On-line Real-time Control Charts System for an Integrated Circuit Manafacturing Company

By

Ms. Aree Chinowuttichai

A Final Report of the Three - Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
Assumption University

November 1999

ī1-LINE REAL-TIME CONTROL CHARTS SYSTEM FOR N INTEGRATED CIRCUIT MANUFACTURING COMPANY

by
Ms. ree Chinowuttichai

A Final Report of the Three-Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
Assumption University

November 1999

Project Title	On-line Real-time Control Charts System for an Integrated Circuit Manufacturing Company
Name	Ms. Aree Chinowuttichai
Thesis Advisor	Dr. Thotsapon Sortrakul
Academic Year	November 1999

The Graduate School of Assumption University has approved this final report of the twelve-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

Approval Committee:

(Dr. Thotsapon Sortrakul)
Advisor

(Prof.Dr. Srisakdi Charmonman)
Chairman

gpyar,14,111

(Dr. Chamnong irapanich)
Dean and Co-advisor

(Assist.Prof. Dr.Boonmark Sirinaovakul)
Member

(Dr. Prapon Phasukyud)
Member

(Assoc.Prof. Somchai Thayarnong)
MUA Representative

November 1999

ABSTRACT

At the early age, the existing system was able to satisfy both internal and external users. The rapid changes in technologies go hand in hand with customers demand, ABC Company needs to be able to respond to users in a timely manner. In the past, it used to take approximately 2 to 3 days to respond to customers need in terms of statistical data. Nowadays, this is unacceptable and for that, ABC Company shall replace the existing system with a computerised system, On-line Real-time Control Charts.

For a successful design of On-line Real-time Control Charts system, System Development Life Cycle (SDLC) was applied and used through out to ease developers in designing quality system. This includes activities of preliminary investigation, requirement determination, and system and user interface design.

During the fact-finding stage, methods used were interview, questionnaire, observation and participation. Data Flow Diagram (DFD) was used extensively in the structured analysis development strategy. Entity Relationship (E-R) diagram and data dictionary were created as a catalogue, a repository, of the data captured in the On-line Real-time Control Charts system. It is a tool that helped developers to know how many characters are in a data item, by what other names it is referenced in the system, or where it is used in the system.

ACKNOWLEDGEMENTS

In the process of preparing the manuscript for this project, a number of people from various kinds of specialty, experience, activity and knowledge assisted by providing concept, sample data, and so on that would make this project possible. For this reason, I would like to take this opportunity to express my gratitude to the following people.

Firstly, Dr. Thotsapon Sortrakul as a project adviser for guidance and recommendations.

Secondly, managers, SPC specialists, and engineers of ABC Company for all the supports, concept, and operational requirements.

Lastly, but not least, Mr. Piyaphong Kobbandith, Mr. Watit Kasempremchit, Mr. Praphant Pavasant and other CEM friends for all the encouragement and supports.

TABLE OF CONTENTS

LIST OF FIGURES

Figure		Page

LIST OF TABLES

I. INTRODUCTION

1.1 Overview of the Project

Quality has become one of the most important consumer decision factors in the selection among competing products and services. The phenomenon is widespread, regardless of whether the consumer is an individual, an individual organisation, a retail store, or a military defence program. Consequently, understanding and improving quality is a key factor leading to business success, growth, and an enhanced competitive position. There is a substantial return on investment from improved quality, and from successfully employing quality as an integral part of overall business strategy.

If a product is to meet customer requirements, generally it should be produced by a process that is stable or repeatable. More precisely, the process must be capable of operating with little variability around the target or nominal dimensions of the quality characteristics of the product. Statistical Process Control (SPC) is a primary tool for achieving this objective. Control charts are the simplest types of statistical process control procedure.

Every integrated circuit manufacturers strive to improve on every aspect possible. On-line real time control chart is part of the total continuous process improvement efforts to propel in this critical mission.

1.2 Objectives of the Project

(a) To design an On-line Real-time Control Charts software to meet users' requirements. These include data collection, data gathering, data retrieving, as well as periodic reports per users' requirements.

(b) To increase customers' satisfaction at all stages. Customers in this sense can be both internal and external customers. Internal customers are users who use the system such as operators, engineers, managers, auditors, etc. Operators need to enter data into control charts. Engineers need data for process improvements and managers need monthly reports to forecast any situation. External customers are customers who use our services or products.

(c) To replace manual control chart in assembly area to On-line Real-time Control Charts system.

(d) To reduce human errors. Often engineers found that operators perform data entry error, calculation error, chart misinterpretation, etc.

(e) To be able to integrate with other systems e.g. MRPII.

1.3 Scope of the Project

The project will cover the following areas:

(a) A computer system analysis and design plan for $X — R$ and Cumulative Count Control Charts for an integrated circuit manufacturing company.

(b) Duration of project design is 3 months.

(c) A recommendation of hardware and software configurations.

(d) A budgeting for computer system investment.

II. LITERATURE REVIEW

2.1 A Control Chart

A control chart may be defined as a graphical method for evaluating whether a process is or is not in a state of statistical control. It consists of a center line (CL), a pair of control limit located above and below the center line, and measurement values (points plotted on the chart which represent the condition of the process). If all plotted values are lying within the control limits without any particular tendency, the process is considered to be in a state of statistical control. However, if some points fall outside the control limits or show a peculiar form, the process is said to be out of control.

Figure 2.1 and Figure 2.2 demonstrate the two different states of control chart.

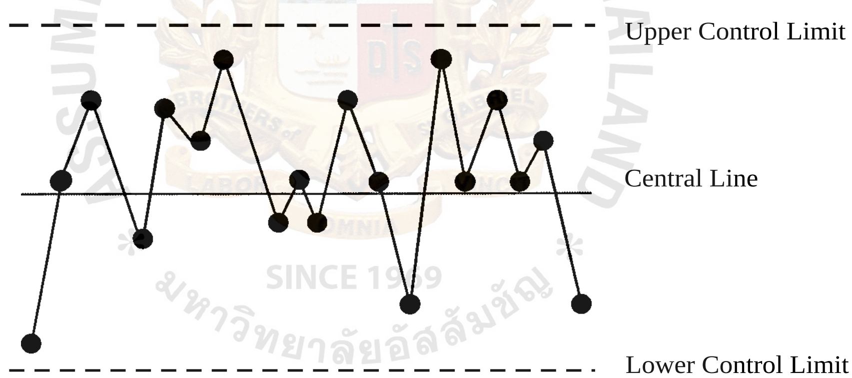


Figure 2.1. Control Chart for a Controlled State.

Dr. Walter A. Shewhart suggests that the control chart may:

(a) Serve to define the goal or standard for a process that the management might strive to attain.

(b) Be used as an instrument for attaining the goal.

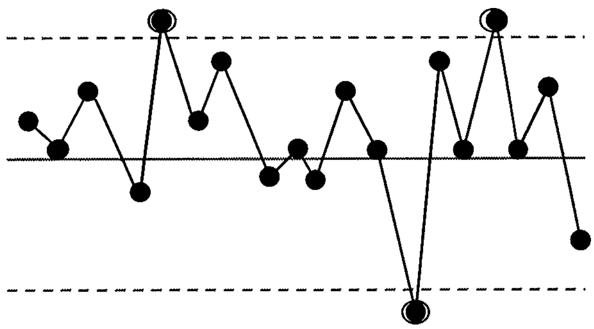


Figure 2.2. Control Chart for an Out-of-Control State.

(c) Serve as a means for judging whether the goal has been reached. It is thus an instrument to be used in specification, production, and inspection, and when so used, brings three phases of industry into an independent whole.

2.2 Basic Concepts Related to Process Control

Before describing the methodology of process control, it would be useful to become familiar with some concepts, terms, and definitions related to process control.

2.2.1 Two Types of Data

When applying statistical principles for process control or for other purposes, we often use either the term variable or attribute, indicating the type of data available. This distinction helps us select the proper statistical technique needed for a particular purpose.

When making a record of an actual measured quality characteristic, such as the strength of a wire bond in grams, or the speed of an electronic device record in nanoseconds, etc., the quality is said to be expressed by variables. When a record shows only the number of units conforming and the number of units failing to conform to the specification requirements, it is said to be recorded defective, percent nonconformities, parts per million, etc For example, the quality level of a semiconductor assembly process is often stated in parts per million. More recently, the terms "conformance" and "nonconformance" have become popular.

2.2.2 Cause of Variation

After a broad study, Dr. Shewhart determined that all manufacturing processes display variation can be divided into two major components:

(a) chance causes of variation that are attributed to inherent variation and

(b) assignable causes of variation that are attributed to intermittent variation.

Dr. Shewhart also concluded that assignable causes could be economically discovered and removed from the process, but that chance (random) causes could not be economically discovered and removed without basic changes in the process. By random causes, we mean a large variety of small influences on the process lying behind a particular measurement. For example, even when measuring the same part several times and trying to keep all conditions as consistent as possible, we will still get slightly different readings. This can be caused by floor vibration, temperature changes, operator influence, and other small sources of variation that we cannot even detect. All of these sources, which have a minor effect individually, together introduce variability into the resulting measurements. There is bound to be natural variation to every process, and this can be observed if the measuring instrument can recognise the variation. The control has a unique ability to detect and identify causes.

2.3 Control Charts for Variables

In the electronic industry, many process characteristics are measured on a continuous scale. This is why control charts for variables are used intensively. The $X — R$ Chart is one of the most popular techniques when working with variable data. This chart provides information not only about the mean value of the quality characteristic but also about its variability.

2.3.1 Procedure for Constructing an $\bar{X}$ —R Chart

(1) Determine the subgroup size (n) and the frequency of sampling. For an $\bar{X}-R$ chart, usually a subgroup sample size *(n)* of 4 or 5 is practical. To calculate the control limits, the number of subgroups *(k)* should be at least 20, preferably 25. The frequency of sampling depends on the production rate and other economical and technical conditions.

(2) Record the data on a datasheet. The datasheet should be designed so that it is easy to compute the values of the average ($\bar{X}$) and range *(R)* for each subgroup.

(3) Compute the average ($\bar{X}$) for each subgroup by the following formula:

$$\bar{X} = \frac{X_1 + X_2 + \cdots + X_n}{n}$$

(4) Find the range *(R)* for each subgroup by the following formula:

$$R = X_{(largest\,value)} - X_{(smallest\,value)}$$

(5) Calculate the overall average ($\bar{\bar{X}}$) by summing all the $\bar{X}$'s and then divide by the number of subgroups (k):

$$\bar{\bar{X}} = \frac{\bar{X}_1 + \bar{X}_2 + \cdots + \bar{X}_k}{k}$$

(6) Compute the average value of the range ($\bar{R}$) by totaling R for all subgroups and then dividing by the number of subgroups *(k):*

$$\bar{R} = \frac{R_1 + R_2 + \cdots + R_n}{k}$$

(7) Calculate the control limits for an $\bar{X}$ chart and R chart by the following formulas:

X chart:

Center line (CL) = X

Upper control limit (UCL) = $X + A_2 R$

Lower control limit (LCL) = $X — A_2 R$

R Chart:

Center line (CL) = R

Upper control limit (UCL) = $D_4 R$

Lower control limit (LCL) = $D_3 R$

A2, D4, and D3 are the coefficients determined by the size of a subgroup *(n)* and are shown in Table 2.1. Note that for R chart LCL is not considered when n is smaller than 7.

(8) Construct the control chart.

(9) Interpret the results based on the chart pattern.

2.3.2 Example for Constructing an $X — R$ Chart

Trimming is the process of removing the link bars from device lead frames. The quality of this process is measured by using an optical comparator. Considering that the measurement process generates variable data, an $X — R$ control chart can be applied here. The procedure for making the chart by using the data from the trimming process follows.

(1) In this case, it was decided to randomly select a subgroup of $n = 5$ units every two hours, and the lead length was measured. A total of $k = 22$ subgroups was sampled.

(2) The results are recorded in a datasheet shown in Table 2.2.

(3) The average for each subgroup is computed and recorded in the $''X''$ column of the datasheet (see Table 2.2). As an example, for subgroup 1:

$$X = \frac{171+172+171+173+174}{5} = 172.2$$

(4) The range for each subgroup is computed and recorded in the $''R''$ column of the datasheet (see Table 2.2). As an example, for subgroup 1:

$$R = 174-171 = 3.0$$

Table 2.1. Factors for Computing Control Limits.

n	A2	A3	B3	B4	D3	D4	E2
2	1.880	2.659	0	3.267	0	3.267	2.660
3	1.023	1.954	0	2.568	0	2.575	1.772
4	0.729	1.628	0	2.266	0	2.282	1.457
5	0.577	1.427	0	2.089	0	2.115	1.290
6	0.483	1.287	0.030	1.970	0	1.924	1.184
7	0.419	1.182	0.118	1.882	0.076	1.924	1.109
8	0.373	1.099	0.185	1.815	0.136	1.864	1.010
9	0.337	1.032	0.239	1.761	0.184	1.816	1.050
10	0.308	0.975	0.284	1.716	0.223	1.777	0.975

Table 2.2. Datasheet for the Lead Dimension Measurement.

		Readings					
Sample	x_1	x_2	x_3	x_4	x_5	$\bar{X}$	R
1	171	172	171	173	174	172.2	3.0
2	172	171	172	175	173	172.6	4.0
3	169	170	170	174	171	170.8	5.0
4	173	174	171	174	175	173.4	4.0
5	174	173	172	172	175	173.2	3.0
6	170	171	170	171	170	170.4	1.0
7	172	170	172	169	174	171.4	5.0
8	173	172	174	170	174	172.6	4.0
9	171	168	172	171	170	170.4	4.0
10	172	170	172	173	175	172.4	5.0
11	170	170	173	171	172	171.2	3.0
12	171	174	171	173	171	172.0	3.0
13	170	172	171	174	170	171.4	4.0
14	170	170	171	172	171	170.8	2.0
15	173	172	173	171	171	172.0	2.0
16	175	171	171	171	172	172.0	4.0
17	174	175	170	173	173	173.0	5.0
18	170	170	173	172	171	171.2	3.0
19	169	170	173	172	170	170.8	4.0
20	170	172	172	175	170	171.8	5.0
21	170	170	170	171	170	170.2	1.0
22	170	171	173	173	171	171.6	3.0
Average						171.7	3.5

(5) The overall average ($\bar{X}$) is calculated as follows:

$$\bar{X} = \frac{172.2 + 172.6 + \cdots + 171.6}{22} = 171.7$$

(6) The average range ($\bar{R}$) is computed as follows:

$$\bar{R} = \frac{3.0 + 4.0 + \cdots + 3.0}{22} = 3.5$$

(7) The control limits are calculated as follows:

X chart:

CL = 171.7

UCL = 171.7 + 0.577(3.5) =173.7

LCL = 171.7 — 0.577(3.5) = 169.6

R Chart:

CL = 3.5

UCL = 2.115(3.5) = 7.4

LCL = not considered

(8) The X — *R* chart is constructed as shown in Figure 2.2.

(9) It was observed that in the X chart from points 3 to 5 there were 2 out of 3 points in Zone C. This indicates that there may be assignable causes in this period. The process improvement team decided to investigate. The results showed that link bars were stuck on the trim bar in that period. Corrective actions have been made.

2.4 Control Charts for Attributes

Many quality characteristics can only be observed as attributes: i.e., by classifying each item inspected into one of two categories, either conforming or nonconforming to the specifications. Note that if a unit of product has at least one defect, then the unit is called "defective" or "nonconforming." These quality characteristics are controlled by a group of techniques called attribute control charts.

