Objectives

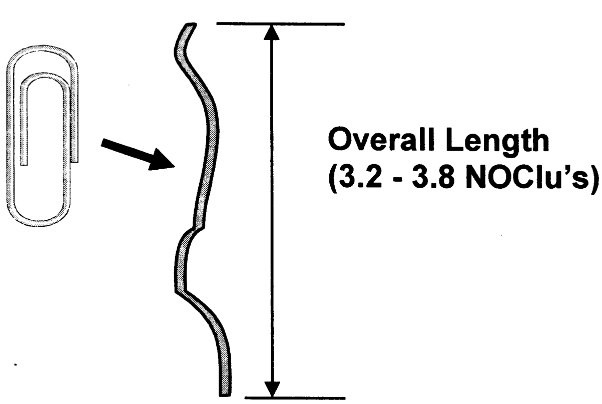
- To gain a basic understanding of steps to create control charts from customer requirements to production.
- To practice calculating $\bar{x}$ and R chart control limits and capability indices
- To create control charts and analyze process capability with Minitab

This scenario used in this exercise is an adaptation of an exercise developed and presented by Jim Imboden and Jim Oxenrider at the 2001 American Quality Congress and is used with their permission. A copy of the paper from the conference proceedings and the PowerPoint slides from which many of the figures are adapted can be found at http://www.qualitystation.com/

Background

A successful manufacturing company will focus on meeting customer requirements for its products. In looking at manufacturing processes and quality control, it is important to keep in mind that decisions are made with the customer in mind. Our company and customer requirements are as follows:

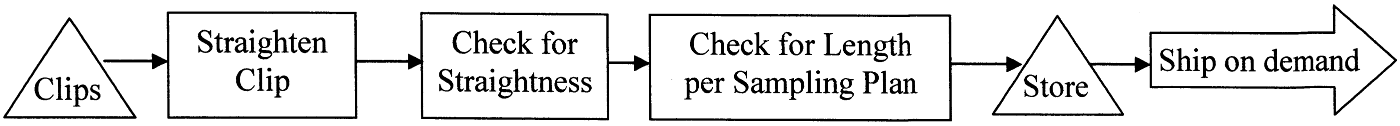
Company:	NEBULAR ORB CORPORATION PAPER CLIP DIVISION
Company Background:	International Conglomerate Quality Producer of Linear Dry Pulp Tension Retainers (LDPTR)
Company Objective:	Keep the customer happy.
Primary Customer:	U.S. Government Use of LDPTR: Classified – Top Secret
Critical Specifications:	Overall length 3.5 ± 0.3 NOCLU's Straightness to pass government issued Straightness Checking Tube



The Linear Dry Pulp Tension Retainers **MUST** be able to drop through the Straightness Checking Tube easily.

PART A. **Establishing the process**

We have a customer and product, now we must define the process and how we will insure that we are producing a level of quality that will keep our customer happy. Our input materials are paper clips acquired from another factory in our division. We establish a flow diagram of the process as follows:



The process requires Operation Descriptions for three operators: Straightener, straightness checker and length checker. An Operation Description provides a clear and concise description of what the operator is to do and how to do it. The operation description for the length checker is below.

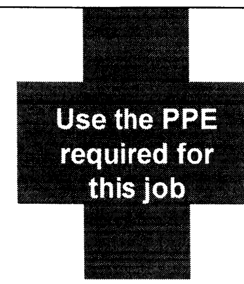
Operation Description

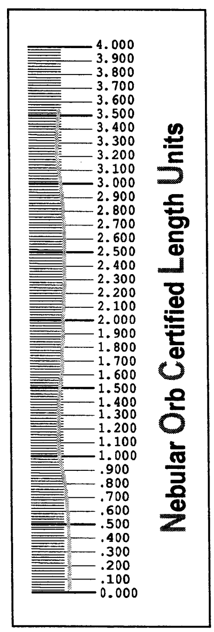
Operation Name	Equip Name	Dept	Group	Business Unit
Measure				

Part Name	LDPTR	Part Number	12345

Item	Elements
	Lay the NoClu gage on a flat surface
	Align one end of the LDPTR with zero on the gage
	Measure to two decimal places
	Use magnifying glass if necessary
	Measure three (3) parts per shift
	Plot average and range on control chart
	Report out of control signals to supervisor
	Report out of spec to supervisor

Don Wegman	Oct, 20, 2000
Completed by:	Rev Date
Jerry Bowen	Oct, 20, 2000
Approved by:	Date



