

**JAIPUR INSTITUTE OF TECHNOLOGY-
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JAIPUR**



**INDUSTRIAL ENGINEERING
LABORATORY MANUAL**

IV B.TECH (Mechanical): VIII SEMESTER

DEPARTMENT OF MECHANICAL ENGINEERING

INDUSTRIAL ENGINEERING LAB

LIST OF EXPERIMENTS

1. P-CHART FOR FRACTION DEFECTIVES
2. C- CHART FOR NUMBER OF DEFECTIVES (CONSTANT SAMPLE SIZE)
3. OPERATING CHARACTERISTIC CURVE OF SINGLE SAMPLING ATTRIBUTES PLAN
4. TEST FOR NORMALITY OF SAMPLE MEANS(NORMAL DISTRIBUTION)
5. TEST FOR NORMALITY OF SAMPLE MEANS(UNIVERSAL DISTRIBUTION RECTANGULAR)
6. \bar{X} , R – CHARTS & PROCESS CAPABILITY
7. PIN BOARD STUDY EXPERIMENT
8. TREAD MILL EXERCISE
9. RATING PRACTICE USING PACK OF CARDS
10. TO DRAW TWO HANDED PROCESS CHART FOR BOLT, WASHER & NUT ASSEMBLY
11. MULTIPLE ACTIVITY CHART (OR) MAN MACHINE CHART
12. ERGOCYCLE EXERCISE

P- Chart for fraction defectives

Aim: To draw P-Chart for fraction defective and to check the control of the process for a given set of plastic balls.

Apparatus Required:

- 1) Sample of marble/plastic balls – 600 nos
- 2) Tray – 1 no

Theory: The quality characteristics, which are not amenable to measurement, are called attributes. Such characteristics can be identified by their presence or absence from the product. For example we may say that the surface of the plastic product is cracked or not cracked. Whether castings produced are having surface defects or not, whether the bottles that have been manufactured contain holes or not. Thus attributes may be judged either by the proportion or units that are defective or by the number of defects/unit.

In general the failure to meet the requirement imposed on an item with respect to a single characteristic is called as a defect. An item the quality of which does not meet the specified requirements is known as a defective item.

The most widely used attributes control chart is the P- chart. The attributes control charts for fraction defective (or percent defective) is called the P-chart. Fraction defective may be defined as the number of defective articles found in any inspection or series of inspection to the number of articles actually inspected where as percent defective is 100 times the fraction defective. If 'P' represents fraction defective, then the expression for 'P' may be written as

$$P = \frac{\text{No of defectives in a sub group or sample}}{\text{No of inspected in the sub group}}$$

$$\text{Percent defective} = 100 P$$

Generally in a production process a sample of items consisting of different sub groups is taken and defective items for each sub group are traced by using suitable inspection methods. Then the fraction defective or percent defective per each sub group will be calculated and these values are plotted on P –chart.

The central line of the P – chart is expressed as

$$\bar{P} = \text{average of all fraction defectives}$$

OR

$$\bar{P} = \frac{\text{Total number of defectives}}{\text{Total number of pieces inspected}}$$

The fraction defectives tend to approach binomial distribution and the control limits (UCL & LCL) are set at 3σ of the fractional defectives from mean \bar{P} . Thus the Upper and lower control limits are given by

$$UCL_p = \bar{P} + 3\sigma_P \qquad LCL_p = \bar{P} - 3\sigma_P$$

Where σ_P = Standard deviation of the distribution of the fraction defectives.

Whenever calculations give a negative value of LCL of P –chart, that limit is recorded as zero.

PROCEDURE:

- 1) Take the random samples of size 50 each (n) and make 12 groups.
- 2) Observe the number of green balls in each sample (d_i).
- 3) Find the fraction defective in each sample (d_i / n).
- 4) Calculate the center line or mean fraction defective ($\bar{P} = \Sigma P_i / 12$).
- 5) Compute the control limits (UCL & LCL)

$$UCL_p = \bar{P} + 3\sigma_P = \bar{P} + 3 \sqrt{\frac{\bar{P}(1-\bar{P})}{n}}$$

$$LCL_p = \bar{P} - 3\sigma_P = \bar{P} - 3 \sqrt{\frac{\bar{P}(1-\bar{P})}{n}}$$

- 6) Draw the P- chart by plotting fraction defectives against each sample.
- 7) Comment the nature of control of the process.

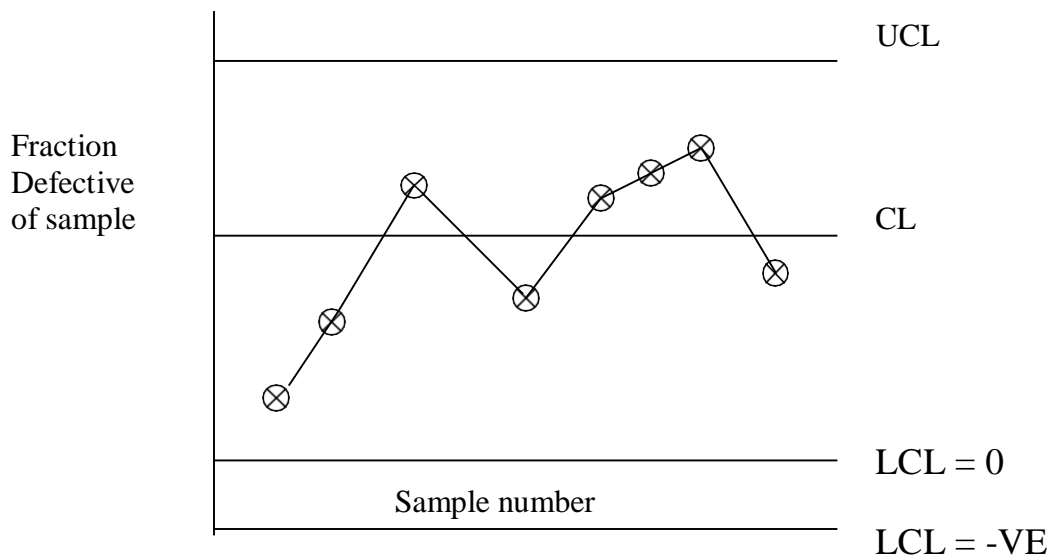
OBSERVATIONS : sample size = n=50

Sample Number(i)	Number of defective Balls (d_i)	Fraction defective of sample ($P_i = d_i / n$)
1		
2		
3		
.		
.		
12		

CONCLUSION : If all the observations are within the upper and lower limits of P- chart, the process is under statistical quality control.

If any value lies outside the control limit, recalculate \bar{P} , UCL_p , LCL_p excluding the data for all those outside lying points. Repeat the process until all values lie within UCL_p & LCL_p .

SAMPLE GRAPH :



EXP 2:

C- chart for the number of defects (constant sample size)

AIM: To draw a C- chart for a given set of metal discs and to check the control of the process by taking each disk with 10 holes of each 6 mm size as one unit.

APPARATUS REQUIRED: 1) Set of metal discs (16 nos)
2) Plug gauge of 6H size (1)

THEORY: Consider the case in which each sample unit may have a number of different non conformities or defects. The variable of interest is the number of defects/units or the average number of defects /unit and the corresponding attributes control chart for the no. of defects is called C- chart.

It is quite possible for a unit to have one or more defects while the unit not being defective. The C-chart is generally preferred for the large and complex parts .Such parts are being few and limited. The procedure consists of selecting a sample of items in a production process and finding the number of defects per each unit in the sample using suitable inspection method .For example a GO and NO GO gauge is a device used to separate conforming from non conforming features such as diameter of a series of similar holes on a disc .Then these noted values are plotted on the graph against each unit.

