**ST. WILFRED'S INSTITUTE OF ENGINEERING AND TECHNOLOGY , AJMER**

# Department of Mechanical Engineering

# B.TECH.

# **Industrial Engineering**

## List of Experiments

| Sr. No. | Title | Date of Performance | Date of submission | Sign | Remark |
|---|---|---|---|---|---|
| 1. | To Study & Prepare Operation Process Chart (OPC) for given assembly. | | | | |
| 2. | To Study & Prepare Flow Process Chart and Flow Diagram for given assembly for OPC. | | | | |
| 3. | To study & Prepare Man-Machine Chart for the given situation. | | | | |
| 4. | To study & Calculate co-efficient of correlation for time study person using performance rating technique. | | | | |
| 5. | To study & Calculate standard time for given job. | | | | |
| 6. | To study & Prepare a frequency Distribution Curve for the data source given. | | | | |
| 7. | To study & Construct X bar- R Chart for given process. | | | | |
| 8. | To study & Construct P-chart for given process. | | | | |
| 9. | To study & Construct C-chart for given process. | | | | |
| 10. | To study about Sampling Plans & Decide about acceptance or rejection of a particular product using sampling plans. | | | | |
| 11. | Tutorial – 1: Example solved on plant layout. | | | | |
| 12. | Tutorial – 1: Example solved on Forecasting. | | | | |

## ST. WILFRED'S INSTITUTE OF ENGINEERING AND TECHNOLOGY , AJMER

# EXPERIMENT NO: - 01

**AIM:** To Study & Prepare Operation Process Chart (OPC) for given assembly.

**OBJECTIVES:** After completing this experiment, you will be able to:

- Identify operations and inspections.
- List the operations and inspections involved in manufacturing process of each part of an assembly or processes.
- Note down details about materials, machines and equipment used for each component of an assembly.
- To understand sub assembly and assembly procedure.
- Construct Operation (Outline) Process Chart.

## Introduction: -

**Work Study: -** It is a generic term for those techniques, particularly method study and work measurement, which are used in the examination of human work in all its contexts, and which lead systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement.

**Method Study:** - Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

**Work Measurement:** - Work measurement is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at defined level of performance. *[Work Study by ILO page no; 28, 29]*

Thus work study is a management technique to increase productivity and is divided into two broader concepts Method Study and Work Measurement.

As per the definition of method study the main objective, is to improve the existing method of doing work and to develop more effective and economical method. Method study uses different methods to record the data.

The most commonly used method study charts and diagrams are as follows:

***A.* Charts: *Indicating process SEQUENCE***

Outline Process Chart,
Flow Process Charts (Man, Material & Equipment type)
Two Handed Process Chart.

***B.* Charts: *using a Time Scale***

Multiple Activity Chart (Man-Machine Chart)
SIMO Chart

*C.* **Diagrams: *Indicating movement***

Flow Diagram
String Diagram
Cycle graph
Chrono cycle graph Travel Chart.

In this experiment we are going to study about Operation (Outline) Process Chart.

**Operation (Outline) Process Chart:** It is a process chart giving an overall picture by recording in sequence only the main operations and inspections.

In an outline process chart, only the principal operations are carried out and the inspections made to ensure their effectiveness are recorded, irrespective of who does them and where they are performed. In preparing such a chart, only the symbols for ‘operation’ and ‘inspection’ are necessary.

**Symbols used for Operation (Outline) Process Chart.**

**Operation: -** The symbol for operation is as shown:

**Operation** indicates the main steps in a process, method or procedure. Usually the part, material or product concerned is modified or changed during the operation i.e. physical / chemical e.g. changing shape in machining, chemical change during chemical process; adding or subtracting during assembly or disassembly.

When man type charts are produced operation is indicated when any activity or work is done by the man who is used for that particular scenario, for e.g. a clerical routine, an operation is said to take place when information is given or received, or when planning or calculating takes place.

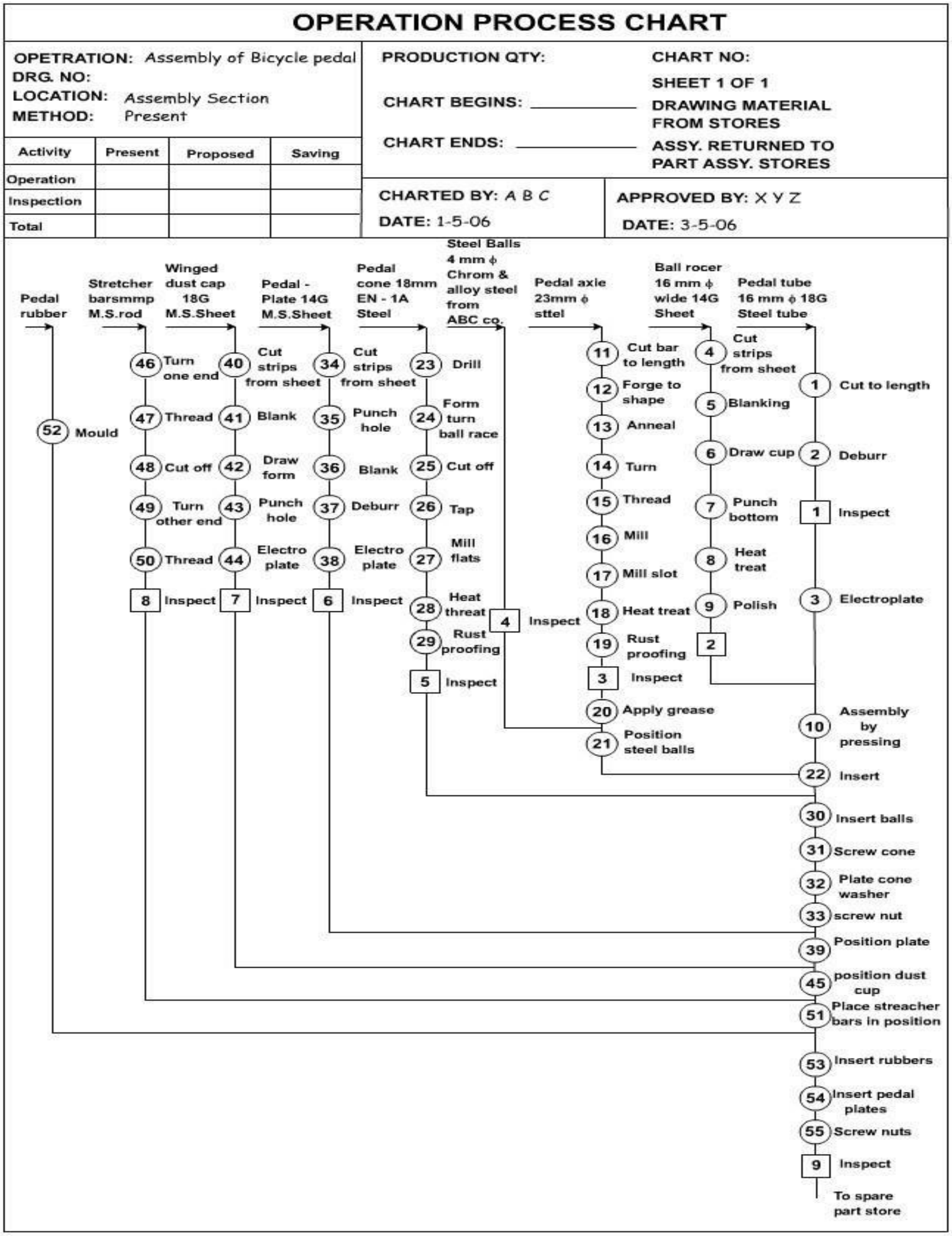
**Inspection: -** The symbol for inspection is as shown: □

**Inspection** indicates an inspection for quality and / or a check for quantity. e.g. measurement of dimension/values, etc., counting number of components etc.,

An inspection does not take place the material any nearer too becoming a completed product. It merely verifies that an operation has been carried out correctly as to quality and/or quantity, were it not for human shortcomings, most inspections could be done away with.

*[Work Study by ILO page no: 70-72]*

**Example of OPC: -** The following is the example of OPC

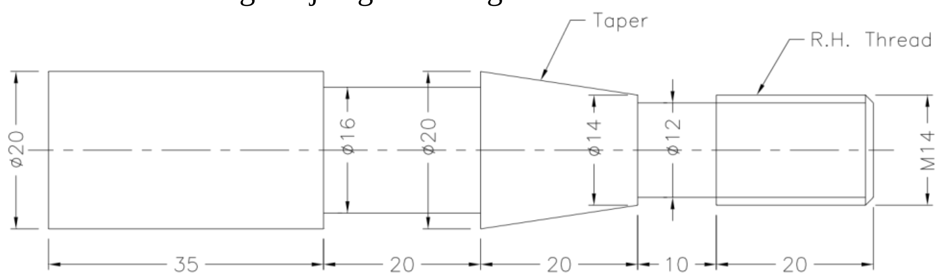



Operation process chart for assembly of bicycle pedal

*Figure 1.1: Example of OPC for an assembly of bicycle pedal*

**Exercise: Construct OPC for the given assembly and situations.**

1. Manufacturing blade assembly of table fan. Each blade consists of the following components: (i) Blade. (ii)Fixing plate. (iii)Three pieces of bolt and nut pairs. (iv) Six pieces of washers
2. Assembly of Nut Bolt and Washer
3. Writing a letter using a short hand typist. :
   Chart Begins: Short Hand typist in his office awaiting for dictation.
   Chart Ends: Short Hand typist put typed letter and its copies in Dispatch Tray.
4. For manufacturing the job given in figure. Construct for both material and machine tool used.




All Dimensions Are In M.M.

5. Repair of Car punctured tyre.

# EXPERIMENT NO: - 02

**AIM:** To Study & Prepare Flow Process Chart (FPC) for given assembly.

**OBJECTIVES:** After completing this experiment, you will be able to:

- Identify operations, inspections, transportations, delays and storage.
- List the various activities involved in manufacturing process of each part of an assembly or processes.
- Decide the type of flow process chart to be constructed.
- To construct flow process chart to be constructed.
- Proposed improved flow process chart.

## Introduction: -

**Flow Process Chart:** A flow process chart is a process chart setting out the sequence of the flow of a product or a procedure by recording all events under review using the appropriate process chart symbols.

Flow process chart is prepared in a manner similar to that in which the Outline Process chart is made, but using, in addition to the symbols for ‘operation’ and ‘inspection’, those for ‘transport’, ‘delay’ and ‘storage’. Whichever the type of flow process charts is being constructed, the same symbols are always used and the charting procedure is very similar. In fact have only one printed form of chart for all the types of flow process charts.

