Quality Improvement at an Out-of-Box Audit (OBA) Station for a Computer Keyboard Manufacturer

By

Ms. Sirimar Auayingsak

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
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Academic Year	November 1999

The Graduate School of Assumption University has approved this 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.

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ABSTRACT

This project is aimed to study how to minimize the defective quantity to reduce the cost of non conforming product, replacement, return scrap, rework and repair by using Statistical Process Control (SPC).

Nowadays, the quantity and customer satisfactions have become the key drive behind some of the most profound change that occurred in the world of work. The SPC is the quality control strategy to highlight the abnormal event in the production process, to identify the problem.

We apply the SPC tools and the maintenance program to decrease the defective quantity. This project is to monitor the possible defect at Out of Box Audit inspection and use the SPC tools to find out the possible root cause and solve the problem by using maintenance program, which is the preventive maintenance and the predictive maintenance.

After applying the SPC tools and the maintenance program, the main defective rate decrease from 42% to 6% making the company reach the company's defect part per million target.

ACKNOWLEDGEMENTS

I am indebted to the following people and organizations. Without them, this project would not have been possible.

I wish to express my sincere gratitude to the Dean and Advisor of the Advisory Committee, Dr.Chamnong Jungthirapanich. His patient assistance, guidance, and constant encouragement had led me from the project inception to the project completion. I would like to express my appropriation to the Project Advisory Committee members; Prof. Dr. Srisakdi Chamonmarn (Chaiman), Dr. Boonmark Sirinaovakul (Senior Dean) and Assoc. Prof. Somchai Thayarnyong (MUA Representative) for their comments and advise throughout the project.

My special thanks to the following people whose support throughout this project has been valuable to me Ms. Sudarat Prachaseree, Ms. Chantana, my colleagues at work, my CEM friends and family.

Finally to my parents, who all played majors roles in my life, I wish to extend my loving and thanks for their support, encouragement and patience.

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I. INTRODUCTION

1.1 The Significance of Quality Control

Our daily lives and schedules depend totally upon satisfactory performance and operation of products and services. While today's buyers continue to purchase with strong attention to price, unlike the buyers of only few years ago, they place increasingly high emphasis upon quality, expecting acceptable products at any price level. Quality is judged by the customer. Quality and customer satisfaction have become the key driven behind some of most profound changes that have occurred in the world of work in all of reworked history.

In the company's view, quality cost is often described as "the cost of doing things wrong". In fact Mr.Phil Crosby speaks of this cost as Price of Nonconformance (PONC) sorting inspection, rework, repeat testing, time spent resolving customer complaints, material scrapped, downtime, and return are a few good examples of the waste we want to avoid. Two major elements of quality cost are as follows:

(a) Internal Failure Costs - costs associated with non conforming materials, components, or products that cause losses due to rework, repair, retest, scrap, sorting, and so on, prior to release to the customer.

(b) External Failure Costs - costs associated with non conforming products that cause losses due to warranties, returns, allowances, and so on, after release to the customer.

Nowadays, the quality has become a cardinal priority in most organizations. This reality has evolved through a number of changing business conditions. These include:

(a) Competition: In the past, higher quality usually meant the need to pay a higher price. Today customers can obtain high quality and low prices simultaneously. It is not sufficient to have a "good quality image". If the internal costs of achieving that image (sorting inspection, rework, scrap) are high, a company will lose sales because of the higher prices needed to cover these costs of poor quality.

(b) Changing customer: Some companies are now entering the industry of consumer markets for the first time. For example, a manufacturer of a small agricultural tractors for the individual farmer is now engine blocks for a major automotive manufacture. That automotive customer not only commands priority based on volume but also demands the "quality system".

(c) Changing product mix: For example, a computer manufacturer has shifted from low-volume, high price mix to a mix that is high volume and low of price. These new products have resulted in a need to reduce internal costs of poor quality.

(d) Product complexity: As systems have become more complex, the reliability requirements for suppliers of components have become more stringent.

(e) Higher levels of customer expectation: Higher expectations, spawned by competition, has many forms. One example is lower variability around a target value on product characteristics even though all products meet the specification limits. Another of higher expectation is improved quality of service both before and after the sale.

Quality control refers to the use of specification and inspection of completed parts, subassemblies, and products to design, produce, sustain, and improve the quality of a product and service. Quality goes beyond inspection by

(1) *Establishing a standard for the product or service, based on the customer* needs, requirements, and expectations.

(2) Ensuring conformance to these standards, poor quality is evaluated to determine the reason why the parts or services provide are incorrect.

(3) Taking action if there is a lack of conformance to standards. These actions may include sorting out the product to find the defects. In service industries, actions may involve the customer and correcting the situation.

(4) Implementing plans to prevent future nonconformance. These plan may include design of manufacturing changes, in service industry they include procedure changes.

These four activities work together to improve the production of product or provision of service. Quality control efforts can be enhanced by the use of other statistics to help decision making.

1.2 Statement of Problem

Electronics Co., Ltd. is a computer keyboard manufacturer which is supported by Board of Investment (BOI). The main process is the assembly, packaging and shipping. In order to improve the quality of output and achieve customer satisfaction, the company has many quality controls over every production unit. The Out of Box Audit (OBA) station is the final inspection audit of finished goods to assure that the finished goods conform to customer specification and requirements before being shipped to the customers. OBA located at the last logical step in the supplier's product/process flow prior to shipment to customer. The OBA will audit finished goods, preferably packaged units ready for shipment. The OBA station will perform as the customers. They are the first person that meet the finished goods after production process.

The quality of the product is based on the assembly process. The OBA station needs to confirm the quality of products. For the company, in this project no formal recording of defects found on the finished products is done. This problem may cause the internal failure costs such as profit/loss, more return, rework, replacement and scraps, especially in the view of the company. We will lose the customers even if we have offered 2 years warranty to them if we do not handle the defective problem.

1.3 Project Objectives and Scope

This project focuses on the OBA final inspection audit process which can be the tools to find the number of defective product and possible defects. We will monitor the OBA station of the product A for one month. After collecting the data, the number of defect and the type of defect will be listed. Then, the Pareto chart may be employed to identify the main defect to find out the root cause. This project is aimed to minimize the defects of the keyboard, controls and improve the quality of the keyboard computer to meet Defective Parts Per Million (DPPM) target by applying the Statistical Process Control (SPC) tools.

II. LITERATURE REVIEW

2.1 Quality Concepts

What is quality?

Quality can mean different things to different people and can be interpreted in a variety of ways by an individual as the quality of a manufactured product and the quality of services received. From the manufacturing standpoint, quality is simply conformance to specifications. The ultimate customer could describe quality as fitness for use. When trying to edge out the competition, quality can be interpreted as producing the very best product or providing the very best service. In some industries a set of classifications have been established by design quality. For example, several levels of design quality exist in the automotive industry, from top-of-the line luxury models down to economy cars. However buyers would expect good conformance quality. In the service sector, the hotels and motels provide luxurious surroundings, exercise rooms, pools and hot tubs, which separate the bargain hotel from the five-star hotel.

Quality can also be linked to customer satisfaction. Some companies have used that definition for years, but there is now a broad move toward defining quality as total customer satisfaction. To use that definition, a company must know its customer, and in the multilevel markets, it must know the customers level for which it produces. The customer is becoming the driving force for quality.

Many companies that initially aimed at improving the quality of their products found that to satisfy the final customer, it was necessary to satisfy a whole sequence of internal customers. Each person involved in the manufacturing process received a partially completed product, performed the assigned operation(s), and passed it on to the next person. At each step in the process the internal customer had to received a quality product and pass on quality product. Away from the manufacturing area, those responsible for the order entry, shipping, and billing were also involved in achieving total customer satisfactionn. Again, the final customers cannot receive a quality product unless the associated internal customers receive a quality product as well. This awareness led to the concept of total quality, that there are no exceptions to producing quality work. Everyone in a manufacturing environment or in the service sector has customers, internal or external, and must maintain total customer satisfaction. The word "customer" is anyone who is impacted by the product or process (Juran 1993).

(a) External customers include not only ultimate users but also intermediate processors, as well as merchants. Other customers are not purchasers but have some connection to the product, e.g. government regulation bodies.

(b) Internal customers include not only other divisions of the company that are provided with components for an assembly but others that are affected, e.g. a Purchasing Department that receives an engineering specification for a procurement.

One more recent development in the definition of quality is that of exceeding the customer's expectations. When the service is so good that the customer feels "special" when a product has an outstanding feature, or when the combination of product, service, and delivery leaves the customer truly amazed, the customer's expectations have been exceeded. Exceeding customer expectations has been extremely effective in building a loyal customer base (Smith 1998).

Quality is:

(a) Fitness for use

(b) Conformance to specification

(c) Producing the very best products

(d) Excellence in products and services

(e) Total customer satisfaction

(f) Exceeding customer expectations

Although there is no universally accepted definition of quality, the various definitions have enough similarity to extract the following common elements :

(a) Quality involves meeting or exceeding customer expectations.

(b) Quality applies to products, services, people, processes, and environments.

(c) Quality is an ever-changing state - what is considered quality today may not be good enough to be considered quality tomorrow.

With these common elements identified, the following definition of quality is provided : "Quality is a dynamic state associated with products, service, people, processes, and environments that meet or exceed current expectations" (Goetsch 1995).

The dynamic state element speaks of the fact that what is considered quality can and often does change as time passes and circumstances are altered.

The products, service, people, processes, and environments element is criteria. It makes a point that quality applies not just to the products and services provided, but also to people and processes that provide them and the environments in which they are provided.

2.2 The Need for Statistical Process Control (SPC)

The constant improvement in quality and productivity is needed to prosper in today's economic climate. Yesterday's standards are not good enough. A company's product has competition from companies throughout the world because modern communication and transportation have created a world marketplace. The quality of product has to be world class, as good as the best in the world, in order to compete. Consumers are looking for the best combination of price and quality before they buy.

Today each company employee must be committed to the use of effective method to achieve optimum efficiency, productivity, and quality to produce competitive goods. Statistical Process Control (SPC), in its broad sense, is a collection of production methods and management concepts and practices that can be used throughout the organization. SPC involves the use of the statistical signals to identify sources of variation, to improve performance, and to maintain control of production at higher quality levels. It can be applied to any area of work done. The statistical concepts that are applied in SPC are very basic and can be learned by everyone in the organization.

As the area of quality evolve, it becomes obvious that there was a need to become more proactive when dealing with quality problems. Thus the emphasis shifted from utilizing statistical quality control methods for the inspection or detection of poor quality to their use in the prevention of defects. Prevention refers to those activities designed to prevent defects, defectives, and nonconformance in products and service. The process is monitored, controlled, and adjusted to ensure correct performance (Summers 1997).

2.3 SPC Goals

(a) Minimize production costs. This with a "make it right the first time" program. This program will eliminate the costs associated with scrapping reworking out-of-specification product.

(b) Attain a consistency of products that will meet production specifications and customer expectations.

(c) To achieve process stability that allows to be made about future products or service.

(d) To allow for experimentation to improve the process and to know the results of changes to the process quickly and reliably.

(e) To support with statistical information concerning the process

2.4 The Tools for SPC

(a) Flow chart : The entire process is diagrammed from start to finish with each step clearly indicated. All involved in the process should know their positions on the flow chart and at least a partial upstream trace from their positions. All should know who their suppliers are and who their customers are in the process flow. Different symbols specify what is being done to the as it progresses from the input stage to the output stage of the process. When problem exist within a process or process segment, the problem-solving team should clearly understand what is being done to the product at the various stages in the process. A complete flowchart should make the step-by-step procedure within the entire team. In addition, the complete flow can help to find the root cause of the problems. The flowchart will bring the product back and forth in the process until the cause of the problem is found or until several good candidates for the root cause have been uncovered, leading the way to further data gathering and analysis.

Flowchart symbol definition: More complicated processes can be flowcharted with the use of standardized symbols to indicate what is being done to the product. This chart requires that everyone using it understand the symbols. Flow chart definition are as shown on Figure 2.1.

(b) Check sheet : A data gathering sheet is prepared that categorizes problems or defects. It will consist of a list of the different types of data to be gathered and a column in which to put tally marks or brief descriptive remarks. The heading on the checksheet should contain information such as the name of the individual gathering data, time frame in which the data are gathered, and any specific information about the source and type of data. Check sheet information may be put on a Pareto chart for prioritized problems or if a time analysis is included, may be used to investigate problem trends over time. A simple check sheet might be designed to collect data in the form of "check marks". The categories in which check marks are placed should be well defined so that there is no overlap between them. Nearly all data must be converted into information. Plotting the data on a Pareto chart, frequency plot, scatter plot, control chart, or other device are common methods of making sense out of data. Another type of check sheet is used in the process, where the check sheet contains a list of specific items that have to be checked if it could contain a picture of the item being inspected with inspection areas highlighted or numbered. Some codes that are used to specify the problem area and type of problem.

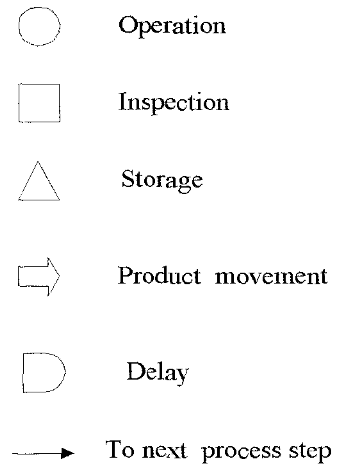

Figure 2.1. Process Chart Symbols.

(c) Histogram : A bar graph shows the comparative frequency of specific measurements. The shape of the histogram can indicate that problem exists at a specific point in a process. It will present a snapshot in time of a set of data. It is useful for seeing the shape, centering and spread of a set of data from some process. If the histogram is stable, the histogram is a picture of what we might expect to see in the future. If the process is not stable, the histogram is only a picture of what happened in the past.

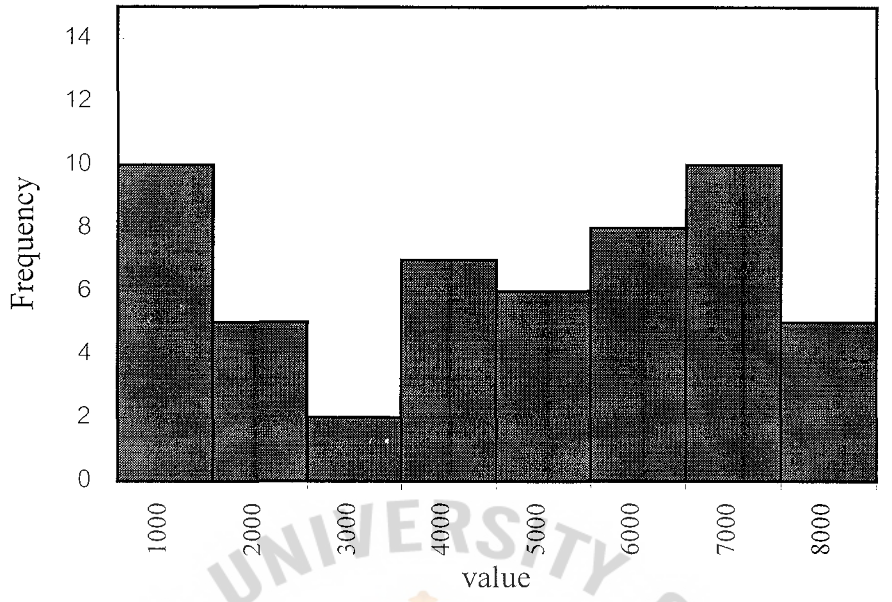

Figure 2.2. Histogram.