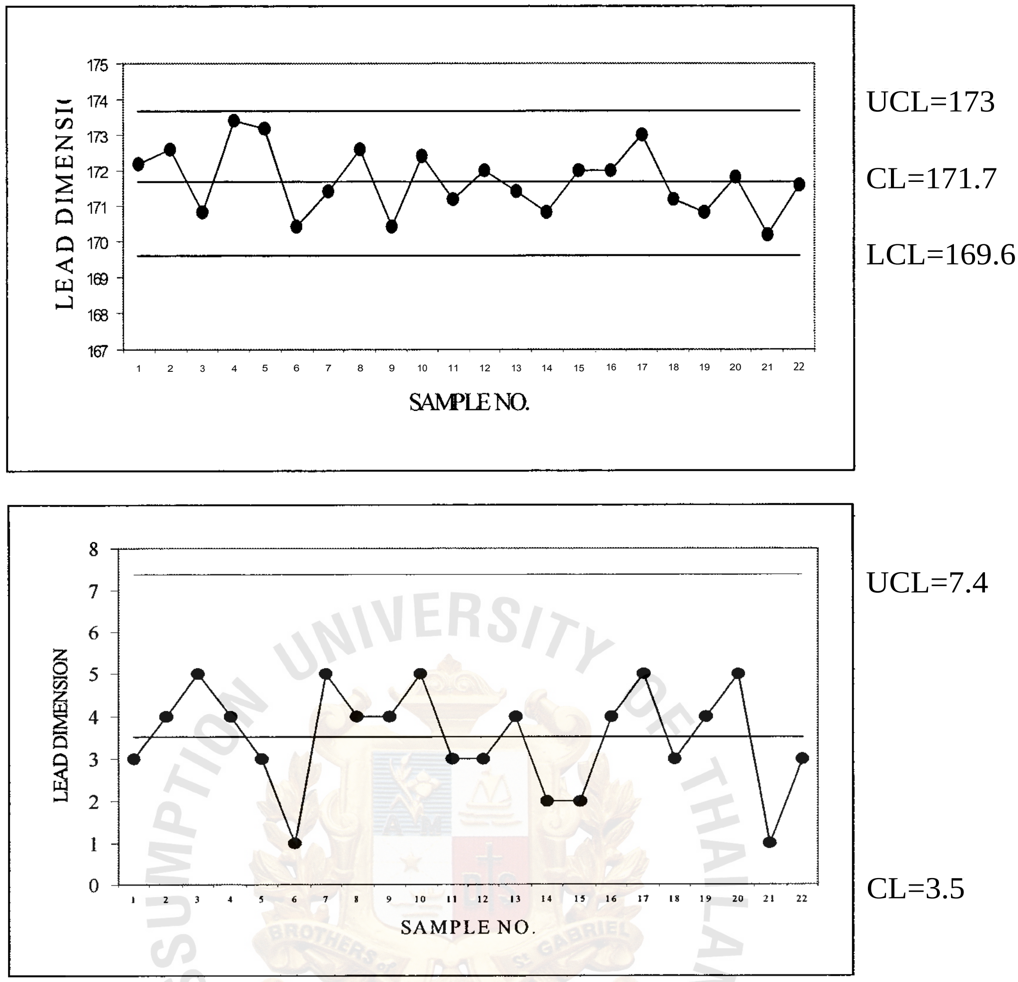


Figure 2.3. $\overline{X} - R$ Chart for Lead Dimension Measurements.

The progress in quality improvement generated new ideas for how to control "close to perfection" processes. Thomas W. Calvin developed a technique that can be used to control processes with low ppm quality levels. The technique uses the approach of plotting on a chart the number of conforming units instead of nonconforming units. The concept itself is very effective because in a low ppm environment sometimes the process runs several weeks, or even months, before finding one nonconforming unit.

The cumulative count control (CCC) chart is based on the geometric distribution, which allows us to determine what the cumulative count of conforming units should be before one nonconforming unit can be expected to occur. Based on this geometric distribution, the control chart parameters can be calculated by using the formulas found in Table 2.3. Thus, given the fraction nonconformity, the center line and the control limits can easily be derived for different probability limits (a). The control chart is constructed on a semi logarithmic paper with a logarithmic vertical scale for cumulative count and a linear horizontal scale for the time period (days, weeks, etc.).

After the control is constructed (see procedure in Section 2.4.1), we plot the cumulative count as follows. During inspection, we maintain a cumulative count of conforming items. Counting may be stopped and the latest cumulative count (n') is noted whenever inspection of a sample is completed. When inspection of the next sample starts, the count continues. However, when a defective item is encountered, n' is also noted but the count number will revert to 0, becoming 1 again for the next conforming item inspected, and so on.

Table 2.3. Formulas for Calculating the CCC Chart Parameters.

Control Chart Parameters	(1)	(2)	(^{3})	(4)
	For any value of a	For $a = 0.10$	For $a = 0.05$	For $a = 0.0027$
1. Center line (CL)	0.7n	0.7n	0.7n	0.7n
2. Lower control limit (LCL)	$(ah_n$	0.05n	0.025n	0.00135n
3. Upper control limit (UCL)	$-nin(a/2)$	3.00n	3.7n	6.6n

2.4.1 Procedure for Constructing a CCC Chart

(1) Make a preliminary estimate of the process fraction defective (p) to be controlled by the CCC chart.

(2) Choose a , the probability that a point will fall outside the limits even when the process is under control.

Note: The traditional p chart has an a =0.0027. When applying a CCC chart, an a of 0/10 is also frequently used, which means that there is a 10% probability that a point will fall outside the limits even when the process is running normally.

(3) Determine the average run length (n), which gives the expected number of items that have to be inspected before a new nonconforming item is found:

$$\overline{n}=\frac{1}{p}$$

(4) Determine the CL, which is the median value ( ):

$$CL= =0.7n$$

(5) Calculate the lower control limits (LCL) and upper control limits (UCL):

$$LCL = \left(\frac{a}{2}\right)n$$

$$UCL = — \text{Tiln}\left(\frac{a}{2}\right|$$

(6) Construct a control chart using the parameters calculated above and semi logarithmic paper. The logarithmic vertical scale is for the number of count (n). The linear horizontal scale is for the plotting sequence of stopping values n'.

2.4.2 Example for Constructing a CCC Chart.

(1) Let us assume that the historical data show that the process average is p =0.0002 (200ppm).

(2) Let α =0.10.

(3) From Step 1 p =0.0002, so

$$n = \frac{1}{0.0002} = 5000$$

(4) From Step 3 $n=5000$, so

$$CL = (0.7)(5000) = 3500$$

(5) From Step 3 $n=5000$ and from Step 2 α =0.10, so

$$LCL = \left(\frac{0.10}{2}\right)5000 = 250$$

$$UCL = -5000\ln\left(\frac{0.10}{2}\right) = 14{,}978.66 \text{ say, } 15{,}000$$

(6) The cumulative count control chart is constructed as shown in Figure 2.4.

The control chart is now ready to be introduced to the manufacturing floor. However, since the chart was constructed based on an estimated process average (p), sometimes in the starting period the segments will frequently terminate even before passing the lower control limit. This is an indication that the preliminary estimate of the process average was too low. The reverse can also happen, when the terminating point of the segment frequently passes the center line or even the upper control limit This is an indication that the process average estimate was too high. In any of these cases, the control chart parameters should be recalculated based on the new data collected. When the terminating points of the segments are distributed equally around the center line (CL), the tentative estimate of the process average is correct and the control chart can be continued until recognisable changes in the process average occur. The chart will indicate a change by having frequently terminating points outside the control limits

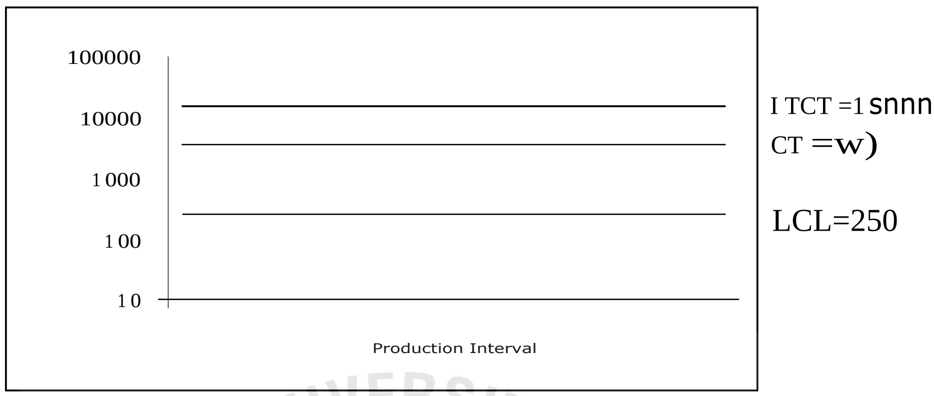


Figure 2.4. An Example of Cumulative Count Control Chart.

2.5 Understanding the Control Chart Signals

In one of the SPC executive audits, when the visitors came close to a workstation, the operator smilingly announced, "Everything is in control." We frequently hear people saying "in control," but what does this term really mean? In short, "control" is when we can predict what will happen. For instance, when the operator said that everything was "in control" he meant that he could predict the process behavior and, if necessary, take corrective actions to make the process behave the way he wants it to. The tool he uses to predict the process is a control chart.

In applying control charts as a statistical method for prediction, it is very important to know how to read and interpret the pattern of the chart. The experience of introducing SPC in the factory showed that it is much easier to learn how to design and introduce a control chart than it is to learn how to extract the necessary information and use it for prediction and prevention. The next section contains some techniques that will allow you to understand what the chart is "telling" you.

2.5.1 The Process Is "In Control"

When the special causes have been eliminated from the process, the control chart will have a natural pattern as in Figure 2.3. The points on a natural pattern will be distributed as follows:

(a) About two-thirds of them will fall near the CL.

(b) A few points will fall close to the control limits.

(c) The points will be located back and forth across the CL

(d) The number of points will be balanced on both sides of the CL

(e) There will be no points beyond the control limits.

(I) If we tally and plot all the points on one side of the chart, they will form a symmetrical distribution as shown in Figure 2.5.

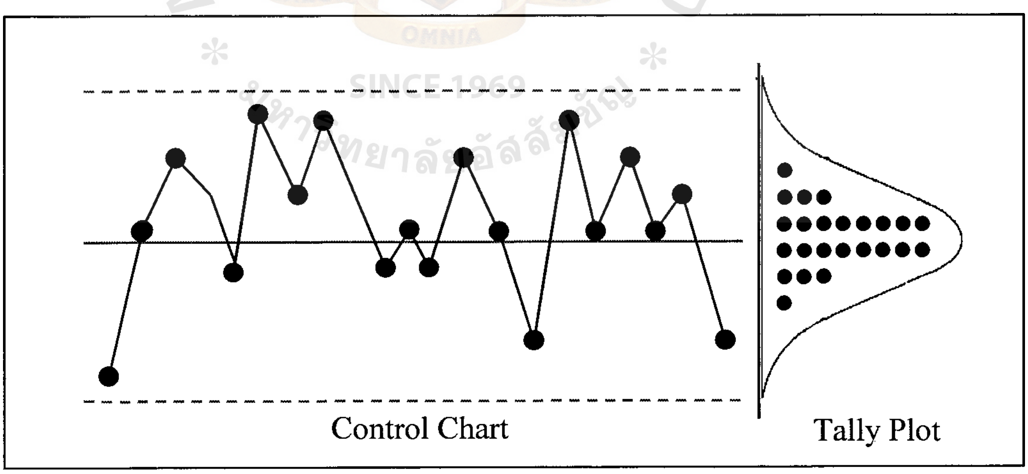


Figure 2.5. A Control Chart with a Normal Pattern.

2.5.2 The Process Is "Out of Control"

When a point made from a subgroup of measurements falls outside its control limits, the process is considered to be "out of control." This means that the process is disturbed by one or more assignable causes of variation (see Figure 2.4). This is the simplest and most frequently used criteria for determining an "out of control" condition. However, a process can also be considered "out of control" when all the points fall inside the control limits. This situation occurs when unnatural patterns of variation are present in the process. For example, it is "not normal" for nine or more consecutive points to fall above or below the center line. There are several other symptoms that indicate an unnatural pattern.

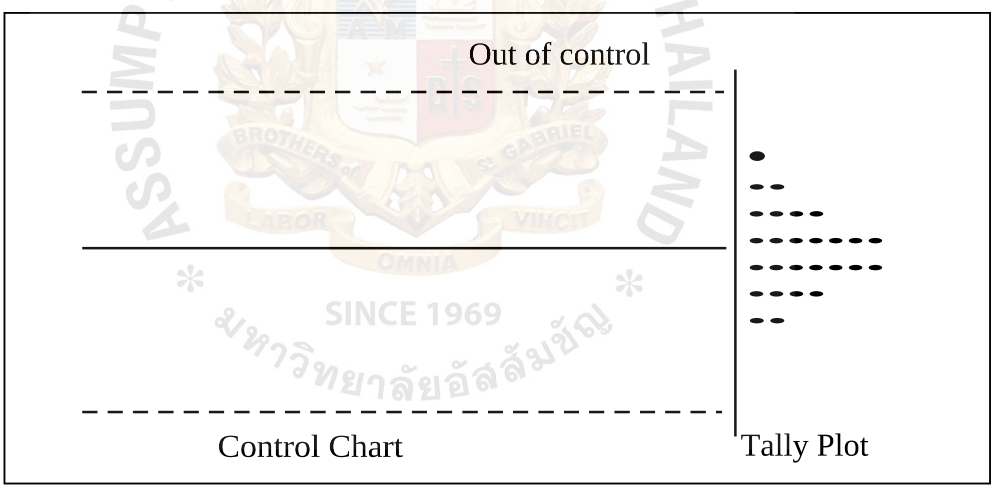


Figure 2.6. A Control Chart with Points Outside the Control Limits.

2.5.3 The Interpretation of Variable Control Charts

To introduce testing for unnatural patterns on the manufacturing floor, the theory of runs from the Western Electric Company as a standard operating procedure is used. Figure 2.7 is the complete set of tests for unnatural patterns.