Flow process charts contain more information than outline process chart because they indicate additionally, storage, delay and transportation also which represent a major portion of the product cost.

**Types of Flow Process Charts:** The following are the types of flow process chart:

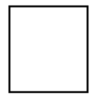
1. **Man Type:** A flow process chart which records what the worker does.
2. **Material Type:** A flow process chart which records how material is handled or treated.
3. **Equipment Type:** A flow process chart which records how the equipment is used.

**Symbols used for Operation (Outline) Process Chart.**

**Operation: -** The symbol for operation is as shown:

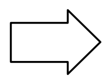
**Operation** indicates the main steps in a process, method or procedure. Usually the part, material or product concerned is modified or changed during the operation i.e. physical / chemical e.g. changing shape in machining, chemical change during chemical process; adding or subtracting during assembly or disassembly.

When man type charts are produced operation is indicated when any activity or work is done by the man who is used for that particular scenario, for e.g. a clerical routine, an operation is said to take place when information is given or received, or when planning or calculating takes place.

**Inspection: -** The symbol for inspection is as shown: 

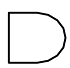
**Inspection** indicates an inspection for quality and / or a check for quantity. e.g. measurement of dimension/values, etc., counting number of components etc.,

An inspection does not take place the material any nearer too becoming a completed product. It merely verifies that an operation has been carried out correctly as to quality and/or quantity, were it not for human shortcomings, most inspections could be done away with.

**Transport: -** The symbol for transport is as shown: 

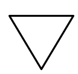
**Transport** indicates the movement of workers, materials or equipment's from place to place.

A transport thus occurs when an object if moved from one place to another, except when such movements are part of an operation or are caused by the operations at the work station during an operation or an inspection.

**Delay: -** The symbol for delay is as shown: 

**Delay** indicates a delay in the sequence of events: for example, work waiting between consecutive operations, or any object laid aside temporarily without record until required.

Examples are worked stacked on the floor of a shop between operations, cases awaiting unpacking, parts waiting to be put into storage bins or a letter waiting to be signed.

**Storage: -** The symbol for storage is as shown: 

**Storage** indicates a controlled storage in which material is received into or issued from a store under some form of authorization; or an item is retained for reference purposes.

*[Work Study by ILO page no: 70-72]*

**Example of Flow Process Chart: -**

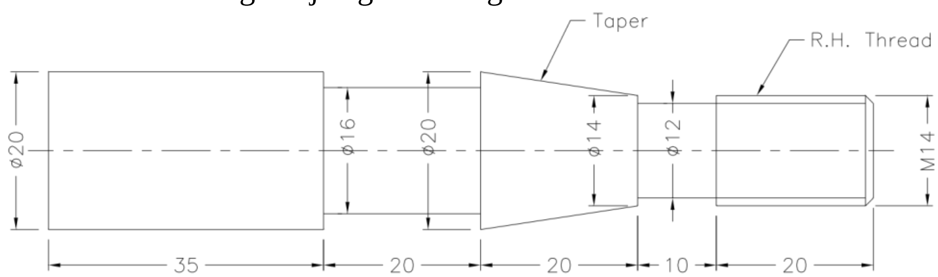
| FLOW PROCESS CHART | MATERIAL TYPE | | | |
|---|---|---|---|---|
| CHART NO:- 5 SHEET NO:- 5 | SUMMARY | | | |
| Subject charted:-P.C.M. | ACTIVITY | PRESENT | PROPOSED | SAVING |
| | OPERATION ○ | 7 | | |
| ACTIVITY:-FLOW OF MELT IN PIG IRON CASTING MACHINE | TRANSPORT ⇨ | 6 | | |
| | DELAY D | 1 | | |
| | INSPECTION □ | | | |
| | STORAGE ▽ | | | |
| METHOD:- PRESENT | TOTAL ACTIVITY | 14 | | |
| LOCATION:-BLAST FURNACE,SAMAGHOGHA | TIME (man-min) | | | |
| :GUIDE BY:- KULDEEP BHATNAGAR | COST | | | |
| | LABOUR | | | |
| CHARTED BY:-Vimal Makwana | MATERIAL | | | |
| APPROVED BY:- | TOTAL | | | |

| DESCRIPTION | QTY | DIST-ANCE | TIME (min) | SYMBOL ○ | ⇨ | D | □ | ▽ |
|---|---|---|---|---|---|---|---|---|
| POURING METAL FROM LADDLE | | | | ● | | | | |
| FORWARD THE MELT TO MAIN RUNNER | | | | | ● | | | |
| FORWARD THE MELT MAIN RUNNER TO SLAG CHUTE | | | | | ● | | | |
| SLAG ARE COLLECTED BY SLAG CHUTE | | | | ● | | | | |
| FORWARD THE MELT TO APRON PLATE | | | | | ● | | | |
| OVERFLOW MELT WILL BE COLLECTED IN APRON PLATE [ TWO STAND ] | | | | ● | | | | |
| TWO STAND PRODUCED CASTING FOR ROTATION | | | | ● | | | | |
| CAST IS COOLED BY WATER | | | | ● | | | | |
| SPRAY THE LIME ON CAST | | | | ● | | | | |
| FORWARD THE CAST FOR DISCHARGE | | | | | ● | | | |
| DISCHARE THE CAST | | | | | ● | | | |
| WAITING FOR CRANE | | | | | | ● | | |
| LOADING THE CAST BY MAGNETIC CRANE | | | | ● | | | | |
| TRANSPORT THE CAST | | | | | ● | | | |
| | | | | | | | | |
| Total | | | | 7 | 6 | 1 | | |

*Figure 2.1: Example of Flow Process Chart (Material Type)*

**Exercise: Construct Flow Process for the given assembly and situations in the following format**

1. Manufacturing blade assembly of table fan. Each blade consists of the following components: (i) Blade. (ii)Fixing plate. (iii)Three pieces of bolt and nut pairs. (iv) Six pieces of washers
2. Assembly of Nut Bolt and Washer
3. Writing a letter using a short hand typist.:
   Chart Begins: Short Hand typist in his office awaiting for dictation.
   Chart Ends: Short Hand typist put typed letter and its copies in Dispatch Tray.
4. For manufacturing the job given in figure. Construct for both material and machine tool used.




All Dimensions Are In M.M.

5. Repair of Car punctured tyre.
6. Construct a Flow Process Chart for the following:

| | |
|---|---|
| i. Move bar stock from store to hacksaw | Dist. 8 meter |
| ii. Cutting of bar stock | Time 4 min |
| iii. Move to lathe machine | Dist. 6-meter |
| iv. Turning Process | Time 5 min |
| v. Move to milling machine | Dist. 7-meter |
| vi. Wait for milling machine | Time 2 min |
| vii. Milling keyway | Time 10 min |

## FLOW PROCESS CHART

**TYPE** ______________

| CHART NO:- SHEET NO:- OF:- | SUMMARY | | | |
|---|---|---|---|---|
| Subject charted:- | ACTIVITY | PRESENT | PROPOSE | SAVING |
| | OPERATION ○ | | | |
| ACTIVITY:- | TRANSPORT ⇨ | | | |
| | DELAY D | | | |
| | INSPECTION □ | | | |
| | STORAGE ▽ | | | |
| METHOD:- | DISTANCE (m) | | | |
| LOCATION:- | TIME (man-min) | | | |
| OPERATIVE(S):- CLOCK Nos:- | COST:- | | | |
| | LABOUR | | | |
| CHARTED BY:- | MATERIAL | | | |
| APPROVED BY:- DATE:- | TOTAL | | | |

| DESCRIPTION | TIME (min) | SYMBOL ○ | ⇨ | D | □ | ▽ | |
|---|---|---|---|---|---|---|---|
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| TOTAL | | | | | | | |

# EXPERIMENT NO: - 03

**AIM:** To study & Prepare Man-Machine (Multiple Activity) Chart for the given situation

**OBJECTIVES:** After completing this experiment, you will be able to:

- Record the activities performed by the operator and machine.
- Identify independent, combined and idle activities.
- Construct man and machine chart.
- Calculate utilization for man and machine.
- Analyze the chart with a view to increase utilization.

## Introduction: -

**Man-Machine (Multiple Activity) Chart:** A man-machine (multiple activity) chart is a chart on which the activities of more than one subject (worker, machine or item of equipment) are each recorded on a common on a common time scale to show their interrelationship.

Man-Machine chart or multiple activity chart is a useful recording tool for situations where the work involves interactions of different subjects. One or more workers looking after different machines or a group of workers on loading materials at one point and dumping the same at a different point are some examples where this type of chart can be used effectively. The fundamental difference between this tool and the other charts described in the previous section are as follows:

**a.** In man-machine (multiple activity) chart a time scale is used. No such time scale is used in the other charts.

**b.** Man-machine (multiple activity) charts can be used equally effectively even if there is no movement of workers involved in the work under consideration. The primary focus of this chart, for situations where the workers are moving as a part of their work, is to identify the idle time on the part of either the workers or the machines. The focus of other charts described so far were primarily to identify excess distances traversed by the workers, which is only indirectly related to the time.

By using separate vertical columns, or bars, to represent the activities of different operatives or machines against a common time scale, the chart shows very clearly periods of idleness on the part of any of the subjects during the process. A study of the chart often makes it possible to rearrange these activities so that such ineffective time is reduced. The man- machine (multiple activity) chart is extremely useful in work involving repetitive operations. For a situation involving a worker handling different machines, this chart can be used to find the number of machines the worker can look after so as to minimize the cost.