(d) Pareto Chart : Parcto is "Prioritization". The number of occurrences of the cost of occurrences for specific problems are charted on a bar graph. All occurrence data will be ordered by type, category, or other classification. The largest bars indicate the major problems and are used to determine the priorities for problem solving. This tool will use the bar graph that ranks problems in decreasing order of frequency, and was adapted for quality control by Joseph M. Juran. The Pareto principle, credited to Italian economist Vilfredo Pareto, involves the concept that the comparative distribution of certain economic factors, such as wealth, follow an inverse relationship. Pareto discovered that 80 % of the wealth in this country in the early 1900s was concentrated in 20 % of the population. Dr. Juran who popularized the term "the Pareto principle" discovered that the 80%- 20 %

split also occurs in quality control. Eighty percent of the scrap is caused by 20% of the quality problems, and 80% of the dollar loss caused by poor quality concentrated in 20% of the quality problems. The important outcome of a Pareto chart is its assessment of process problem priorities. It sifts the vital few problems from the trivial many. Another plus for the Pareto chart is its elimination of receptivity, the tendency to overestimate the importance of the most recent problem. When problem analysis is done for a Pareto chart, data are gathered that give the number of occurrences for each problem and the dollar loss associated with it. When all the data have been gathered, percentages can be tabulated for both the number data and the dollar loss data.

The procedure for making a Pareto Chart is as follows:

(1) Decide on the subject of the chart. Usually the need to set data priorities suggests the use of a Pareto chart. Determine what data are collected. Where is the problem? What are the categories? Where should the data be gathered? Should they come directly off a line? Should they come from a bin of nonconformance that have accumulated in the specified time period?

(2) Be sure the time period for all the categories is the same : Use the number of nonconformance per hour, per shift, or per week.

(3) What type of chart is needed? Should you track the number in each category, the percentage in each category, or the costs in each category? A cost chart is usually included with either a number chart or a percentage chart.

(4) Make a table by gathering the data and tallying the numbers in each category. Find the total number of nonconformance and calculate the percentage of the total in each category. Make a cost of nonconformance column and cumulative percent column.

(a) Arrange the table data from the largest category to the smallest.

(b) Set the scales and draw a Pareto chart.

(c) Include all pertinent information on the chart. Are the categories clear? Has the time frame been specified?

(d) Analyze the chart. The largest bars represent the vital few. The cumulative percentage line levels off and emphasizes the trivial many. If the chart does not show a vital few, check to see if it is possible to recategorized for another analysis. Refer to Figure 2.3.

Table 2.1. Category and Cumulative Data.

PARETO ANALYSIS The number of nonconforming shirts per week			
Category	Number	Percent	Cumulative (%)
Threads	15	33 %	33 %
Tears	10	22 %	54 %
Buttons	8	17 %	72 %
Collar	7	15 %	87 %
Cuff	6	13 %	100 %

(5) Analyze the chart. The largest bars represent the vital few. The cumulative percentage line levels off and emphasizes the trivial many. If the chart does not show a vital few, check to see if it is possible to recategorized for another analysis. Refer to Figure 2.3.

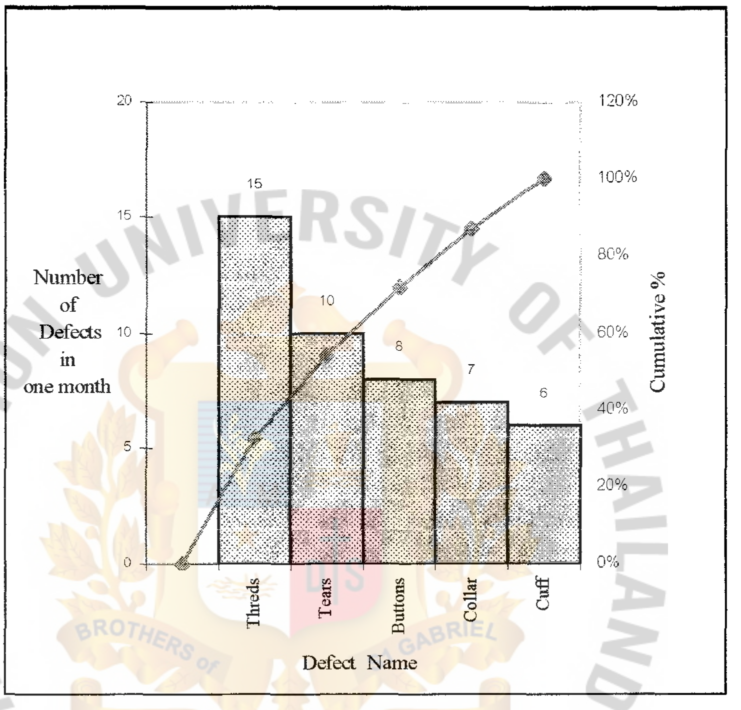

Figure 2.3. Pareto Chart of Nonconforming Shirts.

(e) Cause-and-effect diagram: A problem (the effect) is systematically tracked back to possible causes. The diagram help in the search for the root cause of the problem. A similar diagram can be used to systematically search for solution to a problem. This diagram is a useful tool in a brainstorming session because it organizes the ideas presented.

It is sometimes called a "Fishbone diagram" because of its shape of an Ishikawa diagram after Professor Ishikawa of Japan, who first used the technique in the 1960s. The diagram is a format for logically aligning the possible causes of a problem of effect. A basic way to organize the "rips" or main categories, is to assign them the four M's : methods, machines, measurement, and materials. As ideas are presented, they are inserted as the "bones" or the possible causes of the effect, in the appropriate category. The bones can be sub-categorized as causes of a cause are presented. The subdividing continues until the root cause to the problem is found. There may not always be a single root cause but at least a few potential root causes will surface, and a decision for action can be made. The four M's are generally used as the initial main categories for cause-and-effect diagram. Other categories specific to the particular process may be added if the team decides they are important. Environment is one example of a possible other category. It may be considered important enough to be a main category of problem causes, or it may be a subcategory in any or all of the other categories, depending on the process being analyzed. This chart is useful in a brainstorming session because it organizes the ideas that are presented. The problem is solved from using the chart by being able to separate a large problem into manageable parts. It serves as a visual display to aid the understanding of problems and their causes. The problem or effect is clearly identified on the right hand side of the chart, and the potential causes of the problem are organized on the left hand side. The cause and effect diagram also allows the session leader to logically organize the possible causes of the problem and to focus on one area at a time. Not only does the chart permit the display of the cause of the problem, it also shows sub categories related to those causes.

To construct a cause and effect diagram

(1) Clearly identify the effect of the problem. The succinctly stated effect of the problem statement is placed in a box at the end of a line.

(2) Identify the causes. Discussion ensures isolating the potential causes of the problem. To guide the discussion, attack just one possible cause area at a time. General topic areas are usually methods, materials, machines, people, environment, and information, although other areas can be added as needed. Under each major area, sub causes related to the major cause should be identified. Brainstorming is the usual method for identifying these causes.

(3) Build the diagram. Organize the causes and sub-causes in a diagram format.

(4) Analyze the diagram. At this point solutions will to be identified. Decisions also need to be made concerning the cost effectiveness of a solution as well as its feasibility.

Cause and effect diagrams allow us to isolate potential causes of problems. Once identified, these causes need to be investigated by measuring and organizing the data associated with the process.

Measuring the process will help refine the investigators' understanding of the problem and help to sort out relevant from inrelevant information.

(f) Control Chart: A broken-line graph illustrates how a process or a point in the process behaves over time. Samples are periodically taken, checked, or measured, and the results plotted on the chart. Control charts are the tools that are used in statistical process control to indicate when special-cause variation is present in a process.

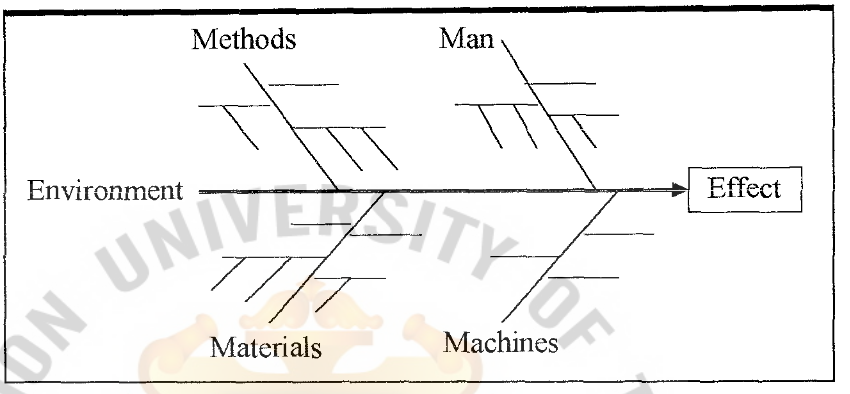

Figure 2.4. Fishbone Diagram.

Their use can provide more information about a process than workers with years of experience. They will tell us if a process is showing stable (or consistent) variation. A stable process is often called an in-control process, a predictable process, or a common cause process. It is said to be in a state of Statistical control. An unstable process is also known as out-of-control, unpredictable, or a "common plus special cause" process. A control chart tells us whether or not a process is stable. All processes have the common variation due to common causes.

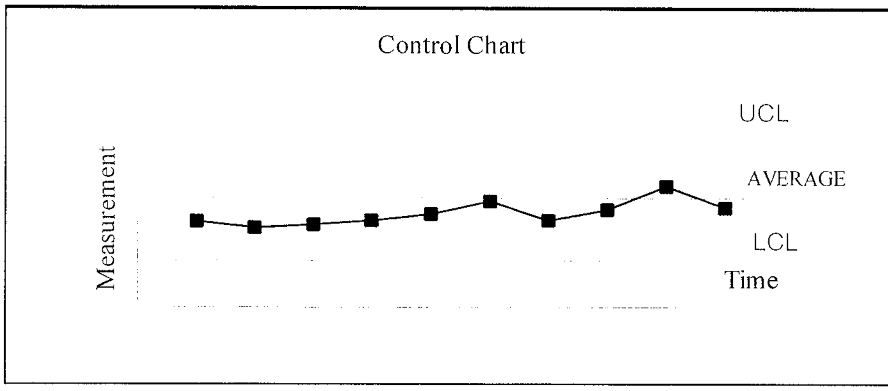

Figure 2.5. Control Chart.

Common causes are those that are inherent in the process over time, affect everyone working in the process, and after all outcomes of the process. If common causes are at work, the only way to reduce or remove them is to make the fundamental changes in the system or the process.

Special causes are those that are not part of the process all the time, do not affect everyone, but arise due to circumstances. If special causes are at work, they can be eliminated by attacking their underlying specific causes.

Variable control charts use actual measurements for charting.

Average and range chart ($\bar{x}$ and R) : The average and range chart, commonly called the x- and R chart, consist of two separate charts on the same sheet of chart paper. One graph tracks the sample mean and the other tracks the sample range R. Small samples of consecutive pieces are taken. The sample size must be the same for all samples and usually consist of three to seven pieces. The dimension of interest is measured, and the measurements are recorded on the chart for each sample. The mean and range for each sample are calculated, recorded, and charted. The chart is analyzed as it develops for indications of special-cause variation, and after about 25 samples, it is analyzed again to determine the location, spread, and shape of the distribution of measurements.

2.5 Why-Why Diagram

The Why-Why diagram, an excellent technique for finding the root cause(s)of a problem is to ask "why" five times. It is the method for determining what factor has to be in place in order to respond to an opportunity. The why-why diagrams organize the thinking of a problem solving group and illustrate a chain of symptoms leading to the true root cause of the problem (Summer 1997). At the end of a session it should be possible to make a positively worded, straightforward statement defining the true problem to be investigated. By using the why-why diagram, the focus group can gain a clear picture of the interrelationships of the cause and the problem.

For the Why-Why technique, the why-why diagram flows from left to right. The diagram will start on the left with the statement of the problem to be resolved. There may be only one cause or there may be several causes that can be separated or interrelated. Regardless of the number of causes or their relationships, the cause should be written on the diagram in a single, clear statement. The investigation is continued through as many levels as needed until a root cause is found for each of the problem statements and the original problem. At the end, this process leads to a network of reasons why the original problem occurred. The ending points indicate the area that needs to be addressed to resolve the original problem. The Why-Why diagram can be expanded to include notations concerning who will be responsible for action items and when the actions will be completed.

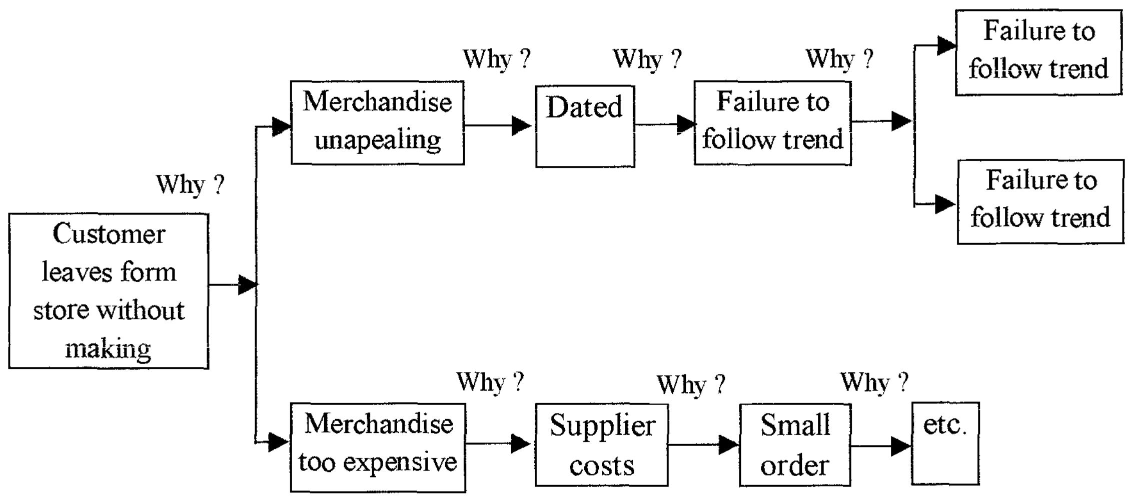

Figure 2.6. Why-Why Diagram.

III. QUALITY CONTROL STRATEGIES

3.1 Current Situation Review

Firstly, the researcher would like to describe the overall production process and station concerned in keyboard manufacturing. Normally, the company orders parts which have been already formed from the approval vendors for both direct and indirect materials. The direct materials include the cable wire, ground wire, rubber sheet, printing circuit film, functional light sticker, keyboard box and keyboard carton, keyboard button, top case (cover plate of keyboard) and bottom case. The indirect materials include the screws, glue and silicone oil. These parts are categorized as the work in process units in the final assembly process. However, the company also orders the raw material to be processed in its own plant facilities as other parts for final assembly process. All processes are shown in Figure 3.1.

