

STATISTICAL PROCESS CONTROL CHARTS - VARIABLES

Statistical Process Control (SPC) means the use of control charting techniques to monitor performance. It relies on the basic laws of probability to put performance history into context. It is now applied throughout many companies e.g. in service, sales, personnel and accounts as well as where it first started - IN MANUFACTURING.

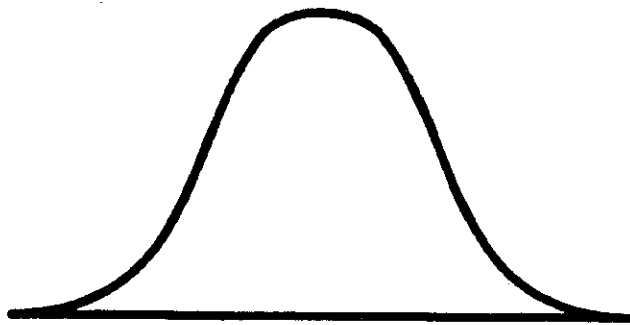
The basic idea is that there are two causes of performance variations:-

- (i) **Common causes** - Sometimes called random causes or inherent process variation, these are due to natural events.

- (ii) **Special causes** - Sometimes called assignable causes which are freak events due to indentifiable factors.

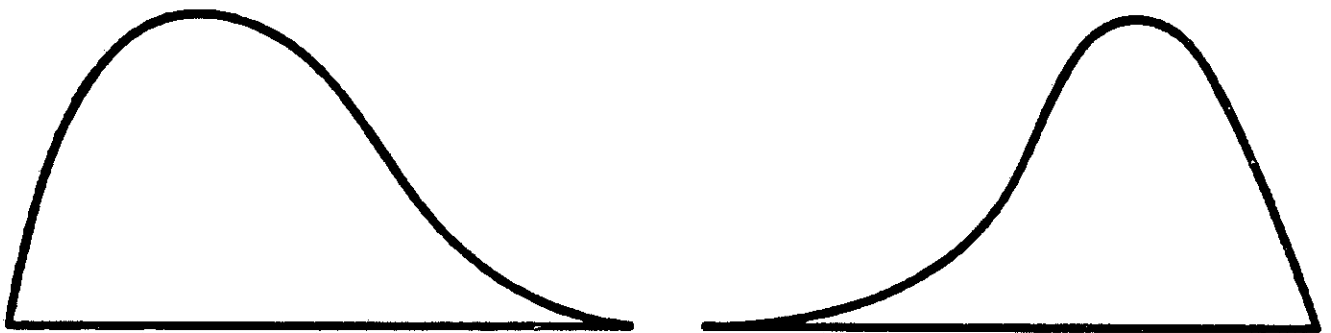
If data is taken from a process and plotted in the form of a frequency distribution or histogram, the following situations can occur:-

**PROCESS WITH ONLY
COMMON CAUSES PRESENT:-**

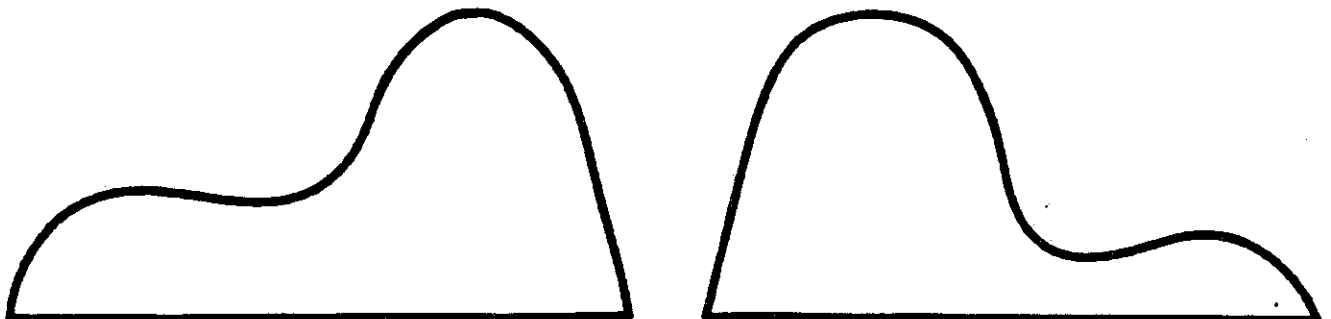


***FREQUENCY
DISTRIBUTION
OF INDIVIDUAL
ITEMS PRODUCED***

**PROCESSES WITH
SPECIAL CAUSES PRESENT:-**



***FREQUENCY DISTRIBUTIONS OF
INDIVIDUAL ITEMS PRODUCED***



Control charts have three basic applications:-

1. To establish a state of statistical control.

This means analysing and removing the special (assignable) causes. Quality engineering, production, maintenance and operators are usually involved in this stage.