*[Work Study by ILO page no: 125-126]*

**Example of Man-Machine (Multiple Activity) Chart: -**

Operator Name : Ram Dyal Sharma
Department : Machine Shop
Activity : Drill hole in casting
Drg.No : C25
Method : Present

**Summary**

| | Man | Machine |
|---|---|---|
| Idle time | 2.50 minutes | 1.25 minutes |
| Working time | 1.25 | 2.50 |
| Total cycle time | 3.75 | 3.75 |
| Utilization | Operator utilization = $\frac{1.25}{3.75}$ = 33% | Machine utilization = $\frac{2.50}{3.75}$ = 67% |

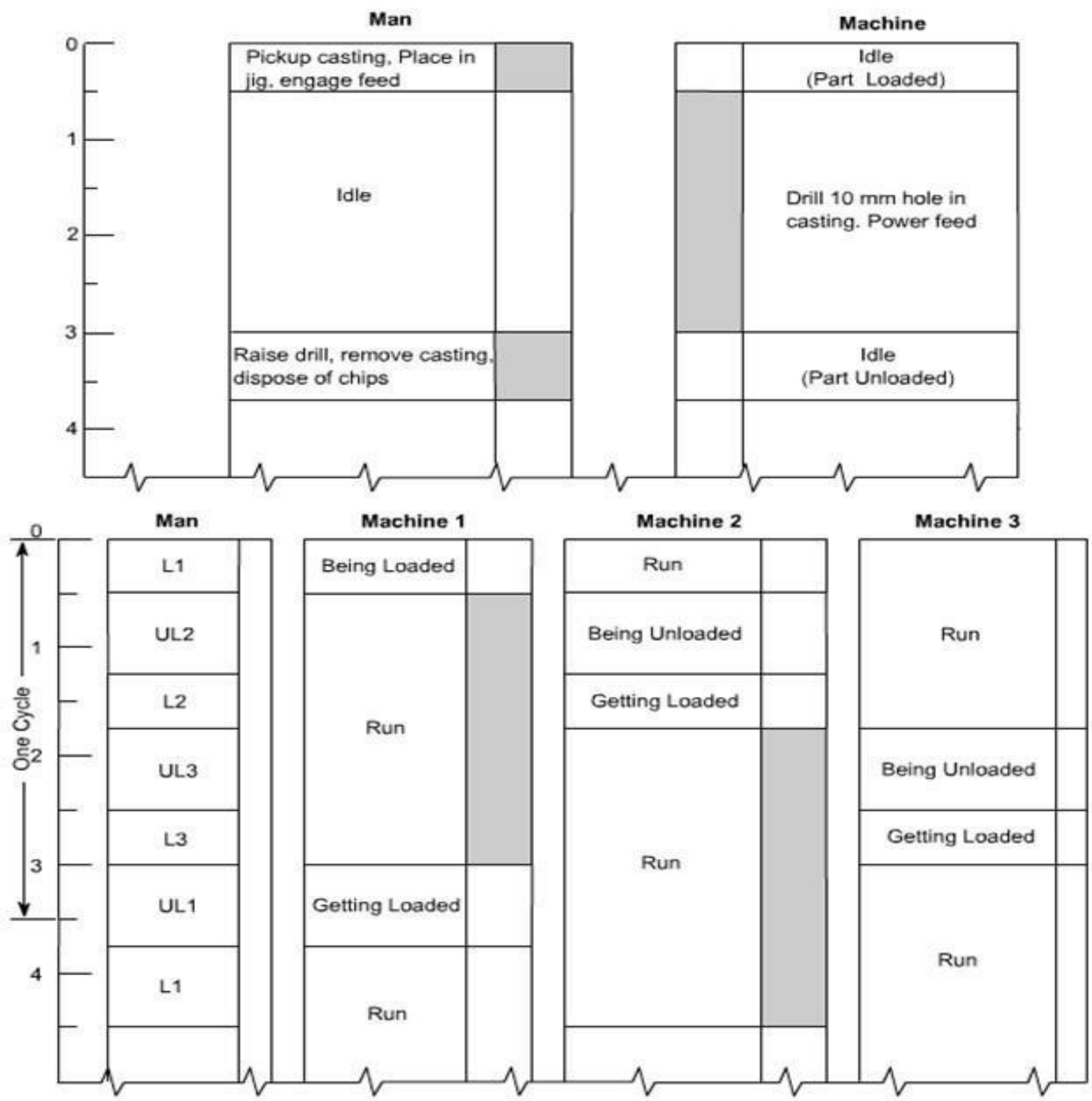


*Figure 3.1: Example of Man- Machine (Multiple) Chart*

**The activities involved during the operations are classified as: -**

1. **Independent Activity:**
   Man: Operator working independently.
   Machine: Auto feed, m/c working independently.
2. **Combined Activity:**
   Man: Operator working with other operator or handling machine (hand feed).
   Machine: Machine loaded or unloaded, servicing of machine.
3. **Idle:**
   Man: Waiting for machine to complete operation.
   Machine: Operator engaged in inspection, etc.

**The color used to show various activities on man and machine chart are:**

1. **Green:** For independent activity.
2. **Orange:** For combined activity.
3. **Red:** For idle time.

**Exercise: Construct Man-Machine (Multiple Activity) Chart for the situations**

1. Each of the two sides of a hand-operated toaster can be operated independently of the other. A spring holds each side of the toaster shut, and each side must be held open in order to insert bread. Assume that the toaster is hot and ready to toast bread. The following are the elemental times necessary to perform the operations. Assume also that both hands can perform their tasks with the same degree of efficiency.
   - Place slice of bread in either side of toaster: 4 seconds.
   - Toast either side of bread: 30 seconds.
   - Turn slice of bread on either side of toaster: 2 seconds.
   - Remove toast from either side of toaster: 4 seconds.

   By using an activity chart for toasting 3 slices of bread, what method would you recommend to obtain the best equipment utilization that is, the very shortest over-all time?
2. A chamfering, turning and threading operation is done on a job on lathe machine. Information of that operation is recorded as under. Show this information on man and machine chart.

| | |
|---|---|
| i. Carry bar stock from the store. | 1 min |
| ii.To fix the job in lathe chuck. | 2 min |
| iii.To carryout manual turning of the job. | 1.5 min |
| iv. To carryout chamfering operation on job | 1 min |
| v. To carryout threading operation on job. | 2 min |
| vi. To bring the saddle back and rearrange it | 0.5 min |
| vii. To carryout threading work on the job. | 1.5 min |
| viii. Inspection of the job. | 1 min |
| ix. To remove the job from the lathe chuck. | 0.5 min |
| x. Carrying completed work piece to store | 1 min |

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# EXPERIMENT NO: - 04

**AIM:** To study & Calculate co-efficient of co-relation for time study person using performance rating technique.

**OBJECTIVES:** After completing this experiment, you will be able to:

- Understand the meaning of Rating.
- Develop skill to rate the worker.
- Evaluate the rating of the given activity.
- Plot graph of observed rating v/s actual rating.

## Introduction: -

**Work Measurement:** Work measurement is the application of techniques designed to establish the time for a qualified worker to carry out specific job at a defined level of performance.

**The qualified worker:** A qualified worker is one who is accepted as having the necessary physical attributes, who possesses the required intelligence and education, and who has acquired the necessary skill and knowledge to carry out the work in hand to satisfactory standards of safety, quantity and quality.

**Rating:** Rating is the assessment of the worker's rate of working relative to the observer's concept of the rate corresponding to standard pace. The society of Advancement of Management National Committee defines rating as that process during which the time study engineer compares the performance of the operator under observations with the observer's concept of proper (normal) or standard performance.

$$Performance\ Rating = \frac{Observed\ performance}{normal\ performance} \times 100$$

**Standard (Pace) Performance:** Standard performance is the rate of output which qualified workers will naturally achieve without over-exertion as an average over the working day or shift, provided that they know and adhere to the specified method and provided that they are motivated to apply themselves to their work. This performance is denoted as 100 on the standard rating and performance scales.

**Rating Scale:** Rating scale is used to compare workers pace with standard pace. The indication of how much worker's pace is more or less as compared to the standard pace. There are different types of rating scales but out of which only three main rating scales are used, they are: (i) 60-80 (ii) 100-133 (iii) 75-100

| RATING SCALE | | | DESCRIPTION |
|---|---|---|---|
| **60-80** | **100-133** | **75-100** | |
| 0 | 0 | 0 | No activity |
| 40 | 67 | 50 | Very slow, confonded, without interest and activity done while sleeping |
| 60 | 100 | 75 | Activity carried out without any haste, slowly but at constant pace. |
| **80** Standard Rating | **133** Standard Rating | **100** Standard Rating | Activity carried out without confidence, past experience and speedily by maintaining accuracy & quality. |
| 100 | 167 | 125 | Activity undertaken by trained worker at more speed, confidence and full capacity. |
| 120 | 200 | 150 | Activity undertaken applying lot of mental and physical ability at abnormal efficiency, speed and with concentration. |

*Table 4.1: Table for Different types of Rating Scale*

**Rating method and calculation:** The rating of 100 is given to the worker working with speed & confidence maintaining the accuracy and quality, if he works with more speed and skillfully then rating of 115 or 125 can be assigned to him. But if the workers work with speed below the standard pace & less skill then rating of 95, 90, 80, etc, can be assigned to him

Conducting time study & recording time by taking required number of observation, workers will be assigned his rating. Thereafter standard time can be calculated as follows:

$$Basic\ time = Observed\ time \times \frac{Rating\ of\ worker}{Standard\ Rating}$$

So, **Actual Rating or Rating factor** of a worker can be found as follows:

$$Actual\ Rating = \frac{Basic\ time}{Observed\ time} \times 100$$

**Procedure of performing this experiment:**

- At a time one student will walk a distance of 25 feet in a normal way.
- Another student (time-keeper) will note down the time taken for that student to walk.

-  All the remaining students will assign rating to the student walking in the observation table.
-  Time-keeper will give time for that student to all the students.
-  Repeat the same procedure changing the time-keeper and the student walking  Find basic time using observations.
-  Find actual rating using basic time.
-  Plot a graph of actual rating v/s observed rating.

**OBSERVATION TABLE**

| Sr. No. | Observed Time in sec. | Observer's Rating | Standard Rating | Basic Time in sec | Actual Rating | Error in rating +/- |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
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| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
| 13 | | | | | | |
| 14 | | | | | | |
| 15 | | | | | | |

**Calculations:**

**For Basic Time:**

$$Basic\ time = Observed\ time \times \frac{Rating\ of\ worker}{Standard\ Rating}$$

**For Actual Rating:**

$$Actual\ Rating = \frac{Basic\ time}{Observed\ time} \times 100$$

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# EXPERIMENT NO: - 05

**AIM:** To study & Calculate standard time for given job.

**OBJECTIVES:** After completing this experiment, you will be able to:

- Use a stopwatch
- Break the job into elements.
- Compute the normal/basic time.
- Calculate standard time.

## Introduction: -

**Work Measurement:** Work measurement is the application of techniques designed to establish the time for a qualified worker to carry out specific job at a defined level of performance.