(1) Insertion components process : This sub production will insert components in the be circuit board including printing circuit board (plastic plate), resistor, jump wire, diode, bead core, chock coil ,electrolytic, connector 9 pin and connector 18 pin.

(2) Keycap process : This station assembles all buttons of keyboard (blank buttons) with top case, then, it is shipped to the next printing process station.

(3) Printing Process : There are two types of button printing patterns which are

(a) Auto printing process which uses the Tampo printing machine to print all characters and marks. Mainly, the rubber pad, ink carrier will stamp on the plate, letter and mark pattern, and carry ink to press on all keyboard buttons.

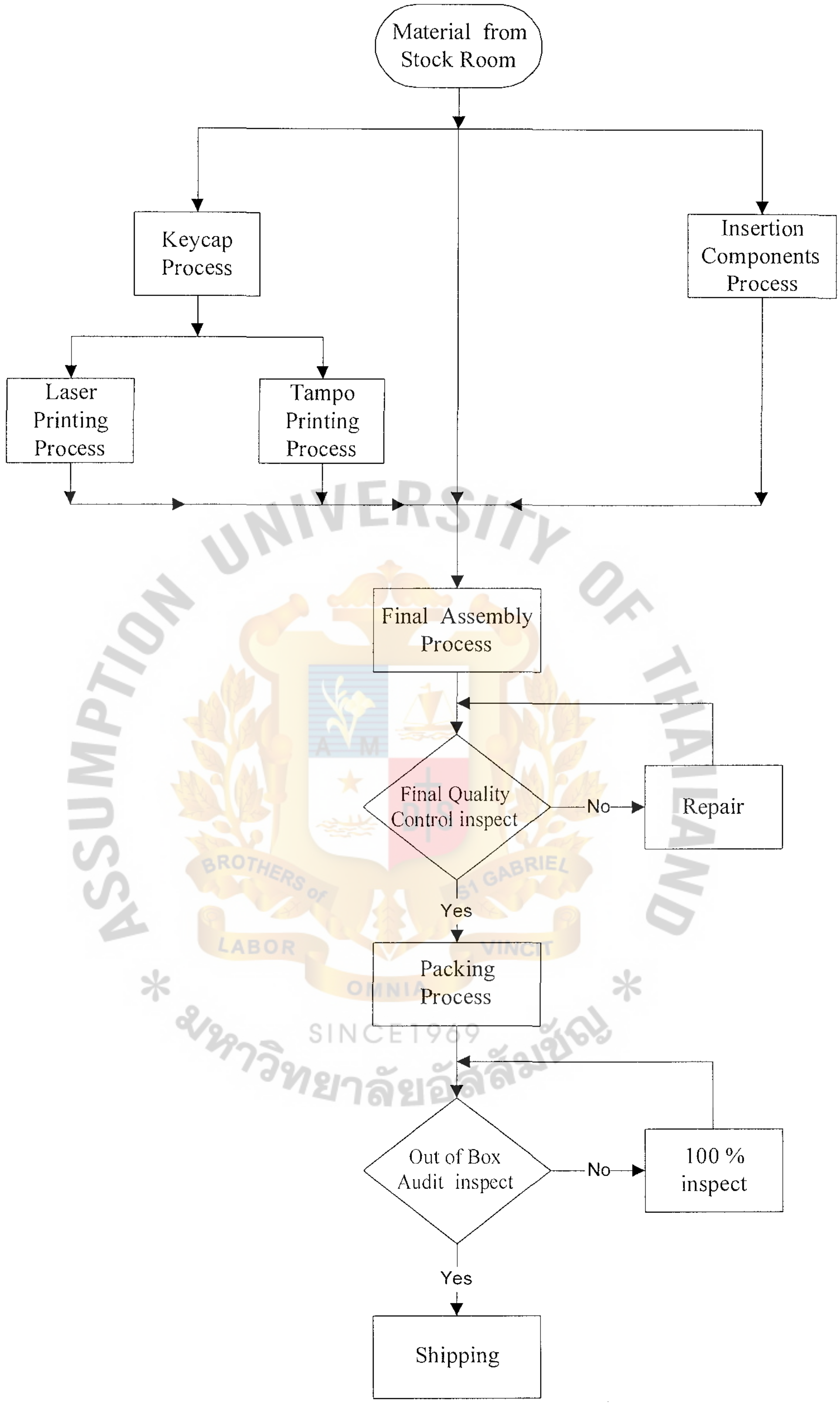

Figure 3.1. Keyboard Assembly Process Flow Chart.

(b) Laser printing process which prints all characters and marks of keyboard button by using the laser printing machine. Normally, there is a specific program for each keyboard model.

Eventually, each keyboard will have the specific printing pattern, language and alignment, and each pattern will be to the customer specification.

(4) Final assembly : The final assembly will assemble all work in process parts together. After the keyboard is assembled, the line inspection will inspect 100% inspection of the keyboard, both cosmetic inspection (dirt, scratch, and printing) and functional inspection (electricity inspection).

(5) After the final assembly, each keyboard lot must be 50% inspected at the final inspection station. If there are any defects, the keyboard will be sent to the repair station.

(6) Packing Process : At this station, all keyboards must be identified with the Identification label (ID label). This guarantees that each keyboard has passed all inspection criteria. This process will pack the good keyboard that has already passed inspection into a plastic bag first, after that the operator will insert the keyboard into the gift box with the keyboard manual. Finally, all keyboards will be packed in the carton and sealed. All sealed cartons will be sent to the out of box audit team later.

(7) At Out of Box Audit (OBA) station, is the final station before releasing the keyboard to the customers. This station uses random sampling method to check the keyboard by using Audit Quantity Level, AQL. If, there is even one defective keyboard in the lot, all keyboards must be rejected. OBA

inspectors will perform the visual inspection, of the layout and electricity of the keyboard. Certainly, the visual inspection is necessary because this is a way to ensure that all keyboards are qualified. The inspection items are dirt, scratch, and character printing. Then the inspectors inspect the layout of the keyboard button. They will inspect the position of the character and marking. After that the inspector tests the function of keyboard by using the specific program-test. After the functional test, the keyboard will be packed into a carton and the whole lot will be sent to the warehouse for shipping to the customer.

In order to improve the quality of output and achieve customer satisfaction, the company has many quality controls for every production unit. The Out of Box Audit station is the final inspection audit of finished goods to assure that the finished goods conform to customer specification and requirements before being shipped to the customers. The OBA station has a record to show the defective parts of the computer keyboard, however; there is no formal report. There is no summary of the defective items in order to see which parts are the most problematic ones. OBA finds many defective parts every month, thus; we need reworking. If the company finds even one defective part, we will have to reject the whole lot. If we could not find any but there is a defective part in that lot, the company has to replace a new one to the customer and pay the warranty charges. We do not want to lose our precious customers in the future because of this solvable but neglectful quality issue.

3.2 Problem Solution Requirements

The OBA station has no formal report to identify the main defect. So, this project will use proper techniques to focus on the main defect by using the data collection at

OBA station. This project needs to minimize the defects of the keyboard, controls and improve the quality of the keyboard computer. On the other hand, OBA 's responsibility for quality control can also decrease the internal failure cost; return, rework, and replacement.

However, the project steps are classified into several steps which are as follows:

(1) Data collection

Firstly, this project has focused on one keyboard model which is Model A at OBA station. The data has been collected for 1 month and focused on two significant inputs. These are defect quantity and defect types of keyboard.

(2) Pareto analysis

The pareto chart will be employed to recognize the problem and establish the problem priority. These tools can only define which problems exist and which one should have the highest priority. In general terms, at this point in the problem-solving process, the specific problem has not been clearly defined.

(3) Defining the problem

After the main defects are defined, the why-why diagram will be implemented. This method will determine what factors have to be in place in order to respond to the opportunity. It organizes the chain of symptoms leading to identifying the root causes of the defect. This will explain how to fit the possible root cause.

(4) Analyzing the problem and process

In this stage, the possible root cause is determined and the involved production process will be measured. All information has been gathered by trial and error and analyzed what happened at the OBA station and recorded the defective keyboards for 1 month. In addition, all information will be used to generate possible solutions.

(5) Developing solution alternatives

After the concerned process are defined, the possible solutions will be generated. This project will focus on the maintenance program which are the preventive and the predictive maintenance program.

(6) Implementing the solutions

The potential solutions have been defined in order to judge whether or not the implementation of the SPC tools would be helpful to the production process.

3.3 Data Collection

Data collection is the beginning step to identify the main defect. Prior to Pareto analysis step, we need to get two components of Pareto which are the types and the number of defect occurrence at the OBA station. The data will be collected daily within one month. We focus on only one model which is model A at the OBA station. The data will be collected in the form of a daily record as Figure 3.2. Then all records are concluded at the end of month to summarize the defect types, summation of quantity of each defect, inspected quantity, and the defective part per million (DPPM) as shown in Table 3.1. The DPPM is calculated by using the formula as below:

$$\text{DPPM} = \frac{\text{Defective Quantity} \times 1{,}000{,}000}{\text{Total Inspection Quantity}}$$

OBA Inspection Records

Model : ______________________________ Date : ________________

Production Line No. : ________________

Inspection Quantity : ________________

Inspection Item	Defects	Defect quantity
1. Visual Inspection		
2.Functional Inspection		
	Total	

Recorded by ___________________

Figure 3.2. Daily Record Form.

3.4 Pareto Analysis

After I have collected the defective keyboards for both defect quantity and defect types of Model A for one month period, I present this data by using the Pareto charts. The data gathered gives the defect types and the number of occurrences for each defect.

Table 3.1. Summary of Model A OBA Records.

Defect	Defect Quantity	Defective Rate (DPPM)
Power on Fail	14	280
Non Action of Button	5	100
Poor Feeling on Button	7	140
Poor Printing on Button	22	440
Wrong Row	4	80
Total	52	1040

Firstly, I make the table by gathering data and tallying the number in each category. Then, the percentages and cumulative percentage will be tabulated. The main defects have the highest number of occurrences from the table. The category is listed by the number of occurrences.

Refer to Table 3.2. The percentage column shows poor printing 42 %, 'Power on' failure 27%, Poor feeling 13%, Non action 10% and Wrong row 8%, respectively. We can monitor that the main defect is button poor printing because the number of occurrences has the highest frequency.

Category	Number	Percent	Cumulative %
Poor Print on Button	22	42%	42%
Power on Fail	14	27%	69%
Poor Feeling on Button	7	13%	83%
Non Action of Button	5	10%	92%
Wrong row	4	8%	100%

This is prioritized by the descending order which is as follows:

(a) Poor printing on Button which is described as incomplete character, button dirty or ink smear on button, wrong alignment, and character distortion. This defect is concerned with Tempo printing process.

(b) Power on fail refers to the keyboard which has a functional problem. The keyboard cannot power on.

(c) Poor feeling on Button which describes that the buttons donot respond as they should. We must have more force while we key in data.

(d) Non action of Button is the defect in which the button is not active after we press during the functional test.

(e) Wrong row which occurs when the operators insert the buttons in the row of the topcase. Because each row has the slope specification to match with the surface slope of the button. After we look through the keyboard from left to right viewpoint, we will see a button if standing in an abnormal position.

All of this information is shown in the Figure 3.3, the categories are ordered from largest to smallest occurrences. The left scale tracks the number of defects per category

(b) The incomplete character

Some characters or marking are missed. The character is not fulfilled in place.

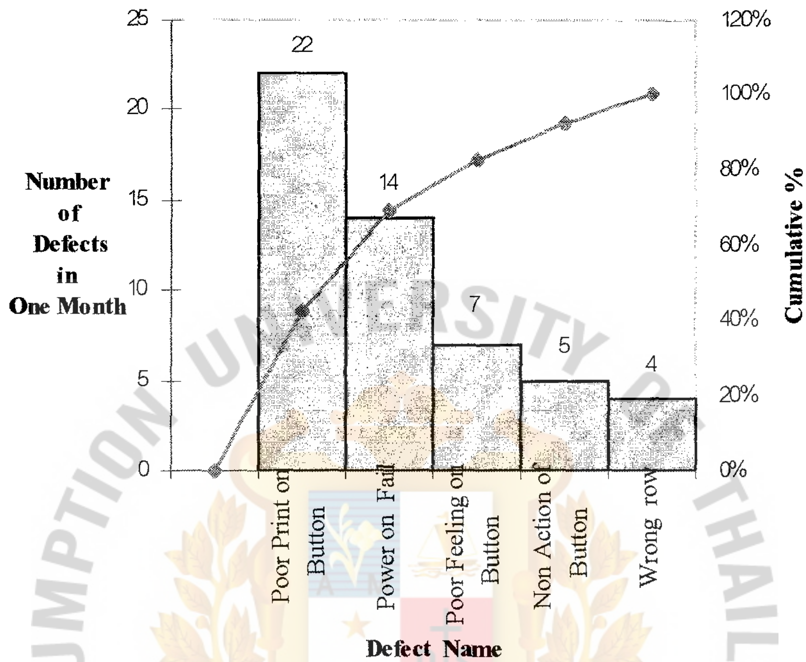

Figure 3.3. Pareto Chart of Defect Priority.

(c) Ink smear on the buttons

After the printing process, we found there was the ink on the keyboard button surface. There was a line of ink or a small dot on the button. Eventually, all defective symptoms will be linked in the form of a chain in the Why-Why diagram. It will start from left to right that shows the defect, possible symptoms, and the possible root causes, respectively. The application of the Why-Why diagram will express a problem as shown in Figure 3.4.

3.6 Analyzing the Problem and the Process

According to the preceding part, the problem is defined and the related of symptom is expressed in a chain of Why-questions in Figure 3.4. The problem will lead to the root causes and the process step concerned.

(a) Distortion of character describes the wrong alignment and ink spread. The wrong alignment occurs when the marking plate is set up in a wrong position. It causes the rubber pad, ink carriers, to miss the character position on the plate. The ink carrier will press on the marking plate then they are moved to stamp on the button of the keyboard. The problem shows the incorrect marking plate set-up. It concerns the technician who will be responsible for this issue. The possible root cause is the technician who did not follow the work instructions strictly. Therefore, the technician must be trained how to set it up.

For the ink spread, the characters are non conformant. It occurs when the rubber pads are pressed on the button with the improper pad down adjustment and abnormal pressure either too high or too low. This affects the smoothness of the outcome. The root cause is the pad down adjustment out of control. The pad down stroke adjustment and pressure specification are defined in the Engineering manual but the technician may not attend the pressure set up. This shows that the technician may not follow the specification. So, the problem identifies the set up of the rubber pad which must be controlled strictly.

