c_{max} .

However, the lumpiness of the task times usually makes it impossible to achieve 100% efficiency.

5.4 ALGORITHM FOR RPWT:

1. Construct a diagram of the precedence relationships among the tasks. Arrows are used to show which tasks must precede others.
2. For each task, add up the task times and al tasks that must follow it directly and indirectly. This value will be called the positional weight for the task.
3. Select the task with the largest positional weight and assign it to the first work station.
4. Select the task with the next largest positional weight and assign it to the earliest possible work station that exists, subject to two restriction:

(a) the total (task) time assigned to the work station cannot exceed c_{max} and

(b) all of the task's predecessors must be assigned to that work station or an earlier one. If the task does not satisfy these conditions for an existing work station, create a new work station and assign the task to it.

The rationale for the RPWT is that the positional weight is a measure of the task's importance as a predecessor. Tasks with the largest positional weights have the most subsequent work and tasks depending on them. By assigning these tasks first, we enlarge more quickly the pool of tasks available for assignment to work station (i.e., those for which all predecessors have been assigned to a work station). This makes it easier to find a task that fits within the limits of the existing work stations.

CHAPTER 7

RESULTS AND DISCUSSIONS

6.1 CALCULATION OF RANKED POSITIONAL WEIGHTS

For each task, add up the task times and al tasks that must follow it directly and indirectly. This value will be called the positional weight for the task.

6.2PREPARATION OF WORKSTATIONS

Select the task with the largest positional weight and assign it to the first work station.

Select the task with the next largest positional weight and assign it to the earliest possible work station that exists, subject to two restriction:

the total (task) time assigned to the work station cannot exceed c_{max} and all of the task's predecessors must be assigned to that work station or an earlier one. If the task does not satisfy these conditions for an existing work station, create a new work station and assign the task to it.

The rationale for the RPWT is that the positional weight is a measure of the task's importance as a predecessor. Tasks with the largest positional weights have the most subsequent work and tasks depending on them. By assigning these tasks first, we enlarge more quickly the pool of tasks available for assignment to work station (i.e., those for which all predecessors have been assigned to a work station). This makes it easier to find a task that fits within the limits of the existing work stations.

6.3 SINGLE OUTPUT

Table 4: Ranked positional weight

OP.NO	POSITIONAL WEIGHT	OP.NO	POSITIONAL WEIGHT
15	525.49	13	413.39
1	486.84	6,7,14&18	403.09
2	480.58	19	361.81
16	464.79	22	164.35
8	460.24	23	158.85
9	448.44	20	150.5
3	440.75	21	136.37
17	438.29	24 & 25	120.65
11	432.18	26	102.72
10	427.59	28	93.75
4 & 5	424.72	29	30.82
12	417.15	30	14.98

Table 5: Station Assignment by RPWT

	1, 2, 12, 22	16, 8, 3	9, 17	4 5, 10, 11	6 7 14 18, 13	19	23, 20	21, 24 25	29, 30, 26	28
ons llel)	55.35	54.33	56.05	50.86	51.58	56.8	52.33	51.58	39.79	56.9 (6 stations in parallel)

CALCULATIONS:

From the table it can be found that

Total work time = **T= 586.67 secs**

Maximum time required in the product cycle = C= 56.9 secs

Maximum allotted time = C_{max}= 57.6 secs

Theoretical minimum no. of workstations required = T/C_{max}

=586.67/57.6= 10.18

Efficiency of the line =**[T / (N x C)] x 100**

= 586.67/(11x56.9) x100

= 93.71%

6.4 TWO OUTPUT-WITHOUT WARNING LIGHT

Table 6: Ranked positional weight

OP.NO	POSITIONAL WEIGHT	OP.NO	POSITIONAL WEIGHT
6	569.7	21	410.97
7	509	13 & 14	408.3
15	502.35	22	400.68
1	492.85	23	390.68
16	490.55	24	378.88
2	486.6	25	365.23
8	482.5	26	346.28
9	471.32	29	148.5
10	458.93	30	143
3	456.47	27	120
17	453.17	28	115.47
4 & 5	440.14	31	99.7
11	438.4	32	81.82
19 & 20	426	33	72.85
18	425.17	34	30.85
12	418.8		