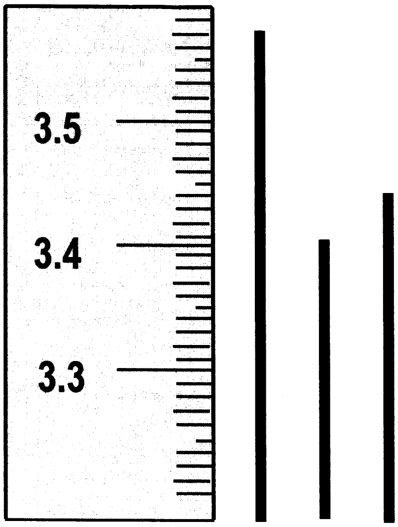


PPE Requirements

Safety Requirements
- •Follow all posted lockout procedures
- •Report any safety concerns to your supervisor

Answer the following from the information provided in the operation description.

What is the sample size? ____________ Sample frequency? ________per shift.

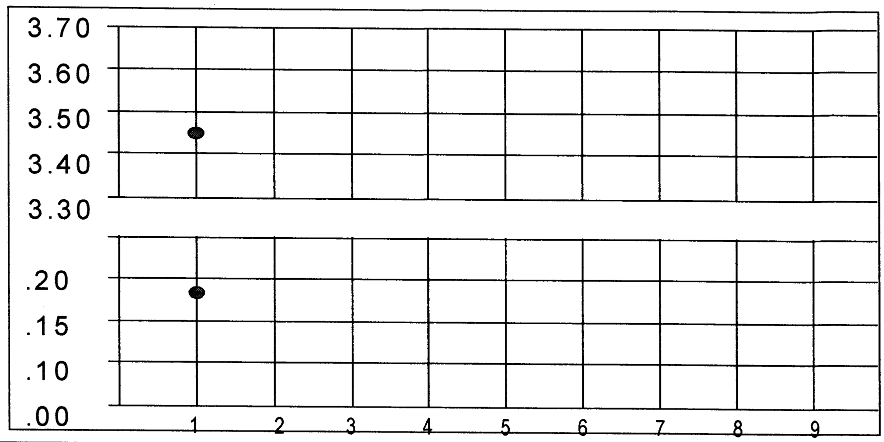


So if we take a sample and our readings are 3.58 3.40 3.44

What is the sample average? ______________

What is the sample range? ________________

Enter the data, average and range on the chart below.



Reading 1	3.58								
Reading 2	3.40								
Reading 3	3.44								
Average									
Range									

We plot our average and range on the chart. Verify that the points already plotted are match your calculations The sample for the next shift will go on the next column.

Take a look at the control chart for the exercise to see how the data fits on the actual chart. (We will ignore readings 4 and 5 and the sum row.)

What does our Operation Description tell the operator to do if they encounter an out of control signal?

____

An out of control signal on the control chart indicates a process has changed. For our facility, an out of control signal will be defined as any of the following:

- One point outside the control limit
- Seven consecutive dots on either side of the central line.
- Seven points continuously increasing or decreasing.

If you understand how to measure the part, record the data and what to do in case of an out of control condition, consider yourself to be a trained inspector.

PART B. Sample collection

Before we can actually monitor the process with a control chart, we must determine the limits of the natural process variation and the associated control limits. We must collect data from the process to do this.

For our process, we have already collected 23 samples of size 3 and the data has been entered on the chart. Notice on the chart for the x values, that the first digit, 3 has been dropped in entering the data.

Twenty five to 30 subgroups should be used to be statistically viable. (Note: The terms subgroup and sample tend to be used interchangeably.)

We take samples at the end of the next two shifts with the following measurements:

Subgroup #24:	3.48	3.40	3.32
Subgroup #25	3.34	3.38	3.38

Enter these subgroups on the chart. Calculate $\bar{x}$ and R and plot the points to complete the initial data collection activity.

PART C. Calculating trial control limits

Once you have the measurements you are ready to calculate trial control limits. We now need to find the average $\bar{x}$ and R. (The sum of the $\bar{x}$'s and R's for subgroups 1 through **23** is 78.71 and 3.72, respectively.)

Calculate: $\bar{\bar{x}} =$ $\bar{R} =$

We can estimate the standard deviation, σ, with $\frac{\bar{R}}{d_2}$.