(b) In the case of incomplete character, the problem occurs when the plate is dirty, button dirty, rubber pad dirty, rubber pad tilted and rubber pad surface rapped, and ink viscosity. Firstly, the marking plate is dirty because the ink sticks in the marking plate hole. This focuses on the operator performance and poor cleaning process. Secondly, the button is oily and prevents action. The buttons have been waxed by oil to prevent the scratch defect during transportation. The ink may not catch the button surface. The cleaning process is needed. Thirdly, the rubber pad is dirty because the ink are dries on the rubber pad. The cleaning process is poor. There is no knowledge of the procedure how to clean the rubber pad. Fourthly, rubber pad tilt and rubber pad rapped problem occur when rubber pad presses on the plate with the abnormal pad down stroke. This is the root cause in the case of an incorrect set-up of the pad down. Lastly, the ink viscosity means the level of ink thickness. The ink viscosity relates to the thinner mixture. The thinner can evaporate any time. From this, the viscosity will be higher. It causes the ink to have high viscosity and affects the quality of printing. This process lacks the control even though the specification is already defined in the Engineering manual. So, the control of the viscosity is a must.

(c) For the Ink smear, there is ink on the button because the metal blade is chipped. Mainly, the problem is caused by the blade set-up. The angle should be set following the work instructions. The blade wipes the marking plate. This causes the metal blade to chip. From time to time, the technician must check the position of the blade. Another problem is the blade pressure adjustment. If too much pressure is applied to the metal blade, the metal blade will be dented and scratch the edge of each character on the marking plate. When the blade is dented, it can not spread out the ink smoothly.

After the problems are clearly defined at the preceding section, the critical process is the Tampo printing process. With reference to Figure 3.5, Tampo printing will receive the WIP from the keycap line. All materials must be cleaned up before operators release them to the Tampo printing. After the WIP printing, the inspector must inspect the printing product. If there is any defective printing, the defect must be sent to the repair station.

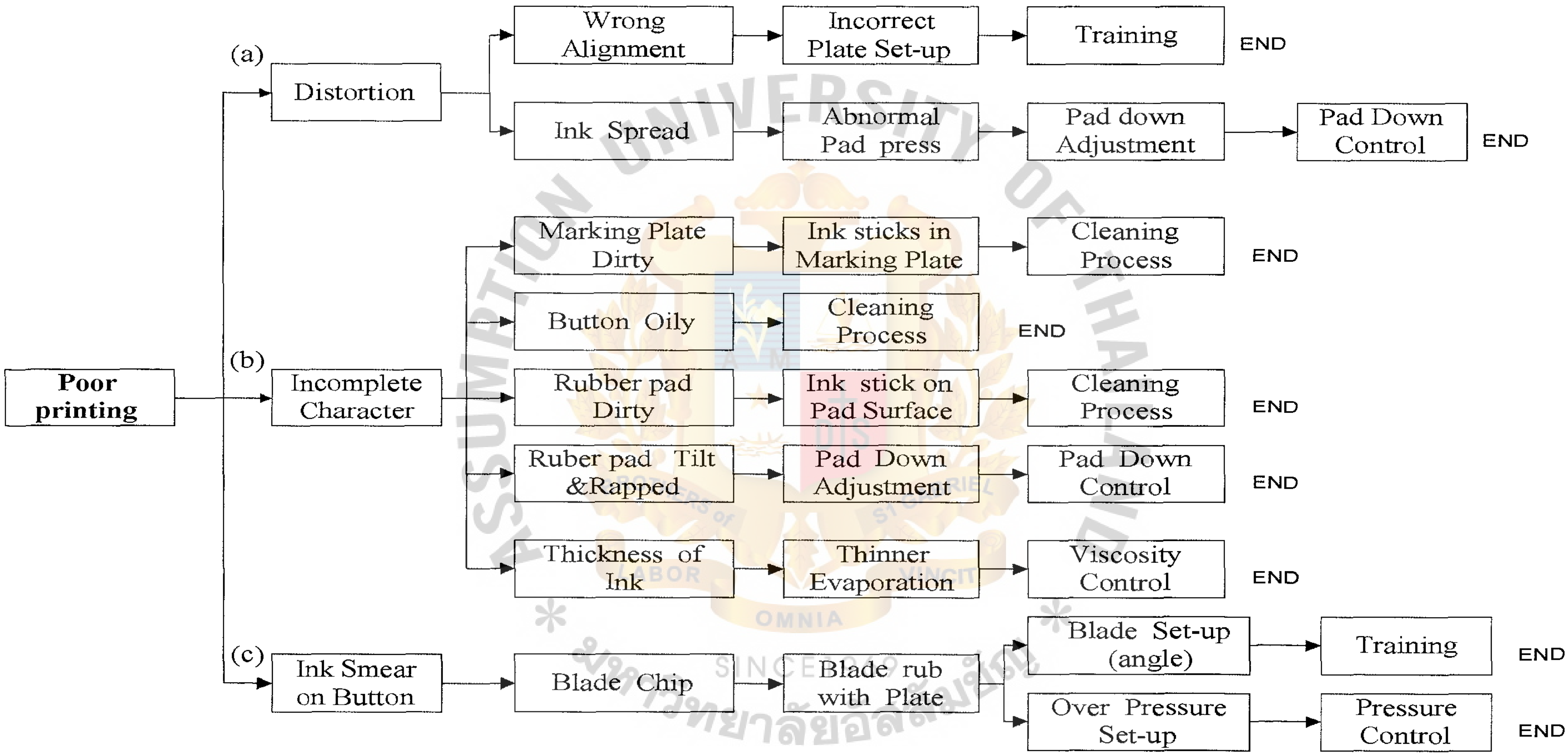

Figure 3.4. Why-Why Diagram of Poor Printing on Button.

Otherwise, the good products will be sent to the final assembly line. At the Tampo printing process, the components of the equipment and the machine are included with the Tampo printing machine, rubber pad, metal blade, marking plate, ink and the top case keyboard that is already filled with the keyboard buttons.

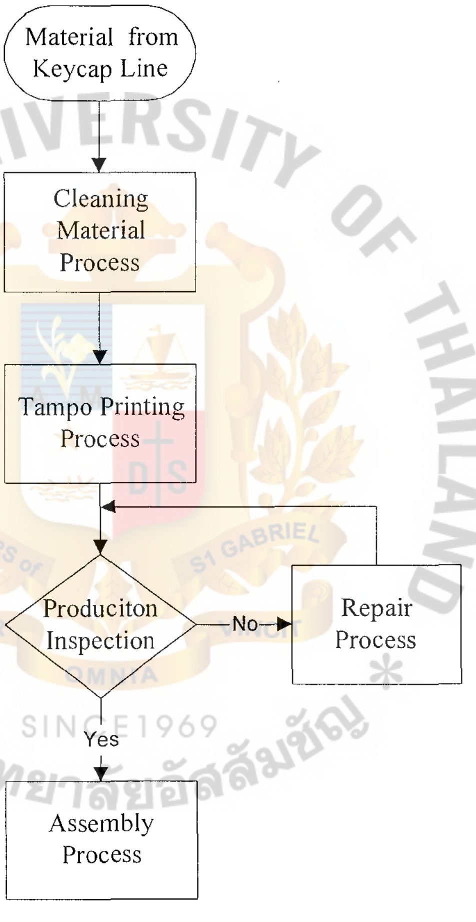

Figure 3.5. Tampo Printing Process.

The problem analysis, identifies that the problem may occur when the equipment is damaged or dirty, improper equipment and machine set-up or adjustment, and dirty materials. However, all possible root causes are concluded and shown on the fishbone diagram. The fishbone diagram will separate the root cause into four parts concerned. These are man, materials, methods, and machine, Figure 3.6.

The first item, Man ,the problem may be concerned with improper training and the instruction ignorance.

The second item defines the problem of the materials which are the button quality and the thickness of ink.

The third item concerns the machine and equipment including the Tampo machine, rubber pad, metal blade and marking plate.

The fourth item concerns the method of cleaning and pressure setup.

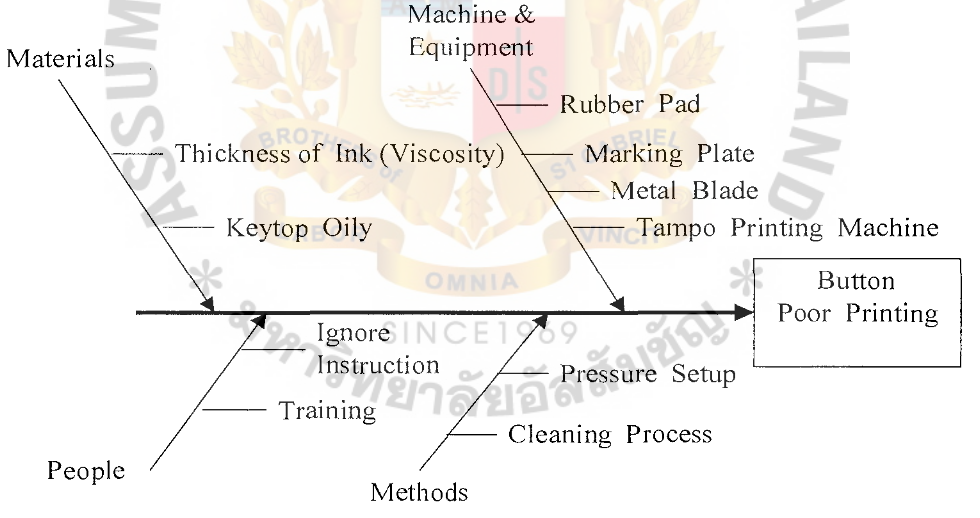

Figure 3.6. Fishbone Diagram of Defect Factors.

3.7 Developing Solution Alternatives

The company needs to control and improve the product quality. This project will lay emphasis on the maintenance program which are the preventive and the predictive maintenance to control the process. From the preceding section, the problems are identified and the factors are listed. In order to see the main factors and select the solutions to solve the problem, we need to implement them. With reference to Figure 3.5, there are many causes concluded in the Fishbone diagram.

In this project, I will select only some main factors that cause defect rate to be high to implement. In this project, the implementation plan will be separated into two parts. First implementation plan is the preventive maintenance program to prevent the equipment and machine damage during production process. It may cause the process to shut down or the defect to occur. Second implementation plan is the predictive maintenance program to control and monitor the process.

The purpose of implementation is aimed to control only some variables or factors that may lead the process to higher quality level. Thus, this project will not implement all factors concerned. It causes the project scope to extend more.

3.8 Preventive Maintenance Program

With reference to Figure 3.6, the M-Machine and equipment will be considered. All equipment and machines used for the printing process will be prevented. In this section, the cleaning process is included. The preventive maintenance program will be set-up for the rubber pad, marking plate, blade and Tempo printing machine. The program will involve the storage, cleaning, check status, and lifetime usage.

Refer to Table 3.3, the preventive maintenance program for all equipment and Tampo machine are shown.

(a) Rubber Pad with preventive maintenance

Usage period is set-up for all rubber pads. They must be changed after nine thousands keyboards are printed in the process or when the rubber pads are unusable. The technician records the usage of the rubber pad during the keyboard printing.

Cleaning Process specifies how to clean the rubber pad correctly. The technician must follow the work instructions strictly. The work instructions do not allow the technician to use any chemical to clean the pad surface. It causes the rubber pad to be destroyed. Especially, the technician must check the rubber pad status before usage. It must be clean and in complete status and ready for use. The dirty or torn rubber pad causes the incomplete character problem because they can not fully catch on the plate pattern. Eventually, the technician must keep the cleaning rubber pad in the defined place.

(b) Metal Blade with preventive maintenance

Usage period is defined and the blade should be changed when it is dented and rusted The technician must check the blade status before and after usage . This program will prevent the dirt and smear problem.

The cleaning process will include how to keep the blade correctly. The blade will be cleaned before and after usage. Firstly, the technician must check the blade status before usage. If the blade is dented, rusted, or dirty, the technician must change to a new one or clean it. The blade must be cleaned and coated with lubricant oil before storing. It will prevent the rust problem. The blade must be kept in a dry place.

Blade set-up has been defined in this program. The blade will be set-up at an angle of 15-18 degrees with the marking plate, the angle set-up will cause the blade to scrape the edge of the plate. It will lead to the dirt or smear problem. Thus, this method will help to prevent the plate from the scratch and the blade from the dent problem.

(c) Marking Plate with preventive maintenance

Usage Period is defined and the plate will be changed when one million keyboards are printed and when the customer's specification changes. However, if there is plate scratch, or rust, the plate will be repaired, cleaned or changed in the vital case.

Cleaning Process is restricted to the part of plate holes cleaning. Naturally, the plate has the characters and sign pattern. There are a lot of hole on the plate surface. The hole pattern is narrow and deep. The operator must pay more attention during cleaning. The special tools are provided to clean up the plate. The operator must use the defined brush to clean the plate until the plate is clean. It will prevent the ink sticking in the plate hole problem that cause the incomplete character symptom. The plate should be checked for status, scratch, rust, and dirt before usage.

(d) Tampo Printing Machine with preventive maintenance

Usage Period is defined 5 years life time.

Maintenance process will have specific maintenance period for maintenance. For daily maintenance, the technician must clean the machine around with a cloth. Then, the technician must check the status of the plate, blade and rubber pad. For weekly maintenance, the technician must grease the acting part with lubricant oil and drain the water from the drain valve. For monthly maintenance, the technician must clean the internal machine parts with cloth and brush. For semi-annual maintenance, the technician must add long life oil on fixed screws to prevent rust, clean and check all parts thoroughly with a multimeter and other tools.

The preventive maintenance is very useful to the firm because it can help to reduce cost and loss of time during machine breakdown and to ensure that the production process can produce the quality products.

Table 3.3. Preventive Maintenance Program.

Preventive Maintenance Program				
Equipment / Machine	Usage Period	Cleaning Process Maintenance Process	Keeping Method	Status
Rubber Pad	1. 9,000 keyboards printing 2. Rubber is torn	1. Chemical is not allowed to be use 2. Clean with sticker tape	Keep in the defined place	Clean No tear
Blade	1. 50,000 keyboards printing 2. Blade is dented 3. Blade is rusted	Cleaning with alcohol and cloth	1.Coated with lubricant oil and packed in plastic bag 2. keep in dry place	Clean No dent No rust
Marking Plate	1. 1,000,000 keybords printing 2. Upon to customer 'spec. 3. Vital scratch or damage	1.Cleaning with lubricate oil 2.Cleaning the hole of plate thoroughly with specific brushes and pointed knife	1.Coated with lubricant oil and packed in plastic bag 2. keep in dry place	Clean No scratch No rust
Tampo Printing Machine	5- year life	Daily Maintenance 1. Clean machine around with cloth 2. Check the status of marking plate, blade rubber pad Weekly Maintenance 1. Add R32 oil in oil valve 2. Drain water from drain valve 3. Grease acting part with lubricant oil Monthly Maintenance Clean the internal machine parts with cloth and brush Semi-annual Maintenance 1. Add long life oil on fixed screws to prevent rust 2. Check and clean all parts thoroughly with tools	Keep on cleanin place Turn off power	Workable

3.9 The Predictive Maintenance

In this part, the predictive maintenance emphasizes on the process monitoring. Thus, I will apply the control chart ($\bar{x}$ and R chart) to monitor the process by using some parameters in the Tampo printing process. With reference to Figure 3.5, I will select pressure the set-up in part of the M-Method and ink viscosity in the part of M-Materials to implement. The parameters which are ink viscosity level, blade down pressure adjustment and rubber pad pressure set-up are to be used to monitor the process.