The center line (CL) or mean (\bar{C}) of the C- chart is expressed as

$$\bar{C} = \frac{\text{Total number of defects observed}}{\text{Total number of units inspected}}$$

The basis of the C-chart is the poisson distribution under the assumption that the number of non conformities is large and probability of occurrence of a defect is small and constant with the inspection unit being the same for each sample .The control limits (UCL& LCL) of C – chart are set at 3σ of the number of defects from mean \bar{C} . Thus the upper and lower control limits are given by

$$UCL_c = \bar{C} + 3\sigma C = \bar{C} + 3\sqrt{\bar{C}}$$

$$LCL_c = \bar{C} - 3\sigma C = \bar{C} - 3\sqrt{\bar{C}}$$

Where σC = Standard deviation of the distribution of the number of defects

One important point that has to be noted is whenever calculations give –ve value of LCL of the C- chart that limit is recorded as zero.

PROCEDURE :

1. Take each disc with 10 holes as one unit and note down the no .of defects (i.e. the holes through which GO end of plug not pass freely.
2. Count the total no. of defects in the entire set of discs .
3. Calculate the center line or mean of the no .of defects
4. Compute the control limits UCL& LCL by assuming 3σ limits from the mean \bar{C}
5. Draw the C- chart by plotting the no .of defects against each unit of disc.
6. Comment on the state of control of process.

OBSERVATION :

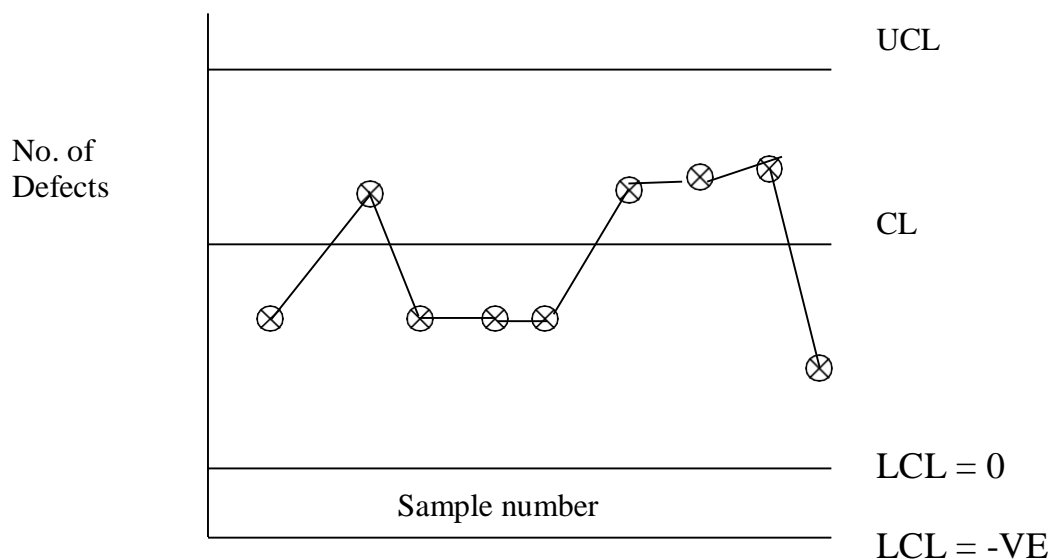
DISC NUMBER (i)	No. of defects (d _i)
1	
2	
3	
·	
·	
16	

$$\bar{C} = \frac{\sum d_i}{n}$$

$$UCL_C = \bar{C} + 3\sqrt{\bar{C}}$$

$$LCL_C = \bar{C} - 3\sqrt{\bar{C}}$$

SAMPLE GRAPH:



Exp 3 :

**OPERATING CHARACTERISTIC CURVE OF SINGLE SAMPLING
ATTRIBUTES PLAN.**

AIM : To plot the operating characteristic curve for a single sampling attributes plan of a given lot of plastic balls and to compare the actual O.C curve with theoretical O.C curve.

APPARATUS REQUIRED : 1. Lot of plastic balls –150 nos.
2. Lot of green balls –50 nos .
3. Tray – 1 no.

THEORY : Acceptance sampling is a major component of quality control and in this inspection is performed on a shipment or lot of incoming materials / products. Samplings are taken from this shipment and certain quality characteristics of the units are inspected. After this inspection ,a certain decision is made concerning the lot. Usually the decision is either to accept or reject the lot.

Acceptance sampling plan can be divided into attributes sampling plan and variable sampling plan. In attributes sampling, a unit is classified as conforming or non conforming on the basis of whether it meets established specification or not. In variable sampling only one quality characteristic of a unit is observed or measured .The advantages of sampling inspection are as follows.

1. The cost and time required for sampling inspection is quite less as compared to 100% inspection.
2. Problem of inspection fatigue which occurs in 100 % inspection is eliminated.
3. Smaller inspection staff is necessary.

There are three important types of sampling plans :

1. single sampling plan.
2. Double sampling plan.
3. Multiple sampling plan.

SINGLE SAMPLING PLAN : A single sampling plan is a procedure in which a sample drawn from a lot and inspected. If the no. of non-conforming or defective units are less than or equal to a specified limit (i.e. acceptance number),the lot is accepted. Other wise the lot is rejected .Three parameters are needed to define a single sampling plan.

- 1 – Number of units (N) or lot size.
- 2 – Number of units (n) to be drawn from the lot (sample size).
- 3 – Acceptance number (c) which is the maximum number of defective units allowed in a sample.

If a single sampling is specified as $N= 3000$, $n=25$, $c = 2$.It means that from a lot size of 3000,a random sample of 25 units is drawn and inspected. If the number of defective units in the sample is less than or equal to 2 ,the lot is accepted otherwise the sample is rejected.

DOUBLE SAMPLING PLAN: In double sampling plan the decision acceptance or rejection of the lot is based on the 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 enough nor bad enough, the decision is based on the evidence of first and second sample combined.

MULTIPLE SAMPLING : The phrase multiple sampling is generally used when three or more samples of stated size are permitted and when the decision of acceptance or rejection must be reached after a stated no. of samples.

The phrase sequential sampling is generally used when a decision is possible after each item has been inspected and when there is no specified limit on the total no. units to be inspected. However sometimes we use two phrases interchangeably.

URVE : O.C.Curve is an evaluation tool that shows the probability of accepting a lot submitted for inspection for a range of fraction defective values. It also displays the discriminatory power of a sampling plan. In other words, it can be used to compare the probability of accepting a lot for various sampling plans.

The probability of acceptance of a lot is the probability that the no. of defectives in a sample is equal to or less than the acceptance no. for the sampling plan. There are three distributions that can be used for finding the probability of acceptance: hypergeometric, binomial and the Poisson distribution. When its assumptions can be met, the Poisson distribution is preferable because of the ease of calculation.

Probability of acceptance that the no of defective in a sample is equal to or less than acceptance number (c) is-

$$(P_a)_{th} = \sum_{i=0}^c \frac{\lambda^i e^{-\lambda}}{i!} \text{ Where } \lambda = np$$

Note: For 0 defectives $(P_a)_{th} = e^{-\lambda}$

n = Sample size; p = Fraction defective of the lot;