For our sample size, n=__________, and d2 = _____________ (from Chart)

Therefore for our process: $\hat{\sigma} = \frac{\bar{R}}{d_2} =$

Since we are taking samples, $\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} =$

So our control chart limits are:

$$UCL_{\bar{x}} = \bar{\bar{x}} + 3\sigma_{\bar{x}} =$$
$$CL_{\bar{x}} = \bar{\bar{x}} =$$
$$LCL_{\bar{x}} = \bar{\bar{x}} - 3\sigma_{\bar{x}} =$$

A short cut to calculate the upper and lower limits is to look up the factor A2 where $A_2 = \frac{3}{d_2\sqrt{n}} =$ ________

$$UCL_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R} =$$
$$LCL_{\bar{x}} = \bar{\bar{x}} - A_2\bar{R} =$$

Calculate the control limits for the range chart as follows:

$$UCL_R = D_4\bar{R} =$$
$$CL_R = \bar{R} =$$
$$LCL_R = D_3\bar{R} =$$

Draw the $\bar{x}$ and R trial control limits on the chart.

PART D Checking the trial limits

The limits you have calculated are considered trial limits. Before we can use them in the shop we need to make sure that we in fact have a stable process.

The central limit theorem tells us when we are taking samples, the sample statistic will follow a normal distribution (whether or not the population was actually normal). So when the process is stable, the plotted points will be normally distributed. Check to see that the points are random about the center line with more points closer to the center than further away. Check for trends, shifts and cycles.

Does your chart pass our cursory normality check? ______________

For the inspector, we have defined a more limited set of out of control conditions.

Are any points out of the control limits? __________
Do you have a run of 7 above or 7 below the center line? _________
Do you have a trend of 7 increasing or decreasing points? _________

If any of the above conditions did occur you would need to investigate. If the process is deemed stable, you could start monitoring the process with the control chart.

PART E. Check your work in Minitab.

The measurement sample data for subgroups 1 through 23 have been saved in the worksheet **noclu_data.mtw**.

Choose **File > New > Minitab Project> OK** *to get a empty project, if you are not starting with an empty project.*
Choose **File > Open Worksheet** *This is a worksheet file, not a project file.*
Find the appropriate directory and select the file **noclu_data.mtw**.

The sample data has been saved in rows. Scroll down to the bottom of the worksheet and add the measurements for subgroups 24 and 25.

You are now ready to calculate the limits.

1. Choose **Stat > Control Charts > Variables Charts for Subgroups > Xbar-R**
2. Select: **Observations for a Sub-group are in one row of columns**
3. Move cursor to box below, highlight the five columns **C2-C4** and click select.
4. Click **Xbar-R chart Options**. Click the **Estimate** tab. Choose **Rbar** as method of estimating standard deviation.
5. Click the **Tests** tab. Use the dropdown to select: **Perform all tests for special causes**. You can leave the default Kvalues – take a look at what the tests are. (If the K values are not there, set the drop down again.)
6. Click **OK.**
7. Click **Labels**. Enter title: Initial No_Clu Measurements.
8. Click **OK** twice.

Verify your calculations of the control limits and that your points have plotted the same as on the chart. (Your standard deviation estimate should be comparable to the "within" StDev.)

PART F Monitoring the Process

As there are no out of control conditions, you assume the limits were established based on a stable process. The limits can be finalized and the chart used to monitor production. A chart is placed into production that has the limits already on it. The inspector will collect and plot data per the plan to monitor for out of control conditions – special causes that must be investigated.

The control limits for the stable process to be used in production monitoring, with a subgroup size of n=3 is

$UCL_{\bar{x}} =$ $UCL_R =$

$LCL_{\bar{x}} =$ $LCL_R =$

1. The inspector takes a sample with the following measurements: 3.25 3.44 3.36.

   For this sample $\bar{x} =$ _______ and R = ___________

   Therefore the inspector should *(select one)* ___ notify the supervisor
   ___ continue monitoring the process

2. The next shift, the inspector takes a sample with the following measurements: 3.35 3.54 3.12.

   For this sample $\bar{x} =$ _______ and R = ___________

   Therefore the inspector should *(select one)* ___ notify the supervisor
   ___ continue monitoring the process

The supervisor determined that the range out of control was due to a material issue where the input clip had been defective. A corrective action was issued to determine the root cause of the problem and determine action to prevent reoccurrence.

PART G
Comparing process variation to the specifications

The control chart tells us if the process is stable (in statistical control) but does not tell us if we are meeting customer requirements. We need to calculate the capability indices to get a measure of how well the requirements are being met.