2. To determine process capability.

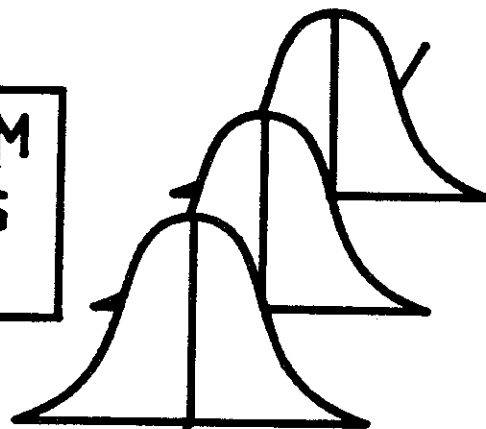
Once the process is in control the capability of the process can be determined by quality engineering.

3. To monitor and control the process.

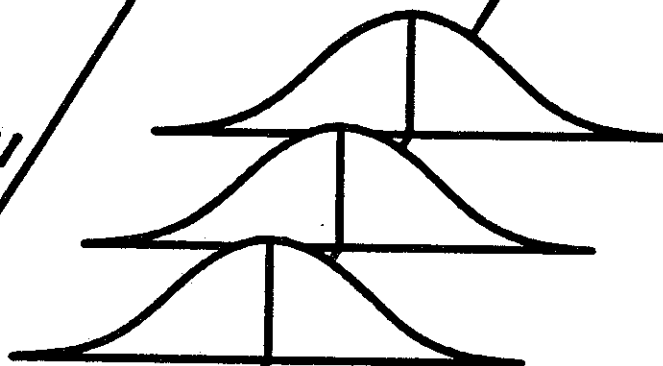
Now the charts are used to maintain on-going control over the process by the person who knows it best - the operator. This approach of process, rather than product, inspection is a preventative strategy.

The operator's role is to reduce the variation from common causes and carry manufacturing towards zero defect production through never-ending improvement.

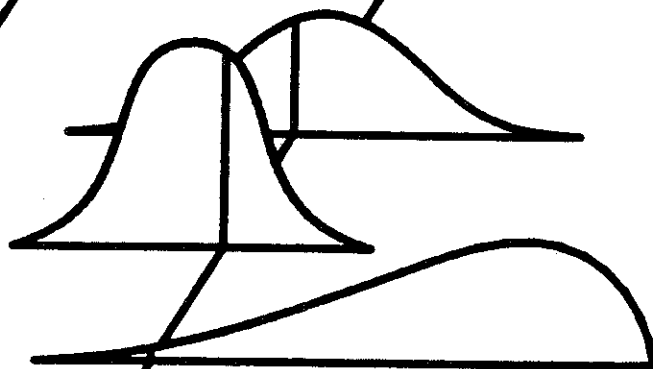
IN CONTROL
[VARIATION FROM
COMMON CAUSES
REDUCED]



IN CONTROL
[SPECIAL
CAUSES
ELIMINATED]



OUT OF CONTROL
[SPECIAL
CAUSES
PRESENT]



TIME

SIZE

All the process variation, whether it is from a common or special cause, can ultimately be traced back to one or more of the following factors:-