For Example : N = 400; n = 20; lot is 5% defective i.e p = 0.05 c = 2

$$\text{Then } (P_a)_{th} = \sum_{i=0}^2 \frac{\lambda^i e^{-\lambda}}{i!} = \frac{\lambda^0 e^{-\lambda}}{0!} + \frac{\lambda^1 e^{-\lambda}}{1!} + \frac{\lambda^2 e^{-\lambda}}{2!}$$

$$\text{But } \lambda = np = 20 * 0.05 = 1$$

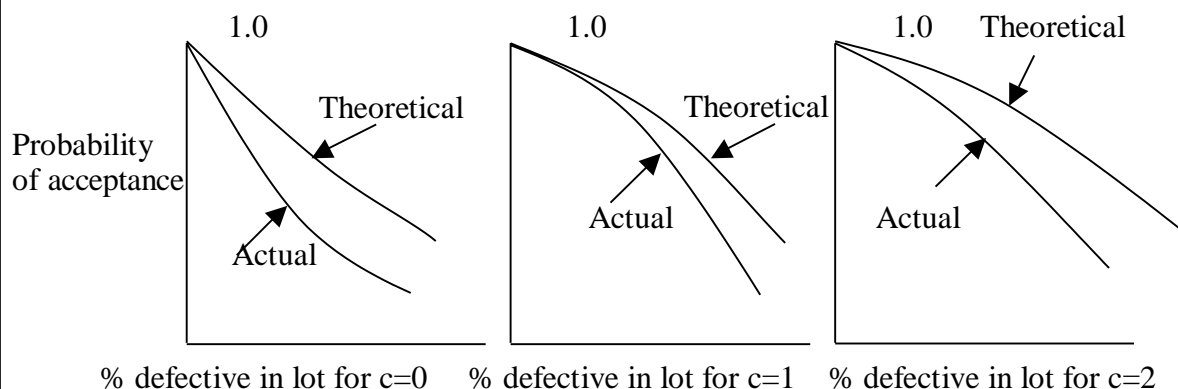
$$\therefore (P_a)_{th} = \frac{1 e^{-\lambda}}{0!} + \frac{1 e^{-\lambda}}{1!} + \frac{1^2 e^{-\lambda}}{2!} = 0.9197$$

PROCEDURE: For the given lot size N = 150

1. First set the acceptance number c = 0.

2. Mix predetermined number of green balls to the lot to get the % defective = 2 % or fraction defective of the lot = 0.2 i.e. add three balls to the lot and remove 3 balls other than green colour from the lot so that the lot size remains = 150.
3. Take a sample of 20 balls from the lot of 150 balls
4. Count the no. of defective items (green balls) in the sample.
5. Recovered whether the lot is acceptable or not i.e. if defective balls are less than or equal to 'C', then note that the lot is acceptable.
6. Replace the sample of the balls into the lot.
7. Repeat the steps 3 to 6 ten times and compute the probability of acceptance of the lot P_a (i.e. if 6 times the lot is accepted in repetitions then $(P_a)_a = 6/10 = 0.6$).
8. Change the % defective to 4,6,8 and 10% by changing the green balls in the lot correspondingly (i.e. add three balls each time and remove three balls other than green balls from the lot so that the lot size remains the same (or = 150)).
9. Repeat the steps 3 to 7 for each value of % defective.
10. Repeat the above procedure for other values of acceptance number $c = 1$ & 2.
11. Also find the probability of acceptance of the lot theoretically for different values of % defective corresponding to the values of $C = 0, 1$ & 2.
12. Plot the actual and theoretical probability of acceptance values for each and every value of $C (=0, 1 \& 2)$.

SAMPLE GRAPHS:



EXPT 4:

TEST FOR NORMALITY OF SAMPLE MEANS (NORMAL DISTRIBUTION)

AIM : To show that sample means for a normal universe follow a normal distribution.

APPARATUS : 1 Set of chips in a bowl – 998 nos
2 Tray - 1 no

THEORY : In order to construct a frequency distribution, we normally take small portion or sample to represent the entire collection of items . From the measurement of the characteristic of the sample we draw conclusion about the characteristic of the entire collection of items. The universe is the whole collection of measurements.

The universe may have a finite number of items such as day's production of spindles. It may be finite or almost infinite such as number of articles produced in a year. Since it is rarely possible to measure all of the universe, a sample is selected at random to represent the universe or population. In order to draw conclusion about the universe, it is necessary to rely on numerical values such as mean ,standard deviation etc.derived from sample drawn from universe.

The normal distribution curve is symmetrical about its mean values and has bell shape. The curve is fully defined by \bar{X} and σ . Theoretically the N.D curve extends from $-\alpha$ to $+\alpha$. However for all practical purposes we can consider normal curve as extending only 3σ values to the left and 3σ values to the right of the mean ($\bar{X} \pm 3\sigma$).

We can say 2/3 of occurrence fall within the standard deviation ,95 % with 2 standard deviations and practically all fall with in 3 standard deviations from the mean .Assume that the numbers on the chips indicate the distribution of certain dimensions measured out of group of similar products and place them in a bowl.

PROCEDURE

1. Note down the numbers on the chips by drawing them one by one till all the chips are over.
2. Prepare a tally diagram of numbers 1 to 61.
3. Group the data by finding the quantity of each number.
4. Plot the frequency histogram and also draw the frequency curve by taking numbers on X –axis and frequency of number on Y- axis.
5. Comment on the nature of distribution of the universe.
6. Find the mean and standard deviation of universe.

7. Mix all the chips in a bowl and stir them well.
8. Draw four chips at a time (random) and note the number marked on the chips. After noting down the numbers, place them back in the bowl.
9. Find the mean and range of the sub group(each 4 chips) and make the tally diagram of the average by taking out the next sub group.
10. Group the data of averages and prepare frequency table.
11. Calculate the mean and standard deviation of the distribution of average / means.
12. Compare the mean and standard deviations of the universe with means and standard deviations of distribution of means.
13. Comment on the result and on the shape of the distribution of averages.

GRAPH TO BE DRAWN :

1. Frequency histogram or histogram of frequency curve of universe i.e. marking on the chips Vs frequency of marking chips.
2. Frequency histogram or the distribution of means i.e. mid values of each group of means Vs frequency of sub groups of means.

TABULATIONS :

	No. of drawing a sub group	Marking on chips in sub group				Mean \bar{X}_i
		1	2	3	4	
Formulas :- 1) Mean or Avg of universal distributi on	1-4					
	5-8					
	9-12					
	..-..					
	..-..					
	389-392					
	393-396					
	397-400					

$$X^{-1} = \frac{\sum f_i X_i}{\sum f_i} = \frac{\sum f_i X_i}{998}$$

2) Standard deviation of universal distribution

$$\sigma^1 = \sqrt{\frac{\sum f_i X_i^2}{\sum f_i} - (X^{-1})^2}$$

3) Mean (or) Avg of Sub group $\bar{X} = \frac{\sum X_i}{m}$

m = no of Sub group = 100

4) S.D of avg of Sub groups $\sigma_x = \sigma^1 / \sqrt{n}$
n = Sub group

Marking on chips /Average \bar{X}_i	Frequency of marking on chips
18 - 20	
20 - 22	
22 - 24	
.. - ..	
.. - ..	
38 - 40	
40 - 42	

SAMPLE GRAPH

Frequency of marking
on chips



Mid value for each group →

ACTUAL POPULATION (universe)

Marking on chips	No. of chips	Marking on chips	No. of chips	Marking on chips	No. of chips
0	1	21	27	41	22
1	1	22	29	42	19
2	1	23	31	43	17
3	1	24	33	44	15
4	1	25	35	45	13
5	2	26	37	46	11
6	2	27	38	47	9
7	3	28	39	48	8
8	4	29	40	49	7
9	4	30	40	50	5
10	5	31	40	51	4
11	7	32	39	52	4
12	8	33	38	53	3
13	9	34	37	54	2
14	11	35	35	55	2
15	13	36	33	56	1
16	15	37	31	57	1
17	17	38	29	58	1
18	19	39	27	59	1
19	22	40	24	60	1
20	24				

Exp 5:

TEST FOR NORMALITY OF SAMPLE MEANS
(UNIVERSAL DISTRIBUTION RECTANGULAR)

AIM: To show that the sample means from a rectangular universe follow a normal distribution

APPARATUS REQUIRED: 1) Set of chips in a bowl-600Nos
2) Tray – 1No.

THEORY: In order to construct a frequency distribution, we normally take a sample proportion or “sample” to represent the entire collection of items. From the measurement of the characteristic of the sample we draw conclusion about the characteristic of entire collection of items. The universe is the whole collection of items.

The universe may have a finite number of items such as day's production of spindle's. It may be finite or almost infinite such as number of articles produced in a year. Since it is rarely possible to measure all of the universe, a sample is selected at random to represent the universe or population. In order to draw conclusion about the universe, it is necessary to rely on numerical values such as mean, standard deviation etc. Derived from sample drawn from universe.