However, all parameter specifications are already defined in the Engineering Manual. This project implement the plan to ensure these parameters setup follow the specification. Thus, I start to collect data by recording every two hours for 3 months. All data gathered will be used to make the control chart and interpret in the form of x and R chart control process. In this part, I will make the control chart to monitor the process by using the data gathered from the parameters setup records for three months. Three parameters which are viscosity level, blade pressure set-up and the pad down adjustment will be monitored respectively.

The specifications of viscosity, blade pressure set-up and rubber pad down adjustment are defined in the Engineering Manual as shown in the table 3.3.

(a) The first parameter, the viscosity parameter will be discussed. The viscosity is the level of ink thickness. The main factor is the thinner. From time to time, the thinner will evaporate. It cause the viscosity level to be high. This problem will cause every symptom of poor printing to occur. The viscosity has affected the pressure set-up or adjustment directly. Thus, this project will focus on the viscosity level by keeping record and make x and R chart to predict the process trend.

The specifications of viscosity, blade pressure setup and rubber pad down adjustment are defined in the Engineering Manual as shown in the table 3.4.

Table 3.4. Tampo Printing Specification.

Description	Specification
Printing ink & Thinner Viscosity	285 ± 10 mPa.s
Blade Down Pressure Adjustment	1.7 ± 0.2 Kgf/CM^2
Rubber Pad Down Adjustment	85 ± 7 Millimeter

The record of the data for three months at the Tampo printing process in the part of ink viscosity or thickness of ink as shown in table 3.5. The viscosity level is kept every two hours during work hours. All data will be used to calculate the Upper Control Limit (UCL), Center Line (CL), and Lower Control Limit (LCL) respectively. Refer to Figure 3.7, the x chart shows the trend of the viscosity level. It shows the changing point at the 22^{nd} data which the trend was decreased, due to Engineering Department change in the specification from 285 ± 10 to 275 ± 10.

According to the x and R formulas and the constants as shown in Appendix A, the center line of first group data 1-25 is calculated.

Table 3.5. The Viscosity Set-up Records.

Specification : 275-295 mPa.s

Sample number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sample Measurements 1	290	284	279	285	281	291	282	292	280	280	284	278	290	281	285	285	285	284	283	285
2	285	282	281	290	290	290	289	287	284	290	285	290	281	285	281	290	291	284	285	285
3	281	292	285	286	282	285	284	288	282	282	288	280	285	286	286	284	284	290	288	284
4	287	288	284	291	280	283	288	281	280	282	286	281	288	282	276	287	282	279	290	280
5	290	287	289	284	279	284	283	286	286	282	291	279	283	279	283	285	280	280	284	281
SUM	1433	1433	1418	1436	1412	1433	1426	1434	1412	1416	1434	1408	1427	1413	1411	1431	1422	1417	1430	1415
$\overline{X} = \frac{\text{No.of Records}}{\text{Sample size}}$	286.6	286.6	283.6	287.2	282.4	286.6	285.2	286.8	282.4	283.2	286.8	281.5	285.4	282.6	282.2	286.2	284.4	283.4	286.0	283.0
R = Highest-Lowest	9	10	10	7	11	8	7	11	6	10	7	12	9	7	10	6	11	11	7	5

Table 3.5. The Viscosity Set-up Records. (Continued)

Specification : 265-285 mPa.s

Sample number		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Sample Measurements	1	285	278	279	282	281	281	281	276	283	278	282	276	278	280	281	279	279	281	280	271
	2	284	280	285	284	272	280	280	280	279	277	279	270	274	280	279	279	272	271	276	275
	3	278	282	275	280	280	271	279	278	285	276	278	280	280	281	271	273	280	281	278	273
	4	287	276	282	280	275	280	282	279	274	279	279	279	275	272	277	276	274	274	279	282
	5	284	288	284	285	279	280	276	271	279	280	277	277	276	282	280	277	281	272	281	278
SUM		1418	1404	1405	1411	1387	1392	1398	1384	1400	1390	1395	1382	1383	1395	1388	1384	1386	1379	1394	1379
$\overline{X} = \frac{\text{No.of Records}}{\text{Sample size}}$		283.6	280.8	281.0	282.2	277.4	278.4	279.6	276.8	280.0	278.0	278.9	276.4	276.6	279.0	277.6	276.8	277.2	275.8	278.8	275.8
R = Highest-Lowest		9	12	10	5	9	10	6	9	11	4	5	10	6	10	10	6	9	10	5	11

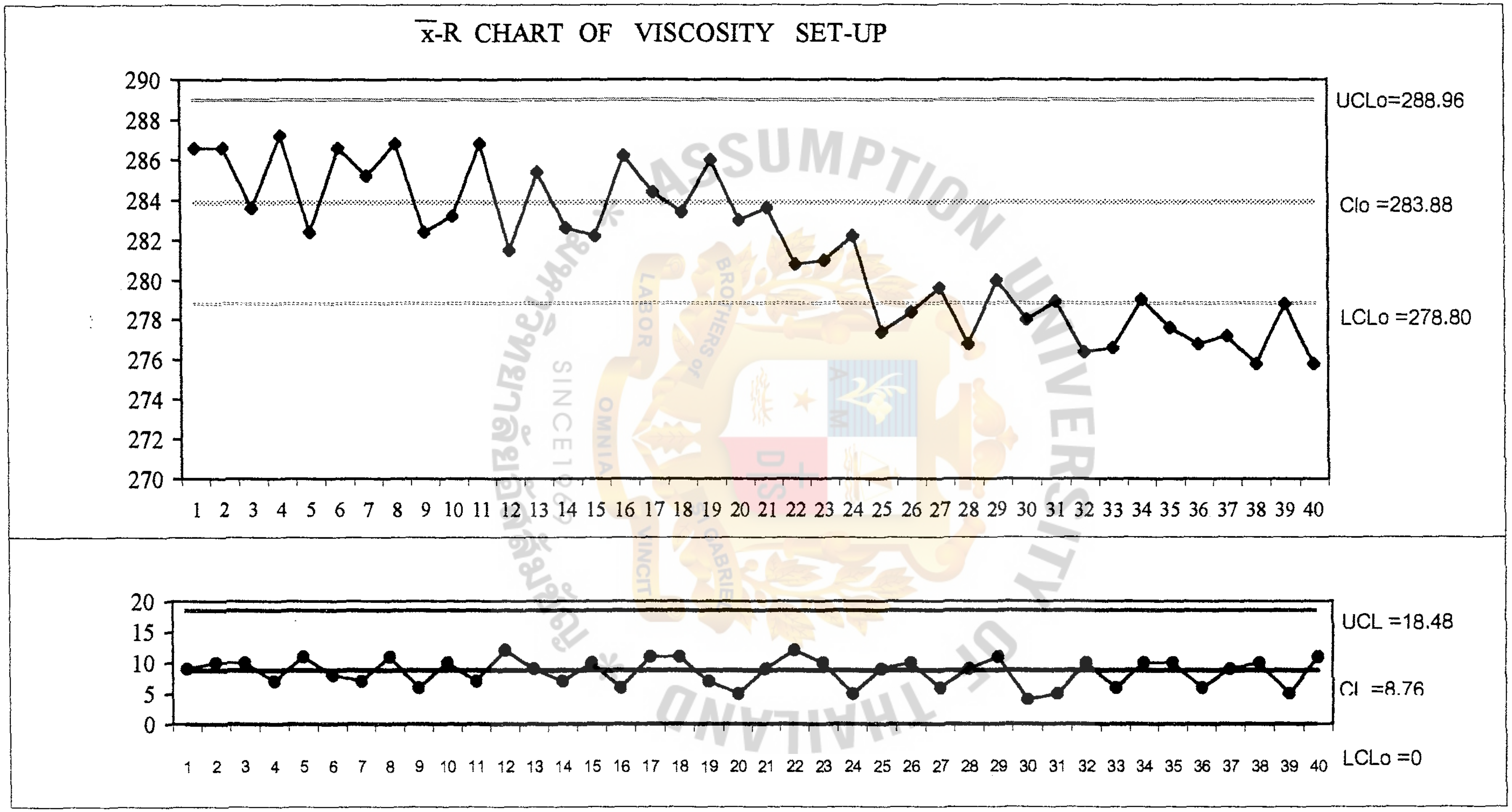

Figure 3.7. $\overline{x}$, R Chart of Viscosity Set-up.

$$\text{Center line of } \overline{x} = \frac{\Sigma \overline{x}}{k}$$

$$= \frac{7{,}097}{25}$$

$$= 283.88$$

$$\text{Center line of R} = \frac{\Sigma R}{k}$$

$$= \frac{219}{25}$$

$$= 8.76$$

From the calculation by using the data 1-25, we know that x is 283.88 and R is 8.76. Next, we will calculate the UCL and LCL of R and $\overline{x}$ respectively. Calculate $UCL_{\overline{R}}$ and $LCL_{\overline{R}}$ as shown below, the constants value are shown in the Appendix A.

$$UCL_{\overline{R}} = D_4 * \overline{R}$$

$$= 2.114 * 8.76$$

$$= 18.48$$

$$LCL_{\overline{R}} = D_3 * \overline{R}$$

$$= 0 * 8.76$$

$$= 0$$

Then, Calculate $UCL_{\overline{\overline{X}}}$ and $LCL_{\overline{\overline{X}}}$ as show below

$$UCL_{\overline{\overline{X}}} = \overline{\overline{X}} + A_2 * \overline{R}$$

$$= 283.88 + (0.577 * 8.76)$$

$$= 288.96$$

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

$$= 283.88 - (0.577 * 8.76)$$

$$= 278.80$$

Now, all UCL, CL and LCL of x and R are already calculated. We used all of them to control and monitor the process.

With reference to Figure 3.8, this will show the computation of UCL old and new, the x and R chart of viscosity set-up after the UCL, CL and LCL the first period shows the process is in control but is based on the old specification. Then, we need to calculate the new UCL, CL, and LCL of the second period that starts from data 25^{th} - 40^{th}.

$$\text{Center line of } \bar{x} = \frac{\Sigma \bar{x}}{k}$$

$$= \frac{4{,}443.04}{16}$$

$$= 277.69$$

$$\text{Center line of R} = \frac{\Sigma R}{k}$$

$$= \frac{131}{16}$$

$$= 8.188$$

From the calculation by using the data 25-40, we know that x is 277.69 and R is 8.19. Next, we will calculate the UCL and LCL of R and x respectively. Calculate UCL_R and LCL_R as shown below,

$$UCL_R = D_4 * \bar{R}$$

$$= 2.114 * 8.19$$

$$= 17.28$$

$$LCL_R = D_3 * \overline{R}$$

$$= 0 * 8.18$$

$$= 0$$

Then, Calculate UCL and LCL as shown below

$$UCL = \overline{\overline{X}} + A_2 * \overline{R}$$

$$= 277.69 + (0.577 * 8.18)$$

$$= 282.44$$

$$LCL_{\overline{R}} = X - A_2 * \overline{R}$$

$$= 277.69 - (0.577 * 8.18)$$

$$= 272.95$$

Now, all UCL, CL and $\overline{x}$ and $\overline{R}$ are already calculated. We used all of them to control and monitor the process.

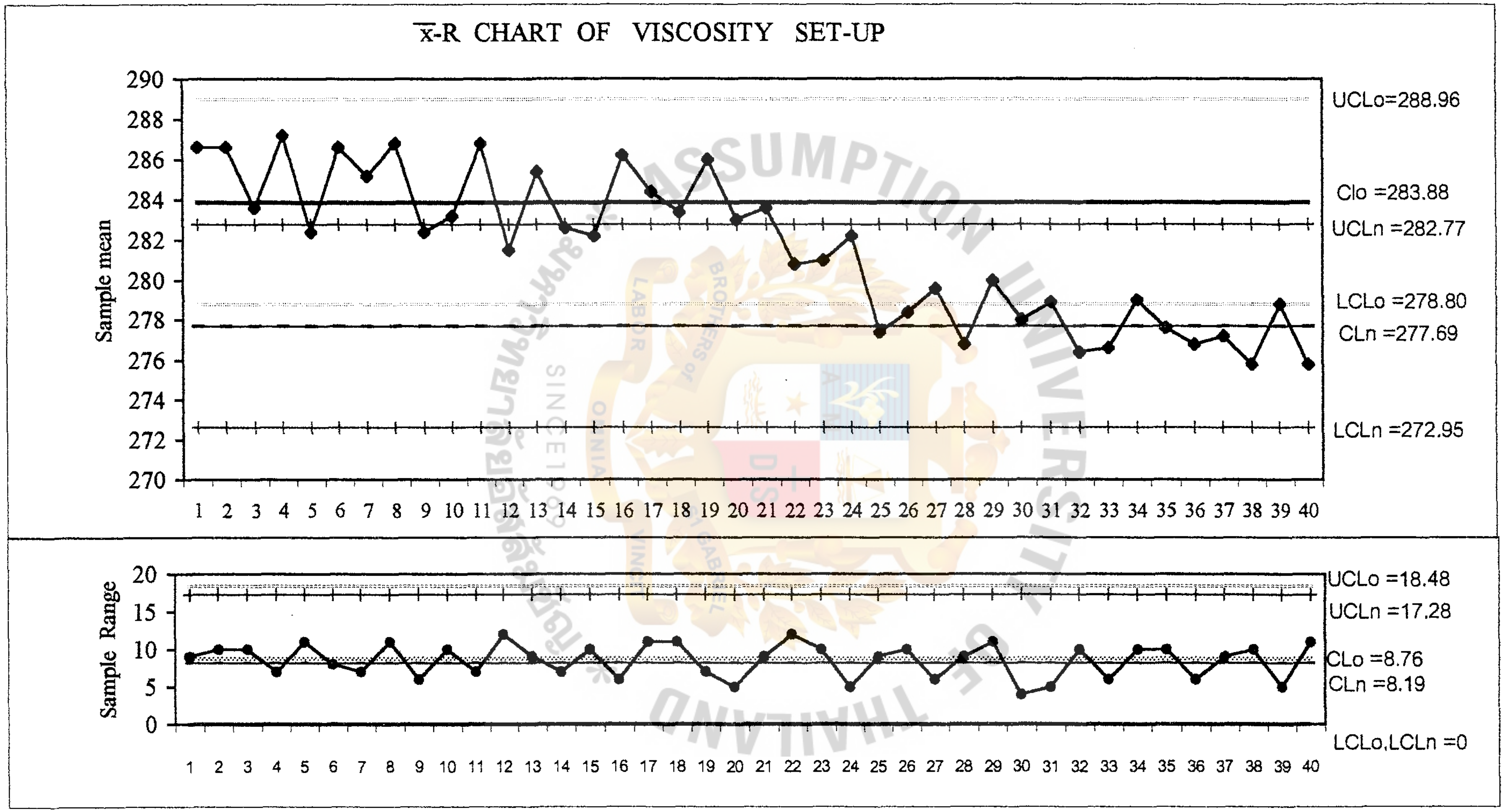

Figure 3.8. $\overline{x}$-R Chart of Viscosity Set-up.

(b) The second parameter is the blade down pressure adjustment. The over pressure causes the blade chip and plate scratch. This problem cause the smear on the button. The implementation plan will control the blade pressure set-up to decrease the dirt/smear problem.

With reference to Figure 3.9, the x and R chart of blade pressure setup after the UCL, CL and LCL the first period show the process is in control.

Then, we need to calculate the new UCL, CL, and LCL of the second period that starts from data 25^{th} - 40^{th}. In order that the blade pressure setup records, as shown in Table 3.5. According to the and formulas and the constants, the center line of first group data 1-25 are calculated.

Table 3.6. The Blade Pressure Set-up Records.

Specification : 1.5 - 1.9 Kgf./ cm^2

Sample number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sample Measurements	1	1.88	1.83	1.77	1.84	1.81	1.87	1.81	1.88	1.81	1.79	1.83	1.76	1.87	1.79	1.85	1.84	1.84	1.83	1.82	1.84
	2	1.85	1.80	1.80	1.88	1.88	1.88	1.87	1.86	1.83	1.88	1.85	1.88	1.81	1.84	1.80	1.87	1.88	1.84	1.84	1.84
	3	1.80	1.88	1.84	1.85	1.80	1.84	1.84	1.88	1.82	1.81	1.87	1.80	1.84	1.85	1.85	1.82	1.83	1.87	1.86	1.83
	4	1.86	1.88	1.83	1.88	1.80	1.82	1.86	1.79	1.79	1.81	1.86	1.81	1.87	1.80	1.75	1.86	1.81	1.78	1.88	1.78
	5	1.88	1.86	1.88	1.84	1.80	1.84	1.83	1.85	1.85	1.82	1.88	1.79	1.81	1.78	1.82	1.84	1.79	1.79	1.83	1.79
SUM		9.27	9.25	9.12	9.29	9.09	9.25	9.21	9.26	9.10	9.11	9.29	9.04	9.20	9.06	9.07	9.23	9.15	9.11	9.23	9.08
$\overline{X} = \frac{\text{No. of Records}}{\text{Sample size}}$		1.9	1.9	1.8	1.9	1.8	1.9	1.8	1.9	1.8	1.8	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
R = Highest-Lowest		0.08	0.08	0.11	0.04	0.08	0.06	0.06	0.09	0.06	0.09	0.05	0.12	0.06	0.07	0.1	0.05	0.09	0.09	0.06	0.06

Table 3.6. The Blade Pressure Set-up Records.(Continued)

Specification : 1.5 - 1.9 Kgf./ cm^2

Sample number		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Sample Measurements	1	1.84	1.75	1.77	1.80	1.79	1.80	1.79	1.75	1.81	1.77	1.80	1.74	1.78	1.78	1.80	1.78	1.78	1.80	1.78	1.69
	2	1.83	1.78	1.84	1.82	1.70	1.78	1.78	1.79	1.78	1.75	1.78	1.68	1.72	1.78	1.78	1.78	1.70	1.69	1.74	1.73
	3	1.76	1.80	1.74	1.79	1.79	1.70	1.78	1.76	1.84	1.74	1.77	1.78	1.79	1.79	1.69	1.72	1.79	1.78	1.77	1.71
	4	1.84	1.75	1.80	1.78	1.74	1.78	1.80	1.78	1.73	1.78	1.78	1.78	1.73	1.70	1.75	1.73	1.72	1.72	1.78	1.80
	5	1.83	1.87	1.83	1.84	1.78	1.78	1.75	1.69	1.78	1.78	1.76	1.75	1.74	1.80	1.78	1.75	1.80	1.70	1.80	1.76
SUM		9.1	8.95	8.98	9.03	8.8	8.84	8.9	8.77	8.94	8.82	8.89	8.73	8.76	8.85	8.8	8.76	8.79	8.69	8.87	8.69
$\bar{X} = \frac{\text{No.of Records}}{\text{Sample size}}$		1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.8	1.8	1.8	1.8	1.8	1.7	1.8	1.7
R = Highest-Lowest		0.08	0.12	0.1	0.06	0.09	0.1	0.05	0.1	0.11	0.04	0.04	0.1	0.07	0.1	0.11	0.06	0.1	0.11	0.06	0.11

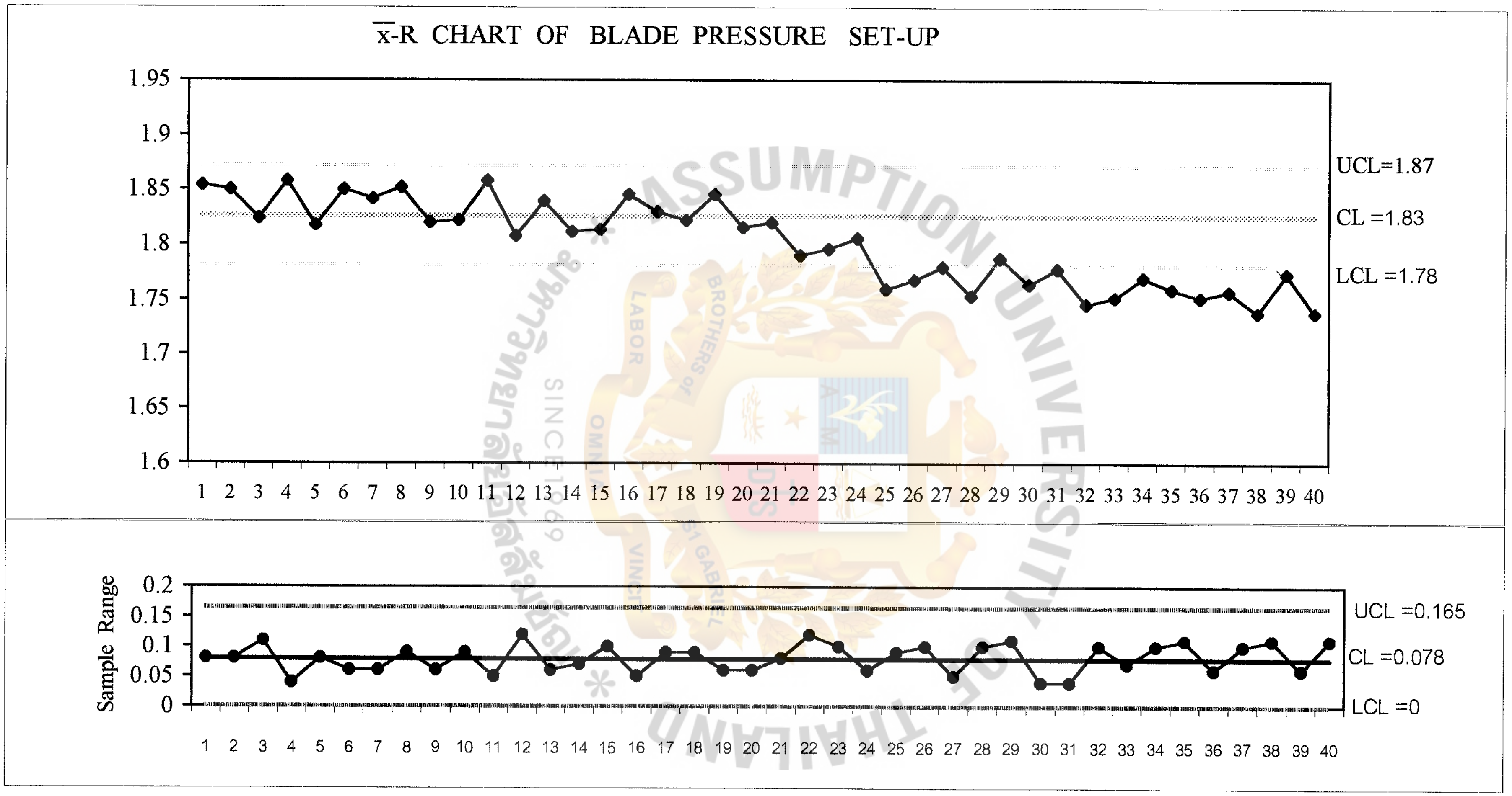

Figure 3.9. $\overline{x}$- R Chart of Blade Pressure Set-up.

$$\text{Center line of } x = \frac{\Sigma x}{k} = \frac{45.75}{25} = 1.83$$

$$\text{Center line of R} = \frac{\Sigma R}{k} = \frac{1.95}{25} = 0.078$$

From the calculation by using the data 1-25, we know that $\bar{\bar{x}}$ is 1.83 and R is 0.078. Next, we will calculate the UCL and LCL of R and x respectively. Calculate UCL_R and LCL_R as show below, the constants value are shown in the Appendix.

$$UCL_{\bar{R}} = D_4 * \bar{R} = 2.114 * 0.078 = 0.165$$

$$LCL_{\bar{R}} = D_3 * \bar{R} = 0 * 0.078 = 0$$

Then, Calculate UCL $\bar{x}$ and LCL $\bar{x}$ as shown below

$$UCL_{\bar{X}} = \bar{\bar{x}} + A_2 * \bar{R} = 1.83 + (0.577 * 0.078) = 1.87$$

$$LCL_{\bar{X}} = \bar{\bar{x}} - A_2 * \bar{R}$$

$$= 1.83 - (0.577 * 0.078)$$

$$= 1.78$$

Now, all UCL, CL and LCL of x and R are already calculated. We used all of them to control and monitor the process.

With reference to Figure 3.10, the x and R chart of blade pressure set-up after the UCL, CL and LCL the first period shows the process is in control. Then, we need to calculate the new UCL, CL, and LCL of the second period that start from data 25^{th} - 40^{th}.

$$\text{Center line of } \bar{x} = \frac{\Sigma \bar{x}}{k}$$

$$= \frac{28.16}{16}$$

$$= 1.76$$

$$\text{Center line of R} = \frac{\Sigma R}{K}$$

$$= \frac{1.34}{16}$$

$$= 0.084$$

From the calculation by using the data 25-40, we know that x is 1.76 and R is 0.084. Next, we will calculate the UCL and LCL of R and x respectively. Calculate $UCL_{\bar{R}}$ and $LCL_{\bar{R}}$ as shown below,

$$UCL_{\bar{R}} = D_4 * R$$

$$= 2.114 * 8.19$$

$$= 17.28$$

$$LCL_R = D_3 * R$$

$$= 0 * 8.18$$

$$= 0$$

Then, Calculate $UCL_{\bar{X}}$ and $LCL_{\bar{X}}$ as shown below

$$UCL_{\bar{\bar{X}}} = \bar{\bar{x}} + A_2 * R$$

$$= 1.76 + (0.577 * 0.084)$$

$$= 1.81$$

$$LCL_{\bar{\bar{X}}} = \bar{\bar{x}} - A_2 * R$$

$$= 1.76 - (0.577 * 0.084)$$

$$= 1.71$$

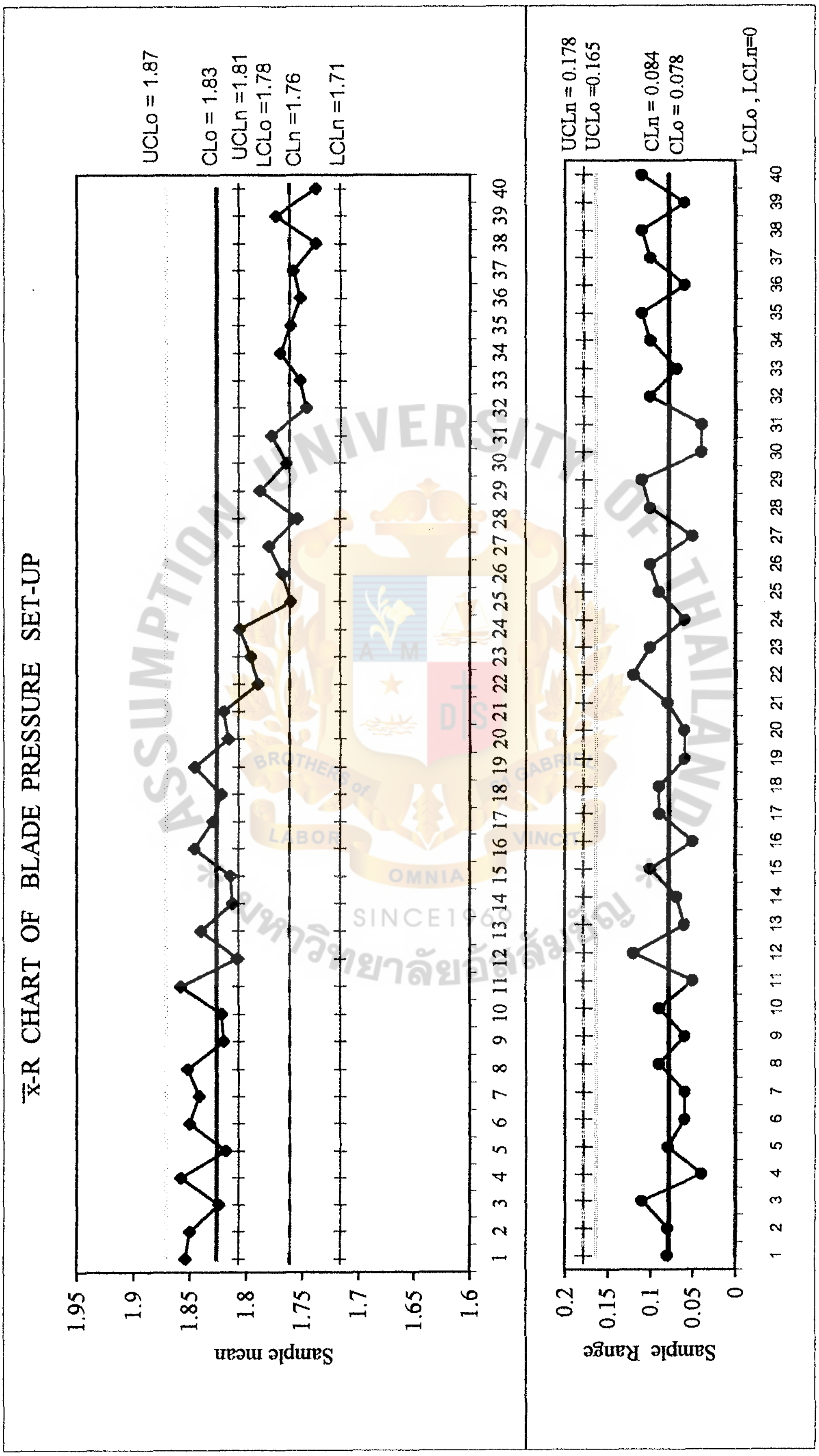

Figure 3.10. $\overline{x}$- R Chart of Blade Pressure Set-up.

(c) The last parameter is the rubber pad down adjustment set-up. The shorter setup causes the character distortion problem to occur while the longer pad down adjustment causes the incomplete character problem to occur. The pad down adjustment set-up should be proper for the printing process. So, this parameter should be controlled.

In order that the rubber pad down adjustment records, as shown in Table 3.7, according to the x and R formulas and the constants, the center line of first group data 1-25 are calculated.

Table 3.7. The Rubber Pad Adjustment Records.

Specification : 78-92 mm

Sample number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sample Measurements 1	85	85	90	86	82	90	83	86	80	82	89	87	88	85	84	84	85	88	85	86
2	90	83	86	84	85	86	84	90	86	86	84	84	84	81	88	81	84	86	89	82
3	83	82	87	89	89	80	87	85	84	84	85	86	81	83	85	82	84	90	88	89
4	87	88	82	83	90	84	80	87	83	87	80	85	86	81	90	86	88	82	79	85
5	84	81	85	84	87	83	85	85	86	85	83	89	88	91	87	90	81	87	84	83
SUM	429	419	430	426	433	423	419	433	419	424	421	431	427	421	434	423	422	433	425	425
$\bar{x} = \frac{\text{No. of Records}}{\text{Sample size}}$	85.8	83.8	86.0	85.2	86.6	84.6	83.8	86.6	83.8	84.8	84.2	86.2	85.4	84.2	86.8	84.6	84.4	86.6	85.0	85.0
R = Highest - Lowest	7	7	8	6	8	10	7	5	6	5	9	5	7	10	6	9	7	8	10	7

Table 3.7. The Rubber Pad Adjustment Records. (Continued)

Specification : 78-92 mm

Sample number	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Sample Measurements 1	88	82	85	88	88	83	81	82	86	83	83	84	90	84	88	87	86	83	86	85
2	86	86	84	86	86	88	84	86	84	86	89	86	89	87	86	89	87	84	85	84
3	83	84	90	82	87	84	88	89	85	82	87	88	85	83	85	88	85	85	84	88
4	84	83	89	85	82	85	85	87	83	89	84	83	83	89	84	87	83	87	89	86
5	87	87	82	84	89	84	89	88	88	84	88	87	86	83	89	83	84	88	87	82
SUM	428	422	430	425	432	424	427	432	426	424	431	428	433	426	432	434	425	427	431	425
X = No.of Records / Sample size	85.6	84.4	86.0	85.0	86.4	84.8	85.4	86.4	85.2	84.8	86.2	85.6	86.6	85.2	86.4	86.8	85.0	85.4	86.2	85.0
R = Highest - Lowest	5	5	8	6	7	5	8	7	5	7	6	5	7	6	5	6	4	5	5	6

Center line of $\bar{x}$ $= \dfrac{\Sigma \bar{x}}{k}$

$= \dfrac{2{,}130.75}{25}$

$= 85.23$

Center line of R $= \dfrac{\Sigma R}{k}$

$= \dfrac{178}{25}$

$= 7.12$

From the calculation by using the data 1-25, we know that x is 85.23 and R is 7.12. Next, we will calculate the UCL and LCL of R and x respectively.

Calculate $UCL_{\bar{R}}$ and $LCL_{\bar{R}}$ as shown below, the constants value are shown in Appendix A.

$UCL_{\bar{R}} = D_4 * \bar{R}$

$= 2.114 * 7.12$

$= 15.02$

$LCL_{\bar{R}} = D_3 * \bar{R}$

$= 0 * 7.12$

$= 0$

Then, Calculate $UCL_{\bar{\bar{X}}}$ and $LCL_{\bar{\bar{X}}}$ as shown below

$UCL_{\bar{\bar{X}}} = \bar{\bar{x}} + A_2 * R$

$= 85.23 + (0.577 * 7.12)$

$$= 89.36$$

$$LCL_{\bar{\bar{x}}} = \bar{\bar{x}} - A_2 * R$$

$$= 85.23 - (0.577 * 0.078)$$

$$= 81.10$$

Now, all UCL, CL and LCL of x and R are already calculated. We used all of them to control and monitor the process.

With reference to Figure 3.11, the x and R chart of Rubber pad adjustment after the UCL, CL and LCL the first period show the process is in control. Then, we need to calculate the new UCL, CL, and LCL of the second period that starts from data 25th - 40th.

Center line of $\bar{x}$ $= \dfrac{\Sigma \bar{x}}{k}$

$$= \frac{28.16}{16}$$

$$= 85.71$$

Center line of R $= \dfrac{\Sigma R}{k}$

$$= \frac{1.34}{16}$$

$$= 5.875$$

From the calculation by using the data 25-40, we know that x is 1.76 and R is 0.084. Next, we will calculate the UCL and LCL of R and x respectively.

Calculate $UCL_{\bar{R}}$ and $LCL_{\bar{R}}$ as shown below,

$$UCL_{\bar{R}} = D_4 * \bar{R}$$

$$= 2.114 * 5.875$$

$$= 12.396$$

$$LCL_{\overline{R}} = D_3 * \overline{R}$$

$$= 0 * 5.875$$

$$= 0$$

Then, Calculate UCL_X and LCL_X as shown below

$$UCL_{\overline{\overline{X}}} = \overline{\overline{x}} + A_2 * \overline{R}$$

$$= 85.71 + (0.577 * 5.875)$$

$$= 89.12$$

$$LCL_{\overline{\overline{X}}} = \overline{\overline{x}} - A_2 * \overline{R}$$

$$= 85.71 - (0.577 * 5.875)$$

$$= 82.31$$

The new UCL, CL and LCL are plotted on the X chart as shown in figure 3.12. Finally, the Pareto analysis will be made again to monitor the defect quantity and to ensure the implementation plan can reach to the quality improvement goal. The result will be discussed in the next section.

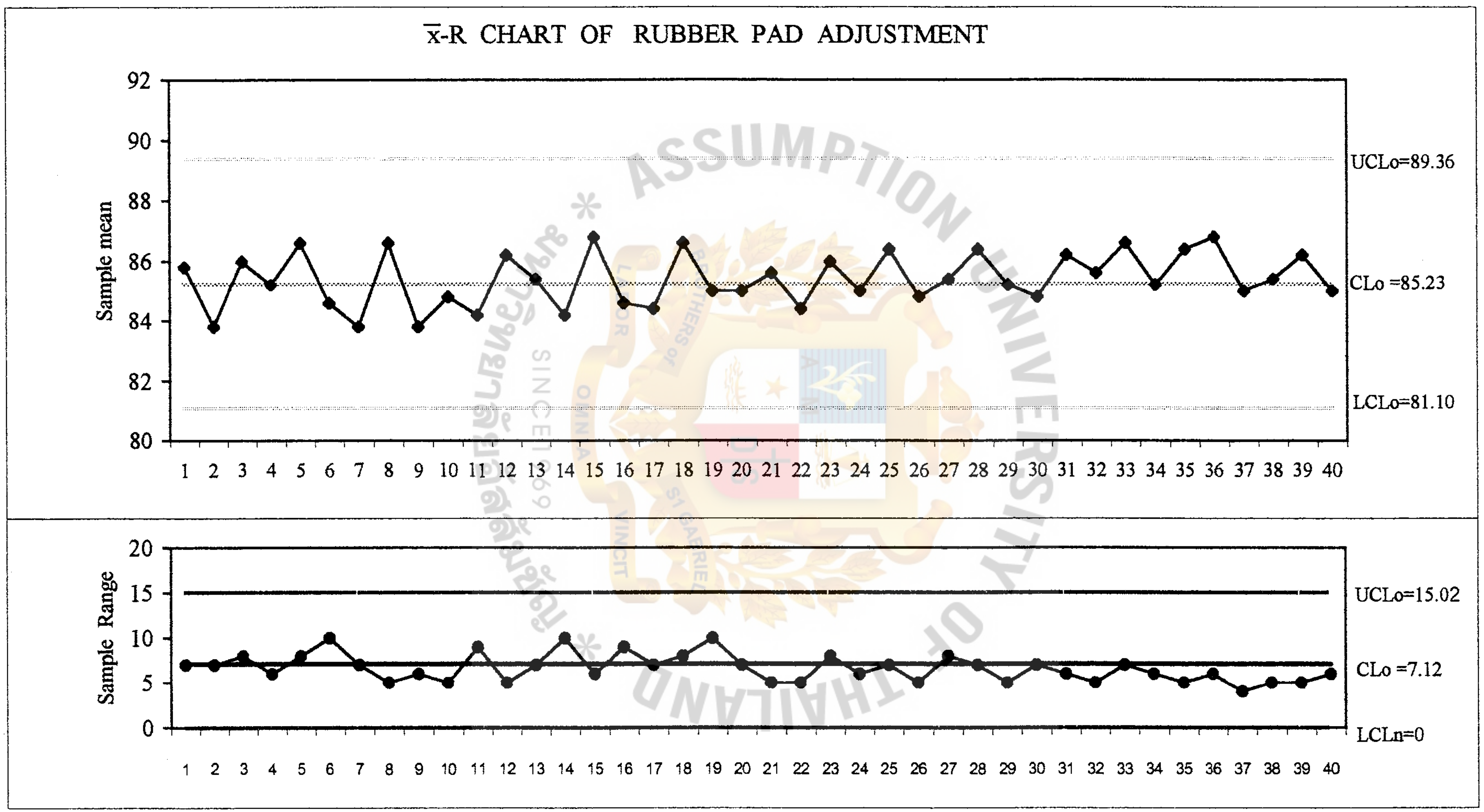

Figure 3.11. $\overline{x}$, R Chart of Rubber Pad Adjustment.

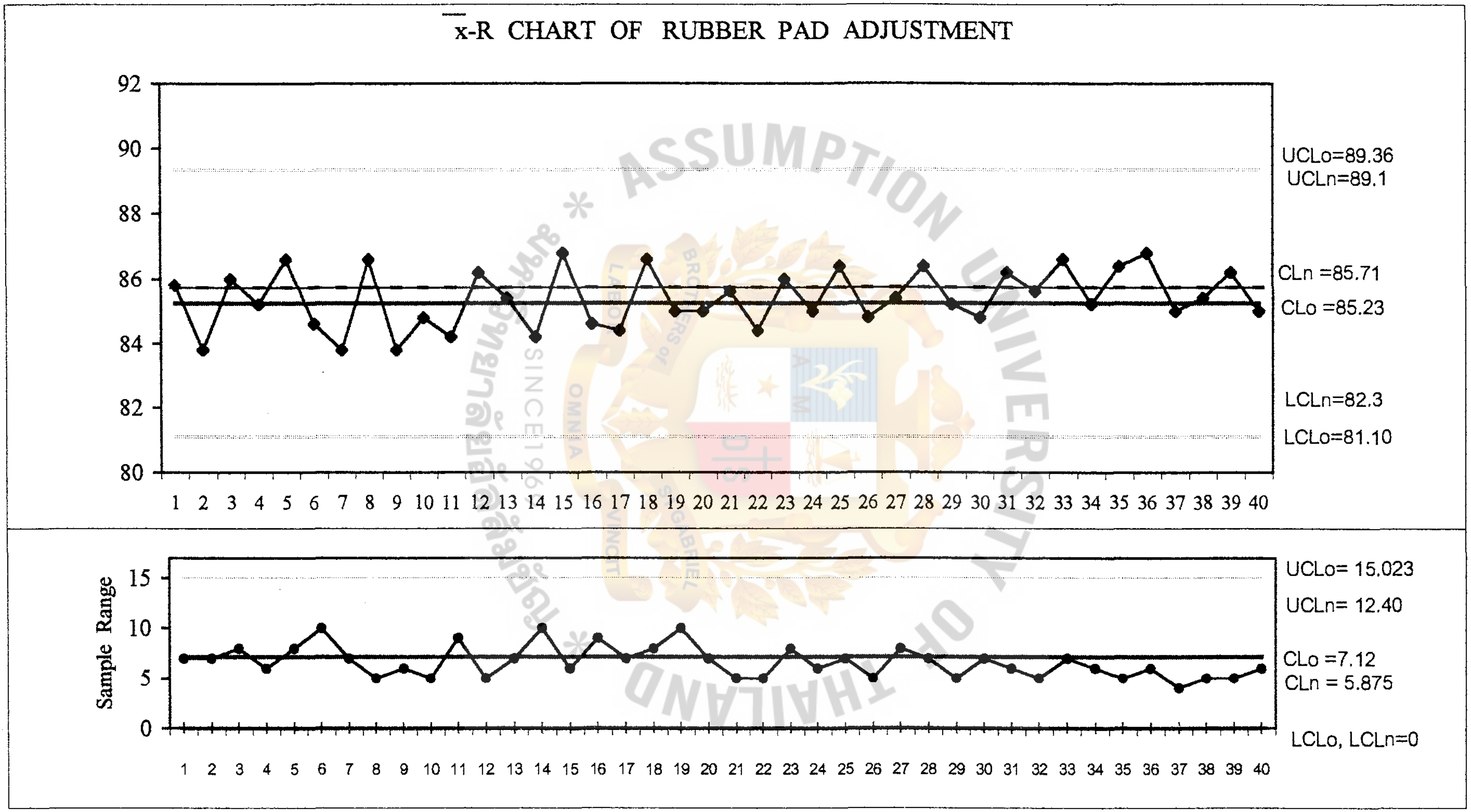

Figure 3.12. $\overline{x}$, R Chart of Rubber Pad Adjustment.

IV. IMPLEMENTATION RESULT AND DISCUSSION

4.1 Predictive Maintenance

(a) Control chart of Viscosity level

As in Figure 3.8, the graph of $\bar{x}$ -R chart shows that the process of sample since 1-25 data is in control, but it still has a high defect quantity as shown in Figure 3.3. The computation results are as below

$$UCL_{\bar{X}o} = 288.96$$

$$CL_{\bar{X}o} = 283.88$$

$$LCL_{\bar{X}n} = 278.80$$

Due to the result, all value on the graph are in the control limit but it is of the high level when compared with the second part that the $CL_{\bar{X}o}$ is only 277.69. The cause of high defect comes from the unsuitability of viscosity specification known as poor printing. The engineers found that the high viscosity of ink will affect to the printing process. Then, we try to solve this problem by adding more Thinner into the mixture in order to reduce the viscosity level. We can see that the trend of the $\bar{x}$ -R chart begins to decrease as the sample 23rd, because the engineer has changed the viscosity specification to improve the quality of printing. Then, we must find the new UCL, CL, and LCL to monitor the process in order to recheck whether the new mixture can cause the process to be in control or out of control. From the computing result, the 25th – 40th data identifies that the process is in control show as below.

$$UCL_{\bar{X}n} = 282.44$$

$$CL_{\bar{X}n} = 277.69$$

$$LCL_{\bar{X}n} = 272.95$$

To ensure that the suitable viscosity will affect to the defects, the engineers have to inspect the number of defects at random with the sample size of 250 pieces at any viscosity level such as 265, 267, 269, 271, 273, 275, 277, 279, 281, 283, 285,287,289, 291, 293, 295.

According to Table 4.1, we will compare the relationship between the density of the viscosity and the number of defects. We found that the high density of the viscosity has directly affected the quantity of defects, as shown in Figure 4.1. The Thinner is added to the ink after we record the data and plot the graph, it shows the trend of defective quantity and the viscosity level.

Table 4.1. Defective Quantity with Viscosity Level.

Viscosity Level	265	267	269	271	273	275	277	279	281	283	285	287	289	291	293	295
Defect Quantity	32	25	18	12	9	5	6	8	12	20	25	28	30	32	32	35
Sampling Size	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250

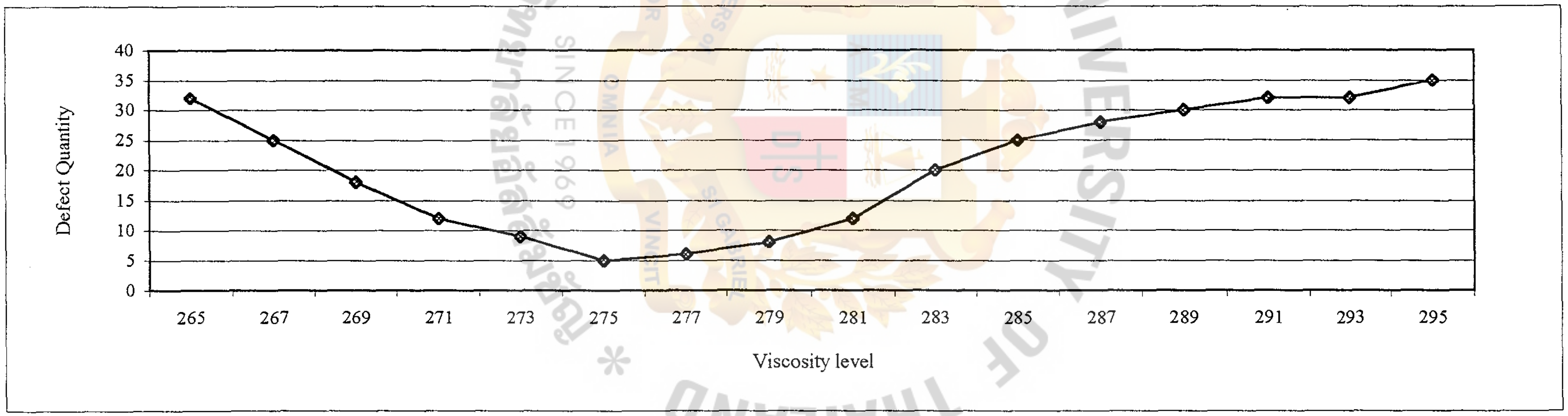

Figure 4.1. Defective Quantity and Viscosity Level.

(b) Control chart of blade pressure set-up

As Figure 3.10, the result can be divided to analyze into two sections. The first part, the result illustrates that the $\overline{x}$ - R chart of blade pressure setup is in control. According to the graph, it shows the result of the 1st – 25th sample as

$$UCL_{Xo} = 1.87$$

$$CL_{Xo} = 1.83$$

$$LCL_{Xo} = 1.78$$

Due to all the values of data still below the UCL and LCL, then we can summarize that our process is in control. In the second part, the result illustrates that the x - R chart of blade pressure set-up is in control. According to the graph, it shows the result of the 25th – 40th sample as

$$UCL_{Xn} = 1.81$$

$$CL_{Xn} = 1.76$$

$$LCL_{Xn} = 1.71$$

From the first result above, even though the process indicates that it is in control but it still is in high pressure. It causes the blade dent, smear problem, and marking plate scratch.

To analyze the second result, the trend of x - R chart is dropping at the 22nd sample, because of the improper viscosity. The viscosity level will directly affect the blade pressure, because the evaporation rate of the Thinner affects the thickness of the ink. Refer to Figure 4.2, it shows the relation between the viscosity and pressure setting is a direct relation. When the viscosity is high, the pressure also is set high such for viscosity 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296 the pressure is 1.68, 1.70, 1.73, 1.75, 1.76, 1.79, 1.82, 1.83, 1.86, 1.87, 1.88, 1.89, 1.90 respectively. Therefore, the set-up of blade pressure will depend on the viscosity level according to the changing viscosity specification. From the second result as 25^{th}–40^{th} data, the process is in control again. Then, we make a comparison between the first result and the second result, and we found that the second result offers a better result than the first. By measuring the defect, it is found the second process can reduce the defects of the sample.

Table 4.2. Scatter Diagram between Viscosity Level and Blade Pressure Setup.

Viscosity Level	270	272	274	276	278	280	282	284	286	288	290	292	294	296
Blade Pressure Setup	1.68	1.70	1.73	1.75	1.76	1.79	1.82	1.83	1.84	1.86	1.87	1.88	1.89	1.90

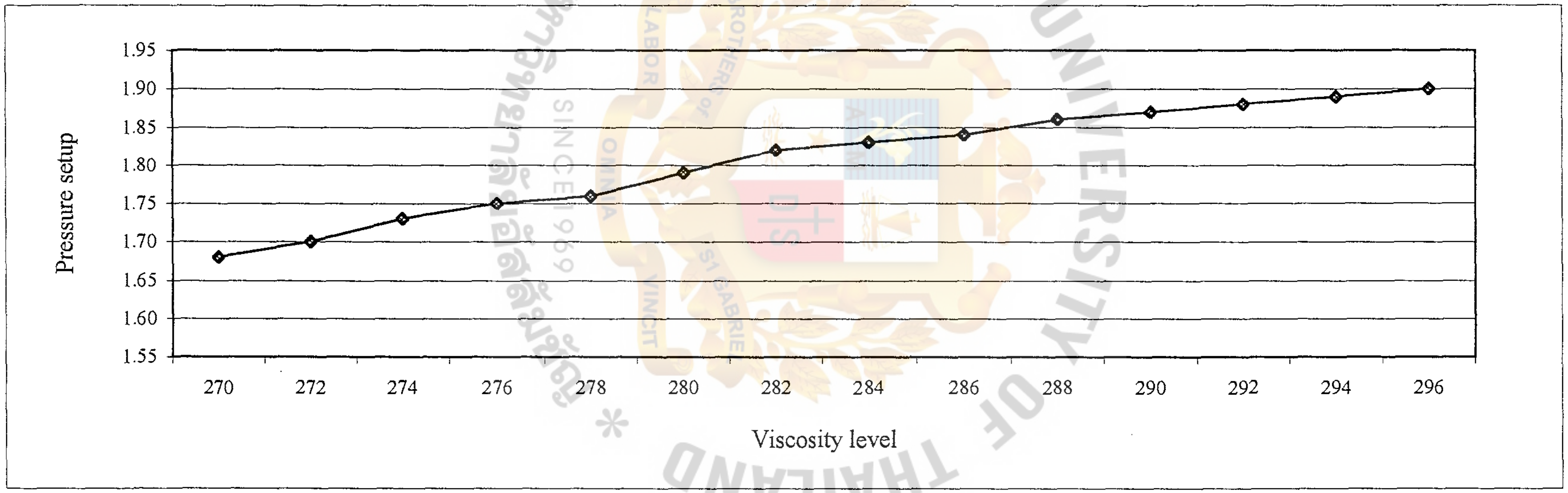

Figure 4.2. Scatter Diagram between Viscosity Level and Blade Pressure Setup.

(c) Control chart of rubber pad down adjustment

From the Figure 3.12, the graph shows that the process is in control and it indicates that the trend of UCL and LCL during 25^{th} -40^{th} is narrower than those of old UCL and LCL.

It means that the process capacity will be increasing. In addition, increasing the process we must specify the range of rubber pad down adjustment specification. If the range of adjustment is getting narrower the process capacity will be higher as shown in the second part of the graph above.

Moreover, the result shows the process is better, it may mean that the preventive maintenance program can help to improve the process such as the Tampo printing machine calibration program, when the machine is calibrated following the instructions strictly, it can help the technician to adjust the equipment effectively. For the preventive maintenance program of rubber pad, the technician follows the instructions well to keep and confirm the rubber pad status before usage. Normally, the pad status affects the pad down adjustment. If the rubber pad surface is torn it will cause the incomplete printing to occur. In addition, the marking plate status affects the quality of printing and causes the rubber pad to tear. The preventive maintenance program can prevent the marking plate scratch that cause the rubber pad surface damage.

4.2 Pareto Analysis

In Table 4.3, the result of the data gathered at the OBA station is shown. The Button poor-printing defects still exist in the process but it has only a small percentage of 6%, after we monitor it to find out and to analyze the root cause.

This technique is used to confirm that the implementation plan is suitable. From the result, even though the control chart shows the process is in control, it does not mean that the process is in the optimal position. We still have to improve the process continuously.

However, the button poor printing defects are decreasing. The production still has the other defects existing such as case scratch as shown in Figure and Table 4.3.

Table 4.3. Defect Category and Percentage Cumulative of Model A. (After Implementation)

Category	Number	Percent	Cumulative %
Case Scratch	15	44%	44%
Power on Fail	9	26%	71%
Poor Feeling	5	15%	85%
Non Action of Button	3	9%	94%
Poor Printing on Button	2	6%	100%

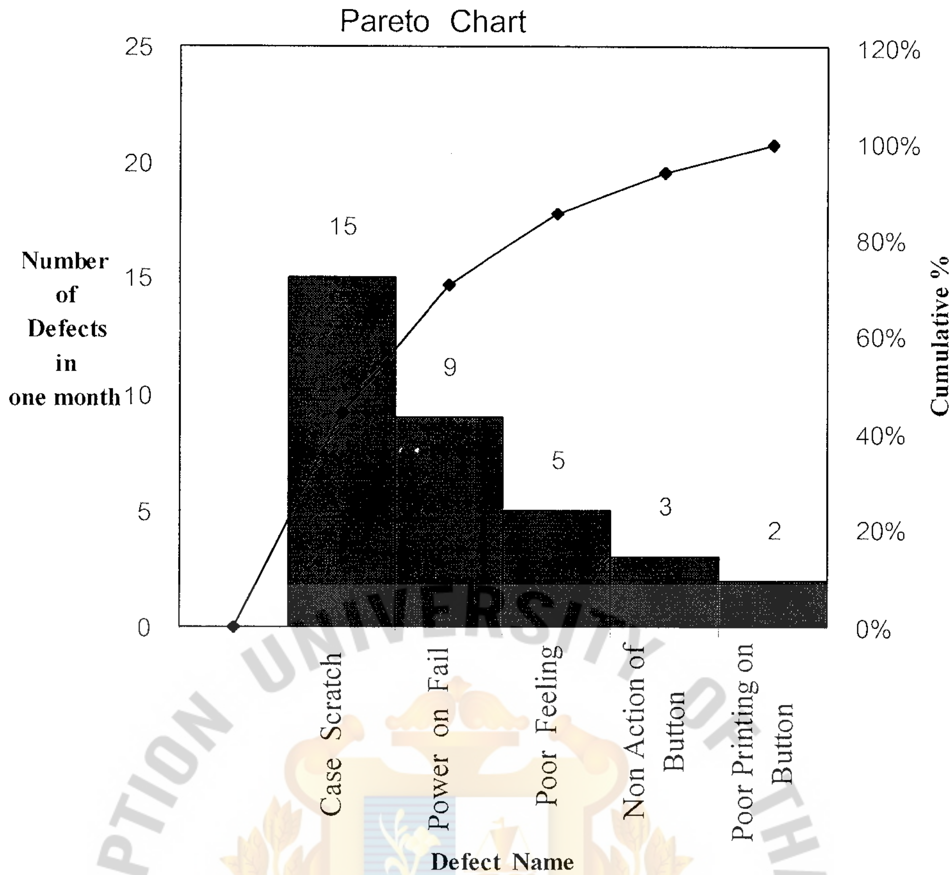

Figure 4.3. Pareto Chart of Defect Priority. (After Implementation)

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The Keyboard company is the keyboard computer manufacturer. This project focuses on the Out of Box Audit final inspection to identify the main defect.

The SPC tools are employed, we use Pareto analysis to identify the main defect at the final inspection. The main defect is the poor printing on button. Then we use the why-why diagram to find out the possible root causes and the chain of symptoms. It shows the main causes are the over blade pressure adjustment, high viscosity level set-up, and the pad down adjustment. We use the control chart to monitor the process in or out of control. In addition, the incomplete equipment status is the one cause of poor printing on button. The main reason is improper preventive maintenance. So, we develop this program in two parts as the preventive maintenance and the predictive maintenance. The equipment must be measured and the status checked before usage.

To prove that above conclusion can reduced the poor printing on button from the current printing process or not, we monitor the process by using the control chart and compute the UCL, CL and LCL of x-R chart to indicate the process status.

From the result of the process parameter monitoring, the engineers found that the viscosity rate has a direct relation with the blade pressure set-up. When we increase the viscosity level, the pressure will be increased too. In the process of viscosity set-up, we found that the specification is not suitable for the printing process. It causes the defect quantity to be high. On the other hand, the number of defect will be decreased if we can find the proper specification of the viscosity. According to the study, we found that the proper viscosity rate is 275 mPs.a. The defect will be decreased from 15 % to 4 %.

Finally, we want to make sure by integrating the Pareto Analysis to monitor the main defect. The result shows that the level of the main defect is changed from the 1st order to the 5th, and the percentage of the defects is reduced from 42 to 6.

5.2 Recommendations

According to the SPC tools, the Fishbone Diagram is not the best tool to define the chain of symptoms of main defects. It just clarifies only the problems. Actually, by eliminating the problems, the engineers must know the roots of the problem to identify and find out the root causes at the end of the chain. Then, we apply Why-Why Technique to fix this problem. The Why-Why Technique can help the engineer to find out the root causes of the symptoms of main defects. It will link the chain of the symptoms and lead us to identify the problem and the process concerned. However, the Fishbone Diagram will be more useful, if we know and understand the nature of the process as well.

After studying the Pareto Analysis, we found that the main defect is the case scratch. However, some new main defects occur in the production. From the second Pareto Chart, the case scratch is the new main defect. Even though different defects have different causes, we can apply all tools in this project to monitor, identify, and find out the root cause of any defect.

APPENDIX A

FORMULAS AND CONSTANTS FOR AVERAGE AND RANGE CHART

FORMULAS AND CONSTANTS FOR CONTROL CHARTS

Average and Range Charts: $\overline{x}$ and R Chart

The sample size n is less than or equal to 10; n is usually three to five consecutive pieces.

The $\overline{x}$ chart:

- Center line: $\overline{x} = \dfrac{\sum \overline{x}}{k}$ for k samples
- Upper control limit: $UCL_{\overline{x}} = \overline{\overline{x}} + (A_2 * \overline{R})$
- Lower control limit: $LCL_{\overline{x}} = \overline{x} - (A_2 * \overline{R})$

The R chart:

- Center line: $\overline{R} = \dfrac{\sum R}{k}$ for k samples
- Upper control limit: $UCL_{\overline{R}} = D_3 * \overline{R}$
- Lower control limit: $LCL_{\overline{R}} = D_3 * \overline{R}$

Table A.1. Constants for an $\overline{x}$ and R Chart.

Sample Size n	Factor for x-chart A_2	Factor for R-chart D_3	Factor for R-chart D_4
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.78
10	0.31	0.22	1.74

BIBLIOGRAPHY

1. Tapireo, S. Charles. The Management of Quality and Its Controls. London: Chapman and Hall, 1996.

2. Goetsch, L. David and Stanley Davis. Implementing Quality. New Jersey: Prentice-Hall International, Inc., 1995.

3. Summers, C.S. Donna. Quality. New Jersey: Prentice-Hall, 1997.

4. Smith, M. Gerald. Statistical Process Control and Quality Improvement, Third Edition. New Jersey: Prentice-Hall, 1998.

5. Evans, R. James. Production/Operation Management Quality : Performance and Value. Fifth Edition. Minneapolis: West, 1997.

6. Juran, J.M. and Frank M. Gryna. Qualilty Planning and Analysis, Third Edition. Singapore: McGraw-Hill, International Edition, 1993.