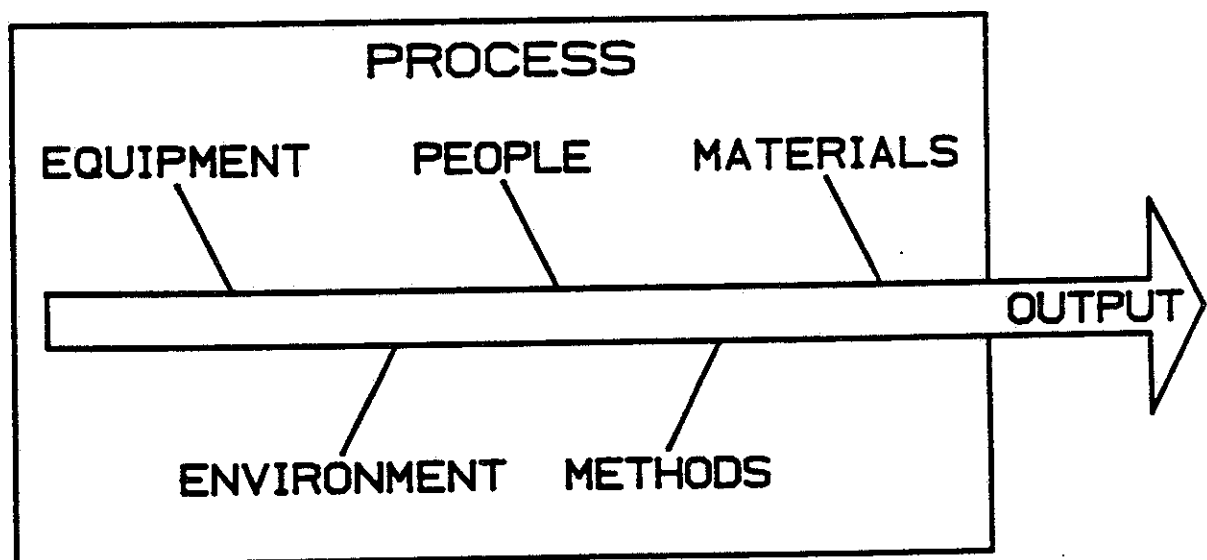
Equipment

People

Materials

Environment

Methods



VARIABLES CONTROL CHARTS

Variables data can be represented by a frequency distribution. To monitor this distribution it is necessary to watch both the position of its centre (average) and spread (range or standard deviation). When both of these are kept stable the distribution is trapped.

The control chart most commonly used for variables data is the Average and Range ($\bar{X}$ and R) chart. The range is used instead of standard deviation because it is much easier to calculate.

[illegible]

SETTING UP CONTROL CHARTS FOR VARIABLES TO OBTAIN STATISTICAL CONTROL

- STEP 1 Decide on process to be monitored.
- STEP 2 Set up process as far as possible at its best.
- STEP 3 Gather data at regular intervals. Small samples (usually $n = 5$).
The last items made.
- STEP 4 Measure sample data.
- STEP 5 Calculate average ($\bar{X}$) and range (R) of each sample.
- STEP 6 Plot on charts.
- STEP 7 Note any changes to the process on the back of the chart.
- STEP 8 After about twenty samples calculate the process average (grand
average) $\bar{\bar{X}}$ and the average range $\bar{R}$ and draw these in as dotted lines
on the charts.
- STEP 9 Calculate the control limits and draw these in as solid lines on the chart.

Upper control limit:- average chart

$$UCL_{\bar{X}} = \bar{\bar{X}} + 0.58 \bar{R}$$

Lower control limit:- average chart

$$LCL_{\bar{X}} = \bar{\bar{X}} - 0.58 \bar{R}$$

Upper control limit:- range chart

$$UCL_R = 2.11 \bar{R}$$

Note - These constants apply to a sample size of 5 only.

STEP 10 Check for process control.

Special causes are present if there is:-

- Any point outside the control limit.
- A run of 7 points - all ABOVE or all BELOW the central line.
- A run of 7 points - going UP (each point greater than or equal to the point before).
- A run of 7 points - going DOWN (each point less than or equal to the point before).

STEP 11 Find and eliminate special causes.

STEP 12 Recalculate control limits.

STEP 13 Repeat steps 10, 11, 12 until process control is obtained.

	1	2	3	4	5	6	7
A V E R A G E S							

R A N G E S							

Step 4 {

DATE	13/4						
TIME	8.00						
S A M P L E S	X ₁	51.1					
	X ₂	50.7					
	X ₃	50.8					
	X ₄	51.2					
	X ₅	50.9					
SUM	ΣX	254.7					
MEAN	$\bar{X}$	50.94					
RANGE	R	0.5					
SIGNATURE	<i>[Signature]</i>						