The normal distribution curve is symmetrical about its mean value and has bell shape. The curve is fully defined by \bar{X} and σ . Theoretically the N.D curve extends from $-\alpha$ to $+\alpha$. However for all practical purposes we can consider normal curve as extending only 3σ values to the left and 3σ values to the right of the mean ($\bar{X} \pm 3\sigma$).

We can say $2/3^{\text{rd}}$ of occurrences fall within the standard deviation, 95% within 2 standard deviations and practically all fall within 3rd standard deviations from the mean. Assume that the numbers on the chips indicate the distribution of certain dimension measured out of a group of similar products and place them in a bowl.

The distribution of averages of samples tend to be approximately normal even though the samples are drawn from the non-normal universe.

Thus even though the distribution of the universe is not normal such as rectangular (markings of the 61 to 90 on chips – 20 each), the distribution for the \bar{X} values tends to be close to normal. The larger the sample size and the more nearly normal universe, the closer will be the frequency distribution of averages approach the normal curve.

PROCEDURE:

1. Note down the numbers on the chips by drawing them one by one till all the chips are over.
2. Prepare a tally diagram of the numbers (61 to 90)

3. Group the data by finding the quantity of each number. It will be found that all numbers on the chips are same in frequency that is 20 each.
4. Plot the frequency histogram and also draw the frequency curve which will be rectangular.
5. Find out the mean and standard deviation of the, universe.
6. Mix all the chips in a bowl and stir them well .
7. randomly take 5 chips at a time and go on noting down the numbers on the chips. After noting down the number on the chips, it should be put back into the bowl. Stir the chips before taking out the next one. This way makes sub groups of size 5. Draw nearly 60 subgroups. Find the averages of each sub group.
8. Make tally diagram of all the averages.
9. Group the data of averages (with convenient cell interval).
10. Calculate the mean and standard deviation of distribution of means or averages.
11. Draw the frequency histogram of the distribution of the means or averages.
12. Compare the mean and standard deviation of the universe if the mean and the standard of the distribution of means.
13. Comment on the results and the shape of the distribution of averages or means.

GRAPHS TO BE DRAWN :

1 Make a plot against mid value of cell or mid value of each sub group of means Vs frequency of the group of means.

Tabulation :

No. of drawing a sub group	Marking on chips in sub group					Mean \bar{X}_i
	1	2	3	4	5	
1-5						
6-10						
11-15						
..-..						
..-..						
-						
296-300						

Averages \bar{X}_i	Frequency of marking on chips
65 - 67	
67 - 69	
69 - 71	
71 - 73	
73 - 75	
75 - 77	
77 - 79	
79 - 81	
81 - 83	
83 - 85	

SAMPLE GRAPH:

Frequency of marking
on chips



Mid value for each group —→

\bar{X} , R – CHARTS & PROCESS CAPABILITY

AIM: To draw \bar{X} and R charts and to determine the process capability from the measurement of large diameter of a given set of stepped pins.

APPARATUS REQUIRED: 1. Set of stepped pins – 96 nos.
2. Tray – 1 no.
3. Vernier calipers.

THEORY: A control chart is a graphical representation of the collected information. The information may pertain to measured quality characteristics are judged quality characteristics or samples. It detects the variation in processing and warns if there is any departure from the specified tolerance limits. Control charts based up on measurement of quality characteristics are called as control charts for variables(Ex: \bar{X} , R, σ charts).

X & R CHARTS: \bar{X} chart shows the centering of the process, that it shows the variation in the average of samples. It is the most commonly used variable chart. R chart shows the uniformity or consistency of the process. It shows the variation in the range of samples. It is a chart for measure of spread. Any control chart consist of limiting values called upper control limit (UCL) and lower control limit (LCL) for a sample quality characteristics. Between the UCL & LCL is a central line which represents no deviation from the sample characteristic is plotted on the control chart. The sample points are usually connected by straight lines so that the sequence of activity over time can be visualized easily. Even if all points are with in the control limits, the process can be out of control. This condition exists when successive points fall in a non- random or systematic manner.

PROCESS CAPABILITY: The three phases in manufacturing of any item are design, production and inspection. Specifications or tolerance limits are usually established in the design phase. In the production phase an attempt is made to conform to the specifications. During inspection the extent to which the unit or units of production conform to the specifications is determined. One such method is process capability ratio. A process operating control may or may not be operating within the specifications. If the process capability exhibits statistical control, estimate of the processing means and the standard deviation may be used to determine the capability of the process to produce within specifications. Thus the process capability study will determine whether the specification can be met or not. The control limits or natural process units of a process (UCL & LCL) are determined by $\pm 3 \sigma$ from the mean. The natural tolerance limits encompass 99.73% of the area under the normal curve and the process capability is defined as 6σ (σ -standard deviation of universe distribution). The process capability ratio (PCR) is defined as

$$PCR = (USL - LSL)/6 \sigma$$

Where USL = upper specification or tolerance limit.

LSL = lower specification or tolerance limit.

The value of PCR = 1, indicates that the specification limits are exactly equal to the natural process limits. If $PCR < 1$, the difference between the specification

limits is less than the tolerance limits and there will be large fraction of production that fails to meet specifications. $PCR > 1$, indicates that the specification limits are greater than the natural process limits and there will be very small fraction of production that fails to meet specifications. If the PCR is larger, say $PCR \geq 2$, the specification limits become too wide and not at all recommended. The recommended value of process capability ratio is 1.5.

PROCEDURE:

1. Make the measurements (larger diameter of pins) by taking the pins one by one.
2. Tabulate the data by taking the subgroup size equal to 4.
3. Calculate the mean (\bar{X}) and range (R) of subgroup.
4. Calculate the center line or mean of means and the center line or mean of ranges i.e. $\bar{\bar{X}}$ & \bar{R} .
5. Compute the control limits(UCL & LCL) of R-chart and \bar{X} -chart by assuming 3σ limits from the mean or both the charts.
6. Calculate the standard deviation of universe distribution σ' .
7. Determine the process capability and the process capability ratio for the manufacture of the given stepped pins.
8. Comment on the nature of control and capability of the process to produce the pins within specifications.

IMPORTANT FORMULA:

- 1.Center line of R chart =Average of ranges

$$\text{i.e } \bar{R} = \frac{\sum R_i}{24}$$

- 2.Center line of (CL) of \bar{X} - chart = Average of averages of subgroup

$$\text{i.e } \bar{\bar{X}} = \frac{\sum \bar{X}_i}{24}$$

3. Upper control limit of R-chart $UCL_R = D_4 \bar{R}$

4. Lower control limit of R-chart $LCL_R = D_3 \bar{R}$

where D_3 and D_4 are factors of number of observations in a subgroup.

For a subgroup of size 4, $D_3 = 0, D_4 = 2.282$ (from tables).