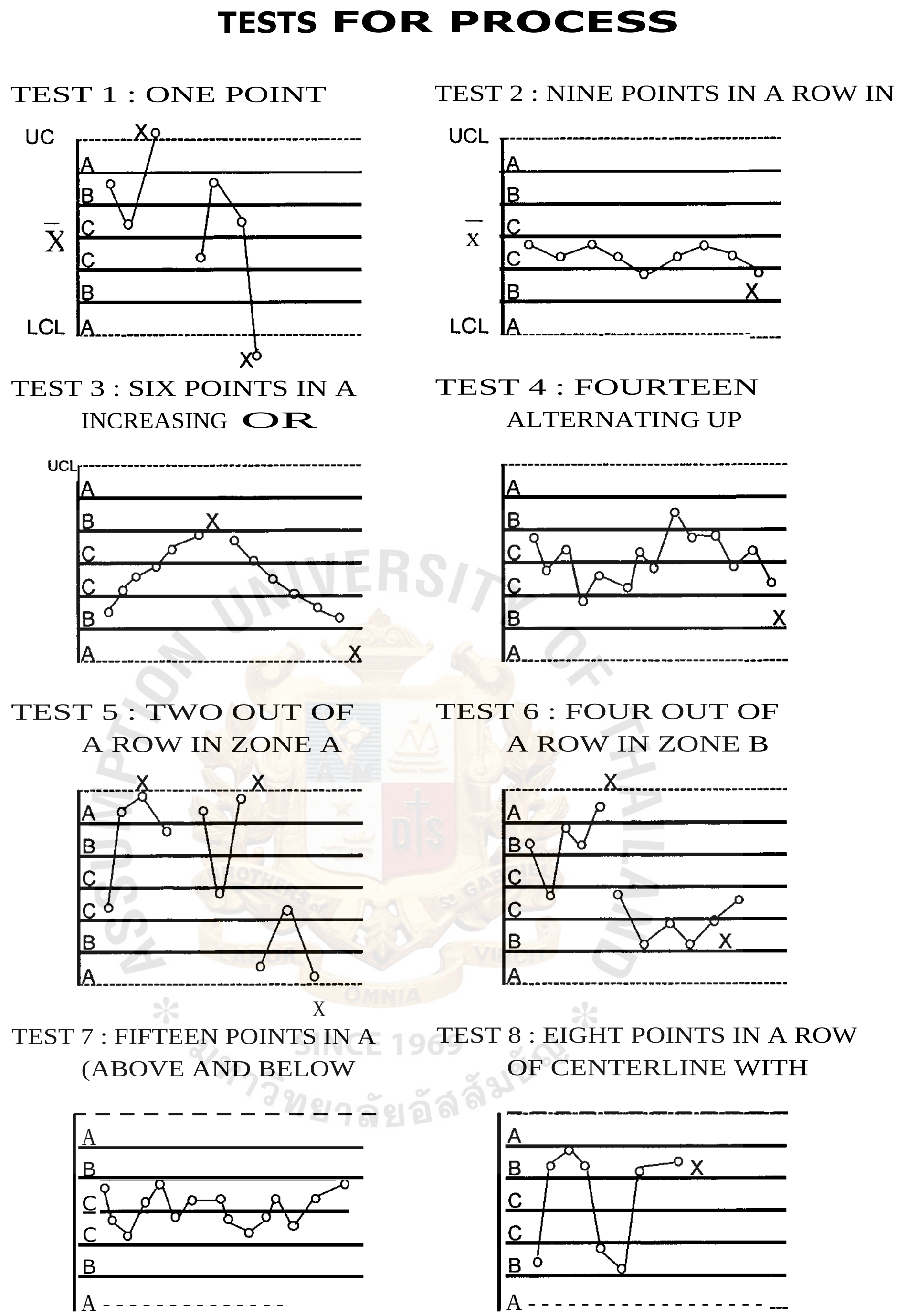


Figure 2.7. Tests for Special Causes.

2.5.4 Interpretation of Attribute Control Charts

(1) If the cumulative line is interrupted (due to finding a nonconforming item)

before passing the lower control limit, it is an indication that the process is out of control. This is shown in Figure 2.8.

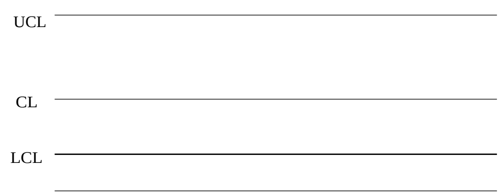


Figure 2.8. One Point below LCL.

(2) If five or more interrupted lines are consecutively below the CL, it is also an indication of process instability. This is shown in Figure 2.9.

Figure 2.9. Five Points in a Row below the CL.

2.6 Process Capability

From a manufacturing point of view, a process is defined as a combination of labor, machines, tools, and methods used in a specific environment to manufacture a given product. The term "process" refers to a system of causes, which introduce variation in the quality of the product. The causes of this variation should be studied and eliminated or reduced if we want to improve the quality of the process output (the product).

In recent years Cp and Cpk indexes have become very popular as a measure of process capability in relation to the specification requirements. Customers have started requesting specific values of Cp and Cpk from their suppliers. In other words, Cp and Cpk create more interest today than all other types of indexes.

Assuming that the process output is normally distributed and in a state of statistical control, we can then calculate the process capability indices from $X - R$ control charts.

2.6.1 Procedure for Computing Cp and Cpk

(1) Calculate Cp, the potential of the process for two sided specification limits

$$Cp = \frac{USL - LSL}{6\left(\frac{R}{d_2}\right)}$$

The value of d_2 can be found from Table 2.1.

(2) Calculate Cpu, the performance of the process relative to the USL.

$$Cpu = \frac{USL - X}{3\left(\frac{R}{d_2}\right)}$$

(3) Calculate Cpl, the performance of the process relative to the LSL.

$$Cpl = \frac{X - LSL}{3\left(\frac{R}{d_2}\right)}$$

(4) Calculate Cpk, the performance of the process relative to the two-sided specification limits.

$$Cpk = Min(Cpu,Cpl)$$

2.6.2 Example for computing Cp and Cpk

Given that USL=11.0 and the LSL=3.0, center line of the $\bar{X}$ chart = 7.64, center line of R chart = 2.52, what is the Cpk of the process?

(1) Calculate Cp, the potential of the process for two sided specification limits.

$$Cp = \frac{USL - LSL}{6\hat{\sigma}} = \frac{11.0 - 3.0}{6\left(\frac{2.52}{2.326}\right)} = 1.23$$

(2) Calculate Cpu, the performance of the process relative to the USL.

$$Cpu = \frac{USL - \bar{X}}{3\left(\frac{\bar{R}}{d_2}\right)} = \frac{11.0 - 7.64}{3\left(\frac{2.52}{2.326}\right)} = 1.04$$

(3) Calculate Cpl, the performance of the process relative to the LSL.

$$Cpl = \frac{\bar{X} - LSL}{3\left(\frac{\bar{R}}{d_2}\right)} = \frac{4.64}{3.24} = 1.43$$

(4) Calculate Cpk, the performance of the process relative to the two-sided specification limits.

$$Cpk = Min(Cpu, Cpl) = \text{Min}(1.04, 1.43) = 1.04$$

III. THE EXISTING SYSTEM

3.1 Background of ABC Company

ABC is a producer of integrated circuits products for communications and networking applications. At this company, employees work in a carefully controlled production environments. Sophisticated quality and process control systems are integrated directly into production lines, giving workers and managers the information they need for continuous improvements of the manufacturing process.

ABC uses Statistical Process Control (SPC) techniques to optimise processes throughout the company. It is used in a proactive manner to prevent problems from occurring. In the manufacturing environment control charts, mainly $X-R$ and CCC charts are used to control and determine the capabilities of all processes and equipment.

3.2 Background of Control Charts at ABC Company

In the past, control charts at ABC have been relying on purely the manual system. In order to support engineering in the process of monitoring as well as to continuously improve the process, engineers have to track the process performance and other monitoring information through paperwork.

As a result, tremendous paperwork is generated. It also makes engineering analysis as well as backtracking a tedious and time-consuming task. Human errors are also often found during the processes that could result in customer satisfaction in terms of quality of products.

3.3 Procedure for Control Charts

Two main types of control chart are being used in the company. These are $X-R$ and CCC charts. The theory of these two types of control charts is described in Chapter II. Based on the theory, ABC has developed and documented the standard operating procedure for $X-R$ and CCC charts in the International Organisation for Standardisation (ISO) document as described below.

3.3.1 Standard Operating Procedure for $X-R$

First operator has to randomly select sample. This sample is drawn from a specific production lot for inspection. The number of units in a sample may vary, depending on the lot size (number of units in a lot). Then operators have to perform the task of measurements as required. Calculate X and R value (as described in Section 2.3), plot the results by placing a point on the respective chart next to the point in time, and join each point by a line as shown in Figure 3.1. After a line has joined the points, the operator has to analyse for out of control situation using the tests for process instability as described in Section 2.5.3. When an out of control situation occurs, the operator has to stop the process and inform the supervisor immediately. The supervisor will then determine cause of problem, make any necessary actions then record the cause and actions into corrective action form provided. Figure 3.2 and Figure 3.3 describe the flow of $X-R$ chart and corrective action form respectively.

3.3.2 Standard Operating Procedure for CCC Chart

Again, the operator has to select a sample from production lot, perform the task of inspection, and plot the results on the specified chart by placing a point equal to your sample size on the chart next to the point in time. See example in Figure 3.4. If the first sample produces no defects, the second sample selected will be added together with the first sample and plotted at the next time period. The operator will continue in this manner until a defect is found. When a defect is found, the operator has to write the quantity defective at the last point on the chart, record the next sample quantity and repeat the method described above. Join each point by a line, except where a defect is found. When a defect is found, the line is terminated, and a new line is begun. Any quantity between defects below the LCL is an indication of an out of control processes and so are five or more consecutive lines terminating below the CL. In this case, the operator has to stop the process and inform the supervisor immediately. The supervisor will then determine and record the cause and corrective action in a form shown in Figure 3.3. The flow chart of CCC Chart is shown in Figure 3.5.

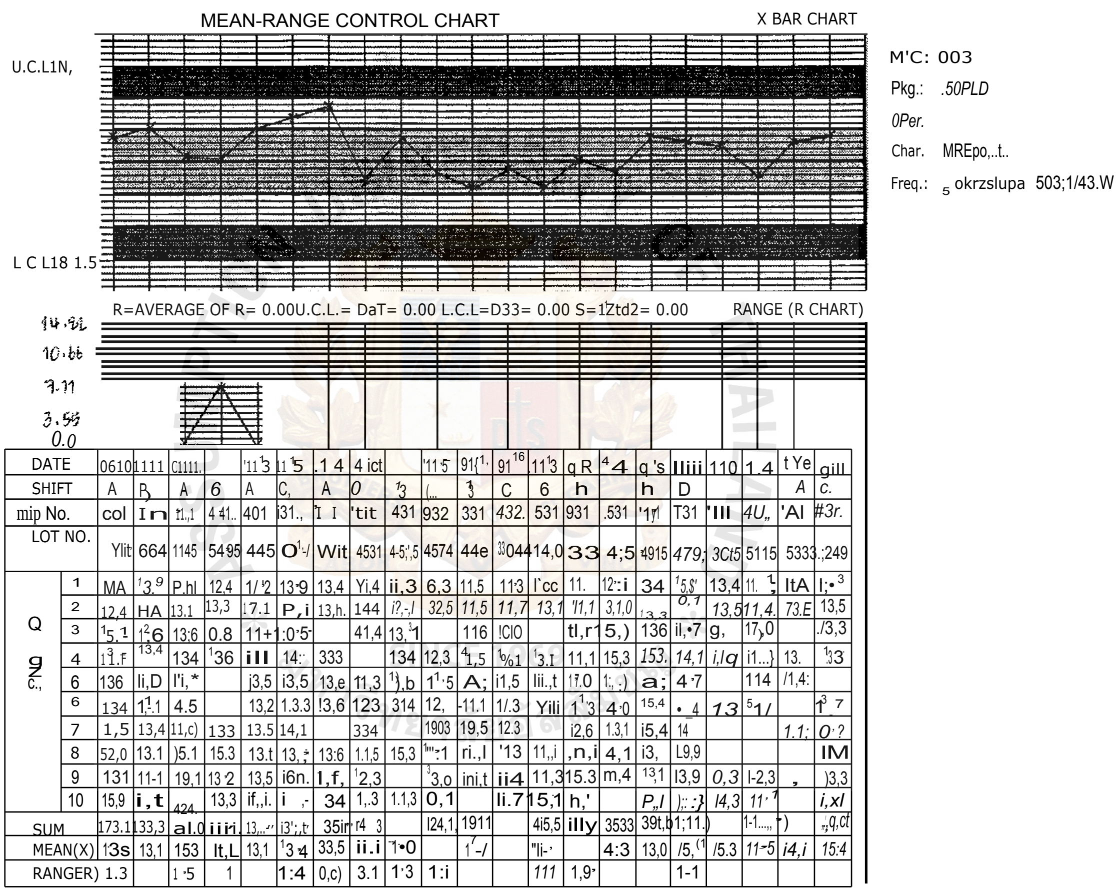


Figure 3.1. $X — R$ Chart.

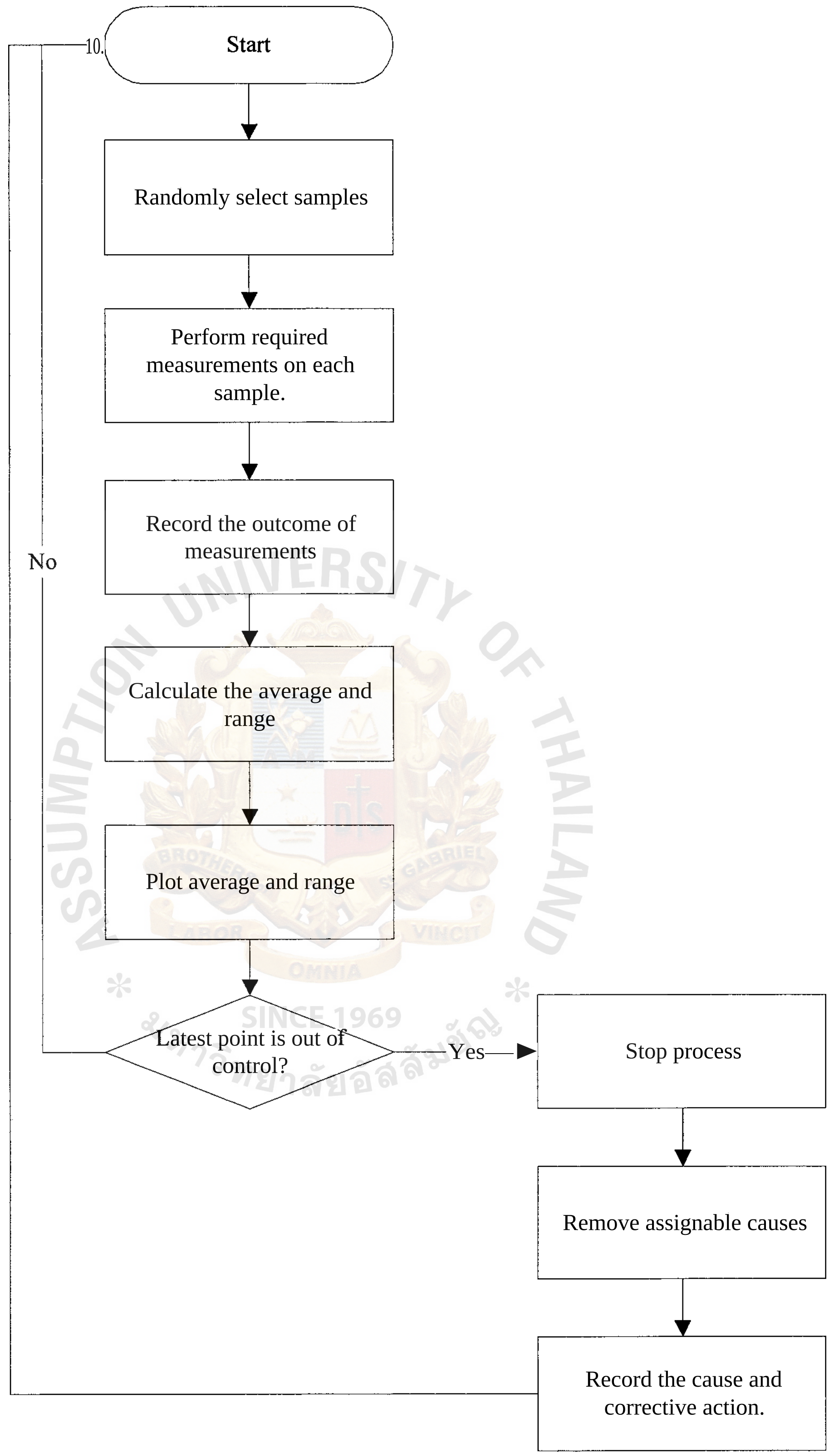


Figure 3.2. Flow Chart of Operations Using $X — R$ Chart.