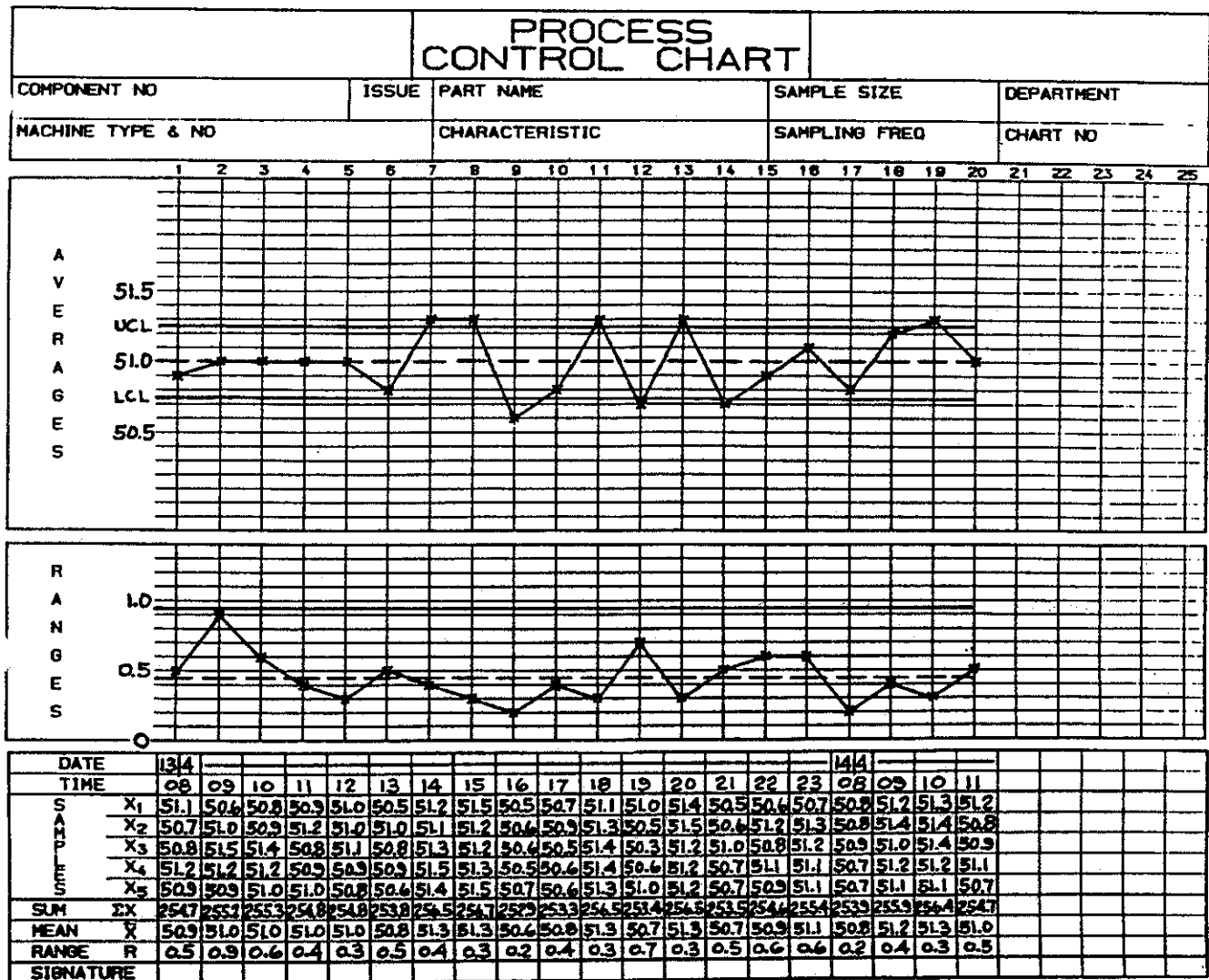
Step 5

Sum of subgroup values $\Sigma X = X_1 + X_2 + X_3 + X_4 + X_5$

$$\Sigma X = 51.1 + 50.7 + 50.8 + 51.2 + 50.9 = 254.7$$

$$\text{Mean } \bar{X} (x \text{ bar}) = \frac{\Sigma X}{n} = \frac{254.7}{5} = 50.94$$

$$\text{Range} = \text{LARGEST } X - \text{SMALLEST } X = 51.2 - 50.7 = 0.5$$



Step 8

$$\text{Process Average (grand average)} \bar{\bar{X}} = \frac{\text{Sum of all } \bar{X}}{\text{No. of } \bar{X}'\text{'s}} = \frac{1020}{20} = 51.0$$

$$\text{Average range } \bar{R} = \frac{\text{Sum of all } R}{\text{No. of } R'\text{'s}} = \frac{8.9}{20} = 0.445$$