5. UCL of \bar{X} -chart $UCL_{\bar{X}} = \bar{\bar{X}} + 3\sigma_{\bar{x}}$ for $n=4$

$$= \bar{\bar{X}} + A_2 \bar{R}$$

For washers $USL = 23.30$

$LSL = 23.18$

6. LCL of \bar{X} chart $LCL_{\bar{x}} = \bar{\bar{X}} - 3\sigma_{\bar{x}}$

$$\bar{X} = \bar{X} - A_2 \bar{R}$$

$A_2 = 0.729$ (from tables)
 = factor for number of observations in a subgroup.
 For a subgroup of size 4, $A_2 = 0.729$

7. Standard deviation of the universe distribution $\sigma' = \frac{\bar{R}}{d_2}$

where d_2 = factor for number of observations in a subgroup.
 For a subgroup of size 4 $d_2 = 2.059$ (from tables)

8. Process capability = $6\sigma'$

9. Process capability ratio, $PCR = \frac{USL - LSL}{6\sigma'}$

GRAPHS DRAWN:

1. Range chart (R- chart)

i.e. subgroup no. Vs range of subgroup values

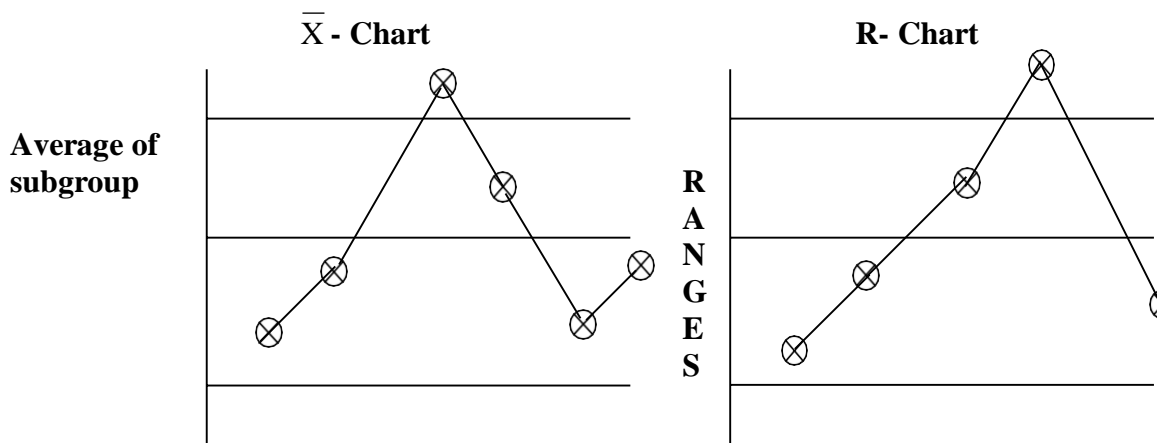
2. Average chart (\bar{X} -chart)

i.e. subgroup number Vs average of subgroup values.

OBSERVATION TABLE:

Subgroup number	Measurement of diameter				Mean or average \bar{X}_i	Range R_i
	Pin-1	Pin-2	Pin-3	Pin-4		
1						
2						
3						
.						
.						
.						
24						

SAMPLE GRAPH:



Exp 7:

PIN BOARD STUDY EXPERIMENT

AIM: To measure the skill and dexterity in the moment of wrist and fingers using pin board.

APPARATUS: 1) Pin boards – 2Nos
2) Set of pins – 30Nos
3) Stop watch – 1No.
4) Trays – 2Nos.

THEORY&OBJECTIVES:

It seems natural for most people when observing another person at work to notice the material being handled or the tools being used rather than the motions made in performing the task after one becomes “motion minded”, that is, after one has learned the classification of hand motion, this situation is changed the observer then notices the motion made with the right hand and those made with the left hand, and then proceeds to use those motions which are easy and effective and to discard awkward, fatiguing and ineffective motions. People who accomplish the most do not necessarily work hardest. Rather they make every motion count. They use good work methods. We are not at all interested in the “speed up” or “stretch out”. We are interested in getting more quality work done with less expenditure of energy. Excessive speed is no substitute for good work methods.

To illustrate what is meant by developing a better method through the analysis of hand motions and the application of principles of motion economy, let us consider the task of filling a board containing thirty holes with 30 wooden pins. You will notice that there are five rows of six holes to a row in the board. The pins are square on one end and bullet shaped on the other. The job is to fill the board with the pins as quickly as possible, inserting the pin in the hole with the bullet nose down.

Most people would fill the board by grasping a handful of pins from the box and holds them while the right hand gets pins from the left one at a time and places them in the board. The right hand is working in an effective manner in as much as it is performing the desired task, that is filling the board with pins. Notice that the left hand is doing very little productive work, most of the time it is merely holding the pins.

If both were to work simultaneously at getting and placing the pins in the holes, the operator's efforts would be much more effective. We are now applying one of the “principles of the motion economy”.

Using this improved method it is obvious that the left hand hold has been eliminated and the left hand like the right now performs useful motions. The two hands work together in a symmetrical manner, getting the pins and placing them in the holes of the board.

One study showed that it requires 0.62 minutes to fill the board using the one handed method, whereas 0.41 minute is required with the two-handed method. This is a saving of 34% in time.

PROCEDURE:

- 1) Arrange the pin boards on the table as per the layout shown in the figure.
- 2) Place the wooden pins in two trays and keep the trays on both sides i.e. one on left side and other on the right side at a fixed distance from the pin boards.
- 3) Pick up pins with left hand and right hand simultaneously from left and right side trays and insert them in the holes with bullet nose end in downward direction.
- 4) Repeat the step-3 until the pin boards are completely filled with pins.
- 5) Measure and record the time for one complete cycle(i.e. for the insertion of 30 pins) by using a decimal stop watch.
- 6) Repeat the above steps for five cycles.
- 7) Calculate the observed time of the activity by taking the average of five cycle times.

THE ABOVE PROCEDURE IS THE IMPROVED METHOD:

Similarly calculate the observed time of the activity by taking the average of the five cycle times by old method. Definitely we will find that the old method which is described in the “THEORY AND OBJECTIVES” paragraph is not economical. In that procedure handful of wooden pins are grasped from the tray. By holding the pins with the left hand and pins one by one are inserted in the holes of the pin board.

TABULATION FOR OLD METHOD:

CYCLE NUMBER	TIME TO FILL THE PIN BOARD WITH PINS t_o
1	
2	
3	
4	
5	

- Similar tabulation is required for improved method (Cycle number Vs T_i)

RESULTS:

Observed time in the improved method = $\frac{\sum_{i=1}^5 t_i}{5} = T_i$

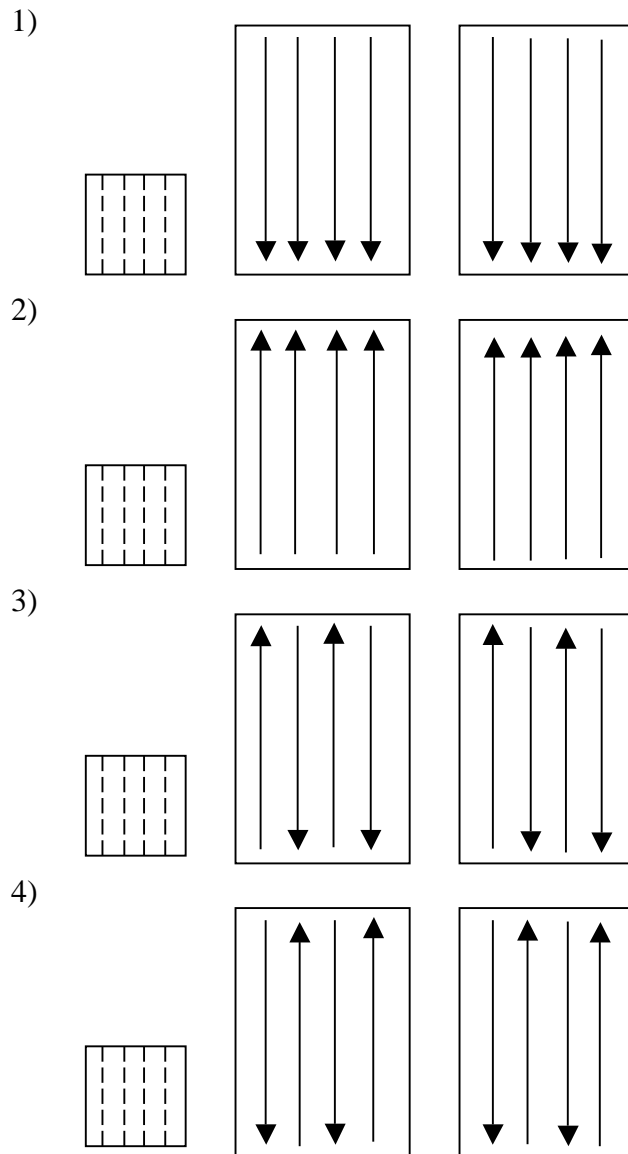
Observed time in the old method = $\frac{\sum_{o=1}^5 t_o}{5} = T_o$

T_o = time taken by old method

T_i = time taken by improved method

Saving in time obtained by improved method = $\frac{T_o - T_i}{T_o} \times 100$

CONFIGURATION FOR IMPROVED METHOD:



EXP 8:

TREAD MILL EXERCISE

AIM: To study the changes in heart beat rate for different subjects using Treadmill.