Corrective Action Form

Month: _______________ Year: _______________

Date	Process	Problem	Corrective Action	By Whom

Figure 3.3. Corrective Action Form.

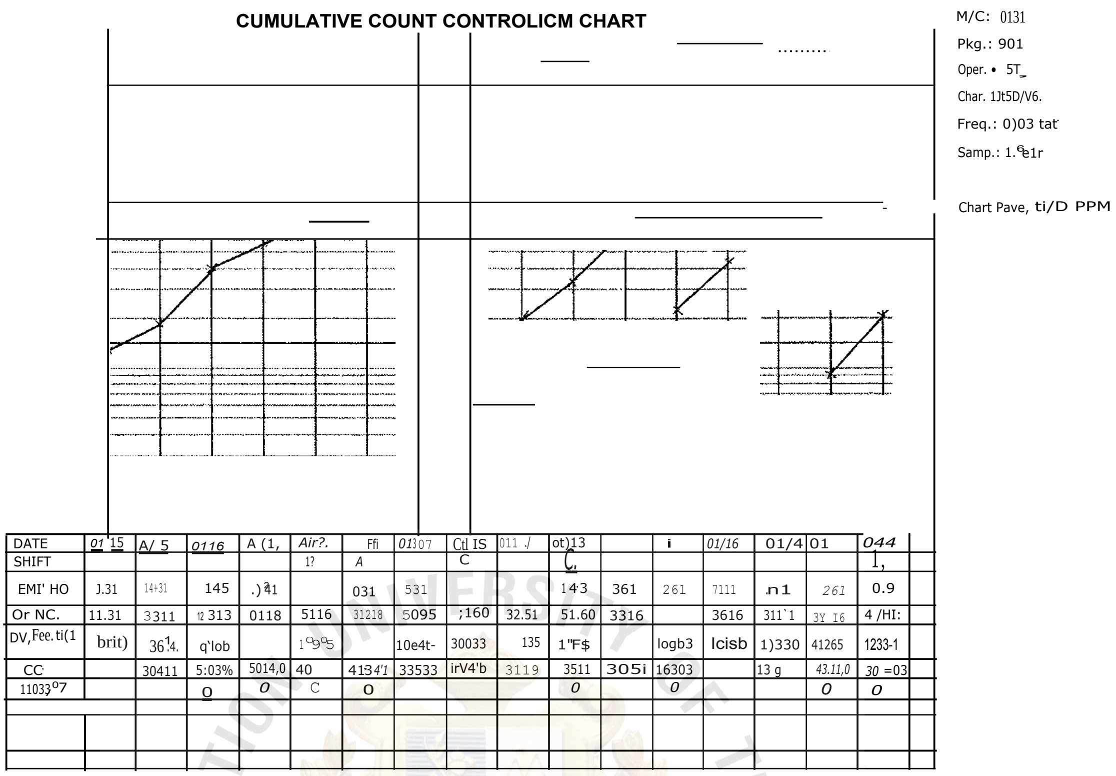


Figure 3.4. CCC Chart.

3.4. Reports Used

Each month, process engineers must submit a process capability and process performance report to management for review. These reports shall be calculated based on the data collected in the control charts. To produce these monthly reports, engineers must collect all necessary data from paper chart, enter to spreadsheet. These data are range from several tens to hundreds of records. This part takes up most time in preparing the reports. It could be days. Then engineer will perform necessary calculation then enter the result in the specified report format. The process capability and process performance report formats are shown in Figure 3.6 and Figure 3.7 respectively.

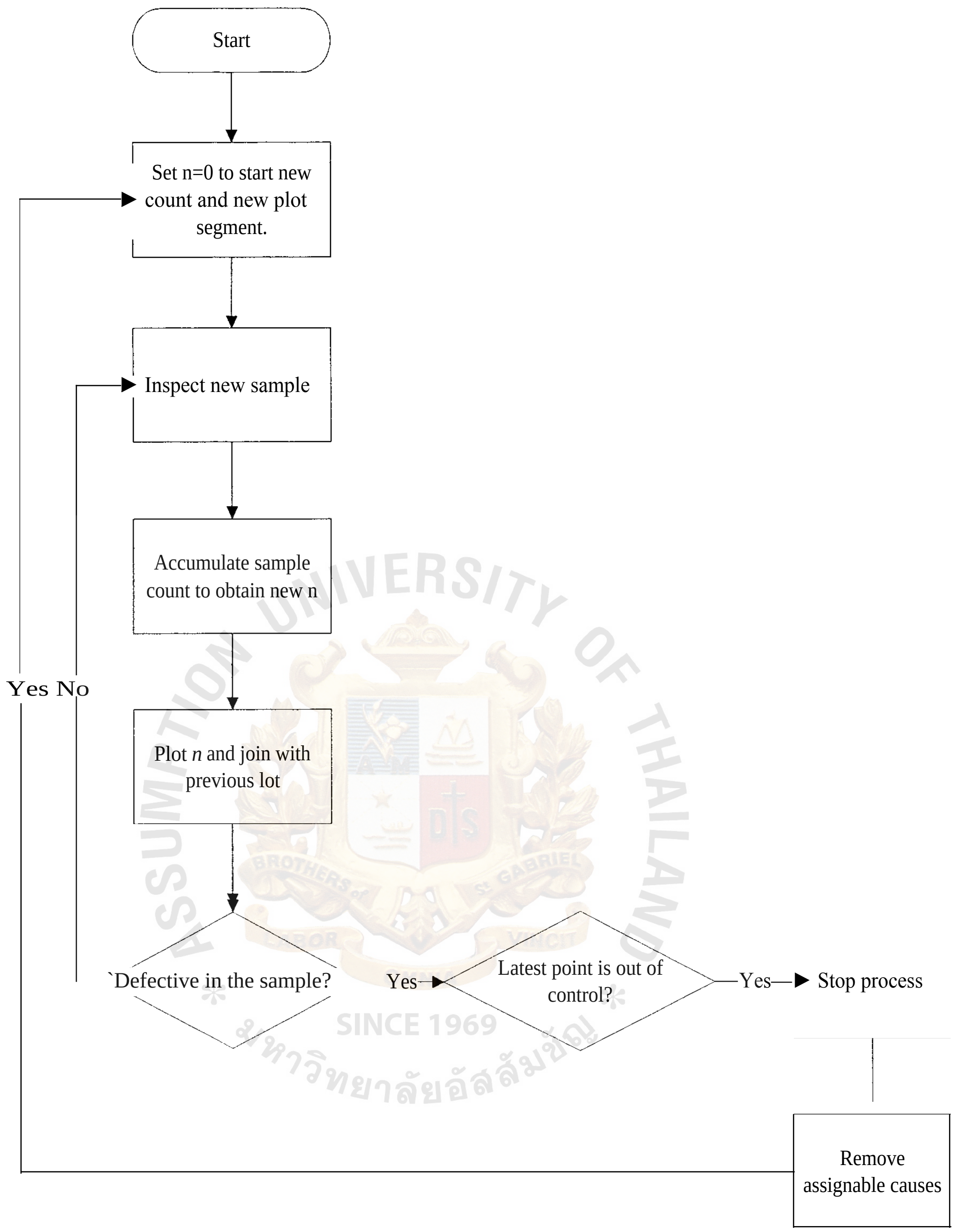


Figure 3.5. Flow Chart of Operations Using CCC Chart.

Monthly Cpk Report

07/01/1999 - 07/31/1999

										No. of Out of Control Point							
Opn	Paramr	Pkg	M/C	UCL	CL	LCL	Cpu	Cpl	Cpk	1	2	3	4	5	6	7	8

Figure 3.6. Process Capability Monthly Report.

Monthly ppm Report

07/01/19 - 07/31/1999

										# of out of ctrl	
Opn	Parameter	Pkg	M/C	Total Qty	#of Rejectt	ppm	UCL	CL	LCL	Rule 1	Rule 2

Figure 3.7. Process Performance Monthly Report.

3.5 Problems of the Existing System

The problems of the existing system lies in the fact that the information relies very much on operators. It also requires a lot of manual work to perform engineering analysis and quality control analysis for continuous process improvement. Some of the reasons why users consider the paper chart system to be inadequate are:

(a) Require much time and effort for manual plotting. Operators need to understand how to compute the measurements then plot those value onto specified chart. This process often generates errors. For example, points are often misplaced on the control chart or wrong calculation. When this occurs, interpreting the graph will not reflect the current process. Hence, accuracy and correctness depends purely on the operator.

(b) Paper based control chart requires further input to spreadsheets or other softwares for further analysis, reporting, etc. With the existing system, paper charts is where you can find all data relating to the control charts. Before analysis or report summation can be carried out, engineer has to gather all required data from various paper charts in various areas then enter the individual data to spreadsheet. These data can be as little as few tens to hundreds of records. This is very time consuming. Many errors are likely to occur during these tasks. For example, typing error, reading error, etc.

(c) High deficiencies found during audit. During an audit, it is most likely that auditor will asks for any specific record at point in time from control chart. In order to response to the auditor's request, ABC's employees must spend a fair amount of time in searching especially when it is being kept in storeroom. Not only auditors but also customers who often request for information in the control charts.

(d) It has to comply with record retention specification. Paper based control charts requires heavy manual work such as collecting, filing, storing, etc. as well as physical space.

All of the above problems were raised by both internal and external users. The computerised control charts system was discussed among users and IT department to solve the mentioned problems as well as to continuously improve process performance in the production line.

IV. ON-LINE REAL-TIME CONTROL CHART

On-line Real-time Control Chart system is a computerised system. This computerised system is designed to reduce or eliminate human errors, increase efficiency and effectiveness of ABC's employees. More importantly, it has to comply with standard operating procedure as describe the previous chapter.

4.1 Problems of the Existing System

The problems of existing system lie in the fact that the information relies very much on operators. It also requires a lot of manual work to perform engineering analysis and quality control analysis for continuous process improvement. Section 3.5 described statement of problems. In summary they are:

(a) Manual plot is very time consuming.

(b) Require further input to spreadsheets or other softwares for engineering analysis, reporting, etc.

(c) High deficiencies found during audit.

(d) Require heavy manual work such as collecting, filing, storing, etc. and physical space.

Both internal and external users raised all of the above problems. The computerised control charts system was discussed among users and IT department to solve the mentioned problems as well as to continuously improve process performance in the production line.

4.2 Determine Users' Requirements

Defining users' requirements requires an understanding of how the paper charts system works. To get the clear picture of the system, developers decided to ask questions, conduct meetings, and participate with the key users. The key users of the computerised system are engineers, supervisors, operators and managers. The users' requirements can be identified as follows:

(a) The computerised system must comply with ABC's standard operating procedure as described in the previous chapter.

(b) The computerised system must be easy to understand and use.

(c) The computerised system must be able to provide raw data to users as required in a timely manner.

(d) The computerised system must be able to provide monthly reports as required by top management in a timely manner.

(e) The computerised system must be year 2000 compliance.

(f) The computerised system must be able to eliminate (where possible) human errors.

4.3 General Design Concept

Based on the users' requirements in the previous section, developers go on with the general design concept. Data Flow Diagram (DFD) is used to represent the new computerised system.

The first steps in requirement determination are aimed at learning about the general characteristics of the business process. The top layer of details is studied. As analyst better understand those details, they delve deeply to collect more specific and detailed information using top-down analysis.

The top-level diagram is often called a context diagram. It contains a single process, but it plays an important role in studying the existing system. The context diagram defines the system that will be studies in the sense that it determines the boundaries. Anything that is not inside the process identified in the context diagram will not be part of the systems study. The manner in which other organisation or external elements (in this study are operators, supervisors, engineers, and managers) function is out of our control and so it will not study them in detail.

The data flow diagram in Figure 4.1 describes the On-line Real-time Control Charts System at a very general (top) level. This diagram shows that the On-line Real-time Control Charts system mainly interacts with four external entities: OPERATORS, SUPERVISORS, ENGINEERS and MANAGERS. In Figure 4.1, the main data flows from ENGINEERS are "chart properties". Later the On-line Real-time control chart receives "production data" from OPERATORS and provides "out of control signal" in return. In response to "out of control signal", SUPERVISORS provides "cause & corrective action" information to the system. MANAGERS and ENGINEERS also provide "chart info" and "duration" data flows to the system and get "Cpk or ppm reports" data flows. ENGINEERS also provide "duration" and "chart properties" data flows to the system and get "raw data" data flows.

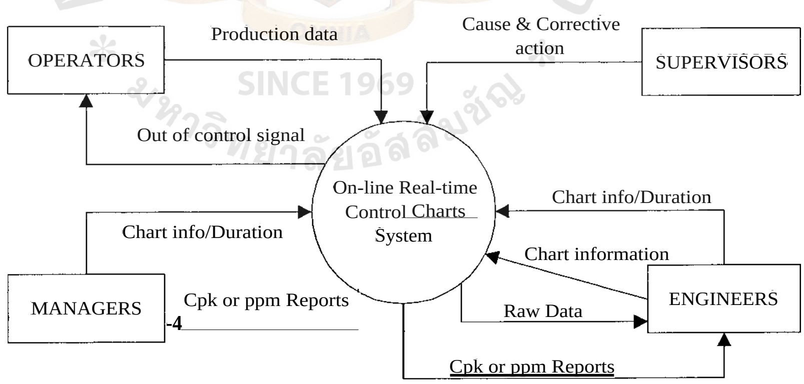


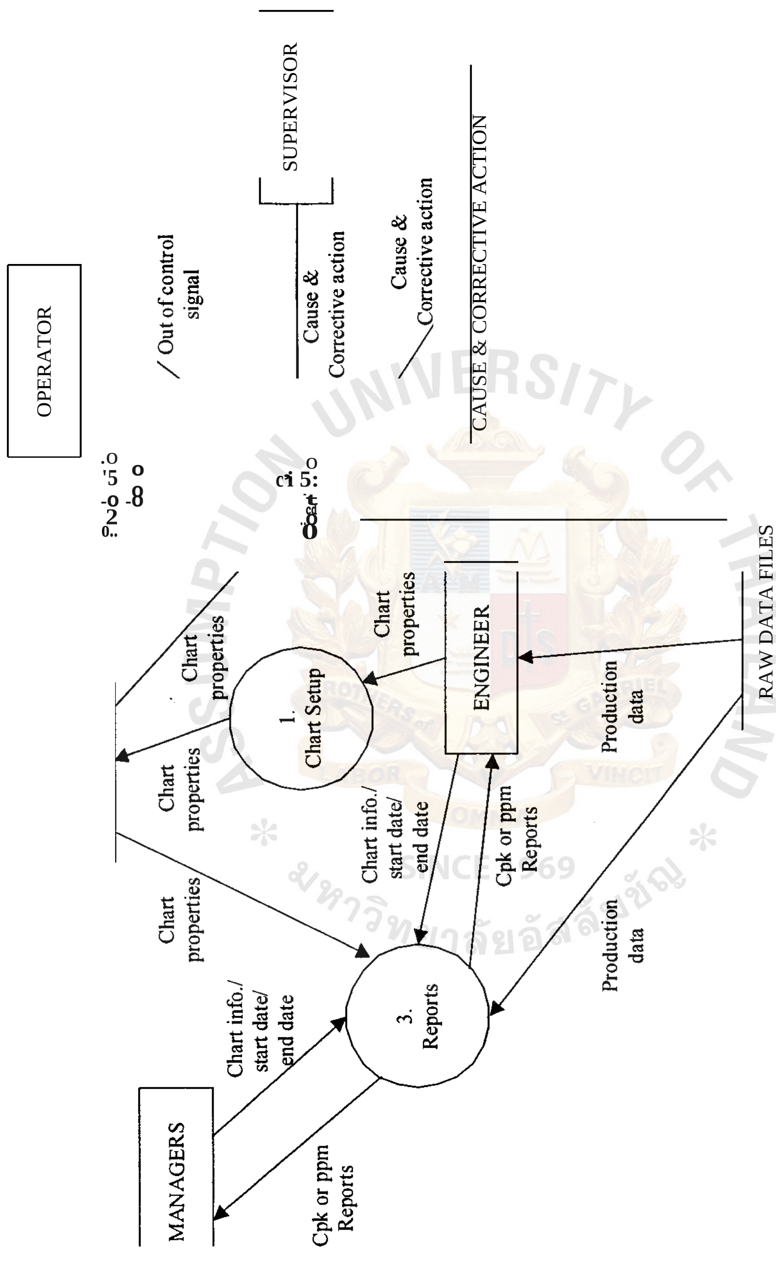
Figure 4.1. The Context Data Flow Diagram.