Table 7:Work Station Assignment by RPWT

	7 15 1 9	16 3	2 10 29	8 12	17 (4, 5) (13, 14)	11 (19, 20) 18 27	21 22 23 24 32	25 28	26	30	31 34	33
	56.95	53.41	56.2	54.66	57.24	53.28	54.72	52.6	56.9	43.26	33.77	42

CALCULATIONS:

From the table it can be found that

Total work time = **T= 672.09 secs**

Maximum time required in the product cycle = C= 57.24 secs

Maximum allotted time = C_{max}= 57.6 secs

Theoretical minimum no. of workstations required = T/C_{max}

=672.09/57.6= 11.66

Efficiency of the line =**[T / (N x C)] x 100**

= 672.09/(13x57.24) x100

= 89.75 %

6.5 TWO OUTPUT-WITH WARNING LIGHT

Table 8: Ranked positional Weight

OP.NO	POSITIONAL WEIGHT	OP.NO	POSITIONAL WEIGHT
6	583	12 & 13	414
7	522.32	21	414
1	506.18	22	404
2	499.9	23	392.2
8	495.8	26	169.45
15	490	27	163.95
14	487.7	24	140.9
16	475.9	25	136.4
9	469.8	28	120.68
3	453.7	29	102.75
4 & 5	451.7	30	93.77
10	439.3	31	51.77
18 & 19	438.1	32	30.84
17	424.3	33	14.98
20	421.6		

Table 9: Work Station Assignment by RPWT

	7 1 15 20	2 14 18 19	8 12 13 26	16 3	9 4 5 17	10 21 22 24 29	23	27	25 28	30 33	31 32
s)	57.19	56.96	57.25	53.41	56.4	54.82	56.75 (8 stations in parallel)	43.26	51.58	56.98	36.77

CALCULATIONS:

From the table it can be found that

Total work time = **T= 694.68 secs**

Maximum time required in the product cycle = C= 57.25 secs

Maximum allotted time = C_{max}= 57.6 secs

Theoretical minimum no. of workstations required = T/C_{max}

=694.68/57.6= 12

Efficiency of the line =**[T / (N x C)] x 100**

= 694.68/(13x56.9) x100

= 90.32 %

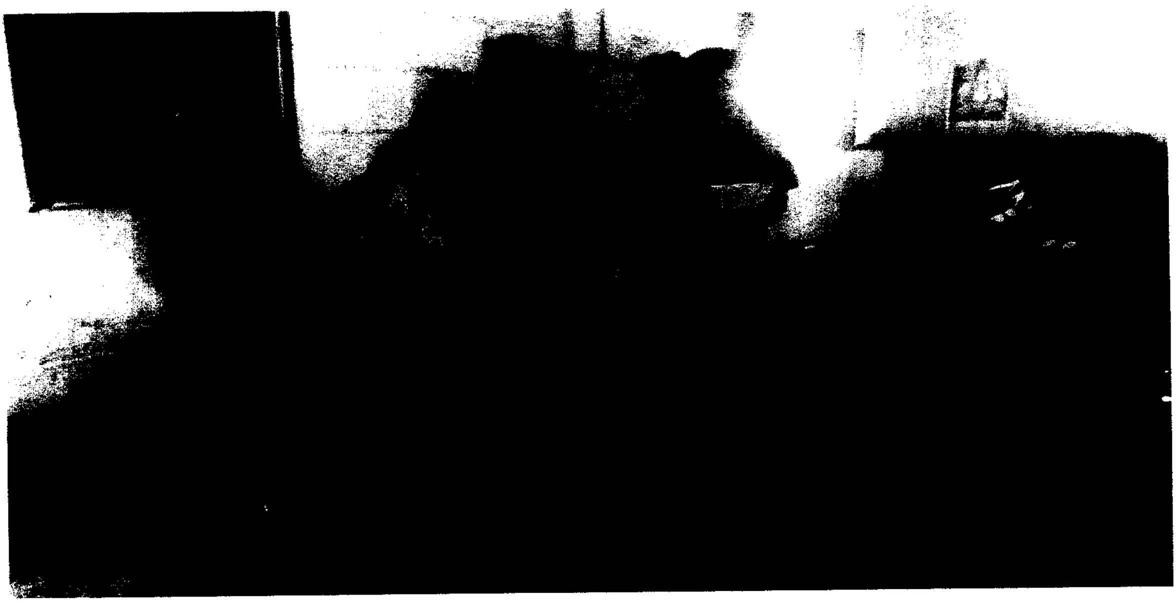
CHAPTER 8

PHOTOS AT INDUSTRY

Pic 1:Work being carried out on a milling machine

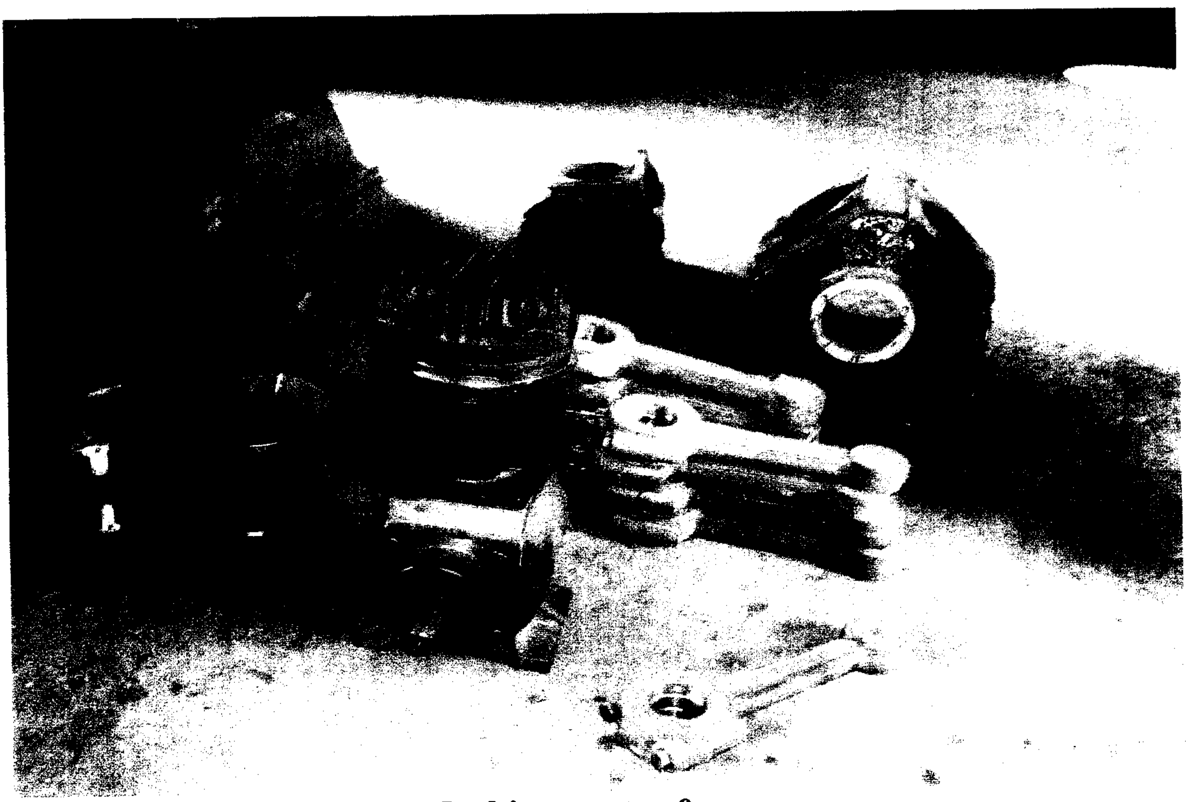
Pic 2:Time study being carried out at a lathe center