**Standard Time:** Standard time is the total time in which a job should be completed at standard performance.

Standard times for operations are useful for several applications in industry, like

- Estimating material, machinery, and equipment requirements.
- Estimating production cost per unit as an input to
  - Preparation of budgets
  - Determination of selling price
  - Make or buy decision
- Estimating manpower requirements.
- Estimating delivery schedules and planning the work
- Balancing the work of operators working in a group.
- Estimating performance of workers and using that as the basis for incentive payment to those direct and indirect labor who show greater productivity.

**Time Study:** Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analyzing the data so as to obtain the time necessary for carrying out the job at a defined level of performance.This technique is based on measuring the work content of the task when performed by the prescribed method, with the allowance for fatigue and for personal and unavoidable delays.

**Time Study Procedure:**

The procedure for time study can best be described step-wise, which are self-explanatory.

**Step 1:** Define objective of the study. This involves statement of the use of the result, the precision desired, and the required level of confidence in the estimated time standards.

**Step 2:** Verify that the standard method and conditions exist for the operation and the operator is properly trained. If need is felt for method study or further training of operator, the same may be completed before starting the time study.

**Step 3:** Select operator to be studied if there are more than one operator doing the same task.

**Step 4:** Record information about the standard method, operation, operator, product, equipment, and conditions on the Time Study observation sheet.

**Step 5:** Divide the operation into reasonably small elements, and record them on the Time Study observation sheet.

**Step 6:** Time the operator for each of the elements. Record the data for a few number of cycles on the Time Study observation sheet. Use the data to estimate the total number of observations to be taken.

**Step 7:** Collect and record the data of required number of cycles by timing and rating the operator.

**Step 8:** Calculate the representative watch time for each element of operation. Multiply it by the rating factor to get normal time.

**Basic Time (Normal time) = Observed time *x* rating factor**

Calculate the normal time for the whole operation by adding the normal time of its various elements.

**Step 9:** Determine allowances for fatigue and various delays.

**Step 10:** Determine standard time of operation.

Standard time = Normal time + allowances

**Selection of Worker for Time Study**

The selection of worker for time study is a very important factor in the success of the study. If there is only one person on the job, as usually is, then there is no choice. But if more than one person is performing the same operation, the time study man may time one or more of the workers. If all the workers are using the same method for doing the job and there is different in the rate of their doing it, it is necessary to select a suitable worker for the study. The worker on which time study should be conducted must

- have necessary skill for the job.
- have sufficient experience with the given method on the job (that is, he should have crossed the learning stage).
- be an 'average' worker as regards the speed of working.
- be temperamentally suited to the study (those who can't work in normal fashion when watched, are not suitable for the study).
- have knowledge about the purpose of study.

**Time Study Equipment**

The following equipment is needed for time study work.

- Timing device
- Time study observation sheet
- Time study observation board
- Other equipment

**Time Study Board:** It is a light -weight board used for holding the observation sheet and stopwatch in position. It is of size slightly larger than that of observation sheet used. Generally, the watch is mounted at the center of the top edge or as shown in Figure3.1 near the upper righthand corner of the board. The board has a clamp to hold the observation sheet. During the time study, the board is held against the body and the upper left arm by the time study person in such a way that the watch could be operated by the thumb/index finger of the left hand. Watch readings are recorded on the observation sheet by the right hand.

**Timing Device:** The stop watch (see Figure 3.1) is the most widely used timing device used for time study, although electronic timer is also sometimes used. The two perform the same function with the difference that electronic timer can measure time to the second or third decimal of a second and can keep a large volume of time data in memory.

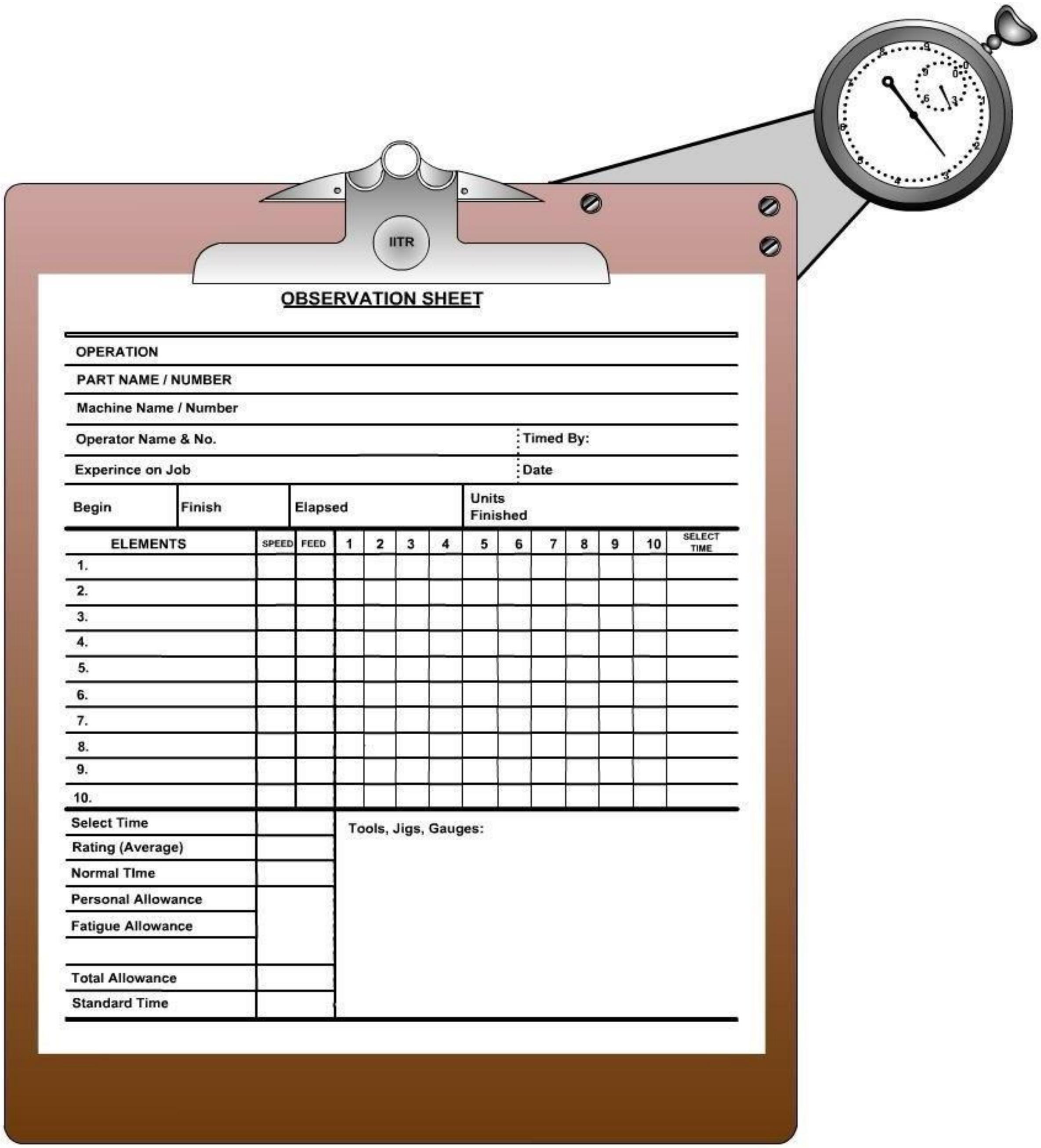



*Figure 5.1: Time Study board and timing device*

**Time Study Observation Sheet.** It is a printed form with spaces provided for noting down the necessary information about the operation being studied, like name of operation, drawing number, and name of the worker, name of time study person, and the date and place of study. Spaces are provided in the form for writing detailed description of the process (element-wise), recorded time or stop-watch readings for each element of the process, performance rating(s) of operator, and computation. Figure5.2 shows a typical time study observation sheet.

**OBSERVATION SHEET**

| | |
|---|---|
| SHEET 1 OF 1 SHEETS | DATE |
| OPERATION | OP.NO. |
| PART NAME | PART NO. |
| MACHINE NAME | MACH.NO. |
| OPERATOR'S NAME & NO. | MALE ☐ FEMALE ☐ |
| EXPERIENCE ON JOB | MATERIAL |
| FOREMAN | DEPT.NO. |

| BEGIN | FINISH | ELAPSED | UNITS FINISHED | ACTUAL TIME PER 100 | NO. MACHINES OPERATED |
|---|---|---|---|---|---|
| | | | | | |

| ELEMENTS | | SPEED | FEED | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | SELECTED TIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 2. | | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 3. | | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 4. | | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 5. | | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 6. | | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 7. | | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 8. | | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 9. | | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 10. | (1) | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 11. | (2) | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 12. | (3) | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 13. | (4) | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 14. | (5) | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 15. | (6) | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 16. | (7) | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 17. | (8) | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |
| 18. | | | | T | | | | | | | | | | | |
| | | | | R | | | | | | | | | | | |

| SELECTED TIME | RATING | NORMAL TIME | TOTAL ALLOWANCE | STANDARD TIME |
|---|---|---|---|---|
| | | | | |

| SKETCH OF COMPONETS: | TOOLS.JIGS.GAUGES: |
|---|---|
| | TIMED BY: |

*Figure 5.2: Time Study Observation Sheet*

**Time Study Allowance:** The normal time for an operation does not contain any allowances for the worker. It is impossible to work throughout the day even though the most practicable, effective method has been developed.

Even under the best working method situation, the job will still demand the expenditure of human effort and some allowance must therefore be made for recovery from fatigue and for relaxation. Allowances must also be made to enable the worker to attend to his personal needs. The allowances are categorized as:

1. Relaxation allowance,
2. Interference allowance, and
3. Contingency allowance.

**RELAXATION ALLOWANCE:** Relaxation allowances are calculated so as to allow the worker to recover from fatigue. Relaxation allowance is a addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological effects of carrying out specified work under specified conditions and to allow attention to personal needs. The amount of allowance will depend on nature of the job.
Relaxation allowances are of two types: fixed allowances and variable allowances.

**Fixed allowances** constitute:

a. **Personal needs allowance:** It is intended to compensate the operator for the time necessary to leave, the workplace to attend to personal needs like drinking water, smoking, washing hands. Women require longer personal allowance than men. A fair personal allowance is 5% for men, and 7% for women.

b. **Allowances for basic fatigue*:*** This allowance is given to compensate for energy expended during working. A common figure considered as allowance is 4% of the basic time.

**VARIABLE ALLOWANCE**: Variable allowance is allowed to an operator who is working under poor environmental conditions that cannot be improved, added stress and strain in performing the job. The variable fatigue allowance is added to the fixed allowance to an operator who is engaged on medium and heavy work and working under abnormal conditions. The amount of variable fatigue allowance varies from organization to organization.

**INTERFERENCE ALLOWANCE**: It is an allowance of time included into the work content of the job to compensate the operator for the unavoidable loss of production due to simultaneous stoppage of two or more machines being operated by him. This allowance is applicable for machine or process controlled jobs. Interference allowance varies in proportion to number of machines assigned to the operator. The interference of the machine increases the work content.

**CONTINGENCY ALLOWANCE**: A contingency allowance is a small allowance of time which may be included in a standard time to meet legitimate and expected items of work or delays. The precise measurement of which is uneconomical because of their infrequent or irregular occurrence.

This allowance provides for small unavoidable delays as well as for occasional minor extra work: Some of the examples calling for contingency allowance are:

- Tool breakage involving removal of tool from the holder and all other activities to insert new tool into the tool holder.

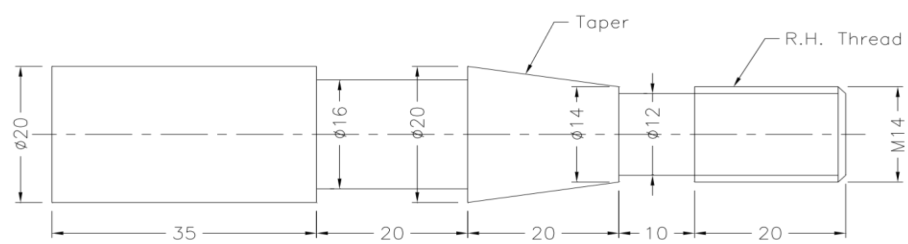
- Power failures of small duration.
- Obtaining the necessary tools and gauges from central tool store. Contingency allowance should not exceed 5%.

**POLICY ALLOWANCE**: Policy allowances are not the genuine part of the time study and should be used with utmost care and only in clearly defined circumstances.The usual reason for making the policy allowance is to line up standard times with requirements of wage agreement between employers and trade unions.

The policy allowance is an increment, other than bonus increment, applied to a standard time (or to some constituent part of it, *e.g.*, work content) to provide a satisfactory level of earnings for a specified level of performance under exceptional circumstances. Policy allowances are sometimes made as imperfect functioning of a division or part of a plant.

**Exercise**

1. **Calculate the standard for given assembly:**




All Dimensions Are In M.M.

**Calculations:**

$$\boldsymbol{Basic\ time = Observed\ time \times \frac{Rating\ of\ worker}{Standard\ Rating}}$$

**Work Content= Basic time + Relaxation & Incidental Allowances**

**Standard Time= Work Content + Other Allowances**

**OBSERVATION TABLE**

| Sr. No. | Name of Elements | Time in seconds | | | | | Avg. time (sec) | Rating | Basic Time (sec) | RA | CA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | t1 | t2 | t3 | t3 | t5 | | | | | |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7** | | | | | | | | | | | |
| **8** | | | | | | | | | | | |
| **9** | | | | | | | | | | | |
| **10** | | | | | | | | | | | |
| **11** | | | | | | | | | | | |
| **12** | | | | | | | | | | | |
| **13** | | | | | | | | | | | |
| **14** | | | | | | | | | | | |
| **15** | | | | | | | | | | | |

**Calculations:**

**For Basic Time:**

$$\boldsymbol{Basic\ time = Observed\ time \times \frac{Rating\ of\ worker}{Standard\ Rating}}$$

**For Actual Rating:**

$$\boldsymbol{Actual\ Rating = \frac{Basic\ time}{Observed\ time} \times 100}$$

**2.** A stop watch time study was conducted for machining shaft on a lathe machine and following data were collected:

| | |
|---|---|
| Loading Time | - 1.80 minute |
| Machining Time | - 6.75 minute |
| Unloading Time | - 1.05 minute |
| Inspection Time | - 0.40 minute |
| Over all cycle rating | - 92 % |
| Allowance for fatigue, etc. | - 12 % |

Find out the standard time for machining work and calculate that how many shaft will be manufactured in 8 hours shift?

**3.** During the production of a machine component the average observed time of four elements are 0.8 min, 0.6 min, 1.2 min, and 1.5 min. Rating for respective elements are 80 %, 100%, 90%, and 110%. If the allowances are 20% find out standard time and also find out production per hour.

**4.** A work has its true standard time as 2.4 min. During stop watch study its observed time is noted as 2.5 min and 90% rating is given for work. If total allowance to be provided is 20% determine that given rating is tight or loose. Calculate the difference between true standard time and calculated standard time. Also state its effect of this difference on workers.

# EXPERIMENT NO: - 06

**AIM:** To study & Prepare a frequency Distribution Curve for the given data source.

**OBJECTIVES:** After completing this experiment, you will be able to:

- Measure variable characteristic
- Record observations in data sheet.
- Make Frequency Tall sheet.
- Calculate mean value and standard deviation of data.
- Plot frequency distribution curve.
- Verify characteristic of normal distribution.

## Introduction: -

**Frequency:** Frequency means the number of times a particular dimension of a part or any data occurs during an observation.

**Tally Sheet:** The preparation of table for the raw data or information available during an observation is called Tally sheet.

**Range:** The difference between maximum value and minimum value of data is called range.

**Class:** When the data is arranged in different groups with their corresponding frequencies then that group is called a class or cell

**Class Boundary:** Each class or cell has two boundaries. One is called upper class boundary and another is called lower class boundary. The maximum and minimum numbers of the class or cell, are considered to calculate boundaries.

For finding the class boundary we take half of the difference between lower class limit of the 2nd class and upper class limit of the 1st class. For example, if the lower class limit of the 2nd class is 20 and upper class limit of the 1st class is 19 then the class boundary can be found as:

$$\frac{20-19}{2} = \frac{1}{2} = 0.5$$

This value is subtracted from lower class limit and added in upper class limit to get the required class boundaries.

**Class mid-point:** Class mid-point can be found out by adding upper class boundary and lower class boundary (or upper class limit and lower class limit) and dividing the sum by 2 which is shown as follows:

**Class Interval:** The difference of upper class boundary and lower class boundary is called interval. It is denoted by ***c*** or ***i.*** the difference between two nearby mid-points is also called interval.

**Frequency Distribution Chart:** The presentation of variable data in the form of graph is called frequency distribution chart. The following four charts are prepared to show the frequency distribution:

**1.** Frequency Histogram.
**2.** Frequency Bar Chart.
**3.** Frequency Polygon chart.
**4.** Frequency Distribution Curve.

The various charts can be drawn on the basis of frequency distribution. The frequency distribution table can be prepared by calculation of lower and upper class boundaries, class midpoint and frequency.

**Frequency Distribution Curve:** For drawing these curves the points of intersection of class midpoints and frequencies are marked on a graph. The points obtained are then joint by a smooth curve. The frequency distribution curve is very much important in Statistical Quality Control. There are three types of frequency distribution curves, which are as follows:

**1.** Normal Distribution Curve.
**2.** Binomial Distribution Curve.
**3.** Poisson Distribution Curve.

**Normal Distribution Curve:** Normal distribution curve shows the simplest pattern of distribution upon the type of thing being measured there is generally a pattern of distribution that indicates the way in which a dimension can vary. If the dimensional variability in products of a system is by chance, then it will follow approximately 'Normal Distribution Curve'

In a normal distribution curve, there are two statistical controls, average and standard deviation. It has been calculated that two times the standard deviation covers about 68% of the total area. Four times the standard deviation covers 95.5% and six times the standard deviation covers 99.73% of the total area.

**Characteristics of Normal Distribution Curve:**

**1.** Inverted bell shape this curve is symmetrical.
**2.** Continuous distribution of numbers and infinite size population is shown by this curve.
**3.** The values of mean, median and mode are same in it.
**4.** Taking mean as zero, curve spreads from $-\infty$ to $+\infty$
**5.** The mean and standard deviation are shown in it as X-bar and $\sigma$ sigma.

**Applications of Normal Distribution Curve:**

1. In day to day routine, the event occurs in which the normal distribution curve can applied is Figures for age of students studying in a class, weight of new born child, and rainfall figures at a place during ten years.
2. Standard deviation is widely used to obtain important findings in the subjects like sociology, psychology and statistics.
3. Standard deviation is useful in controlling quality in industries.
4. To estimate the quality of whole lot, only by drawing & checking a small sample from that lot.
5. To indicate the process this is stable, but not able to produce items within tolerances.
6. To indicate the process this is stable, producing item within tolerances.
7. If this is pulled to one side, then it shows that either there are more number of larger or smaller product than the normal size.

**Central Tendency:** When accurately measured, the dimension of most of the components will concentrate close to the middle of the two extremes. This is called central tendency. In the other words the maximum number of components will have sizes equal to or approximately close to the middle size and the sizes bigger or smaller than the middle size will be least frequent and lie near the two extremes. This numbers have three dimensions:

**1.** Mean **2.** Mode **3.** Median

1. **Mean or Average:** Mean or average is a measure of central tendency or location. The notation $\bar{x}$(x bar) is used to denote mean or average. Thus, if there are 'n' number of observations with valued x1, x2, x3………xn, then

$$\bar{x} = \frac{x_1 + x_2 + \cdots \dots \dots \dots . + x_n}{n}$$

**The mean for grouped data i.e. data having frequency can be find using**

$$\bar{x} = \frac{\Sigma f_i x_i}{n}$$

**Where,** $\Sigma f_i x_i = f_1x_1 + f_2x_2 + f_3x_3 + \ldots + f_n x_n$

$n = \Sigma f = f_1 + \ldots.. + f_n$

2. **Mode:** Mode is the value that occurs most frequently. But the most important one used in statistical quality control is half the mean or average.

**3.**

**For grouped data where frequency is given:** Mode will be the value with the largest frequency

**If class or cell is given:** The mode can be found out by using the formula:

$$mode = L + [\frac{f_2}{f_1 + f_2}] \times i$$

Where, L= Lower Boundary of the class having maximum frequency

$f_1$ =Frequency of the class before the class having maximum frequency

$f_2$=Frequency of the class after the class having maximum frequency

$i$ = Class interval.

4. **Median:** Median is the magnitude of middle class, i.e, the value that has the observation above its half and half below it. Therefore, median can be said as middle observation, dimension or figure.

**For simple data:** First arrange the data in ascending order and then find the middle value. If the observation is even, then adding the two middle values and divide it by 2.