What are upper and lower engineering specification limits? (**NOT** the control chart limits.)

USL ____________ LSL ____________________

What is your estimate of the standard deviation for the process? $\hat{\sigma} = \dfrac{\bar{R}}{d_2} =$ _________

Calculate the process capability ratio: $C_p = \dfrac{USL - LSL}{6\sigma} =$

Assuming your process were centered, is it capable? Why or why not?

Calculate the capability ratios at the upper and lower end:

$$C_{pu} = \frac{USL - \bar{x}}{3\sigma} = \qquad\qquad C_{pl} = \frac{\bar{x} - LSL}{3\sigma} =$$

The "worst" case is the minimum of these two, C_{pk}: This represents the actual capability of the process.

$$C_{pk} = \min\left[C_{pu}\right],\left[C_{pl}\right] =$$

Is the process capable?

What percent of the product is non-conforming? (Sketch the distribution and determine the % above the upper spec limit and below the lower spec limit – this is a basic normal distribution problem using population data.)

PART H **<u>Check capability analysis in Minitab</u>**

To run a capability analysis in Minitab:

1. Choose **Stat > Quality Tools > Capability Analysis > Normal**
2. Select: **Sub-groups across rows of**
3. Move cursor to box below, highlight the five columns **C2-C4** and click select.
4. Lower Spec: **3.2**
5. Upper Spec: **3.8**
6. Click: **Estimate**. Select **Rbar** as method of estimating standard deviation. Click **OK**.
7. Click the **Options**. Choose Perform Analysis: **Within subgroup analysis and Overall Analysis.**
8. Select Display: **Percents** and **Capability Stats (Cp, Pp)**.
9. Enter a Title. Click **OK.**
10. Click **OK.**

Enter results here:	Cp =	CPL =
	Cpk =	CPU =

Compare these results to your answers.

It is obvious from the graphic that the process is not centered. If you did not have the graphic, how could you tell that it is not centered from the capability indices?

Also notice the following from the results

Expected % below LSL (using within) = Expected % above USL (using within) =

Observed % below LSL = Observed % above USL =

Verify that your expected % nonconforming are the same as the expected values here.

What is the observed % and why might it be different than the expected %. (Use Minitab help if you do not understand what the observed % is.).

PART I. <u>One more Minitab Run</u>.

The capability indices are only valid if the population is normally distributed.

Does the histogram with the previously run capability analysis look normal?

We would really want to be more certain of the assumption of normality so a normality plot should be run.

Typically, when doing a capability analysis, you would generate the control charts, run the histogram, run a normal probability plot, then look at the indices. Minitab will let us do this all at once

1. Choose **Stat > Quality Tools > Capability Sixpack > Normal**
2. Select: **Sub-groups across rows of**
3. Move cursor to box below, highlight the four columns **C2-C4** and click select.
4. Lower Spec: **3.2**
5. Upper Spec: **3.8**
6. Click the **Tests** tab. Choose: **Perform all tests for special causes**. Click **OK**
7. Click: **Estimate**. Select **Rbar** as method of estimating standard deviation. Click **OK.**
8. Click the **Options**. Enter an appropriate title. Click **OK.**
9. Click **OK.**

Looking at the normality plot, can you now state with more certainty that normality is a reasonable assumption? Yes / No

Compare the output from Part H to Part I. What does Part I give you that H does not?

PART J. Conclusions

What actions should be taken regarding this process?

CONTROL CHART

PLANT	DEPT	OPERATION	DATE LIMITS CALCULATED	SPECIFICATION	PART NO.
MACHINE	DATES	CHARACTERISTIC		SAMPLE SIZE / FREQUENCY	PART NAME