The description of the On-line Real-time Control Charts system in the context diagram requires further details. The next step is to describe the system as level 1 of the process hierarchy chart; that is, to identify the data flows, data stores, inputs, and outputs that links together. Figure 4.2 (logical DFD) and Figure 4.3 (physical DFD) show the top level DFD of the On-line Real-time Control Chart. It consists of 3 major processes. The first process, "Chart Setup", requires input, "Chart properties", from ENGINEERS which will then be kept in database. Chart properties can be classified according to chart type, in this case it is $X - R$ and Cumulative Count Control chart. For $X - R$ chart, its properties are area, process, parameter, package, machine number, specification limits, control limits, number of readings and rules used. For Cumulative Count Control Chart, its properties are area, process, parameter, package, machine number, control limits, sample size, reject code and rules used. Operators and supervisors will use this information prior to entering production data. Managers and engineers will also use this information for reports.

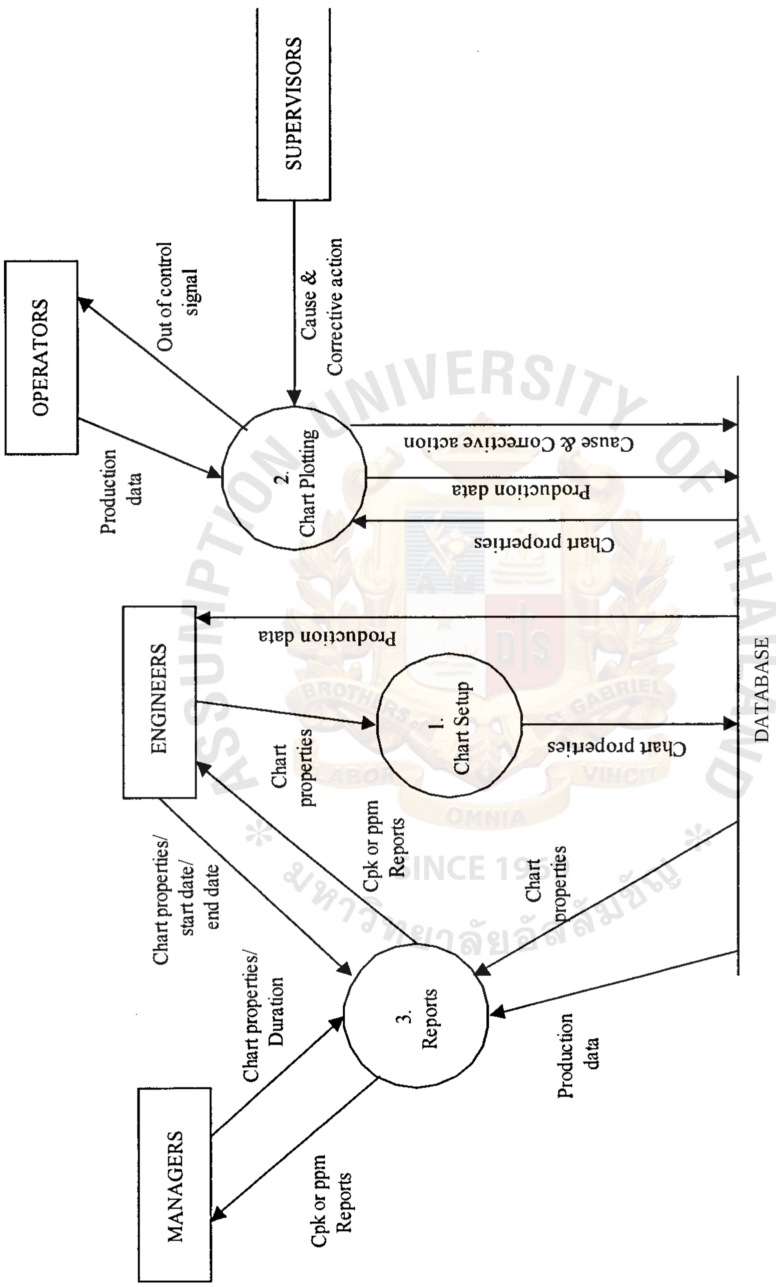
For total continuous process improvement, engineer needs production data for further analysis. To access the production data, engineer needs to provide chart properties and duration to the "reports". The "reports" will then retrieve the required data from database, arrange it in a format as shown in Appendix A. From this engineer has the choice of printing it out or saving it in a spreadsheet format.

Every month managers and engineers require process capability, Cpk and process performance, and ppm report. Managers or engineers provide chart properties such as area, process, parameter, package, or machine to "Report". "Report" will then retrieve required data from database and perform Cpk or ppm calculation. Cpk and ppm reports are shown in Appendix A.

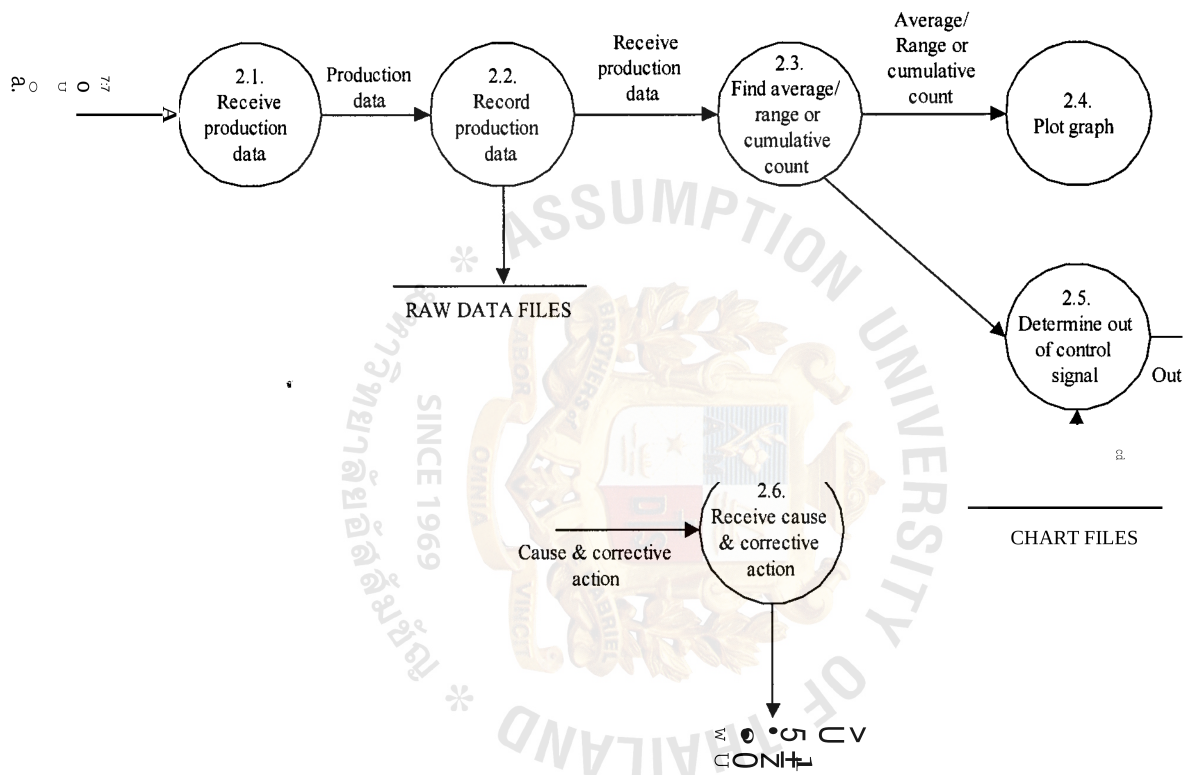
Because the information contained in the level 1 diagram in Figure 4.2 and 4.3 are inadequately to fully explain system requirements, the developers would like to describe the logical view of the "Chart Plotting" process in more detail. Figure 4.4 has



ci) C.) O o E 7l r:4 a) O c+1 cd bA ct bA O c`i bA



The Physical Data Flow Diagram for On-line Real-time Control Chart System.



The Logical Data Flow Diagram for Expansion of "Chart Plotting" Process.

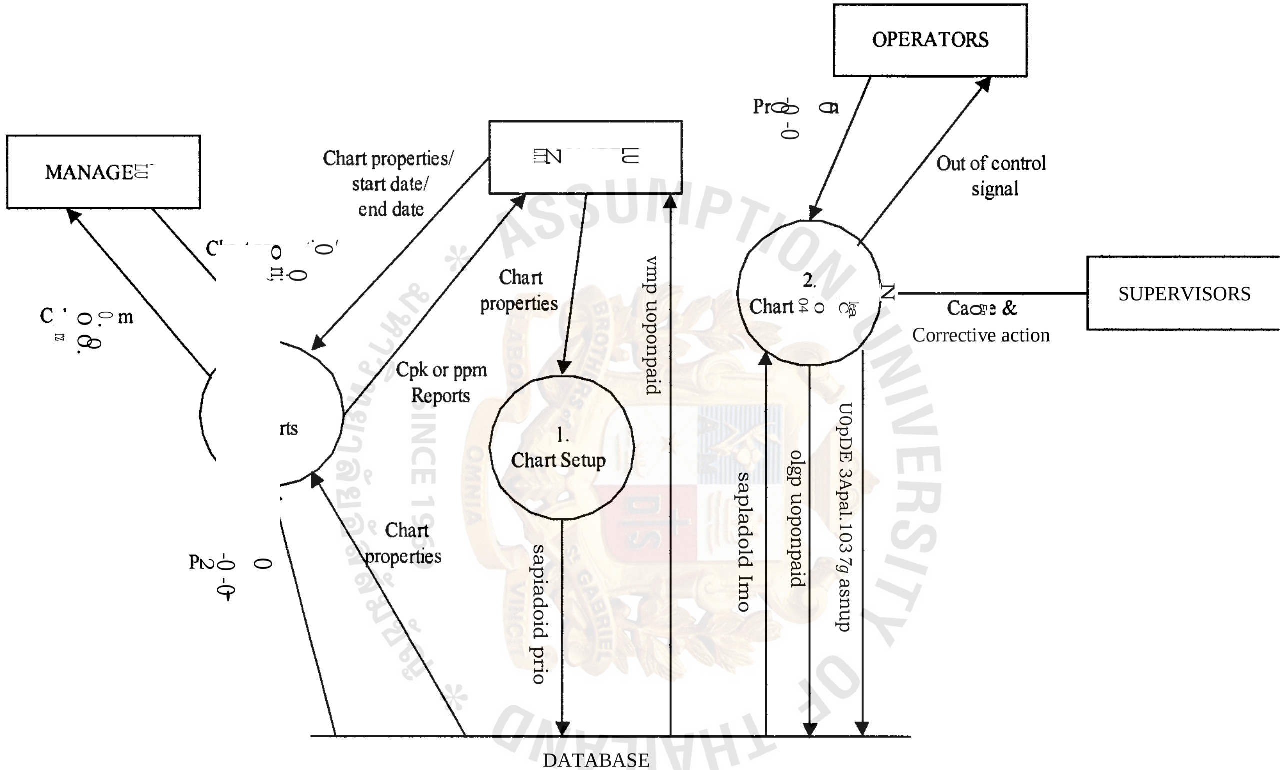


Fig 4.5 The Physical Data Flow Diagram for Expansion of "Chart Plotting" Process.

"exploded" chart-plotting process identified in the higher-level diagram shown in Figure 4.2. Figure 4.4 shows the original process exploded into six subprocesses, which add details to the understanding of the chart plotting process. In here, "production data" is entered and recorded into the database. Based on the production data that just entered, it will then calculate average and range (in the case of $X - R$ chart) or cumulative count control chart (in the case of Cumulative Count Control chart). The average and range values are use to plot on X and R chart respectively while Cumulative Count Control chart uses the cumulative count. The process 2.4 simply determines the plotted data for any out of control signal and provides the out of control signal. When an out of control signal occurs, the supervisor has to enter cause and corrective action which will then be recorded in the database. Figure 4.5 shows the physical DFD.

After the data flows diagrams are completed, developers move to the analysis of the system data. Using entity-relationship (E-R) analysis, developers start to identify the system entities. After defining entities, developers look at how entities interact with each other and model this interaction by relationship. Figure 4.6 shows the entities and interaction of each entity.

Attributes, relational database tables and data dictionary of the E-R diagram are shown in Appendices B, C and D respectively.

4.4 Hardware and Software Requirements

(a) Hardware Requirements

(1) Application & Database Server

(a) Sun Enterprise Compatible

(b) 9GB of hard disk

(2) Network

(a) TCP/IP

(b) Cabling

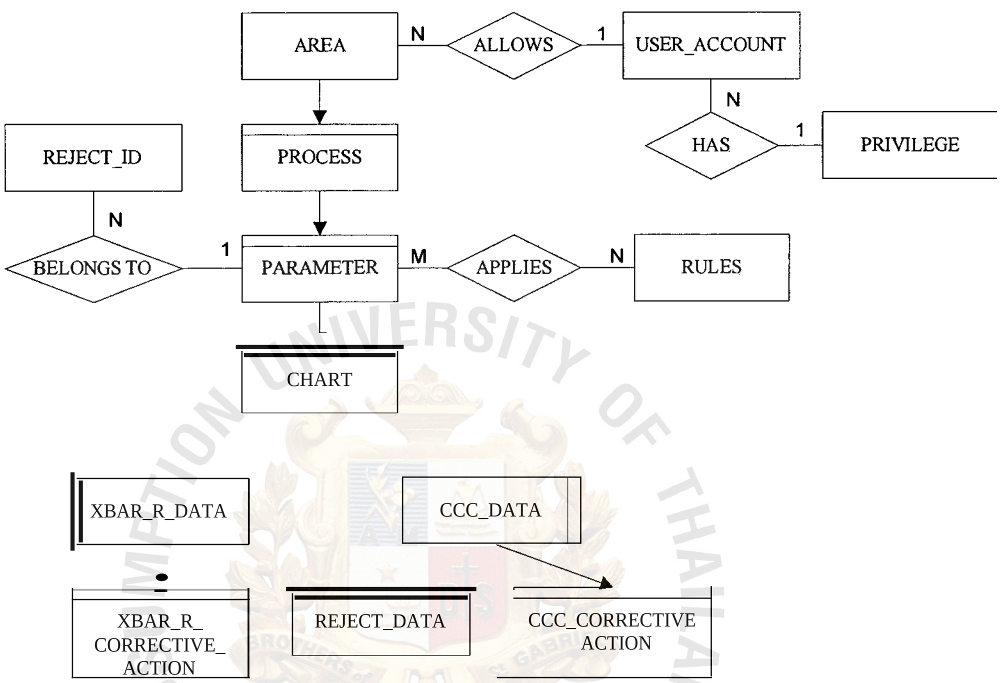


Figure 4.6. The Entity Relationship Diagram.