Step 9

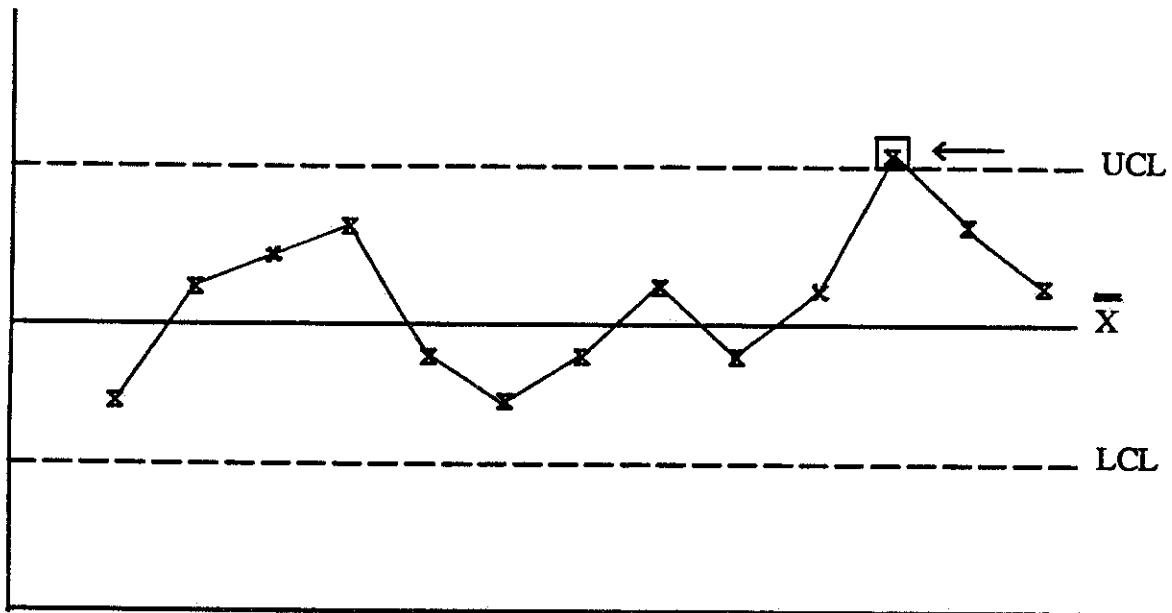
$$UCL_{\bar{X}} = \bar{\bar{X}} + 0.58 \bar{R} = 51.0 + (0.58 \times 0.445) = 51.26$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - 0.58 \bar{R} = 51.0 - (0.58 \times 0.445) = 50.74$$

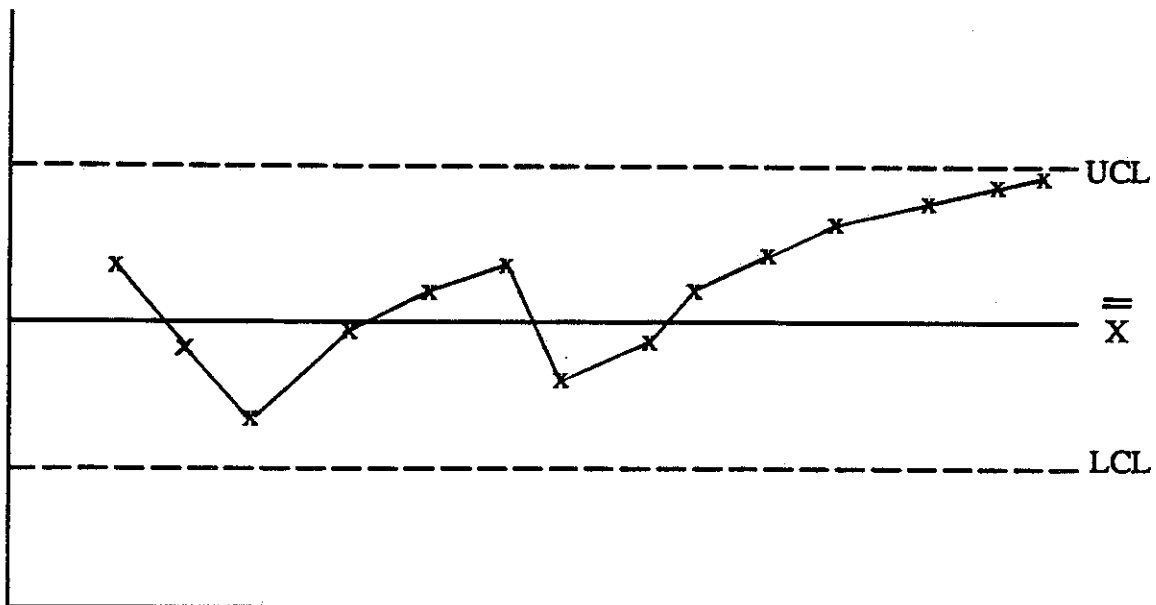
$$UCL_R = 2.11 \bar{R} = (2.11 \times 0.445) = 0.94$$