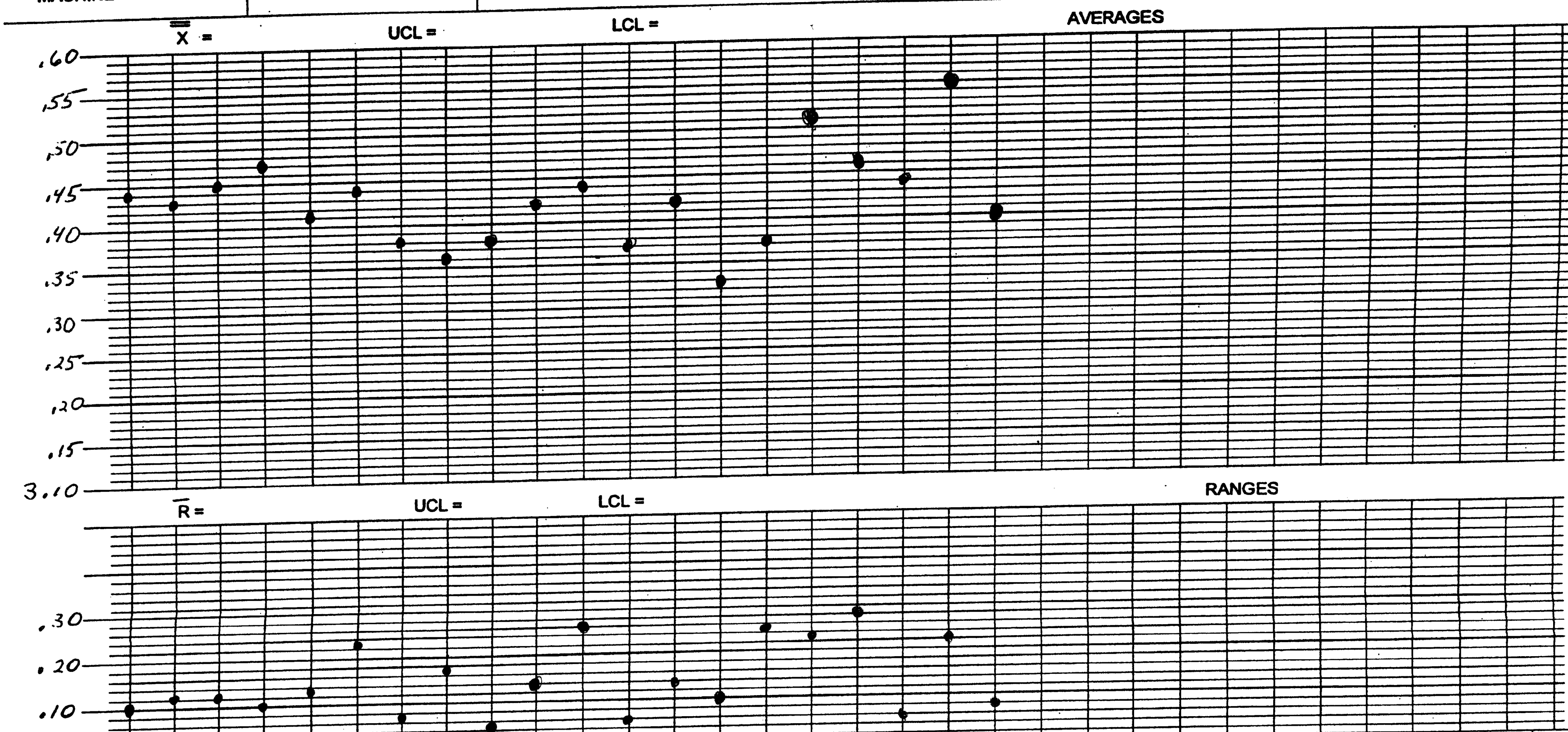
$\overline{\overline{X}}$ = UCL = LCL = AVERAGES

$\overline{R}$ = UCL = LCL = RANGES

Date / Time	
READING	1
	2
	3
	4
	5
SUM	
$\overline{X}$ =	
R =	

CONTROL CHART

PLANT	DEPT	OPERATION	DATE LIMITS CALCULATED	SPECIFICATION	PART NO.
MACHINE	DATES	CHARACTERISTIC		SAMPLE SIZE / FREQUENCY	PART NAME



Date / Time	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
READING 1	3.50	.48	.42	.50	.39	.35	.35	.42	.38	.36	.54	.40	.37	.30	.51	.37	.57	.46	.58	.45	.38	.45	.24		
2	3.40	.36	.52	.40	.35	.58	.42	.25	.40	.40	.50	.34	.51	.39	.34	.60	.29	.46	.43	.38	.62	.56	.25		
3	3.43	.46	.40	.50	.48	.40	.38	.40	.36	.60	.28	.38	.37	.29	.26	.57	.56	.40	.65	.37	.39	.28	.54		
4																									
5																									
SUM																									
$\bar{X}$ =	3.44	.43	.45	.47	.41	.44	.38	.36	.38	.42	.44	.37	.42	.33	.37	.51	.47	.44	.55	.40	.46				
R =	.10	.12	.12	.10	.13	.23	.07	.17	.04	.14	.26	.06	.14	.10	.25	.23	.28	.06	.22	.08	.24				