(3) IBM-PC Compatible

(a) Pentium II 300 MHz processor or compatible.

(b) Minimum of 32 MB of RAM

(c) Minimum of 2GB of hard disk space.

(d) Network card

(e) 15" monitor

(f) 102 keyboard, Mouse

(b) Software Requirements

(1) Server

(a) Sun Solaris

(b) Oracle version 7.X or above

(c) On-line Real-time Control Chart System

(2) Clients

(a) Microsoft Windows NT 4.0 Thai Enabled

(b) PowerBuilder Deployment Kit

(c) SQLNet

The application & database server is connected to the network as shown in Figure 4.7. Each workstation from various areas in the company is connected to the server via network. All existing workstations have access to the On-line Real-time control chart application and its database without extra hardware or software. At the initial stage, developers could use one of the existing servers to be application and database server. When the number of transaction increases and performance of the server drops dramatically, we will then request for a new server.

4.5 Programming and Testing the System

After designing the DFD and E-R Diagram, developers continue on to the programming stage. In this stage, programmers use PowerBuilder as a programming language and Oracle to be the backbone database following the standard programming language and database of the ABC Company.

During programming stage, programmers test each module thoroughly to ensure it functions correctly before the program processes actual data and produces information on which people will rely.

After the On-line Real-time Control Chart software is completed, a small group of users is set to test the program using test data. This testing is carried out to identify and eliminate both execution errors, which are errors that cause the program to abnormally terminate, and logic error, which are errors in the accuracy and completeness of a program's processing. When this is done, the On-line Real-time control chart is ready to be released.

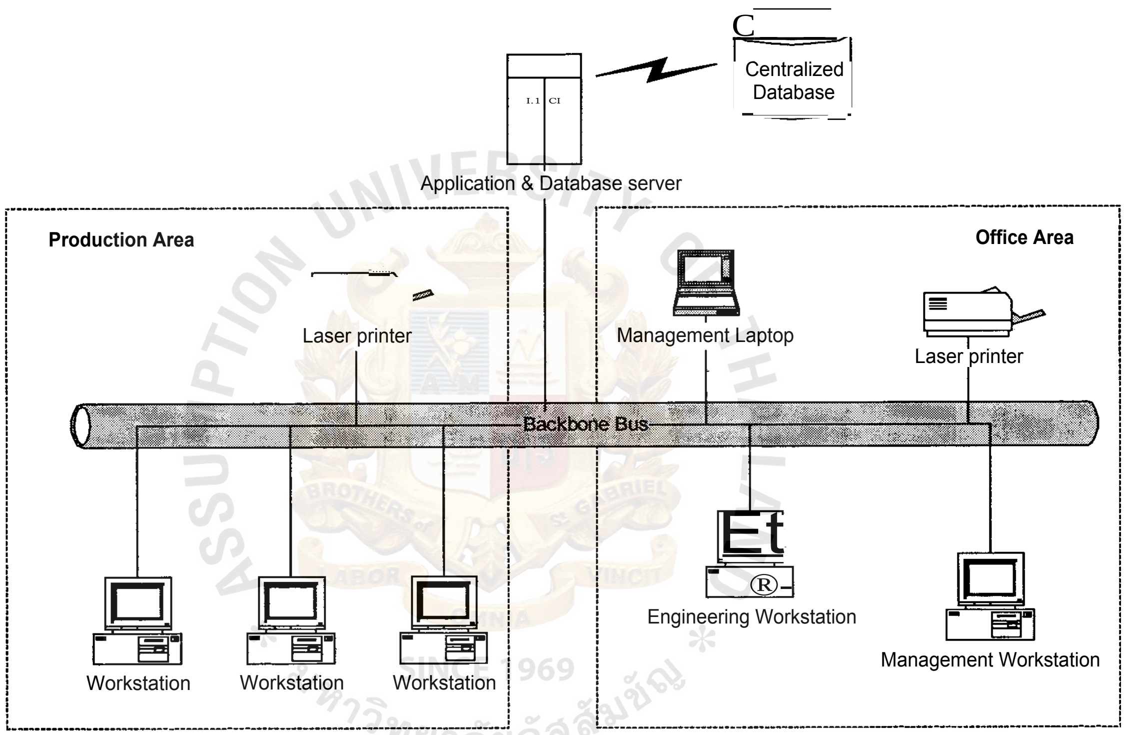


Figure 4.7. The System Configuration.

4.6 Implementing and Evaluating the System

When the systems implementation and evaluation begin, all the software and hardware for the On-line Real-time Control Chart is complete and available. Next is the training of the end users, operational personnel, and other people who will interact with the On-line Real-time Control Chart system.

Having a training department in the ABC Company, the developers first develop user's manual as shown in Appendix A. When user's manual is completed, developers train the trainer how to create charts, enter data into the system and lastly how to retrieve data/information from the system. Once the trainers understand all the features of the On-line Real-time Control Chart, they will conduct group training for all users in the ABC Company.

Apart from training, developers must consider how the system changeover will take place. The standard procedure at ABC Company is to use parallel operation. In this way, both the manual and computerised systems are in full operation for some period of time. As the data is generated and collected during the parallel period, it is input to both systems. The output generated by the On-line Real-time Control Chart system is compared to the equivalent output from the manual system. When all users are satisfied that the computerised system is operating correctly, the manual system is stopped.

When the On-line Real-time Control Charts system is completely implemented, developers transfer the knowledge to the maintenance group. Training classes are conducted for system transfer. This class includes the DFD, E-R diagrams, relationship database tables, application and system requirements.

4.7 Benefits and Costs Analysis

Some of the common methods that organisations use to analyse benefits and costs are payback approach, present value approach, internal rate of return approach, etc. Historically, the methods used to measure tangible benefits are most useful for justifying transaction-processing systems, which normally have a relatively high proportion of such benefits. Information systems in the decision support and office automation areas like On-line Real-time Control Chart - whose benefits may be largely intangible - are often not justified using traditional cost-benefit methods. However, at

ABC Company, developers need to justify the benefits of the On-line Real-time Control Charts system. Benefits can be divided into 2 types tangible and intangible.

(a) Tangible Benefits

Numerous approaches were developed to measure the value of a proposed project to an organisation. Payback approach is normally used within ABC Company. The assumptions of this approach is that the On-line Real-time Control Chart will take 16 months to develop and system once developed will be used for at least 5 years.

Initial cost

(1) 35 KUS for application and database server.

(2) 50 KUS for Oracle license

(3) 20 KUS for development cost.

Total initial cost is 105 KUS.

Maintenance cost (per year) from year 2

(1) 8 KUS for database license (10 concurrent users).

(2) 6 KUS for miscellaneous.

Total maintenance cost per year is 14 KUS.

Benefits per year for the first five years

(1) 20 KUS for paper charts.

(2) 15 KUS for inventory cost of paper charts.

(3) 10 KUS for labour cost.

Total benefit per year is 45 KUS.

Note: 1KUS = 1,000 US$.

Costs and Benefits for the first 6 years are summarised as shown in Table 4.1.

Table 4.1. Costs and Benefits.

Year	Cost (KUS)	Benefits (KUS)
1	105	0
2	14	45
3	14	45
4	14	45
5	14	45
6	14	45
Total	175	225

The payback period for this project is 4.38 years. Figure 4.8 shows the costs and benefits in terms of graph.

(b) Intangible Benefits

As said earlier, the On-line Real-time Control Chart system is classified as decision support system and office information system therefore its benefits are largely intangible. Intangible benefits are as follows:

(1) Computation errors, plot errors and chart misinterpretation will cease. All these will be done by On-line Real-time Control Charts system instead of operators.

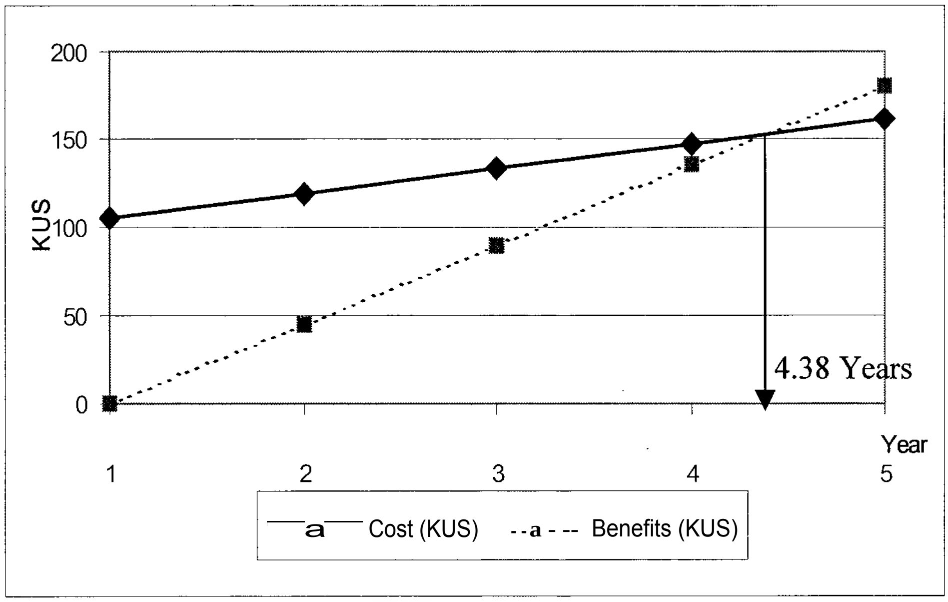


Figure 4.8. Payback Period for On-line Real-time Control Charts System.

(2) Productivity increases for all engineers and production workers. This is a result from production data report, Cpk and ppm report. Having these reports built in for On-line Real-time Control Charts, engineers do not have to spend time on entering the data into the spreadsheet for reports or other statistical software for engineering analysis. This feature saves a significant amount of time in reporting and analysing the data.

(3) Customer response time reduces from 1 to 2 days to just a few minutes. There are times that customers request for SPC data of the products received. It used to take 2-3 days for ABC employees to respond back to the customers but after this implementation, it only takes ABC employees a few minutes to respond to the customers.

Although it takes 4.38 years for the payback period, the management of the ABC

Company strongly supports this On-line Real-time Control Chart mainly because of its intangible benefits hence the cost saving becomes a small factor in justifying this system.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The current system of control chart of ABC Company is a manual system. Production workers must understand how to compute and plot data on paper chart, as well as how to interpret the graph. Accuracy purely depends on production workers. Very often engineers found out that production workers incorrectly compute the data and interpret the control charts. This problem can bring the company into a censorious position in terms of customer satisfaction and quality control.

The main objective of this project is to design the computerised system for $X - R$ and Cumulative Count Control charts for ABC Company. In order to solve problems mentioned in Chapter IV, internal users requested to have the On-line Real-time Control Charts system.

If developers successfully implement the On-line Real-time Control Charts system, ABC Company will positively receive the following advantages.

(a) Human errors are reduced significantly

Computation, writing, and plot error, as well as chart misinterpretation will be totally eliminated. The On-line Real-time Control Charts system will execute the mentioned tasks.

(b) Time spent is reduced to zero in preparing monthly report to management

With the computerised system, managers will be able to review the process capability and process performance at the tip of their fingers.

(c) Engineering analysis becomes easier and requires less time in data gathering

After the implementation, engineers do not have to go through tedious task before performing engineering analysis. By that time, engineers can easily retrieve the required data in a matter of seconds.

(d) Customers' response time reduces from 1-2 days to minutes

Every now and then customers require statistical data relating to products received. For this, ABC Company will be able to respond to customers' request in a timely manner using the On-line Control Charts system to reply to queries.

(e) The computerised system does not require a large physical storage space for data retention

The On-line Real-time Control Charts system will eliminate the paper chart hence ABC Company will not need to rent physical storage space to retain paper charts as required by ISO documents. The company will save 15 KUS from the rental cost.

5.2 Recommendations

Further enhancement is recommended after the On-line Real-time Control Chart has been fully developed and deployed into the production floor. These are:

(a) Machine interface for variable data collection

Instead of operator having to key in the measurement values to the On-line Real-time Control Chart system, developers can further develop machine interface capability to collect measurements directly from the machines and equipment used. This will reduce time taken for data collection as well as human error.

(b) Daily and weekly summary report for any out of control points to all concerned engineers via e-mail

With the current practice, supervisors have to summarise problems found and inform engineers on a weekly basis. This is a time consuming task for supervisors apart from the fact that the information could be too late and not accurate. By implementing the daily and weekly summary report, the weekly reports from supervisor will cease. Instead, engineers will receive daily or weekly reports via e-mail every morning.

(c) Establish a redundancy system and disaster recovery for On-line Real-time Control Charts

ABC Company considers the On-line Real-time Control Charts system to be hypercritical to the operation of the production line. The application needs 100% availability. Redundancy system for hardware and software will reduce the risk of system being down while disastrous recovery will reduce the downtime to a minimum when the redundancy system fails.

(d) Data archival. Users may experience slow response from the system once the data become enormous

Data archival is a way to solve this problem.

(e) Introduce the use of barcode scanners and other portable devices

Instead of keying in the lot number, operators can use barcode scanners or other portable devices to collect data where appropriate. This will eliminate the typo error.

(f) Upload and download information among systems

Various systems can share data among themselves. For example, MRPII system can obtain reject quantity from On-line Real-time Control Chart system.

APPENDIX A

REPORTS FOR ON-LINE REAL-TIME CONTROL CHARTS SYSTEM

V3iIV	SS30M:Id	iiRI3INV2:1Vd	39V)10Vc1	#ANIHOVIN	31VG	31A111	'ON 33A0lciN3	1JIHS	'ON 101	0(	ZX	EX	17X	9X	9X	LX	8X	6X	01.X	X JO Vuns	2:1V9X	3ONVI	#3īna 1MA'Kinn an 1 nn

$\overline{X} - R$ Data Point Report.

V321V	SS30Mid	2i3131A1VHVd	#3N1HOV1A1	31VO	31A111	'ON 33A01c11A13	1J1HS	ON 101	A10 03c1SNI	iNnoo 3Aliv1nvuno	A10 103f321 iviOI	3000 ioArai	ADD	3000 103r32i	A10	3000 103r321	AID	3000 103r321	AID

bA

CCC Data Point Report.