Pic 3. **Overall View of the Plant**

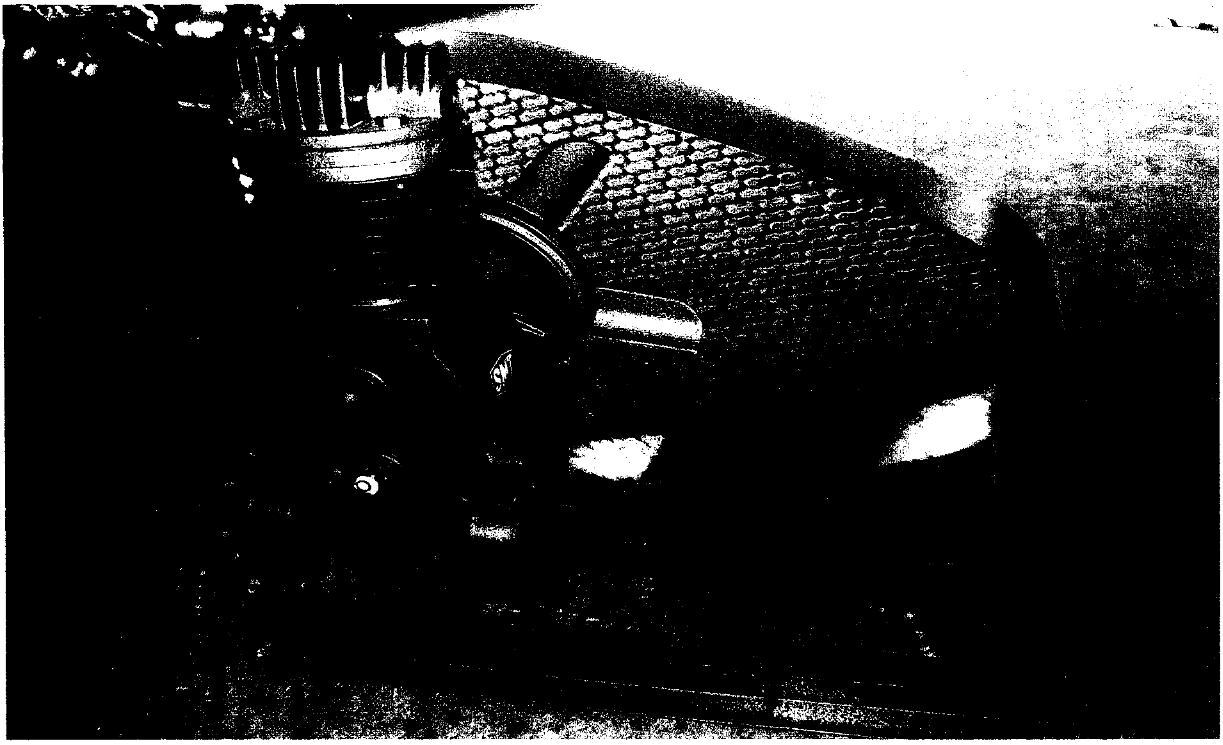


Pic 4. **Time study being carried out for a turning process**

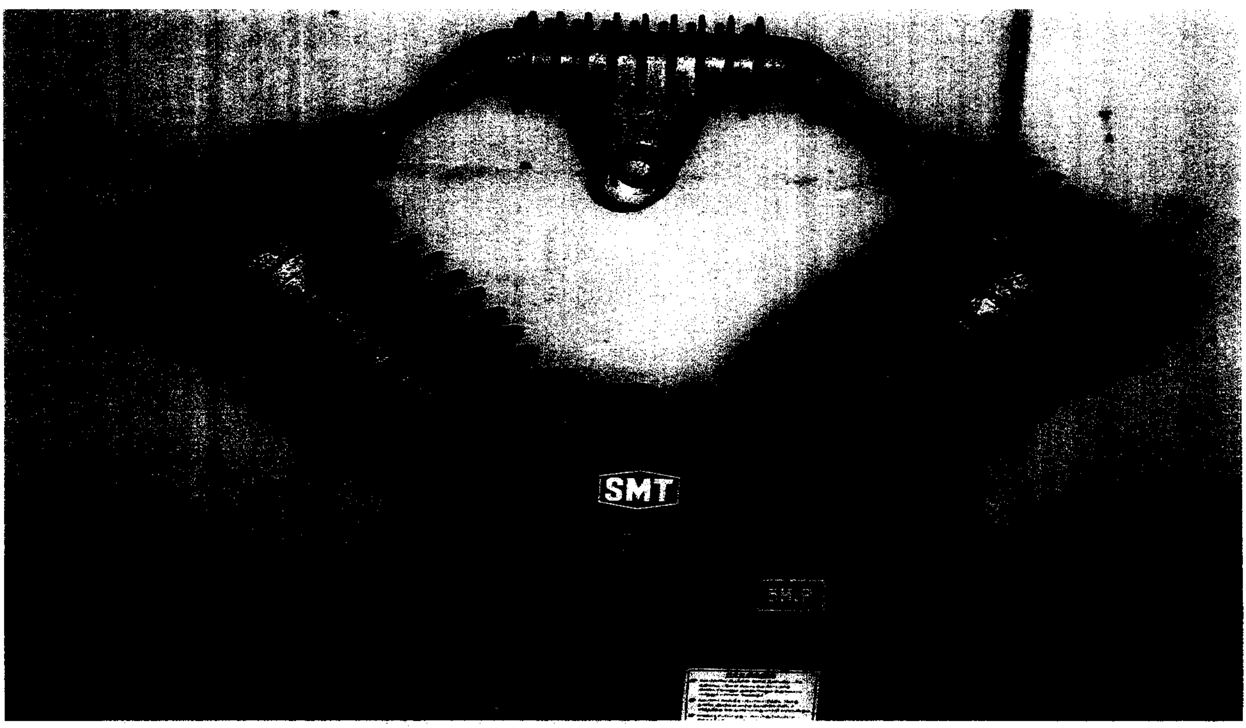
Pic 5: **Milling machine inspection**



Pic 6: **Machine parts of a compressor**



Pic 7: **Air Compressor after assembly and inspection**



Pic 8: **Various Products of SMT (Two stage air compressor)**

CHAPTER 9

CONCLUSION

8.1 CONCLUSION

State-of-the art technique RPWT and heuristics was used to improve the efficiency of the pressure transducer assembly line. With the help of these methods the overall production rate was increased from 350 components to 500 components per day. Also the overall efficiency of the line was significantly improved by improvising upon the RPWT using improvement heuristics. The sub-assemblies were also included which was not done earlier. As a whole this project has decreased number of operators required. The results obtained using various line balancing procedures were also compared.

Through dynamic programming many possibilities for grouping the tasks were proposed so that the firm can decide upon which particular combination would work for them practically. By performing the line balancing procedure for all the three variants of pressure transducer the flexibility of the line is ensured.

The Various data obtain are as follows:

For Single Output Transducers Assembly Line:

Total work time = T= 586.67 secs

Maximum time required in the product cycle = C= 56.9 secs

Maximum allotted time = C_{max}= 57.6 secs

Theoretical minimum no. of workstations required =10.18

Efficiency of the line = 93.71%

For Double Output without warning light Assembly Line:

From the table it can be found that

Total work time = T= 672.09 secs

Maximum time required in the product cycle = C= 57.24 secs

Maximum allotted time = C_{max}= 57.6 secs

Theoretical minimum no. of workstations required = 11.66

Efficiency of the line = 89.75 %

For Double Output with warning Light Assembly Line :

From the table it can be found that

Total work time = T= 694.68 secs

Maximum time required in the product cycle = C= 57.25 secs

Maximum allotted time = C_{max}= 57.6 secs

Theoretical minimum no. of workstations required = 12

Efficiency of the line = 90.32 %

8.2 LIMITATIONS OF THE PROJECT

Taking the space constraints into account layout modifications was not ventured.

The scope of this project is limited to only line balancing and not re-designing of the component or the assembly procedure. The results of the project are applicable only at this point of time and if the customer requirement increases further the whole procedure has to be redone again. Hence there is a need of computer software which can give instantaneous results for various production rates.

8.3 SCOPE FOR FUTURE WORK

A computer program can be developed. The algorithm required for this program is provided in this work. The processes adopted for assembly can be automated.

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