ANALYSIS AND INTERPRETATION OF CHARTS

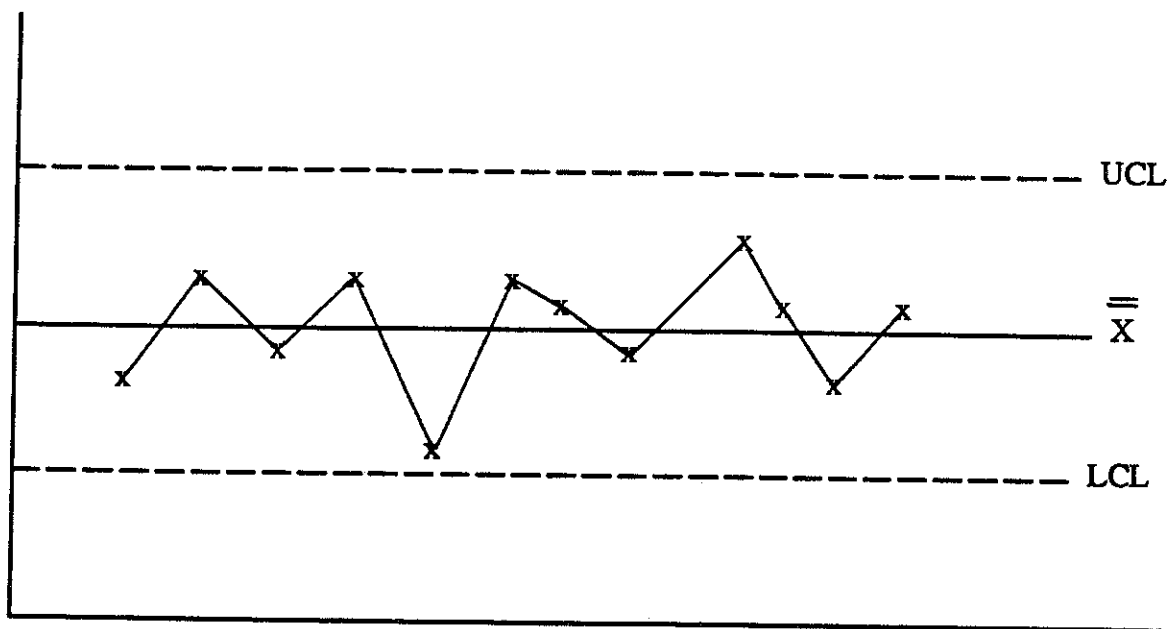
The statistical analysis of the charts is based on the pattern of the plotted points. Typical patterns are shown below.