Summary Report of Xbar-R Chart

[illegible]	Machine	[illegible]	[illegible]	[illegible]	Spec Limit		C	Control Limit (CL)						Quantity Out of Control Rules															
								Xbar-Chart			R-Chart			Xbar-Chart								[illegible]							
					[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..-	cv	M	er	Co	to	rs	co		iv	M	et	CO	co	r-	on

3

[illegible] N ________ Parameter: ________

[illegible]	[illegible]	[illegible]	TTL	QTY of Reject by Category					Total	Out of Control Rules		Control Limit		
			Insp. QTY	Process	[illegible]	Machine	[illegible]	[illegible]	Reject	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] Summary Report of CCC Chart.

APPENDIX B

ATTRIBUTES FOR E-R DIAGRAM

Entity USER ACCOUNT

Employee ID
Name
Shift
Password
Privilege_Level

Entity PRIVILEGE

Privilege Level
Description

Entity AREA

Area ID
Area_Desc

Entity PROCESS

Area ID
Process ID
Process_Desc

Entity PARAMETER

Area ID
Process ID
Parameter ID
Parameter Desc

Entity RULES

Rule No
Description

Entity CHART

Area ID
Process ID
Parameter ID
Machine ID
Product_ID
Chart_ID
Chart_Type
CL
UCL
LCL
Sample_Size
No_of Reading

P+ • ary

Entity REJECT_ID

Area ID	Process ID
Parameter ID	Reject ID
Reject_Desc	

Entity CCC_DATA

Chart ID	Date
Time	Employee_ID
Shift	Lot_No
Sample_Size	Reject_Qty
Fail Rule	

Entity REJECT_DATA

Chart_ID	Date
Time	Reject ID
Quantity	

Entity XBAR_R_DATA

Chart ID	Date
Time	Employee_No
Shift	Lot_No
X1	X2
X3	X4
X5	X6
X7	X8
X9	X10
Fail Rule	

Entity CCC_CORRECTIVE_ACTION

<u>Chart ID</u> <u>Date</u>

<u>Time</u> <u>Rule No</u>

Employee_ID Cause

Action

Entity XBAR_R_CORRECTIVE_ACTION

<u>Chart ID</u> <u>Date</u>

<u>Time</u> <u>Rule No</u>

Employee_ID Cause

Action

APPENDIX C

RELATIONAL DATABASE TABLES

Table C.1. Relational Database Tables.

TABLE AREA

Area_ID	Area Desc

TABLE PROCESS

Area_ID	**Process_ID**	Process Desc

TABLE PARAMETER

Area ID	**Process_ID**	**Parameter_ID**	Parameter_Desc

TABLE RULES

Rule No	Description

TABLE REJECT ID

Area_ID	**Process_ID**	**Parameter_ID**	**Reject ID**	Reject_Desc

TABLE CHART

Area ID	**Process_ID**	**Parameter_ID**	**Machine ID**	**Product ID**

Chart_ID	Chart_Type	CL	UCL	LCL	Sample_Size	No_of Reading

TABLE CCC DATA

Chart_ID	**Date**	**Time**	Employee_No	Shift	Lot No	Sample_Size

Reject_Qty	Fail_Rule

Table C.1. Relational Database Tables. (Continued)

TABLE REJECT DATA

Chart_ID	**Date**	**Time**	**Reject_ID**	Quantity

TABLE CCC CORRECTIVE ACTION

Chart_ID	**Date**	**Time**	**Rule_No**	Employee_ID	Cause	Action

TABLE XBAR_R_DATA

Chart ID	**Date**	**Time**	Employee_ID	Shift	Lot No	X1	X2	X3

X4	X5	X6	X7	X8	X9	X10	Fail Rule

TABLE XBAR_R_CORRECTIVE ACTION

Chart_ID	**Date**	**Time**	**Rule_No**	Employee_ID	Cause	Action

TABLE USER ACCOUNT

Employee_ID	Name	Shift	Password	Privilege_level

TABLE PRIVILEGE

Privilege_level	Description

APPENDIX D

DATA DICTIONARIES

Table D.1. Data Dictionaries.

TABLE AREA

Attibutes	**Field Length**	**Field Type**	**Field Description**
Area_ID	2	Char	Unique code for area, Auto increment.
Area Desc	30	Varchar2	Description of area's ID

TABLE PROCESS

Attibutes	**Field Length**	**Field Type**	**Field Description**
Area_ID	2	Char	Unique code for area, auto increment.
Process_ID	3	Char	Unique code for process, auto increment
Process Desc	30	Varchar2	Description of Process's ID

TABLE RULES

Attibutes	**Field Length**	**Field Type**	**Field Description**
Rule_No	2	Char	Unique code for rule no according to the test.
Description	30	Varchar2	Description of rule no.

TABLE PARAMETER

Attibutes	**Field Length**	**Field Type**	**Field Description**
Area_ID	2	Char	Unique code for area, Auto increment.
Process_ID	3	Char	Unique code for process, auto increment
Parameter_ID	4	Char	Unique code for parameter, auto increment
Parameter Desc	30	Varchar2	Description of Parameter's ID

Table D.1. Data Dictionaries. (Continued)

TABLE REJECT ID

Attibutes	Field Length	Field Type	Field Description
Area_ID	2	Char	Unique code for area, Auto increment.
Process_ID	3	Char	Unique code for process, auto increment.
Parameter_ID	4	Char	Unique code for parameter, auto increment.
Reject_ID	3	Char	Unique code for each rejects. User specified.
Reject_Desc	30	Varchar2	Description for Reject_ID

TABLE CHART

Attibutes	Field Length	Field Type	Field Description
Area_ID	2	Char	Unique code for area, auto increment.
Process_ID	3	Char	Unique code for process, auto increment.
Parameter_ID	4	Char	Unique code for parameter, auto increment.
Machine_ID	3	Char	Unique code for machine ID, user's specified.
Chart_ID	6	Char	Unique code for each chart.
Chart_Type	15	Varchar2	Type of chart - XbarR or CCC Chart.
CL	10,2	Number	Value of CL.
UCL	10,2	Number	Value of UCL.
LCL	10,2	Number	Value of LCL
Sample_Size	10	Number	Quantity for each sample.
No_of Reading	2	Number	How many readings?

TABLE REJECT DATA

Attibutes	Field Length	Field Type	Field Description
Chart_ID	6	Char	Unique code for each chart
Date	8	Char	Current date.
Time	8	Char	Current time.
Reject_ID	3	Char	Unique code for each reject. User specified.
Reject_Qty	3	Number	Reject quantity found per reject ID

Table D.1. Data Dictionaries. (Continued)

TABLE CCC_DATA

Attibutes	Field Length	Field Type	Field Description
Chart_ID	6	Char	Unique code for each chart
Date	8	Char	Current date.
Time	8	Char	Current time.
Employee_No	4	Char	Employee's ID of the person who keys in the data.
Shift	1	Char	Employee's shift
Lot_No	6	Char	Product identifier.
Sample_Size	10	Number	Quantity for each sample
Reject_Qty	3	Number	Reject quantity found.
Fail_Rule	2	Number	Rule that fail.

TABLE XBAR_R_DATA

Attibutes	Field Length	Field Type	Field Description
Chart ID	6	Char	Unique code for each chart
Date	8	Char	Current date.
Time	8	Char	Current time.
Employee_No	4	Char	Employee's ID of the person who keys in the data.
Shift	1	Char	Employee's shift
Lot No	6	Char	Product identifier.
X1	10,2	Number	Value of X1
X2	10,2	Number	Value of X2
X3	10,2	Number	Value of X3
X4	10,2	Number	Value of X4
X5	10,2	Number	Value of X5
X6	10,2	Number	Value of X6
X7	10,2	Number	Value of X7
X8	10,2	Number	Value of X8
X9	10,2	Number	Value of X9
X10	10,2	Number	Value of X10
Fail_Rule	2	Number	Rule that fail.

Table D.1. Data Dictionaries. (Continued)

TABLE CCC CORRECTIVE ACTION

Attibutes	Field Length	Field Type	Field Description
Chart ID	6	Char	Unique code for each chart
Date	8	Char	Current date.
Time	8	Char	Current time.
Fail Rule	2	Number	Rule that fail.
Employee_ID	4	Char	Employee's ID of the person who keys in the data.
Cause	50	Varchar2	Cause of out of control.
Action	50	Varchar2	Action that has been done to solve the problem.

TABLE XBAR R CORRECTIVE ACTION

Attibutes	Field Length	Field Type	Field Description
Chart_ID	6	Char	Unique code for each chart
Date	8	Char	Current date.
Time	8	Char	Current time.
Fail_Rule	2	Number	Rule that fail.
Employee_ID	4	Char	Employee's ID of the person who keys in the data.
Cause	50	Varchar2	Cause of out of control.
Action	50	Varchar2	Action that has been done to solve the problem.

TABLE USER ACCOUNT

Attibutes	Field Length	Field Type	Field Description
Employee_ID	4	Char	Employee's ID - Unique code
Name	25	Varchar2	Login name
Shift	1	Char	Employee's shift
Password	6	Varchar2	Employee's password
Privilege_Level	1	Char	Access level

TABLE PRIVILEGE

Attibutes	Field Length	Field Type	Field Description
Privilege_Level	1	Char	Access level
Description	30	Varchar2	Description of access level

APPENDIX E

USER'S GUIDE

Logging into the System

1. Double click the On-line Real-time Control Charts icon.
2. From Figure A.1, enter your User Name and Password.
3. Click Ok button when you finished.

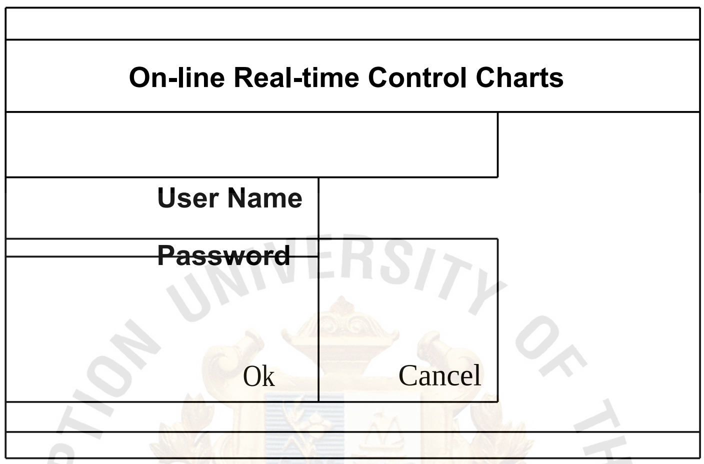


Figure E.1. Login Screen.

4. Select chart type. Either $X - R$ chart of CCC chart.

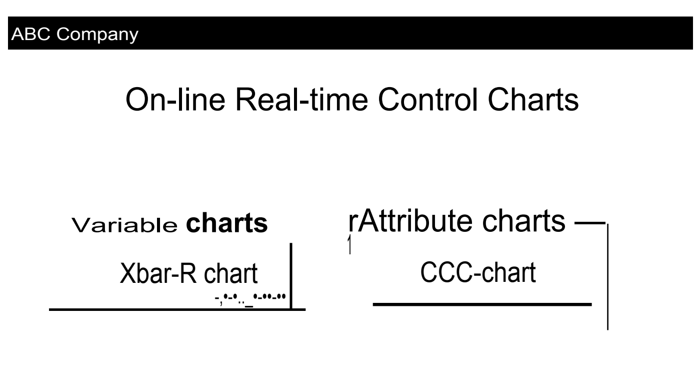


Figure E.2. On-line Real-time Control Charts.

For $\bar{X}$ - R Chart.

1. Chart display screen is shown below.

2. At the top right corner, select Area, Process, Parameter, Machine, and Package.

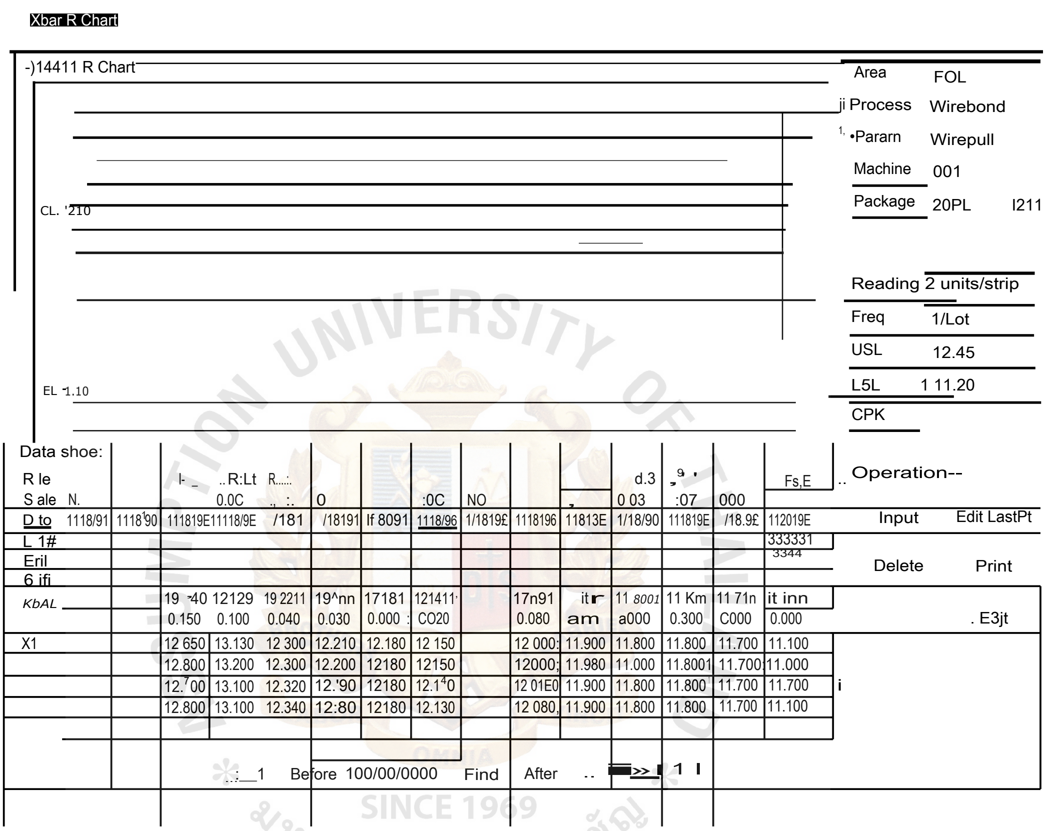


Figure E.3. Display Screen for $\bar{X}$ - R Chart.