**For grouped data having frequency:** The median can be find using the following formula:

First divide the frequency by 2, we will get the class by answer of the division then using the formula

$$median = L_m + \left[\frac{\frac{N}{2} - Cf_m}{f_m}\right] \times i$$

Where, Lm= Lower Boundary of the median class

N =Number of observations

$f_m$ =Frequency of the median class

$Cf_m$ = Sum of frequencies of all classes below median class

i= Class interval

**Spread or dispersion:** The manner in which the observation is spreader between minimum and maximum is called spread or dispersion. They are of two types:

**1. Range 2. Standard Deviation.**

1. **Range:** It is a measure of dispersion and it is the difference between the largest observed value and the smallest observed value of a set of observations. It is represented by the symbol 'R'.
2. **Standard Deviation:** It is defined as the root mean square deviation of the observed value from their arithmetic mean. It is denoted as σ (sigma)

   **So,**

$$\sigma = \sqrt{\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 \pm \cdots \ldots \ldots \ldots \ldots + (x_n - \bar{x})^2}{n}}$$

**Variance:** The square of standard deviation is called variance.

3. **Normalized deviation of Z-value:** For measuring the areas under normal distribution curve, the normal deviation is used. It is also called Z-value

$$Z = \frac{x_i - \bar{x}}{\sigma}$$

Where, $x_i$= The value up to which area is to be found

$\bar{x}$ =Mean Value

$\sigma$ = Standard Deviation

**Exercise:**

**1.** From the given data in the table find out mean and standard deviation.

| Class | 0-4 | 5-9 | 10-14 | 15-19 | 20-24 | 25-29 | 30-34 |
|---|---|---|---|---|---|---|---|
| Frequency | 5 | 10 | 15 | 20 | 14 | 11 | 6 |

**2.** Draw Normal Distribution curve from the following data:

Upper & lower specification limits of shaft diameter are 30.20 and 30.00mm respectively. Mean diameter of shaft is 30.05mm and standard deviation is 0.05mm. Find out how many parts out of 400 will be accepted.

| **Z-value** | **Area** |
|---|---|
| 3 | 0.4987 |
| -1 | 0.3413 |

**3.** Draw Histogram, Frequency Bar Chart, Frequency Polygon and Frequency Distribution Curve from the following data:

75, 80, 63, 65, 70, 12, 18, 22, 31, 33, 34, 35, 38, 40, 52, 55, 57, 60, 41, 45, 47, 49

**4.** Calculate mean, median, mode and range for the following data:

2, 4, 5, 4, 9, 6, 4, 6

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# EXPERIMENT NO: - 07

**AIM:** To study & Construct $\bar{x}$ – R Chart for given process.

**OBJECTIVES:** After completing this experiment, you will be able to:

- Draw random samples for inspection.
- Inspect given products as per procedure.
- Compute upper control limit and lower control limit.
- Find process capability.
- Plot $\bar{x} -$ R chart from observation data.

## Introduction: -

**Variable (continuous data.):** Things we can measure. Example includes length, weight, time, temperature, diameter, etc.

**Attribute (discrete data.):** Things we count. Examples include number or percent defective items in a lot, number of defects per item etc.

**Control Charts:** A control chart is a graphical representation of the collected information. The information may pertain to measured quality characteristics or judged quality characteristics of samples. It detects the variation in processing and warns if there is any departure from the specified tolerance limits.

**Statistical Basis for Control charts:** There are two types of quality viz.

1. Variable Quality: This variable quality can be measured. Diameter of shaft, length of bolt, radius of pulley, hardness of materials, strength, density, weight and temperatures are the examples of variable quality.
2. Attribute Quality: This product based quality cannot be measured. Its quality can be said as good (defect less) and bad (defective). For example, concept of surface finishing, brightness of surface, blow holes, dents, spots, color, are the different qualities. If there are blow holes I n a casting, then that casting can be said as a defective. Bright surface is good but when the desired brightness of surface is not there, the surface can be said as bad or defective.

**Control Charts for variables**

Variable control charts are of two types viz.

**1.** $\bar{x} -$ R chart. **2.** $\bar{x} -$ σ chart.

**1** **$\bar{x}$– R Chart:** This type of control charts is used for manufactured parts which the inspector checks by measurement and not by gauging. This method of control is more expensive. It reveals much more about the behavior of the process. The $\bar{x} -$ R charts supply a basis on which to judge the stability of the pattern of variation. To found out whether the process is in the state of control or not, control limits are setup. The control chart is usually maintained for averages and not for individual components. The distribution for individual may or may not be normal but the distribution for averages follow normal distribution. In any manufacturing process there is some variation from piece to piece. Two kinds of variation exist in manufacturing. The variation due to chance causes & assignable causes. The chance causes are inevitable in any process. This inherent process variation is a characteristic of the process and is the result of random causes. These random fluctuations cause the process to deviate either side of the average.

2 **$\bar{x}-\sigma$ Chart:** By drawing σ chart along with $\bar{x}$ chart the information can be also obtained. Both these charts are called variable charts. σ Chart is used to control the standard deviation under control by knowing the standard deviation of the process.

**Objectives of control charts for variables:**

1. To decide whether the manufacturing process is complying the specifications or not.
2. To ascertain product quality.
3. To find and remove the causes of process which is not under control.
4. To obtain information to decide whether to change the method of inspection or to decide the method for inspection.
5. To decide whether the product manufactured is to be accepted or rejected.

**Method of drawing variable quality chart:**

1. Take random sample from production process, and measure its important quality such as length, diameter. Indicate this dimension as $\bar{x}$ **-** variable for all such sub-groups it is necessary to take 4 or 5 observations. For inspection take such 25 sub-groups.
2. Calculate $\bar{x}$ and R for all sub groups. R is the difference between the maximum and minimum value of individual subgroup.
3. The values of **-** and R follows the principle of standard deviation. Calculate the mean of‾ and R as under:

$$\bar{\bar{x}} = \frac{\Sigma x}{n} \qquad and \qquad R = \frac{\Sigma R}{n}$$

Where $\bar{\bar{x}}$ = mean of or mean of average of subgroup
$R$= mean of Spread-R
$\bar{x}$ = Average or mean of the subgroup
R=spread
N=No. of random sample

$\bar{\bar{x}}$ is the central or middle line of $\bar{x}$ chart.
$R$ is the central or middle line of R chart.

4. Calculate the upper control limit- UCL. This line is at a distance of 3σ from the central line of **chart**, above the line.

$$UCL = \bar{\bar{x}} + 3\sigma \quad OR \quad UCL = \bar{\bar{x}} + A_2\bar{R}$$

The is constant which depends upon size of subgroup and can be found from the table of constants.

5. Calculate lower control limit-LCL. This line is at a distance of 3σ from the central line of chart, below the line.

$$LCL = \bar{\bar{x}} - 3\sigma \quad OR \quad LCL = \bar{\bar{x}} - A_2\bar{R}$$

6. To draw control lines for R-chart. Calculate as mean of R observations & then find upper control limit (UCL **)** lower control limit (LCL)**,**

$$UCL = d_4\bar{R} \quad \& \quad LCL = d_3\bar{R}$$

Where $d_3$ & $d_4$ are constants which are obtained from the table of constants

7. To draw each chart mark, the value of $\bar{x}$ and R & obtain corresponding points. Joint these points by straight lines.
8. Calculate standard deviation using formula as given below:

$$\sigma = \frac{R}{d_2}$$

9. Calculate Process capability, $\acute{\sigma} = 6 \cdot \sigma$

**Where $d_2$, is the constant for standard deviation which is given in table of constants.**

**Table for constants:** The following is the table of constant:

| **Sample Size** | **Constant for -chart** | **Constants for R-chart** | | **Constant for Standard Deviation** |
|---|---|---|---|---|
| ***n*** | $A_2$ | $D_3$ | $D_4$ | $d_2$ |
| 2 | 1.880 | 0 | 3.268 | 1.128 |
| 3 | 1.023 | 0 | 2.574 | 1.693 |
| 4 | 0.729 | 0 | 2.282 | 2.059 |
| 5 | 0.577 | 0 | 2.114 | 2.326 |
| 6 | 0.483 | 0 | 2.004 | 2.534 |
| 7 | 0.419 | 0.076 | 1.924 | 2.704 |
| 8 | 0.373 | 0.136 | 1.864 | 2.847 |
| 9 | 0.337 | 0.184 | 1.816 | 2.970 |
| 10 | 0.308 | 0.223 | 1.777 | 3.078 |

*Table 7.1: Constant for control charts.*

**Selection of Samples:** Following factors are important for the selection of samples:

1. Always take sample as random. Do not fix any time for sample selection.
2. Take samples on which the effect of changes in process is effecting.
3. Keep sample size equal. It is suitable to take 4 to 5 readings per sample. Small sample size containing same no. of parts gives increased dissimilarity in different samples.
4. Samples for control chart can be taken on daily, monthly, half yearly and yearly production.
5. 25 numbers of samples are considered proper or suitable.

**Applications of variable control chart:**

1. To decide whether the quality of product is within the specification limit or not.
2. To find assignable causes for process and machines. If any defect is found, then to remove that defect for maintaining the quality of products.
3. To decide which process is the economical out of the available processes.
4. To reduce inspection cost.
5. To decide the process capability.
6. To decide which type of inspection will be needed for quality control.

**Exercise:**

**Construct -R Chart and show calculations for the following:**

1. From the given data find out control limits for X-bar & R chart. Calculate standard deviation and process capability.

| **Observation No.** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|
| $\bar{x}$ | 26.00 | 34.00 | 28.50 | 32.75 | 29.25 | 26.00 | 27.25 | 30.25 |
| **R** | 30 | 17 | 18 | 23 | 30 | 15 | 19 | 18 |

**$A_2$=0.73, $D_4$=2.28, $d_2$=2.059**

2. A machine is working to a specification of 12.58 $\pm$ 0.05mm. A study of 50 consecutive pieces shows the following measurements for 10 groups of sample:
   Construct $\bar{x} - \mathbf{R}$ chart and show the calculations. Find process capability

| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|
| 12.54 | 12.58 | 12.61 | 12.57 | 12.57 | 12.58 | 12.6 | 12.65 | 12.6 | 12.65 |
| 12.58 | 12.57 | 12.6 | 12.61 | 12.60 | 12.59 | 12.62 | 12.57 | 12.59 | 12.61 |
| 12.62 | 12.6 | 12.64 | 12.56 | 12.62 | 12.59 | 12.61 | 12.57 | 12.6 | 12.6 |
| 12.56 | 12.6 | 12.58 | 12.59 | 12.61 | 12.56 | 12.67 | 12.56 | 12.63 | 12.62 |
| 12.59 | 12.61 | 12.64 | 12.59 | 12.58 | 12.57 | 12.6 | 12.61 | 12.56 | 12.62 |

# EXPERIMENT NO: - 08

**AIM:** To study & Construct P-chart for given process.

**OBJECTIVES:** After completing this experiment, you will be able to:

- Know attribute quality and carry out inspection by attribute quality checking.
- Divide good quality as acceptable and bad quality as projectable.
- Compute control limits and mean.
- Plot P chart.
- Infer causes of variations.