APPARATUS REQUIRED:

Stethoscope – 2 nos
Stopwatches – 2 nos

THEORY & OBJECTIVES: Physical work results in changes in oxygen consumption, heart beat rate, pulmonary ventilation, body temperature and lactic acid concentration in the blood. Although some of these factors are only slightly affected by muscular activity, there is a linear correlation between heart beat rate, oxygen consumption and total ventilation and the physical work performed by an individual. Of these three, the first two-heart beat rate and oxygen consumption are the most widely used for measuring the physiological cost of human work.

The performance of physical work requires the use of group of muscles. Some muscles are needed to maintain the body posture while others perform the task. Davis and miller have classified physical effort tasks into three types : 1) Full body work which utilizes the large muscle groups usually involving 2/3 or 3/4 of the body's total muscles, 2) Localized muscular work which requires less expenditure of energy because fewer muscle groups are used to perform the task and 3) static muscular work during which the muscles are used to exert a force but no mechanical work is done. Static requires the contraction of muscle groups and can be very demanding. The physiological cost of performing a task is affected by the number and type of muscles involved, either to move a member of the body or to control antagonist contraction. When a person is at rest heart beat rate and rate of oxygen consumption are at a fairly steady level. Then when the person does muscular work, that is, when he changes from a resting level to a working level both the heart beat rate and oxygen consumption increase. When work ends, recovery begins and the heart beat rate and oxygen consumption return to the original resting level.

In many industries, the workload in certain task is often so heavy that it exerts physiological stress on the workers and consequently results in heavy fatigue. Under fatigue conditions, there is a gradual decrement in capacity of work as well as in the agility and alertness of individual, thereby leading to accidental potentialities and lower productivity. The knowledge of acceptable workload is therefore of great help, practical importance in occupation involving prolonged heavy muscular work.

PROCEDURE:

1. Record weight, height and initial resting time of the subject (or person) considered.
2. Before doing the exercise on tread mill, measure and record the heart beat rate of the person during the last 30 seconds of 1st, 2nd, 3rd, 4th and 5th minutes.
3. Let the person start walking/running on the track of treadmill at 2 KMPH for 5 minutes without break so that the heart beat rate increases rapidly.
4. After the work stops measure and record the heart beat rate of the person during the last 30 seconds of the 1st, 2nd, 3rd, 4th and 5th & so on until the heart beat rate comes to the normal.
5. Repeat the steps 2 to 4 for these speeds of the tread mill i.e 4 KMPH and 6 KMPH.
6. Repeat the steps 1 to 5 for other person of the group / at different slopes of treadmill track.
7. Plot a graph between heart beat rate Vs time before, and after the physical work for the individual or entire group of the subject.
8. Compare the graphs and thereby determine the allowable physical working capacity of the group of the subjects.

PRECAUTIONS:

1. The persons should be healthy and should not be suffering from any cardiac disease.
2. The subjects or persons should have good sleep in the previous night and have taken morning breakfast.
3. They should be acquainted with the experimental protocol and willing to participate in the study.

OBSERVATIONS:

Name of the person / subject :

Age of the person / subject:

Weight of the person / subject:

Height of the person / subject:

For slope:

Speed of subject KMPH	Heart beat before exercise (Beats / Min)					Heart beat after exercise (Beats / Min)						
	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th	11 th	12 ^h
2												
4												
6												

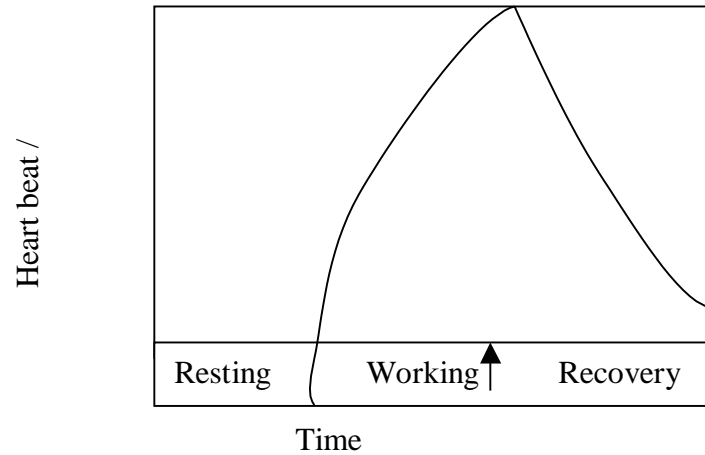
GRAPH:

Time Vs heart beat rate in beats / minute of the subject considered.

Sample Graph:

Name of the person:

For slope:



EXP 9:

RATING PRACTICE USING PACK OF CARDS

AIM: To learn performance rating through observation of the activity of dealing pack of 52 playing cards.

EQUIPMENT USED: Table, Playing cards, Fly back, Stop watch

THEORY: Rating is that process during which the time study analyst compares the performance (speed or tempo) of the operator under observation with the observers own concept of normal performance. Later this rating factor will be applied to the selected or observed time value to obtain the normal time for the job.

Rating is a matter of judgement on the part of the time study analyst and unfortunately there is no way to establish a time standard for an operation without having the judgement of the analyst enter into the process.

The performance-rating factor of any operator doing a particular activity or job can be found by using six methods.

1. Skill and effort rating
2. Westing house system of rating
3. Synthetic rating
4. Objective rating
5. Physiological evaluation of performance level and
6. Performance rating.

The most widely used system of rating is that of rating a single factor-operator speed, pace or tempo. This system is called “PERFORMANCE RATING”. The rating factor may be expressed in percentage, in points per hour, or in other units. Here we shall use the percentage system with normal performance equal to 100%. The formula for computing the performance-rating factor is

$$R = \frac{N}{A} \times 100$$

Where R = Performance rating factor
 N = Actual time of completion of the activity as per the analysts own concept of normal performance (Standard time)

 A = Observed time of completion of the activity (to be measured by the stop watch)

A person dealing a deck of playing cards in to four equal piles in 0.50 minute (30 sec) is often considered to be exhibiting normal pace.

ACTIVITY: The normal time required for dealing a pack of 52 cards in 30 sec as per indian standard condition. When dealt with four standard locations with specific distance apart. The concept of normal rating can be grasped by observation the activity being performed at various levels of efficiency with feed back at the end of each trial. If the rater is to learn, the magnitude of error should progressively decrease. This is as shown in the expected rating curves and rating is done in performance rating.

PERFORMANCE RATING: Performance rating is defined as the comparison by a trained work study engineer of the performance level of a worker with his own concept of standard performance of induced among other things, pace as an important element.

PROCEDURE:

a) ACTIVITY OF PERSON WHO DEALS CARDS:

1. The operator is seated and deals a standard deck of 52 cards in the following way. The deck is held in the left hand and the top card is positioned with the thumb and the index finger of the left hand. The right hand grasps the positioned card, carries it and tosses it on to the table. The four piles of cards are arranged on the four corners of a 30 cm square.
2. As soon as the time keeper gives the signal to deal cards, start dealing the cards by sitting in a comfortable adjustable chair.
3. Repeating the process by varying the speed of the deal.

b) ACTIVITY OF THE TIME KEEPER:

1. As soon as the cards dealer settles down, first initial time is checked using the stop watch.
2. Then the time taken for dealing 52 cards are taken and the values are given to the rater.
3. Every time the activity is finished the time knob is set to zero.

c) ACTIVITY OF THE RATER:

1. As soon as the card dealer settles in the place start watching his first standard dealing (i.e watching his hand movements) from 1m apart.
2. Now rate the speed of the hand movements keeping standard speed of 50 centiminutes as 100.
3. Repeat the process at least 10 times.
4. Tabulate the readings and calculate the % error.
5. Plot the graph indicated.