3. Click Input button to key in data.

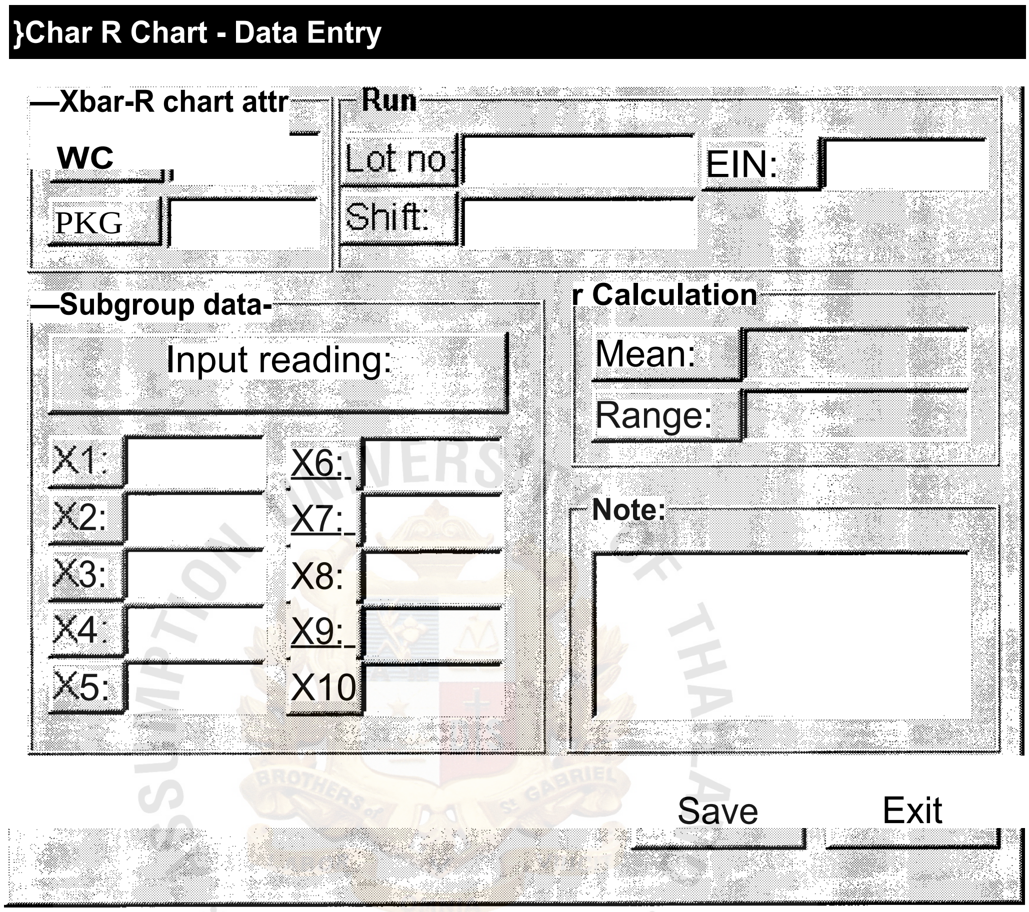


Figure E.4. Data Entry Screen for $X - R$ Chart.

4. If out of control situation occurs, the following screen will appear.

5. Corrective Action Screen for Corrective Action.

6. Fill in possible cause and corrective action in the box provided. Click Update to return to chart display screen.

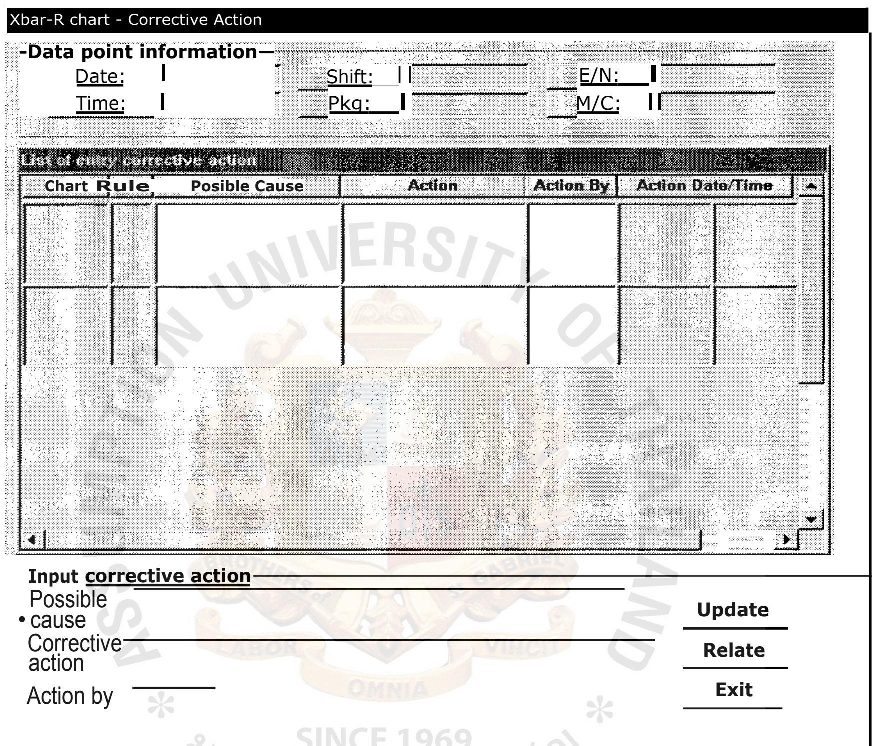


Figure E.5. Corrective Action for $X — R$ Chart.

For CCC Chart

1. Chart display screen is shown below.

2. At the top right corner, select Area, Process, Parameter, Machine, and Package.

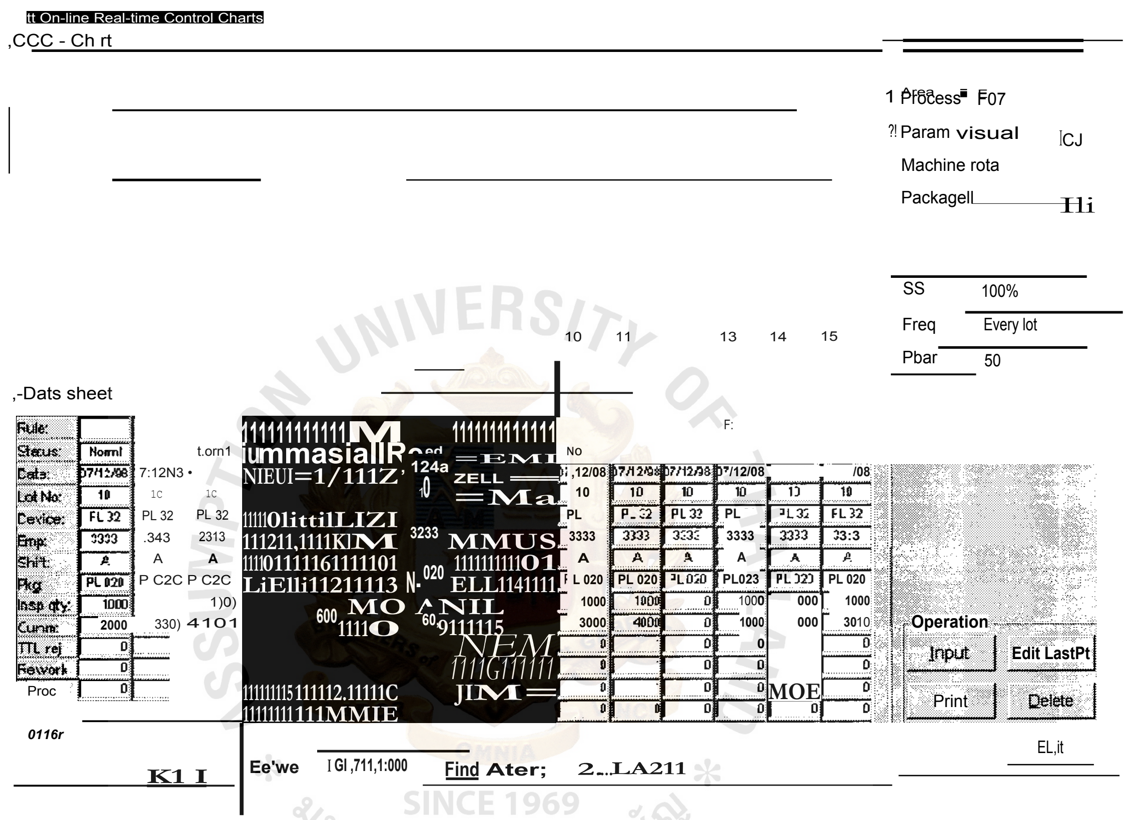


Figure E.6. Display Screen for CCC Chart.

3. Click Input button to key in data.

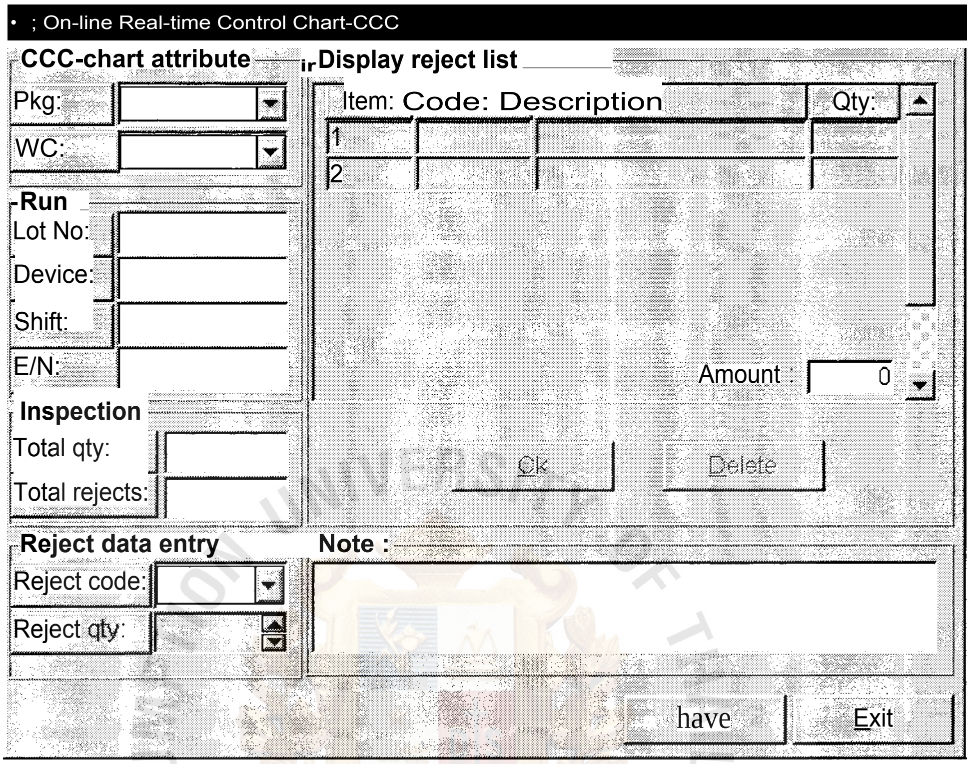


Figure E.7. Data Entry Screen for CCC Chart.

4. If out of control situation occurs, the following screen will appear.

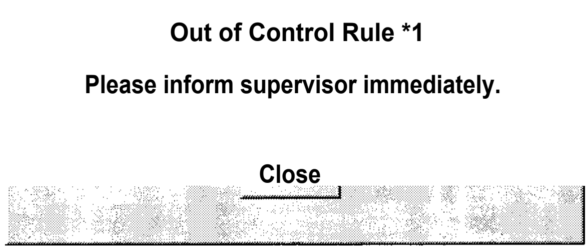


Figure E.8. Out of Control for CCC Chart.

5. Corrective Action Screen for Corrective Action.

6. Fill in possible cause and corrective action in the box provided. Click Update to return to chart display screen.

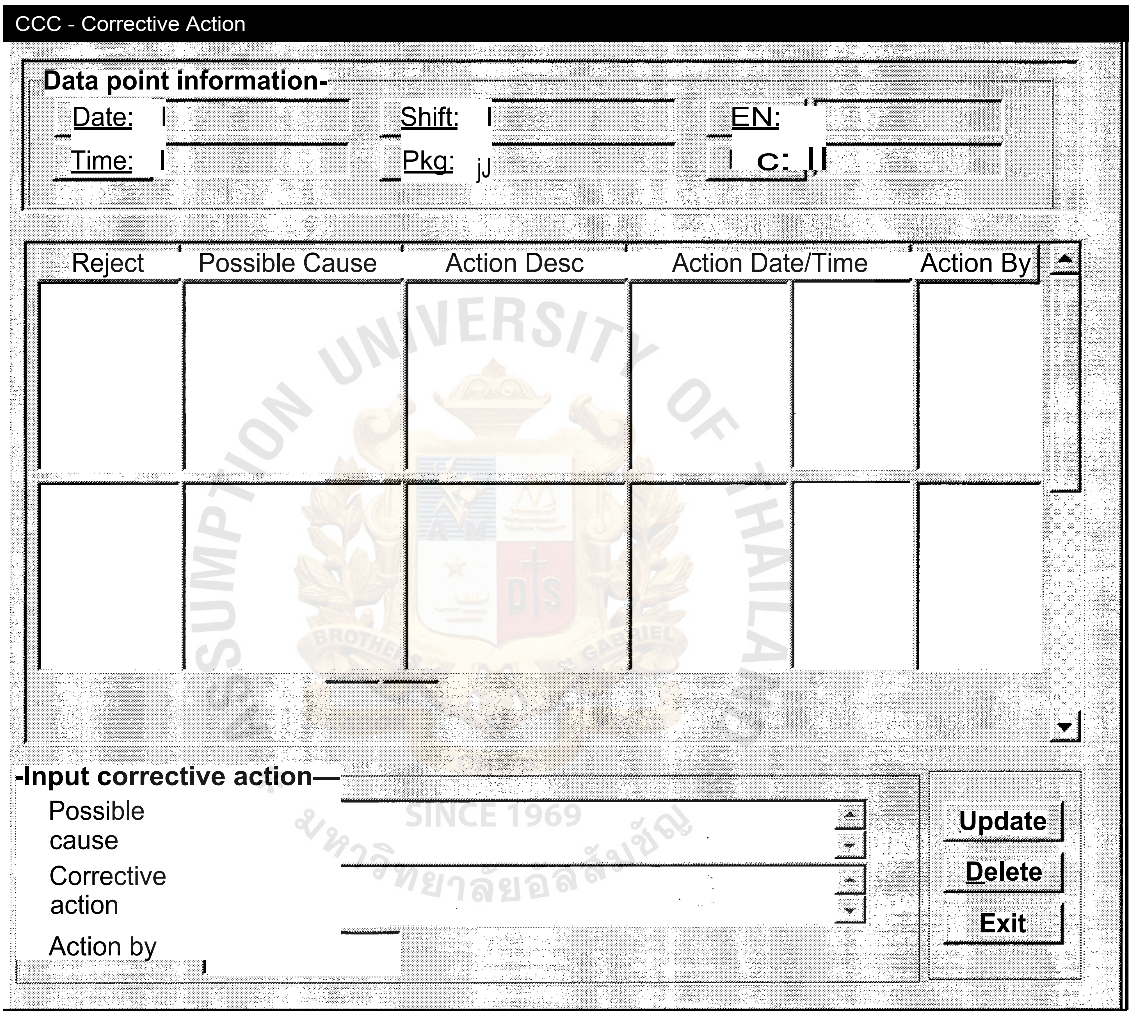


Figure E.9. Corrective Action Screen for CCC Chart.

BIBLIOGRAPHY

1. Drain, David. Statistical Methods for Industrial Process Control. United States of America: Chapman & Hall, 1997.

2. Hawryszkiewycz, Igor Titus. Introduction to Systems Analysis and Design. Fourth Edition. United States of America: Prentice-Hall, 1998.

3. Montgomery, D. C. Introduction to Statistical Quality Control. Third Edition. United States of America: John Wiley & Sons, 1996.

4. Parker, C., and T. Case. Management Information Systems Strategy and Action. Second Edition. United States of America: McGraw-Hill, 1993.

5. Smith, Gerald M. Statistical Process Control and Quality Improvement. United States of America: Prentice-Hall, 1998.