## Introduction: -

**Attribute (discrete data.)**: Things we count. Examples include number or percent defective items in a lot, number of defects per item etc.

**Control Charts for Attribute Quality:**

When the quality of product is not measurable then for quality control of each product, control charts for attribute quality are drawn. Due to the certain characteristics of the product, it can be said good or defective. If such quality does not exhibit by the product, it is said defective. This way the products can be divided into two groups namely defective & defect less. The appearance, brightness, color, cracks, blow holes, spots, surface finishing, etc. is called the attribute quality of the product.

Such quality can only be seen or observed but cannot be measured. From production process certain size of samples are taken at random. Products of such samples are observed and the defects in them are found out. In some products there may be more than one defect listed above. Over and above using 'GO' and 'NO GO' gauge defective products are found out in mass productions.

**Defect:** The characteristics of the product which render a product unacceptable is called defect.

**Defective:** The product having one or more defect is called defective.

**Fraction Defective:** The ratio of defective products in a sample to the sample size is called fraction defective.

**Types of Attribute Quality Charts:**

**1.** P chart: Fraction defective
**2.** 100P-Chart: Percentage defective
**3.** np-Chart: No. of defective chart

**1. P-Chart:** Samples are taken from manufactured product and numbers of faults or defects in it are counted. The size of the defect is not measured. For example, say 100 pins are inspected out of which 12 are found defective then it is rejected. Note that the size, location or shape of the defects is not important and not measured.

Fraction defective, **P** is defined as the ratio of number of defective units in each lot inspected to the number of units in the lot.

Suppose we have taken a lot of 'n' number of products from the process, out of which 'd' number of products found defective, then fraction defective of that lot can be found out as under:

$$fraction\ defective, p = \frac{d}{n}$$

 The P-chart is based on binomial distribution. So the standard deviation for p-chart can be found out using the following:

$$standard\ deviation, \sigma_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

Where, =Average fraction defective of the lot from which the same is taken

n= Sample taken

**Average fraction defective, $\bar{p}$** can be calculated as follows"

$$\bar{p} = \frac{\Sigma p}{N}$$

$\Sigma p$ = Number of defective products in all samples

$N$ = Number of samples taken

**Control limits of the P-chart can be calculated as follows:**

**1.** Upper Control Limit: $UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$

**2.** Lower control Limit: $LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$

**Exercise:**

1. There are 10 samples of shaft taken for inspection. Draw P-chart and state whether the process is under control or not, from the data given as under:

| **Number of Products** | **200** | **200** | **200** | **200** | **200** | **200** | **200** | **200** | **200** | **200** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Defective Products** | 12 | 4 | 8 | 3 | 7 | 6 | 0 | 8 | 5 | 9 |

2. In a production of bearings 10 samples each of sample size of 100 were taken and inspected. After inspection, following defectives as shown in table under were observed. Draw P-chart and state whether the process is under control or not, from the data given as under:

| **Sample No.** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Defective bearings in a Sample** | 12 | 4 | 8 | 3 | 7 | 6 | 0 | 8 | 5 | 9 |

3. No. of defectives Spark plugs for ten samples are 4,3,4,5,3,4,5,3,5,4 in a sample size of 100. Selecting suitable control chart, find upper control limit and lower control limit. Also give your comment either the process is under control or not.
4. For observing 10 samples of 150 each defective pieces noted as 4,7,5,6,4,8,7,10,8,9. Find out control limits for appropriate chart and give your comment regarding process.

# EXPERIMENT NO: - 09

**AIM:** To study & Construct C-chart for given process.

**OBJECTIVES:** After completing this experiment, you will be able to:

-  Identify number of defects in single unit of production.
-  Inspect each unit of production as per standards laid down.
-  Plot C-Chart.

## Introduction: -

**C-Chart:** When more than one defect is occurring in the manufactured product, then C-chart is drawn. E.g. sample from a cloth of a 900 meter is inspected by taking 100 square meter as a unit of sample. The radio manufacturer wants to know the defects in the products. One radio set can be considered as unit and subjected for inspection. The inspection results can be complied for investigation. There can be number of such situations where C-chart can be successfully applied. More examples can include inspection of furniture, inspection of weldments, etc.

It is reasonable to assume the distribution of variations in the number of defects per unit following very closely Poisson distribution.

The number of defects per unit can always be translated into fraction defective which must be quite less. It satisfies the condition of small number of defects & large sample size. This is possible only when the number of defects per unit can be converted into fraction defective. Defects in assembly of engine, T.V. set, Radio, etc. are shown by C-chart.

-  The control limit of C-Chart is based on Poisson's distribution. So the center line of C-chart can be found out using the following:

$$Average\ defect, \bar{C} = \frac{Total\ number\ of\ defects}{No.\ of\ assembly\ inspected}$$

**Control limits of the C-chart can be calculated as follows:**

**1.** Upper Control Limit: $UCL = \bar{C} + 3\sqrt{\bar{C}}$

**2.** Lower control Limit: $LCL = \bar{C} - 3\sqrt{\bar{C}}$

**Exercise:**

1. During the production of Nano Car, 10 cars were inspected and defects in each car were as under. Draw C-chart, control limits and comment about the process:

| **Nano Car No.** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Defects in Nano Car** | 1 | 3 | 13 | 4 | 2 | 5 | 3 | 3 | 4 | 5 |

2. In a car manufacturing company, 10 assembly of a car was inspected and the defects were found as under. Draw C-chart, control limits and comment about the process:

| **Car Assembly No.** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Number of defects** | 5 | 4 | 4 | 10 | 5 | 9 | 7 | 3 | 2 | 1 |

3. The following table shows the number of point defects in the surface of a bus body on august 2011. Construct C-Chart for the data given below:

| **Body No.** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Number of defects** | 2 | 2 | 4 | 7 | 5 | 6 | 7 | 14 | 2 | 9 |

| **Body No.** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Number of defects** | 3 | 0 | 5 | 1 | 3 | 10 | 4 | 3 | 12 | 6 |

# EXPERIMENT NO: - 10

**AIM:** To study about Sampling Plans & Decide about acceptance or rejection of a particular product using sampling plans.

**OBJECTIVES:** After completing this experiment, you will be able to:

- Identify number of defects in single unit of production.
- Inspect each unit of production as per standards laid down.
- Plot C-Chart.

## Introduction: -

**Acceptance Sampling:** Acceptance sampling or acceptance by sample is a technique for quality control by which material, components & product samples are inspected and based on inspection outcome, the acceptance or rejection decisions for whole lot is taken.

Therefore, a procedure and decision rules are fixed up to finalize the size of a sample and the minimum number of defective it could contain for the whole lot to be acceptable. This method or procedure is called acceptance sampling.

Acceptance sampling attempts to assure the quality rather than controlling the quality. It is an inspection technique and not a quality control method. It is the purpose of control charts to control the quality.

**Techniques of material acceptance:** There are two main methods of inspecting the material & components purchased by industries from outside: **A.** No inspection.

**B.** 100% inspection

**C.** Arbitrary inspection.

**D.** Scientific inspection

**Principle of Inspection by Samples:**

It is impossible to inspect whole lot produced but it can be done easily with the help of sample inspection. Methods for inspection of samples are as under:

1. Divide the lot in different parts or sub-lots, which has taken for inspection.
2. Take sample of pre-decided size from the lot at random.
3. Check the quality of items of the sample.
4. Accept or reject the lot based on the information gathered by inspection.

**Acceptance sampling on the basis of variable quality:** Acceptance sampling on the basis of variable, i.e. actual measurement of the dimensions, i.e. measuring weight, density, length, width, diameter, etc.

**Acceptance sampling on the basis of attribute quality:** Acceptance sampling on the basis of attributes, i.e. GO & NO GO gauges. Items are checked for color, finishing, blowholes, spots, scratch etc. If it is sound good, then the lot is accepted.

**Uses of Acceptance Sampling:** In general, acceptance sampling is used under the assumption when the quality characteristics of the product are under control and relatively homogenous. However, this technique is extensively used when:

1. Possible losses by passing defective items are not great and the cost of inspection is relatively high. In the limiting situation, this can mean no inspection at all.
2. The destructive testing is inevitable and hence 100% inspection is prohibited. Therefore, sampling method is the solution under such situation. For example, when it is necessary to determine the strength of the component by pulling it apart, under this situation, acceptance of the entire lot can be based on the acceptance of sample.
3. Handling of any kind is likely to induce defects, or when mental or physical fatigue is an important factor in inspection.

**Sampling Plan:** There are four sampling plans

In all the sampling plans, following symbols will be used:

N= number of products in a given batch or lot.

*n*= number or random samples drawn from the batch or lot of N.

*C*= Acceptance number. It is the maximum number of defectives, allowed in a sample size of it.

**Some important definitions used in sampling plans:**

1. **Lot:** It may be defined as the number of items or component parts, drawn from a lot, batch or population for the purpose of inspection.
2. **Sample:** It may be defined as the number of items or component parts, drawn from a lot, batch or population for the purpose of inspection.
3. **Acceptance Number:** It may be defined as the Number of defective items can be allowed in a lot for its acceptance. Acceptance number is denoted by letter 'a' or 'c'.
4. **Rejection Number:** It may be defined as the Number of defective items in a lot for its rejection. Rejection number is denoted by letter 'r'.
5. **Item:** It may be defined as an object or part on which inspection is done. Item may or may not comply the specification framed for it.

**Acceptance Quality Level (AQL):**

It indicates a small proportion of bad components in a lot such that the lots having less than this proportion of bad components have a high probability of acceptance or getting accepted. It is the highest percentage of defective in a lot which is acceptable to the purchaser. It is considered satisfactory as process average.

Suppose that 3% acceptance quality level is fixed for a lot for its acceptance/rejection. It means that 3% defective items of the lot are acceptable to the purchaser. This acceptance level is fixed as an understanding between seller and purchaser.

**Inspection Level:**

How much tight inspection is carried out during acceptance sampling, there are five levels of inspection. The range of inspection from too light to tight has been divided into 5levels. The number I, II and III are assigned to the light types of inspection. Whereas by accepting the defective item, the loss occurring is less, the light levels I, II and III are used. The inspections IV and V are used to carry out tight inspection.