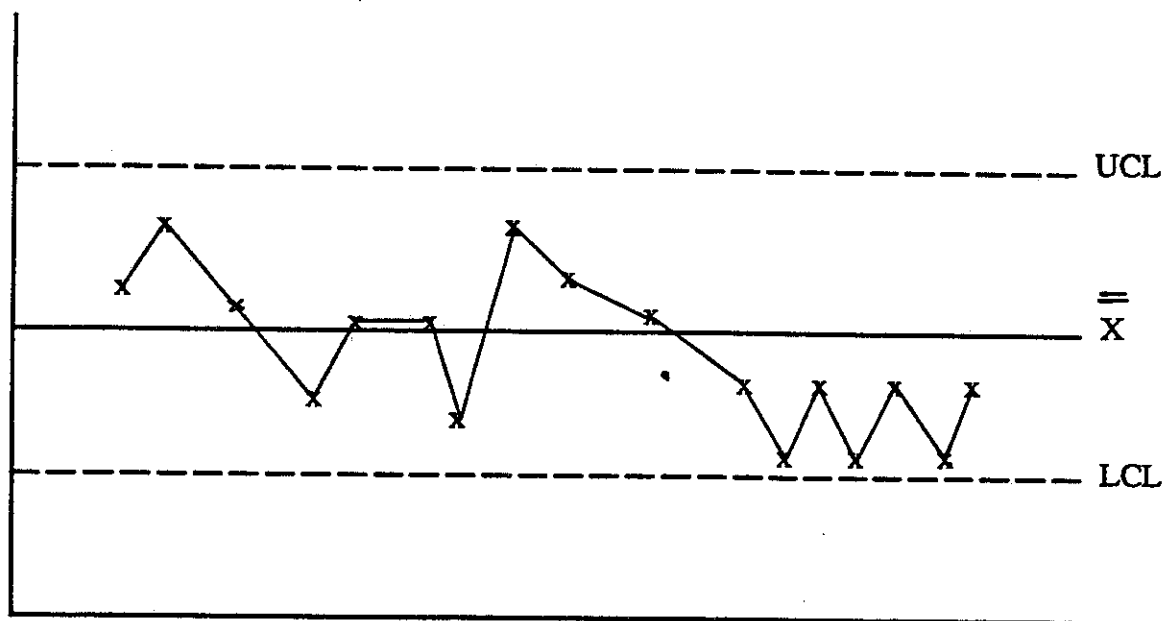
ANY POINT OUTSIDE THE UPPER OR LOWER CONTROL LIMIT



7 INTERVALS IN A ROW INCREASING OR DECREASING



A PROCESS IN CONTROL



7 POINTS IN A ROW EITHER SIDE OF THE MEAN

Any statistically significant movement on the average chart is usually considered to mean a loss of control and a requirement for action.

On the range chart this also applies, except for a downward trend or seven points below the average range which indicates an improvement in the process. This should be investigated to find the cause, and this cause then incorporated in the process if possible.

The information on process adjustments and changes made on the back of the chart is a vital aid in tracing causes. This is often a technical analysis and the help of the operator is crucial to success.

OPERATOR CONTROL

Once the process has been shown to be under statistical control the charts can be handed over to the operators to be used for ongoing process control and improvement. It should be noted that the $\bar{X}$ value on the average chart is now set at the target value or centre of the specification.

Operator training is obviously required in most cases and the introduction of S.P.C. charts must be done gradually through an organisation because extensive backup will be required in the early stages of implementation.