FORMULA USED:

$$\text{Actual rating} = R_a = \frac{\text{Std. Time}}{\text{Actual Time}} \times 100$$

Where standard time = 50 centiminutes

$$\begin{aligned} \% \text{ Error} &= \frac{\text{Observed Rating} - \text{Actual Rating}}{\text{Observed Rating}} \times 100 \\ &= \frac{R_o - R_a}{R_o} \times 100 \end{aligned}$$

GRAPHS TO BE PLOTTED:

1. Observed rating Vs Actual Rating

TABULAR COLUMN:

S.No	Actual time taken in minutes	Actual Rating (R _a)	Rating by Observer (Observed rating) (R _o)	% Error
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

SPECIMEN CAL:

$$R_a = \frac{\text{Standard Time}}{\text{Actual Time}} \times 100 = \frac{50}{67} \times 100 = 74.63cm$$

$$\% \text{ Error} = \frac{R_o - R_a}{R_o} \times 100 = \frac{75 - 74.63}{75} = 0.49$$

EXP 10:**TO DRAW TWO HANDED PROCESS CHART FOR BOLT,
WASHER & NUT ASSEMBLY**

AIM: To draw left and right hand process charts and to conduct time study for the bolt, washer & nut assembly of present and improved methods.

APPARATUS REQUIRED:

1. Stop watch
2. Brass spindles
3. Nylon washers
4. Lock washers
5. Hexagonal nuts

THEORY: For those who are trained in the micro motion study technique-that is, those who are able to visualize work in terms of elemental motions of the hands left and right hand process chart is a very simple and effective aid for analyzing an operation. No timing device is needed and on most kinds of work the analyst is able to construct such a chart from observations of the operator at work. The principle purpose of such a chart is to assist in finding a better way of performing the task, but this chart also has definite value in training operators.

The first step in making a left and right-hand chart is to draw a sketch of a work place, indicating the contents of the bins and location of tools and materials. Then watch the operator and make the mental note of his or her motions, observing one hand at a time. record the motions or elements for the left hand on the left hand side of a sheet of paper, and then in a similar manner record the motions for the right hand side of the sheet. Because it is seldom possible to get the motions of the two hands in proper relationship on the first draft, it is usually necessary to redraw the chart.

PROCEDURE: Under this study the operator assembles two different washers, nut and a bolt. Moreover the operator performs his assembly activity in two different methods i.e present and proposed methods and compares the two methods.

PRESENT METHOD:

1. The operator picks up a spindle from a bin of spindles with his left hand and a lock washer with his right hand from the bin of lock washers.
2. The operator assembles the lock washer with his right hand as the bolt, which is being held in left hand.
3. The operator then picks up a nylon washer with his right hand and assembles nylon washer with his right hand on the bolt, which is being held in left hand.

4. The operator again picks up a hexagonal nut by the right hand while holding the sub assembly firmly with left hand and assembles the hexagonal nut with right hand.
5. Finally the operator with his left hand carries and drops the bolt, washer & nut assembly into the bin provided for carrying the assemblies. This completes one cycle.
6. The timer measures and records the time taken by operator in doing the operations from steps 1 to 5.
7. The above steps are to be repeated for 10 cycles.
8. Calculate the average time taken for one assembly operation under present method.
9. Draw the left hand and right hand process chart for the present method as per the illustration given by following the sequence of steps in page no.3.

IMPROVED METHOD: The operator after being seated in front of the wooden fixture, picks up with his left and right hands from bin and positions same in the two counter sunk holes simultaneously. Such that threaded portion is upwards.

1. The left and right hand of the operator grasps lock washers respectively and positions these washers on to two counter sunk holes on the top of brass spindles simultaneously.
2. The left and right hands of the operator again grasp nylon washers from the next set of bins placed on the left and right hand sides respectively and slides and positions the washers in the two counter sunk holes on the top of lock washers simultaneously.
3. The left and right hands of the operator again grasp hexagonal nuts from the bins and slides and positions the nuts.
4. The operator with his left and right hand carries and releases simultaneously the two assemblies into the drawer provided between the operator and bins. This completes one cycle.
5. The timer measures and records the time taken by operator for steps 1 to 5.
6. The above steps are repeated for 10 cycles.
7. Calculate the average time taken for one cycle and for one-assembly operations under the improved method.
8. Draw the left and right hand process chart for the improved method as per the illustration given by following the sequence of steps in page no 4.
9. Compare the average time taken by the present and improved method for one assembly operation.


TABLE:

Method	Time taken / One complete cycle										Avg. time taken / cycle	Avg. time taken for an assembly (Sec)
Present (Old)	1	2	3	4	5	6	7	8	9	10		
Improved (New)												

$$\% \text{ of time saved} = \frac{\left(\frac{\text{Average time Taken for an assembly (Old Method)}}{\text{Average time taken for an assembly (Old method)}} - \frac{\text{Average Time Taken for an assembly (New Method)}}{\text{Average time taken for an assembly (Old method)}} \right) \times 100}{1} \leq$$

LEFT AND RIGHT HAND PROCESS CHART FOR BOLT, WASHERS & NUT ASSEMBLY (PRESENT METHOD)

1 Assembly	2 Brass spindle	3 Lock washers	4 Nylon washers	5 Hexagonal nuts
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 → Seating place for an operator

LEFT HAND	RIGHT HAND
Reaches for brass spindle in bin - 2	Reaches for lock washer in bin -3
Grasps spindle from bin - 2	Grasps lock washer from bin -3
Carries spindle to central position	Carries lock washer to central position
Holds spindle	Position lock washer
	Assembles lock washer on to bolt
	Reaches for nylon washer in bin - 4
	Grasps nylon washer from bin - 4

	Carries nylon washer to bolt
	Position nylon washer
	Assembles nylon washer
	Reaches for hexagonal nut in bin – 5
	Grasps hexagonal nut from bin – 5
	Carries hexagonal nut to bolt
	Positions hexagonal nut
	Assembles hexagonal nut
Carries finished assembly to bin-1	Releases finished assembly

PROCESS CHART FOR BOLT, WASHER & NUT ASSEMBLY
(IMPROVED OR NEW METHOD)

Left Hand	Right Hand
Reaches for brass spindle in bin - 4	Reaches for brass spindle in bin – 4
Grasps brass spindle from bin - 4	Grasps brass spindle from bin – 4
Slides brass spindle to counter sunk hole	Slides brass spindle to counter sunk hole
Positions such that threaded portion is upwards in counter sunk hole 5	Positions such that threaded portion is upwards in counter sunk hole 5
Reaches for lock washers in bin - 3	Reaches for lock washers in bin –3
Grasps lock washers from bin - 3	Grasps lock washers from bin – 3
Slides lock washers to counter sunk hole	Slides lock washer to counter sunk hole
Positions lock washer with spindle	Positions lock washer with spindle
Reaches for nylon washers in bin - 2	Reaches for nylon washers in bin – 2
Grasps nylon washers from bin - 2	Grasps nylon washers from bin – 2

MULTIPLE ACTIVITY CHART (OR) MAN MACHINE CHART

AIM: To draw multiple activity chart or man-machine chart for the subject of toasting 3 slices of bread in one electric double compartment toaster.

APPARATUS REQUIRED:

1. Electric toaster – 1no (* which can toast the bread slice only one side)
2. Pack of sliced bread – 1no
3. Stop watches – 2 nos
4. Bread boxes – 2 nos


THEORY: A 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 time scale to show their inter-relationship.


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 multiple activity chart is extremely useful in organizing teams of operatives on mass-production work and also on the maintenance work when expensive plant can not be allowed to remain idle longer than is absolutely necessary. It can also be used to determine the number of machines which an operative or operatives should be able to look after.