**Types of Sampling Plans:**

1. Single sampling plan.
2. Double sampling plan.
3. Multiple sampling plan.
4. Sequential sampling plan.

**Single sampling plan:**

In this plan only one sample is drawn & inspected to take the decision of acceptance or rejection of the lot. The method of using single sampling plan is as under:

There is always a difference of 1 in acceptance & rejection numbers. Therefore, either the lot will be accepted or rejected.

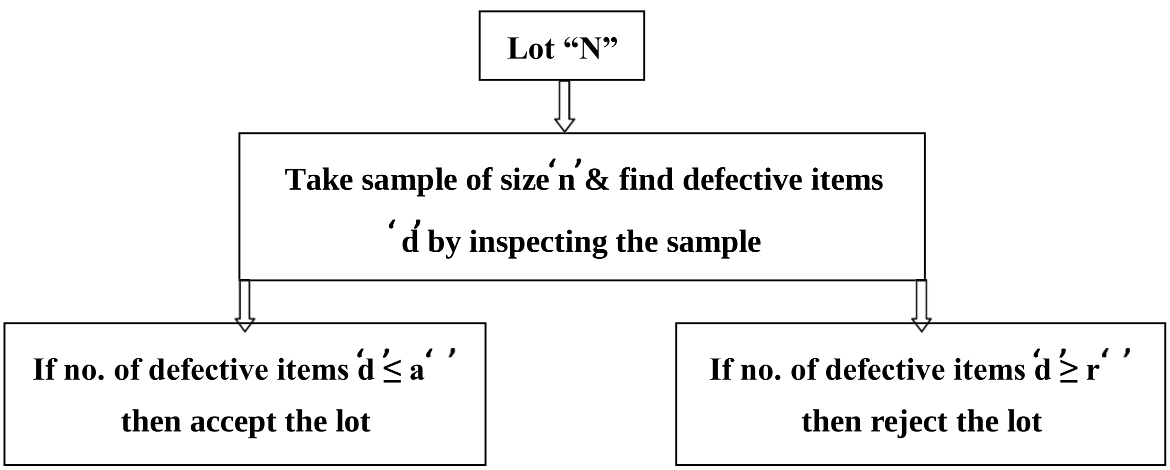


*Figure 10.1:* Single Sampling Plan

**Double sampling plan:**

In double sampling plan the decision on acceptance or rejection of the lot is based on two samples. A lot may be accepted at once if the first sample is good enough or rejected at once if the first sample is bad enough. If the first sample is neither good or bad enough, the decision is based on the evidence of first and second sample combined.

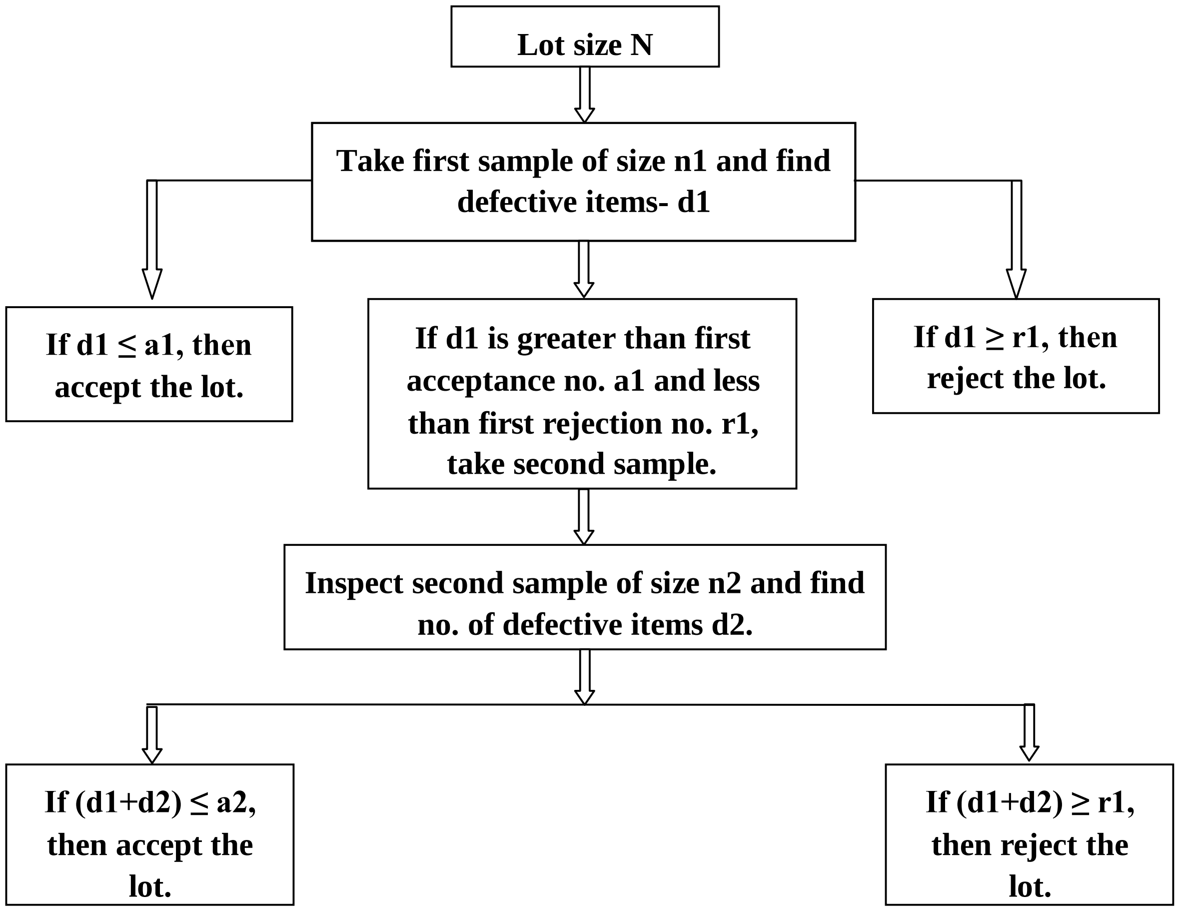


*Figure 10.2:* Double Sampling Plan

**Exercise:**

**1.** Following data is related to Double Sampling Plan used for Inspection of 2400 Gudgeon pin lot. take AQL as 4 %

| **Sample** | **Sample Size (n)** | **Acceptance no. (a)** | **Rejection no. (r)** |
|---|---|---|---|
| **First** | 80 | 5 | 9 |
| **Second** | 80 | 12 | 13 |

Draw the plan and Explain how it is operated.

**2.** Explain double sampling plan for the following data with usual notations.
N=2400; n1=150; n2=150; a1=4; a2=9; r1=8; r2=10.

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# EXPERIMENT NO: - 11

# Tutorial - 1

## Examples

1) A company is to decide on the location of a new plant. It has narrowed down the choice to 3 locations A, B, and C; data in respect of which is furnished below: Use suitable criterion and advise the company on the best choice.

| Cost in Rs. | Location | | |
|---|---|---|---|
| Data | A | B | C |
| Wages & salaries | 20000 | 20000 | 20000 |
| Power, water supply expenses | 20000 | 30000 | 25000 |
| Raw material & other supplies | 80000 | 75000 | 60000 |
| Total initial investment | 200000 | 300000 | 250000 |
| Distribution expenses | 50000 | 40000 | 60000 |
| Miscellaneous expenses | 40000 | 25000 | 30000 |
| Expected sales per year | 225000 | 250000 | 225000 |

Hint: Solution based on the economics of various sites.

2) From the given table choose a best suitable location for a plant. Relative weightage will be given in the table.

| Cost in Rs. | Location | | Values (Relative weightage) |
|---|---|---|---|
| Factors | A | B | |
| Cost of land, building, construction | 500000 | 300000 | 4 |
| Power cost | 20000 | 30000 | 4 |
| Taxes | 20000 | 50000 | 4 |
| Community attitude | 1.5 | 2 | 1 |
| Product quality | 3 | 2 | 6 |
| Flexibility to expansion | 1 | 6 | 3 |
| Union attitude | 2 | 4 | 5 |

Hint: Solution based on Dimensional analysis

3) A company intends to select one of the three locations. All the relevant data for the location are given below:

| Cost in Rs. (in Thousands) | Location | | |
|---|---|---|---|
| Particulars | A | B | C |
| Total initial investment | 250 | 325 | 270 |
| Total Revenue | 410 | 515 | 360 |
| Cost of raw material | 89 | 100 | 98 |
| Distribution cost | 40 | 60 | 30 |
| Utilities Expenses | 50 | 40 | 25 |
| Wages & salaries | 25 | 30 | 28 |

Hint: Solution based on Dimensional analysis

***Sol. 1.***

***Sol. 2.***

***Sol. 3.***

# EXPERIMENT NO: - 12

## Tutorial - 2

### Examples

1) The past data on the load on the machine is shown below:

| Sr. no. | Month | Load |
|---|---|---|
| 1. | May-96 | - |
| 2. | June-96 | 585 |
| 3. | July-96 | 610 |
| 4. | Aug.-96 | 675 |
| 5. | Sep.-96 | 750 |
| 6. | Oct.-96 | 860 |
| 7. | Nov.-96 | 970 |

a) Compute the load on the machine centre using 3rd and 5th moving average for the month of Dec. 1996.

b) Compute a weighted three month moving average for Dec. 1996 where the weights are 0.5 for last month, 0.3 and 0.2 other month respectively.

**Formulas:** The formula for a simple moving average is

$$F_t = \frac{A_{t-1} + A_{t-2} + A_{t-3} + \ldots\ldots\ldots\ldots + A_{t-n}}{n}$$

The formula for a weighted moving average is

$$F_t = w_1 A_{t-1} + w_2 A_{t-2} + w_3 A_{t-3} + \ldots\ldots\ldots\ldots + w_n A_{t-n}$$

2) The past data regarding the sales of SPMS for the last five years is given. Using the least square method, fit a straight line, estimate the sales for the year 1996 and 1997.

| Year | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|
| Sales ('00) | 35 | 56 | 79 | 80 | 40 |

3) N Forecast the demand for the following series by exponential smoothing method. (take $\alpha = 0.3$)

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Actual demand | 10 | 12 | 8 | 11 | 9 | 10 | 15 | 14 | 16 | 15 |

***Sol. 1.***

***Sol. 2.***

***Sol. 3.***