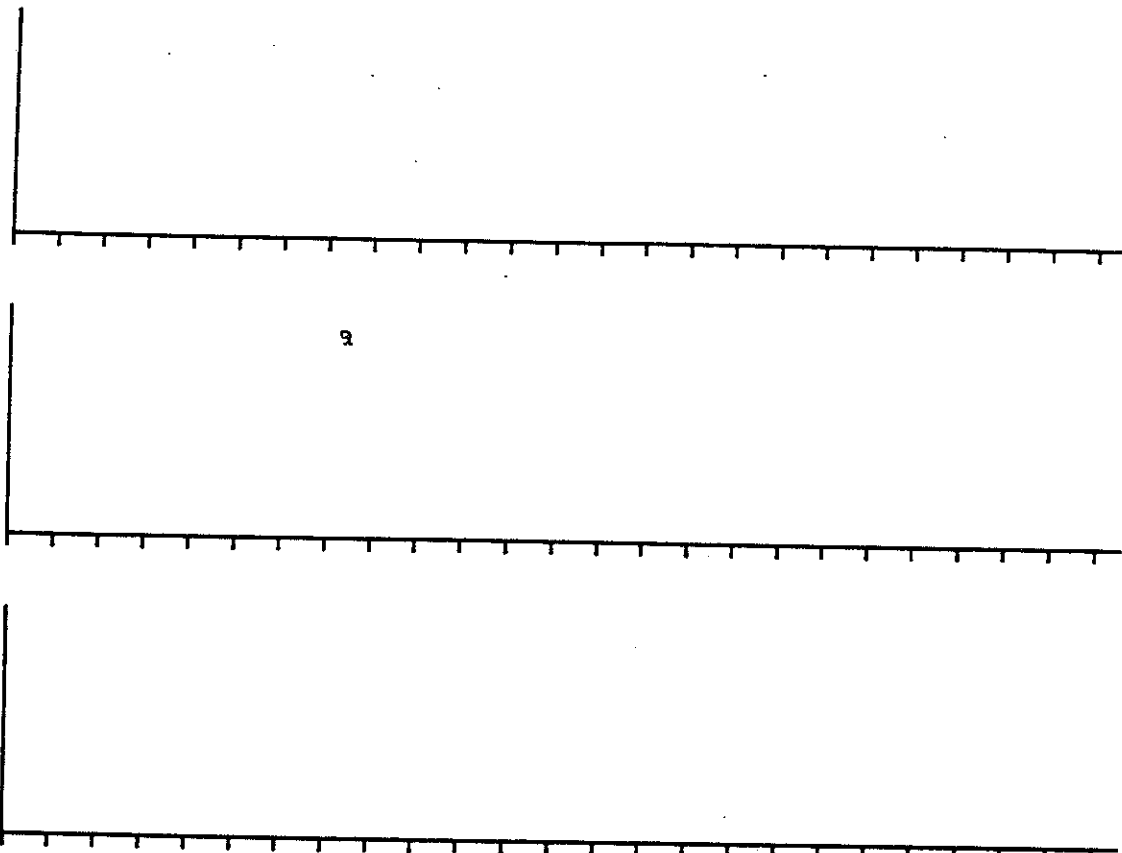
FURTHER WORK IN CONTROL CHARTS

A major benefit of control charts is that they provide a factual form around which the process can be discussed by all personnel. They should be analysed, and if necessary recalculated, at regular intervals. The building up of diagnostic charts, shown below, enables processes to be effectively monitored and information to be gathered for detailed analysis.

DIAGNOSTIC CHART

FAULT	CODE	ACTION	CODE
UNDERSIZE	A	ADJUST TOOLS	1
		CHECK BAR	2
		MOVE CARRIER	3
OVERSIZE	B	-----	1
		-----	2
		-----	3
		-----	4
POOR FINISH	C	-----	1
		-----	2
		-----	3

When a fault is found and action taken the relevant code e.g. A2 is marked on the chart. A repeating code indicates the need for further investigation.



THE POLYTECHNIC OF WALES					PROCESS CONTROL CHART										DEPARTMENT OF MECHANICAL & PRODUCTION ENGINEERING														
COMPONENT NO					ISSUE		PART NAME					SAMPLE SIZE					DEPARTMENT												
MACHINE TYPE & NO					CHARACTERISTIC					SAMPLING FREQ					CHART NO														
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25																								
A V E R A G E S																													
					R A N G E S																								
DATE																													
TIME																													
S A M P L E S	X ₁																												
	X ₂																												
	X ₃																												
	X ₄																												
	X ₅																												
SUM		ΣX																											
MEAN		$\bar{X}$																											
RANGE		R																											
SIGNATURE																													

OPERATORS ROLE UNDER S.P.C.

Take sample of 5 components from the process at set intervals.

Measure each component.

Calculate the average $\bar{X}$ and range R of each sample.

Plot their values on the charts.

Check whether or not the process is still under control.

ACTION CAUSES:-

Any point outside the control limit.

A run of 7 points - all ABOVE or all BELOW the central line.

A run of 7 points - going UP (each point greater than or equal to the point before).

A run of 7 points - going DOWN (each point less than or equal to the point before).

Interpret fault and take action or call for assistance.

Learn about the process.

Work Sheet 7

CONSTRUCTION AND USE OF CONTROL CHARTS - VARIABLES

1. Data has been taken from a process and is given on the attached sheet.
20 samples of size 5.
2. The average and range of each sample has been calculated.
3. Set off measurement scales for $\bar{X}$ and R charts.
4. Plot $\bar{X}$ and R for each samples.
5. Calculate $\bar{\bar{X}} =$ $\bar{\bar{R}} =$
6. Draw in dotted average lines on each chart.
7. Calculate control limits.

$$UCL_{\bar{X}} = \bar{\bar{X}} + 0.58 \bar{\bar{R}} =$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - 0.58 \bar{\bar{R}} =$$

$$UCL_R = 2.11 \bar{\bar{R}}$$

8. Draw in control limits.
9. Check for process control on both charts.

[illegible][illegible][illegible][illegible]

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PROCESS CONTROL CHART

SCHOOL OF DESIGN AND
ADVANCED TECHNOLOGY

COMPONENT NUMBER	ISSUE	PART NAME	SAMPLE SIZE	DEPARTMENT
MACHINE TYPE AND NUMBER		CHARACTERISTIC	SAMPLING FREQUENCY	CHART NUMBER

[illegible][illegible][illegible]