In making a chart, the activities of the different operatives or of the different operatives and machines are recorded in terms of working time and idle time. These times may be recorded by ordinary wristwatch or by stopwatch, according to the duration of the various periods of work and idleness (i.e whether they are a matter of minutes or seconds). Extreme accuracy is not required but timing must be accurate enough for the chart to be effective. The times are then plotted in their respective columns shown in the figure.

The following graphical representations (or symbols) may be used to show the working time and idle time of either man or machine.

 Loading & Unloading

 Operation

 Inspection

 Idle

PROCEDURE:**PRESENT METHOD:**

1. Connect the electric toaster to the required electric power supply.
2. Set the temperature of timing level at any desired value by rotating the corresponding knob.
3. The operator places two slices of bread with both hands in either side of toaster and keep the pop up knob in bottom most position.
4. The time is measured and recorded for the above activity of operator.
5. As soon as the knob is kept in the bottom most position, the toaster toasts the two slices of bread simultaneously.
6. As the toaster is an automatic popup type electric toaster, the two slices of the bread will popup at the end of proper toasting.
7. The time is again measured and recorded for the above activity of the toaster.
8. Repeat the steps from 3 to 7 for toasting the second side of the two slices. Measure the unloading and loading times of operator for the second side toasting.
9. Unload both the slices which are toasted both the sides.
10. Load the third slice for toasting.
11. Follow the same old procedure. Measure the timings and thus complete the toasting of third slice both the sides leaving the other compartment of the toaster unutilized. This method has to be improved because of non-utilization of the second compartment while toasting the 3rd slice in the first compartment.
12. Draw the man-machine chart corresponding to the above subject as per the sample illustrated.
13. Calculate the percentage utilization of operator and toaster compartments 1 & 2.

IMPROVED METHOD:

1. Method of toasting, loading & unloading is same. But the sequence of steps in toasting the 2 sides of 3 slices is different in this improved method.
2. Place the two slices in two compartments. One side of each slice gets toasted.
3. Now unload the slice –2 and keep it in the tray and load slice 3. Unload & load the slice 1 for other side toasting.

4. After toasting unload the slice 1 which is toasted both the sides. Then unload & load slice 3 for toasting second side. Load slice 2 in first compartment for 2nd side toasting.
5. Thus after finishing the complete toasting of 3 slices, calculations have to be done.
6. Draw the man-machine chart corresponding to the above subject as per the sample illustrated.
7. Calculate the percentage utilization of operator and toaster compartments 1 & 2.

PRESENT METHOD:

OBSERVATIONS:

S.No	Activity	Trial 1 Sec	Trial 2 Sec	Average Sec
1	Loading slice 1 and slice 2			
2	Toasting slice 1 & slice 2 1 st side			
3	Changing the position of slice 1 and slice 2 for toasting 2 nd side.			
4	Slice 1 & slice 2 for 2 nd side toasting			
5	Unloading slice 1 & 2			
6	Loading slice – 3 in one compartment			
7	Toasting for slice – 3 one side			
8	Changing the position of slice – 3 for toasting 2 nd side			
9	Toasting time for slice – 3 2 nd side			
10	Unloading slice – 3			

IMPROVED METHOD:

OBSERVATIONS:

S.No	Activity	Trial 1 Sec	Trial 2 Sec	Average Sec
1	Load slice 1 & slice 2 for toasting first side			
2	Toasting time for 1 st side of slice 1 & slice 2			
3	Unloading slice 2 after one side toasting			
4	Loading slice 3 for toasting 1 st side			
5	Changing the position of slice 1 for toasting 2 nd side			
6	Toasting time for slice 1 2 nd side & slice 3 first side			
7	Unloading slice –1			
8	Change the position of slice 3 for 2 nd side			

	toasting			
9	Loading slice 2 for 2 nd side toasting			
10	Toasting time for slice 2 & 3 2 nd side			
<u>MULTIPLE ACTIVITY CHART (Present method):</u>				

MULTIPLE ACTIVITY CHART (Improved method):

SUMMARY:

S.No	Description of Activity	Operator		Toaster compartment - 1		Toaster compartment - 2	
		Present	Improved	Present	Improved	Present	Improved
1	Idle time						
2	Working time						
3	Total cycle time						
4	% Utilization						

EXP 12:**ERGOCYCLE EXERCISE**

AIM : To study the changes in heart beat rate for different subjects using Ergocycle.

APPARATUS REQUIRED : 1.Ergocycle
2.Digital heart beat monitor
3. Stop watches – 2 nos.

THEORY AND OBJECTIVES : Physical work results in changes in oxygen consumption ,heart beat rate,pulmonary ventilation ,body temperature and lactic acid concentration in the body. Although some of these factors are only slightly effected by muscular activity ,there is a linear correlation between heart beat rate ,oxygen consumption and total ventilation and the physical work performed by an individual . Of these three ,the first two – heart beat rate and oxygen consumption are the most widely used for measuring the physiological cost of human work.

The performance of physical work requires the use of group of muscles . Some muscles are needed to maintain the posture while others perform the task. Davis and Miller have classified physical effort takes into three types : 1) Full body work which utilizes the large muscle groups usually involving 2/3 or 3/4 of the body's total muscles ,2) Localized muscular work which requires less expenditure of energy because fewer muscle groups are used to perform the task and 3) Static muscular work during which the muscles are used to exert a force but no mechanical work is done. Static requires the contraction of muscle groups and can be very demanding. The number and type of muscles involved ,either to move a member of the body or to control antagonist contraction affect the psychological cost of performing a task. When a person is at rest heart beat rate and rate of oxygen consumption is at a fairly steady level .Than t when he person does muscular work ,that is when changes from a rusting level to a working level both the heart beat rate and oxygen consumption increase .When work ends recovery begins and the heart beat rate and oxygen consumption returns to the original rating level.

In many industries the work load in certain tasks is often so heavy that it exerts psychological stress on the workers and consequently results in heavy fatigue. Under fatigue conditions ,there is gradual decrement in capacity of work as well as in the ability and alert ness of individual ,there by leading to accidental potentials and lower productivity. The knowledge of acceptable workload is therefore of great help, practical importance in occupation involving prolonged heavy muscular work.

PROCEDURE :

1. Record weight, height and initial resting time of the person considered.
2. Before doing the cycling exercise, measure and record the hearty beat rate of the person during last 30 seconds of 1st,2nd,3rd,4th and 5th minutes.
3. Set the friction knob at a particular position ,which means applying load on the person .

4. At this particular load, person has to do cycling exercise.
5. At different constant speeds of cycling measures the heart beat rate(i.e. / minute).
6. Record readings such as load- a ,speed heart beat rate at 1st,2nd,3rd,4th and 5th minutes.
7. Repeat the same thing at different friction al knob positions ,which indicates the increasing load on the person.
8. After stopping cycling ,record the heart beat rate(same procedure which was already followed)
9. Record the data.
10. Draw the graph according to the procedure given in the tread mill exercise manual.

PRECATIONS :

1. The person should be healthy and not be suffering from any cardiac disease.
2. The subjects or persons should have good sleep in the previous night and have taken morning breakfast.
3. They should be acquainted with the experimental protocol and willing to participate in the study.

OBSERVATIONS :

Name of the person/Subject :

Age of the person/Subject :

Weight of the person/Subject :

Height of the person/Subject :

Observation table

For load at position A of frictional knob.

For slope:

Sl no.	Speed in KMPH	Heart beat before exercise/min					Heart beat during exercise/min					Heart beat after exercise/min				
		1 st	2 nd	3 rd	4 th	5 th	1 st	2 nd	3 rd	4 th	5 th	1 st	2 nd	3 rd	4 th	5 th
1																
2																
3																
4																
5																

GRAPH:

Time Vs Heart beat rate in beats/minute of the subject considered.

SAMPLE GRAPH:

